Research Techniques in Astronomy Assignment 1

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Abstract

The three colour images of M64 were successfully layered on top of each other. A short analysis was done on the composite image. The QUEST data was extracted and passed through a Python script which corrected for the bias, dark and flat fields, obtaining a reduced sky-subtracted image. An additional combined image was made for clarity. From the three final reduced science images, four moving objects were marked, which are believed to be Neptune's moons.

I. M64 COMPOSITE COLOUR IMAGE

A. *Introduction*

The Black Eye galaxy also known as M64 or NGC 4826, is a spiral galaxy located 5.3 Mpc away. The naming originates from a dust cloud around its nucleus, prohibiting light from coming through[1][2][3].

Three images in the red, green and blue bands were provided of M64 in this part of the assignment. The goal was to create a composite image in DS9 with all bands present and control the scaling to obtain a clear image of the galaxy. The subsequent objective was concerned with finding an interesting region of the galaxy image.

B. *DS9 procedure*

The whole process of adding the three images is rather straightforward as DS9 has an option to create an RGB image in the "*Frame*" menu. Selecting the red, green and blue options and opening the corresponding colour file, creates the RGB image.

The difficult part comes from working with the scaling and finding the right amount of each colour to get a good resolution on the galaxy, specifically its spiral arms and the centre.

Originally a combination of *"z-scale"* and *"log"* was used to create the image, but the spiral arms were difficult to see and the nucleus was almost indistinguishable. A much more successful approach was using the "*Scale parameters*" in the "*Scale*" menu, providing additional control to the user.

C. *Final image*

Figure 1 shows the final image after using "*Scale parameters*" with limits of -1350 for "low" and 1700 for "high".

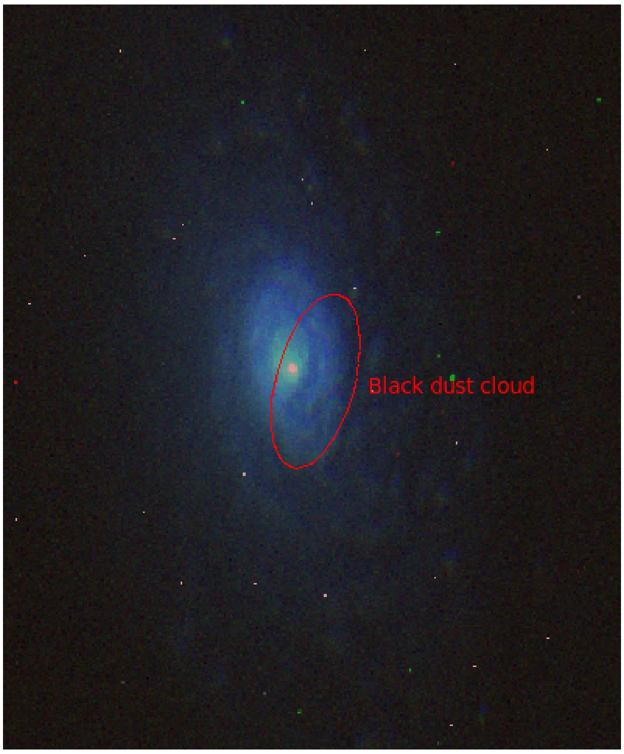

Fig. 1: A composite colour image of M64 with the dust cloud specified in red

D. *Analysis*

The result shows a nice view of M64 and more specifically enough detail for the dust region and the spiral arms to be present as well.

II. QUEST DATA IMAGE PROCESSING

A. *Introduction and objectives*

Neptune has 14 moons and using images from the night sky we can track their movement against a still image of the gas giant[4]. Using the QUEST data provided by Yale University and analysis was done on the available 3 sets of science data. The images used for the analysis first went through a series of corrections which include accounting for bias, dark and flat fields, obtaining a reduced image and subtracting the sky from it as well. The three images were then matched based on 4 reference stars so they have the same x and y values. Finally, by using the "*blink*" functionality 4 moving objects were found which are believed to be some of Neptune's moons.

B. Image processing

All of the corrections on the images were done via Python utilising the NumPy and SciPy packages. Two bias-corrected dark field files were used, one for the flat images with an exposure time of 10 seconds and one for the science images with an exposure time of 180 seconds. The fits files came in their folders when extracting the data so the python script works by looking for what's necessary on this folder basis.

1) Flat field images overscan correction: The flat images available were sky flat images and first needed to be bias-corrected. An overscan region between the 599 and 636 pixels on the x-axis was used. A median of said overscan region was taken and applied to each image separately. The dark field was also subtracted on an image by image basis. After this, the images were stacked in a 3D array and median combined together. The overscan region was removed as it became redundant at this point. The normalisation of the values followed which was done by dividing the median combined flat image by its median value. As it can be seen in Fig. 2 the mean value is now 1. This image served as the master flat.

