

# ***Hidden Image***<sup>TM</sup>

## **User's Manual**

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If you find any problems with Hidden Image, please send us a report explaining exactly how the bug occurs. If possible, include any HI.INI or data file necessary to cause the bug to occur, as well as copies of your CONFIG.SYS and AUTOEXEC.BAT. We will attempt to correct the problem and send you an updated version of the software. Our ability to correct the problem depends on the quality of your bug report, so try to be thorough.

If you have any suggestions or comments on Hidden Image or this manual, feel free to drop us a line. We are always looking for ways to improve the product!

## **Technical Support**

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# **1. INTRODUCTION**

The development of the i386, i486 and Pentium microprocessors by Intel in the late 1980s combined with the recent availability of low cost CCD cameras for amateur astronomers has created a vast and as yet untapped potential for amateurs to take advantage of very advanced image processing techniques.

Hidden Image provides an implementation of the Maximum Entropy Method (MEM) deconvolution algorithm along with the tools to use it effectively and easily. It provides a robust technique known to be capable of consistently yielding gains in resolution of 2-3 times. Our tests have shown that instruments of moderate aperture (8 to 16" aperture) can consistently yield detailed CCD images, many of which are comparable to published, film-based results on 100" telescopes.

With Hidden Image, image processing capabilities previously afforded only to big-budget professional institutions are now available to small college observatories. Also, amateur astronomers - using widely available, low-cost CCDs - can now utilize this same technology to produce professional-quality results. It is now possible to reliably discern small structure in deep space objects and resolve significant, changing surface detail on large planets, even with less-than-optimal atmospheric conditions and imperfect optics.

## **Features of Hidden Image**

Hidden Image was created especially for performing Maximum Entropy Deconvolution - a reliable technique for dramatically improving the resolution of images. The authors of this package are professional image processing engineers, amateur astronomers and CCD camera users. In the course of developing and using this package, it was discovered that a number of tools are essential for making MaxEnt effective and easy to use. In addition to these tools, we decided to add a number of other powerful image processing functions. We have found these functions to be essential for obtaining the best possible images.

Hidden Image features include:

**Maximum Entropy Deconvolution** - a sophisticated "de-blurring" technique capable of reducing seeing effects, guiding errors, and optical aberrations. Because Maximum Entropy is a processing-intensive function, the core processing algorithms were carefully hand-coded to provide the maximum possible speed on 386, 486 and Pentium processors. The user can watch the image "developing" on the screen as the processing works.

**Elegant User Interface** - mouse-driven with pop-down menus and dialog boxes. Hidden Image makes sophisticated image processing techniques available even to the novice user. The user interface was designed by astronomers for astronomers. Features include:

**Photo View Mode** - for taking pictures of the computer monitor.

**Blink Mode** - for doing a comparative analysis between two images.

**Automatic Stretch Modes** - instantly view images with automatically calculated contrast adjustment.

**Night Vision Mode** - for using Hidden Image at the telescope; includes mouse-only operating mode - no keyboard required!

**Two Image Frames** - allows displaying of "before" and "after" images for direct comparison.

**Histograms** - each displayed image can have an associated histogram. Mouse-controlled cursors on the histogram allow the user to change the stretching and gamma correction of the display.

**MaxEnt Setup Tools** - Maximum Entropy Deconvolution requires a "point-spread function" and noise estimate in order to work correctly. Several easy-to-use tools are provided for extracting this information directly from your image:

**Point-Spread Functions** - extract a star image to tell Hidden Image how the image was blurred; just point and click! Or use an "analytical" point-spread function. Hidden Image will also allow you to graphically match an analytic function to the shape of an extracted star image.

**Noise Estimate** - extract a noise estimate by pointing a box cursor at a dark area of the image with the mouse.

**High Precision** - unlike some packages, all images are stored and processed as floating-point numbers. Any number of processing steps can be performed without losing any image detail.

**Image Calibration** - calibrate CCD images using Bias Frame, Dark Frame and Flat Field compensation.

**FFT Filtering** - variable cutoff and order lowpass, highpass, and bandpass filters. Much more sophisticated than common "kernel" filters - uses a "Butterworth" filter shape for superior results.

**Cosmic Ray Removal** - removes ugly cosmic ray bright spots from your image.

**Dead Pixel Removal** - removes CCD array defects.

**Histogram Equalization** - overcomes the limitations of your computer display to give stunning images of galaxies and other deep sky objects. Allows viewing the full dynamic range of an image without losing contrast.

**Gamma Correction** - a popular form of non-linear contrast adjustment. Gamma is controlled graphically or numerically.

**Unsharp Masking** - suppresses large-scale brightness variations while preserving low-contrast details. Perfect for displaying planetary images.

**Median Filtering** - suppress spiky noise.

**Stretching** - allows graphical or numerical control of the brightness and contrast of the display, without affect the actual stored image. Hidden Image also allows you to permanently stretch an image; this is useful for generating optimized TIFF files for exporting to other applications.

**Sum and Offset** - Add, subtract, and scale images for special effects.

**Image Combination** - Combine multiple CCD exposures while adjusting the registration to permit unguided long duration imaging. Provides a computer-assisted registration function to align the images.

**Statistical Information** - User can extract statistical information on an area of the image using a box-shaped cursor. Information includes mean and standard deviation, maximum and minimum values, and the X and Y centroid of a star in the box.

**Measurements** - User can read the pixel value of any point in the image using a cross-hair cursor.

**Copy Star** - Allows user to copy original stars over processed stars to remove objectional side effects of processing (i.e. black donuts).

**Image Frame Sizes** - Hidden Image can extract a 128x128, 256x256, 512x256, 512x512, 1024x512 or 1024x1024 size frame from any sized image (limited by available memory and disk space and version dependent).

**Make Square Pixels** - Images from cameras with non-square pixels can be interpolated to square pixels to give the correct aspect ratio when images are moved to packages not designed for CCD cameras with non-square pixels.

**Video Modes** - Supports 320x200, 640x400, 640x480, 800x600 and 1024x768 VGA and Super-VGA (VESA) video modes. Display is in 256 colors (grayscale for images) in all modes (16 color mode is also supported in 640x480 for laptops).

**File Formats** - The following file formats are supported: TIFF (8 and 16 bit), FITS, All the SBIG Type III (ST-6, ST-8 etc), ST-4, Electrim, PC-Lynxx, Raw Integer, and Raw IEEE Floating Point.

## Hardware Requirements

Hidden Image requires a PC-compatible computer with one of the following processors:

<u>Processor</u>	<u>Notes</u>
i386SX or DX	Requires 387 math coprocessor
i486SXRequires	487 math coprocessor
i486DX	
Pentium™	

Memory required depends on the image size being processed. Hidden Image is able to use the hard drive in place of system memory; however a significant speed penalty may result.

Recommended memory configuration is as follows:

<u>Frame Size</u>	<u>Minimum</u>	<u>Recommended*</u>
128x128	4 MB	4 MB
256x256	4 MB	4 MB
512x256	4 MB	8 MB
512x512	8 MB	16 MB
1024x1024	16 MB	64 MB

\* Hard drive free space plus system memory must equal at least the recommended size.

This means that 4 MB of memory is recommended for use with PC-Lynxx, ST-4 and Electrim cameras. For ST-6 cameras, 8 MB of memory is recommended for processing a full-sized image.

A mouse is required to operate Hidden Image.

Hidden Image supports standard VGA displays at 320x200 256-color and 640x480 16-color. This provides maximum compatibility with laptop computers. It also supports a large number of Super-VGA video cards using an included universal VESA driver. See the explanation of video modes in Chapter 6 (under "View Menu"). The following 256-color Super-VGA modes are available depending on the video card used: 640x400, 640x480, 800x600 and 1024x768.

## **About Sehgal Corporation**

### A Virtual Corporation

Sehgal Corporation was founded in May 1991 with the goal of bringing powerful software techniques used by professional astronomers and major institutions to a wider audience. Sehgal Corporation is far from being a large software development house employing hundreds of programmers. Instead, in the tradition of most astronomical software companies, Sehgal Corporation's researchers and engineers are both amateur astronomers with many years of experience as well as programmers. As we progress into the next century, personal computers and high speed digital communication have ended the need for large centrally controlled corporations which do everything under one roof. Sehgal Corporation is a virtual corporation in that it is able to tap a large body of talent and expertise which is distributed across North America.

### Ajai Sehgal

The founder and President of Sehgal Corporation has been an amateur astronomer since he received his first Pentax refracting telescope when he was eight years old. A member of the Royal Astronomical Society of Canada, Mr. Sehgal is Sehgal Corporation's image processing engineer. He has a Master of Electrical Engineering from Carleton University with a concentration in image processing. Mr. Sehgal is an aerospace engineering officer with the Canadian Air Force and currently working with imagery enhancement.

Ajai wrote the image processing code for Hidden Image and is the resident expert on Maximum Entropy Deconvolution.

### Doug George

Doug George is an amateur astronomer who happens to be a systems engineer during the day. He received his Master of Engineering from Carleton University and his Bachelor of Applied Science (Engineering Science) from the University of Toronto. He has been a member of the Royal Astronomical Society of Canada since 1976 and is noted for his co-

discovery of Comet Skorichenko-George (1989e1). His observing interests include CCD and film astrophotography, minor planet and comet astrometry, and eclipse and occultation chasing.

Mr. George utilized his engineering and astronomy experience to write the user interface for Hidden Image. He also wrote some of the image processing software and consulted on issues concerning astronomical imaging.

### Robert Morris

L. Robert Morris is a Professor of Systems and Computer Engineering at Carleton University, Ottawa. He received a B.A.Sc. from the University of Toronto, and a Ph.D. from Imperial College, University of London. Dr. Morris has conducted pioneering research into time-efficient Fast Fourier Transforms. Morris has initiated and supervised three astronomy-related M.Eng. theses: with Doug George, which resulted in a joint US patent (5,133,050) for "a computer-driven astronomical telescope guidance and control system with superimposed star field and celestial coordinate display"; with Ajai Sehgal, which became the nucleus of the Hidden Image software; and with Dan Showalter, which proposed - for purposes of light and climate control - construction of a polar orbit, sun-synchronous, passive ring system for planet earth. (This latter project has not yet been realized.)

Dr. Morris is the author of *Digital Signal Processing Software* (1983, DSPS Inc.) and co-author of both *Minicomputer Systems* (1979, Prentice-Hall Inc.) and *Lawrence of Arabia: the 30th Anniversary Pictorial History* (1992, Doubleday Inc.). Morris is founder and President of DSPS Digital Signal Processing Software Inc.

Bob has provided valued advice and suggestion with respect to code optimisation.

### Paul Boltwood

Paul Boltwood is a long time armchair amateur astronomer of 49 years age with recent observational experience. He made the optics for,



constructed and used several telescopes 20 years ago. Recently he built an observatory equipped with an Astrophysics 7" f/D 9 Starfire refractor on an 800 mount and a homemade CCD camera. The CCD camera was a major electronic, mechanical, thermal, software and image processing undertaking. He currently is taking astrophotos with the camera and plans to do star cluster photometry.

He has done computer systems design for real-time, control, communication and scientific applications for over 30 years. He specializes in software but also has substantial electronic and mechanical hardware knowledge, and has signal and image processing experience. He runs a one-man consulting company which he is trying to move into fields closer to astronomy. Paul wrote the FITS file interface for Hidden Image.

### Other Contributors

This project depended heavily on the contributions of our "beta-testers" to tell us about problems, suggest additional features, and provide us with images to experiment with. Paul Boltwood, in addition to his official efforts in writing the FITS file interface, provided important technical feedback about the product. Jack Newton also suggested a number of features and improvements which make the package more flexible and easier to use. Both Paul and Jack provided us with excellent images to experiment with; the experience we gained helped us improve the product and this manual.

The inspiration for pursuing Maximum Entropy Deconvolution began with Dr. Nigel Sharp of the National Optical Astronomical Observatories in Tucson Arizona. His enthusiasm, encouragement and advice helped make this project a success.

## 2. GOALS OF THIS MANUAL

Having been computer software users for many years, the engineers at Sehgal Corporation have experienced first hand the frustrations of trying to use ill-explained and poorly designed software. As a result, we have endeavored to create a product that is intuitive, easy to use and effective from a user's perspective. This manual attempts to complement Hidden Image with a complete, comprehensible explanation of both the program's functioning as well as the theory behind it. The user interface is probably more intuitive than our explanations; you might want to play with the program as you read the manual.

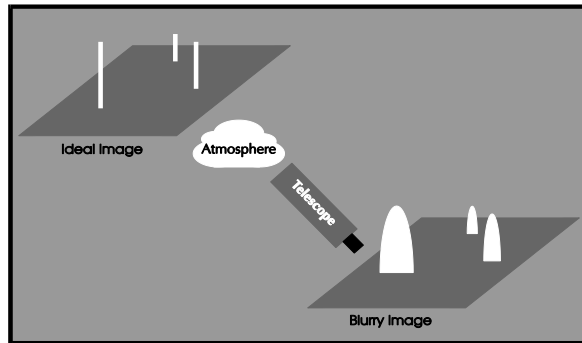
Given the wide range in academic backgrounds of Hidden Image's users, this manual must address image processing at many different levels. Maximum Entropy Deconvolution is a very complex algorithm and even simple explanations may seem complicated. To attempt to keep things simple, this manual deals with the theoretical issues at two levels. The first level is targeted to the "average user" and tries to explain things using words and analogies, keeping the math to a minimum. The second level is targeted towards the user who has a strong background in mathematics. By strong background we mean typically an individual with a university degree in science, engineering or mathematics. In fun, we have termed such individuals "Math Masochists" because, to the "average user", someone who enjoys reading explanations packed with integral signs must be a masochist of some kind!

***It is important to note that understanding the theory behind Maximum Entropy is not required to effectively use it as a tool.*** An analogy is "one does not require a physics degree to use a crowbar as a lever". Hidden Image presents Maximum Entropy as tool and provides the support to effectively use that tool without having an advanced understanding of it. We have found that trial and error sometimes works just as well as the application of sound theory.

### 3. WHY MAXIMUM ENTROPY DECONVOLUTION?

With the number of very good image processing packages available on the market the question "Why Maximum Entropy Deconvolution?" is a fair one. The answer is quite simple: the physics of the imaging situation require some form of deconvolution to get good resolution and maximum entropy is one of the few reliable techniques.

Let us consider what happens to the light as it travels to your CCD camera.



