Giotto to Visit Comet P/Grigg-Skjellerup in 1992

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The Mission Background

Shortly after its successful encounter with comet P/Halley on March 14, 1986, which provided a wealth of exciting new data, the GIOTTO spacecraft was put into hibernation with the prospect to reactivate it later on and to retarget it for an encounter with comet P/Grigg-Skjellerup in 1992.

After nearly four years in hibernation the spacecraft was reactivated on February 19, 1990. Subsequently, the check-out of the spacecraft and the scientific payload demonstrated that GIOTTO is in a state to support such an extended mission and that a complement of at least six – of the original eleven – science instruments was functional and able to provide data of high quality during a second cometary encounter.

Science investigation, which can be made with this payload, include:

- characterization of the changing features of the solar wind flow and observation of cometary pick-up ions and anomalous acceleration
- determination of electron densities
- observation of upstream waves, determination of the location of the various boundaries (bow shock, ionopause, cometopause, etc.)
- observation of the magnetic pile-up region and cavity
- determination of the dust spatial density and size distribution and of the optical properties of the dust grains
- discrete gaseous emissions
- combined dust and gas densities

Despite the fact that the Halley Multicolour Camera (HMC) will not provide any images of the nucleus – the aperture of the HMC is blocked most probably by a piece of the outer straylight baffle that has been severely damaged during the close encounter with P/Halley – and that the Neutral Mass Spectrometer had all detectors damaged, ESA's Science Programme Committee confirmed the high scientific value of a GIOTTO Extended Mission at its meeting on June 12 and 13, 1991.

The Orbit

With an aphelion distance of 4.94 AU comet P/Grigg-Skjellerup belongs to the Jupiter family of comets. The perihelion distance of 0.99 AU – together with other characteristics – makes this comet very attractive for an encounter with GIOTTO on July 10, 1992, just 12 days before perihelion passage of the comet. Table 1 contains the most recent orbital parameters of P/Grigg-Skjellerup determined at the European Space Operations Centre ESOC in Darmstadt. The times are ephemeris times ET, the angles are referred to the ecliptic of mean equinox 1950.0 and the definition of the non-gravitational parameters A1 and A2 is that of Marsden et al. (1973). As can be seen from Table 1, the non-gravitational forces are found to be small and perturb the cometary motion only slightly.

The Visibility Before the Encounter

For the forthcoming perihelion passage the visibility of P/Grigg-Skjellerup from Earth starts in July/August 1991 (morning sky). The comet can be observed from both hemispheres of the Earth up to about May 1992. It will stay relatively close to the celestial equator (between +13 and −6 deg declination). The number of dark hours per night is higher for observers located in the northern hemisphere until April 1992 (see Fig. 1). Though the visual brightness of the comet may be rather faint (see Fig. 2), measurements of astrometric positions and physical properties of the comet can certainly be obtained by large telescopes during this time interval.

Within two months before the GIOTTO encounter with P/Grigg-Skjellerup the comet will be observable from the southern hemisphere only. The brightness and activity of the comet will increase towards perihelion passage. However, intensive observations may suffer from both the rather moderate total coma brightness (about 13 mag in the maximum; see Fig. 2) and the small elongation of the comet from the Sun which will result in just one to two hours observing time at low elevation in the evening sky. However, scientific observations, both astrometric and astrophysical ones, collected during this time interval, will be of high importance for the success of the fly-by and the interpretation of the GEM data.

The Light Curve

For most apparitions the visual brightness of P/Grigg-Skjellerup was estimated during about a two-month time interval before and after perihelion passage. Only very little is known about the light curve outside this arc of the

