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An Unusual Meteor Shower on September 1, 2007

In 83 BC, when young Julius Caesar was just leaving the priesthood, comet Kiess (C/1911 N1) passed by the Sun, ejecting a cloud of dust particles. On September 1, 2007, Earth will encounter this 2000-year old dust, causing a meteor shower known as the Aurigids. The comet returned in 1911, after completing one orbit, but the dust travelled in slightly wider orbits and has been returning ever since, forming a trail of dust particles that usually passes just outside Earth's orbit. Earth encountered this trail of meteoroids in 1935, 1986 and 1994. Earth will again be hosed by meteoroids in 2007 when the combined gravity of our planets moves the trail back into Earth's path. A brief shower of tens of meteors will radiate from the constellation of Auriga, many as bright as the brightest stars on the sky. The Earth will be in the thick of it during the one hour centered on 04:36 a.m. PDT. The shower will be visible by the naked eye from locations in the Western United States, including Hawaii and Alaska, from Mexico, and from the Western provinces of Canada (Figure 1), a region with a population of about 150 million people. The shower is compliments of a dangerous type of comet that remains elusive. Each meteor is a message-in-a-bottle providing insight into the comet's activity at the dawn of Western civilization.

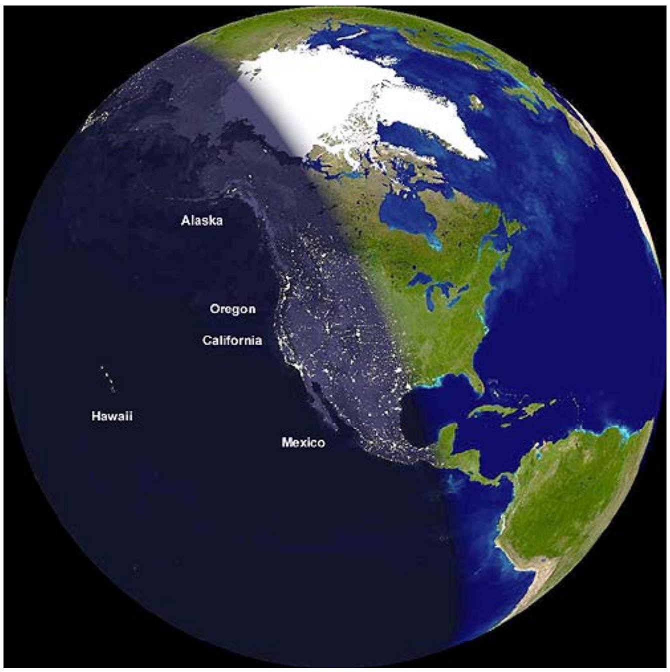

Figure 1 - Target Earth. Earth as seen from the perspective of the approaching dust grains at the peak of the predicted meteor outburst.

Long-period comets, such as Kiess, move on highly elliptical orbits and take more than 200 years to return to the inner solar system. They still spend the majority of their time in the cold regions of the Oort cloud, where they were kept in cold storage for most of the age of the solar system. Upon return, they tend to approach the Earth from all possible directions, typically at a high velocity (56 km/s most probable value), and because they can be bigger than asteroids, they have long been thought to be responsible for some of the largest impact craters on Earth [e.g., Zimbelman 1984, Weissman 2007]. They offer little advanced warning, except for a trail of dust particles released during their previous return to the Sun. The Earth encounters these dust trails on occasion, causing brief 1-2 hour duration meteor showers.

