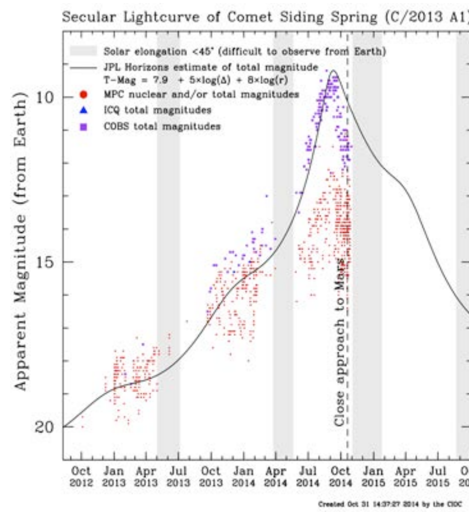
Results From the CIOC Comet Siding Spring at Mars Observing Campaign. C.M. Lisse[1] and the CIOC Team, [1]Johns Hopkins University Applied Physics Laboratory, 11100 Johns Hopkins Road, Laurel, MD 20723 carey.lisse@jhuapl.edu

Abstract: In this paper we present an overview of the observing results and cometary behavior found for C/2013 A1 (Siding Spring) (hereafter CSS) during its 2014 close flyby of Mars and perihelion passage. We also present a list of initiatives tried and lessons learned from the coordinated Comet Investigative Observing Campaign (CIOC), including the use of modern digital era resources, that could be applied to future comet observing campaigns.

Introduction: In January 2013, NASA requested a volunteer through the SBAG process to aid in coordinating observations of comet C/2012 S1 (ISON), colloquially known as ISON. The comet was predicted to have a number of unusually close and bright encounters with the inner planets, and it was important to have an expert in place to help marshal all available resources. What were not predicted well were the comet's unusual activity pattern and the method of its demise, nor the public's immense interest. Given my 25+ years of comet observing expertise, including the Comet Halley, Hyakutake, Hale-Bopp, Tempel 1, and Hartley 2 coordinated observing campaigns, my location at APL along with members of the MRO, MSL, and MESSENGER teams and long-term HST, Keck, and IRTF comet observers, and my long tenure on the Keck/IRTF MOWG, I estimated I was in a position to provide most of the required support, and so responded to the call for a volunteer. Figuring that the task would likely need much more expertise, I turned to a number of capable young and mid-level comet scientists at the SBAG meeting, and asked them to help, and the **Comet Investigative Observing Campaign** (CIOC) was created.

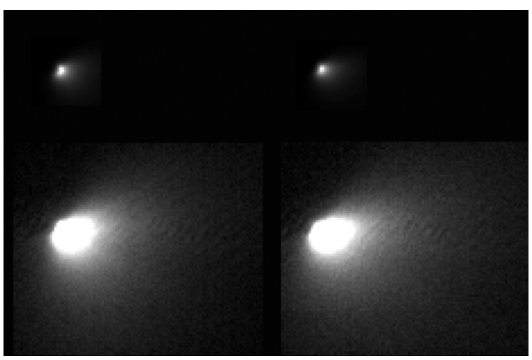
Building on the successes and learning from the problems of campaigns in the past, the CIOC consciously built an effort to maximize the observations made and science returned by utilizing the free market, *i.e.* by providing as much information about science opportunities to observers and assets in the professional, amateur, solar, planetary, and astrophysical domains. We utilized the PEN and DPS newsletters, as well as a direct email exploder available to all interested registrants. Letters describing the opportunity were sent to the NSF and NSO offices in anticipation of comet observing requests. Well-subscribed public observing campaigns at the IRTF and Keck were created. We established a website to provide quick access to the latest facts and observing results for the comet, and ran two webstreamed observer's workshops to help coordinate and stimulate measurements while identifying any gaps in observer coverage, but did not attempt to archive any data. Our campaign was a great success, in that we captured the attention of millions of people, obtained observations with unprecedented levels of observing coverage over many weeks of the comet's in flight and eventual demise at perihelion, and have helped guide world studies of the life and death of a dynamically new sungrazing comet.



In 2014 NASA HQ again asked for a collaborative effort to study another dynamically new comet, Comet 2013 A1/Siding Spring (CSS), a "Mars grazer", with closest approach expected within 138,000 km of the planet. The goal was to use the extensive Mars s/c assets in collaboration with other space and ground based assets to study the interaction of a comet with a planet *in situ*. We added Mars s/c experts to the CIOC team and used all the lessons learned from the ISON campaign to set the table for CSS: an interactive website dedicated to CSS, with up to date news, blog postings, observers' reports, and publications listings was established; notifications were posted in the DPS and PEN newsletters and to observatories; 2 workshops were held at APL & JPL hosting observers from the comet and Mars communities, where collaborations between the Mars s/c and comet communities were actively fostered.

