CCD Imaging of STF 93 C & D

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Abstract: Polaris (STF 93) is a bright Cepheid variable, thus most interesting to the astrophysicist . One, for instance, may ask if the birth of these milepost stars typically involve the formation of additional physical components. Close study of Polaris and its 5 attendants, one spectroscopic, perhaps one interferometric and three visual, may help in the understanding of these special object's evolution. In addition to Sir William Herschel's early discovery of the B component, Burnham, in 1884, discovered C&D, both much fainter companions of Polaris. The last observation and measurement of "C" was by Burnham in 1890 and "D" was recently (1999) identified in 2 MASS images. Described here is the technique used to recover C and solidly image both C&D in the presents of the bright primary. These images were measured (results reported elsewhere) to obtain accurate positions angles and separations of the B, C & D components. Preliminary color measurements of C&D were performed and is reported here. This work is in response to a challenge by Dr. Brian Mason of the USNO to the double star group to recover and measure the positions of these two faint components. The observing period was March13 through April 16, 2005.

Introduction

Measuring faint components in the presence of a bright primary presents an especially difficult task, even with a CCD detector. As the exposure is increased to reveal the dim attendant stars, the light scatter in the telescope, CCD saturation effects, reflections off the pixel array to the chamber widow and back, and the Airy rings themselves, all add to an image blur of the primary perhaps 40 times or more greater in diameter than a properly exposed image. When the light ratio between the primary and faint components reach about 60,000 or about 12 magnitudes, the direct detection of these are limited to separations on the order of 50 arc seconds. Special instruments are currently employed to overcome these limitations and are patterned after Lyot's white light solar coronagraph where special occultors block, not only the offending star, but also the strong diffracted light originating at the entrance pupil rim. Great care is taken to also reduce various other instrumental sources of scattered light. Currently, circumstellar disks surrounding bright nearby stars, such as Beta Pictoris, are being revealed with such instruments.

A much simpler and older method, called the focal plane masking bar, can achieve satisfactory results for less demanding work. Visual observers sometimes use a bar mask in the field stop of their eyepiece to better view faint adjacent objects. In the measurements described here, a mask was placed against the outer surface of the CCD chamber window. Because the mask was located about 12mm before focus, some annoying mask diffraction was present, but not so harsh as to prevent a satisfactory result. Placing the mask against the chip face was considered, but the risk of damage was considered too great. The 1mm wide masks were of two types. The first a totally opaque foil and the second a #29 Kodak red gelatin filter. In the second type the filter, when combined with a photometric V-band filter, greatly attenuated the primary, but left the faint components "in the clear," transmitting through the V-band alone. This optical trick allowed the measurement of PA and Separation of all components. Proceeding with example CCD images, I tell my little story.

The Images

All CCD images were obtained with an ST-7XE

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camera manufactured by Santa Barbara Instrument Group (SBIG). The camera employs a Kodak KAF0401E chip without an anti- blooming gate. The camera is used at the 278.8-inch focus of an 9-inch medial refractor. Except where noted, North is up and East is left in the following images.

Figure 1 is a short (1 sec) exposure of Polaris and its popular companion, a view familiar to us all. A photometric R-band filter was used to improve contrast. Slight saturation of the primary is evident.

Next, an attempt was made to directly detect components C&D. This image (see Figure 2), although revealing their presence, left the primary saturated,

