COMETS

Comets are distinguished visually from asteroids by showing, at least some of the time, not only a star-like point but a cloudy coma and sometimes a tail. A comet's nucleus is a "dirty snowball" of ice and dust (though it may have a rocky core like an asteroid); when it comes near enough to the Sun, some of the surface ice sublimes, releasing dust. Gas and dust spread to form the coma, far vaster than the nucleus; driven slowly outward by radiation-pressure from the Sun, the dust forms a curved tail; driven outward more rapidly, the gas forms a straighter tail.

Comets are divided for convenience into two kinds:

—Non-periodic (or long-period), which arrive unpredicted, from any direction, in orbits close to parabolas, so that after departing they will not be seen again for centuries, if ever. They are thought to have been disturbed out of orbits in the far outer solar system, the Kuiper Belt and the Oort Cloud. Passage near the planets deflects some of them into hyperbolic orbits, meaning that they will leave the solar system.

—Periodic (or short-period), with orbital periods shorter than 200 years. They are comets of the other kind that have been captured by the gravity of the planets. They have smaller orbits, still tending to be more elliptical and inclined than those of the asteroids and planets. but mostly in the usual counterclockwise direction around the Sun.

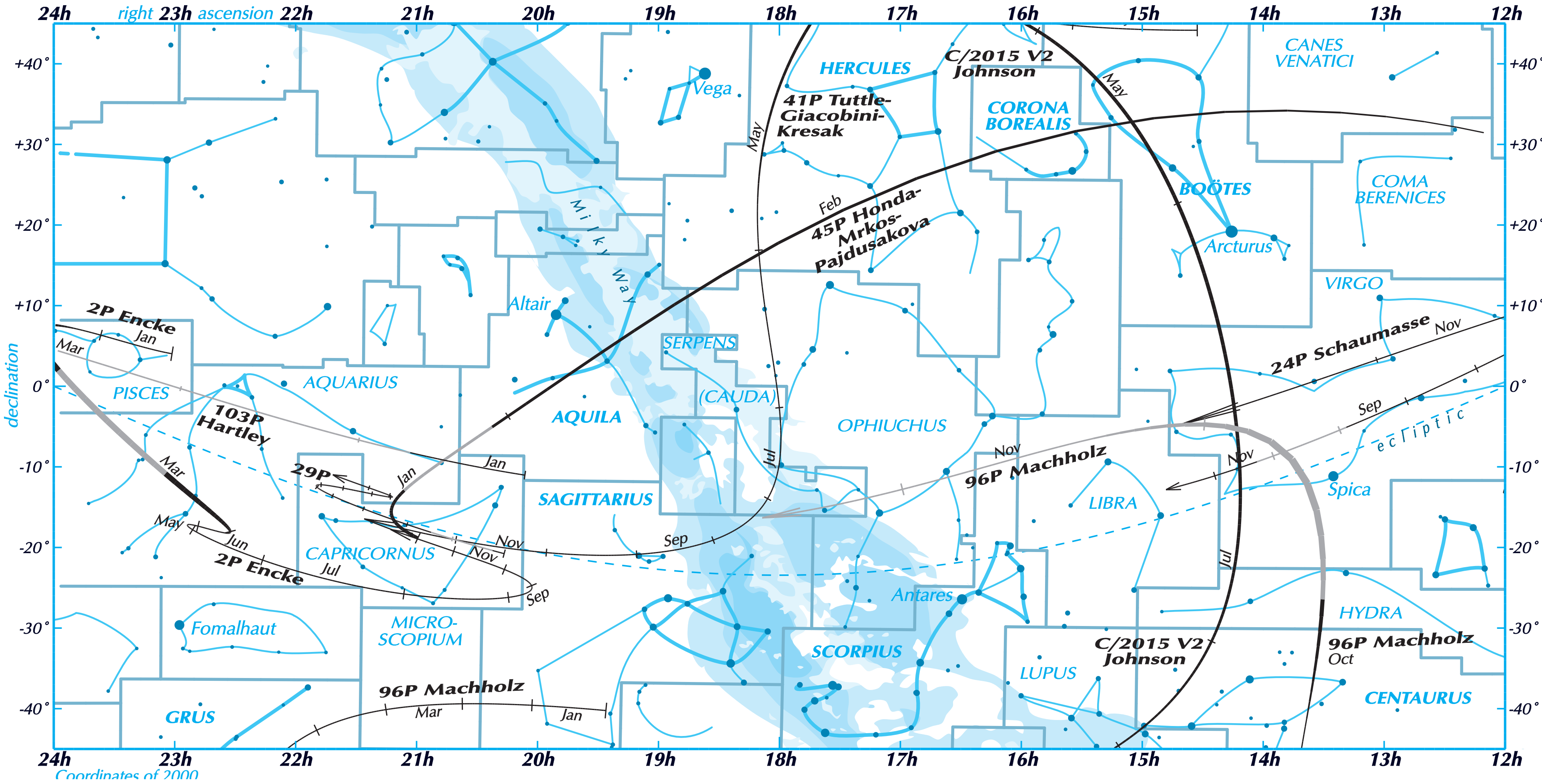
Comets' apparent brightnesses depend on distance from Sun and Earth, but predictions are notoriously unreliable, because of variations in the dust-producing activity on comets' surfaces. Even if becoming bright, to be observable they need favorable geometry: arriving near enough to Earth at times when they are in a dark sky. And even if a comet shines at its predicted magnitude of, say, 6 (about the naked-eye limit), it will be less easily seen than a star of that magnitude, because it has lower surface brightness: its light is spread over a fuzzy patch instead of being concentrated in a point.

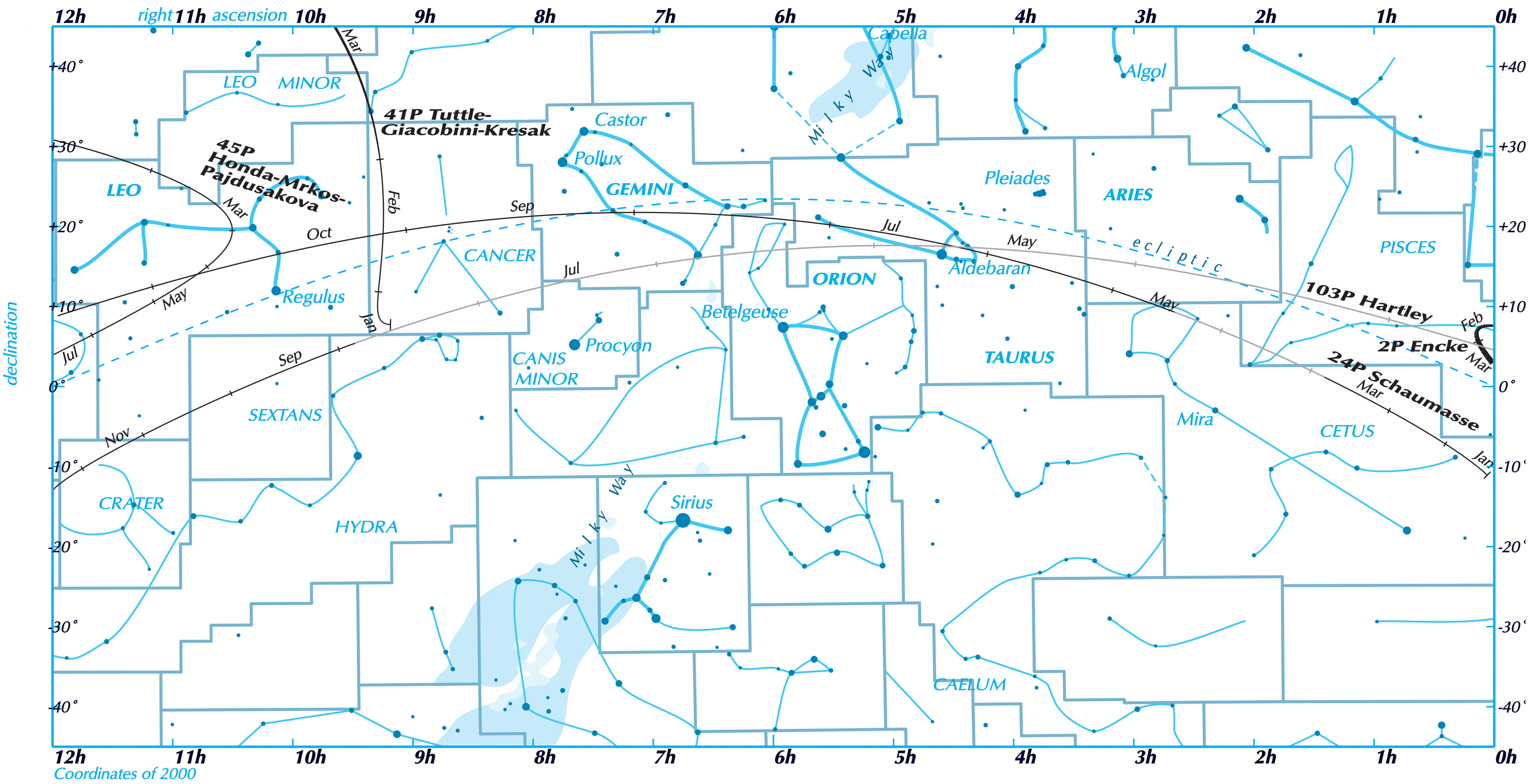
Most comets are inconspicuous, including most of the 48 periodics predicted to return to perihelion this year. The few naked-eye comets are either those that happen to pass very close to Earth, or some of the non-periodics. A newcomer of this kind can arrive at any time.