#### **Convolution: Perfect Points (Stars) Become "Blobs"**

The light from the object of interest travels through space, in some cases for millions of years, without any major distortion (aside from the odd gravitational lens!). Then the inevitable happens: it hits the Earth's atmosphere. As it passes through the different areas of turbulence and temperature gradients, the light is distorted. Light which once started as a point source is spread around and is now a blob. To add to the mess, before reaching the imaging elements of the CCD camera, the light must pass through the optics of the telescope which in many cases are less than perfect. In some cases guiding errors or accidents can further distort the final image. Instead of the pristine point source stars, we get a collection of blobs. The same blurring also affects any extended objects in the image. The technical term which describes what happened to the light during its passage through the atmosphere and optics is called "convolution".

Typical astronomical image processing software can improve the appearance of the image in many ways. We can adjust contrast, filter the image, etc., but we still fundamentally have a blurry image. If everything works just right - the seeing is wonderful, the telescope optics are perfect, and the drive guides correctly - we can get a good image. In the real world, the results are far from perfect.

To eliminate the atmospheric and optical effects and change the blobs back into point sources requires a special technique. This technique undoes the convolution, so it is called (you guessed it!) "deconvolution". The basic theory of deconvolution is actually very simple and elegant: it is, effectively, just a simple division operation with something called a "Fourier Transform" thrown in for good measure. Unfortunately simple deconvolution doesn't work on real-world images because of noise. And, of course, noise just happens to be the worst problem with CCDs.

Hidden Image provides one of the few deconvolution techniques which professional astronomers trust: Maximum Entropy. It has a strong mathematical basis, and it has proven effective for radio astronomy, ground-based optical astronomy, and of course the Hubble Space Telescope. The Maximum Entropy Method (MEM) results in an image with no false structure (structure which isn't in the original image). Any information loss that occurs is well known, expected, and can be easily eliminated without changing the "truth" in the image. The only obvious information losses are the black "donuts" which sometimes appear around stars embedded in nebulosity.

Maximum Entropy Deconvolution is a complex mathematical process that can be very effective. With this technique, Hidden Image has the potential to radically change your world of CCD imaging.

## 4. INSTALLATION

### Hidden Image Versions

There are presently four versions of Hidden Image. The full versions, known as HI256, HI512 and HI1024 include all of the features included in this manual. The small version, HI-LIGHT, has all the features of HI256 but is restricted to doing Maximum Entropy Deconvolution on image frames of 128x128 pixels.

### System Requirements

The minimum requirements to run Hidden Image are an IBM PC-AT compatible computer with at least a 386 processor and a 387 math coprocessor. A 486DX processor is preferred. Note that the 486SX will not work unless an external math coprocessor is used because its math coprocessor is disabled. Of course, a DX/2 or Pentium processor is even better.

#### Compatible Processors

<u>Processor</u>	<u>Notes</u>
i386SX or DX	Requires 387 math coprocessor
i486SX	Requires 487 math coprocessor
i486DX	
Pentium™	

Hidden Image runs under DOS 3.3 or higher. A mouse or track ball is required, as well as a VGA display. "Super-VGA" is recommended. At least 4 MB of memory is recommended for use with 256x256 images. At least 8 MB of memory is recommended for use with 512x256 images. At least 16 MB of memory is recommended for use with 512x512 images. At least 32 MB of memory is recommended for use with 1024x1024 images.

If you do not have sufficient memory in your system, Hidden Image will use "virtual memory", which means it will use your hard disk to

supplement the system memory. Depending on how much additional memory Hidden Image requires, it may operate very slowly. In order to reduce memory and processing time requirements, use the smallest frame size consistent with your image size.

Because of the virtual memory capabilities of Hidden Image, you cannot actually run out of memory unless you have first run out of disk space! If you do get an out of memory message from Hidden Image, you might have simply filled up your disk. Quit the program, make some room, and run it again. It is very easy when playing with CCD images to run out of space!

When using virtual memory, a very large amount of disk space may be necessary. Please keep this in mind. As much as 16 megabytes of disk space may be required for the 512x512 frame size if you do not have sufficient random access memory (RAM).

### **Recommended Memory Configuration**

<u>Frame Size</u>	<u>Minimum</u>	<u>Recommended</u>
128x128	4 MB	4 MB
256x256	4 MB	4 MB
512x256	4 MB	8 MB
512x512	8 MB	16 MB
1024x512	8 MB	16 MB
1024x1024	16 MB	64 MB

Hidden Image uses the FlashTek DOSX extender to access extended memory and to run in 32-bit protected mode. DOSX has been tested with many different memory managers and there are no known compatibility problems as of this writing. Avoid running Hidden Image from within a Windows DOS box.

## Installing the Software

The installation of Hidden Image is quite easy. Assuming the floppy is in drive B:, the following commands will do:

```
> b:  
> install
```

All this does is copy the following files onto your hard drive:

hi.exe	Hidden Image executable program
hi.ini	Initializes Hidden Image to process the "quick-start" image.
univesa.exe	Universal VESA driver for SVGA operation
univesa.doc	Documentation for univesa
m51.raw	A sample image of M51, the whirlpool galaxy
jupiter.raw	A sample image of the planet Jupiter
quick.raw	A sample "quick-start" image
readme.txt	A text file containing any last-minute items not in this manual

These files are placed in a directory called "HI". You may move them to any other directory if you wish.

If you want to be able to access Hidden Image from any directory on the hard drive, you should add it to your PATH statement in the AUTOEXEC.BAT file. For example:

```
set path=c:\dos;c:\hi
```

Hidden Image requires that as much system memory as possible be available for use. For this reason, you should temporarily disable any drivers which use large amounts of extended memory: for example, SMARTDRV. Simply place a REM command in front of the offending command in your CONFIG.SYS or AUTOEXEC.BAT file. In DOS 6, you may want to use the "multi-boot" feature to allow your system to have different memory configurations. Remember that after changing your CONFIG.SYS file you must re-boot your computer.

To start running Hidden Image, just type:

```
> hi
```

If you are not in the "\HI" directory, the PATH variable must reference it as described above. Alternatively, you can access the file directly by typing:

```
> \hi\hi
```



## **Quick Start**

Upon installation, Hidden Image is set up to run a quick demo. To run the demo, first run Hidden Image by typing "HI" and hitting enter. Next place the mouse cursor on the "File" menu at the top of the screen and click any mouse button. Move the mouse cursor to the "Load Parameters" entry on the menu and click any mouse button. Type "quick.ini" on the keyboard and press return. Next Click again on "File", then on "Load Frame 1", then on "OK". Now click on "Maxen" and then "Go". Watch what happens.

## **Other Things To Do Before Running Hidden Image**

### Setting the TEMP System Variable

It is a good idea to have a TEMP directory set up on your system. Many programs such as Microsoft Windows require one, so you may already have one set up. If not, add the following to your AUTOEXEC.BAT file:

```
set temp=c:\temp
```

And run the following command:

```
md c:\temp
```

The swap file used by Hidden Image when virtual memory is required will be located in this directory.

## VESA Drivers

Hidden Image works best with "Super-VGA" video cards. The main reason for this is that 256 color modes are best for displaying CCD images, but standard VGA is only capable of 256 colors in the 320x200 resolution mode. This is the default mode Hidden Image uses when you first start the program. This is a pretty ugly video mode, but we use it because it is sure to work. The first thing you will want to do is change modes.

The ATI Technologies VGA Wonder series of video cards is directly supported at up to 800x600. When you start Hidden Image for the first time, use the mouse to select the "View" menu, and select the "Video Mode" entry. This allows you to change the resolution of the screen. If you have an ATI card, select "ATI" under "Card", then select "640x480" under "Screen Resolution", and hit "OK". If you want to run an ATI card at 1024x768 resolution you need a VESA driver as described below.

Many other video cards are compatible with Hidden Image if you first load a VESA driver. Usually such a driver is supplied with your video card. If not, a program called "UNIVESA" has been included with the package.

The reason for the VESA drivers is a lack of standards for Super-VGA video cards. The drivers make your video card look like it has a standard interface, so Hidden Image can talk to it. For more information, refer to the description of the video mode dialog box, and see the file "UNIVESA.DOC" on the distribution disk.

## Hidden Image and Microsoft Windows

It is *possible* to run Hidden Image from a DOS box within windows. There may be problems if Hidden Image tries to access virtual memory (this usually will not happen until you try to perform a deconvolution). Also, Hidden Image will run much more slowly under Windows. There will also be less memory available. It is best to limit the use of Hidden Image to file translations and simple functions like "Permanent Stretch" while running in Windows.

We recommend that you quit Windows before running Hidden Image.

## 5. PROCESSING TUTORIAL

In this section we take the user through a step-by-step procedure showing how images are processed using Hidden Image. The first section explains how to set up the video mode and introduces some of the terminology used in operating Hidden Image. If you are already familiar with this type of user interface and have your video mode set up, you can skip ahead to the next section. The following sections explain how to process the example images supplied with Hidden Image.

This tutorial assumes that the default settings are in use. To restore the default settings, delete the "HI.INI" file from your working directory before starting the program.

### Program Setup

Install Hidden Image following the instructions in the installation section of this manual.

If you have a Super-VGA video card, load the VESA driver supplied with the card. If no driver was provided with your card, run the UNIVESA program supplied with Hidden Image. UNIVESA may not work with some cards. If this happens contact the manufacturer of your card and request a VESA driver. Hidden Image can still be used in VGA mode. Unfortunately only two modes are available: 320x200 with 256 colors, and 640x480 with 16 colors. The 16-color display mode provides a limited-quality display which is often useful on notebook computers. To run UNIVESA, type:

```
> univesa
```

Now start up Hidden Image as follows:

```
> hi
```

The program defaults to the 320x200 display, which is not very attractive but is supported by all VGA-compliant video cards. We will next select a more attractive video mode. For the purposes of this tutorial, we will use

the VESA 640x480 video mode. If you do not have a VESA driver, you can either use ATI or VGA as appropriate.

There is a menu bar at the top of the screen. The menus are "File", "View", "Process", "MaxEnt", and "Utility". Using the mouse, place the arrow on the "View" menu and click any mouse button. A pop-down menu appears.

Now place the mouse cursor on the "Set Video Mode" menu entry and click any mouse button. The "Set Video Mode" dialog box appears. Place the tip of the mouse cursor over the small circle (a "selector") beside the "640 x 480" heading and click a button. Now move the mouse cursor over the VESA selector and click any mouse button. Now place the mouse over "OK" and click.

The screen will briefly disappear as the video card is re-initialized, and the screen will re-appear in the new video mode. If an error box appears, you have selected an illegal mode (e.g. 1024x768 with VGA selected). If the program aborts with the message "cannot initialize graphics", you have selected an incorrect video card or you forgot to load the VESA driver. The program aborts because it cannot initialize the card. Simply restart Hidden Image and check your settings.

You do not have to run Hidden Image from the same directory that the images are stored in. To tell Hidden Image where the files are, place the mouse cursor on the "File" menu and click. Click on the "File Path" menu item, and a dialog box appears. Enter the correct path to the files using standard DOS format in the space provided, and hit enter. If you typed in a non-existent path, an error box will appear. Simply hit "OK", click on the directory text field, and try entering the path again. Instead of re-typing the whole field, you can backspace.

You are now ready to work with images.

## **Image of M51**

The image of M51 is copyright (c) 1991 by Neyle Sollee, and is provided with his permission for tutorial use only. Do not distribute or publish this image in any form without the permission of the copyright holder.

Run Hidden Image as described above. Make sure the video mode is set to 640x480, and that the file is in the current working directory (or use "File Path" as explained above).

First we must load the image. Click on the "File" menu, and then click on the "Load Frame 1" menu item. Now click on the "Format" button to bring up a second dialog box. On the "File Format" selector list, click on the "FITS" button.

The original dialog box reappears. Click on the "File Name" text field. Enter "\*.hi" using the keyboard. Click on the "Search" button. If the file is in your working directory (i.e., the "File Path" was correctly set), all files with the extension ".hi" will appear in the box. Double-click on the file M51.HI. The image should appear on the left side of the screen.

Notice there are a few problems with the image. The star images are trailed slightly, and there is a dark spot in upper right of the image (probably caused by dust in the camera).

First we will play with contrast stretching the image. Click on the "View" menu and then on the "Histogram" menu item. A histogram of the image will appear at the bottom of the screen. The left side of the histogram represents the darker image pixels, and the right side represents the brighter image pixels. The height of the histogram at any point shows you how many pixels there are of that brightness. The mathematically inclined should note that these are "log-log" histograms.

Also notice the cursors at the bottom of the histogram. The cursors indicate how the image is stretched. Anything between the red and green cursors is displayed as a gray scale. Anything above the green cursor is displayed as bright white (saturated). Anything below the red cursor is displayed as black. The yellow cursor is used to adjust gamma. We'll come back to gamma in a moment.

Hidden Image has several automatic stretch settings which automatically adjust these cursors based on the histogram. These settings are compromises and manual adjustment is usually required for the best display. The cursors can be adjusted using the mouse.

To see the core of the galaxy better, move the green cursor to the right. To do this, place the mouse cursor where you want the green cursor to end up. Click on the right mouse button. Try several different settings and see what happens.

To move the red cursor, use the left mouse button. Experiment with the setting of both cursor to see how they work.

Restore the automatic stretch by hitting the "F6" key. Now try moving the gamma cursor to the right using the middle button on the mouse. If you do not have a three-button mouse, click *both* the left and right buttons simultaneously. If you move the gamma cursor half-way to the right side, you will see more detail in faint regions of the spiral arms. Experiment with both the red and green cursor. Moving the gamma cursor to the left will generally result in excessive contrast between the bright and dim areas of the image.

You probably noticed that changing the gamma caused the display to slow down. To turn the gamma back off, click on the "View" menu, then on the "View Options" menu item. Set the "Frame 1 Gamma" text field to 1 using the mouse and keyboard, and click "OK". A gamma of 1.0 is the off position. Alternatively, you can click off the "Enable Gamma" button, but now gamma adjustment with the cursor will not be available.

Now, let's try to remove the dark spot. The spot is located between the spiral arms on the upper right portion of the image. Click on the "Process" menu, then on the "Nonlinear Filters" menu item. Under the "Function" selector list click on the "Dead Pixel" button. Using the mouse and keyboard set the "Dead Pixel Thr." to 90. Click on "OK". The processed image will appear on the right side of the display. This will take a while to calculate.

This algorithm works best on single dark pixels, such as those caused by a defective pixel on the CCD camera. The algorithm was designed to not damage the image, so it is gentle in its action. Since this is a large dust spot, it will require a few applications of the algorithm. To apply the dead pixel removal again, click on the "Process" menu, then on the "Copy 2→1" menu item. This will move the image back to the left side. You can now

repeat the dead pixel removal procedure by clicking on the "Process" menu, then on the "Nonlinear Filters" menu item, then on "OK". Repeat this copy and process cycle for a third time, and the dark spot will be entirely gone. Other areas of the image will not be affected by this procedure. Copy the image back to the left side in preparation for the next step.