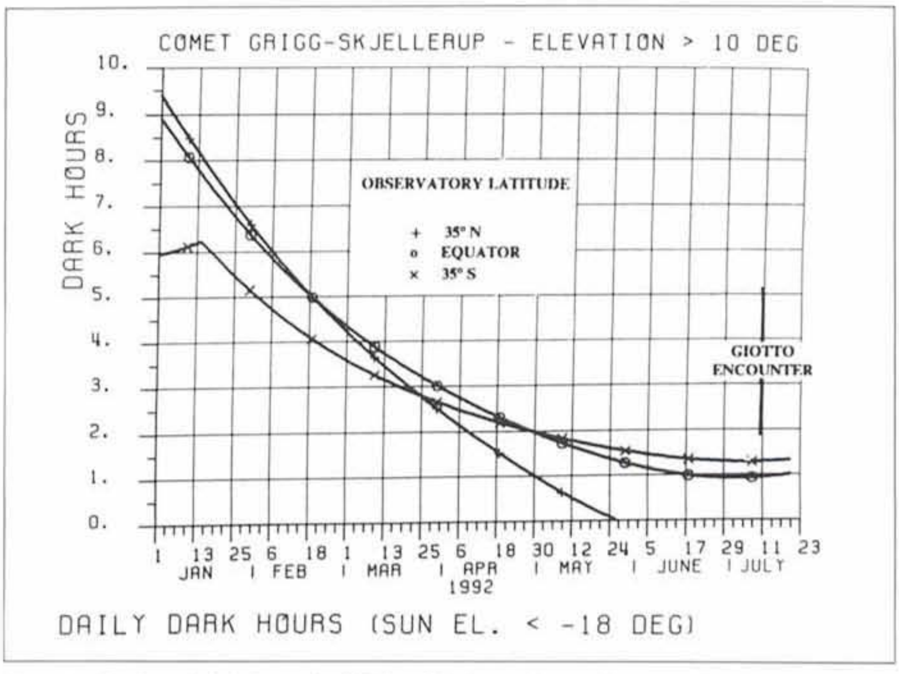

Figure 1: *Number of dark hours for P/Grigg-Skjellerup observations at +35, 0 and −35 latitude on Earth.*

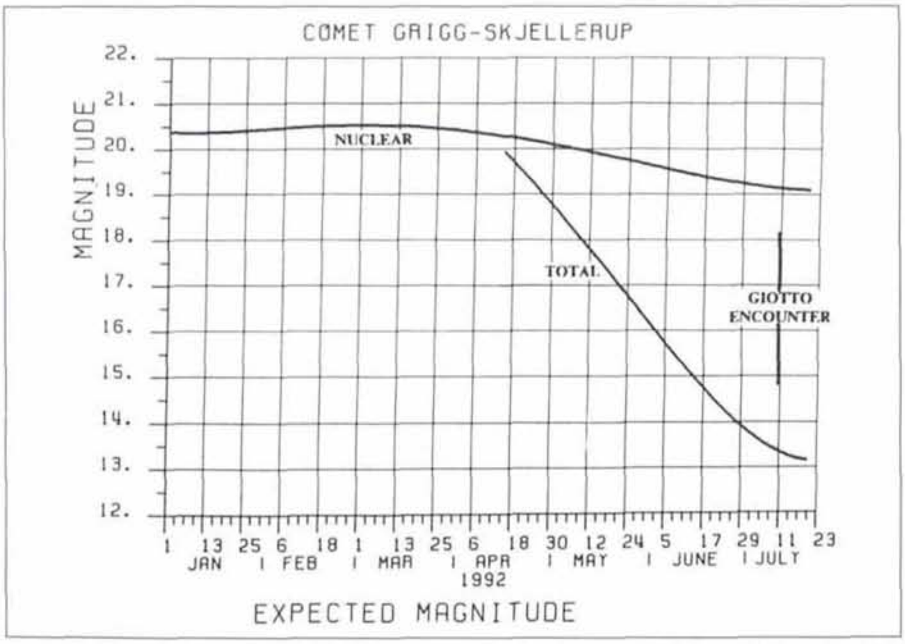

Figure 2: *Predicted nucleus and total coma brightness of comet P/Grigg-Skjellerup in 1992 until the GEM encounter.*

orbit. Some – partly puzzling – measurements of the nucleus' brightness are available from the 1986/87 apparition of the comet. The total and the nucleus light curve of comet P/Grigg-Skjellerup is plotted in Figure 2. The data were calculated from the light curve coefficients published by Nakano and Green (1991).

From the beginning of 1992 until the GIOTTO encounter the nucleus brightness should increase only slightly from about 20.5 to 19 mag. For the total coma brightness a maximum value of about 13 mag can be expected around perihelion passage which is close to the GIOTTO fly-by. The light curve of Nakano and Green indicates that the comet may show a rather late onset of significant coma development and a steep brightness increase pre-perihelion. However, this prediction of the early coma activity may be prone to errors because of the fragmented observational coverage of this phase during previous apparitions.

