

Bright comets in 2013

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Come March and November of 2013 and prepare to witness comets that should reach naked-eye visibility, namely, the Comet Pan-STARRS (C/2011 L4), Comet Lemmon (C/2012 F6) and the Comet ISON (C/2012 S1) respectively, all recent discoveries. In the course of their passage through the inner Solar System, the objects are expected to get very bright when near the Sun and may qualify to be bright or great comets. The orbit of the Comet ISON is so eccentric that it will be virtually grazing the Sun during its perihelion passage. In that phase of its journey, it is expected to reach exceptionally high visual brightness. According to some estimates, its brightness might reach a good fraction of that of the Full Moon and in turn become the comet of the century.

What is a comet?

Comets are serendipitous celestial visitors, though members of the Solar System. These are made of rocky material and icy mixture of water, carbon dioxide, ammonia, methane etc. Their eccentricities are large and the orbital parameters such that they pass most of their time way beyond the orbit of Pluto (39.537 AU, mean distance from the Sun). As a comet approaches the Sun, the heated surface starts to sublimate. The gas and dust released create a head (coma) about $10^4 - 10^5$ km and sometimes a tail directed away from the Sun that can reach millions of kilometres in length giving it a distinct appearance. Hidden inside the head is the comet's nucleus that is just a few kilometres across.

As the tiny form approaches the Sun, say a distance about 4 AU (1 Astronomical Unit = 149597870.691 km), the ices of the nucleus begin to melt and loosen up. The process also loosens up the dirty parts of the nucleus, the meteoroids. The coma consists of gases like water vapour, carbon monoxide, carbon dioxide, nitrogen, methane and ammonia. The gas molecules are ionized by the radiation of the Sun and begin to glow with a bluish tinge due to fluorescence of the ions. The swarm of high energy charged particles in the solar wind sweeps them away forming a straight bluish ion tail. It starts developing when the comet reaches 1.5 AU from the Sun and can get several millions of kilometres long. Its spectrum shows up with the emission bands of carbon monoxide (CO^+), carbon di-oxide (CO_2^+), nitrogen (N_2^+), cyanogen (CN^+) etc. The plasma tail shows up with structure like knots, streamers and helical forms. Sometimes it is in conjunction with the dust tail and not separately visible. As the comet approaches the Sun it gets brighter. The dust released in the process also is pushed away by the Sun's radiation pressure. The process is relatively mild and so the dust tail is not necessarily straight but more along the orbit. The dust tail increases in extent as the comet approaches the Sun and vice versa. It too can get millions of kilometres long. The dust particles are typically 10^{-4} cm. The dust tail does not glow but shines by the sunlight and is white to pale yellow in appearance.

There are supposed to be billions of comets as members of the Solar System. These reside in mainly two regions, the so-called Kuiper Belt and the Oort Cloud. The Kuiper belt extends from near the orbit of Neptune (about 30 AU) to about 1000 AU

in which the orbits lie close to plane of the planetary orbits and the comets move around the Sun in the same direction as the planets. The Oort Cloud is centered on the Sun and extends from 10,000 to about 100,000 AU with the cometary orbits completely randomly oriented.



Comet Hale-Bopp (C/1995 O1): the Great Comet of 1997 (IIA Archives)

In a year about 20-25 comets may be seen. About half of these are new while the other apparitions are *encore* (old comets). Periodic comets follow elliptical orbits. Those with periods $P < 20$ years are termed short-period comets. Comets with periods $20 < P < 200$ years are the intermediate-period ones. Halley's Comet is the singular intermediate period comet that is naked eye and spectacular. Comets with periods in excess of 200 years are called the long-period ones.

