Feature Story: Comet C/2012 S1 (ISON)

From 'Comet of the Century' to 'Thanksgiving Turkey'

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Online Readers

Left-click your mouse on the e-mail address in blue text to contact the author of this article, and selected references also in blue text at the end of this paper for more information there.

Cover Image Details

Comet C/2012 S1 (ISON) with star trails as imaged by Van Macatee of Rutledge (near Atlanta), Georgia USA (33°33'49"N, 83°37'28"W) starting at 5:39 a.m. EDT, on November 11, 2013. Comet magnitude estimated at 7 to 8. Equipment: Explore Scientific 80mm APO Triplet, Canon T3i, Astor Tech Field Flattener, Orion EQ-G mount, Guided, un-filtered. The image is based on 6 RAW frames, 180 seconds each, at ISO 1600, CCD recorded 13 degrees C, custom White Balance. Stacked in Nebulosity, processed in PixInsight. PixInsight workflow included Cropping, Dynamic Background Extraction, Color Calibration, HDR Multi-scale Transform, Histogram Transformation, and ACDNR. The seeing was good (estimated 8 out of 10) and the Transparency was an very good at an estimated 5 out of 6. Source: Van Macatee, *van.macatee@evermore.biz*

Introduction

Since its discovery in late 2012, Comet C/2012 S1 (ISON) has been heralded as a possible naked-eye spectacle. Labeled by the media and even some comet researchers as the "Comet of the Century", a large-scale observing campaign was coordinated by NASA to study the comet. Due to the comet's close approaches to Mars, Mercury and the Sun, spacecraft in orbit around these bodies or dedicated to studying them were tasked with observing ISON. Unfortunately, rather than becoming a brilliant comet for the public to see, ISON played the part of "Thanksgiving Turkey" as it apparently disintegrated in the hours prior to perihelion. (Note: The comet's date of perihelion was Thanksgiving Day in the United States where the traditional Thanksgiving dinner consists of a main course of turkey. The word "turkey" is also a colloquialism for a flop or failure.) This article is an overview of Comet ISON's observed history and apparent demise. A scientific analysis of its apparition will be published in a future issue of this journal.

Discovery and Orbit

Comet ISON was first imaged on 2011 September 30 by the Pan-STARRS asteroid survey at the University of Hawaii. Over the next four months, Pan-STARRS and the Mount Lemmon Survey (MLS) at the University of Arizona imaged the comet on another six nights. On those nights, the comet was either not picked up by automated detection software or was indistinguishable from an asteroid and not flagged as interesting. On 2012 September 21, astronomers