Now we will perform the Maximum Entropy Deconvolution. Stretch the image so you can see the dimmest parts of the galaxy. The core and spiral arms should be saturated or "burned in". Click on the "MaxEnt" menu, then on the "Basic Setup" item. Set the "Iterations" field to 15, and the "Photons Per A/D Unit" to 6.67 (this is the setting for the ST-6 camera used to make this image). Click on "OK".

The next step is to obtain an estimate of the image background level by sampling the image in several areas. This level is used by the Maximum Entropy algorithm to help obtain a correct estimate of the noise in the image.

Now click on the "MaxEnt" menu, then the "Noise" menu item. The dialog box should already be set correctly; just verify that "Distribution" is set to "Poisson" and "Extract From Image" is enabled (with an X in the box). Click on "OK". The mouse cursor will change to a box shape. Using the left, right and middle mouse buttons, adjust the size of the box to its second-smallest setting. We now want to use this cursor to get a sample of the background of the image. The darkest areas of this image contain only background. Move the cursor to one of the corners farthest from the galaxy. Be careful to avoid the padding bands at the top and bottom of the image. These bands are there because the ST-6 camera images do not completely fill the 256 pixel height of the image buffer. Now click on the left mouse button to sample the background. A statistics box appears on the screen to indicate various measurements; this can be ignored. Select several different dark locations in the image in the same manner. Normally the size of the box is adjusted to be as large as possible without including any bright area. Only use the very darkest areas of the image.



After taking three or four samples of different areas, move the mouse cursor to the top menu bar and click the left button. An information box will appear in the lower left corner of the screen. The value indicates the calculated background level. This number will be around 1350, but the exact value will depend on where you sampled the image. If it is much higher, you have accidentally sampled a bright area; in that case, repeat this procedure.

Now we need to select a point-spread function. The point-spread function tells Maximum Entropy how the image was blurred. Luckily, we can simply use one of the blurred stars as the point-spread function. In almost all deep-sky images there are suitable stars available.

We want to pick a good star for this purpose. The ideal star is not double, does not lie on top of nebulosity, and is not saturated. A saturated star will not have the correct shape because the top is flattened. The star should be as bright as possible without being saturated. Look at the stars carefully, adjusting the stretch to see anything faint near the star. For example, the star in the upper right of the image is close to saturation and is very near another star. Stars located in the spiral arms would not be a good choice because of the bright background. They could be tried if there were no other good choices. There is a pair of bright stars on the left side of the image. The leftmost of these two appears to be the best choice in this image.

First stretch the image so that the faintest outer portion of the star image is visible. Click on the "MaxEnt" menu, then on the "Select PSF" menu item. The dialog box should already be set correctly, but verify that the "Function Type" is set to "From Image", and click "OK".

The cursor again changes to a box. Adjust its size using the right and middle buttons to include all of the star, including the faint outer parts. Because of the trailing in the image, the box needs to be at the third biggest size. Center the box carefully on the star. Press the spacebar or the left mouse cursor to select the star. The spacebar is safer because you won't accidentally move the mouse. A statistics box appears on the right hand side of the screen. The right-hand image changes to show just the extracted star. You can examine the star image by adjusting the stretch on

the right-hand image. The star image is also saved in a special image buffer which you can't see, so you could change the right-hand image without affecting MaxEnt.

Before starting MaxEnt, hit the "F6" key to enable automatic stretching. To begin Maximum Entropy processing, click on the "MaxEnt" menu, then click on "Go".

Maximum Entropy Processing will require a substantial amount of time to complete, depending on how fast your machine is. The processing algorithm was carefully designed for the maximum possible speed on a PC. Prior to Hidden Image, this algorithm was only available for very powerful and expensive mainframes and workstations.

Watch the right hand image develop. An information box in the lower left corner indicates the progress. At first it shows "Init" while various internal arrays are set up. Next it shows "0", indicating that the first iteration has started. It then counts 1, 2, 3 and so on. If you decide the image looks good enough, you can hit the <ESC> key to stop iterating. The current iteration will complete before MaxEnt will stop, so there could be a fairly long delay if you have a slower computer.

The image will get worse before it gets better. You will notice that there will be a dark ring around any very bright stars that appear on top of the spiral arms. This is normal for Maximum Entropy processing. When it is finished, the left hand image will look out of focus in comparison! The stars in the processed image are noticeably smaller, and tiny details are visible in the spiral arms. When the final iteration is complete or when processing is stopped manually, a special dialog box will appear on the screen. This dialog box is unique in that you can still manually adjust the stretch of the right-hand image while the box is displayed. If you want to temporarily view the images without the dialog box present, hit the "Hide" button. Press any mouse button to restore the box. You can request more iterations by entering a number and hitting "OK". In the case that the image is completely processed; just hit "Stop". Once you hit "Stop" you cannot ask for more iterations without starting over.

For the best possible view of the galaxy, there is one more step we can do: Histogram Equalization. This procedure is useful because computer displays lack the ability to display a wide range of intensities. This algorithm compresses the overall contrast range of the image without affecting the contrast of subtle features.

Copy the image back to the left-hand size using the "Copy 2→1" menu item under the "Process" menu. Select the "Process" menu again and click on the "Hist. Equalization" menu item. On the "Equalization Type" selector list click on the "Exponential" item. Make sure that the "Auto Scale" switch is enabled (showing an "X"), and click "OK". Adjust the stretch on the right hand image for the most pleasing display. Now you can trace the spiral arms right into the center core while still viewing detail in the outer areas of the galaxy. After histogram equalization, you might notice that the cores of the galaxies have a small dark spot in the center. This was caused by saturation in the original image. For ideal reconstructions, it is better to add up several unsaturated images (shorter exposures) using the image combination feature of Hidden Image.

You might want to reload the original image into Frame 1, and compare it to the processed image in Frame 2. It might be hard to believe that these are the same image!

The next step is to save the image (not available in demo version). Parts of the image may now be brighter than they were in the original image. Also, the brightness range of the image may be larger than the desired file format allows. Let us save this as a TIFF image, which has only an 8-bit brightness range. First click on "Process" and "Copy 2→1". Adjust the stretch on the left-hand image for the most pleasing display; this will be how it is saved. Next click on "Process" and "Permanent Stretch". This feature allows you to save the stretching you have just performed. Select the "256" option under the "Gray Levels" selector list. Select "From Screen" under the "Stretch Mode" selector list. Hit "OK", and the rescaled image will appear in the right-hand frame. Now you can safely save Frame 2 as a TIFF file.

Select "File" and "Save Frame 2". Click on "Format". Under the "File Format" selector list select "TIFF". Make sure "Compress File" is enabled

(to save disk space), and click "OK". Enter in the desired file name, such as M51.TIF, and click "OK". This file can now be read by many different applications, such as word processors and photographic image manipulation programs.

Congratulations! You have performed your first Maximum Entropy Deconvolution! You should try experimenting with the various features of Hidden Image to see what they all do to this image.

## **Image of Jupiter**

The image of Jupiter is copyright (c) 1993 by Terence Dickinson and Alan Dyer, and was taken at the University of Toronto Southern Observatory at LasCampanas, Chile. It is provided for tutorial use only. Do not distribute or publish this image in any form without the permission of the copyright holders.

Run Hidden Image as described above. Make sure the video mode is set to 640x480, and that the file is in the current working directory (or use "File Path" as explained above).

First we must load the image. Click on the "File" menu, and then click on the "Load Frame 1" menu item. Now click on the "Format" button to bring up a second dialog box. On the "File Format" selector list, click on the "FITS" button.

The original dialog box is restored. Click on the "File Name" text field. Enter "\*.HI" using the keyboard. Click on the "Search" button. If the file is in your working directory (i.e., the "File Path" was correctly set), all files with the extension ".HI" will appear in the box. Double-click on the file JUPITER.HI. The image should appear on the left side of the screen.

Set the automatic stretch by clicking on "View" and "Planet Stretch". If you want, you can manually fine tune the stretch as described above.

Now we will perform the Maximum Entropy Deconvolution. Click on the "MaxEnt" menu, then on the "Basic Setup" item. Set the "Iterations" field to 30, and the "Photons Per A/D Unit" to 80 (this is the setting for the camera used to make this image). Click on "OK".

Now click on the "MaxEnt" menu, then the "Noise" menu item. For planets, it usually works better to select the uniform noise model. Select the "Uniform" button under the "Distribution" selector list, and click "OK". This time, we will be extracting not just the background level, but also the noise level. The measurements is made in the same manner as before. Make sure that "Extract From Image" is enabled (with an X in the box). Click on "OK". The mouse cursor will change to a box shape. We now want to use this cursor to get a sample of the background of the image. The darkest areas of the image contain only background. Most of this image contains glare from the planet; use the very corner of the image. Adjust the mouse cursor to a medium size using the right and middle buttons. Move the cursor right up to the corner of the image and click the left button. A statistic box appears on the screen to indicate various measurements; this can be ignored. Move the mouse cursor to the top menu bar and click the left button. An information box will appear in the lower left corner of the screen. The value indicates the calculated background level. This number will be around 100, but the exact value will depend on where you sampled the image. If it is much higher, you have sampled a bright area; in this case, repeat this procedure. If you check the "Noise" dialog box again, the "Uniform Noise Level" should be set around 12.

Now we need to select a point-spread function. The point-spread function tells Maximum Entropy how the image was blurred. Unfortunately, we don't have a star in the image. We couldn't have even used the image of a moon of Jupiter, because the moons are not stars - they are resolved by the telescope and show small disks. Instead we will have to use an analytical point spread function. The problem is guessing what the size of the blur is; for now we'll just tell you the right answer.

Click on the "MaxEnt" menu, then on the "Select PSF" menu item. Set "Function Type" to "Gaussian". Set the "Pixel Aspect" selector to "1:1". Enter 1.8 in the "Standard Deviation" field, and click "OK". The standard deviation is our estimate of the size of the blur circle. A simple and fast experimental procedure you can use to find this value is described in the Tips section.

Before starting MaxEnt, hit the "F10" key to enable automatic stretching. To begin Maximum Entropy processing, click on the "MaxEnt" menu, then click on "Go". As before, watch the image develop in the right-hand frame. This image is relatively difficult to process because most of the image is uniformly bright; therefore it will take many iterations. Also a bright spot will appear in the image temporarily; this is normal and will disappear after sufficient iterations. When the program has finished iterating hit the "Stop" button on the dialog box.

You might want to try an unsharp mask on the resulting image. This boosts the contrast of surface details. First click on "Process" and "Copy 2→1". Next select "Process" and "Unsharp Mask". Set "Weight" to 40, "Radius" to 5, and "Order" to 1. Hit "OK". The resulting image should be impressive. Try adjusting the stretch controls for an optimal display. You can also try experimenting with the "Weight" and "Radius" value.

The next step is to save the image. Parts of the image may now be brighter than they were in the original image. Also, the brightness range of the image may be larger than the desired file format allows. Let us save this as a TIFF image, which has only an 8-bit brightness range. First click on "Process" and "Copy 2→1". Adjust the stretch on the left-hand image for the most pleasing display; this will be how it is saved. Next click on "Process" and "Permanent Stretch". This feature allows you to save the stretching you have just performed. Select the "256" option under the "Gray Levels" selector list. Select "From Screen" under the "Stretch Mode" selector list. Hit "OK", and rescaled image will appear in the right-hand frame. Now you can safely save Frame 2 as a TIFF file.

Select "File" and "Save Frame 2". Click on "Format". Under the "File Format" selector list select "TIFF". Make sure "Compress File" is enabled (to save disk space), and click "OK". Enter in the desired file name, such as JUPITER.TIF, and click "OK". This file can now be read by many different applications, such as word processors and photographic image manipulation programs.

The image of Jupiter you have produced shows fine detail much more clearly than the original. Note especially the detail inside the Great Red Spot.

## **6. USER INTERFACE OPERATION**

If you are familiar with Windows, OS/2, or Macintosh operating systems, you will feel right at home in Hidden Image. If you are very familiar with these types of interfaces and want to "cut to the chase", first read the keyboard/mouse quick reference section at the back of the manual, then skip ahead to the tutorials. You will want to come back later to read this chapter, especially the sections on the Processing and MaxEnt menus.

We recommend that you read this section with the computer handy. It is much easier to understand the concepts if you try them out in Hidden Image.

### **Principles and Goals**

The user interface for Hidden Image was designed by an amateur astronomer who has more than 20 years of experience at observing, and who has logged many hours using a computer at the telescope. The most significant finding from this work is that most astronomical software wasn't designed by people who have ever used a telescope!

The user interface for Hidden Image was derived from software used to control a telescope in the field. Therefore many of the user interface functions are designed around the requirement to operate in the dark, free of a visible keyboard. Although this may or may not be the way you use Hidden Image, this user interface will be standard for Sehgal Corporations products, many of which will be used at the telescope during observing. As a result, Hidden Image's operation centers around the use of a mouse or other pointing device to avoid needless memorization of commands and hunting for the right letter on a keyboard. All operations can be performed using the "point and click" approach including typing of file names and parameters - a feature unique to Hidden Image. Anyone who has used a CCD camera in total darkness will appreciate the convenience of this!

The primary purpose of a user interface is to simply make the functions of the program available to the user. However, the difference between a

functional program and a good program is how easily the user can operate it. It can be difficult to design a user interface which is simultaneously easy for a novice to learn, yet convenient for the "power user".

The current trend in user interfaces is the "Graphical User Interface" or GUI. This term really means that there are a bunch of pretty buttons and things to click on with a mouse. Typically, this means the use of "pop-down menus" and "dialog boxes". We have adopted this method because it eliminates "modes", is clear and simple, provides sufficient flexibility, and eliminates the need to memorize commands and function keys. For some frequently used operations, function keys are available to the user. Using them or not is a matter of preference.

One important feature of Hidden Image is the way the images are displayed. The user can adjust the contrast, brightness, and gamma of the displayed image without actually altering the data. That way you can always have the display adjusted optimally without affecting subsequent image processing steps. There are also a set of convenient "auto-stretch" settings available. These automatically adjust the display settings depending on the content of the image.



## **General Operation**

Hidden Image makes use of the screen by dividing it up into areas which are visible or invisible depending on the operation being performed. The most evident on program startup is the menu bar which consists of pop-down menus to control the operation of Hidden Image. Other areas include the image areas, dialog box areas, information box areas and progress box areas. Each area is dealt with below.