The Fly-by of GIOTTO

After the encounter with comet P/Halley on March 14, 1986, the GIOTTO spacecraft was put into hibernation, an operations state of minimal on-board activities without control from Earth. In February 1990 GIOTTO was reactivated by ESOC for the first ever swing-by of an interplanetary space probe at Earth. The swing-by was successfully performed on July 2, 1990. GIOTTO was redirected to an encounter with comet P/Grigg-Skjellerup in July 1992. After this trajectory change GIOTTO was again put into hibernation. It will be reactivated in May 1992 for the preparation of the comet fly-by.

Based on the present knowledge of the GIOTTO and P/Grigg-Skjellerup orbits the GIOTTO fly-by at the comet will take place on July 10, 1992 15:25 ±00:10 UT at 1.01 AU distance from the Sun and 1.43 AU distance from the Earth. The relative fly-by velocity will be 13.99 km/s. Figure 3 sketches the pre-encounter approach of both objects together with the respective position of the Earth. The final targeting of GIOTTO for the fly-by will be performed by ESOC about 2 days before encounter at the latest. However, in any case GIOTTO will pass the orbital plane of the comet from North to South during the encounter.

A Request for Astrometry

Comet P/Grigg-Skjellerup was observed during all 13 apparitions since 1922. Because the 1987 apparition was the last one before the GIOTTO swing-by at the Earth on July 2, 1990, which redirected the satellite towards P/Grigg-Skjellerup, ESOC has instigated an appeal for astrometric measurements of the comet to the observers. Altogether 60 accurate position measurements were obtained – more than double the number collected in 1982 and several times as many as at most other apparitions.

In 1992, high-quality astrometry of P/Grigg-Skjellerup is needed at ESOC for the final targeting of GIOTTO towards an optimum fly-by at the comet on July 10, 1992. The importance of ground-based astrometry for the orbit determination of P/Grigg-Skjellerup is even higher than during the Halley campaign in 1985/86 since for GIOTTO there will be no Pathfinder Project (Muench et al., 1986) using observations from other cometary missions. Therefore, ESOC is seeking the direct collaboration with professional observers who are able and willing to obtain astrometric positions of P/Grigg-Skjellerup in 1991/92 before the encounter. The observers should be able

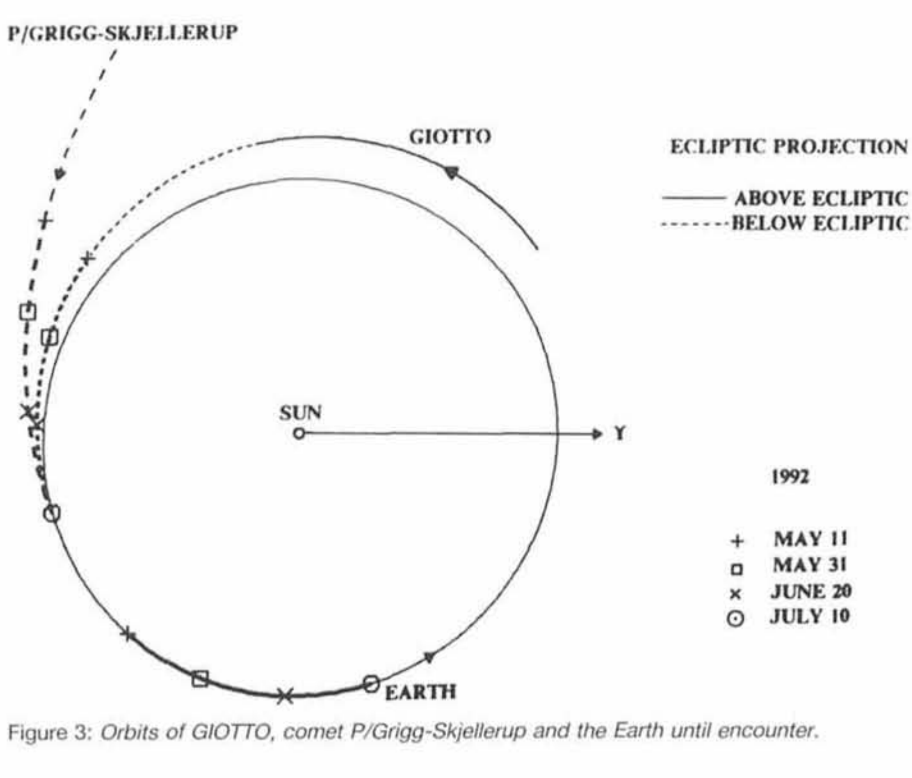

Figure 3: *Orbits of GIOTTO, comet P/Grigg-Skjellerup and the Earth until encounter.*