The visual brightness of a comet varies inversely as square of its distance from the Earth (Δ^2) and inversely as r^n where r is its distance from the Sun. The quantity n is photometric exponent that is typically about 4. The other crucial factor to decide the brightness is the comet's absolute magnitude. When the sky is dark and clear, the faintest star human eye can see unaided has a magnitude near +6. In contrast, a comet is a diffuse form and can be noticed with the unaided eye in a dark sky when shining

at a magnitude of +3.4, an apparent brightness similar to that of the Andromeda galaxy. Compare it with the Milky Way that is just about visible, shining at +5.0 mag and closer to the limiting magnitude of a point object. Yeomans D K, Rahe J and Freitag R S (1986 The history of Comet Halley, *J Roy Astron Soc Canada*, **80**, 62-86) have given estimated brightness of the Halley's Comet on different dates of the visible phase in its apparitions recorded since 240 BCE. One can easily make out that in all the apparitions, the comet reached its brightest when it was passing closest by the Earth.

As of Nov 2012, there were a reported 4557 comets (Johnston's Archive <http://www.johnstonsarchive.net/astro/index.html>). Of the lot, over 1500 are Kreutz Sungrazers. Needless to say, it is an ever growing tribe. The studies of comets are important for in them lie the clues to the past and present of the Solar System and even to origin of life on the Earth.

Great comets

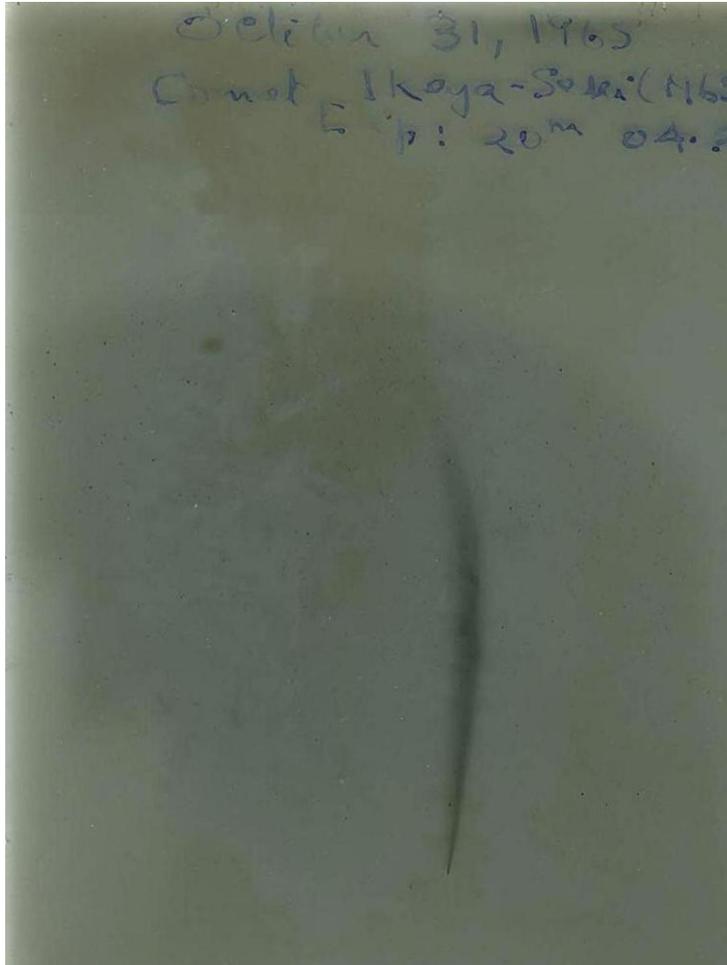
A number of comets have been described very bright and many are classed as great comets for becoming spectacular. The bright comets can be generally as bright as the brightest stars but are not bright enough to cast a shadow. Very few comets can match or surpass the brilliance of the planet Venus. Such comets would but be too close to the Sun to allow an easy observation. In general, a comet that has a large and active nucleus, a large active surface area and shall pass by the Sun from about 0.5 AU or less and the Earth at close distances, and as observed from the Earth does not get obscured out of view by the Sun when at its brightest could become a great comet. Though not well defined, it shall normally get brighter than mag +2. John Bortle counted 40 comets that reached maximum visual brightness of magnitude 0 or brighter in between the period 1800-2000 (<http://www.icq.eps.harvard.edu/bortle.html>). As noted in the *International Comet Quarterly* of Feb 2009 (<http://www.cfa.harvard.edu/icq>), the brightest comet since 1935 was C/1965 S1 (Ikeya-Seki; $q=0.0078$) that reached a peak visual magnitude of -10. On average there is a comet brighter than mag +4 once in two years, brighter than +2 in 5.5 years, brighter than mag +1 in 10 years and brighter than mag 0 in 15 years, with exceptions of course. In Dan Yeomans's (2007) list of great comets, Halley's Comet has figured as one in twenty two of its 27 apparitions that took place between the years 87 BCE – 1910 CE (http://ssd.jpl.nasa.gov/?great_comets).