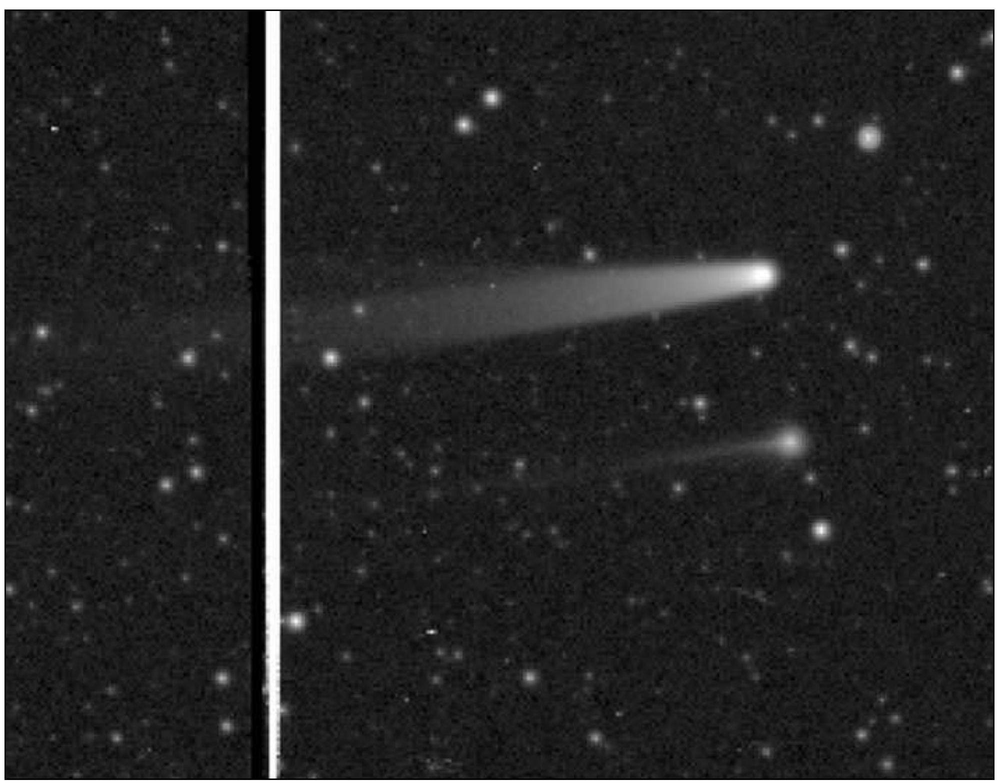

Figure 1, Comets ISON (top) and 2P/Encke (bottom) in a H1A image from NASA's STEREO spacecraft on November 25 at 03:19 UT. The thick saturation spike (top-to-bottom line) to the left of the comets is from the Earth-Moon system. Credit: NASA/STEREO.

Figure 2, Image of Comet ISON taken with the LASCO C2 imager on the NASA/ESA SOHO spacecraft on 2013 November 28 @ 17:36 UT or one hour prior to perihelion. Credit: NASA/ESA/SOHO.

Figure 3. ISON shows an extensive ion tail in this average of 4x180-s exposures from the Virtual Observatory robotic 0.43-m telescope in Ceccano, Italy taken on 2013 Nov. 14 UT. The diffuse glow to the left of the comet's tail is a faint galaxy. Credit: Gianluca Masi/Virtual Observatory.

Vitali Nevski of Belarus and Artyom Novichonok of Russia discovered ISON as a 17^{th} magnitude object with a 0.4-m (16-in.) reflector of the International Scientific Optical Network (ISON) (Green 2012). Though at first the discoverers only suspected its cometary nature, additional follow-up observations with larger telescopes uncovered its true nature.

On 2012 September 24, the Central Bureau of Astronomical Telegrams announced the comet as C/2012 S1 (ISON) on Central Bureau Electronic Telegram (CBET) 3238. Thanks to some of the Pan-STARRS and MLS pre-discovery astrometry, the comet already had a well-defined orbit at the time of announcement. When discovered by Nevski and Novichonock, the comet was located at a distance of 6.29 AU from the Sun. The comet was 9.39 AU from the Sun, roughly the Earth-to-Saturn distance, when the first pre-discovery observation by Pan-STARRS was made. Excitement was high as ISON was predicted to approach to within 1.2 million km (0.75 million miles) of the surface of the Sun on 2013 November 28. The orbit was also similar to that of the Great Comet of 1680 and led to speculation that the two might be related. We now know that ISON's original orbit (before it was perturbed by the planets) is slightly hyperbolic and as a result, any relation to the 1680 comet is in doubt. A hyperbolic original orbit also means it is a dynamically new comet likely to be on its first trip into the inner Solar System.

Some of the greatest comets of recorded history have been sungrazing comets with very small perihelion distances. Though the perihelion distance of ISON is small, it is not related to the Kreutz family of sungrazing comets that produced such well-known comets as the Great Comets of 1843 and 1882, C/1965 S1 (Ikeya-Seki) and more recently C/2011 W3 (Lovejoy).

From Pre-discovery to Perihelion and Beyond

The initial forecasts of the brightness of ISON near perihelion were based on the comet's brightness at the time of discovery and extrapolated forward as if the comet were to brighten at a steady and "typical" rate for a long-period comet. Such predictions over a large range of heliocentric distances are fraught with uncertainty (for example, Comet Kohoutek). This is especially true for dynamically new comets like ISON, which have a history of brightening at slow rates.

To say the brightness behavior of ISON was like a roller coaster ride is an understatement. The comet's intrinsic brightness rose and fell in fits and starts (intrinsic magnitude is defined as the observed brightness normalized to distances of 1 AU from the Sun and Earth). At first the comet would seem to be doing well for a few months only to be followed by a few months of underperformance. As the comet approached the Sun, these "up and down" periods would alternate on the timescales of days. The following timeline summarizes its behavior and is based on visual and CCD observations posted on various online Yahoo groups (comets-ml, CometObs), comet photometry websites (International Comet Quarterly, Cometas de la LIADA) and the NASA Comet ISON Observing Campaign site.

