LUNAR AND PLANETARY METEORS.
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Introduction: Since at least 1993, collisions between solar system bodies have been studied in great detail. These include observational, experimental, and theoretical studies and involve natural or man-made collisions between a tiny object (meteoroid, comet, or spacecraft) traveling at hypervelocity (at least several km per second) and a much larger target body such as the Moon and Jupiter. Recently, three meteors or their remnants have been observed at Jupiter, including two point flashes in 2010 and a dark stain thought to have been the result of an asteroid impact in July 2009.

In this paper I briefly consider the current status of the study of lunar and planetary impact phenomena, featuring some recent notable events. I also consider the current status of lunar meteoroid impact research and tie these two areas together in consideration of an ongoing professional-amateur collaboration.

Background: [1] provides an excellent overview of our knowledge of meteoroid-planet interactions and provides some suggestions on how to further this knowledge. This involves a three tiered approach that starts with existing equipment to better characterize the rate of observable impacts at a given location. The second step is the design and deployment of observing campaigns and planetary missions designed specifically to look for meteors on other planets. The third relies on the results of the first two to set up long-term, short lead-time response networks able to monitor meteors from space- and ground-based platforms. All these taken together have the potential to produce significant scientific rewards.

Although meteoroids (technically defined as objects between 100 μm and 10 m in size) and asteroids make up a continuum of object sizes, two areas of focus involve the smallest objects (trails of dust left from comets as they orbit the Sun [2]) and the largest objects (individual asteroidal or cometary objects impacting planetary surfaces). The former contributes to the study of the dust distribution within the solar system; the latter helps to characterize the inventory of small objects in the solar system.

Collisions with the Moon and Planets: Lunar meteoritic impact patrols around the world continue to monitor the moon for impacts. A recent campaign in search of lunar Geminids in December 2010 revealed twelve impact candidates over a five hour period [3]. The NASA-Meteoroid Environment Office has logged 210 impacts over a five year period from November 2005 to November 2010, and a number of private individuals have also recorded confirmed impact events.

Figure 1. Confirmed Impact March 13, 2008, 2:04:21UT, courtesy of George Varros.

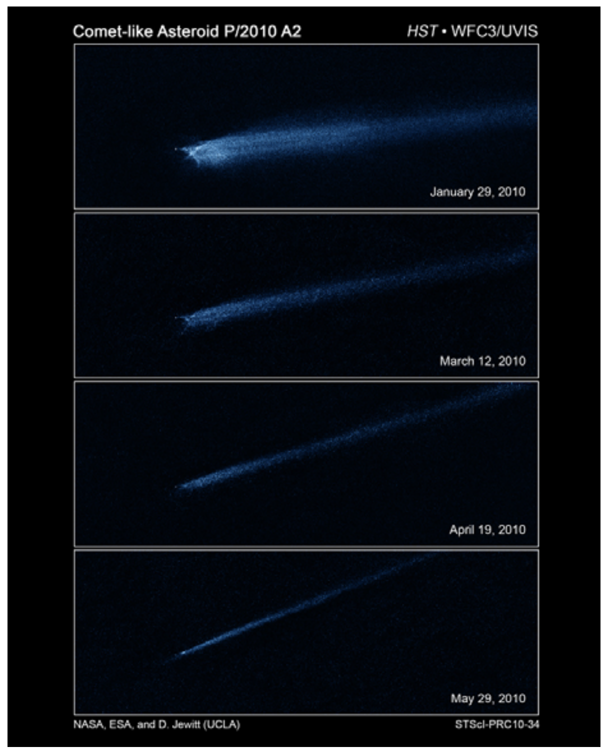

Figure 2. HST image sequence showing a comet-like asteroid over a four-month period. This behaviour is likely due to a collision between two asteroids in the Asteroid Belt.

On Mars. Although impact events themselves have not been recorded, with the possible exception of an atmospheric meteor in Mars's atmosphere by one of the Mars Exploration Rovers, very fresh craters (on the order of days to months in age) from impacts have been imaged from orbit by the Mars Global Surveyor in 2006. These are typically small craters by tiny bodies which (usually) leave behind dark markings on the Martian surface. In some of the impacts, the markings are bright colored against a darker background. Recently, images taken by the Context Camera on board the Mars Reconnaisance Orbiter in 2009 show fresh impact craters of both the dark and bright varieties. One of the key applications of these findings is the detection of water ice excavated by the impacts themselves.