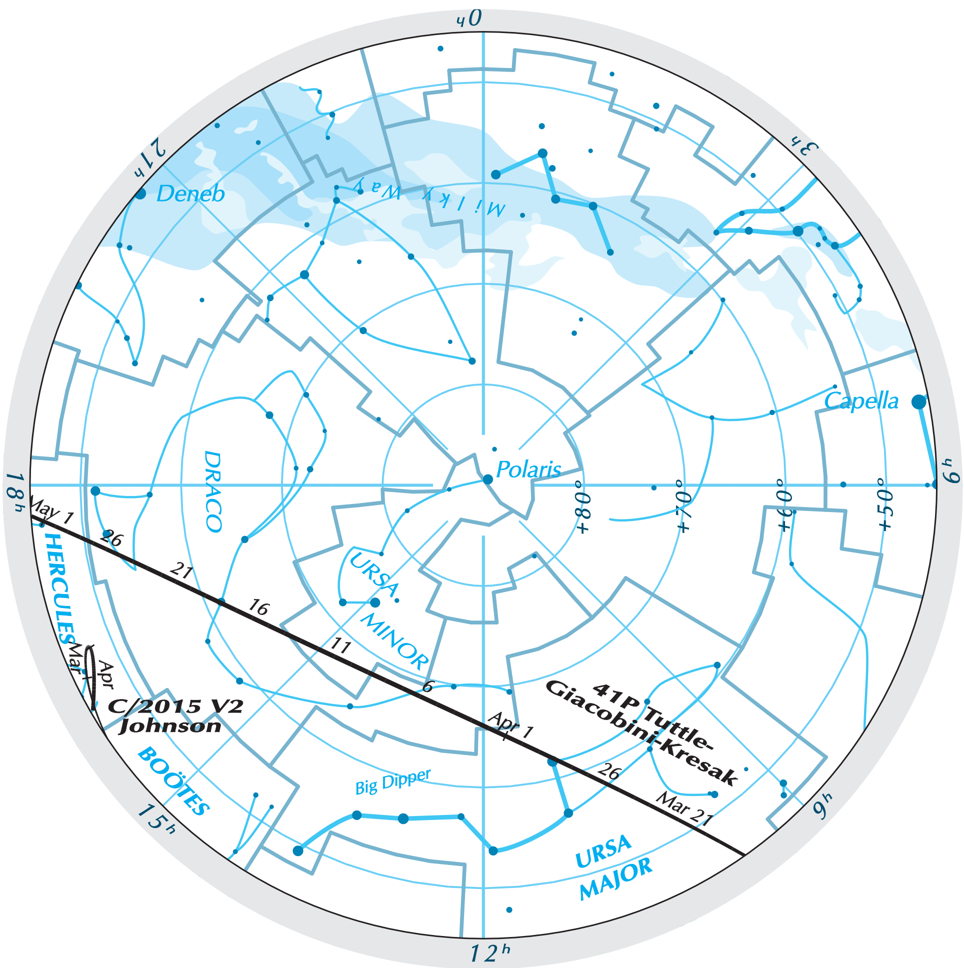
Featured here are comets that, as far as was known at the beginning of the year, should at some time in the year be brighter than magnitude 11: seven of them. This does not necessarily mean they are ever, while bright, at convenient elongation from the Sun. 29P Schwassmann-Wachmann is added because, though usually far dimmer, it occasionally flares up.

GENERAL MAPS of comets' paths on the sky during the year. Ticks are at 1st of each month. Paths are drawn thicker where the comets are brighter; and are gray when the comets are less than 15° from the Sun as seen from the Earth.

The general charts on the preceding pages were based on orbital elements as known in late 2016, whereas later elements were used in the illustrations for the individual comets. The earlier charts are left unchanged so that you may see some interesting slight differences. Orbital elements change as the result of more recent studies or of perturbations by the planets.







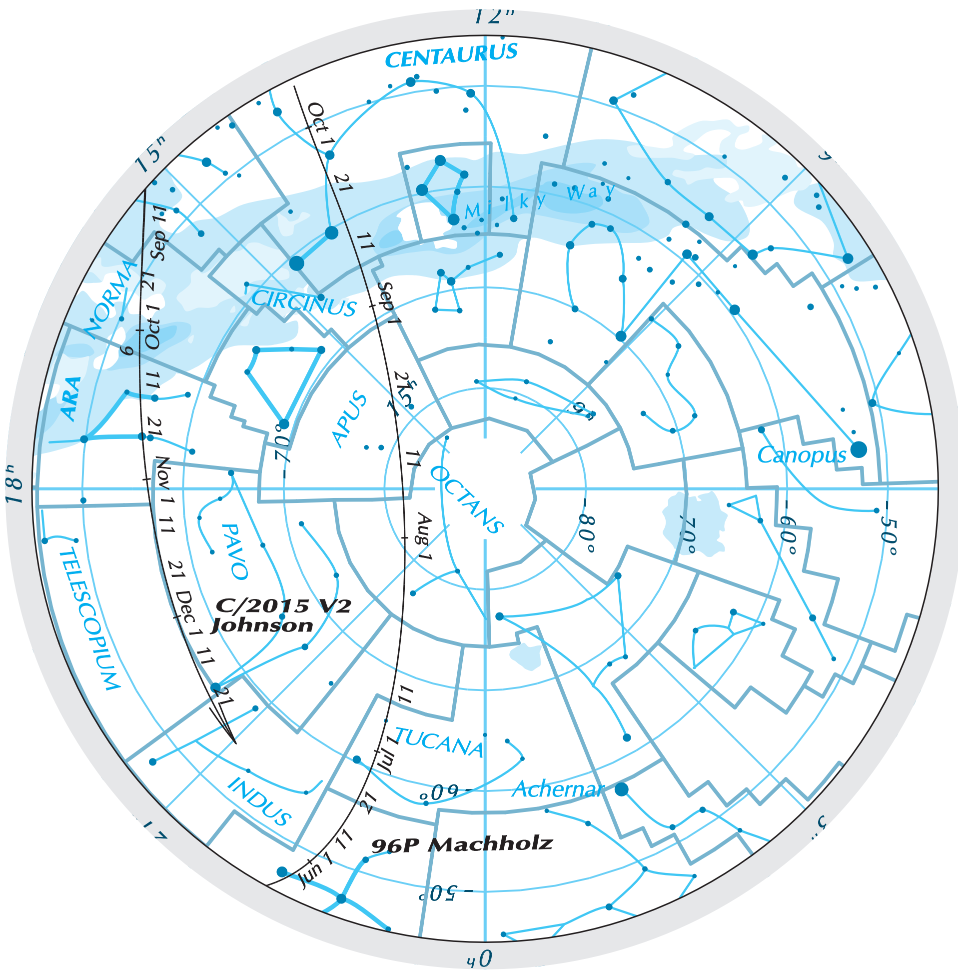


Table of characteristics

designation: "P" means periodic comet, i.e. with a period shorter than 200 years. "C" is a comet with a longer or parabolic orbit. "D" is used for periodic comets that have become lost. Periodic comets of more than one observed visit, with well-established orbits, are numbered "1P," "2P" . . . up to (as of 2017 Jan) "345P." Single visits of comets are distinguished by e.g. "1991 C2," where "C2" means the 2nd discovery in the first half of February.

name: usually the discoverer; sometimes the first two, or three, independent discoverers; sometimes a person associated with the comet in a different way (Halley, Encke, Crommelin). "Brooks 2" is the 2nd short-period comet discovered by Brooks; this is not done for long-period comets, and has (officially) ceased for short-period ones also.

T: date of perihelion (nearest approach to the Sun).

P: orbital period, in years.

e: eccentricity, or shape of orbit. 0 would be a circle; all periodic comets have elliptical orbits, with eccentricity between 0 and 1; 1 would be a parabola, as the orbits of very long-period comets appear to us; more than 1, a hyperbola, in which a comet is not bound to the solar system.

q: perihelion distance, least distance from the Sun, in AU (astronomical unit, the average Sun-Earth distance).

a: semimajor axis of orbit, average distance from the Sun.

Q: aphelion distance, greatest distance from the Sun.

i: inclination to the ecliptic. Inclination greater than 90° implies retrograde motion—in the general direction opposite to that of the planets.

