School of Physics and Astronomy

Senior Honours Project
Astrophysics

Deep Stacking of AGN Hypervariables

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Abstract

In this project, I examine the unusual luminosity of the galactic nucleus SDSS J094511 located at redshift $Z =?$ using data gathered with the Liverpool Telescope on Las Palmas between 2012 and 2018. I develop several algorithms for centroiding on the object, for resampling to obtain higher resolution, and for stacking images to increase the S/N ratio in the frame. I extract radial and linear cross sections from the object and compare these to the point-spread-function of the Liverpool Telescope CCD to corroborate the hypothesis that linear increases in the luminosity are *not* due to instability of the viscous AGN accretion disk, but a gravitational microlensing event by a star in an intervening galaxy or dwarf galaxy.

Declaration

I declare that this project and report is my own work.

Signature: Alex Wheaton Date: April 2, 2020

Supervisor: Professor A. Lawrence, FRSE, FRaS 12 Weeks

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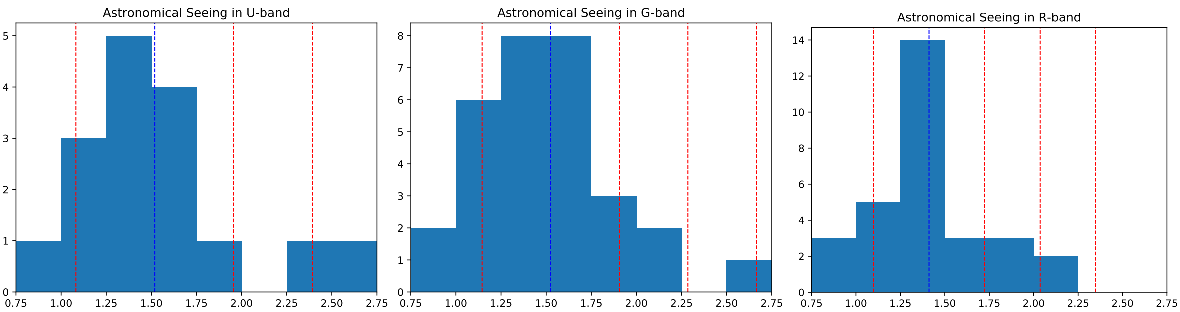

Figure 1: Astronomical seeing of the LT data in Johnson UGR bands.

There are several technical problems associated with the Liverpool Telescope (LT) data. In many frames, astronomical seeing is very poor. All frames, particularly in the U-band, are littered with hot pixels or cosmic rays detections.

A single image of J094511 in the U-band has a seeing of $r_0 = 999.0''$, which is likely an error. For this reason, the image has been thrown out and its seeing parameter excluded from the calculation of the mean and standard deviation of the seeing data.

2.1 S/N Ratio and Astronomical Seeing

3 Centroiding on J094511

3.1 Initial Guess: Max-Value Centroiding

3.2 Initial Guess: WCS Centroiding

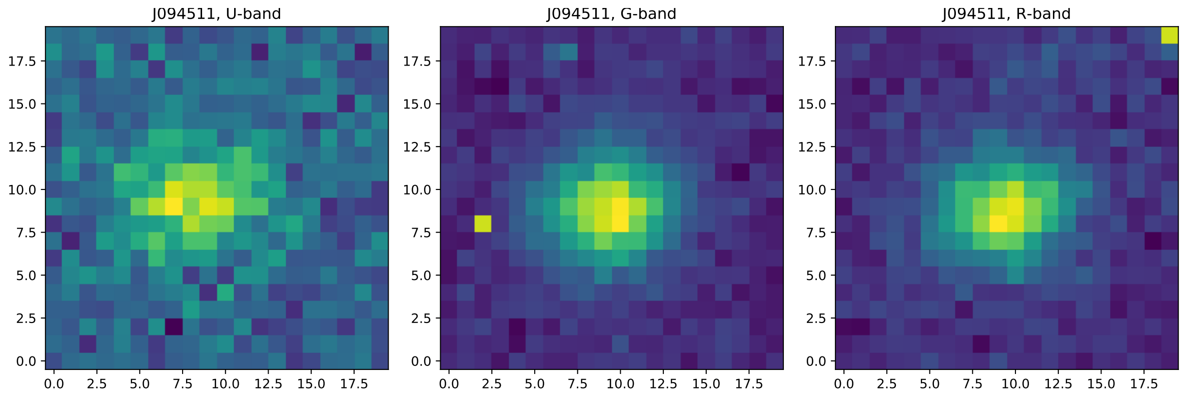

Figure 2: Image stack of J094511 in the Johnson UGR bands.

3.3 Refinement: Two Dimensional Weighted Mean

3.4 Refinement: Gaussian Fitted Centroiding

In two dimensions, the power to which e is raised in the Gaussian function is any negative-definite quadratic form. Consequently, the level sets of the Gaussian will always be ellipses. A particular example of a two-dimensional Gaussian function is:

$$f(x,y) = A \exp\left(-\left(\frac{(x-x_0)^2}{2\sigma_x^2} + \frac{(y-y_0)^2}{2\sigma_y^2}\right)\right) \tag{1}$$

Here, the coefficient A is the amplitude, (x_0, y_0) is the center and σ_x, σ_y are the x and y spreads of the blob. In general, a two-dimensional elliptical Gaussian function is expressed as:

$$f(x,y) = A \exp\left(-\left(a(x-x_0)^2 + 2b(x-x_0)(y-y_0) + c(y-y_0)^2\right)\right) \tag{2}$$

Where the matrix:

$$\begin{bmatrix} a & b \\ b & c \end{bmatrix} \tag{3}$$

Is positive-definite. For the general form of the equation the coefficient A is the height of the peak and (x_0, y_0) is the center of the blob. If we set:

$$a = \frac{\cos^2\theta}{2\sigma_x^2} + \frac{\sin^2\theta}{2\sigma_y^2} \tag{4}$$

$$b = -\frac{\sin 2\theta}{4\sigma_x^2} + \frac{\sin 2\theta}{4\sigma_y^2} \tag{5}$$

$$c = \frac{\sin^2\theta}{2\sigma_x^2} + \frac{\cos^2\theta}{2\sigma_y^2} \tag{6}$$

then we rotate the blob by a clockwise angle θ (for counterclockwise rotation invert the signs in the b coefficient).

3.5 Aperture Centroiding

3.6 Challenges in the U-band

4 Cross Sections of J094511

4.1 Linear and Radial Cross Sections

4.2 Excess Luminosity in the Wings

4.3 Point Spread Function Subtraction

5 Analysis

6 Conclusion

Appendix A: Alignment Algorithm