SMART-1 IMPACT OBSERVATION AT THE CANADA-FRANCE-HAWAII TELESCOPE.

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Introduction: Thanks to a well-planed ending of its mission, the SMART-1 spacecraft crashed on the near side of the Moon on the 3rd of September 2006 at a site not illuminated by the Sun and visible from many large observatories in the Americas and the Pacific region. An observing campaign coordinated by the SMART-1 team triggered many attempts by both professional and amateur astronomers to observe the impact from the Earth. Bad weather in many observing sites and the difficulty to observe the Earthshine-lit crash site so close to the Sun-illuminated lunar surface led to only one successful observation at Canada-France-Hawaii Telescope and a possible detection of the impact flash by an amateur in New Mexico.

The image of the impact flash, made available in near real-time by CFHT, brought visual closure to a very successful mission, and the detection of the impact plume on subsequent frames opened the possibility to study for the first time the dynamics of the ejecta from an impact on the lunar soil.

Observing setup: The instrument available on the CFHT 3.6-m telescope at the time of impact was a brand new wide-field infrared camera, WIRCam. Each WIRCam image covers a 20'x20' field, thanks to a mosaic of four very sensitive Hawaii-2 RG detectors. The 16 MPixels images are read in a few seconds. Image scale is 0.3"/pixel. With a 5-second gap between images and not knowing the exact time of impact, it was decided to set the exposure time at 10 seconds, giving a 2/3rd probability of actually observing the impact. With the sunshine lit lunar surface close to the impact site and the relatively bright (for WIRCam) Earthshine lit impact area, the narrowest filter available in the camera was used: a molecular hydrogen emission filter H2 v=1-0 S(1) at 2130nm. Test images were made of the crash site the day preceding the impact, allowing a reconnaissance of the impact area and the landscape features to be used as reference for the impact observation.

The impact flash: The impact did not happen between two images and was, luckily, recorded. The telescope was pointed so that the smallest portion of the mosaic would see the Sunshine lit area. The impact was therefore located very close to a corner of the mosaic. he corresponding image showing the whole detector on that corner is seen on Fig 1. Scripts processing the images in real time allowed a release of the flash image a short time after it was observed. The data actually consist in a long sequence of 10s images covering nearly an hour (20mn before the impact and 40mn after). As the Earthshine lit Moon has a very low contrast, features are not easily seen. For this work, the Virtual Moon Atlas [1] was very useful. The impact was localized on the slopes of a mountain seen on the SMART-1 image of the impact zone (Fig 3).

Fig 1 - The 2Kx2K detector used for the impact observation. The sunshine lit Moon is at the extreme upper right of the detector (saturated – hence black). The Earthshine lit Moon is seen with the starry sky in the background. Various ugly reflexions from the bright Moon are seen in many places… The impact flash is the bright spot at the top of the image, close to the terminator.

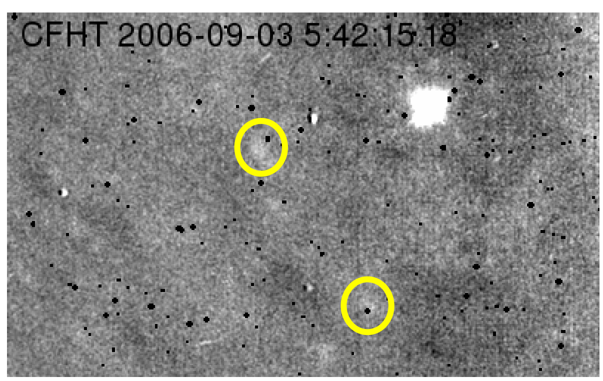

Fig 2 *– The impact flash and, circled, the two craters used to reference the image on the lunar surface: Lehmann C (top) and Drebbel D (bottom).*

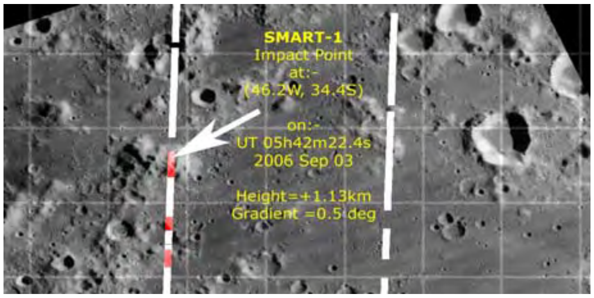

Fig 3 – *The impact site identified on an image taken with AMIE on SMART-1. It corresponds to the location found using the reference craters (see Fig 2).*

The impact happened a few seconds within the exposure and it is extremely over-exposed. The resulting image is saturated and it is very difficult to estimate the magnitude of the flash. The observation of bright stars using the same filter at the same location on the detector are being done and should allow a rough estimate of its brightness, at least on a narrow band (40nm) around 2130nm. It should also give a good idea of the possible remanence of the saturated flash on the following image(s).

The ejecta, a processing challenge: Differencing the pre- and post-impact images clearly shows the ejecta cloud spreading over a wide area before getting to faint to be detected. The sequencing of the infrared images obtained with WIRCam wide-field camera makes the processing of the data a real challenge: with 10 second exposures and 5 second gaps between them, it is like trying to get sharp images of a racing car from a series of images taken with an old photographic plate camera! The ejecta images have already been precisely located with respect to the lunar surface and the spatial extent of the plume can already be estimated. Surprisingly enough, the cloud in the 10 to 20 seconds following the impact is not centerd on the trajectory, as seen on Fig 4.

Information on the landscape is retrieved from the SMART-1 images when these lines are written and more should be presented at the time of the conference. A careful removal of the extremely bright flash signal from the impact exposure should also uncover the plume produced in the first seconds after impact. A precise timing of the following sequence of images is now available and the study of the profile of the plume on each of them should lead to an evaluation of the plume expansion velocity.

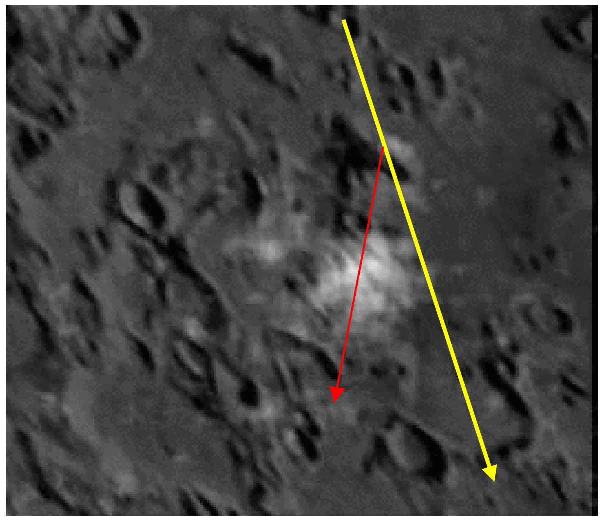

Fig 4 – *The direction of the trajectory is shown on the long arrow pointing to the lower right of the picture. The short arrow is starting at the impact point on the mountain also seen on Fig 3, and goes through the center of the cloud seen between 10 and 20 seconds after the impact. The saturated image of the impact flash itself is also elongated in a direction pointing to the cloud seen here.*

References: [1] Chevalley P. and Legrand C. *http://www.astrosurf.com/avl/UK_index.html*