Ω: "longitude of the ascending node," angle from the March equinox point to the orbit's ascending node. **ω**: "argument of perihelion," angle from the ascending node to the comet's perihelion. These give the orbit's orientation. Ω+ω gives the longitude of perihelion, a helpful quantity. For instance, if it is 180°, perihelion is outside the March part of our orbit, and if the comet arrives there in March it will be at opposition as close as it can be to Earth.

The three angular elements, *i*, Ω, and ω, are given in relation to the ecliptic and equinox-point of the present year.

m: brightest apparent magnitude the comet may reach this year—far from certain! And not necessarily at a good position for observation.

For orbit calculation, minimum and sufficient elements are six: *T, e, q, i*, Ω and ω. *a* could be used instead of *q*.

* and ~ : these draw attention to unusually high and low values. They help to extract what is interesting from the table.

Most comets in the inner solar system are of an ordinary short-period kind: with orbits of length 6-9 years and shape half way between circle and parabola (*e* about 0.5), taking them from aphelion near Jupiter's orbit (5.2 AU)—often near the perihelion of it (longitude 13°)—to perihelion near Mars's orbit (1.5 AU); all going the same way around the Sun as the planets, with sometimes greater inclinations than the planets but not usually more than 20°. This is Jupiter's "family" of comets, most of them intrinsically faint.

The more noticeable comets tend to be those with odder orbits—very long (like 1P Halley) or short (like 2P Encke), more eccentric, more inclined or even retrograde. Brightest of all are some of the non-periodic comets which arrive unpredictably.

designation and name	discov.	T	P years	e	q AU	a AU	Q AU	i °	Ω °	ω °	m
45P Honda-Mrkos-Pajdusakovß	1948	2016 Dec 31	5.26~	0.82*	0.533~	3.02	5.52	4.2~	89	326	7*
2P Encke	1786	2017 Mar 10	3.30~	0.85*	0.336~	2.21~	4.09~	11.8	335	187	4*
41P Tuttle-Giacobini-Kresßk	1858	2017 Apr 13	5.42~	0.66	1.045~	3.08	5.12	9.2	141	62	7*
103P Hartley	1986	2017 Apr 20	6.48	0.69	1.066~	3.48	5.89	13.6	220	181	10*
C/2015 V2 Johnson	2015	2017 Jun 12	..	1.00	1.637	..	..	49.9*	70	165	7*
96P Machholz	1986	2017 Oct 27	5.29~	0.96*	0.124~	3.03	5.95	58.2*	94	15	2*
24P Schaumasse	1911	2017 Nov 16	8.26	0.70	1.206	4.09	6.96	11.7	80	58	10*
29P Schwassmann-Wachmann	1927	2019 Mar 21	14.76*	0.04~	5.765*	6.02*	6.27	9.4	312	49	15

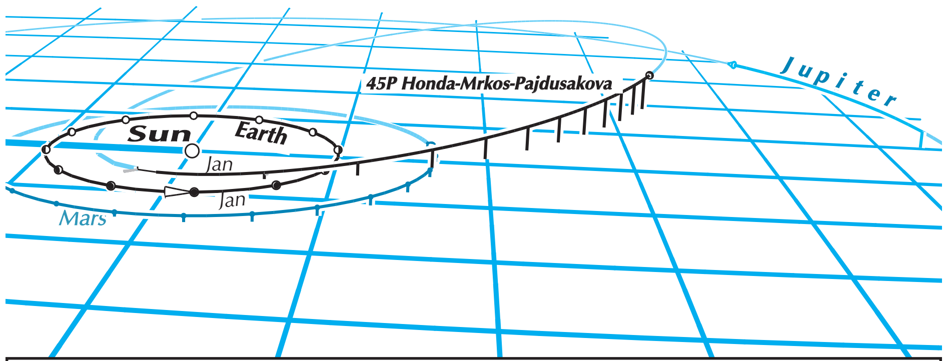
PHENOMENA. Columns: date (Universal TimeT); right ascension (hours, minutes, seconds) and declination (degrees, minutes), for epoch 2000; distance from Sun and Earth, in astronomical units; elongation from Sun (degrees; negative = westward); magnitude.

	r.a.(2000)	dec.	hedis	gedis	elo	mag
45P Honda-Mrkos-Pajdusakova						
Jan 29 9 conjunc.with sun	20 35 17	-6 50	0.796	0.194	-11	8.0
Feb 27 10 opposition	11 17 4	27 54	1.209	0.232	-159	12.0
2P Encke						
Mar 10 2 perihelion	23 38 33	-3 2	0.336	0.663	4	3.5
Mar 11 15 conjunc.with sun	23 29 40	-5 11	0.338	0.656	2	3.5
Aug 2 21 opposition	21 2 9	-25 53	2.286	1.277	-171	17.4
41P Tuttle-Giacobini-Kresak						
Feb 8 23 opposition	9 29 35	14 21	1.334	0.347	180	12.7
Apr 12 18 perihelion	16 24 59	60 21	1.045	0.152	-102	6.7
103P Hartley						
Apr 20 12 perihelion	2 13 51	13 17	1.066	2.062	5	10.6
Jul 24 14 conjunc.with sun	8 8 4	11 41	1.630	2.628	-8	14.8
C/2015 V2 Johnson						
Apr 28 2 opposition	15 57 58	44 58	1.745	1.040	-117	7.5
Jun 12 8 perihelion	14 24 56	10 17	1.637	0.825	125	6.7
96P Machholz						
Jul 18 24 opposition	22 1 11	-73 1	2.072	1.316	-125	17.4
Oct 23 3 conjunc.with sun	13 30 11	-23 42	0.245	0.879	-13	5.4
Oct 27 23 perihelion	13 45 29	-9 9	0.124	0.954	-7	2.0
24P Schaumasse						
Apr 19 9 conjunc.with sun	1 58 9	5 3	2.660	3.655	7	24.2
Nov 16 20 perihelion	12 11 60	7 39	1.206	1.458	-55	10.2
Schwassmann-Wachmann 1						
Jan 26 22 conjunc.with sun	20 38 2	-19 15	5.862	6.846	1	15.9
Aug 13 15 opposition	21 30 32	-12 55	5.818	4.806	178	15.1

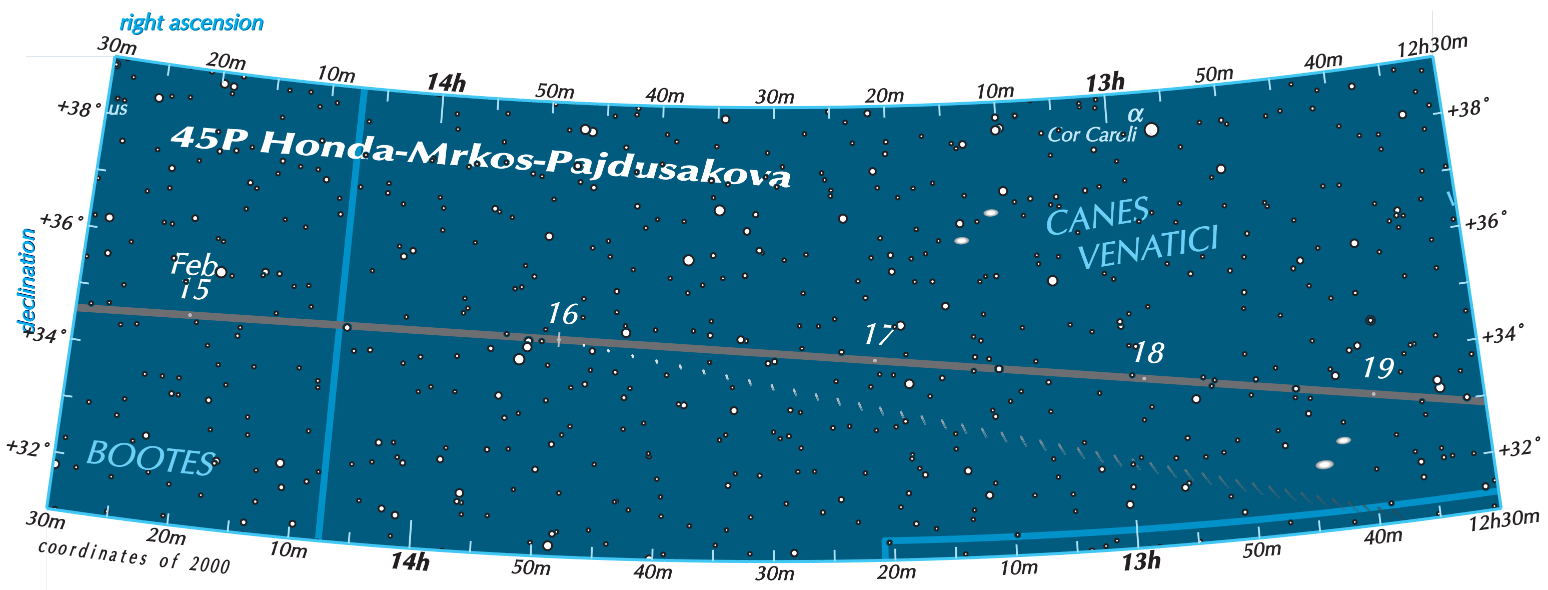
The Planetary Science Institute has a campaign (http://www.psi.edu/41P45P46P) in which it invites all amateur and professional astronomers to contribute their images of three comets making close approaches to Earth: 45P Honda-Mrkos-Pajdušáková and 41P Tuttle-Giacobini-Kresák in early 2017, and 46P Wirtanen in late 2018.