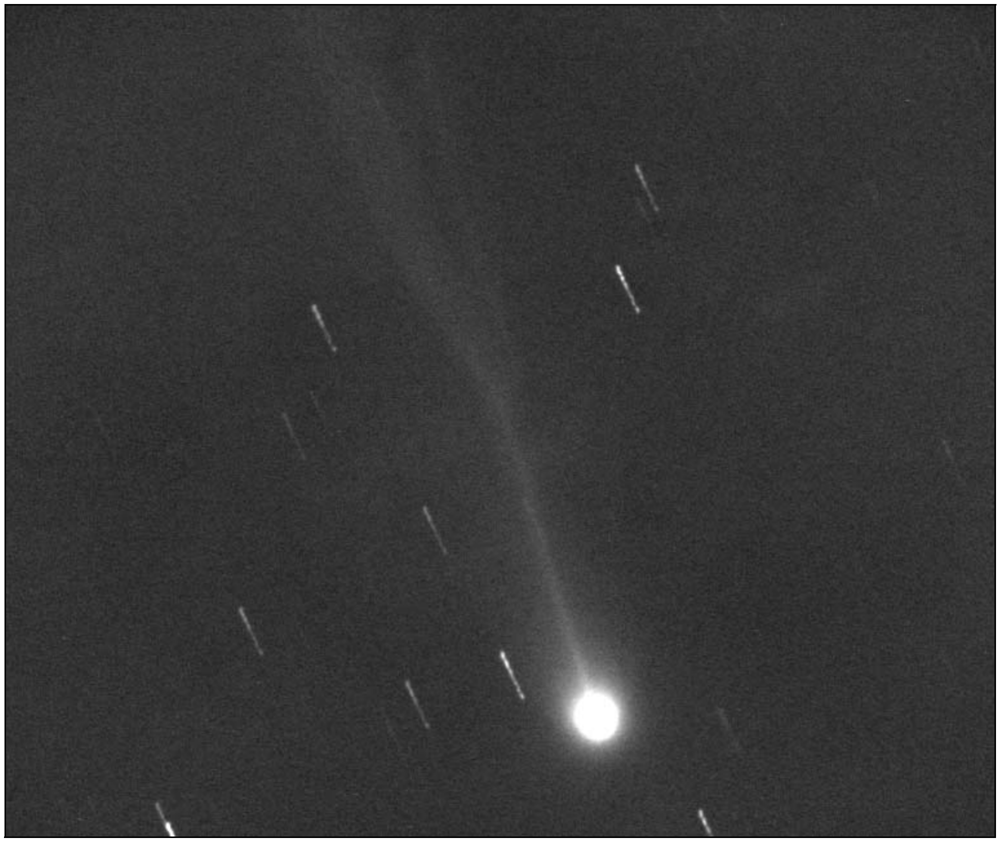

Figure 4. Complex ion tail structure can be seen in this average of 6x90-s exposures from the Virtual Observatory robotic 0.43-m telescope in Ceccano, Italy. The image was taken on 2013 Nov. 18 at 4:50 UT. Credit: Gianluca Masi/Virtual Observatory.

- 2011 September to 2013 January – The comet brightened intrinsically at a steady rate. From Earth, the comet brightened from 19th to 15th magnitude as its heliocentric distance decreased from 9 to 5 AU. During this time the comet's tail was first observed.
- 2013 January to June – The brightening trend not only stopped around 5 AU from the Sun, but the comet started to fade intrinsically by nearly a magnitude as the heliocentric distance decreased to ~3 AU. From Earth, the comet continued to sport a short tail but its apparent magnitude actually faded a small amount from 15th to 16th magnitude.
- 2013 August to early October – For much of the summer, ISON was too close to the Sun for observation from Earth. When it was recovered after conjunction in early August a new rapid brightening trend has started. The trend would only last ~2 months before once again stopping near a heliocentric distance of 1.5 AU. By this time, the comet was at an apparent magnitude of 10-11.
- 2013 early October to November 11 – As the comet moved from 1.5 to 0.7 AU from the Sun, it stayed roughly constant in intrinsic brightness. Due to the decrease in distance from the Sun and Earth, the comet brightened to 7th-8th magnitude as seen from Earth.
- 2013 November 11-22 – Multiple professional groups detected an outburst in the production rate of various molecules in the coma starting on November 11 UT (Biver et al. 2013, Crovisier et al. 2013, Opitom et al. 2013). By the 15th UT, visual observers were reporting a ~3-magnitude increase in brightness up to an apparent magnitude of ~5. Over the next 10 days, the comet's brightness would fluctuate by over a magnitude as a number of outbursts occurred. CCD observers were imaging a complex ion tail that extended over 5 degrees in length. To visual observers, the comet displayed a strongly condensed blue-green coma with a tail that extended over a degree – even in small binoculars. By November 21 UT, these outbursts seemed to subside as the comet moved to within 0.38 AU of the Sun.
- 2013 November 22-27 – During this period, ISON's distance from the Sun decreased from 0.38 to 0.16 AU. At this time, the comet was lost to Earth-based observers but could be followed in the STEREO H1A camera. The comet experienced a ~3-magnitude drop in intrinsic brightness as its period of outburst activity ceased.
- 2013 November 27-28 – The comet was now visible in the FOV of the SOHO LASCO C3 camera. Around November 27.0 UT, a major outburst occurred, resulting in a ~5-magnitude outburst in brightness. At the peak of the outburst around November 28.2 UT (~14 hours

