Comet Investigative Observing Campaign (CIOC)

C/Siding Spring Mars Flyby Results

**CIOC Team** established Jan 2013 at SBAG-8. Team has a mix of experiences, skillsets, and research specialties. Abundant contributions from early- and mid-SBAG scientists. Reported monthly to Lindley Johnson, Kelly Fast, & Jim Green.

**Members chosen from SBAG, MEPAG**: Lisse, Battams, DiSanti, Farnham, Fernandez, Kelley, Knight, Lemmon, Li, Seelos, Vervack, Warner, Yanamandra-Fisher.

**Mantra**: Facilitate, facilitate, facilitate. Bottom line is to maximize the science returned from Comet Siding Spring by involving every telescope available (mainly Southern on Earth, high sensitivity remote, + Mars Fleet) for observations.

**CIOC Contact Info**: [http://www.cometcampaign.org](http://www.cometcampaign.org)  

Jan 7, 2015
CIOC  C/Siding Spring Campaign

• **Observing Opportunities from Ground Limited:** *Southern Twilight* Comet, Brightest from Earth in mid- to late-September => Good opportunities to characterize the comet pre-Mars, pre-perihelion.

• **Observing focused mainly on (1) Early s/c based** hazard related characterization; *(2) Inside 2 AU Earth-based characterization; and (3) Mars encounter observations* Oct 17 – 21.

• **Mars Fleet:** MRO, Mars Odyssey, MEX, MSL, Opportunity, MOM, MAVEN. 2013’s Comet ISON flyby at 0.07 AU was practice for *Comet C/2013 A1 (Siding Spring)*’s *VERY* close Mars approach on 10/19/14

• **Helio Fleet:** *STEREO, SOHO (?)*

• **Astrophysics Spacecraft:** *SWIFT, WISE, HST, Spitzer, Chandra, Kepler*

• **Websites:** CIOC (FAQS, news, lightcurves, schedules/logs)  http://www.cometcampaign.org
  Mars Program (“ “, mission news) http://mars.nasa.gov/comets/sidingspring/

• **PRO-AM COLLABORATIONS:** Facebook, Twitter, and Pinterest groups; COBSA & other “professional amateurs”; Jet Morphology campaign; Ion tail campaign

• **NASA HQ EPO:** Ask an Astronomer; FAQs; Media Point of Contact.
Comet Siding Spring Observing Campaign Website

New CIOC Website Established: [http://www.cometcampaign.org](http://www.cometcampaign.org) (site name purchased from GoDaddy)

- Latest news/updates about the comet
- Updated MPC lightcurve
- Workshop information
- Resources for amateur/pro-amateur/professional astronomers
- Blog posts from CIOC Team members
- Observer on-line schedule
- Observing logs
- List of papers/CBETS published
- Feedback form
- Associated: email news exploder
How NASA Assets Observed COMET SIDING SPRING

Closest Approach to Mars on October 19, 2014

- **BOPPS**, a sub-orbital balloon, observed the comet in September 2014
- NASA's Infrared Telescope Facility observed the comet in Jan., Sept. and observed Mars in Oct. 2014
- Mars Reconnaissance Orbiter observed the comet in October 2014
- Mars Odyssey observed the comet in October 2014
- ESA's Mars Express observed the comet and Mars in October 2014
- MAVEN observed the comet and Mars in October 2014
- Opportunity Rover observed the comet in October 2014
- Curiosity Rover made observations in October 2014
- Hubble observed the comet in Oct. 2013 and Jan/Mar 2014,* and observed the comet and Mars in October 2014
- Swift observed the comet multiple times since November 2013
- STERE detects the comet in its observations
- SOHO detects the comet in its observations
- NeoWISE observed the comet in January, July and September 2014
- Spitzer observed the comet in March and October 2014
- Kepler observed the comet in October 2014
- Chandra observed the comet in October 2014

*Comet image shown was processed by Hubble on March 11, 2014
**India’s Mars Orbiter Mission obtained orbit 09/24/14

http://mars.nasa.gov/comets/sidingspring
http://cometcampaign.org

#JOURNEYTOmars
Comet Siding Spring at Mars Observer’s Workshops: Summary Findings & Important Issues

- **Characterization of CSS Now Made**: comet acting like ISON long term, but 0.5-0.75 mags brighter than JPL predicts; H₂O has turned on. Much more to come in Sept 2014.

- **Range of Predictions for Dust, Gas Effects on Mars from Encounter (most seem low)**; major effects likely to be from Heating of Mars Meso/Exosphere.

- **Pro-Am Collaborative Astronomy (PACA) CSS/Mars Data Available for Scientist Use** (but requires dedicated archive location until ingested into PDS after proper review).