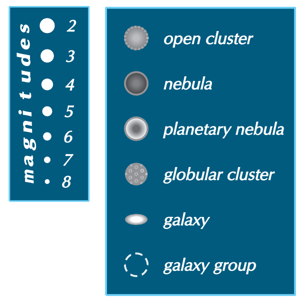
45P Honda-Mrkos-Pajdušáková can be quite prominent, yet was left for visual discovery quite late into the era of photographic searches. It was discovered after its 1948 perihelion first by Minoru Honda in Japan, then by Ludmilla Pajdušáková and Antonin Mrkos independently of each another though both at the Skalnata Pleso observatory in Czechoslovakia. t can come close to Jupiter, Earth, and Venus. The orbit (modified by a very close pass of Jupiter in 1935) rivals that of 2P Encke in shortness and eccentricity, looping from just north of Jupiter's to nearly halfway inward of Earth. IIt is one of the faintest of comets, but shows rapid brightening in the time just around perihelion; the speed of its dashes through the inner solar system explains why it had not been noticed earlier. The tail must spray out over us, and at one time the Capricornid meteors of July-August were thought to derive from it. It has been observed at all but one (1959) of its visits. In 1982 another close aphelion pass of Jupiter gave the orbit a sharp twist: instead of cutting south through the perihelion area at an inclination of 13°, it cuts north there at only 4°. At one time HMP was being considered as a target for a fly-by or rendezvous space mission. In Aug.-Sep. 2011 it passed 0.06 AU from us and was sensed by radar.

It was recovered in late 2016 as it came up from the south behind Earth, and was at perihelion in the late hours of Dec. 31—–inside and south of the November part of our orbit. Moving faster than Earth, it ascends through the ecliptic plane on Jan. 10, overtook us on the inside on Jan. 29, and climbs out in front of us over our orbit. It is nearest to us (0.08 a.u.) on Feb. 11, reaching magnitude 7; farthest north on Feb. 15, and races eastward across our high morning sky.



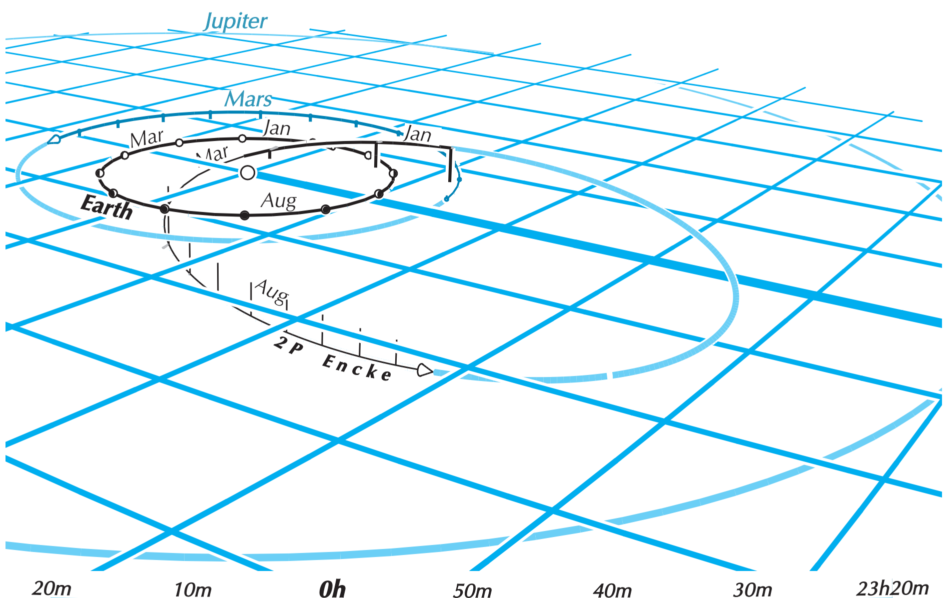
In the spatial diagrams for the comets, the viewpoints are all at a distance of 10 a.u. from the Sun and from latitude 15° north of the ecliptic, but from various longitudes. Grid lines on the ecliptic plane are 1 a.u. apart; the thick one is the vernal-equinox direction. Stalks from the bodies' paths to the ecliptic plane are at one-month intervals. Short sunward ticks mark dates of perihelion. The rest of each orbit is shown by a blue curve. The orbit of Earth is always shown; those of Mars and Jupiter are sometimes included. The globes of Earth and Sun are vastly magnified.

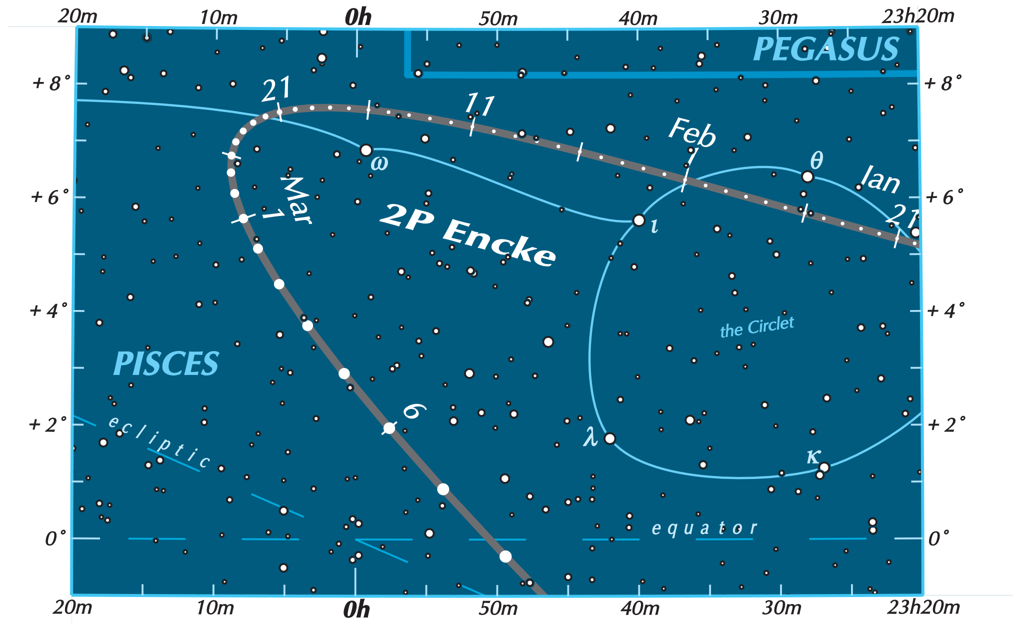




2P Encke is of all comets the second most familiar. 1P Halley with its lifetime-like period of 76 years has made 30 recorded visits (starting in 240 B.C.); Encke's is now making its 63rd, because of its period of only 3.3 years (the shortest known, except for 3200 Phaethon, the asteroid-or-dead-comet that gives us the Geminid meteors). Like Halley's it is named not for a discoverer but for the thinker who revealed its nature. When interest in comets surged after the first successfully predicted return, that of Halley's in 1759, one of the most productive searchers was Pierre Méchain; he found this comet in 1786; it was rediscovered in 1795 by Caroline Herchel, and in 1805 by Pons, Huth, and Bouvard. (The 3.3-year period means that similar apparitions come roughly each third time, or 10th year; in these three discovery years the comet followed about the same favorable path.) When Pons yet again discovered it in 1818, Johann Franz Encke (then 27 and an assistant at a Swiss observatory) calculated the orbit on a better basis than he had before, connected it (in six weeks' work) with the three comets out of the past, and predicted an 1822 return. This came about so exactly that the comet was called Encke's. Since then it has been seen every time except wartime 1944. We now number it "2P" as second, after Halley's, to join the set of predictably periodic comets. Its orbit though small is very elongated, from within the orbit of Mercury to more than 4/5 of the way to Jupiter. In 1913 it was (at the suggestion of E.E. Barnard) found and photographed at aphelion, thus becoming the first "annual" comet, essentially detectable in any part of its orbit. It may have been in this orbit for thousands of years, protected from perturbations by not going out as far as Jupiter; yet no ancient observations of it have been found. Diffuse dust from it appears as the Taurid complex of meteor streams (daylight Zeta Perseids and Beta Taurids of June, North and South Taurids of October-November). It was Fred Whipple who in 1940 connected the Taurid meteors to Comet Encke, and in 1983 he connected the Geminids to 3200 Phaethon.