### Image Areas

There are one or two image areas depending on the user selectable mode of operation. Each area is capable of displaying one image frame at a time. There are two image frames called Frame 1 and Frame 2. A frame can be thought of as a buffer which holds the image for display and processing. In single frame mode there is one image area in the center of the screen which can be toggled to display either Frame 1 or Frame 2. In two frame mode there are two side by side image areas with the left side displaying Frame 1 and the right side displaying Frame 2.

Image processing is often a trial-and-error process, and there are various techniques with many different options. To support this, the user interface has been designed with two visible frames. Frame 1 contains the starting image, and Frame 2 contains the result of the processing. The user can try different techniques, and each time the same image from Frame 1 is processed and the result placed in Frame 2. The original data is never overwritten or destroyed. When the user is happy with the results, the Frame 2 image can be transferred back to Frame 1 in preparation for the next step, if desired. This arrangement holds true for all of the functions under the "Process" and "MaxEnt" menus.

It is possible to view both frames simultaneously, or one at a time. The reason for having two modes is the screen resolution. If the frame size selected is larger than the area available on the screen, the image is scaled down to fit. For example, if the screen resolution is 800 pixels wide by

600 pixels high and the frame size selected is 512 pixels by 512 pixels, there is not enough room to fully display two side by side frames. What Hidden Image does is display only every other pixel, so the images are displayed at lower resolution. Only the 1024x768 video mode is capable of displaying two full 512x512 frames side-by-side. In other modes, you may want to switch to single-frame viewing when examining the images.

## Histogram Areas

There is one histogram area per frame displayed (i.e., one in one frame mode, two in two frame mode). The histogram area consists of a horizontal bar at the bottom of the screen with an optional histogram graph above it (see above screen diagram). The histogram area includes up to three movable cursors which control the high stretch value, low stretch value and gamma correction value. The histogram itself is displayed in a log-log fashion, which compresses the dynamic range.

The screen can only display a limited range of brightness, so the user has to compromise. If you adjust the high stretch value to 4096, then any pixel with this or a higher value will be displayed as maximum brightness. You might want to adjust the display of a galaxy so that the core is saturated in order to see the spiral arms.

The low stretch value determines what pixel value is shown as black. If you adjust the low stretch value to 1000, then any pixel with a value of 1000 or less appears as black.

The base of the histogram is the stretch bar. The stretch bar is visible at all times. The histogram can be turned on or off using via the View menu or using the F11 function key. The histogram can be turned off because in some video modes it extends over part of the image (e.g., 320x200).

On the stretch bar there are adjustable cursors which serve to control the image display for the above image frame. Changing the cursor only affects how the image is displayed, the actual data in the buffer is unaffected. The red "^" cursor indicates the low stretch value. The green "^" cursor indicates the high stretch value. The actual range of values along the stretch bar depends on the range of pixel values in the image.

The yellow "|" cursor indicates the relative gamma value displayed when the gamma option is enabled (see below under "View Options" for how to turn gamma control on and off). When the cursor is at the left side, gamma is set to 0.1; when it is at the right side, gamma is set to 2. Gamma is used to change the contrast of the image in a non-linear way. This means that you can display low-brightness features at high contrast while simultaneously displaying bright features at low contrast. The reverse is also possible. The best way to understand what gamma does is to load an image and play with the gamma and stretch cursors.

You can view the actual numerical values for these three cursors by selecting the Manual Stretch dialog box using the View pop-down menu.

There are three methods to control the stretch cursors. The first method is by using the mouse. The mouse cursor arrow is placed along the scroll bar at the position where the cursor is to move to. To move the low stretch cursor to that position the left mouse button is clicked once. To move the high stretch cursor to that position the right mouse button is clicked once. The second method to control the stretch cursors is via the function keys as follows:

- F1 - Moves low stretch cursor lower for Frame 1
- F2 - Moves low stretch cursor higher for Frame 1
- F3 - Moves high stretch cursor lower for Frame 1
- F4 - Moves high stretch cursor higher for Frame 1
- Shift F1 - Moves low stretch cursor lower for Frame 2
- Shift F2 - Moves low stretch cursor higher for Frame 2
- Shift F3 - Moves high stretch cursor lower for Frame 2
- Shift F4 - Moves high stretch cursor higher for Frame 2

Each press of the key moves the cursor a certain fraction of the length of the scroll bar. The rate of movement is controllable as follows:

- Ctrl F1 - Step Increment is very fine
- Ctrl F2 - Step Increment is fine
- Ctrl F3 - Step Increment is medium
- Ctrl F4 - Step Increment is coarse

The function keys allow for more precise control of the stretch values for images where small changes make large differences (low contrast). In addition, using the function keys allows stretching beyond the scale provided by the histogram bar.

The third method to control the stretch cursors is by using the Manual Stretch dialog box under the View pop-down menu.

The gamma control cursor alters the display gamma correction factor for the image frame associated with a particular histogram area. For the purposes of gamma correction the scroll bar can be considered to be a scale between 0.1 and 2.0 with 1.0 being the center. The gamma cursor is controlled by two methods. The first method is similar to the mouse control for the stretch cursors. The mouse cursor arrow is positioned to the desired location for the gamma correction cursor. The cursor is moved by clicking the center mouse button on a three button mouse, or by clicking the left and right buttons simultaneously. The second method to control the gamma correction cursor is via the Manual Stretch dialog box under the View pop-down menu as explained below. Using the Manual Stretch method permits entering gamma values beyond the 0.1 - 2.0 range of the gamma control cursor.

Using gamma slows down the display. For faster display, either turn off gamma using the dialog box or set the gamma to exactly 1.0.

## Dialog Box Areas

Dialog box areas are transient areas which appear on the screen on an as-required basis in response to user action. A dialog box is a box which provides information about items to the user and allows the user to provide information back to the program. They essentially permit "dialog" between the user and the program. Dialog boxes are displayed centered on the screen.

Most dialog boxes have a standardized set of controls and control buttons. The most prominent control area appears in the lower left corner of the dialog box. It consists of alphanumeric characters in a shaded box. This control is a substitute for the keyboard and is provided for use under low

light conditions. Any file name or numerical information required by a dialog box can be entered by clicking on the field requiring the information, then clicking once on each required number, letter or character. Note that this control area only appears if there are alphanumeric entry fields in the dialog box. The "<" key in this control area is used as the backspace key. Of course the same information can be entered using the keyboard. Note that editing is limited to backspace. If you wish to edit text already present in the field, start by hitting backspace; otherwise the original text is automatically deleted when the first key is pressed.

The next control common to all dialog boxes is the OK control button. Clicking once on this button commits the information entered in the dialog box and commences the action to be performed (such as loading a file). An alternate method to activate the OK control is by hitting the "Enter" key on the keyboard. The Cancel control button terminates the dialog box returning all information to its previous state. An alternate method to activate the Cancel control is by hitting the "Esc" key on the keyboard.

In dialog boxes which permit file access there are three other possible buttons. The Path control button opens another dialog box which permits the user to specify the DOS path for finding a file. The path must be fully specified as per standard DOS. The Format control button opens the File Format dialog box which permits the user to change the file format specification. For areas requiring file name input, a third control button called Search will be present. Clicking once on the Search control button will search in the present directory. The search parameters can be specified by entering standard DOS wild cards (e.g. \*.tif , jup\*.fts) in the file name field.

When the search button is hit, another dialog box appears with a list of the files found. If no matching files are found, or if the file name field is left blank, the entire directory is listed. The user can scroll up and down the list by clicking on the up/down arrows. When the desired file is located, click on the file name and then click on OK. Alternatively you can double-click on the file name.

## Information Box Areas

Information box areas, like dialog box areas, are transient areas which appear on the screen on an as-required basis. There are three principal areas for information boxes. Error boxes and Warning boxes appear in the center of the screen. Information boxes which provide information about Frame 1 appear on the lower right side of the screen (so as not to impinge on the image in Frame 1). Information boxes which provide information about Frame 2 appear on the lower left side of the screen (so as not to impinge on the image in Frame 2).

## Progress Box Area

There is one progress box area on the lower left side of the screen. This area is only active during a Maximum Entropy run. This box serves to indicate the number of complete iterations of the Maximum Entropy algorithm.

## **Pop-down Menus and Dialog Boxes**

All Hidden Image functions are accessed through mouse controlled pop-down menus. There are five principal menus: File, View, Process, MaxEnt and Utility. The menu is activated by positioning the mouse cursor arrow over the menu item and clicking any mouse button once. Menu items are selected by positioning the mouse over the desired menu item and clicking any mouse button once. Activating a menu item in this manner will either result in opening a dialog box for input or will result in some predetermined action as described below for each menu item.

### File Menu

Clicking on the File pop-down menu provides a menu of mostly file input/output-related functions. Exception to this include the Shell To DOS menu item, the About menu item and the Quit menu item which are grouped under the File menu because of graphical user interface tradition (most users would expect to find them here).

## **Set Frame Size**

The Set Frames Size menu item enables the Set Frame Size dialog box

The buttons in this box simply select the frame size corresponding to the button. All available frame sizes have dimensions which are a power of two. The principal reason for this is the extensive use of Fast Fourier Transforms (FFTs) for most of the processing done in the package.

Having dimensions which are a power of two is a requirement of the FFT algorithm used in MaxEnt and in the linear filters. Images which are loaded into Hidden Image are padded or clipped as-required to fit the selected frame size.

The speed of processing, for both MaxEnt and filtering, is proportional to the size of the frame. If on a particular computer an operation requires 10 seconds for a 128x128 image, it will require 50 seconds for a 256x256 image, 100 seconds for a 512x256 image, and 200 seconds for a 512x512 image. You will want to use the smallest frame size which holds your entire image. Note that often the object of interest will not occupy the entire CCD frame; it may be more convenient to choose a smaller frame size in that case.

## **Load Frame 1**

Clicking on the this menu item opens the Load Frame 1 dialog box.

This dialog box prompts the user for the file name of the image to load in Frame 1. The lower left corner of the dialog box consists of alpha-numeric characters. This control is a substitute for the keyboard provided for use under low light conditions. The file name can be entered by clicking on the File Name field, then clicking once on each required number, letter or character. Alternatively the file name can be entered with the keyboard. Clicking once on the Search control button will search in the directory specified by the path for the files specified by standard DOS wild cards (e.g., \*.tif , jup\*.fts) in the File Name field and open a

new dialog box which lists the found files. If the File Name field is blank when the Search button is clicked all the files in the directory will be listed. The required file can now be selected by either double clicking on the file name or highlighting the file by clicking once on the file name and clicking on the OK control button. The Path control button opens the File Path dialog box which permits the user to specify the DOS path for finding a file. The path must be fully specified as per standard DOS. The Format control button opens the Load File Format dialog box which permits the user to change the file format specification. More details on the Path and Load File Format dialog boxes are provided below.

Once you are sure the contents of the dialog box are correct, click on the OK button to start the file loading. An alternate method to activate the OK button is by hitting the "Enter" key on the keyboard.

The Cancel control button terminates the dialog box returning all information to its previous state. An alternate method to activate the Cancel control is by hitting the "Esc" key on the keyboard. The manner in which the file selected is loaded is controlled by the Load File Format dialog box. Items of particular note are the Enable Scroll button and the Pad Percentile field.

Once the image has been loaded, you may be placed into image scroll mode. This happens if scroll mode is enabled and the image is larger than the frame size. See "Enable Scroll" below.

## **Load Frame 2**

Clicking on the this menu item opens the Load Frame 2 dialog box. This dialog box operates in the same manner as the Load Frame 1 dialog box described above but applies to Frame 2.

## **Load File Format**

Clicking on the this menu item opens the Load File Format dialog box. This dialog box controls the format of the files loaded into Hidden Image as well as the manner in which they are loaded.



## File Format

The buttons under this heading specify the type of the file to be loaded into Hidden Image. If the file loaded does not correspond to the format selected an error message box will appear. (With some formats Hidden Image may not be able to tell if the format is correct.)

### SBIG TYPE 3

Enabling this button causes the file to be loaded to be treated as a Santa Barbara Instruments Group Type 3 format file. This format is appropriate for ST-4X, ST-5, ST-6, ST-7 and ST-8 CCD cameras. The SBIG format has evolved over time and consists of an "Old Format", a Type I, Type II and Type III format with both compressed and uncompressed options. Hidden Image supports all listed formats for image loads. The header information available from ST-4X, ST-5 and ST-6 images is preserved throughout processing and is saved with the image if the save format supports headers (i.e., SBIG Type 3 and FITS).

### SBIG ST-4

Enabling this button causes the file to be loaded to be treated as a Santa Barbara Instruments Group ST-4 CCD camera format file (Note do not use this for ST-4X images).

### PC-Lynxx

Enabling this button causes the file loaded to be treated as a SpectraSource PC-Lynxx CCD camera format file.

### FITS

Enabling this button causes the file to be loaded to be treated as a Flexible Image Transport System (FITS) format file. Hidden Image fully supports the Draft FITS Standard NOST 100-0.3b for two-dimensional images. This standard is in wide use by professional astronomers and is one of the most common standards for astronomical imagery.

Hidden Image can read any *legal* FITS image with BITPIX = 8, 16, 32, -32 or -64. Numeric conversions are done automatically. Pixels with the BLANK keyword value or a NAN value are set to zero. BSCALE and BZERO values are handled appropriately.

In addition to standard FITS files, proprietary FITS packed files are also fully supported for integer pixel images (BITPIX = 8, 16, or 32). These packed files contain all of the information in a standard FITS file and when unpacked they are exactly the same as the original FITS file, bit for bit. They are however 2 to 4 times smaller. The packing algorithm uses a modified Huffman coding technique operating either on the raw pixels, or on the differences between successive pixels. The algorithm is much more effective for deep sky astronomical images than the common DOS packing routines PKZIP and LHARC. Because the packing algorithm is bit for bit lossless, it cannot compress FITS files saved in floating point mode. The format of these FITS packed files is not in the FITS standard. Hopefully there will be a standardized compression format in the near future; in the meantime this function can save significant amounts of disk space. *In the event that you want use FITS files saved by Hidden Image with another program, you must be sure to save them in the uncompressed mode.* Hidden Image reads packed files and regular FITS files transparently.

This format is not available in HI256.

## TIFF

Enabling this button causes the file to be loaded to be treated as a Tagged Image File Format (TIFF) file. Hidden Image supports the TIFF V5.0 Specification for both LZW compressed and uncompressed files. The TIFF file should be a single plane 8 or 16-bit TIFF which are the most common TIFF type for gray-scale images. Meade camera users can import the native Meade 16-bit TIFF format. The current version of Hidden Image does not support the input of 24-bit color TIFF files.