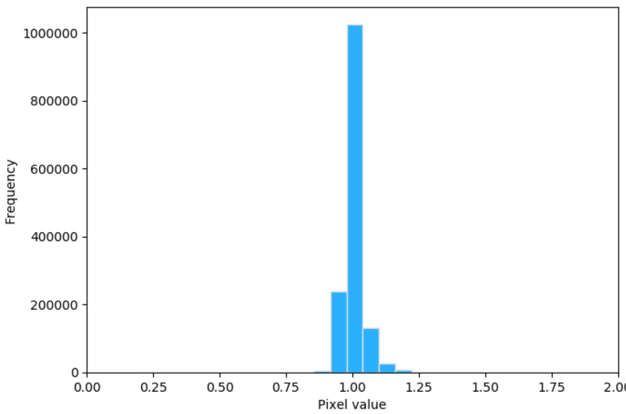

Fig. 2: Pixel values of the entire master flat field file

2) Reduced and sky-subtracted images: An identical approach was taken for the correction of the science images. The overscan region had the same coordinates and the only major difference was the use of a different dark field file with an exposure of 180 seconds, the same as the science one. Once the images were corrected, the master flat field was used to remove the two dust marks and other imperfections from the original. A comparison can be seen in Fig. 3 and 4.

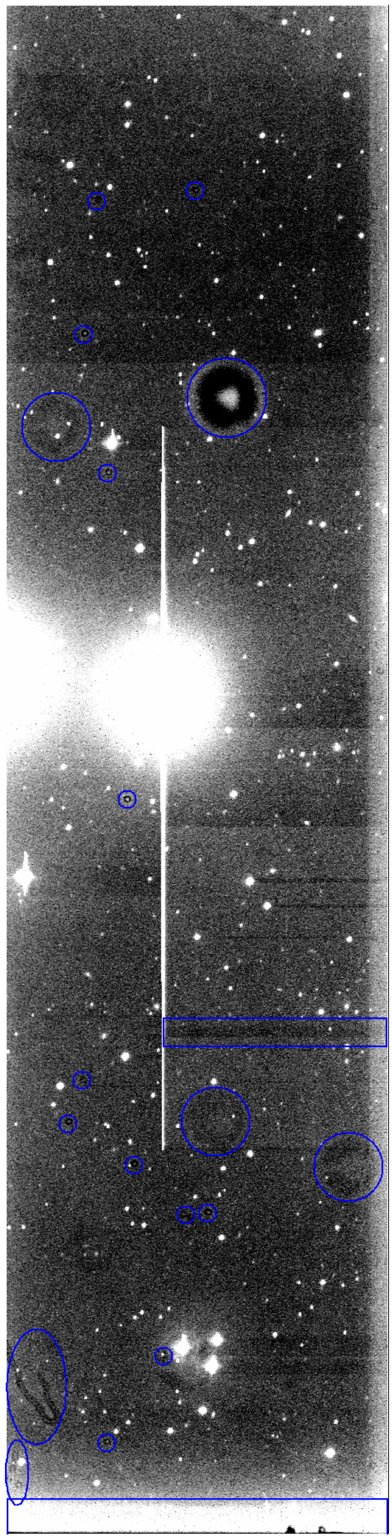

Fig. 3: Original science image with some of its faults marked

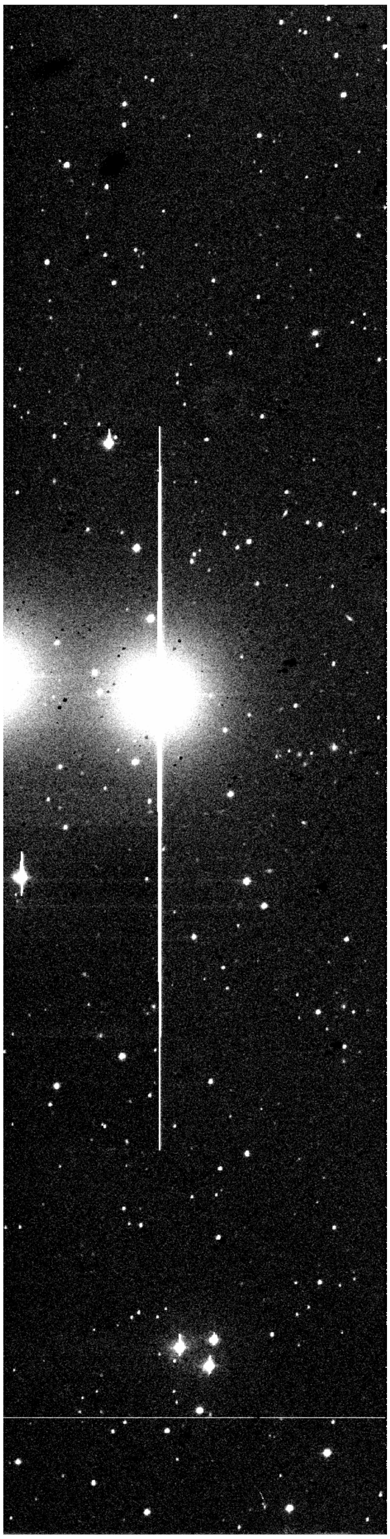

Fig. 4: A reduced version of the same science image

This is followed by sky-subtraction which takes the mode of the reduced images and subtracts it from all pixel values.