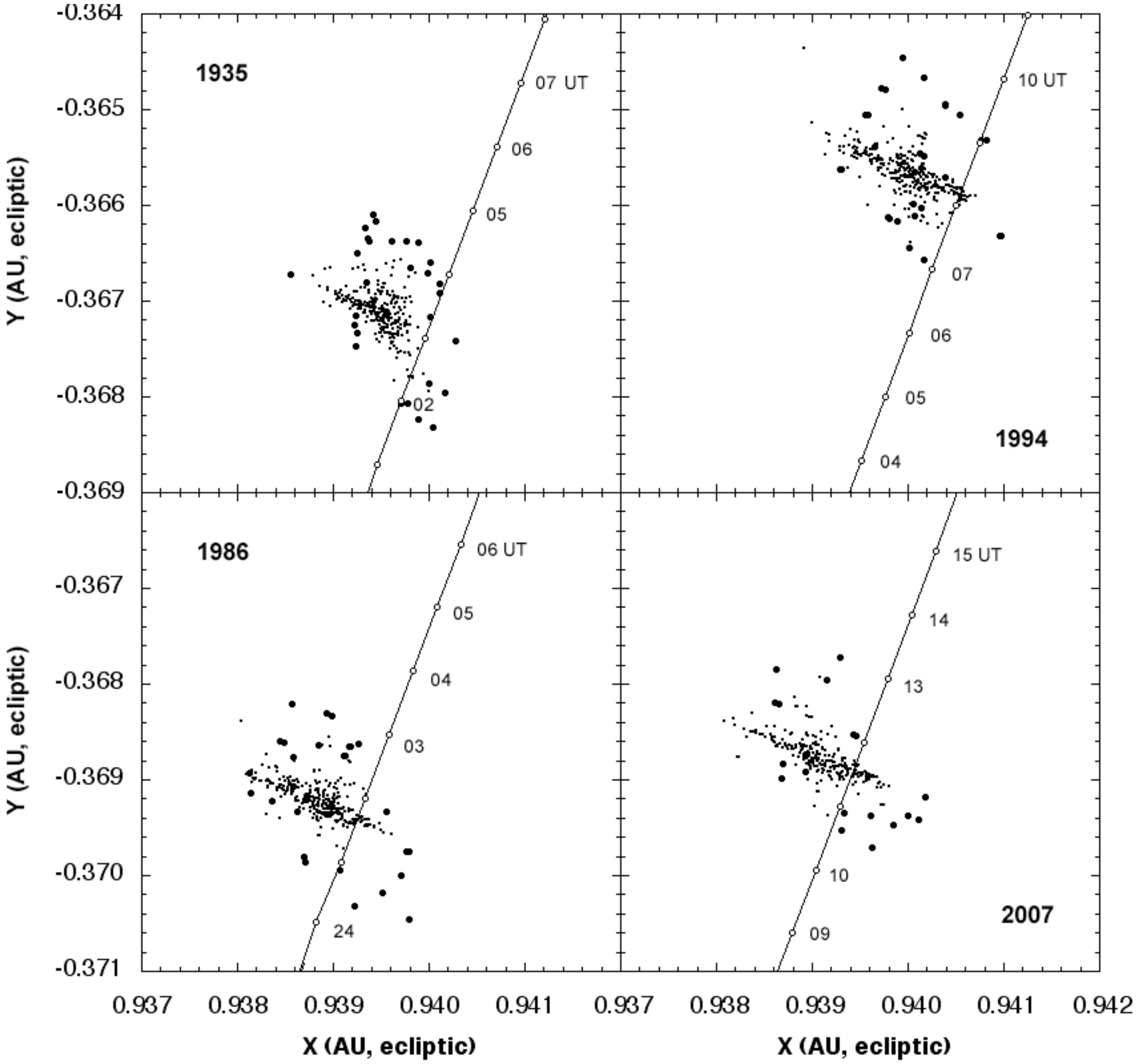

Fig. 2. Location of the dust trail on September 1. The scatter diagrams show where individual meteoroids crossed the ecliptic plane at the time of past Aurigid showers in our model simulation. Small dots show the large meteoroids that cause visible meteors (0.2 - 2 cm in size, +3 to -3 magnitude meteors), while crosses show the smaller (0.1 - 0.2

cm diameter) meteoroids that cause faint ~ +6 magnitude meteors. The position of Earth is marked in intervals of one hour.

Now, the imminent encounter with the dust trail of comet Kiess may teach us how long-period comets loose large dust grains, how to translate the observed dust trail crossings into physical data of the parent comet, and even to find more evidence for the hypothesized "pristine crust" of a comet [e.g., Cooper et al., 2003; Stern, 2003].