Hidden Image does not support random-access LZW compressed files. Most modern programs use sequential access files. If Hidden Image is unable to read a compressed TIFF file, load the file back into the application it came from and write it out as an uncompressed TIFF.

This format is also appropriate for Electrim CCD camera files. The Electrim camera software can save images in two principal formats.. Hidden Image automatically handles the aspect ratio correction for interlaced and non-interlaced Electrim images.

### Raw

Enabling this button causes the file to be loaded to be treated as a Raw file. A Raw file is an image of known dimensions and data-type stored row by row in a single unformatted file. Hidden Image supports Raw files of any dimension in the formats specified below. For Raw file input the X-Size and Y-Size as well as Raw Data Format must be specified as described below. Error checking is performed by checking the size of the file named against the X-Size, Y-Size and data format specified. If an inconsistency exists an error message information box is displayed and the file load is aborted.

### Enable Scroll

Selecting this button enables the scroll bars on image load. If the image being loaded is larger than the frame size selected, enabling scroll allows the user to pan around the image to select the frame sized window on the image to process. After the image is loaded, two yellow scroll bars appear on the screen. A single click of the left mouse button with the mouse cursor arrow positioned along the scroll bar will cause the scroll bar cursor to move to that mouse position, panning the image. Once the

desired portion of the image is visible a single click of the left mouse button with the mouse cursor arrow positioned anywhere on the top main menu will commit that portion of the image for processing. Essentially a frame sized portion of the image is clipped out for processing. If any dimension of the image is smaller than the frame size, the scrollbar corresponding to that dimension will not function.

During scroll the stretch bar is active. The mouse can be used to move the stretch cursors. The function keys can also be used to change the stretch mode.

### Pad Percentile

This field applies to images which have any dimension smaller than the selected frame size. The pad percentile is the histogram percentile to use to pad out the image with to fit the frame size.

If 30% of the pixels in an image are at or below a value of 65, then the 30th percentile is 65. When you load this image with pad percentile set to 30, the blank portions of the image frame will be filled with 65. The idea is to get a number which is equal to the average background level. Images vary considerably in how much background is in the image (e.g., a sparse image of a few stars versus a crowded field). The exact setting is usually not critical; the setting is a compromise that usually does not need to be changed.

The reason for padding the image is that when MaxEnt is run, the large step at the edge of the will result in an ugly "ringing" area.

If you do not want the image padded, enter 0 (zero).

### Interpolate Pixels to Square

On Image load the user can optionally "Make Square Pixels" for images with non-square pixel formats. This feature helps those who will later use a third party product such as PhotoStyler to combine images into color

ones. These packages were designed around scanners which have square pixels. The Maximum Entropy function works better with square pixels. The screen may need to be adjusted for the correct aspect ratio if this feature is used.

If pixel aspect ratio information is available in the header of the image format selected it will be used unless the Override Header Pixel Sizes check box is selected. In this case the Manual Pixel Aspect Ratio fields will be used. These fields are also used for file formats with no pixel aspect ratio information in the header.

Sanity checks are made on dialog box pixel sizes input by the user. Note: for TIFF images the XResolution and YResolution tags do not provide X and Y pixel dimensions. If header values are used these values are properly interpreted to make the pixels square. For images with square pixels the best screen resolution is 640x480 to get the correct aspect ratio.

### Raw/FITS Format

The button under this heading only apply if the *File Format* selected is *FITS* or *Raw*. This button opens a dialog box which allows the user to define the data type of the FITS/Raw file to be loaded as well as the image dimensions. In addition for Raw files a value for the number of header bytes to skip can be specified.

### IEEE Float

Enabling this button causes the bytes of the Raw file being read to be interpreted as IEEE Floating Point standard where each image pixel value is represented by a 32-bit floating point real number.

## 8 Bit Int

Enabling this button causes the bytes of the Raw file being read to be interpreted as short integers where each image pixel value is represented by an unsigned eight-bit integer (one byte).

## 16 Bit Int

Enabling this button causes the bytes of the Raw file being read to be interpreted as integers where each image pixel value is represented by an unsigned 16-bit integer (two bytes) in Intel standard order (least significant byte followed by most significant byte).

## 32 Bit Int

Enabling this button causes the bytes of the Raw file being read to be interpreted as long integers where each image pixel value is represented by an unsigned 32-bit integer (four bytes) in Intel standard order.

## X-Size

This field is only checked if the File Format selected is Raw. This field specifies the width or X-dimension size of the Raw image being read in.

## Y-Size

This field is only checked if the File Format selected is Raw. This field specifies the height or Y-dimension size of the Raw image being read in.

## Skip Header Bytes

This field allows the user to specify a value for the number of bytes to skip before beginning to read image data. This is useful for treating a file with a header as a Raw file. You can directly read the image data after skipping the header.

## **Save Frame 1**

Clicking on the this menu item opens the Save Frame 1 dialog box.

This dialog box prompts the user for the file name in which to save the image in Frame 1. The lower left corner of the dialog box consists of alpha-numeric characters. This control is a substitute for the keyboard provided for use under low light conditions. The file name can be entered by clicking on the File Name field, then clicking once on each required number, letter or character. Alternatively the file name can be entered with the keyboard. The Path control button opens the File Path dialog box which permits the user to specify the DOS path for the saved file. The path must be fully specified as per standard DOS. The Format control button opens the Save File Format dialog box which permits the user to change the file format specification. More details on the Path and Save File Format dialog boxes are provided below. Clicking once on OK button commits the file name entered in the File Name field and commences the file saving. An alternate method to activate the OK control is by hitting the "Enter" key on the keyboard. The Cancel control button terminates the dialog box returning all information to its previous state. An alternate method to activate the Cancel control is by hitting the "Esc" key on the keyboard. The manner in which the file selected is saved is controlled by the Save File Format dialog box. Items of particular note are the Compress File button and the Preserve Size field.

## **Save Frame 2**

Clicking on the this menu item opens the Save Frame 2 dialog box. This dialog box operates in the same manner as the Save Frame 1 dialog box described above but applies to Frame 2.

## **Save File Format**

Clicking on the this menu item opens the Save File Format dialog box.

## File Format

The buttons under this heading specify the type of file to be written by **Hidden Image**. This format is independent of the Load Format box. This is convenient if for example you are taking FITS files and saving them as TIFF files for importing into other software.

### SBIG Type 3

Enabling this button causes the file to be saved as a Santa Barbara Instruments Group Type III uncompressed format file. The header information available from ST-4X, ST-5 and ST-6 images are preserved through out processing and is saved with the image.

### SBIG ST-4

Enabling this button causes the file to be saved as a Santa Barbara Instruments Group ST-4 CCD camera format file.

### PC-Lynxx

Enabling this button causes the file to be saved as a PC-Lynxx CCD camera format file.

### Electrim

Enabling this button causes the file to be saved as a non-interlaced Electrim CCD camera format file.

### FITS

Enabling this button causes the file to be saved as a Flexible Image Transport System (FITS) format file. **Hidden Image** fully supports the Draft FITS Standard NOST 100-0.3b for FITS file creation. This standard is in wide use by professional astronomers and is one of the most common standards for astronomical imagery.



BSCALE is set to one. BZERO is set to zero except for BITPIX = 16 where it is set to -32768.

In addition to standard FITS files, proprietary FITS packed files are also fully supported for integer pixel images (BITPIX = 8, 16, or 32). The packing of the file is controlled by the Compress File button in the Save File Format dialog box. The BITPIX value of the new FITS file is controlled by the Data Format button in the Save File Format dialog box as described below.

This format is not available in HI256.

## TIFF

Enabling this button causes the file to be saved as an 8-bit single plane Tagged Image File Format (TIFF) file with Intel byte order. Hidden Image supports the TIFF V5.0 Specification for both LZW compressed and uncompressed files. Some applications do not support compressed TIFF, so the uncompressed mode is provided for maximum compatibility. The TIFF file generated can be imported into many popular word processing and photographic processing packages.

## Raw

Enabling this button causes the file to be saved as a Raw file. A Raw file is an image of known dimensions and data-type stored row by row in a single unformatted file. The dimensions of the Raw file created normally correspond to the selected frame size. This size can be overridden using the Preserve Size button in the Save File Format dialog box, if the originally-loaded image had a file header (i.e., was ST-6 or FITS).

## Data Format

The buttons under this heading only apply if the File Format selected is Raw or FITS. These buttons define the data type of any Raw file to be saved and the BITPIX value of any FITS file saved. The BITPIX value determines whether the file is 8-bit, 16-bit or 32-bit integer, or IEEE floating point format.

## IEEE Float

Enabling this button causes the bytes of the Raw file being saved to be written as IEEE Floating Point standard where each image pixel value is represented by a 32-bit floating point real number. If the File Format is FITS the BITPIX value in the FITS header is set to -32 causing the pixels in the FITS file to be written as IEEE floating point numbers.

## 8 Bit Int

Enabling this button causes the bytes of the Raw file to be written as unsigned short integers where each image pixel value is represented by an eight-bit integer (one byte). If the File Format is FITS the BITPIX value in the FITS header is set to 8 causing the pixels in the FITS file to be written as unsigned 8-bit integers.

## 16 Bit Int

Enabling this button causes the bytes of the Raw file to be written as integers where each image pixel value is represented by an unsigned 16-bit integer (two bytes) in Intel standard order (least significant byte followed by most significant byte). If the File Format is FITS the BITPIX value in the FITS header is set to 16 causing the pixels in the FITS file to be written as 16-bit integers. The FITS header for BZERO is set to -32768 allowing the full dynamic range of an unsigned 16-bit integer to be stored and interpreted correctly (please see the FITS standard documents for further information).

## 32 Bit Int

Enabling this button causes the bytes of the Raw file to be written as unsigned long integers where each image pixel value is represented by a 32-bit integer (four bytes) in Intel standard order. If the File Format is FITS the BITPIX value in the FITS header is set to 32 causing the pixels in the FITS file to be written as signed 32-bit integers.

## Compress File

Selecting this button causes the file to be saved to be compressed if the file format selected supports image compression. Hidden Image compresses TIFF files using the TIFF standard LZW process. FITS files saved as integers are compressed using an efficient proprietary technique. *Note: compressed FITS files do not adhere to the FITS standard and cannot be read into any other software.* Hidden Image can be used to translate the FITS files back to the standard uncompressed format. The advantage of saving in the compressed mode is that many more images can be saved in the same disk space. Unless you are exchanging files with other applications, we recommend the use of the FITS compressed mode for storing files since this requires the least disk space (even on compressed disks).

Hidden Image does not support the compression of ST-6 format images (although Hidden Image can read compressed ST-6 format files).

## Preserve Size

Selecting this button causes the dimensions of the saved image to be automatically adjusted to reflect the original image size of the loaded image. For images that were padded to the frame size for processing, this causes the padded area to be clipped off. If the image was loaded as a clipped window, the saved image is padded out to its original size using the Pad Percentile defined in the Load Image Format dialog box. This function is normally used when the saved image is smaller than the frame size.

## **Load Parameters**

Selecting this menu item enables the Load Parameters dialog box.

This dialog box allows the user to specify the name of a parameter file previously saved by Hidden Image. The parameters loaded replace all parameters entered into all dialog boxes. Note that the Manual Stretch dialog box always reflects the most recent stretch settings and so cannot be saved.

Note that the video card and video mode selection is also saved in the dialog box. This means that loading parameters can change the video mode. If the saved video mode is not supported, Hidden Image will abort. This could happen if you haven't loaded your VESA driver, or if you copy your files to a different computer.

## **Save Parameters**

Selecting this menu item enables the Save Parameters dialog box which is similar to the Load Parameters dialog box described above. This dialog box allows the user to specify the name of a parameter file in which to save all parameters entered into all dialog boxes. The parameter file can later be loaded to reproduce the exact same processing results. This option saves only parameters entered into dialog boxes. Images are not stored with the parameters. For example a Point Spread Function (PSF) extracted from an image is not automatically saved with this option. The PSF must be saved as an image and its file name entered into the appropriate dialog box (see below under MaxEnt - PSF). Upon exiting Hidden Image a default parameter file called HI.INI is automatically saved. This file is automatically loaded the next time Hidden Image is executed.

Parameter files are convenient for remembering the setup used for processing an image. Note that we do not guarantee compatibility of the parameter files with future versions of Hidden Image.

## **File Path**

Selecting this menu item or a single click on the Path button in a file oriented dialog box enables the File Path dialog box.

This dialog box permits the user to specify a separate DOS file path to use for the loading images, saving images and for calibration files required by Hidden Image (ie dark, flat and bias frames). The path must be specified in standard DOS format. Do not place a trailing "\" after the path (e.g., use "\\ccd\\images" instead of "\\ccd\\images\\").

## **About**

The about dialog box provides information about the current version of Hidden Image. Along with the current version number, the name of the registered licensee is provided.

## **Shell To DOS**

The Shell to DOS menu item spawns a DOS shell. To return to Hidden Image the user must type "exit" and hit the "Enter" key. *Note: the user should return to the directory Hidden Image was originally executed from prior to typing exit.* This is to ensure that Hidden Image is able to find any temporary files created. If there is insufficient memory, the Shell-to-DOS command may not function.

## **Quit**

Clicking once on this menu item terminates Hidden Image. Any changes to unsaved files will be lost. A keyboard alternative to this command is ALT-X.

## View Menu

Clicking on the View pop-down menu produces a menu of image viewing related function.

## **Set Video Mode**

This menu item enables the Set Video Mode dialog box.

This dialog box allows the user to select the video card, screen resolution and display appearance of Hidden Image.

## Screen Resolution and Video Card Type

Hidden Image supports five screen resolution as listed above. The screen resolution selectable is dependent on the type of video card and the amount of video memory available. The screen resolution selected in combination with the frame size selected (see below) determines the quality of the image displayed on the screen. It may seem obvious that the higher the image resolution the better the image quality. What may not be so obvious is that matching the frame size and image resolution to the maximum number of pixels your camera can produce is essential to extract the most detail from your images. For example if one is using a PC-Lynxx camera which produces an image of 192x165 pixels, the image will fit nicely into a 256x256 frame (all frames must have dimensions which are powers of 2). If we want to display two frames at full resolution we need 512x256 pixels which will fit well into a screen with 640x400 pixel resolution. Choosing a higher screen resolution would only shrink the image providing no better image resolution (the pixels get smaller which sometimes gives the appearance of better resolution).

## VGA

With a standard VGA video card with 256K bytes of memory, Hidden Image supports two screen resolution: 320x200 pixels with 256 colors and 640x480 pixels with 16 colors.

The 640x480 resolution is provided for maximum compatibility, especially with the limited video displays of many current laptop computers. It is not recommended for normal use. The mouse cursor will move more slowly in this video mode. Images will often appear "contoured" in areas where the brightness changes slowly.