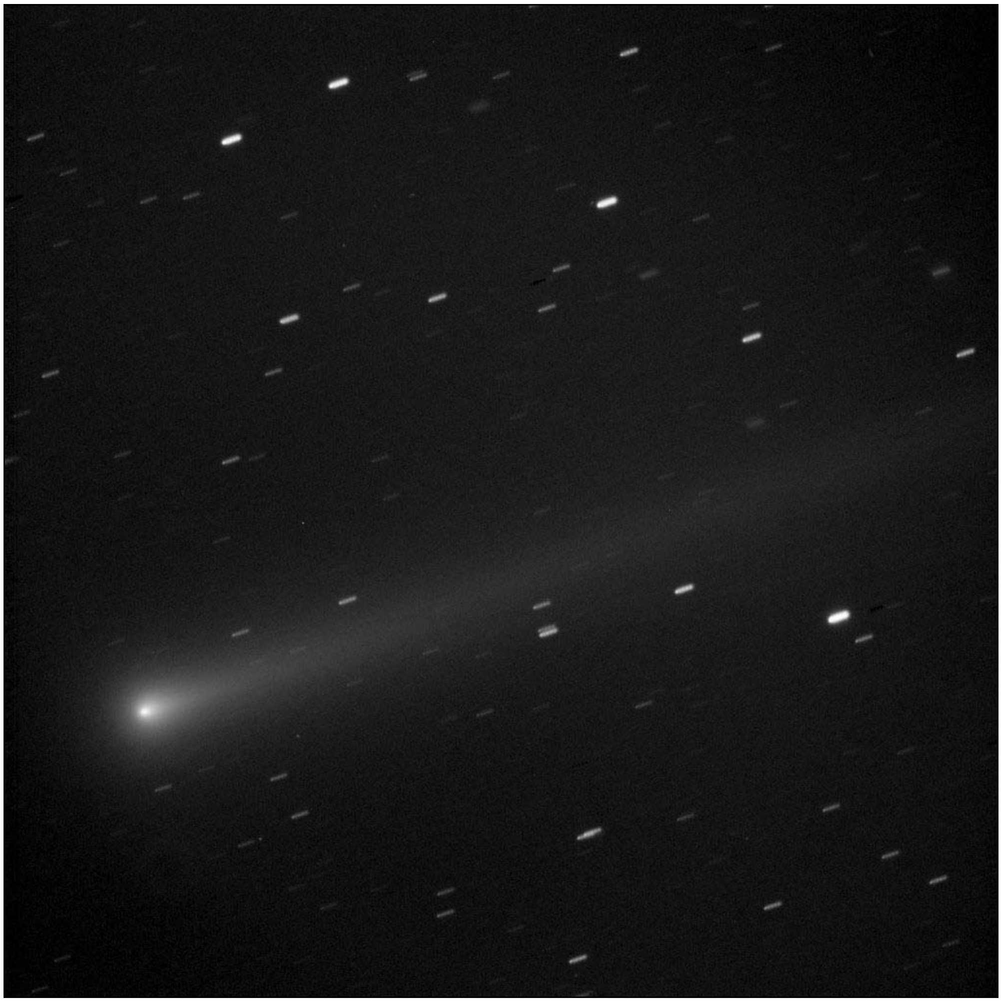

Figure 5. The dust tail of ISON is the highlight of this 6x60-s exposure taken by John Sabia on 2013 Nov. 04.40 UT.

prior to perihelion), the comet reached its peak apparent magnitude of -2.