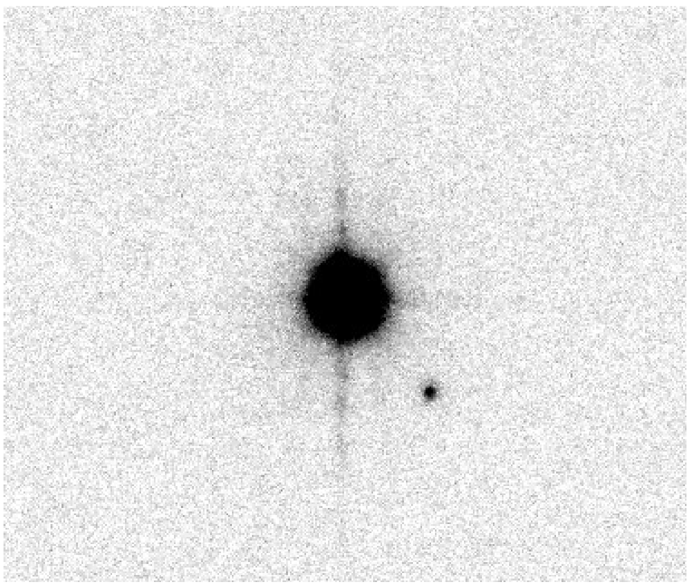

Figure 1: Polaris and its well known physical companion. Exposure: 1 second in R-band. No binning.

thus leaving no hope of determining its centroid. The signal to noise level of the faint components is also rather poor for accurate work. The scattered light surrounding the primary shows both a peculiar diffraction pattern and diffraction "spikes" typical of a 4 vane spider, yet the aperture is un-obscured. This pattern is, instead, most likely caused by CCD saturation and reflections from the CCD array itself and the chamber window. The non-telescopic origin of the bulk of this "scatter" is easily demonstrated by rotating the CCD head, where the pattern remains fixed in orientation and appearance with respect to the display.

To measure positions the color filter bar mask was employed and a typical image in this mode can be seen in Figure 3. Varying the background and level

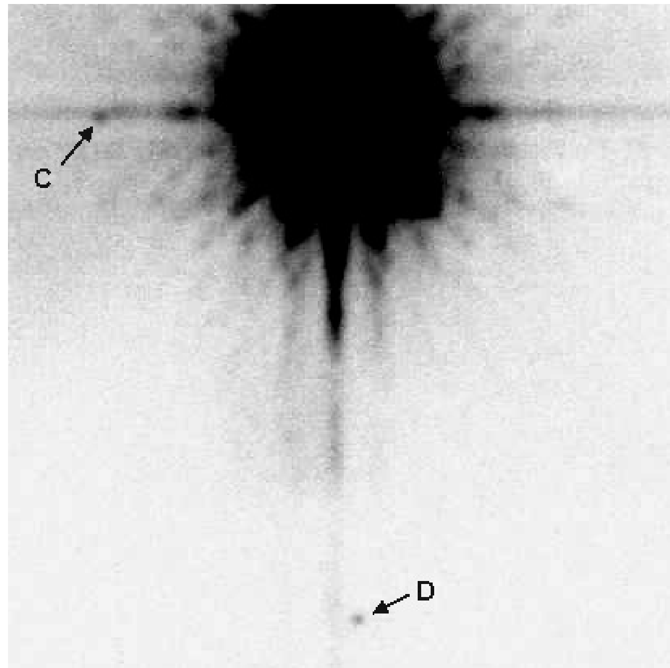

Figure 2: Two stacked 40-second exposures of Polaris in R-band. No binning.

controls allowed good initial location of the primary centroid and could be sensitively trimmed to near zero error by careful adjustment of the sample area and its location. From there the other component's PA and separation is just a few keystrokes away. Polaris trails were used to correct the PA errors introduced from working so close to the true pole. Many images were taken and measured to reduce errors.