## ATI

With most versions of ATI SVGA video cards, Hidden Image supports all modes up to 800x600 pixels at 256 colors. The 1024x768 mode which is available on some cards is supported in the VESA mode.

## VESA

Hidden Image supports most Super-VGA (SVGA) cards at high resolution by using the VESA standard. This allows a wide range of video cards to be used with Hidden Image.

To use VESA, you may need to run a driver supplied by the video card manufacturer. In the event that no driver was supplied, you can run the included "UNIVESA" driver before running Hidden Image. UNIVESA supports a large number of different video cards.

For those wanting more information on VESA, an explanation follows:

The IBM VGA has become a de-facto standard in the PC graphics world. A multitude of different VGA offerings exist in the marketplace, each one providing BIOS or register compatibility with the IBM VGA. More and more of these VGA compatible products implements various supersets of the VGA standard. These extensions range from higher resolutions and more colors to improved performance and even some advanced graphics processing capabilities. Intense competition has dramatically improved the price/performance ratio, to the benefit of the end user. However, several serious problems face a software developer who intends to take advantage of these "Super VGA" cards: there are no standards. Almost every card available is unique in how the SVGA functions are made available to the software. Because of this, it is difficult and expensive to

design software to run on every video card available. Often users discover that their new piece of software doesn't support their particular card.

The solution to this is the VESA standard. VESA defines a set of standard VGA BIOS extensions and standard video modes. The VESA software assists the application software in initializing and programming the video card. The card manufacturer normally supplies the VESA software, either built into the video card, or as a driver program (TSR) which the user can load when required.

Using VESA, the application software can use the full capabilities of the SVGA card. However, some video card manufacturers may not supply a VESA driver. To overcome this problem, the Hidden Image package includes a driver program written by Kendall Bennett from Victoria, Australia called UNIVESA (or Universal VESA TSR). The Universal VESA TSR will only run on machines that have an 80386 or better CPU (which is required for Hidden Image anyway). Currently the Universal VESA TSR supports the following SuperVGA chipsets (note that not all of these have been fully tested):

ATI Technologies 18800, 28800 Video7 V7VGA versions 1-5  
Ahead A & B Tseng Labs ET3000, ET4000  
Chips & Technologies 82c451/452/453 AcuMos AVGA2  
Everex S3 86c911/924/801/806/928  
Genoa Systems GVGA Advance Logic AL2101 SuperVGA  
OAK Technologies MXIC 86010 SuperVGA  
Paradise PVGA1A Primus 2000 SuperVGA  
NCR 77C20/21/22E RealTek 3106 SuperVGA  
Trident 88/8900 Cirrus CL-GD 5422 SuperVGA

More information on the UNIVESA TSR and how to install it can be found in the document file on the distribution disk.

## Display Appearance

The buttons under the Display Appearance heading control the way the menus and dialog boxes look on the screen. There are three options:



## Normal

When this button is selected the display appears in its default mode. The display has a three dimensional feel much like many other graphical user interfaces.

## Wire Frame

The Wire Frame button when selected changes the display to a simple wire frame appearance which is useful for some monochrome VGA monitors.

## Night Vision

The Night Vision button alters the display to one appropriate for use at night where one wishes to keep ones night vision. Most menu items and dialog boxes become red wire frame and the images are shown in shades of red. Some features are displayed in deep blue. It is a little-known fact that blue light is just as safe as red light for night vision use. The reason blue lights are not normally used for night vision is that the eye has very poor resolution in blue (due to chromatic aberration).

## **View Options**

The View Options menu item enables the View Options dialog box.

This dialog box allows the user to manually control options which effect the manner in which the image are displayed on the screen as well as the way histograms are calculated. Note that the Gamma fields are shared with the Manual Stretch dialog box explained later.

## Frame 1 Gamma

The Frame 1 Gamma field permits the user to manually enter a gamma correction value to apply to the display of the image in frame one. The current Gamma value is also displayed.

## Frame 2 Gamma

The Frame 2 Gamma field permits the user to manually enter a gamma correction value to apply to the display of the image in frame two. The current Gamma value is also displayed.

## Enable Gamma

The Enable Gamma button controls whether or not gamma correction is applied to the images displayed in any frame. The on-the-fly calculation of gamma values can be time consuming on slower 386 machines. When gamma correction is disabled, image display is sped up. Display is also sped up if the gamma value is set to exactly 1; in this case no gamma processing occurs even though gamma is enabled.

## Histograms

The two buttons under this heading control the manner in which histograms are calculated for both frames. When the Complete button is selected, the histogram is calculated for each pixel in the frame. When the Fast button is selected, only a small sampling of the pixels in the image are used to calculate the histogram. The Fast option still provides accurate and useful histograms and greatly speeds up the histogram calculation for slower machines.

## **Show Frame 1**

The Show Frame 1 menu item is a color coded toggle which controls the display of Frame 1. When this menu item is colored green, Frame 1 (only) is being displayed. When it is red, Frame 1 is hidden or the screen is in two frame mode.

## **Show Frame 2**

The Show Frame 2 menu item is a color coded toggle which controls the display of Frame 2. When this menu item is colored green, Frame 2

(only) is being displayed. When it is red, Frame 2 is hidden or the screen is in two frame mode.

## **Show Both**

The Show Both menu item is a color coded toggle which controls the display of two frame mode. When this menu item is colored green, Frame 1 and Frame 2 are being displayed simultaneously. When it is red the screen is in a single frame mode with either Frame 1 or Frame 2 being displayed (see above).

## **Photo View**

The Photo View menu item enables the Photo View mode. In Photo View mode all menu items, histograms and cursors are hidden to allow the user to take an unobstructed photograph of the screen. The image is adjusted for a full screen photo view using a bilinear interpolation. This feature works automatically when Photo View is selected from the View menu list while in one of the SINGLE FRAME modes (i.e. Show Frame 1 or Show Frame 2). The frame is interpolated up to match the screen pixel resolution and stops when one of the sides (X or Y) matches the corresponding screen resolution. For example, a 512x256 frame in a 640x480 video mode is interpolated up until the 512 goes to 640 and stops. A 512x512 frame in the same video mode would remain unchanged since one side already exceeds the corresponding screen resolution. If you are ensuring that you pixels are square, the correct aspect ratio is obtained with the 640x480 mode with most monitors.

## **Blink Mode**

This mode allows the user to blink the image in Frame 1 with the image in Frame 2 to show differences (perhaps a supernova, a comet or an asteroid in motion). The blink rate is variable. The user first enters a starting rate in the Blink Image dialog box. The number entered should be in tenths of a second and must be 1 or greater and less than equal to 600. The images are scaled to fill the screen using a bilinear interpolation in the same way

as for the Photo View and the blinking starts. While blinking, the user can vary the rate in increments of 1 by using F1 to decrease and F2 to increase. The rate can be varied in increments of 10 by using Shift-F1 and Shift-F2.

### **Low Stretch (F5)**

The Low Stretch menu item enables a preset low stretch mode. This stretch mode can also be enabled by using the F5 function key. Using the histogram, the low cursor is set to 95% of the 50th percentile level. The high cursor is set to 105% of the 99.9th percentile level. This is useful for deep-sky images.

### **Medium Stretch (F6)**

The Medium Stretch menu item enables a preset medium stretch mode. This stretch mode can also be enabled by using the F6 function key. Using the histogram, the low cursor is set to 95% of the 33rd percentile level. The high cursor is set to 105% of the 97th percentile level. This is useful for deep-sky images.

### **High Stretch (F7)**

The High Stretch menu item enables a preset high stretch mode. This stretch mode can also be enabled by using the F7 function key. Using the histogram, the low cursor is set to 95% of the 15th percentile level. The high cursor is set to 105% of the 95th percentile level. This is useful for low-contrast deep-sky images.

### **Moon Stretch (F8)**

The Moon Stretch set stretch mode which appropriate for lunar images can only be enabled by using the F8 function key. Using the histogram, the low cursor is set to the 0.01th percentile level. The high cursor is set to 105% of the 99.9th percentile level. This is useful for images of objects such as close-ups of the moon where there is no dark background.

## **Planet Stretch (F9)**

The Planet Stretch menu item enables a preset stretch mode appropriate for planetary images. This stretch mode can also be enabled by using the F9 function key. Using the histogram, the low cursor is set to the 25th percentile level. The high cursor is set to 130% of the 99.9th percentile level. This is useful for displaying planets where no part of the image should be displayed saturated.

## **Manual Stretch (F10)**

The Manual Stretch menu item places the display in manual stretch mode and enables the Manual Stretch dialog box.

This dialog box serves two purposes. First it allows the user to manually input numerical stretch values and gamma correction factors for each frame. Second, it indicates numerically the values for Min and Max stretch as well as gamma correction factor as previously set on the histogram scroll bars. Manual stretch can be engaged without bringing up this dialog box by hitting F10, clicking on the stretch bar, or by using the manual stretch function keys.

Note that the Gamma fields are repeated in the View Options menu.

## **Histogram**

The Histogram menu item is a color coded toggle which controls whether or not histograms are visible. Both frames are controlled by this one toggle.

## Process Menu

Clicking once on the Process pop-down menu item produces a menu of image processing functions. All processing functions with the exception of image calibration and exposure compensation are performed with Frame 1 as the source image and Frame 2 as the destination image. *Any image in Frame 2 is overwritten when a processing operation is performed.*

## **Image Calibration**

Perhaps the most essential first step in the processing of CCD images (after actually making an exposure) is the proper calibration of the image with respect to the CCD used to make the exposure. Unfortunately this of all image processing functions is probably the least well understood and least appreciated. Applying the correct image calibration functions can in themselves result in a substantial improvement in the CCD image. To illustrate how critical image calibration is, it is useful to remember that each 7°C rise in temperature of the CCD chip doubles the thermal noise in the image. Use of this feature requires small amount of preparation by the user prior to taking actual exposures.

First let's get the terminology in sync. For the purposes of this manual the following definitions will be used:

*Bias Frame:* A bias frame is obtained by taking a zero-length exposure with the camera. Due to various electronic idiosyncrasies the output from the camera is not the expected totally black image even though there is no exposure.

*Dark Frame:* During any exposure noise builds up in the CCD chip due to thermal noise effects (even with cooled cameras). An exposure with the lens cap on (or shutter closed) of some given length (usually the same length as the final exposure will be) is called a dark frame. This dark

frame consists of both the thermal noise and the bias noise from the camera.

*Thermal Frame:* A thermal frame is similar to a dark frame. Many people often incorrectly use the terms interchangeably. In fact, a thermal frame is a dark frame that has been corrected for bias noise. That is to say the bias frame has been subtracted off the dark frame, giving a thermal frame. This distinction is for a very good reason as discussed below.

*Flat Field Frame:* Each pixel in the CCD array has a slightly different sensitivity to light. To compensate for this a flat field frame is used. A flat field frame is an image of a plain, light toned, evenly illuminated target such as a projection screen or white piece of bristol board.

The Image Calibration menu item activates the Image Calibration dialog box.

This dialog box allows the enabling and disabling of the various image calibration functions.

Before going into detail of the three corrections possible, it is useful to make the distinction between thermally regulated and unregulated CCD cameras. With respect to thermally cooled CCD cameras, there are basically two distinct varieties: those that have the CCD chip temperature regulated to maintain constant temperature during an observing session (e.g., SBIG ST-6) and those whose CCD chip temperature is unregulated (e.g., ST-4, Lynxx-PC, Electrim). This distinction affects the way you may choose to perform thermal and bias image calibration.

## Thermal Calibration for CCD Cameras with No Temperature Regulation

With unregulated cameras, there is no electronic control of the CCD chip temperature. As an evening's observing progresses and the ambient air temperature changes, the thermal noise level in the CCD images will also change. In fact the noise level can change in the course of a long exposure (minutes). The optimal method for accounting for this variation is to take two dark frames, one before and one after the actual exposure, both of the same duration as the actual exposure. These two dark frames should be saved with names that are accessible by a DOS wild card (e.g, dark.1, dark.2). Care should be taken in selecting the file name so that only the two frames desired are actually accessible by the wild card. The Enable Dark box should be checked and the dark frame files specified by the wild card (i.e., dark.\*). No bias frame is required as the bias frame is included in each dark frame. Hidden Image will average the two dark frames and automatically calibrate the image as it is loaded. This works with the Load Frame 1 and Load Frame 2 menu items, as well as for image co-addition using the Combine menu item. For combining many short exposures, the dark frames should be taken before the first exposure and after the last exposure.

## Thermal Calibration for Temperature Regulated CCD Cameras

Those who have temperature regulated cameras can save a lot of telescope time using Hidden Image. Temperature regulated cameras usually use a negative feedback electronic or computer control to regulate the temperature of the CCD array. The power supplied to the Peltier coolers is varied according to the temperature actually measured at the CCD chip. This allows for a constant temperature throughout an evening's observing. Provided that the camera is working correctly the temperature of the CCD array should remain constant to within tenths of a degree over many



months of observing. Note that extreme ambient temperature variations can affect the accuracy of the regulation. Given constant temperature, the time consuming process of taking a dark frame before and after each exposure can be made unnecessary. In this case a set of dark frames should be taken, each of the same exposure length. They should be saved with names that are accessible by a DOS wild card (e.g., dark.1, dark.2). The length of the dark frame exposure should be several times longer than any exposure planned to be corrected using this set of dark frames. In addition to the dark frames, a set of bias frames should be made. Each frame should be saved with a file name that is accessible by a DOS wild card (e.g., bias.1, bias.2, bias.3,... etc.). The Enable Dark and Enable Bias boxes should be checked and the dark frame and bias frame files specified by wild cards (i.e., dark.\* and bias.\*). Hidden Image makes each dark frame into a thermal frame. The thermal frames are averaged and can now be used by the exposure compensation feature detailed below. Images are now automatically calibrated for both bias and thermal noise as they are loaded. This applies to the Load Frame 1 and Load Frame 2 menu items as well as for image co-addition using the Combine menu item.

In order to use this method, Exposure Compensation must be enabled as detailed below.

### Flat Field Calibration

To calibrate images for flat fielding error, a flat field is taken by shooting the twilight sky or much preferably, an image of a large, evenly illuminated projection screen or white card. Even illumination is essential for a good flat field. The exposure length should be enough to give an average pixel value of at least half the full dynamic range of the CCD camera system with no pixels saturating. For example, if you have a 16 bit camera with a maximum pixel value of 65536, each flat field exposure should have

an average pixel value of 32768. Many flat fields should be taken to be averaged. Each frame should be saved with a file name that is accessible by a DOS wild card (e.g., flat.1, flat.2, flat.3,... etc.). The Enable Flat box should be checked and the flat field frame wild cards (i.e., flat.\*). Hidden Image will average the flat field frames and automatically calibrate the image as it is loaded. This applies to the Load Frame 1 and Load Frame 2 menu items as well as for image co-addition using the Combine menu item.