Since the confirmed detection of the long-period 1995 alpha-Monocerotid meteor shower from an unknown comet [Jenniskens et al., 1997] and the subsequent short-period Leonid storms, the basic physical principles behind these transient showers are understood [Kondrat'eva and Reznikov 1985]: Dust ejected from the parent comet is dispersed due to small differences in orbital period from ejection speed and radiation pressure. Upon return, the dust forms a trail that wanders in and out of Earth's path due to planetary perturbations by the major planets, which work slightly differently on particles at different positions along the trail. A meteor shower outburst is observed only when the trail is moved into the Earth's path at the exact time when Earth passes by the trail [e.g., Jenniskens, 2006].

The most recent returns of comet Kiess to the inner solar system occurred in 1911, 83 BC, and about two thousand years prior. The oldest dust trail has now been perturbed beyond recognition [Lyytinen & Jenniskens, 2003], while the dust from 1911 still surrounds the comet as a cloud of dust and has not yet spread into a trail. Thus if a meteor outburst occurs on September 1 of this year, the dust will have originated in the 83 BC return of the comet.

Until now, the 1995 alpha-Monocerotids was the only shower observed by modern instruments that was caused by the dust trail of a long-period comet. These meteoroids were very unusual compared to those of short-period comets. They were extremely low in sodium [Borovicka et al., 2005] and penetrated 5 km deeper in Earth's atmosphere than other meteoroids of similar size and speed [Jenniskens et al. 1997]. It is theorized that this difference occurs because long-period comets have not frequented the inner solar system enough to completely lose the pristine crust that is formed by cosmic ray bombardment during their time in the Oort Cloud. Short-period comets such as 55P/Tempel-Tuttle, the parent of the Leonid shower, have long lost this pristine crust.

Predictions for the 2007 Aurigid shower

The September 2007 encounter of Earth with the dust trail of comet Kiess was modeled to predict the expected peak time, duration, and peak rate of the meteor shower. We investigated the dispersion of dust using a comet ejection model developed by Crifo & Rodinov [1997], and calculated rigorously the planetary perturbations on the particles from the point of ejection until intersection with Earth's orbit (for a full review of the method see Vaubaillon et al. [2005]).

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One million meteoroids ranging in size from 0.2 mm to 20 cm were ejected from the comet orbit in 83 BC, which is the perihelion time of the nominal comet orbit listed in the *Minor Planet Center* comet orbit database, when integrated backward in time. Forward integration confirms that planetary perturbations occur only on the inward leg. As a result, the precise position of the dust trail is not sensitive to the adopted perihelion time of the comet in that previous return.

Despite the large number of particles in our calculation, we still need to consider all particles in a relatively long section of the trail to map out the trail cross section. These particles get much spread out along the orbit of the comet. Fortunately, we can correct accurately for the daily motion of all particles because in a 2 month section of the trail there are no gaps or strong density variations. In 1935 and 1994, planetary perturbations caused the trail to move rapidly from outside to inside Earth orbit around the time of the outburst. In 1986, the trail moved from inside to outside Earth orbit. In contrast, the trail will be nearly stationary in 2007.

We find that the model puts the dust trail at the exact same position in all years (Figure 2), which provides strong support that the Aurigids will return on September 1, 2007.

However, the current model both fails to predict this year's shower and also the showers that already have been observed. The calculated trails are always just inside Earth orbit, first noticed by Lyytinen and Jenniskens [2003]. In the same way, the calculated dust trails of comet 55P/Tempel-Tuttle were found to be just outside Earth orbit, displaced by 0.00025 AU. This discrepancy is thought to be due to ejection conditions being slightly different than those in the Crifo model. New observations of the upcoming Aurigid shower will help calibrate the ejection model.