- **Need to Coordinate HST, MRO/MAVEN/Odyssey Observations**

- **Ephemeris Updates Required within C.A. -10**

- **Adequate DSN Available for C.A.?**

- **Quicklook Data Plans for 19 Oct 2014?**

- **Post 11 Aug 2014 Workshop Talks, Next Meetings to Discuss CSS + Mars**

- **Important to continue to foster Mars Project + CIOC cooperation**

- **Large, mainly Webex based community forums are of use but of substantially different character to run.** Attendance at 30+ at APL + 50+ WebEx + 130+ Livestream for 11 Aug 2014 Workshop.
Comet Siding Spring (C/2013 A1) is racing toward Mars for a close encounter in October 2014.
C/Siding Spring has likely spent the 4.5 Gyr since its formation far from the Sun and the planets in the deep freeze of the Oort Cloud. For C/SS to come from the depths of the Cloud, with more than a year’s notice, at \( \sim 129^\circ \) inclination to the ecliptic and have an extremely close encounter with Mars at/near perihelion is very rare.
How Close is 138,000 Km?

• 1/3 the average Earth-Moon distance.
• 1/16 the distance of the closest comet to flyby Earth in the last 500 years.
• The C.A. distance of a very good NEA-Earth flyby.
• 15x the mean distance of R = 11 km Phobos from Mars.
• 6x the mean distance of 6 km Deimos from Mars (note that at $R_{CSS, nuc} = 0.3 – 5$ km, CSS is smaller than the moons by 1.2x to 35x).
• $R_{Hill \ Sphere, \ Mars} \sim 577,000$ km
• In the outer coma ($10^5 – 10^6$ km) of an active comet.
Siding Spring: Hazard mitigation

- Studies of dust hazard to Martian fleet (2014):
  - Farnham et al.,
  - Farnocchia et al.,
  - Moorhead et al.,
  - Tricarico et al.,
  - Vaubaillon et al.,
  - Ye and Hui

- Consensus results: despite the very close approach at 56 km/sec relative, Mars fleet is likely safe
  - Observations have constrained activity level and trend.
  - S/c put behind Mars during CA + 90 min orbit for extra security.

  - Dust large enough to cause damage (>50 \( \mu \text{m} \)) must have been released 6 – 12 months earlier in order to reach Mars
  - Dust tail modeling and outflow velocities indicate hazardous grains unlikely to have been released early enough or with high enough velocity
Some Recently Updated Observing Plans:

**BOPPS**
9/24 - 25/14?
Balloon Observation Platform for Planetary Science

+ IRTF/SPeX Support Obs.
9/23-27/14

**Kepler**
10/20, 10/25-27

**IRTF/SPeX Support Obs.**
9/23-27/14

**HST**
10/19-20/14 (22 orbits)

**Chandra**
10/19-20/14 (15 hrs, 5 pointings)

- **MRO Visibility & Planned Obs**
  - **Kepler**
  - **Chandra**

(1) 25 hrs over a ~1020 pixel-long track 20 Oct 2014 10 UT to 21 Oct 2014 11 UT.
(2) 41 hrs over a ~1200 pixel-track from 25 Oct 2014 12 UT to 27 Oct 05 UT.
Rovers: best viewing pre-dawn and post-dusk on 19 Oct 2014 Sol
Science Findings Summary (1/7/2015)

Despite a 2x drop in Comet Activity, rising Martian Dust Storms, and a CME that arrived at Mars on Oct 19th:

We Found
- Direct evidence for cometary mass/energy input into the ionosphere of another terrestrial planet
- Mars as a giant cometary dust detector (à la Jupiter as a small body detector)
- First resolution of the nucleus of a dynamically new Oort Cloud comet.
- First images of a comet from the surface of another planet
- Resolution of a jet activity puzzle using remote + in situ observations

And Didn’t Find
- Damage to any Martian s/c asset
- Any bright meteor trails
- Any evidence for cometary gas input into the upper Martian atmosphere (expected lots since Dust/Gas ~ 1.5; but hard to detect CHON volatiles vs. a CO$_2$/N$_2$/H$_2$O dominated atmosphere)
- Any evidence for induced Martian aurorae or expansion of the exosphere due to heating
- Any major effects on the comet due to tidal perturbations from the close flyby

All these issues are currently being worked by the associated science teams.
Optical Images of the Close Flyby as seen from Earth.