Sungrazing comets

An unusual class of comets is the Sungrazing comets that pass extremely close to the Sun at perihelion and get exceptionally bright, some visible even in daytime. These have perihelia $q \sim 0.005$ AU, or about 50,000 km from the photosphere, and periods in the range 400-800 years. At times, the passage can be from a few thousand kilometres of the surface of the Sun only and the rendezvous can lead to damaging consequences. In such an event, small Sungrazing comets can be completely evaporated. The larger ones can survive a number of perihelion passages. Here a crucial factor is the Sun's own separation from the bary-centre of the Solar System that is about $\sim 1 R_{\odot} = 0.00465$ AU. A majority of the Sungrazing comets belong to the so-called Kreutz group. These presumably originated from some great comet that broke up into several smaller ones when it ventured into the inner Solar System the first time. A very large number of the Sungrazing comets observed with SOHO, the

Solar and Heliospheric Observatory launched in 1995 by NASA and ESA for the study of the Sun, are members of the Kreutz group.

Brian Marsden in his 2005 *Annual Reviews* article adopted q values around 10-12 R_{\odot} (0.0465 – 0.0558 AU) for a Sungrazer.



The Great Comet of 1965 Ikeya-Seki; image taken at the Kodaikanal Observatory.

Legend on the cover of the plate: ‘October 31, 1965 Comet Ikeya-Seki (1965f) Emulsion: OaE (Kodak) Tessar f/4.5 7” focus+24” coelostat; Exp: 04 20 – 04 40 (IST)=20 mts; BNB+PSH’.

The observers are - B N Bhargava and P Shahul Hameed; image scale, object location not given. The comet had passed its perihelion on Oct 21; comet location is Corvus, $r=0.495$ AU, $\Delta=1.049$ AU, as inferred from the ephemeris of C/1965 S1-A generated using Jet Propulsion Laboratory’s Horizons System (IIA Archives).

In 2013, three new comets to reach naked-eye visibility

Comet Pan-STARRS (C/2011 L4)

The Comet Pan-STARRS was discovered on June 6, 2011 as a +19.4 mag object using the 1.8 m Pan-STARRS 1 telescope (PS1) when it was 7.9 AU from the Sun. The robotic Panoramic Survey Telescope & Rapid Response System is installed at Mount Haleakala in Maui Island in Hawaii for wide field imaging. The telescope is in fact the largest digital camera in the world at 1.4 billion pixels. Each image is about 3 gigabytes in size that it takes approximately every 45 seconds. The telescope photographs more than 1,000 square degrees of the sky in a night. Its main goal is to

detect and study Earth approaching bodies – asteroids and comets that might be hazardous. The comet was named after the telescope itself. Its pre-discovery images were recovered quickly and an orbit could be computed within two days of the discovery. The comet Pan-STARRS passes its perihelion in March 2013 when it should become very bright, brighter than 0 mag, and be visible naked eye. It will pass closest by the Earth on Mar 5 from 1.097 AU and its perihelion on Mar 10 when it will be an evening object. It shall begin to lead the Sun from Mar 29.



Comet PanSTARRS, Jan 23, 2013, with the 0.3m F(Photometric Robotic Atmospheric Monitor—FRAM, Argentina (Source: <http://spaceweather.com/>).