Given that the trail will be at the same location as in past returns, we can use the sparse data from past Aurigid observations to predict what to expect from the 2007 encounter. The calculated and observed peak times in past encounters were off by 16 minutes in 1986 and 1 minute in 1994. Therefore, our best estimate for the peak time, 11:36 Universal Time (UT), has an uncertainty of about ± 20 minutes. The predicted encounter time makes the shower favorable for viewing from California, where the radiant of the shower will be high in the sky just before dawn in the early morning of September 1 (Figure 1). The meteors will radiate with a speed of 67 km/s from the direction (called the shower radiant) Right Ascension = 92º and Declination = +39º (J2000) in the constellation Auriga.

Each of the past observed showers lasted about 1.5 hours, with the rate being above half that of the peak (Full Width at Half Maximum) during ~ 28 minutes. Our model predicts FWHM = 27 minutes for 1986 and 33 minutes for 1994, in good agreement. The prediction for 2007 is ~25 minutes, but the actual width will depend critically on where we cross the trail. Based on past Leonid storm observations, the width of the trail is wider when we pass further from the trail center [Jenniskens 2006], causing a longer shower.

The Zenith Hourly Rate (ZHR) is the rate of meteors observed by a typical visual observer (observer perception 1.0) under clear sky conditions with the radiant in the zenith and the faintest stars visible in the sky being of magnitude +6.5. Our model predicts that the Zenith Hourly Rate in 2007 will be nearly the same as that in past returns. Unfortunately, past data is limited by bad observing circumstances. During the 1935 outburst, meteor rates were still rising when twilight interfered in Germany and the Czech Republic (ZHR > 100 /hr). The single eyewitness of the 1986 outburst, Istvan Tepliczky of Hungary, derived an average ZHR = 39.6 ± 8.1 from the period between the first and last Aurigid (00:47 - 02:12 UT), during which 24 Aurigids were seen [Tepliczky 1986]. Based on 10-minute intervals, this corresponds to a peak ZHR = 200 ± 25 /hr. Finally, observations in 1994 were hampered by a low radiant elevation. For the hour between 7:22 and 8:22 UT, with the radiant being at 13º elevation at 7:49 UT, Zay and Lunsford [1994] calculated an average ZHR = 55 /hr and 37/hr, respectively. In small 10-minute intervals, this again corresponds to a peak ZHR of 200 ± 25 per hour.

Hence, depending on the exact position of the trail crossing, meteor rates in 2007 are expected to increase to ZHR ~ 200 /hr in a short 10-minute time interval at the center of the outburst, a rate that is three times that of the annual Perseid shower in summer.

Though the moon will be four days past full, this will not dampen the display much, because past Aurigid outbursts were predominantly bright -3 to +3 magnitude meteors, with few faint ones. The model explains the lack of fainter meteors correctly by having the smaller meteoroids disperse more along the comet orbit due to higher ejection velocities.

In 2007, we will be only 15% further from the comet than in 1994. Hence, the particle size distribution will be much the same. Our model shows that large particles can make it out to this position in the trail, and the model predicts that rare meteors as bright as magnitude -10 (almost full Moon brightness) may be observed. The short duration and the abundance of bright meteors will make for a very impressive shower.

The meteors themselves may also be very unusual. Since we do not know how many orbits the comet has completed since it first entered the inner solar system, we cannot know if there was any pristine crust left to release into the dust trail. However, George Zay and Bob Lunsford of San Diego, California, the only two visual meteor observers to witness the previous 1994 Aurigid outburst, described the outburst Aurigids as having a greenish or bluish look to them [Zay & Lunsford 1994]. That suggests that the meteoroids produced unusually strong iron and magnesium atom line emissions from ablating metal atoms. This points towards a different particle morphology of outburst Aurigids than other fast meteoroids of similar size.

The use of modern instruments is warranted to take full advantage of this rare opportunity. Over the next 50 years, the dust trail of Kiess will continue to move in and out of Earth's orbit, but the model shows that it will not hit the Earth itself again. In fact, no other known long-period comet has predicted dust trails crossings with a similar track record of past outbursts to be able to anticipate small discrepancies in the predicted trail positions. At present, the September 1 Aurigid shower seems to be the only sure deal in the next fifty years.