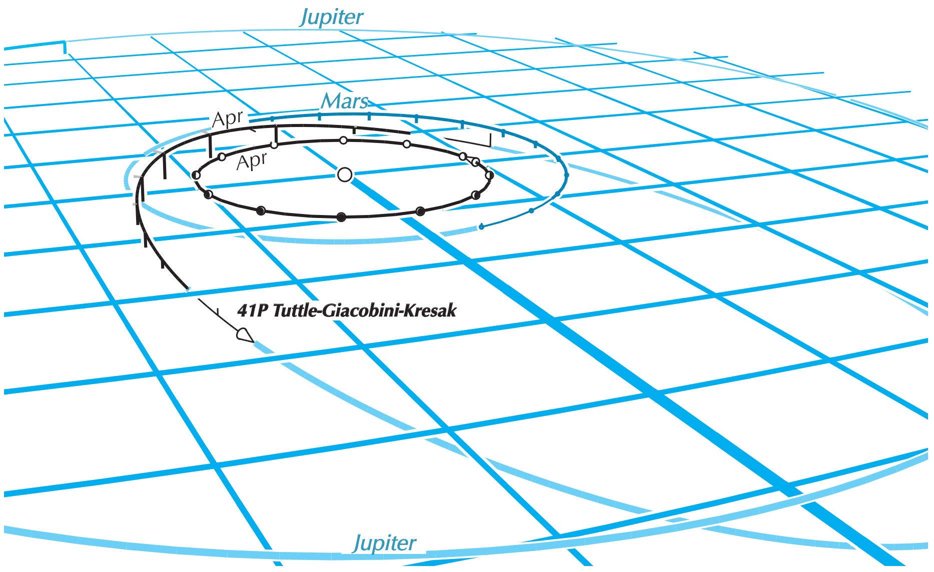
Because of the 3.3-year period, 2007's performance is almost repeated in 2017: Encke was at perihelion 2007 April 19 and arrives now for a perihelion of 2017 March 10. It crosses inward over our orbit, behind us and therefore in the evening sky, on Jan. 26. Through February, getting rapidly nearer to the Sun, it gets rapidly brighter, but also drops closer toward the sunset horizon. For the northern hemisphere the angle of the ecliptic is favorable, so the comet is vertically above the Sun. It brightens to magnitude perhaps 6.5 by Feb. 24 and 4 by March 6, when 15° from the Sun. It passes lmost directly between Earth and Sun—–perihelion March 10, Sun-conjunction March 11. On the way out, it is at opposition on August 2, but now more than 1¼ a.u. from us, farther south (–26°_, and down to magnitude 17.

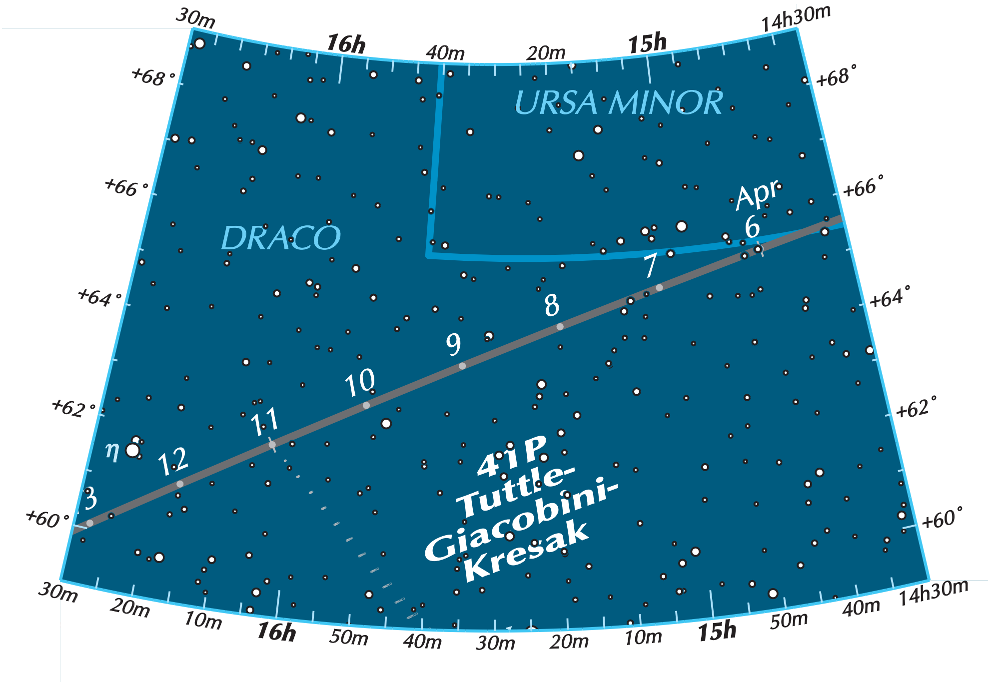


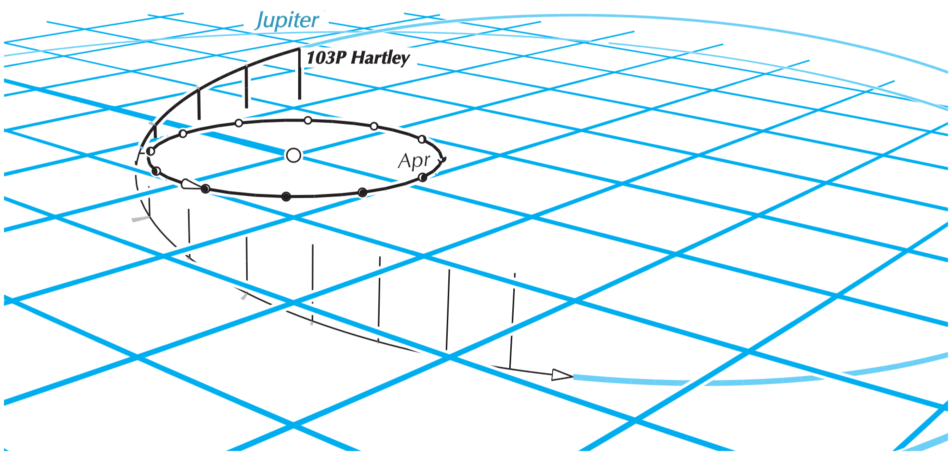


41P Tuttle-Giacobini-Kresák was discovered in May 1858 by Horace Tuttle at Harvard College Observatory. It was in Leo Minor, very faint though exactly at perihelion and only 0.36 a.u. from Earth. It faded quickly, was last seen a month later. The period was estimated only roughly (5.8-7.5 years), so the comet was lost. On 1907 June 1, Michel Giacobini at the observatory of Nice in southern France discovered a faint comet that likewise was near perihelion, faded, was lost in two weeks. In 1914 Pickering suggested the identity of the 1858 and 1907 comets; in 1928 Crommelin linked them mathematically and predicted that the next perihelion would be in Nov. of that year; but the return was unfavorable and no searches were made; Crommelin reinvestigated the orbit in 1933 but without success. Thirdly, in April 1951 Lubor Kresák with large binoculars at the Skalnate Pleso observatory in Czechoslovakia discovered a comet that was better observed and was soon identified with the lost Tuttle-Giacobini. The failed predicting had chiefly to do with the uncertain period: this turned out to be around 5.5 years, so that there had been 8 unseen visits between 1858 and 1907, 7 more between 1907 and 1951. And, because of that roughly half-year fraction, TGK has tended to have alternate bad and good returns: missed in 1957, observed in 1962, missed in 1967, observed in 1973—when it twice cast off its dim character, flaring to amazing magnitudes of 4 and 4.5, so that several Japanese amateurs "rediscovered" it. After this its orbit lessened rather sharply in inclination (from 14° to 10°) and also continued a tendency to slew around counterclockwise. The quite strongly elliptical orbit now takes it from fairly deep south of Jupiter's orbit (the part where Jupiter is in 1999 and 2011) to a perihelion rather close north of the April part of Earth's orbit. It was observed in 1978, missed in 1984, observed in 1989-90, 1995, 2006; missed in 2011.

This is one of the returns with with excellent timing: for a perihelic opposition, just outside and steeply north of the April part of our orbit. It will actually be nearest to us (0.14 a.u.) on Apr. 1, and farthest north (declination nearly 66°) on Apr. 3, and may between then and its Apr. 12 perihelion and Apr. 13 opposition reach magnitude 6.6, or better if flaring. From May to August, departing and sloping southward, it stays roughly outward from us, thus appearing to take a long sinuous dive all the way from Draco to Sagittarius.