Its essential information is as follows:

	<i>i</i>	<i>q</i>	<i>e</i>	Perihelion
C/2011 L4	84°.1988	0.30161 AU	1.00009	2013 Mar 10.1499

(Above, *i* is the inclination angle made by the orbital plane of the comet with the plane of the ecliptic (counted 0° to 180°), *q* the perihelion distance and *e* the eccentricity; source: Jet Propulsion Laboratory's On-Line Solar System Data Service).

An eccentricity > 1 implies that the Comet Pan-STARRS is entering the inner Solar System the first time ever. It is thus carrying pristine material in its head, and immaculate at that, so that while nearing the Sun, it shall outgas the first time ever since its formation, or, that of the Solar System. The orbit is so inclined to the ecliptic plane that it arrives nearly vertically, venturing inside Mercury's orbit. The comet developed a coma suggestive of active dust production even at 4.6 AU that it was on May 18, 2012 and a tail-like form was visible in the images. The comet touched mag 8.3 on Dec 26 2012. It was estimated to reach mag 5.3 on Jan 31, 2013. Yet on Jan 25, the comet was reported at only 8 mag. Beginning February, it glowed at 6.7 mag.

The comet will be visible in the northern hemisphere in March and April 2013 when it emerges from the Sun and gets bright enough. Observers in the southern hemisphere

get its good view much earlier since the comet enters the inner solar system from below the ecliptic plane. An observer in London will get to see the comet from Mar 13. For observers in India, the comet's best view commences early March. For instance, as at Bangalore on March 3, the Comet's altitude reaches 7.5° at the time of sunset (12:57 UT) whereas at Delhi the comet reaches an altitude of 8° at the time of sunset (12:49 UT) on Mar 6. For a view, the Sun must go down nearly as much so that the evening sky is no more so bright and the comet can be traced hovering right over the western horizon about 15° south of the point the Sun set at. The situation, however, improves each day, with the comet also gradually shifting its location northwards.

Between Mar 8 when it is in the constellation of Cetus and Mar 14, 2013 while in Pisces, the comet is expected to touch -0.19 mag, dropping down to -0.07 mag. According to another estimate, the comet might be brighter, fading in this phase from a high of -2.0 mag to -1.6 mag. A solar elongation of about 15° places it pretty close to the Sun but an hour after the sunset a dark sky should allow a naked eye view of the comet right near the horizon. Its being a New Moon on Mar 11, the comet might present an enchanting view with a long bright tail on several days around it. The comet tail is going to swing substantially in this phase, from east to north. For a good view, places like the Thar, Ladakh or any place far away from city lights or offering high altitudes are ideal. We need to remember that comet brightness predictions are not always right. There is already a pointer to it, for, recently, the Comet Pan-STARRS has not been brightening up as believed previously and it might peak at mag $+2$ or $+3$ only. At that, it would still become a naked eye object. Beginning April, the brightness may drop to $+4$ mag when a binocular will be needed for a view.

Comet Lemmon (C/2012 F6)

The Comet Lemmon was discovered on Mar 23, 2012 by Tomas Vorobjov, an amateur astronomer from Slovakia who used through the internet the 32 inch Schulman Telescope at the Mount Lemmon SkyCenter, Arizona, run by the Deptt of Astronomy, University of Arizona for remote use by astronomers and citizen scientists (<http://uanews.org/story/comet-discovered-mt-lemmon-skycenter>). The orbit of the comet is highly eccentric though < 1 that makes it a periodic one. For a period of 10750 years, it returns now to the inner Solar System in as many years. Its essential information is as follows:

	<i>i</i>	<i>q</i>	<i>e</i>	Perihelion
C/2012 F6	82.6084	.7313	.998499	2013 Mar 24.5165

(Source: Jet Propulsion Laboratory's On-Line Solar System Data Service).