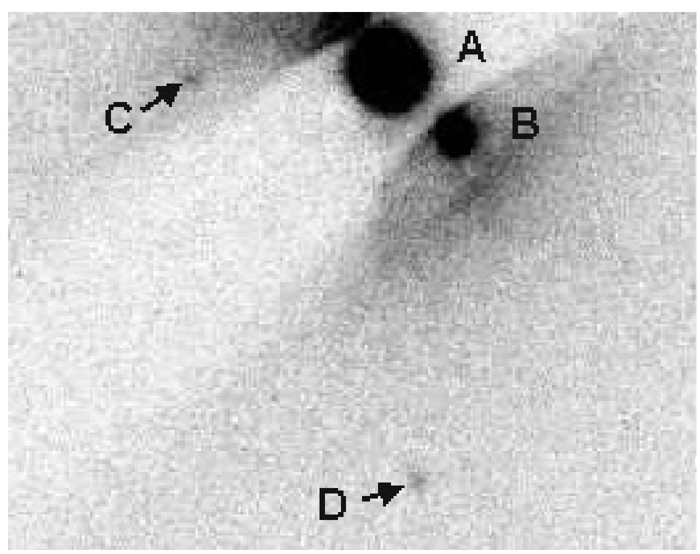

Figure 3: Polaris attenuated with red gelatin mask and V-band photometric filter. Image 2X2 Binned

Finally, an attempt to measure the color index of C&D was made using opaque occulting bars and mini cones suspended on 0.007 wire. The occulting bar method proved best and an example unfiltered image, shown in fig 4, reveals many very faint field stars with the C&D components well exposed. The CCD head was rotated to better situate "C" so North is now upper left. Many exposures in V, R, and I-bands were made to arrive at preliminary magnitudes and color indices as follows: C component: V-band mag = ~13.80 R-I = 0.56, D component: V-band magnitude 14.3 R-I= 0.67, V-I = 1.08, Obtaining V-I values for "C" proved very difficult due to excess scatter in V-band for this closer in star.

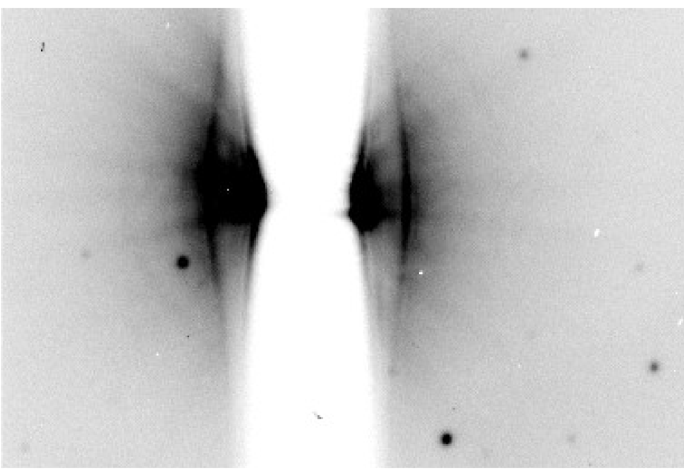

Figure 4: This image shows Polaris occulted with a foil bar. The faint components C and D are now well revealed. Exposure: 200 seconds, unfiltered.

Tentative Conclusion

The color work in R and I-bands show both components lying somewhere near a spectral class K5V or perhaps slightly redder. Polaris is a supergiant of spectral class F7 1b with an absolute magnitude of -3.64 . Assuming C and D are main sequence K5V objects, their absolute magnitude is about 7.4. Stars of these two spectral classes (F8 1b & K5V would show a magnitude difference of ~11.0 if at the same distance. Polaris is listed at magnitude 1.97 so using LSO magnitudes a Δm of 11.8 for AC and 12.3 for AD is obtained. The color / magnitude slope in the region of K5 is steep and small errors of color measurement can swing the predicted Δm considerably either way. Also the measure of the V-magnitude is noisy and uncertain, further limiting the precision. Despite these difficulties the data do weakly infer that C and D may be physical with Polaris!

Future Studies

Obviously, the occulting method needs improvement to reduce scattered light in B & V-bands. I am presently designing a prime focus occulting arrangement to make use of the coronagraphic properties of the medial instrument. This color index work on Polaris's faint outer companions is an ongoing project, and hopefully in the spring of 2006 the instrumentation will be fully up to the task. A well made stellar coronagraph could prove to be a useful tool for amateur studies of other binaries.

Jim is a retired optical research worker and presently lives in southern NH. He measures doubles from his homemade backyard observatory located at an elevation of 1,300 feet. He reminds us to note that Polaris's very close companion Ab was recently resolved by Hubble in an imaging program headed up by Dr.Nancy Evans of CfA.