Image Analysis
Observational Astronomy

Name: ____

Introduction

In this activity you will use image processing software to manually calibrate and analyze a CCD image. You have used some of the varied capabilities of MaxIm DL in earlier activities, but this activity will be more systematic.

Manual calibration

Up to this point, you have used MaxIm's **Process** > **Calibrate** command to perform image calibration. However, this can be done manually using the **Process** > **Pixel Math** cammand. This command lets you perform a variety of operations on the pixel values of an image. In the window that appears, you can choose two images from among the open images, and the **Operation** you select is performed. For example, you can subtract one image from another in a pixel-by-pixel manner. If you specify a positive or negative number under **Add Constant**, that value is added to every pixel in the final image after the specified operation is performed. If an operation you specify results in pixels with negative values, MaxIm will set them to zero. So, when subtracting in **Pixel Math**, make sure you have a constant large enough to prevent negative pixel values. Always check the statistics and histogram for the image, but 1000 seems to work as a safe default value.

For the first part of the activity, you will work on the supplied raw images of M51. Open one in MaxIm and examine it by adjusting the **Screen Stretch**.

1. Describe how the unprocessed image looks:

The first calibration step is to subtract a *dark frame*. To review, this is an image taken with a closed shutter for the same length of time as the actual image. Subtracting a dark frame removes any thermal signal from your image; themal noise is minimized by averaging several dark frames together. (A dark frame subtraction automatically includes a **bias frame** subtraction.) You need to find a dark frame that matches the exposure time and CCD temperature of the image. You can view these (and many more) properties of an image by using **View** > **FITS Header**. Look under the DATA\CALIBRATION\MASTERS directory, find a dark frame with matching exposure time and temperature, and use **Pixel Math** to subtract it from the raw image. Note that these master files are already made of many averaged dark frames.

2. Describe how the dark-subtracted image looks:

Next it is a good idea to divide the image by a *flat frame*. This is an image taken of a uniformly illuminated surface (a screen in the dome, or the sky) and picks up on any nonuniformities in CCD response, as well as any dust in the telescope/camera optics. The trouble is that the optical setup cannot be changed once you have your flats. In your case however, there is an good averaged flat under the DATA\CALIBRATION directory. Check its History in its Fits Header and dark-subtract the flat, if necessary. Then use **Pixel Math** to divide your image by the flat.

3. Describe how the dark-subtracted image looks:

Bad pixels and hot pixels

There are some bad pixels in the CCD chip (these appear as hot spots or streaks in all images). MaxIm has a feature called the **Bad Pixel Map**, which takes a list of identified bad pixels and replaces them with the averages of the surrounding good pixels. The auto-calibration command is currently set to do this, but it can be invoked manually with the **Process** > **Bad Pixel Map** command. When the bad pixel window appears, a bad pixel map should already be defined. Just click on the image you want to process and click on **Process** to apply the current map. Do this for your image.

4. Describe how the image looks with the bad pixels removed:

There are still hot pixels not due to intrinsic defects (probably from cosmic rays striking the CCD). These can be removed with the **Filter** > **Kernel Filters** command. Select **Hot Pixel** and (while watching the preview) adjust the threshold until the hot pixels go away.

Combining images

When dealing with faint images, it is often useful to combine them images, either through addition (to increase signal) or averaging (to reduce noise). At this point in the activity, you will need all the available raw frames of M51 open and calibrated up through hot pixel removal. Once this is done, go to the **Process** > **Combine** command. Select the images you wish to combine in the dialog that appears, then click **OK**. You then need to choose alignment options (review earlier activities on image alignment if necessary), and the **Output** type. Choose **Average** click **OK**; there will now be a new averaged image.

5. Describe how the new averged image looks, especially compared with the unaveraged versions:

Stretching an image

You should be well used to adjusting the **Screen Stretch** as you work, but for objects with both bright and faint parts (such as galaxies), it is sometimes helpful to perform a permanent logarithmic stretch to bring out the full range of brightnesses in the image. Use the command **Process** > **Stretch** to do this. Set the **Type** to **Log**, and the **Input Range** to **Screen Stretch**. If you plan to save the image as a JPEG, set the **Output Range** as 8-bit; otherwise you can set it higher. You can then adjust the Screen Stretch to choose the brightness range to include in the stretch. Keep watching the preview: This is the place to tease out the faint details in M51. Click **OK** when you are satsified.

6. Describe how the logarithmic stretch has changed the appearance of the image:

Final touches

You have now covered the basic tools of image processing. You may want to experiment with the other filters under the **Filter** menu. (You'll find that the **Dilation** filter under **Kernel Filters** can smooth out some graininess in an image, but this is mainly a cosmetic touch.) When you are satisfied with your processed image of M51, save it as a JPEG and print a copy to turn in to the TA.

If time permits, try processing another image in this manner.

Photometry

Accurately measuring the brightness of of stars is called *photometry*, and is a very important astronomical technique. When working with CCD images, photometry amounts to counting how many photons were collected. This can be easily done using Maxim's **Information Window**, which you can find under **View** > **Information Window**.

Open and calibrate any image containing at least one star. In the **Information Window**, set the **Mode** to **Aperture**. When you move the cursor over the image, you will see concentric rings instead of the usual pointer. The inner circle is the *aperture*, the inner ring is the *gap*, and the outer ring is the *annulus*. You can control the size of all of these by right-clicking on the image. Adjust the aperture size to fit around a star, and the gap and annulus sizes so that the annulus samples an area away from the star. (If you double-click on the image, the aperture will stay there, and you can then move it with the arrows keys.)

Now look at the **Information Window**. **Intensity** is the total number of counts in the aperture region after the background average (from the sky in the annulus) has been subtracted.

7. Record the intensities for a few stars. Define one star as a reference magnitude and compute the relative magnitudes of the others. (Remember: $m_a - m_b = -2.5 \cdot log(\frac{I_a}{I_b})$)