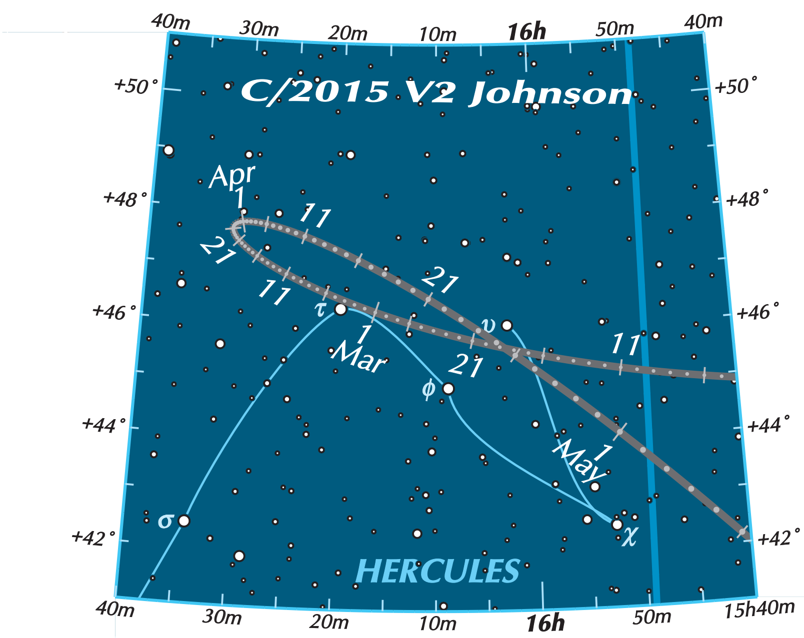


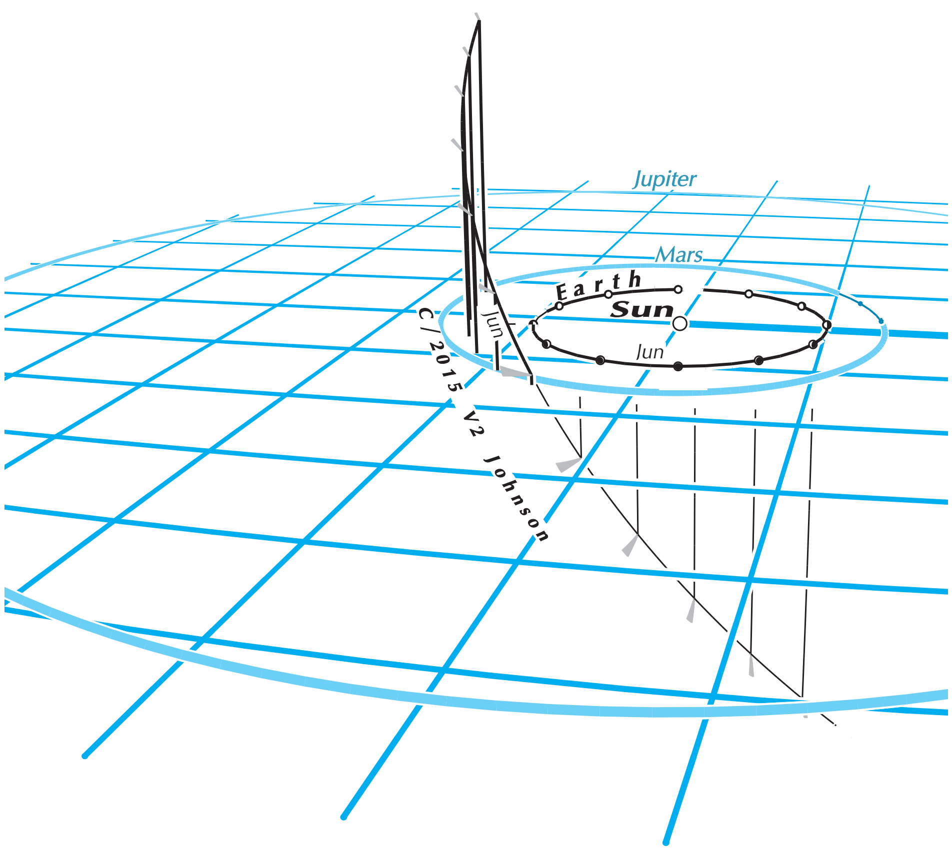


103P Hartley 2. Malcolm Hartley, a Briton working at the Siding Spring observatory in Australia, made two amazingly similar finds in February and July of 1982: a split comet which proved to be the lost du Toit 2 of 1945, and a comet which proved to be the lost Peters of 1846; their names were changed to du Toit-Hartley and Peters-Hartley. He went on to discover, from 1983 to 1995, periodic comets Hartley-IRAS, Hartley 1-3, Parker-Hartley, West-Hartley, and McNaught-Hartley, and long-period comets Hartley, Hartley-Good, and Hartley-Drinkwater.

103P Hartley 2 was discovered in March 1986, 9 months after perihelion. Its orbit, which takes it out near Jupiter, has been lengthening; the perihelion has moved outward across Earth's orbit. It returned in 1991, 1997, 3004, and 2010. The Deep Impact spacecraft was to be sent to fly by Comet 85P Boethin; this proved to be lost, so the spacecraft instead visited Hartley 2 on 2010 Nov. 4, finding it to be a "hyperactive, small and feisty" comet.

The 2017 visit is about as unobservable as it can be, because the comet aims for a perihelion in late April outside the opposite late-October part of our orbit. So it is always about as far as it can from us; nearest—still more than 2 a.u.—and brightest at perihelion almost exactly beyond the Sun.





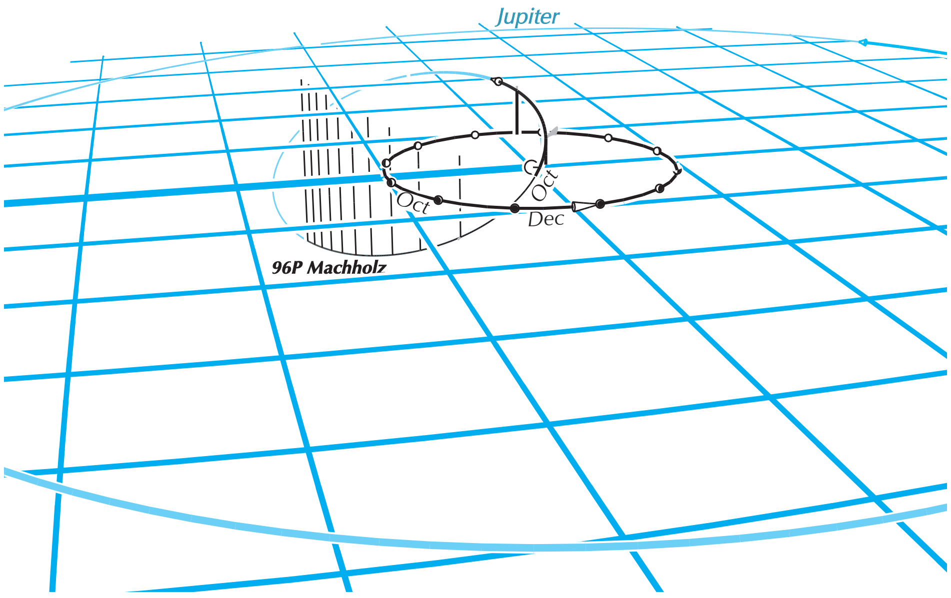
C/2015 V2 Johnson was discovered on 2015 Nov. 3 by Jess Johnson of the Catalina Sky Survey. It was falling from a vast distance of something like 160 a.u. in the outer solar system, but its passage among the planets will deflected it into a hyperbolic orbit—that is, into interstellar space.

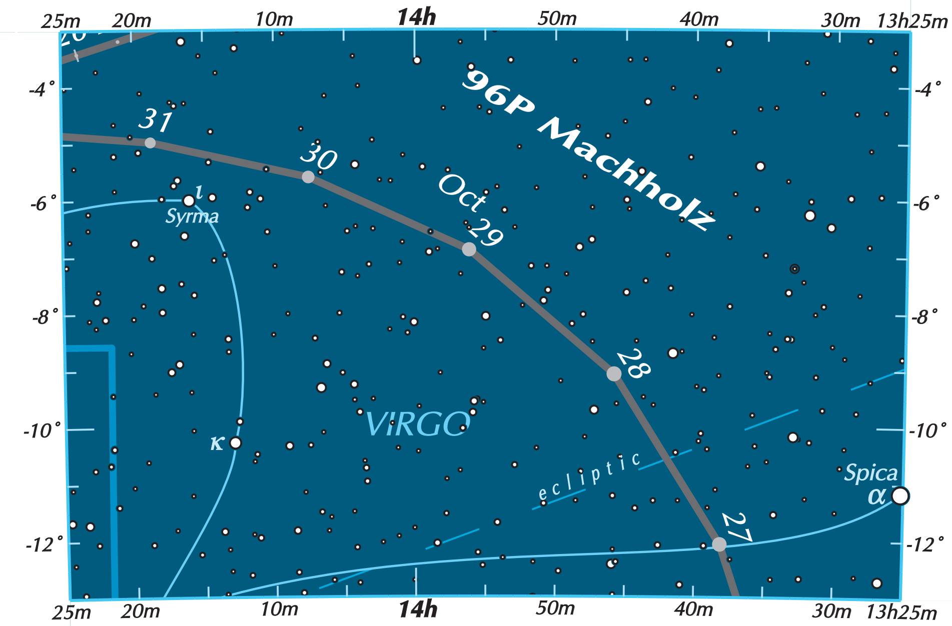
As we move through the part of our orbit below it, it is at opposition on April 28, 45° north, in Hercules, perhaps at magnitude 7.5. Then as it dives past Arcturus it ,may become a a magnitude brighter, verging on the naked-eye limit, as it reaches perihelion on June 12; we are now looking back on it, so it is 125° from the Sun in the evening sky, but at a lower angle to north-hemisphere horizons because now more southerly than the Sun.