The Image Calibration function is not automatically initialized when you start Hidden Image; you must go to the dialog box, verify the correct files are listed, and click OK. Progress is indicated by tones after each calibration is done.

*Note that the Image Calibration setup is cleared if you change the read file format and when you first enter the package.*

### Bias Frame File

The Bias Frame File field allows the user to specify the file or files (via DOS wild card syntax) containing the bias frame to be used for image calibration. The file(s) must be in the directory specified in the Load File Path dialog box.

### Dark Frame File

The Dark Frame File field allows the user to specify the file or files (via DOS wild card syntax) containing the dark frame to be used for image calibration. The file(s) must be in the directory specified in the Load File Path dialog box.

### Flat Field File

The Flat Field File field allows the user to specify the file or files (via DOS wild card syntax) containing the flat field to be used for image

calibration. The file(s) must be in the directory specified in the Load File Path dialog box.

### Enable Bias

The Enable Bias box when checked enables bias frame calibration.

### Enable Dark

The Enable Dark box when checked enables dark frame calibration.

### Enable Flat

The Enable Flat box when checked enables flat field calibration.

## **Exposure Comp.**

The Exposure Comp. menu item activates the Exposure Compensation dialog box.

To properly use this feature requires a CCD camera which is thermally regulated via some form of electronic control (e.g., SBIG ST-6). If this feature is used with images from an unregulated camera, the results are unpredictable and highly dependant on how constant the CCD chip temperature remains. The steps detailed above for Image Calibration for temperature regulated cameras must be followed prior to activating Exposure Compensation.

Exposure Compensation allows users with temperature regulated CCD's to save time at the telescope by using a thermal frame which is much longer (several times longer) than the longest expected exposure. Since the camera is thermally regulated this same thermal frame can be used over and over for different observing sessions as long as there are no extreme swings in ambient air temperature. The correct thermal compensation is applied for the exposure time of the image.

## Enable Compensation

When the Enable Compensation box is activated exposure compensation is automatically applied when images are loaded.

## Thermal Exposure Duration

The Thermal Exposure Duration field allows the user to specify the average duration of the thermal frames used (i.e., the duration of one thermal frame). It is important that all the averaged thermal frames have the same exposure duration. Note: The term "Thermal Frame" is used instead of "Dark Frame". This is because as each dark frame is read, the bias is subtracted resulting in a thermal frame. It is essential that thermal frames be used for accurate exposure compensation of the thermal noise.

## Image Exposure Duration

The Image Exposure Duration field allows the user to specify the duration of the image exposure for the image that will be read in. This field should be in the same units as the Thermal Exposure Duration field. It does not matter whether you choose milliseconds, seconds, minutes or hours as long as the units are the same for both.

## **Perm. Stretch**

The Perm. Stretch menu item activates the Permanent Stretch dialog box.

Any stretching or gamma correction performed on the images in Frame 1 or Frame 2 using the histogram bar or dialog boxes affect only the image as it is displayed on the screen. To make a stretch permanent so that it can be saved with the file requires the use of the permanent stretch dialog box. Permanent stretch stretches the image in Frame 1 and places the result in Frame 2. This dialog box has two options:

## Gray Levels

The buttons under this heading control the number of gray levels to be used in the final stretched image. The number of gray levels is directly

related to the number of bits used to store each image pixel. For an 8-bit image for example, the maximum number of gray levels is 256 (this is the typical setting for a TIFF file). Hidden Image supports intensity scaling of images to 8, 12 or 16 bits. The manner in which the image is scaled in intensity is controlled by the next set of buttons.

### Stretch Mode

The Stretch Mode buttons control the manner in which the image is intensity scaled and stretched to fit within the number of gray scales assigned.

### From Screen

The From Screen button uses the current stretching and gamma settings for Frame 1 and applies a direct mapping to the number of gray levels in order to make the resulting permanently stretched image visually appear to be the same as the stretched image in Frame 1. This is the most commonly used mode.

### Max Pixel

The Max Pixel button adjusts the intensity scaling by mapping the maximum pixel value of the image in Frame 1 to the maximum pixel level as defined by the Gray Levels button. Zero is left as zero. No stretch or gamma is applied.

### Clip To Range

The Clip To Range button performs no mapping of the intensity values. The resulting permanently stretched image is the image in Frame 1 with the pixel values clipped to the maximum value as defined by the Gray Levels button. No stretch or gamma is applied.

### **Linear Filters**

The Linear Filters menu item opens the Linear Filters dialog box.

This dialog box provides the parameter values for the linear frequency domain filtering performed by Hidden Image. There are two types of filters: low pass and high pass each of which removes a certain type of information contained in an image. High frequency information is information representative of fast intensity transitions, sharp detail or spiky noise. Low frequency information is representative of smooth features and slow intensity transitions. The low pass filter actually filters out high frequency information and "passes" low frequency information. It can be thought of as a blurring or smoothing filter. The high pass filter, on the other hand, filters out low frequency information and passes high frequency information. The "sharpen" filters offered in some image processing packages are in fact types of high pass filters.

In Hidden Image, both low pass and high pass filtering can be performed simultaneously resulting in a "band pass" or "band stop" filter (depending on radius selection) where a band of information between the low and high information cutoff areas is either passed or blocked. The severity of the filter (i.e., how blurry the low pass or how sharp the high pass) is controlled by the Radius field.

## Radius

Radius controls the severity of the filtering operation.

For high-pass filters, the least severe filtering occurs when the number is small; the most severe filtering occurs when the number is 1/2 the frame size (e.g., 128 in 256x256 frame mode).

For low-pass filters, the least severe filtering occurs when the number is 1/2 the frame size; the most severe filtering occurs when the number is small. *This is the opposite of high-pass filtering.*

All filtering in Hidden Image is performed in what is mathematically called "the spatial frequency domain". The original image is passed through a set of mathematical operations (called an Fast Fourier Transform) and is transformed to have a new representation. In the new representation the details of the image are ordered in a circle based on their sharpness or blurriness. The blurriest (low frequency) features are

concentrated towards the center of the circle and the sharpest (high frequency) features are progressively concentrated towards the outside of the circle. The outermost region of the circle has the same diameter as the frame size selected (or a radius of half the frame size selected). The Radius field for the low pass filter specifies the portion of the original frame size circle to keep in the filtered image. The larger the low pass radius, less high frequency information is removed, and the less severe the filter. For high pass filtering, the Radius field specifies the portion of the original frame size circle to eliminate from the filtered image. The larger the high pass radius, the more low frequency information is removed and the more severe the filter.

## Order

The filters in Hidden Image define a smooth transition between the frequencies removed and the frequencies passed. The Order field specifies how fast the transition is. This field should usually be kept at 1 but the filter can be made more aggressive by changing the order to higher values.

If a softer filter is desired than that provided by an order of 1, try adding a percentage of the original image to a filtered version of the image. This can be done with the sum/offset box.

## **Nonlinear Filters**

The Nonlinear Filters menu item enables the Nonlinear Filters dialog box.

This dialog box provides the user with a set of functions which are all nonlinear type filters. The nonlinear filters are "kernel" based. Pixels are compared to their neighbours and a decision is made on how to modify the pixels on the basis of this comparison. The size of the kernel used is determined by the Size of Kernel buttons. The larger the kernel size, the more severe the filtering and the longer the filtering takes. Note: Dead Pixel and Cosmic Ray filters always operate at the 3 x 3 kernel size regardless of the dialog box setting.

Six types of filters are defined:

## Dead Pixel

The Dead Pixel button selects the dead pixel removal filter. This filter is designed to eliminate the effects of any dead pixels in the CCD array. Dead pixels manifest themselves as "black holes" in an image. The Dead Pixel Threshold field controls the severity of the dead pixel removal. If pixels which are not dead are removed this value should be decreased. Alternatively, to remove more marginal pixels (perhaps pixels obscured by dust which were not removed by flat fielding) this value can be increased. Dust spots may require successive applications of this filter to remove them completely.

## Cosmic Ray

The Cosmic Ray button selects the cosmic ray removal filter. This filter is designed to eliminate the effects of cosmic rays striking the CCD array during an exposure. Cosmic rays usually manifest themselves as intense single pixel bright spots or false stars in an image. The Cosmic Ray Threshold field controls the severity of the cosmic ray removal. If pixels which are not cosmic rays are removed this value should be decreased. Alternatively, to remove questionable pixels which may be cosmic rays this value can be increased.

This filter can also be used to remove hot pixels (at the same time).

## Mean

The Mean filter button enables a filter which replaces the center pixel in the kernel with the average value of all the pixels in the kernel. The resulting filter has a blurring effect on the image. This is actually a linear filter operation but it is grouped with the nonlinear filters because it is kernel-based.

This is an alternative to the more sophisticated linear low-pass filter function. It has advantages when there are very bright stars in the image since it will not generate "ringing" around bright stars.



## Median

The Median filter button enables a filter which replaces the center pixel in the kernel with the median value of all the pixels in the kernel. The resulting filter removes any spiky noise in the image and has an overall slight blurring effect.

## Dilation (Max)

The Dilation filter button enables a filter which replaces the center pixel in the kernel with the maximum value of all the pixels in the kernel. The resulting image has the lighter regions of the image emphasized.

## Erosion (Min)

The Erosion filter button enables a filter which replaces the center pixel in the kernel with the minimum value of all the pixels in the kernel. The resulting image has the darker regions of the image emphasized.

## **Unsharp Mask**

The Unsharp Mask menu item enables the unsharp mask dialog box.

This dialog box enables the user to enter appropriate parameters and perform an unsharp mask operation on the image in Frame 1. Unsharp masking takes a low pass filtered version of the image in Frames 1 and subtract a portion of it from the original image. This operation has proved useful especially on planetary images. The operation is controlled by three parameters:

## Weight

The Weight field controls the severity of the unsharp mask. The unsharp mask performed by Hidden Image is designed so that there is no overall intensity drop in the resulting image. This field controls the amount of emphasis to put on the low frequency components being subtracted.

The range of values is between 1 and 49 and represents a percentage content in the resulting image. The overall brightness of the image is automatically adjusted so that it remains constant before and after processing.

## Radius

This field controls the radius of the low pass filter used. It operates the same as the Radius field described under Linear Filters - Low Pass. The smaller the radius the more severe the filtering of the mask.

## Order

This field controls the order of the low pass filter used (usually set to 1). It operates the same as the Order field described under Linear Filters - Low Pass.

## **Hist. Equalization**

The Hist. Equalization menu item enables the Histogram Equalization dialog box.

Histogram equalization is a very useful technique that reassigns pixel intensities to make better use of the video display. Astronomical objects often have a very large dynamic range, making it impossible to display all parts of an object with good contrast. Histogram equalization reduces the differences between bright and dark areas without reducing the contrast of either. This is a highly non-linear processing function; images can be made "unreal-looking". However it is a particularly effective technique to use on galaxy images. Galaxies usually have very bright cores and much fainter spiral arms; histogram equalization makes it possible to view both parts of the galaxy simultaneously.

This dialog box allow the user to provide the parameters and perform one of five types of histogram equalization on the image in Frame 1. Normally the Auto Scale function is used and the Min and Max fields are ignored. Auto Scale preserves the minimum and maximum values in the

original image. If Auto Scale is not used, the Min and Max fields define the boundary values that the resulting equalized image will contain.

There are several types of histogram equalization; each generates a particular shape of histogram. Experiment to find the best type for your image. The five types of histogram equalization available are as follows:

### Uniform

Uniform is useful for high contrast images where fine detail of nebulosity is desired without saturating bright stellar detail.

### Exponential

Exponential is useful for deep space objects such as spiral galaxies which have detailed cores as well as dimmer fine detail in spiral arms.

### Hyperbolic (Log)

Hyperbolic log has been found to be useful on full frame planetary images.

### Hyperbolic (Cube Root)

Hyperbolic cube root has been found to be useful on full frame planetary images (similar to above with a slightly different effect).

### Rayleigh

Rayleigh has been found to be useful on deep sky objects. Similar in effect to the Exponential but less severe. A good choice for galaxies.

### **Sum/Offset**

The Sum/Offset menu item enables the Sum Images With Offset dialog box.

This dialog box provides the user with the ability to sum percentages of each image frame and/or add a constant value to the resulting image.

There are three user definable fields:

### Add Frame 1 %

This field defines the percentage of Frame 1 added into (subtracted from) the resulting image. The value may be zero or negative and may exceed 100%.

### Add Frame 2 %

This field defines the percentage of Frame 2 added into (subtracted from) the resulting image. The value may be zero or negative and may exceed 100%.

### Add Constant

This field defines the constant value to add to (subtracted from) the final resulting image.

If a constant is subtracted (negative value entered), Hidden Image will not allow the resulting pixel values to go negative. Negative pixels will be set to zero. This allows you to clip an image at any desired level.

## **Combine Files**

The Combine Files menu items enables the combine files dialog box.

This dialog box provides the user the ability to combine multiple image exposures contained in separate files into a single image with the ability to shift images for correct registration. The user gets a box which is centered on a star on each of the successively loaded images. The images are shifted and added together. The files must be selectable using a DOS-style wild card. The first image (the first one found in the DOS directory) determines the overall centering. When selecting the registration star, the right mouse button controls the size of box, the left mouse button selects the star. In the case of an image which is not wanted (maybe it was badly

trailed), clicking off the image (anywhere out of Frame 1) will cancel that image. The average of all the registered images appears in Frame 2.

*Since the frames are averaged it is important that all the exposures be of equal length.*

### File Name Search

The File Name Search field is used to select files for adding by wild card selection (e.g., jup\*.ccd).

### Auto Center

The Auto Center button calculates the centroid of the star in the box to one tenth of a pixel accuracy and uses that when calculating the image shift. When off, the cursor position is used directly. This should normally be left on unless you are centering on something other than a star.

### **Copy 1→2,→**

The Copy 1→2 menu item copies the image in Frame 1 into Frame 2.

### **Copy 2→1→**

The Copy 2→1 menu item copies the image in Frame 2 into Frame 1. This is frequently done when you want to perform another processing step on an image.

## MaxEnt Menu

The MaxEnt pop-down menu item provides a menu of Maximum Entropy Deconvolution related parameters as well as the command to start a deconvolution run.

### **Basic Setup**

The Basic Setup menu item enables the MaxEnt Basic Setup dialog box.