Beginning February, it glowed at 6.2 mag. with a greenish hue that is due to the presence of CN and diatomic carbon C_2 in its coma. It has brightened up more than expected. Around perihelion when it begins to lead the Sun again, it is expected to reach 3 to 2 mag in visual brightness. Through Feb-Apr, 2013, the comet moves from high southern declinations northwards nearly straight, passing closest by the Earth on Feb 5, 10:00 UT from 0.98489 AU. From India, it should be traceable in April. For example, at Bangalore the comet altitude at sunrise on Apr 7 is 7° (2° at Delhi), on Apr 14, it is 14° (10° at Delhi), etc. However, by this time it will have somewhat faded and a binocular may be needed.



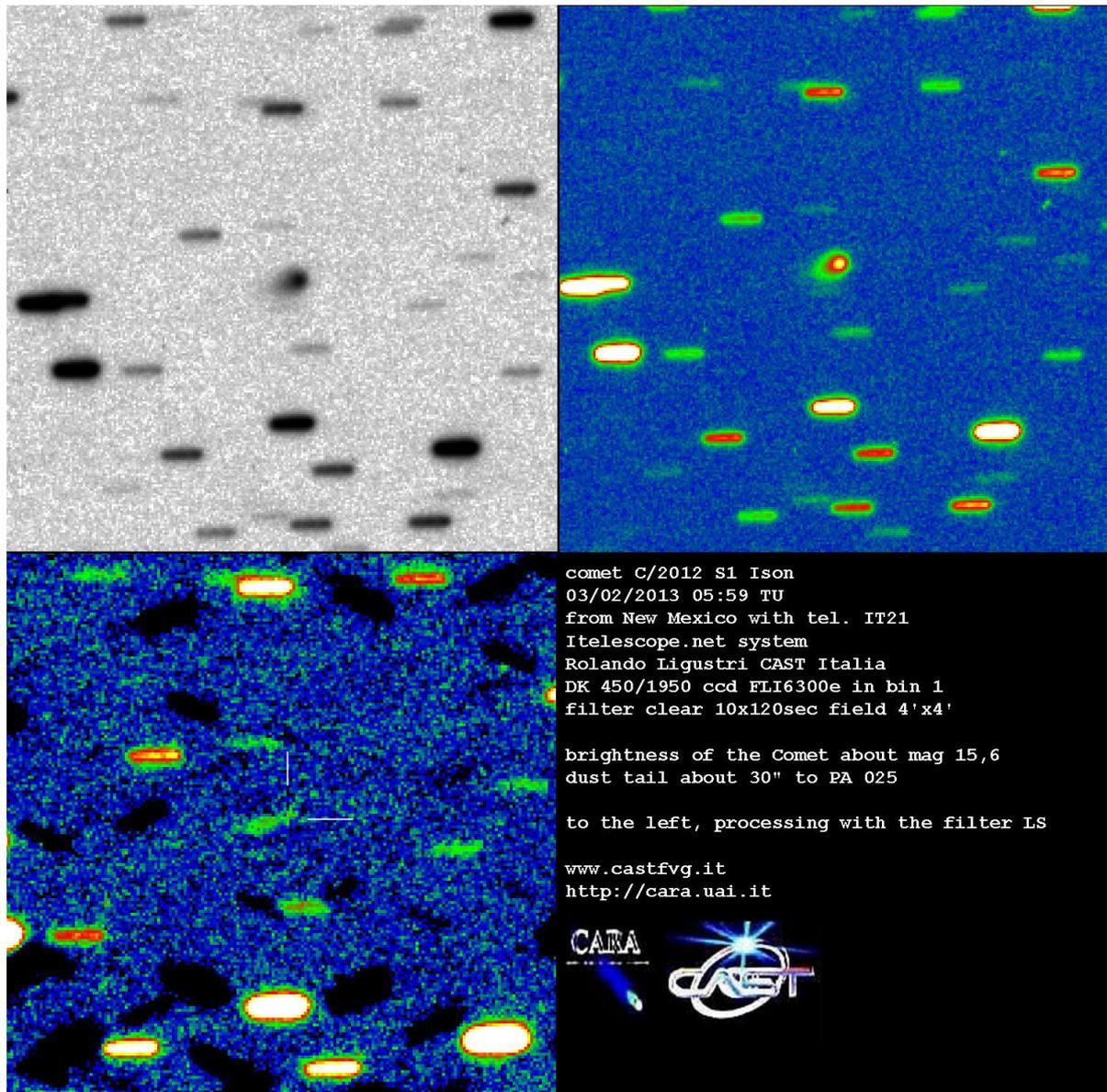
Comet Lemmon: on Jan 28, 2013, taken by Rolf Olsen (Source <http://spaceweather.com/>).