96P Machholz 1. Don Machholz, an American amateur, is the most prolific living visual comet discoverer of comets: 11 of them, from 1978 to 2010. Two were shared with Japanese discoverers, and two are periodic: this one and 141P Machholz 2. (William Bradfield, Australian, sole discoverer of 18, all sole, died in 2014.)

96P, discovered in 1986, has one of the shortest orbits, about 5¼ years. It returned in 1991, 1996, 2002, and 2007. The orbit is very eccentric, coming up from the south to a perihelion little more than 0.12 from the Sun, inside the December part of Earth's orbit; near perihelion the comet can be very bright but difficult to see.

In 2017 it aims to reach perihelion in October. It starts the year far out and very faint. When in July we overtake it, it is still 1.3 a.u. away and we are looking steeply south at it; though it is rising toward the ecliptic, our motion past it makes it appear to dive even farther south, to within 8° of the south celestial pole in early August. In late September it arrives within 1 a.u. of the Sun, then of Earth. In October it appears to shoot steeply northward from Centaurus into Virgo, ahead of us and therefore in the morning sky. On Oct. 23 it is nearest to us (0.88 a.u.), 12° directly south of the Sun. On Oct. 27 it rushes up through ascending node and, only 11 hours later, perihelion. and is at its brightest, perhaps a fine naked-eye magnitude of 2—if only it weren't 7° from the Sun! As it climbs back out across our orbit through November and December, it is ahead of us but curving away, so that from our point of view it stays nor far north of the Sun.

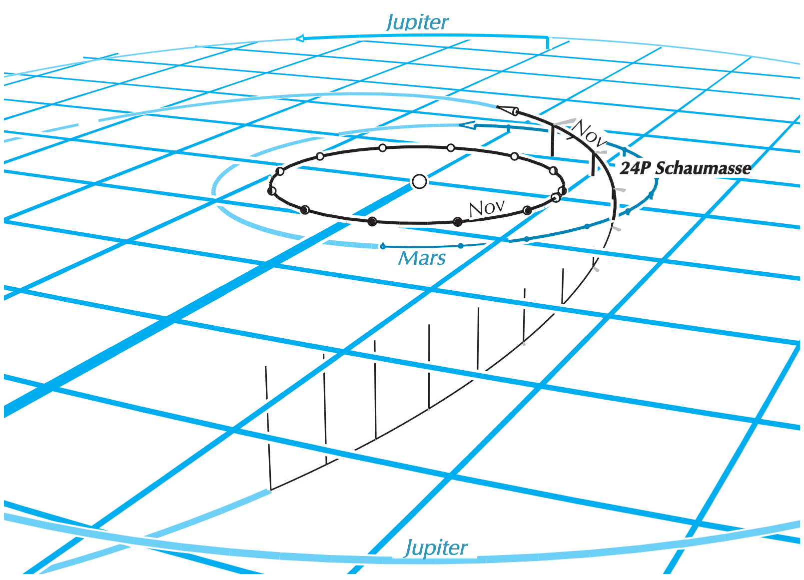


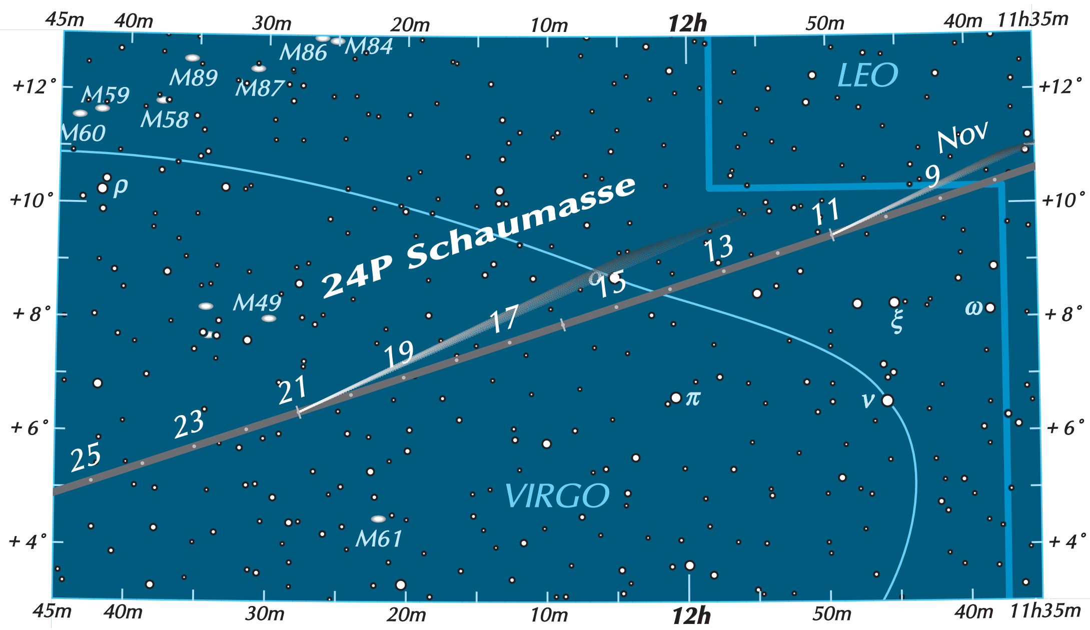


24P Schaumasse was discovered just after its perihelion in 1911 by Alexandre Schaumasse at the observatory of Nice in southern France. He later discovered two long-period comets, in 1913 and 1917.

24P has a period varying around 8 years. It was seen at its returns of 1919 and 1927; missed in 1935; seemed also to be missed in 1943 but was recovered in 1944, 7° away from its predicted position because of "non-gravitational" jet effects. At a very favorable return in 1952 it had an outburst to magnitude 4.9, theoretically at least naked-eye level. It was observed again in 1959-60, missed in 1968, and in 1976 except for a spot on a plate taken by Elizabeth Roemer that might have been this comet but was not confirmed by further observations. As Gary Kronk says in his *Comets: A Descriptive Catalog*, published in 1984, its "apparent loss . . . is a current puzzle to astronomers." Yet, later in 1984, it was rediscovered, and the observations confirmed Roemer's 1976 identification. It was again recovered in 1992, seen in 2001. but not since then, since the geometry was unfavorable in 1993.

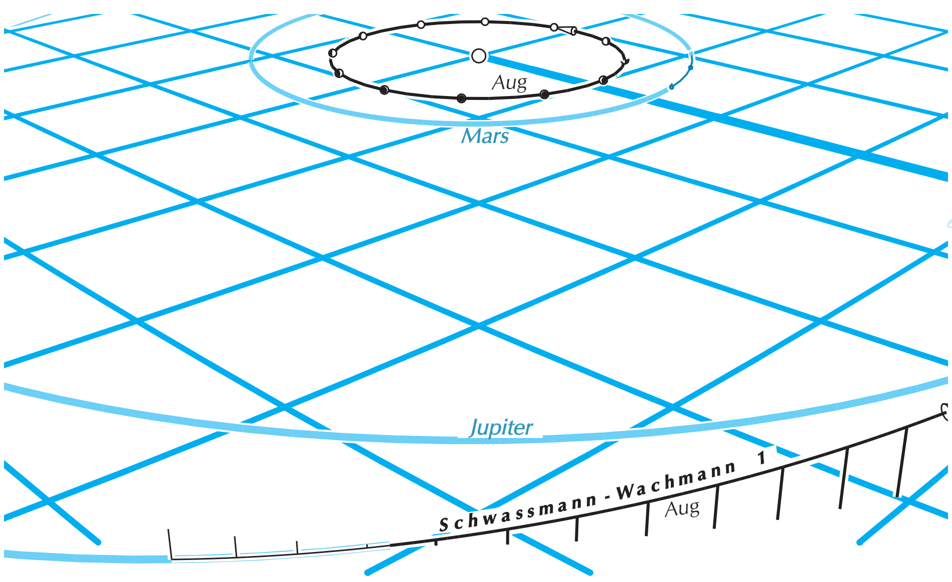
Its perihelion point is outside and north of the Jan.-Feb. part of our orbit, and this time it should arrive there ahead of us, in November.
In April it is beyond the Sun, and from then on is always in the morning sky, gradually higher, and we get nearer to it, but slowly; it rises through the ecliptic plane on Sep. 8. At perihelion on Nov. 16 it will still be nearly 1.5 a.u. away, perhaps reaching magnitude 10, 55° out from the morning Sun, in Virgo.