At middle and high latitudes, these impact events dredge up ice, which sublimates after a short period. Studies of the frequency of occurrence of these impacts will indicate how often these events occur. It is hoped that one day, a spacecraft equipped with a wide angle lens and low-light camera, will be able to image the impact flashes. Multi-spectral imaging (temperature data) combined with analysis of the crater left behind could yield much about the luminous efficiency of the impact along with the nature of the impactor itself and Martian subsurface.

In the Asteroid Belt. A collision between a pair of asteroids produced the object shown in a sequence of images in Figure 2. What is left is a 125 meter long rock, the remnant of the larger asteroid that was hit by a 3 to 5 meter long object sometime in February or March 2009. Another such collision is thought to be responsible for a more recently observed object, 596 Scheila, recently found to have a debris cloud or coma-like cloud surrounding the object.

Several such instances of asteroids bearing comet-like features have been documented, and spectral analysis should discriminate between outbursts intrinsit to the object itself or bona-fide collisions between two objects.

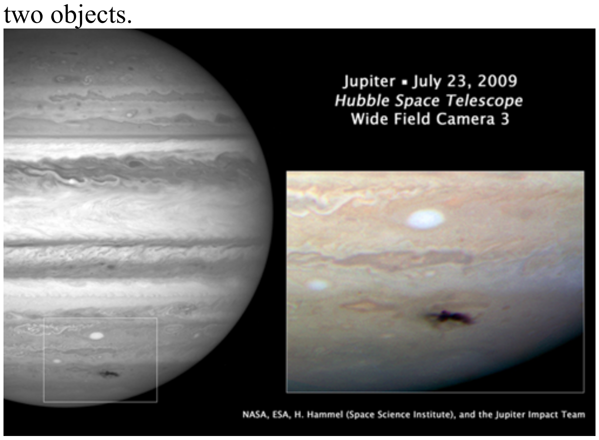

Figure 3. Impact scar visible on Jupiter as a result of an asteroidal impact, courtesy of NASA, ESA, and H. Hammel (STScI).

On Jupiter. One of the most notable events of recent times was the multiple impact event on Jupiter by Comet Shoemaker-Levy, 16-23 July 1994. These events provided a wealth of information about impactor-planet physics as well as Jupiter's atmosphere and the makeup of comets [4]. Fifteen years later, on 19 July 2009, another impact took place on Jupiter, leaving a single impact scar reminiscent of the impact scars left by the Shoemaker-Levy comet.

Two luminous meteors were observed on Jupiter by amateur video on 3 June and 20 August 2010. In each case, the flash appeared as a bright point lasting up to 2 seconds. In both cases, no visible stain remained in the atmosphere of the planet. This points to the likelihood that unlike the 1994 and 2009 events, and the lunar meteor events, these two 2010 events were meteoroids or small asteroids burning up in the Jovian atmosphere, creating fireballs so bright they were able to be seen from nearly one billion kilometers away.

Figure 4. Meteoric flash image frame from a video obtained by Anthony Wesley on 3 June 2010.

Pro-am collaboration. Given the widespread availability of high-quality equipment for astronomical observations, amateur astronomers have become much more involved in recent years, in making scientific contributions to planetary and space science. One advantage of this group is their availability to make observations on a more regular basis and with greater flexibility than their professional counterparts. It is to this end, and to merge the best of both worlds of astronomy, that the Lunar Meteoritic Impact Search section of the Association of Lunar and Planetary Observers exists to maximize scientific potential of the burgeoning field of solar system collisions.

References: [1] Christou A. A. et al. (2007) *Planet. & Sp. Sci., 55,* 2049–2062. [2] Domokos A. et al. (2007) *Icarus, 191,* 141-150. [3] Bill Cooke (2010) private communication. [4] Rogers, J. H. (1996) *J. Br. Astron. Assoc., 106,* 69–80.