Comet ISON (C/2012 S1)

On the night of Sept 21, 2012, two Russian amateur astronomers Vitali Nevski and Artyom Novichovok discovered with a 40 cm telescope and a CCD camera of the International Scientific Optical Network (ISON) near Kislovodsk, Russia an object that is destined to be a Great Comet in 2013. A search through images taken by the Mount Lemmon Survey revealed it from 28 Dec 2011 and by Pan-STARRS from Jan 28, 2012. The comet has been designated C/2012 S1 (ISON). Since discovery, the comet has been under constant watch and now well talked about. At discovery, it shone at +18.8 mag. Before it can brighten up and turn a visual treat hovering above the horizon near you, it is shining in the virtual skies – blogs, Face Book, Google Plus, Twitter, print media etc.

The orbit of the comet has been computed that indicates it is a Sungrazer. Its eccentricity $e= 1.000002666578981$ suggests that like the Comet Pan-STARRS, the

Comet ISON too is closing in for the first time. For an orbital inclination $i = 61^\circ.785$ with respect to the ecliptic plane, the comet arrives into the inner solar System rather steeply, moving southeast as seen from the Earth. Its perihelion passage is on Nov 28.8147, 2013 (at around 19:00 UT) when it is estimated to touch a visual magnitude -13. Magnitude estimates of the comets for such a close approach to the Sun should be taken with caution. The comet and the Sun will then be located at the top of the constellation of Scorpio. Thereafter it turns to move northeast, reach high declinations to become circumpolar in early January 2014. After reaching $\sim +87^\circ$ in declination on Jan 7, it turns southeast again.



Rolando Ligustri, Feb 30, 2013 ((Source <http://spaceweather.com/>)).

The most interesting phase of the apparition will be centered over the few days around Nov 28, and even thereafter. For a perihelion distance $q=0.0125$ AU ($= 2.6896 R_\odot$, about 1.87 million km), the comet will pass by the Sun from very close quarters, down to $1.69 R_\odot$ from its surface. That is a journey through the middle corona of the Sun, so to say, and not safe for a comet. However, this distance is much larger

compared to the distance of $0.45 R_{\odot}$ from the surface of the Sun what Comet Lovejoy (C/2011 W3), also a Kreutz family Sungrazer discovered on Dec 2, 2011 by Tony Lovejoy, passed by during its perihelion passage on Dec 16, 2011. The Comet Lovejoy is supposedly a smaller comet in comparison to the Comet ISON. While coursing through the turbulent environs, the Comet Lovejoy had the risk of total destruction. However, it belied all apprehensions and survived the close encounter with the Sun. The movement of the Comet Lovejoy with its wriggling tail and its emergence from behind the Sun about an hour later is vividly revealed in a Solar Dynamics Observatory footage (http://science.nasa.gov/science-news/science-at-nasa/2011/16dec_cometlovejoy/). The Kreutz family comets have typically small cores, just a few tens of metres or so. According to Matthew Knight, the core of the Comet Lovejoy therefore had to be larger, at least about 0.5 km as to survive the kind of mass loss it would have suffered due to solar heating. On Oct 21, 1965, the great comet Ikeya-Seki passed its perihelion ($q=1.7 R_{\odot}$) and was noticed to have fragmented just before perihelion by T Hirayama and F Moriyama while carrying out its coronagraphic observations.