- 2013 November 28 - After peaking at magnitude -2, the comet began a rapid decline in brightness. Also a few hours before perihelion, the coma started to elongate and lose condensation. Many small sungrazing comets observed by SOHO have shown a similar appearance, which has been interpreted as the complete disruption of the nucleus. By the time of perihelion, the comet was too faint to be observed by the Solar Dynamics Observatory (SDO) spacecraft.

- 2013 November 28 – December 9 – To the surprise of many, the comet reappeared after perihelion in the FOVs of STEREO and SOHO (for a short-period around perihelion the comet was behind the occultation disk used by the imagers to block the Sun). Rather than a healthy looking condensed comet, a diffuse cloud of remnant dust was observed moving away from the Sun. The lack of detection by SDO, radio telescopes in the days after perihelion, and modeling of ISON's post-perihelion dust cloud and tails all point to an end-of-dust/gas release in the hours around perihelion (Biver et al. 2013, Boehnhardt et al. 2013, Pesnell 2013, Sekanina 2013).

Current Status

At the time of writing (2013 December 9), a few visual observations of the remnant dust cloud have been reported, though no CCD observers have captured an image of the dust cloud. Based on the comet's brightness while in the STEREO H1A images and our experience with the remnants of other disappeared comets, ISON's dust may be followed by visual and CCD observers for many weeks.

The question of whether any sizable fragments of the nucleus still exist will wait till the comet is far enough from the Sun to be safely observed by large telescopes. By the time you are reading this, HST may have provided an answer to this question, as it is scheduled to image ISON in mid-December.

To put the demise of ISON in perspective, comet disintegrations are not rare events. SOHO has observed roughly 2000 small Kreutz sungrazing comets, and all but one disintegrated prior to perihelion (the exception being C/2011 W3 (Lovejoy) which disintegrated a day or two after perihelion). Even comets that don't get as close to the Sun as the sungrazers can disintegrate. Comet C/2013 G5 (Catalina), which was featured on the front cover of the Summer 2013 issue of this Journal, is an example of a comet that faded from view at a distance of ~1.6 AU while still inbound towards perihelion.

The mechanisms that cause the complete disruption of comet nuclei are still being debated. Possible mechanisms include breakup due to tidal forces, rapid rotation, gas pressure stresses, thermal stresses and erosion via gradual fragmentation and sublimation.

The story of Comet ISON is really only beginning. Due to the concerted work of amateur and professional observers from around the world, an immense amount of data was produced. Analysis over the next few years will undoubtedly unlock many of Comet ISON's secrets.

References

Biver, N. et al. (2013). CBET 3711.

Biver, N. (2013). Yahoo Group comets-ml #22743.

Boehnhardt, H. et al. (2013). CBET 3731.

Crovisier et al. (2013). CBET 3711.

Green, D.W. (2013). CBET 3238.

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Pesnell, D. (2013). 'Where was Comet ISON?', SDO is GO blog, http:// *http://sdoisgo.blogspot.com/2013/11/where-was-comet-ison.html* .

Sekanina, Z. (2013). CBET 3731.

Figure 6. A composite of B, V and Rc band images taken by Bruce Gary on 2013 November 8 UT with a Celestron CPC 1100 (0.28-m), Optec 0.5x focal reducer and SBIG ST-10XME CCD. All exposure times were 20 seconds. Number of images used were 40 B, 30 V and 27 Rc. The FOV is 30'x19' with north up and east to the left. Credit: Bruce Gary.

Figure 7. Fig. 7. Another image by Bruce Gary taken with the same set-up as Figure 6 but on 2013 November 19 UT. The sharpest 11 20-second r' band exposures were used. MaxIm DL's digital development used to enhance contrast of small scale structure while reducing contrast of large scale structure. Credit: Bruce Gary.

