IMAGING DETECTORS IN PLANETARY AND SPACE SCIENCE.

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Introduction: Work has been ongoing with a relatively new type of instrumentation that shows promise in planetary science. This instrumentation involves the use of a Complementary Metal Oxide Semiconductor (CMOS) imaging detector system developed with Kodak and Micron CMOS sensors and assembled by [1] and [2] from NASA-JSC. Although the technology itself has been around for over 30 years, it has only been within the last decade or so that the quality of imaging produced by this technology has matched that of more widely used CCD technology [3]. In some cases CMOS imaging is being used in commercial electronics and the medical field and is now being applied to the physical sciences. The CMOS sensor system has also been used in detecting radiation particles and is currently being tested at Prairie View A&M University in astronomical applications including lunar and planetary imaging work.

We provide a brief overview of the CMOS Imaging system, compare it to CCD systems, and then discuss a few current and potential uses for the system in planetary and space science with the primary focus being on lunar imaging applications.

The CMOS Imaging Detector System: Both CCD and CMOS systems use the photoelectric effect to convert photons into electric charge. Whereas CCD technology is limited to silicon as its detection material, CMOS uses a number of different materials hybridized to a CMOS integrated circuit to provide detectors that are sensitive to the ultraviolet, visible, or infrared parts of the spectrum.

Another difference between CCD and CMOS is the readout process. In both cases, the basic unit is the pixel which is a photodiode. In the former case, the array is read out, pixel by pixel via charge transfer, and all of this is then passed through an output amplifier that performs the conversion from charge to voltage. In CMOS, each pixel performs charge generation, charge integration, and charge to voltage conversion. The readout is performed through the multi-plexing of pixel voltages; each pixel amplifier is connected to a common bus. Various options for readout are available: analog output, amplified analog output, and analog-digital conversion for digital output (figure 1 of [3]).

One of the potential applications for the CMOS imaging system is its use on planetary in situ missions. This is possible because of the flexibility of the system and its portable nature (i.e. “camera-on-a- chip” [4]). In addition, the high resolution imaging capability, lower power consumption, and high quality of the images (e.g. less blooming, less dark current, less artifacts) show promise for planetary application

Some Initial Results: We present some initial results of our work with the CMOS imaging system as it applies to astronomical applications, specifically ground-based photometric study of the moon.

Figure 1: Image of waxing gibbous Moon obtained by Saganti on 18 November 2010. The unprocessed image was made with a 20.3cm Schmidt-cassegraine telescope and 1/1000 sec integration.

Lunar Imaging. Figures 1, 2 and 3 are unprocessed images of the Moon taken by Dr. Saganti with CMOS and a 20.3 cm SCT. These three images are representative of a total of a dozen images collected thus far during the lunations of November and December 2010. The image quality is similar, if not superior to conventional CCD images. Our study is in conjunction with professional-amateur collaborative groups such as the Association of Lunar and Planetary Observers (ALPO), and involves taking a series of images of the moon over the course of several lunations to study various aspects of the lunar surface

The aim of obtaining the images is to provide consistent photometry among all of the Earth-facing lunar features, since the entire lunar disk (or the majority of the disk) is captured in a single, high resolution image. The images will enable photometric curves of individual features to be obtained over several lunations to look for any changes in the properties of these features [5]. In so doing, this will provide another vehicle for the study of transient lunar phenomena (TLP) in a more quantitative sense. With this in mind, the images will be processed and analyzed and preliminary photometric results obtained to show the feasibility of the project.

Figure 2: Image of the Full Moon obtained by Saganti on 22 November 2010. The unprocessed image was made with a 20.3cm Schmidt-cassegraine telescope and 1/1000 sec integration.

Figure 3: Image of waning gibbous Moon obtained by Saganti on 24 December 2010. The unprocessed image was made with a 20.3cm Schmidt-cassegraine telescope and 1/1000 sec integration.

Comparison with CCD technology. How do the results obtained with CMOS compare and contrast with CCD? At first glance they are similar, but upon closer inspection the CMOS does have the advantage that blooming (the bleedout / smearing of light from very bright sources) is limited or nonexistent, which prevents corruption of the scientific quality of the rest of the image. With bright objects such as the Moon and the planets, this is a quality that is invaluable.

We have yet to obtain the “side-by-side” images of the moon for more detailed analysis and comparison between the CMOS and the CCD results. This is one of the plans underway to characterize the former versus the latter, verifying the scientific usefulness as applied to ground- and space-based lunar imaging.

Future Plans and Considerations: With the lunar imaging campaign underway, plans are being made to expand the observing program beyond the moon with the CMOS detector system.

Ground-based Lunar Studies. In conjunction with ALPO we will continue the systematic study of lunar ray structures throughout the lunar phase cycle and not merely at Full Moon when rays are most easily visible. By imaging the moon during the entire phase cycle, we are able to ascertain information about the structure of the rays systems by measuring the photometric variation of ray systems with phase angle.

In addition to the photometric study of the rays structures on the moon, imaging the Moon throughout the lunation provides abundant data on the photometric variation of all the Earth-facing features on the lunar surface [5]. By using the same setup with consistent exposures during the entire lunation, one can get a set of images from which a wealth of photometric data can be produced. Also, as hinted at above, selected areas historically suspected to host Transient Lunar Phenomena will be studied further in order to characterize this phenomena.

Earthshine studies have been carried out from time to time to gauge the changing albedo of the earth’s surface. Carefully planned and executed observations of earthshine may provide valuable information on the albedo of the Earth over a period of time and aid in the modeling of the earth system in the study of climate change.

Planetary Photometry. Even with the advent of spacecraft exploring the planets, there is the need for whole-disk photometric data to characterize such behavior of the planets and their satellites. This is especially true for the remote planets Uranus and Neptune, where little is known about their photometric variation over an entire orbital period.

Mutual Events of Jovian Satellites. Every six years the Galilean Satellites of Jupiter undergo mutual events such as eclipses and occultations. Lightcurves of these events during the recent season show that Io and Europa have tenuous atmospheres whose presences has been verified by several independent methods [6]. Observations of these events in the coming years will help to constrain the density distribution and other properties of these tenuous, extended envelopes as well as to reveal any changes over time to these atmospheres.

References: [1] Holland D. et al. U.S. Patent-7521682, 2009. [2] Holland D. et al. U.S. Patent-7411198, 2008. [3] Hoffman A. et al. (2005) *Experimental Astronomy 19* 111-134. [4] Fossum E. R. (1997) *IEEE Transactions on Electronic Devices 44*, No. 10 1689-1698. [5] Bailey, W. (2010) personal commuication. [6] Degenhardt, S. et al. (2010) prepublication submitted to *Society for Astronomical Sciences Newsletter*.