Twenty-three Missions at ESO-La Silla

Research Based on Discoveries and Rediscoveries of About 1400 Planets with the GPO

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Which Interest?

The science of minor planets is modern research. It influences both astrometry and celestial mechanics, and also related sciences, such as mathematics, physics, astronautics.

Let us recall some important results:

1. Determination of the Astronomical Unit (A.U.), the base of all distances in astronomy;
2. Computation of planetary masses, particularly of those of Venus and Mercury which have no natural satellites;
3. Improvement of our knowledge about the Earth's orbit and rotation;
4. Calculation of systematical errors in stellar positions;
5. The advance of the Icarus perihelion, five times greater than the one of Mercury, supports the Theory of General Relativity;
6. Several problems within celestial mechanics and astronautics benefit from our knowledge about minor planets.

The experience of the minor planets' specialists leads to:

1. Compilation of sky maps and catalogues;
2. Identification of radio sources, quasars, pulsars with optical objects and location of variables, binaries;
3. Determination of the *Einstein effect* during a total solar eclipse, e.g. by means of the simulation method (Debehogne, 1977);
4. Study of the dynamical, physical and chemical properties of space astronomy experiments;
5. Control of artificial satellite network;
6. Research on natural satellites, transplutonian objects, and planetary systems;
7. Determination of stellar proper motions and parallaxes.

Still young after two centuries, this kind of research is a test for astronomical photography, is noticed by the public in connection with the Earth grazers or with targets for interplanetary rockets and takes part in the study of the ring systems whose creation and evolution may explain the origin and evolution of the solar system.

Some peculiar interests are: the discovery of a second ring of asteroids beyond Neptune, the computation of orbits, the families, the poles of rotation, their size, the chemical constitution, their number (4225 minor planets have been numbered by October 1989)...

Preparation of the Missions

The choice of plate centres comes from the ITA (Institute of Theoretical Astronomy, Leningrad) diskette, from Ephemeridi Malikh Planet and from the Minor Planet Center (MPC) diskette. For three years now we are computing at Uccle graphs at whatever scale, date, number of positions (T. Pauwels' programmes).

Methods of Observations

Three exposures (1 to 21 minutes × 3) are made with an off-set along δ between each of them. Sometimes, we have two or more fields on the same plate using the Trépied-Metcalf method. Three images permit: safer and easier asteroid identification and discovery; studies of the accuracy of the stellar positions and proper motions; identifications of nearby asteroids; improvement of the possibilities to compute a preliminary orbit.

Measurements and Reductions

We measure and reduce by means of the OPTRONICS at ESO-Garching with West's programmes, or on the ASCORECORD (Valongo-Univ. Fed. Rio de Janeiro or Brussels).

See *Acta Astronomica* (Debehogne, 1986) for the description of the problem in algebra and modern language. Bijections, between sky and plate, are determined by means of sub-sets (reference stars) and with determination of the normal equations by matrix multiplication. We use the Catalogue SAO given on magtape by the "Centre de Données Stellaires à Strasbourg".

Results

Thousands of positions have permitted improvements of orbits or the determination of new ones; 1400 discoveries or rediscoveries have been obtained until October 10, 1989. The 3 discoveries in 1976 became 274 in September 1989 (following the asteroids present on the MPC diskette of 1986). As special observations, let us recall:

1. V 348 Sgr observed in 1979 with a magnitude variation from 12.0 to 17.0 in four days;
2. The Halley Comet, with R. West, the first and only observations 5 days after the perihelion passage, supporting the approach by Giotto;
3. The Earth grazer (distance to the Earth = 900.000 km) which could be a satellite 70.000 km high, but not known by the Satellite Service of the Institute of Space Aeronomy of Brussels.

Users and Orbits

We try to serve all computers of orbits: Minor Planet Center (MPC), Institute of Theoretical Astronomy of Leningrad (ITA) and ourselves. We do not agree with observers who limit their work to two nights, when it is possible to have more. How to compute orbits if each observer limits his observations at two nights for a given asteroid? He has, then, more time to obtain very many discoveries, confirmed by those observers who observe more than two nights and, thus, who make fewer discoveries!

In special and rare cases, I agree that the discovery is given to both observers: first the observer whose observations give an orbit and, secondly, the one who has the first night (see below). On the *Minor Planet Circulars,* many discoveries, with 75% and more observations noted 809 (ESO La Silla-Observatory), are given to another observatory.

More than 1000 orbits were calculated at Uccle by us, using the Gauss-Encke method with amelioration owing to the variations computation (Stracke, 1929).