Table 1. *Orbital Parameters of Comet P/Grigg-Skjellerup*

Epoch	1992/07/10.60226 ET
Perihelion Time	1992/07/22.13729 ET
Perihelion Distance	0.9946892 AU
Eccentricity	0.6643366
Argument of Perihelion	359.27567 deg
Longitude of Ascending Node	212.63159 deg
Inclination	21.10411 deg
Non-gravitational Parameter A1	+0.0153 E-8 AU/day^2
Non-gravitational Parameter A2	−0.0012 E-8 AU/day^2

to communicate the astrometric positions of the comet to ESOC within a few hours to two days after observations in order to allow an immediate update of the cometary orbit for the fly-by planning of GEM. All positions of the comet reaching ESOC before July 8, 1992, will be considered in the planning for the GIOTTO encounter. However, of highest priority for the fly-by targeting are position measurements of P/Grigg-Skjellerup obtained within two months before the encounter. During this period the comet will be best observable from the southern hemisphere though it might be a difficult task since the comet will be faint and close to the horizon. Observations are being planned at ESO La Silla, in collaboration with R. West, who also observed Halley in 1986. For the improvement of the orbit determination accuracy so far unpublished position measurements of the comet obtained during previous apparitions (in particular in 1987, 1982, 1977) are very welcome at ESOC.

Astronomers who are interested to contribute to the P/Grigg-Skjellerup astrometry campaign for the GIOTTO fly-by may contact for further information:

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References

Marsden, B.G., Sekanina, Z., Yeomans, D.K.: 1973, Comets and nongravitational forces. V. *Astron. J.* **78,** 211–226.

Muench, R.E., Sagdeev, R.Z., Jordan, J.F.: 1986, Pathfinder: accuracy improvement of comet Halley trajectory for GIOTTO navigation, *Nature* **321,** 318–320.

Nakano, S., Green, D.W.E.: 1991, 1992 Comet Handbook, International Comets Quarterly 13/1a, SAO publication.

The Vaca Muerta Mesosiderite

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The lonely Atacama desert is a perfect place to study distant celestial bodies in the space around us. The following story shows how this may be done, not only through powerful astronomical telescopes at isolated mountain-top observatories, but also down on the barren desert plain in a much more direct way.

We have just completed a detailed study of a gigantic, but little known meteoritic impact in a remote region of the Atacama Desert. Over a period of four years we carefully searched a large area in the middle of nowhere and collected seventy-seven specimens of the Vaca Muerta ("Dead Cow") meteorite with a total mass of more than 3400 kg. This meteorite is of the rare stony-iron type (mesosiderite) and our finds have more than tripled the available material of this type which is of great importance for the study of the early history of our solar system. We did this work in our spare time and should like to express our great appreciation for the excellent collaboration with meteorite-oriented scientists in various countries as well as with the Chilean authorities.

Two of us are used to observe remote objects in space, but it was really great fun for once to do down-to-Earth astronomy and to work with our geologist-colleagues!

The Fall of the Vaca Muerta Meteorite

In addition to the large planets and their moons, there are many smaller solid bodies which move in elliptical orbits in the solar system. They come in all sizes, from *minor planets* with diameters above a few hundred metres, to metre-sized *meteoroids* (boulders) and down to microscopic *dust*.

From time to time, a small dust grain from interplanetary space enters the Earth's atmosphere with a very high velocity, often of the order of 10 km/sec or more. It is immediately heated by the friction with the air and begins to glow; this is what we call a *meteor* (a "shooting star"). Such events are very frequent and can be seen on every cloudfree night. More rarely a larger object, even a small boulder, may enter and will then be seen as a bright *bolide*. It leaves a luminous trail across the sky which can sometimes be seen in full daylight. If the boulder is big enough, a part of it will survive the descent through the atmosphere and will hit the ground, where it may be found as a *meteorite*.

About 3500 years ago, a large meteorite with a mass of several tons and measuring at least one metre across fell from the sky over the central part of the Atacama Desert in northern Chile. During its rapid passage through the Earth's atmosphere the big stone disintegrated into numerous smaller pieces which impacted in the desert sand over an area of some 20 km^2. Here they remained in well-preserved condition, due to the extremely dry conditions in the desert.

The fall-zone lies in a very remote part of the desert and most of the meteorite