This dialog box allows the user to enter two basic setup parameters necessary for a Maximum Entropy Deconvolution run.

### Iterations

The first field, Iterations, is the number of unattended iteration of Maximum Entropy Deconvolution that Hidden Image is to perform. This is only the initial setting; more iterations can be requested when processing stops. In addition, processing can be stopped at any point by hitting a key (the current iteration is completed before control is returned to the user). When processing is stopped the Processing Stopped dialog box appears where additional iterations can be requested (see below).

### Photons Per A/D Unit

A CCD camera is essentially a photon counting device. The image that is stored numerically provides a representation of the number of photons that hit the CCD chip and where they hit (which forms an image). The actual numerical values saved as an image for most cameras are not the actual number of photons but a number, called an analog to digital unit (A/D Unit or ADU) which represents the number of photons. For example, for the SBIG ST-6 camera the number of photons required to increase the count by 1 ADU is 6.67 photons. The value for the SpectraSource PC-Lynxx camera is 36.6.

The photons per ADU are available from camera manufacturers. Sometimes the number is not explicitly given but it can be calculated

from:

full well capacity / highest pixel value used

The photons per ADU should be entered in the Photons Per A/D Unit field.

Note that this value is in terms of photons actually detected by the CCD (i.e., photoelectrons) and therefore numbers such as quantum efficiency do not need to be factored in.

Hidden Image includes a feature to calculate the photons per ADU automatically from a series of flat fields. This procedure is explained below for the Photons menu item under the Utility menu.

## **Noise**

The Noise menu item enables the Noise Estimate dialog box.

This dialog box has the tools which allow the user to provide Hidden Image with an estimate of the noise in an image. Additional information on noise estimation is provided in the "Tips" section of the manual.

## Distribution

The Distribution buttons allow the user to select between two noise distributions commonly found in astronomical images. The most commonly used is Poisson. Uniform is most effective on planetary images.

## Uniform Noise Level

If the Uniform Noise button is selected, the noise level to use should be specified in this field. This is normally set to the standard deviation of the noise background. Normally this is set automatically using the "Extract From Image" option. If Uniform Noise is not selected this field has no effect.

## Black Level Offset

If the user at some point of previous processing subtracted off a constant from the image, the amount subtracted should be specified in this field. This value is normally zero. Dark frame subtraction does not affect this value.

## Background

Hidden Image needs to know the average sky background level in the image. This value should be specified in the Background field. Normally the Extract From Image feature is used to set this automatically.

## Extract From Image

To assist the user in determining the average background a tool is provided and is activated by the enabling the Extract From Image button. This tool is also used to set the uniform noise level if uniform noise is selected.

If this button is enabled, after hitting the OK control button, a cursor box will appear on the screen. The right mouse button controls the size of the box. The box should be positioned over a section of the image containing sky background. The left mouse button when clicked once records the statistics for that section of sky.

This procedure should be repeated for as many patches of background as practical (usually three is sufficient; one will do in a pinch). Be sure to adjust the stretch of the image so that areas of faint nebulosity can be seen and avoided.

Once finished, the user must move the box to the pop-down menu bar and click once. The correct background is automatically calculated and entered into the Noise Estimate dialog box (equal to the average background minus two standard deviations). While selecting areas of sky, a Statistics Information Box appears on the right side of the image (see below under Utility - Box for further explanation).



## Select PSF

The Select PSF menu item enables the Point-Spread Function dialog box.

This dialog box allows the user to specify the Point Spread Function (PSF) Hidden Image is to use for the deconvolution process. The PSF tells Hidden Image how the image was blurred. A single star image shows exactly how the light was spread about; therefore it represents a point-spread function. If a suitable star is not available in the image, "analytical" PSFs can be used.

Additional information on PSFs is provided in the "Tips" section of the manual.

## Function Type

The Function Type buttons permit the specification of the type of PSF to use for deconvolution.

### Gaussian

This button selects an analytical PSF with a Gaussian distribution with standard deviation as specified in the Standard Deviation field. This PSF should be used when a star cannot be extracted for use as the PSF, and the distortion in an image is dominated by atmospheric seeing effects.

### Exponential

This button selects an analytical PSF with an Exponential distribution with standard deviation as specified in the Standard Deviation field. This PSF should be used in cases where no star is visible in the image frame and the distortion in an image is dominated by instrumental effects.

### Fit Gaussian

This button is similar to the Gaussian button, but allows the standard deviation to be selected by "fitting" the Gaussian function to an imperfect PSF candidate in the image (an imperfect PSF candidate can be a faint

star, an object which is not a point source such as a moon, the edge of a planet or a star embedded in nebulosity). When the OK control button is hit, a box cursor appears. A star or other imperfect PSF candidate can be selected by adjusting the size of the box with the right button and clicking the left button when the object is centered in the box. A horizontal slice profile through the brightest part of the object appears at the bottom of the screen. A prototype Gaussian curve also appears superimposed on the slice. Two vertical bars represent the position of the standard deviation and may be moved with the cursor and left button. When the two shapes appear similar, click on the top menu bar. When fitting to an object that is not a point-source, such as a moon of Jupiter, make the fitted curve smaller than the slice profile.

## Fit Exponential

This button is similar to the Exponential button, but allows the standard deviation to be selected by "fitting" the Exponential function to an imperfect PSF candidate in the image (an imperfect PSF candidate can be a faint star, an object which is not a point source such as a moon, the edge of a planet or a star embedded in nebulosity). When the OK control button is hit, a box cursor appears. A star or other imperfect PSF candidate can be selected by adjusting the size of the box with the right button and clicking the left button when the object is centered in the box. A horizontal slice profile through the brightest part of the object appears at the bottom of the screen. A prototype curve also appears superimposed on the slice. Two vertical bars represent the position of the Standard Deviation which may be moved with the cursor and left button. When the two shapes appear similar, click on the top menu bar.

## From Image

This is the preferred method of determining the PSF; it is also the easiest. The user can extract a star (or other point source) directly from the image being processed.

When the OK control button is hit, a box cursor appears. The star or other point source PSF candidate can be selected by adjusting the size of the

box with the right button and clicking the left button when the object is centered in the box. The selected PSF *overwrites the image in Frame 2* and is available for inspection. The selected PSF is also saved in an internal buffer, so Frame 2 can be changed without affecting the PSF.

### From File

When selected, this button allows the user to specify a PSF by providing the name of a file containing the PSF in the File Name field. The PSF file must be the same size as the currently selected frame.

### Standard Deviation

This field allows the user to specify the Standard Deviation of the Gaussian or Exponential PSF in pixels. This field is overwritten if either of the Fit Gaussian or Fit Exponential buttons are selected.

### File Name

This field specifies the name of the PSF file if the From File button is selected.

### Pixel Aspect Ratio

For the four possible analytical PSFs the pixel aspect ratio for the camera used must be specified using the buttons under this heading. If the camera used is not listed the Custom button should be selected with the appropriate value placed in the Custom Ratio W/H field. If the pixel ratio is unknown the 1:1 button (defining a square pixel) can be used as an approximation.

### Custom Ratio W/H

This field specifies the custom pixel ratio if the Custom button is selected. The pixel ratio provided should be the pixel width divided by the pixel height (i.e., W/H).

The custom mode is also useful if the image is trailed due to poor guiding and an "analytical" PSF is used (Gaussian, Exponential, Fit Gaussian, or Fit Exponential). If the camera is accurately aligned so that the stars trail parallel to the CCD array, the pixel shape can be deliberately warped to account for the guiding error.

## **Go**

This menu button begins Maximum Entropy Deconvolution iterations. Be sure the image in Frame 1 is displayed the way you like it. The image in Frame 2 will be displayed the same way, and it is impossible to adjust the stretch during processing (the computer is busy!).

## **Processing Stopped Dialog Box**

At the end of the specified number of iterations, or if the user hits a key during iterations, the Processing Stopped dialog box appears. This dialog box allows the user to continue iterating, stop iterating, inspect the developing image, and save the developing image. The developing image in Frame 2 can be stretched or gamma corrected using the histogram scroll bar or function keys. The image in Frame 1 cannot be altered or stretched during this procedure.

## Iterations

This field specifies the number of additional iteration to perform if the OK button is selected.

## Hide

This button allows the user to inspect the developing image. It operates in the same way as the Photo View item under the View pop-down menu.

## Save

This button allows the user to save the image in Frame 2. A dialog box similar to the "Save Frame 2" box appears. After the image is saved

control is returned to the Processing Stopped dialog box. If you accidentally hit Save and wish to continue processing, hit the "Skip" button. Clicking "Cancel" will stop the processing run.

### Stop

This button stops the Maximum Entropy Deconvolution run. Once the run is stopped, it cannot be continued without starting from scratch.

### OK

This button resumes the Maximum Entropy Deconvolution run for the number of iterations specified in the Iterations field.

## Utility Menu

The Utility pop-down menu item provides two tools to help the user to analyze images. The first tool is oriented around single pixels. The second tool is oriented around a group of pixels within a defined box.

### **Pixel**

The Pixel menu item turns on a pixel analysis tool. This tool is a crosshair cursor which can be positioned over any pixel in either frame. When the left mouse button is clicked, an information box appears on the side opposite to the Frame clicked in. This box provides the X and Y location of the pixel relative to the bottom left corner of the frame as well as intensity. This tool is turned off by clicking once with the cursor positioned on the top pop-down menu bar.

### **Box**

The Box menu item turns on an area analysis tool. This tool is a resizable box cursor which can be positioned over any group of pixels in either frame. The right and middle mouse buttons can be used to change the size of the box. When the left mouse button is clicked, an information box appears on the side opposite to the Frame clicked in.

This box provides the location (X, Y) of the center of the current box position, the minimum (Min) and maximum (Max) intensity values in the box, the average (Avg) pixel intensity value, the standard deviation (Dev) of the pixel intensity values in the box and the centroid location (CeX, CeY) of the box. The X coordinate is horizontal and the Y coordinate is vertical. The bottom left pixel is at the 1,1 coordinate.

The calculations are performed on the data *inside* the box; the area under the border is not included. Note that the centroid is only accurate if there is a single star in the box.

This tool is turned off by clicking once with the cursor positioned on the top pop-down menu bar.

## Copy Star

This “donut” removal function cosmetically eliminates the ringing which appears around stars embedded in nebulosity or dust after Maximum Entropy Deconvolution. The new function is under the Utility menu item and is called Copy Star. When selected after performing Maximum Entropy Deconvolution, a box similar to the select PSF box appears. This can be sized to fit using the right mouse button. The box should be placed over a star which has a donut and should be sized to fully encompass the star and any ringing (bright and dark). When the left mouse button is clicked, the original star and information around is copied into the new image, eliminating the ringing while preserving all the fine detail in the dust lanes and nebulosity which was brought out by Maximum Entropy Deconvolution. The BACKSPACE key acts as an UNDO if you do not like the result.

## Photons

It was discovered that the Photons Per Analogue to Digital Unit reported by some camera manufacturers is inaccurate. The correct value actually varies from individual camera to camera (even of the same make and model). To overcome this Hidden Image has a method to calculate the photons per ADU from a series of flat fielded images. The method described below must be closely followed to get an accurate count.

To do this you must take a large number of flat fields with no filters, the more the better but a minimum of 5. You must then take a large number of bias frames (minimal exposure dark frames). Load **one** of the flats into frame 1 making sure that all image calibrations are performed as described above in the section on Image Calibration. Select Photons from the Utility menu item. The photons per ADU are automatically calculated and inserted into the correct dialogue box.



## APPENDIX 4 KEYBOARD/MOUSE QUICK REFERENCE

The following special keys are defined:

F1	Move frame 1 low stretch cursor down
F2	Move frame 1 low stretch cursor up
F3	Move frame 1 high stretch cursor down
F4	Move frame 1 high stretch cursor up
shift F1	Move frame 2 low stretch cursor down
shift F2	Move frame 2 low stretch cursor up
shift F3	Move frame 2 high stretch cursor down
shift F4	Move frame 2 high stretch cursor up
ctrl F1	Set stretch adjust rate very low
ctrl F2	Set stretch adjust rate low
ctrl F3	Set stretch adjust rate medium
ctrl F4	Set stretch adjust rate high
F5	Set low stretch
F6	Set medium stretch
F7	Set high stretch
F8	Set planet stretch
F9	Set moon stretch
F10	Set manual stretch
F11	Toggle histograms on/off
<ESC>	Stop MaxEnt processing, abort dialog box (same as clicking Cancel)
<RET>	Accept dialog (same as clicking OK)
SPACEBAR	Use instead of left mouse button for PSF/Noise extract operations
ALT-X	Quit Program

The following special mouse functions are available:

Histogram/Stretch Bar: To move the low stretch cursor, point the cursor to the desired location and hit the left button. To move the high stretch cursor, point the cursor to the desired location and hit the right button. To move the gamma cursor, point the cursor to the desired location and hit

the center button (on a three-button mouse), or hit both the right and left buttons simultaneously.

Clicking on the stretch bar with the mouse automatically engages the manual stretch mode. By engaging the manual stretch with the menu instead, a dialog box is available to set numerical stretch values. This same box also enables/disables the gamma adjust mode (gamma enabled slows down the display).

PSF Extract, Noise Extract, Box Utility: To enlarge the box, press the right mouse button. To make the box smaller, press the center button. To select an area of the image, press the left button or hit the spacebar. To stop the extraction process, click in the menu bar at the top of the screen.

Pixel Utility: To extract a pixel measurement, click the left button or hit the spacebar. To stop the measurement process, click in the menu bar at the top of the screen.

Image Scroll Bars: To move the image, point the cursor to the desired location on the scroll bar and click the left button. To accept the scrolled position, click in the menu bar at the top of the screen.

Photo View Mode: To restore normal operation, click any mouse button.

About Box: To restore normal operation, click any mouse button.

Two Button Mouse: Any function that is available by clicking the center button on a three button mouse can also be accessed by clicking both left and right buttons simultaneously. This allows the use of all functions with a two button mouse.

Dialog Box Text Editing: After selecting a text field in a dialog box, the first key pressed will erase the original contents. If instead you want to edit the text, simply hit the backspace key to start deleting characters from the end of the text.

Mouse Text Entry: Text can be entered into a field on a dialog box by clicking the mouse on any of the characters in the text entry box. Click on the "<" symbol to backspace.

File Search Function: The file search function is operated by entering the search parameters in the filename field using standard DOS wildcards (e.g., \*.ccd). All the files matching this search parameter are then displayed in a nested dialog box. The user can scroll through the list by clicking on the scroll buttons to the right of the list. To select a file, either click on the filename then on "OK", or double-click on the filename.