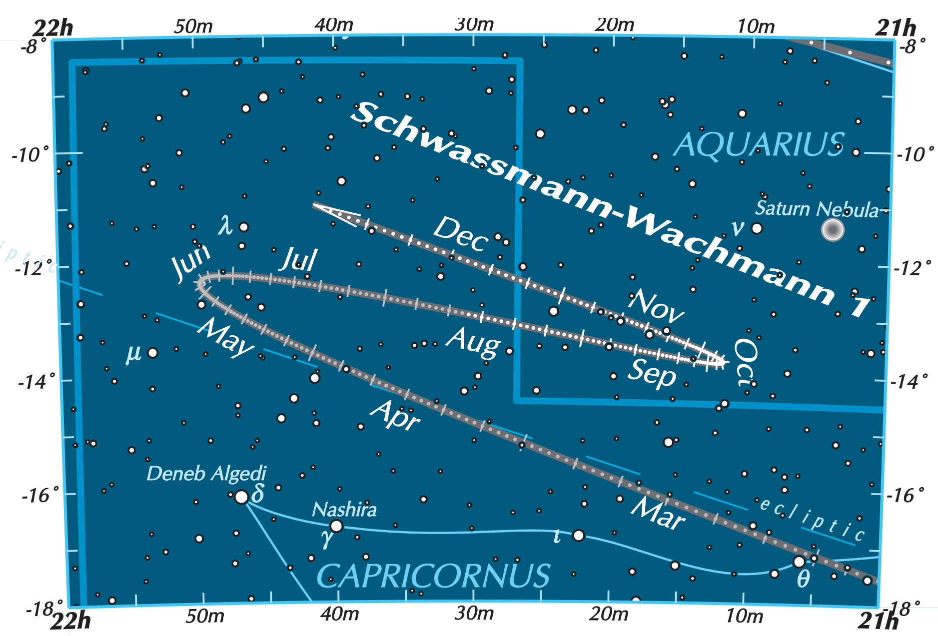


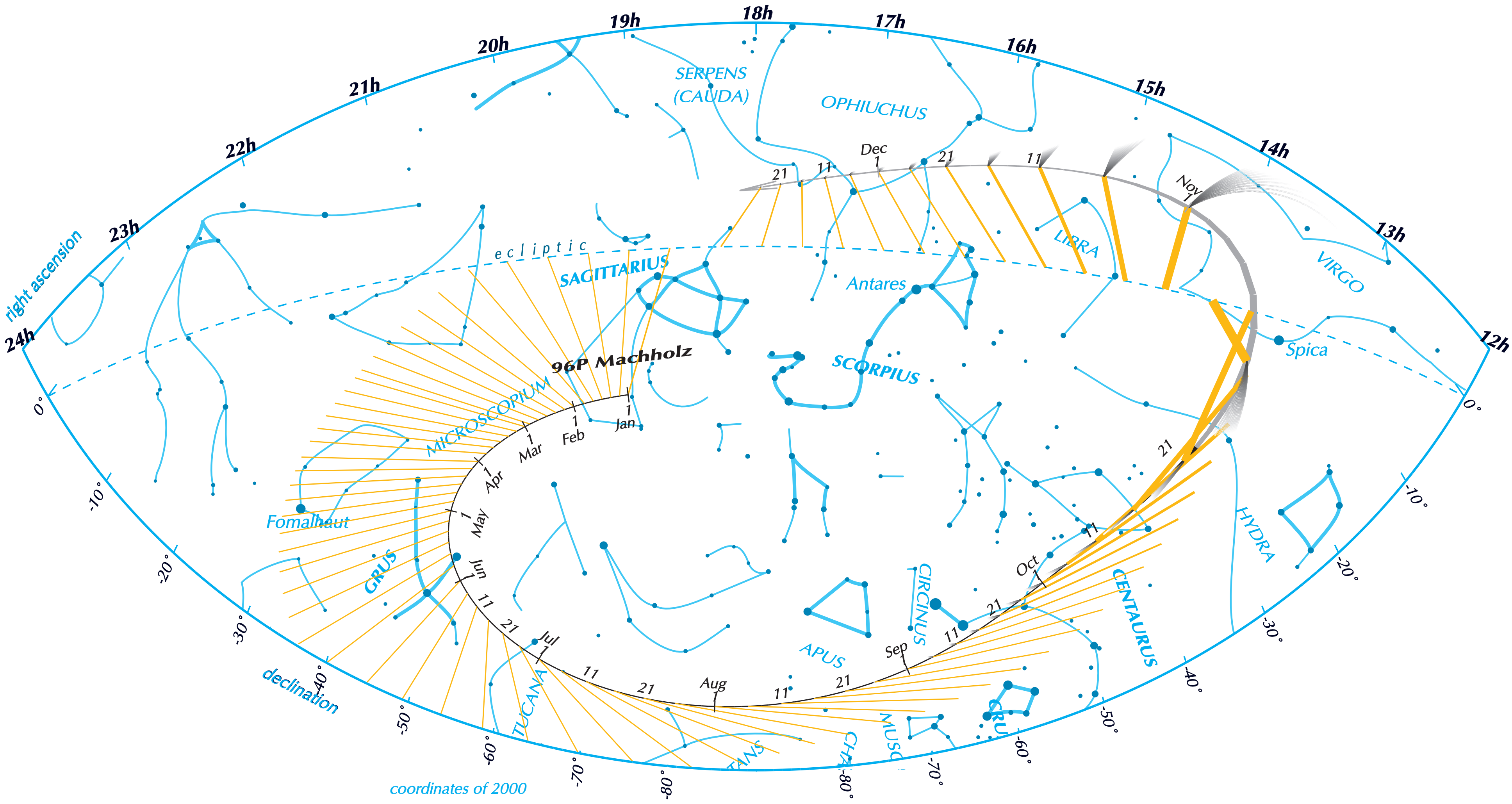


29P Schwassmann-Wachmann 1. Friedrich Karl Arnold Schwassmann and Arno Arthur Wachmann, working at the Bergedorf Observartory at Hamburg, discovered three periodic comets, in 1927, 1929, and 1930. A non-periodic comet that they discovered earlier in 1930 is designated C/1930 D1 Peltier-Schwassmann-Wachmann, because Leslie Peltier of Ohio found it a day later but was first to report it.

29P was found photographically in 1927, but in 1931 images of it turned up that had been recorded back in 1902 by Karl Reinmuth. It is a highly unusual comet: in an almost circular orbit, at a great distance—beyond Jupiter. It and comet 39P Oterma, which is now in a similar orbit, are sometimes classed with the "Centaurs," minor planets whose orbits are between or crossing those of the four giant outer planets and are therefore unstable. To attain its usual magnitude of about 16, 29P must be large; its nucleus is estimated to be 31 km wide. Even so, it would be scarcely observable but for its characteristic outbursts, 7 of them a year on average: it brightens suddenly by 1 to 4 magnitudes, occasionally as much as 7—a factor of 4,000 in light. It was in outburst at discovery, and when recorded in 1902. One of its 2015 outbursts reached mag. 12. It was last at perihelion in 2004, so in its 15-year orbit it is now drawing slightly closer, toward its next perihelion in early 2019, in the Pisces direction. It is worth monitoring for outbursts, especially as we come around to our view outward toward it at opposition in August.







Another way of showing the changing observability of a comet (or other moving body). Lines point from its position to that of the Sun. (To reduce clutter, the lines don't reach all the way, if they would be very long. The position of the Sun is always on the ecliptic.)

One could think of these lines as "sunbeams"; or as tethers holding the comet to the Sun. They correspond to the "radius vector" of the comet's elliptical orbit at each instant. The lines are thicker when the comet is brighter. Thus they simultaneously show magnitude, elongation, and position angle—the three quantities that govern observability.

For instance, Comet 96P Machholz starts the year far south, faint, and at great angular distance. Though it is rising northward toward the ecliptic plane, it seems as it comes nearer to be even farther south, at an extreme in August. As it continues to move northward and nearer, in October it becomes a target for south-hemisphere observers, but there is a balance between increasing brightness and increasing nearness to the Sun. It comes to be due south of the Sun, and too close to it. At its brightest, it makes a curl close around the west side of the Sun. Because of this sharp curvature, the tail driven outward by the Sun's radiation pressure curves markedly backward. Then the comet arches less closely over the north of the Sun, and in November, as it begins to fade, it seems to try, but fail, to get farther away from the Sun northeastward.