PROJECT DESCRIPTION:
Weak Gravitational Lensing From Space

1. ABSTRACT

Prior to the launch of future Weak Gravitational Lensing satellites, studies are needed to determine constraints on such a telescope, to ensure confidence in the data returned. Research this summer set preliminary restrictions on mirror size for a Weak Lensing satellite. This project will continue the investigation into the effect of mirror size on the quality of data, studying a larger set of simulations and comparing different shear recovery methods.

2. INTRODUCTION

The accelerating expansion of our universe was discovered in 1998, and in the decade since, the study of cosmology has been transformed by this finding. We now understand that the structure of the universe on the largest scales is dominated by a mysterious force known as Dark Energy, a kind of anti-gravity percolating from the vacuum of empty space. Currently very little is understood about Dark Energy, and precise measurements of the universe's rate of expansion as a function of time will be required to distinguish between competing theories on the subject.

Weak Gravitational Lensing is an excellent method for mapping the distribution of Dark Matter in the universe, the time-evolution of which provides a means of determining the expansion rate of the universe as a whole. Weak Lensing relies on a consequence of General Relativity, that light follows curved paths near massive bodies. This leads to a measurable amount of cosmic shear, as the image we detect is warped by the presence of a large mass between the image source and the telescope. Shear is defined as a two dimensional vector that produces a uniform stretching of objects in the image. The measurement of the shear is complicated by the Point Spread Function (PSF) of the telescope, which includes atmospheric and instrumental effects that distort the image by up to 10%, far more than the effects of Weak Lensing alone, a 1-3% effect.[1]

Because of the difficulty in accurately deconvolving the PSF from the image, the full power of the Weak Lensing technique will require space-based studies, where the size and time-variability of the PSF is reduced significantly. Much research is needed to determine the constraints on a potential Weak Lensing satellite, predominately that of the mirror size. The cost of such a mission increases even more rapidly than the square of the mirror's diameter, and yet larger mirrors have an intrinsically smaller PSF. Due to this trade-off, it is vitally important to know the minimum mirror size that can reliably obtain Weak Lensing data from space.

3. OBJECTIVES

The central question to be addressed by this research will consist of how accurately shear can be recovered from telescopes with different mirror sizes. A wide range of mirror diameters will be examined, as well as a variety of values of input shear. The results of different shear recovery methods will be compared to determine the extent to which the accuracy in measuring shear depends on the method used, and how much is intrinsic to the images. This will establish a firm lower limit for the mirror size of a future space-based Weak Lensing telescope.

4. PLANS FOR RESEARCH

Images will be simulated using the Shapelets[1] method, and will be representative of mirror diameters ranging from a very small 20 cm to the size of Hubble, 2.4 meters. For each mirror size, images will be created at two different exposure times and 13 different values of shear, and stellar images will be produced separately from the galaxy images. Members of the Shear TEsting Programme collaboration (STEP is an international group of scientists dedicated to improving their shear recovery methods for the next generation of Weak Lensing surveys) will be encouraged to analyze these images using their shear recovery method of choice (e.g. KSB[2]). Their results will be compared to those obtained by this proposed research project, which uses the RRG method.[3]

The steps of RRG analysis begin with running SExtractor, a program commonly used by astronomers to locate objects within an image and create a catalog of many useful measurements including positions and moments. Next the moments are recalculated with the RRG method, and the stellar images are used to measure the PSF of the telescope. Knowing the PSF, it can be removed from the corresponding galaxy images, and the most sensitive step is then to decide which galaxies to use to measure shear. Bad galaxies get cut based on their moments, ellipticities, size compared to PSF size, and signal-to-noise ratio. The remaining galaxies can be used to measure shear by examining the global trends in ellipticities, which should be randomly oriented in the absence of Weak Lensing.

5. TIMETABLE

The simulation of images for this study is already underway, and the expected completion date is around October 15th. Members of STEP will then be formally invited to analyze these images at the end of October. Running of SExtractor should be completed by the beginning of November, and the moments recalculated by early December. Measuring the PSF from the stellar images takes a significant amount of time, and should be completed by mid January. The PSF correction of the galaxy images should be finished by the end of January. February and March will be spent investigating the effects of different galaxy cuts on the measured shear and shear error, and comparing the results that others have obtained using different methods. The student will travel to JPL during February to meet with co-mentor Jason Rhodes to discuss the results and conclusions of the research. The final paper will then be prepared in April, and presented to various audiences.

6. PLANS FOR DISSEMINATION OF RESULTS

This research will culminate in the student's senior thesis, which will consist of a written paper and a presentation given to the UNR Physics Department, Spring 2008. In addition, presentations of the paper will be given at the Nevada Undergraduate Research Symposium and the National Conference for Undergraduate Research, both in April 2008. The results of this research will be submitted for publishing in a peer-reviewed journal at the completion of the project.

7. REFERENCES

[1] J. Berge, *An Introduction to Shapelets Based Weak Lensing Image Processing*, Version 1.0 (2005), (http://www.astro.caltech.edu/~jberge/shapelets/manual/shapelets_manual.pdf)
[2] N. Kaiser, G. Squires, T. Broadhurst, Astrophys. J. **449**, 2 (1995).
[3] J. Rhodes, A. Refregier, E. Groth, Astrophys. J. **536**, 79 (2000).