## 1. MEASURING THE PROPER MOTION OF THE CRAB NEBULA

IN THIS TELESCOPE EXPERIMENT, YOU WILL OBTAIN NARROW-BAND [$OIII$] and H$\alpha$ IMAGES OF THE CRAB NEBULA AND DETERMINE THE EXPANSION SPEED OF THE GAS. IN THE SECOND PART, YOU WILL COMPARE YOUR IMAGE TO A SIMILAR IMAGE OBTAINED IN 1973 AT THE KITT PEAK 4m TELESCOPE TO DETERMINE THE EXPANSION VELOCITY OF THE NEBULA SINCE 1973.

1. BE SURE TO FOCUS THE TELESCOPE USING THE H$\alpha$ FILTER PRIOR TO OBTAINING YOUR IMAGES. Use the same focus for both the H$\alpha$ on-band and off-band and [$OIII$] observations.

2. Obtain 5 minute images of the Crab Nebula (M 1) through both the H$\alpha$ and [$OIII$] on-band and off-band filters. Try to place the Crab (and so its nearby stars) close to the same locations on the CCD.

3. Obtain dark exposures with the same exposure time (5 minutes). The filter is irrelevant for these. Why? Record the operating temperature that you have set for the CCD for your observations. The darks should be obtained at the same operating temperature Why?

4. First, use the darks you obtained to compare the level of the dark with the level of sky in regions of your images well away from the Crab Nebula. How do they compare? If the levels are the same or nearly the same, then your images are limited by the dark counts and the colder you run the detector, the lower the background in your images. If the level of "sky" is significantly above the dark level, then your images are sky limited. a). Are your narrow-band images dark or sky limited? b). Are 5 minute exposures that you obtained the same night through the off-band filter dark or sky-limited?

5. Using the images of the Crab Nebula on the next page, identify the pulsar on your image. Assume that the pulsar, which is the remnant of the core of the star that exploded, is at the center of the nebula. Measure the angular distance in pixels and then in arcsecs for a few of the filaments which lie as far from the pulsar in all directions as you can find. (Why use these filaments?). Using these angles and the distance to the Crab Nebula (2200$\pm$ 300 parsecs) determine the distances in parsecs from the explosion point to the current-day location of the filaments you selected. Based upon Chinese records and native American rock art, the explosion that created the Crab Nebula took place on July 4th, 1054 AD. Compute the average speed with which the filaments have expanded.

SECOND PART

6. We will show you in lab how to: a. blink your on- and off-band H$\alpha$ and [$OIII$]

images of the Crab using XIMTOOL or DS9; b. Align the two images; c. Scale and subtract the two images to obtain H$\alpha$ only and $[OIII]$ images (i.e., scale and subtract so that there are no stars!).

*** ONLY ATTEMPT THE PART OF THIS PROJECT BELOW IF THE SEEING IN YOUR IMAGES IS THREE (3) ARCSECS OR BETTER. IF THE SEEING IN YOUR IMAGES IS WORSE THAN THAT AMOUNT, WE WILL SUPPLY IMAGES FOR YOU TO USE FOR THIS PART. ****

7. In the same manner as the above description (i.e., blink, align and subtract), use this image and the 1973 image to measure the distance on the sky, and thus the recent speed, that the gaseous filaments you previously selected have moved on the sky. You will thus obtain a proper motion for these knots of so-many arcsecs in (2005-1973)= 32 years, and thus the speed. How does this recent speed compare to the average speed since the explosion? Why are they related in this way? Make sure to discuss the accuracy with which you can make these comparisons.