Li et al. 2014 – CSS detected in CN, BVR dust

NASA/ESA, HST WFC3/UVIS, STScI-PRC14-45
MAVEN, MRO/SHARAD MEX Evidence For Metal Input Into the Martian Upper Atmosphere
For the MAVEN Mg signal to be from cometary dust, we require excesses in Fe/Si/Na/K as well...Thank You, NIGMS 😊
Time Sequence of MRO/HiRISE CSS Images
MRO/HiRISE ~8 Hour CSS
Nucleus Rotation period same
as HST (and NEOWISE?)
MRO/HiRISE
Comet Siding Spring
Nucleus Stretch Images from C.A. 19 Oct 2014
CSS Jets at Close Approach

No Obvious Jets in HST Remote Imaging
(Color gradient, tail curvature normal for ~100 um particles fragmenting out towards tail)

4 Strong Jet Signatures
(3 of them sunward) in Repeated HiRISE Images

Questions:
Why is the blue curve so low?
Why no shift in peak during 30 minutes of possible rotation?
What does the shape change tell us?
CRISM early results

0 Jets, 4 Jets, CRISM Sees 2 Jets....

“Blue” Jet

“Red” Jet

CRISM Siding Spring Spectrum

No obvious strong gas emission lines

Red Dust Continuum, Slope S_{1000} similar to other comets

credit NASA/JPL/JHUAPL, images provided by the CRISM team
Comet Siding Spring from the Surface of Mars (!)

19 October 2014
Upcoming Venues Where Comet C/2013 A1 (Siding Spring) Will be Discussed

• Observer’s Workshop, (11 Aug 2014) APL/JPL/WebEx
• Mars Fleet Tag-Up Workshop, (19 Sept 2014) APL/JPL/WebEx
• AAS/DPS 09-14 Nov 2014, Tucson, AZ USA
• Winter 2014 AGU (14-19 Dec), San Francisco USA
• LPSC 2015 (15-20 March), Houston, TX USA
• AAS/DPS (09-14 Nov 2015), Washington, DC USA

• Special issue of Icarus for the Comet Siding Spring observing results? Submission deadline approximately Winter 2015, publication in late 2016 to mid 2017. No...
CSS at Mars Findings & Lessons Learned

- **Need for coordination across planetary astronomy communities.** Very good response and collaboration from ~100 interested members of the science community. We would not have seen obtained most of the useful science results without coordinated observations – the last week’s ephemeris fix is an excellent example. Multiple papers are being enabled by Comet/Mars community collaborations.

- **CSS was unscathed by close flyby.** We learned a lot about the comet from the Mars fleet close flyby: found 3 or 4 close-in jets, an ~0.5 km radius, the nucleus appears smaller than expected. Terminator, limb hard to establish. Team still needs to work out size and shape using time series of images + rotating shape models.

- **Mars affect for a sol, mainly, at 80 – 120 km altitude** by 10 – 100 um dust particles. Current debate as to how much mass (10^3 – 10^4 kg total injection) and if any meteors apparent; <= 2 m radius boulder total equivalent. Regardless, the timescales observed for transients require quick atmospheric mixing.

- **Kepler data still TBD, but first good comet study by this platform.** Will need good HST context image to produce accurate lightcurve photometry, but even 0.1% precision (1000 ppm, trivial for Kepler) would be an excellent comet science result.

- **Pro-ams were vital to establishing the real-time story** on 19-20 Oct 2014 and getting the word of the comet’s survival out.

- **The 2014 CIOC CSS at Mars campaign was exciting, challenging, and highly cost effective, but also exhausting.** The CIOC is going on hiatus for a rest-cure until the next great predicted comet apparitions in 2017 – 2018. See you then!
Issues I Hope the CSS + Mars Observations Will Address:

- Comet Siding Spring will be the largest Km-sized Cometary Object to come within 130,000 km of a planet since ~1 km sized D/Shoemaker Levy 9 hit Jupiter in 1992/1994 and the 0.06 – 0.20 km Toguska [Asteroid or Comet (?)] Bolide hit Earth in 1908.

- Siding Spring’s Encounter Geometry is the equivalent of a decent comet flyby, at a not-so-good ~90° phase angle throughout – but it is the first ever to resolve an Oort Cloud comet nucleus (except for Halley....) – MRO/HiRISE

- Siding Spring’s Immediately Up(Solar)Wind encounter geometry from Mars makes studying the Martian exosphere and mesosphere very interesting – MAVEN, MOM

- Comet Siding Spring is not the first comet to interact closely with Mars. Given the water ice we are finding on other terrestrial planets, and the idea that to terraform Mars we would increase its volatile inventory by dumping comets onto it, it will be very interesting to compare the dirty H₂O+CO₂ Martian polar caps with the dirty H₂O+CO₂ ices in comets. – MRO/CRISM, MEX

- While many comet orbit and orbit plane crossings have been studied and predicted to lead observable meteor showers, not even for the Leonid storms of 55P/ Tempel-Tuttle has the Earth passed through the orbit plane within 2 hrs and a few x 10⁵ km of the parent body. While most models suggest only a low rate of meteor hits, we should watch just in case – Opportunity, MSL