In 2013 – 2014, Comet Siding Spring (CSS) came fresh from the Oort Cloud as predicted, flying within 0.001 AU of Mars on 19 Oct (although a last-minute ephemeris improvement to ensure accurate s/c pointing was required using organized community input). Its brightness and activity pre-encounter was, if anything, better than initially predicted by ~50%, up until about

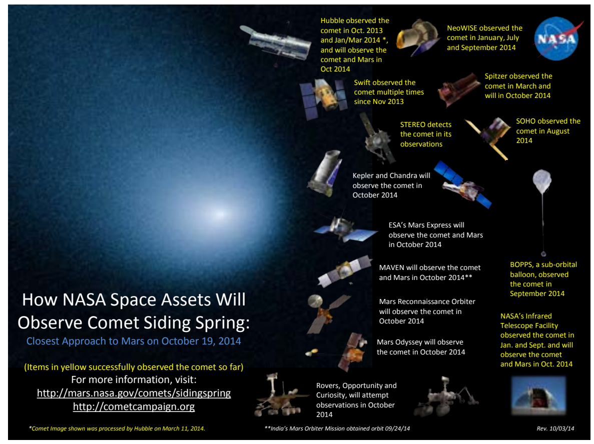
10 days before flyby, when it began to drop by 1-2 magnitudes. (Important near real-time results for the flyby were obtained by monitoring the pro-amateur community postings.) The sudden drop in activity made it more difficult to detect the comet with the Mars s/c assets, but nevertheless good detections were found by MRO, MAVEN, MEX, MER, MSL, and MOM. The comet was also detected by BOPPS, Chandra, HST, and SOHO, STEREO, Spitzer, and SWIFT [1,2]. Its nucleus was resolved by MRO/HiRISE, and observations of the comet from the rovers produced the first images of a comet from the surface of another planet. While no obvious large scale expansion or auroral effects in the Martin exosphere and ionosphere were found using remote observations by Chandra and HST during the flyby, and no direct measurements of meteor trails in the Martian sky were obtained by either remote observations or the surface based Mars rovers, *in situ* measurements of the Martin exosphere and ionosphere by MRO, MAVEN, and MEX detected the input of cometary dust and electrons within a few hours from the time of closest approach of the comet, suggesting some 10^3 -10^4 kg of dust input into the Martians skies. Continual observing found effects that lasted for up to 1 sol, with dissipation soon afterwards.



MRO/HiRISE detection of Comet Siding Spring's coma (bottom) and nucleus (top) 2 hrs before the comet's close flyby of Mars. [2]

The comet, for its part, seemed to have little reaction to its close flyby of the planet. No sudden change in its optical lightcurve was found after closest approach, and the imagery of the comet obtained from MRO/HiRISE was consistent with one consolidated nucleus of ~0.5 km radius w/ 3 jets rotating at with an ~8 hr (single peaked) rate consistent with the ~8.2 hr (single peaked) rate found by HST and NeoWISE (and potentially by Kepler observations as well).

Over 19 spacecraft ultimately pointed at the comet, including assets from NASA's astrophysics, heliophysics, and planetary divisions, with at least 13 reporting detections of it ranging from the x-ray through the infrared. Some problems were encountered with the comet's inexplicable dip in activity the week before the Mars flyby; by a week later, right after its perihelion passage, the comet had increased in brightness and activity again by a factor of 2 to 3. Even though it was poorly situated for optimal observing from the Earth, more than 20 ground based observatories (incl. ALMA & the IRTF) observed CSS at UV to radio wavelengths.



Important findings concerning the comet's size, rotation state, dust to gas ratio, composition, and coma and tail structure were made during CSS's apparition. Given the incredible diversity of professional interest in the comet, having a neutral, responsible, and knowledgeable centralized team of experts was useful for maximizing the scientific return while diffusing some of the more unusual cometary theories that were promulgated. The CIOC was also highly useful for the public and press to refer to in promoting NASA's business and for disseminating astronomical learning. Resources ultimately created by the CIOC include: weekly cometary lightcurves derived from MPC data, a CSS FAQS page, an on-line observer's schedule, posted observer's logs, a CSS news email exploder, a list of current CSS publications, and a daily to weekly expert blog. While the CIOC is currently on hiatus until 2017 when the next great comet apparition is expected, these resources could be of use in maximizing the scientific return and public engagement for other solar system happenings and mission events in the meantime.

References.

[1] Li, J.-L. *et al.* (2014) Fall AGU Abstract; Lisse, C.M. et al. AAS/DPS Abstract (2014)
[2] Delamere, A. et al. AAS/DPS Abstract (2014)
[3] www.cometcampaign.org

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