3) Coordinates fix and image stacking: The resulting images are then adjusted for differences in x and y via interpolation. Image *20130910234901s.C22* was used as a reference for this task. By using four or more stars as an anchor and finding the difference in their coordinates across images a shift for each non-reference image is determined. They are then moved by that amount in the two directions.

These final images were also stacked into a single image which combined cleaned up the empty space left over from interpolation and increased the strength of the more prominent features in the picture.

4) Moon recognition and final images: Using the *"blink"* function the now fully corrected and synced images 4 objects were found to be moving at a steady pace between images. These can be seen marked on the images in Fig. 5.

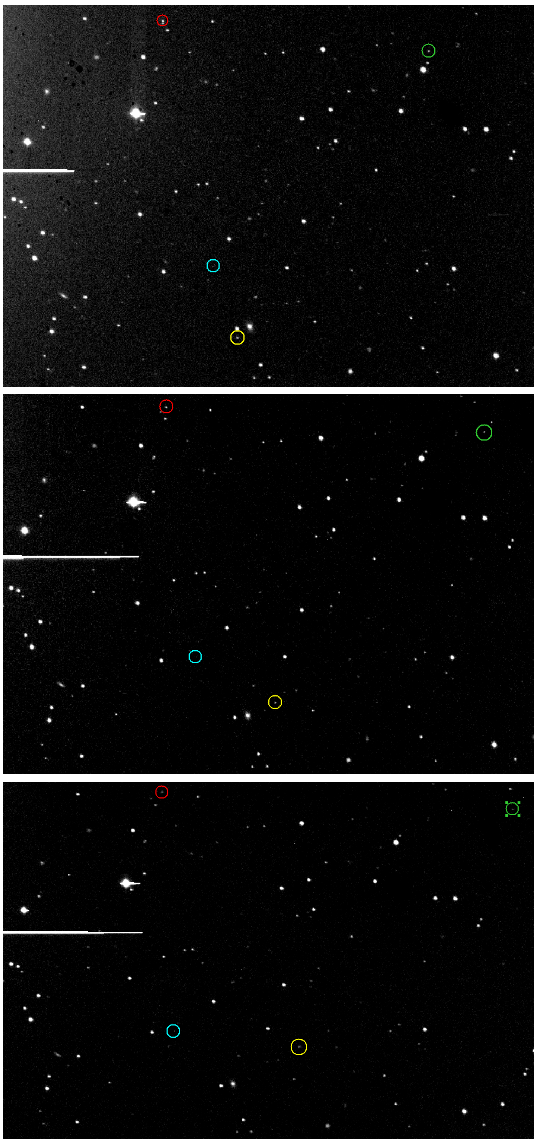

Fig. 5: Neptune moon tracking through calibrated science images. First image: 901s; second image: 246s; third image: 543s

The stars move through the coloured regions with the coordinates found in Table 1.

TABLE I: Coordinate evolution for coloured moons

	901s		246s		543s	
	x	y	x	y	x	y
Red	18	1771	22	1770	26	1754
Green	430	1993	469	1927	506	1867
Cyan	404	1791	400	1806	398	1830
Yellow	46	2337	59	2244	72	2158

A shorthand version of the science names has been used here and in the images in Fig. 5, where only the last 3 numbers of the name are used. The images are taken around 2 hours apart from one another with *901s* being the first done on the 10th of September 2013 at 23:49 UTC.

C. Final images and discussion

The final results from the previous section were very satisfying to obtain as it can be seen from Fig. 3 and 4 that the initial corrections did what they were intended to do.

A limitation of using the sky flats in this specific case was the inclusion of black blobs which are stars captured during the exposure. Future work should include a way for these stars to be masked out from the master flat file so that the final results are cleaner.

Another point of contention is the charge bleeding observed on Neptune and a close-by star. A solution to this was not found and left in the image as it did not impede the task at hand, but ideally should be removed in the future.

D. Conclusion

The original science images were successfully corrected using the provided sky flats and dark files. The overscan region was used in both the flats and science images to remove bias and the already bias-reduced darks also were used based on their exposure time on the two sets of data. The sky-reduced images were lined up properly and used to find the moving Neptune moons. The main objective of this part of the project was accomplished with some room for improvement in the future regarding images calibration.

References

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[2] F. P. Israel, “Ci and co in nearby galaxy centers,” *Astronomy Astrophysics*, vol. 493, no. 2, pp. 525–538, Nov. 2008, ISSN: 1432-0746. DOI: 10.1051/0004-6361:200810655. [Online]. Available: http://dx.doi.org/10.1051/0004-6361:200810655.

[3] H.-W. R. Rix, J. Kennicutt Robert C., R. Braun, and R. A. M. Walterbos, “Placid Stars and Excited Gas in NGC 4826,”, vol. 438, p. 155, Jan. 1995. DOI: 10.1086/175061.

[4] D. D. R. Williams, “Neptune fact sheet,” *NASA*, [Online]. Available: https://nssdc.gsfc.nasa.gov/planetary/factsheet/neptunefact.html.