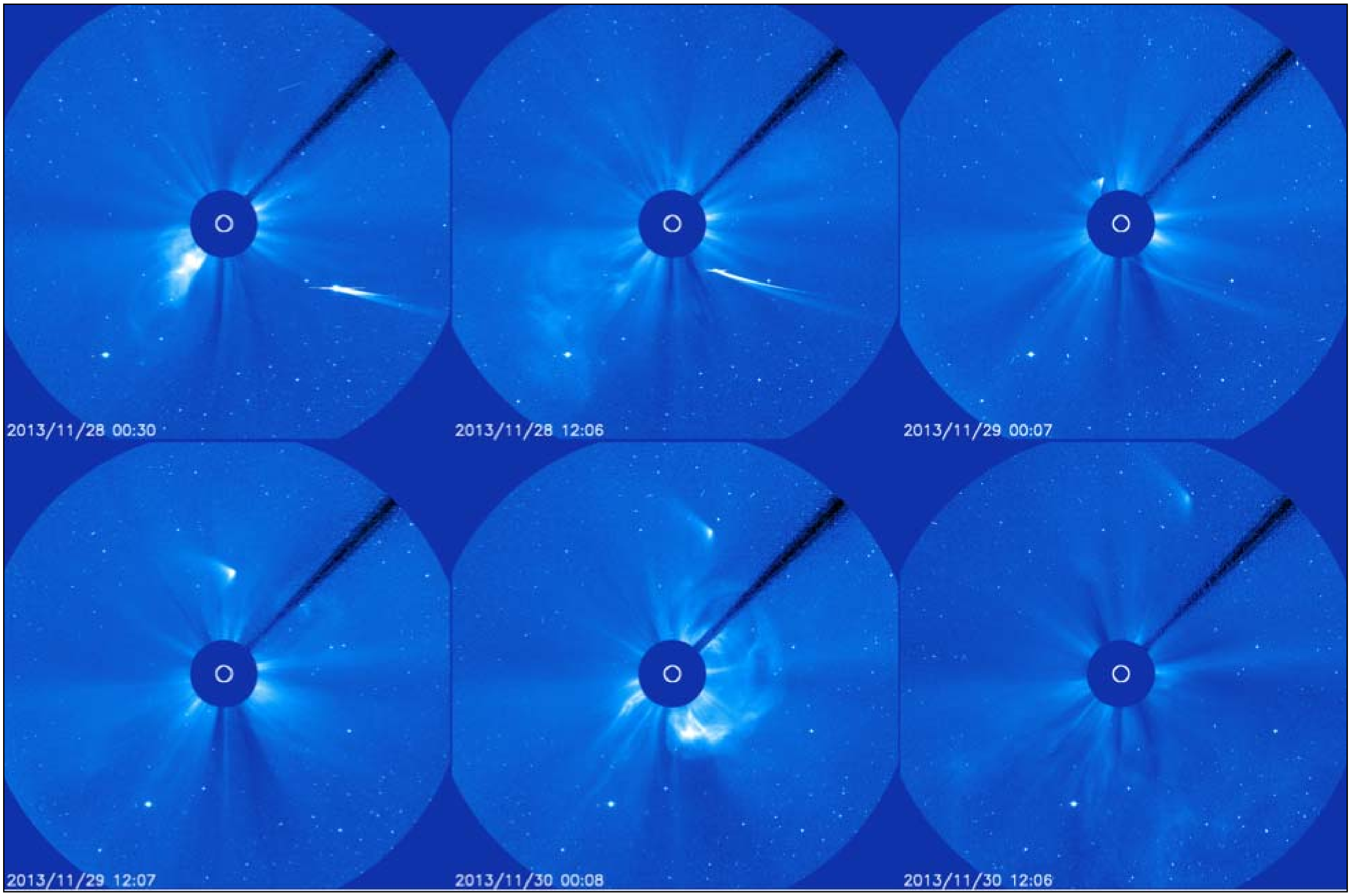

Figure 8. This mosaic consists of images taken by the SOHO LASCO C3 imager of ISON at 12 hour intervals between 2013 Nov. 28 00:30 UT and Nov. 30 12:06 UT. The transformation from healthy comet to remnant dust cloud is apparent. Credit: ESA/NASA/SOHO/LASCO.

Comet Report Form: Visual Observations

Send copies of these completed forms to:

Carl Hergenrother
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Acting Assistant Coordinator
4101 North Sunnywood Place
Tuscon, AZ 85749

Please print or type the following: date of observation to 0.01 day, brightness to 0.01 magnitude, coma diameter to 0.01', and tail lengths to 0.01°. Each sheet should be devoted to only one comet, and any drawings or photographs that pertain to the observations on this sheet should be included.

Comet Designation: ____________________

Observer: ____________________

Address: ____________________

Date (UT)	Magnitude		Instrument				Coma		Tail		Sky	Rem
(yy/mm/dd.dd)	Mag.	Ref.	Apr (cm)	Type	F/	Pwr	Dia (°)	DC	Len (°)	PA (°)	LM	

Remarks