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http://leonid.arc.nasa.gov/aurigids.html.


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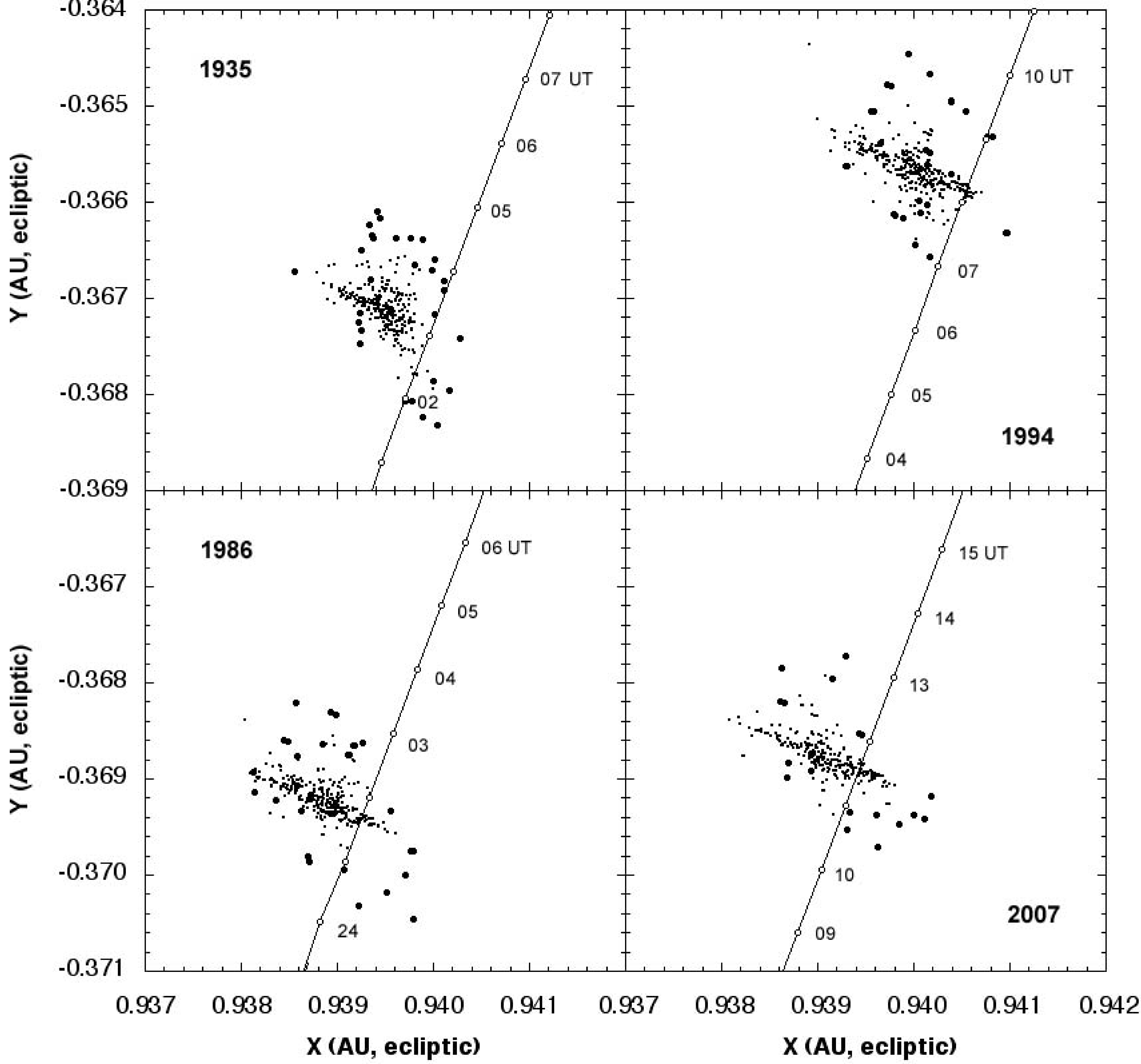

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