A German engraving of the Great Comet of 1680; printed in 1707 (Source: <http://wordcraft.net/comets5.html>)

The orbital elements of the Comet ISON resemble those of the Great Comet of 1680 and according to some astronomers, the two objects might be related or even be the same:

	ω	Ω	i	q (AU)	e
C/2012 S1	345°.501	295°.751	61°.785	0.0125045	1.000002666578981
C/1680 V1	350°.613	276°.634	60°.678	0.00622	0.999986

(Above, i is the inclination angle, Ω the longitude of the ascending node taken eastward from the vernal equinox, ω the angle of the perihelion from the ascending node measured in the ecliptic plane, q the perihelion distance in AU and e the eccentricity; 1 AU = 149597870.691 km; source: Jet Propulsion Laboratory's On-Line Solar System Data Service).

On Jan 7, 2013, the Comet ISON was seen through a 15" telescope at 14.5 mag. Computations suggest +6 mag on Nov 1, +3 on Nov 18 and 0 mag on Nov 23, 2013. The Comet ISON should brighten up to be seen with small telescopes in August 2013 and is expected by some to reach naked eye visibility in October-November to stay so until the middle of Jan 2014.

All through November until Jan 6, 2014, the comet leads the Sun, except for a very brief period around the time of its perihelion passage. Note that Full Moon occurs on Nov 16 and Dec 17, 2013. Around the time of its perihelion passage, its brightness as variously estimated is expected to touch between -11 to -16 that may make it to be the brightest comet in human history. The Full Moon shines at -12.7 and so the Comet ISON should become visible daytime. Its tail around then will stretch unusually long, about 90° or so. Whether it would actually attain the estimated brightness can not be said with confidence at present. Its solar elongation at perihelion will be 0°.48 when its brightness will be highly suppressed in the glare of the Sun. Still it should get bright enough. On Dec 26, 2013, 23:00 UT, the Comet ISON will pass the closest by the Earth from 0.429 AU if it survives its close passage by the Sun. By then it will have lost much of its brightness, down to +4 mag or so.

Should it lose some mass or break up, the event and its view will be even more exciting. In a break up, the components will continue to move in the same orbit. At the same time, more surface area exposed to the intense solar radiation means that the sublimation will get speeded up only. In a year of high solar activity, the comet's passage through the middle corona thus offers an exciting opportunity to study, better if multi-wavelength, the impact of solar magnetic field and hot plasma on the motion of the comet material and would be followed by observatories in space and on ground alike.

Astronomers are already considering the Comet ISON as big as the Comet Hale-Bopp and so a great show is expected. Comets like Hale-Bopp ($1.6 - 2.7 \times 10^{17}$ gm), Halley's (2.2×10^{17} gm) and Tempel 2 are massive comets; others are much smaller. However, astronomers are often wary of comet brightness predictions. The Comet Austin (C/1989 X1) turned out to be much fainter than expected. Similarly, the Comet Kohoutek (C/1973 E1) that was first seen in 1973, and tipped to be the comet of the century, did not rise to the occasion. Part of its nucleus broke when it reached a certain distance to the Sun. Though its brightness did not touch the expected highs, it did reach naked eye visibility.

With the Jet Propulsion Laboratory's On-Line Solar System Data Service, we looked into the orbit of the Comet ISON for an interesting possibility, particularly around the time of its perihelion passage on Nov 28, 2013. Since the perihelion distance is only $2.69 R_{\odot}$, for a short while the comet and the Sun shall come apparently very close to

each other as viewed from the Earth. Can there be an occultation or a transit of the comet, or both? This can happen if the ecliptic coordinates of the comet lay within $\pm 0^\circ.25$ of the Sun's while it arrives at and crosses the ecliptic plane. The limiting figure, about one solar radius, corresponds to a grazing incidence. This can happen on Nov 28, 2013 only within a time window from 18:42 UT when the ecliptic latitude β of the comet that arrives from below the ecliptic plane reaches $-0^\circ.25$ until 19:48 UT when the same crosses the limiting value $+0^\circ.25$. It now turns out that the comet's orbit is so oriented that during this brief period, it remains slightly ahead of the Sun, meaning the events, as viewed from the Earth, are missed by just $0^\circ.25$ in longitude (from the Sun's limb). Judging from the relative distances to the comet and the Sun from the Earth, even a transit is not going to be, as obvious from the following:

2013-Nov-28, 18:42 UT

	r	Δ	El	λ	β
Comet	0.012510189857	0.99577362540989	0.4851 /T	247.1144406	-0.2469489
Sun	0.000000000000	0.98649572419030	0.0000 /?	246.6967710	-0.0001503
Difference in distance from the observer: 1387954 km.					

2013-Nov-28 18:54 UT

Comet	0.012444276918	0.99550256746739	0.4964 /T	247.1757617	-0.1582358
Sun	0.000000000000	0.98649434577124	0.0000 /?	246.7052123	-0.0001500
Difference in distance: 1347611 km					

2013-Nov-28, 19:15 UT

Comet	0.012645796263	0.99480807634851	0.5510 /T	247.2709847	0.0006043
Sun	0.000000000000	0.98649193408905	0.0000 /?	246.7199843	-0.0001494
Difference in distance: 1244077 km					

2013-Nov-28, 19:48 UT

Comet	0.013703421089	0.99323536658083	0.6904 /T	247.3869835	0.2492116
Sun	0.000000000000	0.98648814571859	0.0000 /?	246.7431978	-0.0001486
Difference in distance: 1009370 km					

(Above, r is the Heliocentric range of the comet centre and Δ that with respect to the observer – both in AU, El the solar elongation and λ and β are, respectively, the ecliptic longitude and ecliptic latitude of the target in degrees; '/T' means the comet is trailing the Sun; figures generated using Jet Propulsion Laboratory's On-Line Solar System Data Service).

In this computation, the comet has been taken as a point object and the observer location is geocentric. On way to its perihelion, the comet passes its closest by the planet Mercury on 22 Nov. As it gets near the Sun, it is likely to lose mass or fragment and its orbit may get altered when near the Sun. What places on the Earth are right for these moments? Requiring that the Sun be risen, the locations would have to be in the southern hemisphere. Mainland places like Sydney, Canberra, Brisbane and Melbourne, for instance, are the border locations in the areas where the sunrise that day would be well near the start of the above-mentioned time window. Further east, Auckland sees sunrise over an hour earlier while Tokyo up north misses out the moment for the place sees the sunrise at 21:30 UT. With a low Sun at the moments of perihelion passage of a Sungrazer, what more can a ground-based observer ask for other than a clear horizon?

Recall that many astronomers could see the Great September Comet (C/1882 R1) around the time of its transit on Sept 17 unaided when one needed only to cover the eye from the direct sunlight. The comet was a Sungrazer that went on to become so bright that it could be seen in daylight for over two days. Just when it was about to transit the Sun, it was noticed late afternoon continuously making into the boiling of the Solar limb by astronomers at the Cape of Good Hope with telescopes suitably prepared for the observations (Finlay W H 1882 The Great Comet (b) 1882 -

Disappearance at the Sun's Limb, *MNRAS* **43**, 21-22). The other well-known case is that of the Great Comet C/1927 X1. The comet had a perihelion $q=0.176157$ AU and so it was not quite a Sungrazer. It became so bright that it could be seen on December 15 through the day as also daytime on Dec 16-17. As A C D Crommelin later estimated, the comet must have been very bright, at least -6 mag., and that was before it passed its perihelion on Dec 18.1809.

Comets in their bright phase generally have small solar elongation. While watching a comet or its nucleus through a binocular or a small telescope, make sure that the Sun is well out of the field of view.

Do not ever view the Sun through optical devices directly.

Last updated: Feb 11, 2013.