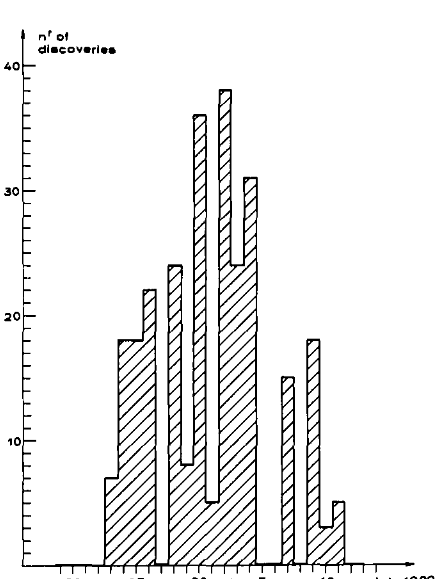

Figure 1: *Discoveries in September–October 1989. To lose a night in the central part of the mission is a catastrophe. Discovery is taken in the sense that the orbital elements are not on the MPC 1986 diskette.*

Connections between CCD and GPO at La Silla

During the night of October 1, 1989, O.H. Hofmann and H. Rabhan found a fast-moving asteroid with a CCD from their home institute, mounted on the ESO 1-m telescope. It was recognized later as 4197 1982 TA, a very recently numbered asteroid.

The following nights, till October 12.0 (Moon = 0.88) and perhaps October 13.0 (Moon = 0.95), we observed this asteroid at the GPO (magnitude equal to 15.6).

M. Hoffmann writes about this collaboration: "Visual discoveries of asteroids by chance have become unusual in astronomical research during this century. New observing techniques, however, have led to a new variety of this "method". When CCD images of star fields are displayed in the control rooms of the telescopes, there is a finite probability that unexpected objects also appear on the screens. Unfortunately, a large fraction of this recorded information remains unnoticed and will be erased from the magtapes eventually.

We had an opportunity to combine the ESO 1-m telescope with a CCD-camera system of the DLR for a programme of photometry of near-Earth asteroids. These objects use to move quickly through considerable angles in the sky.

The night of October 30/31, 1989, we suddenly noticed that one of the background stars in a field of (4197) 1982 TA jumped a little westward from frame to frame. From its speed and direction of motion we concluded that it might be a normal main-belt asteroid close to opposition and estimated its position for the next night. It could then be recovered on exposures of the GPO and followed during the next days.

It is obvious that a CCD camera can lead to many similar discoveries when pairs of images are compared during the subsequent image processing."

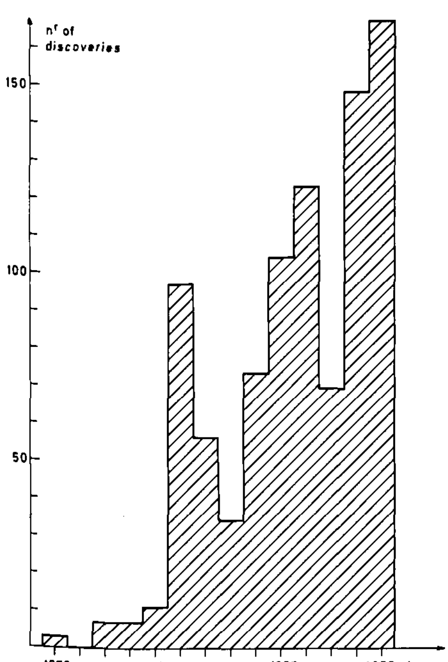

Figure 2: *Discoveries from 1976 to 1989. Discovery is taken in the sense that they are recognized as ours by the Minor Planet Center (MPC). Numbered: 62.*

Institutions Involved

The Observatorio do Valongo, Universidade Federal do Rio de Janeiro (UFRJ), the Observatories of Uppsala, Belgrade, Turin, Rio de Janeiro, the University of Teheran and the Royal Observatory of Belgium (Uccle-Bruxelles) have all taken part in the missions.

Theoretical Developments: New Ideas

Theorem of the minimum. In the reductions (more generally, in the rectangular algebraic systems), the error effect where the error is acting will be minimum at the gravity centre of the reference stars (of the independent terms) only for systems of odd degree (1, 3, 5, 7 . . .), not for even degree (Debehogne, 1972).

The *Einstein effect* must be solved by the simulation method (Debehogne, 1977). This is a work only for astrometrists skillful in asteroids.

In the orbital computations, the effect on the elements of *systematical errors* on the observations is a linear function of the error value and a sinusoidal one of the error direction: for each element we find two directions with an error effect equal to zero for whatever error value (Theorem of the two directions without error effect) (Debehogne, 1988).

The test stars are used to study the *external accuracy* (Debehogne, 1970). Fictitious reference stars and fictitious errors (Debehogne, 1972) are also used.

If it is necessary to use observational sequences from instruments with different focal lengths and to use uncatalogued stars, except on the instrument with the shorter one, then the final accuracy will be the accuracy of the measurements on the plate taken with the larger one, when the subsets of intermediate reference stars are sufficient: the number of stars for each instrument should be equal to 10 times the degree of the bijections used.

Conclusions

Editors, editorial boards and referees ought to support the publication of positions of known and also of new minor planets. The *Minor Planet Circulars* are important, but they are not accepted as publications by the "Money Authorities"?

Each position is the determination of a bijection between two sets of points (sky and plate) by means of two subsets (reference stars). That implicates the resolution of one or two rectangular, algebraic systems of equations (reduced to squared ones, by the matrix or by the least squares method). Such discoveries, such mathematical developments, such theorems, coming directly from the observations and having implications in mathematics, ought to be supported. The lack of publication possibilities is a pity; a new "Journal des Observateurs" would be highly desirable.

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