among very metal-poor stars, no combination of element abundances can plausibly explain the order of magnitude differences observed in the UV1 passband.

Unless the reported observations are completely unreliable, our arguments suggest an explanation outside the conventional limits of single stars.

Conclusions

The external evidence for radial velocity variability among metal-poor stars presented above, which is at variance with previous observations, would seem to deserve a more extended systematic approach, preferably with a fast radial velocity spectrometer like the CORAVEL. Whereas the results of our abundance analyses definitely rule out the possibility of producing heavy elements by purely explosive carbon and silicon burning, more observational efforts must be dedicated to the nucleosynthesis of r- and s-process elements. In order to measure reliably the equivalent widths of faint rare earth lines, a resolution of 50 to 80 mÅ and a signal-to-noise ratio of 50 to 100 would be necessary. Unfortunately, at present, these specifications cannot be attained for halo subdwarfs. HD 89499 has emerged to be the first subdwarf observed to have a close companion. Its Ca II line emission cores as well as the large satellite UV excesses observed for some metal-poor stars strongly recommend further observations in the ultraviolet.

Our report would not be complete without mentioning the support of the ESO technical staff and night assistants, who helped to ensure a successful observing run.

Faint Satellites of Outer Planets

Ch. Veillet, CERGA, Grasse

Introduction

In astronomy, as in other matters, the charm of novelty is one of the important factors that govern the choice of the observations. How many objects saw suddenly many eyes or kinds of detectors looking at them, before finding again, some months or years later, their sidereal quietness! . . . However, it is often after a long time of regular observations that they confide a (small) part of their secrets. The faint satellites of planets don't transgress this fortunately approximative rule. The deficiency in observations during many consecutive years makes the determination of their motion very difficult, and it is often too late to make up for lost time. We shall try to illustrate this fact in the next lines using the observations of the systems of Saturn, Uranus and Neptune we made in April 1981 on the Danish-ESO 1.5-m reflector.

Saturn

Except for sparse observations (like those by J. D. Mulholland with the 2.1-m reflector at McDonald Observatory, USA), the vicinity of Saturn has been poorly observed in order to look for faint satellites inside the orbits of the inner satellites. All the energies have been devoted to the rings. Suddenly, during the passage of the Earth through Saturn ring plane in 1979–80, and probably strongly incited by the Voyager flyby, the astronomers discovered many objects orbiting between the rings and Dione, i.e. at less than 45 arcseconds from the edge of the rings. If some of them are only visible while the rings are seen edge-on, the others can be observed even with an open ring, as is the case for Dione B (moving on Dione orbit) and for other bodies the observations of which remained unlinked up to our work.

The focal length and aperture of the Danish-ESO 1.5-m reflector are well suitable for a search for faint objects near a planet: Only a few minutes are necessary to record objects at magnitude 17–18 and the scale permits a good determination of the positions on the plates. You can see on Fig. 1 Dione B and a satellite moving on Thetys orbit which has been identified during an observing run at this telescope. A differential guiding has been used to follow the motion of Saturn during the exposures (less than 8 minutes) and a mask with eight circular apertures in the arms of the secondary mirror support vanes has been set at the front of the instrument in order to avoid the diffraction cross around the overexposed image of the planet which unfortunately would have been in the direction of the ring plane!).

The plates have been measured on a Zeiss measuring machine. The well-known satellites (Saturn II to VI) permitted to determine the parameters of the field around Saturn (scale, orientation, coordinates of the centre of the planet). Then the positions of the studied bodies could be obtained, and a least squares programme determines the best angular separation from Dione (or Thetys) which fits each observation. Fig. 2 shows the results obtained for the Thetys L_5 object. Its libration motion appears clearly, but the determination of its period is impossible: This satellite has not been observed at another epoch in 1981. . . .

Eight quasi-consecutive nights provided a series of positions of three faint satellites on the L_4 Lagrangian point of Saturn-Dione (Dione B) and the L_4 and L_5 points of Saturn-Thetys. This series has allowed the determination of an accurate position of the L_4 and L_5 Thetys objects, and thus to establish unambiguously the existence of one satellite at each of these points. We have also discovered a periodic variation of Dione B which can be explained by an eccentricity of about 0.012, five times the value found for Dione. An interesting point can be made after these observations: The facility in recording these objects (photographic plates at the Cassegrain focus of a reflector. . .) even with an open ring suggests the examination of old plates taken in equivalent conditions in order to get other positions or to affirm they were not present at a given epoch (for more information, cf. Ch. Veillet (1981, *Astron. Astrophys.* **102**, L5-L7). Some months later Voyager 2 observed both the Thetys objects as small rocks (50–60 km . . .).

Uranus

Going on with our trip among the planets, we stop near Uranus, planetary system forsaken by the observers for a long time. We find only a few observations from Miranda discovery in 1948 till the detection of the rings in 1977. The motion of Ariel, Umbriel, Titania and Oberon, the four "old" satellites, is quite well determined. But it is not so with the "youngest"! More than half of the available positions of this faint satellite up to 1977 cover the year following the discovery! However, an accurate determination of the motion of Miranda would permit a better knowledge of the gravitational parameters of the Uranian system: The mean motions of Ariel, Umbriel and Miranda

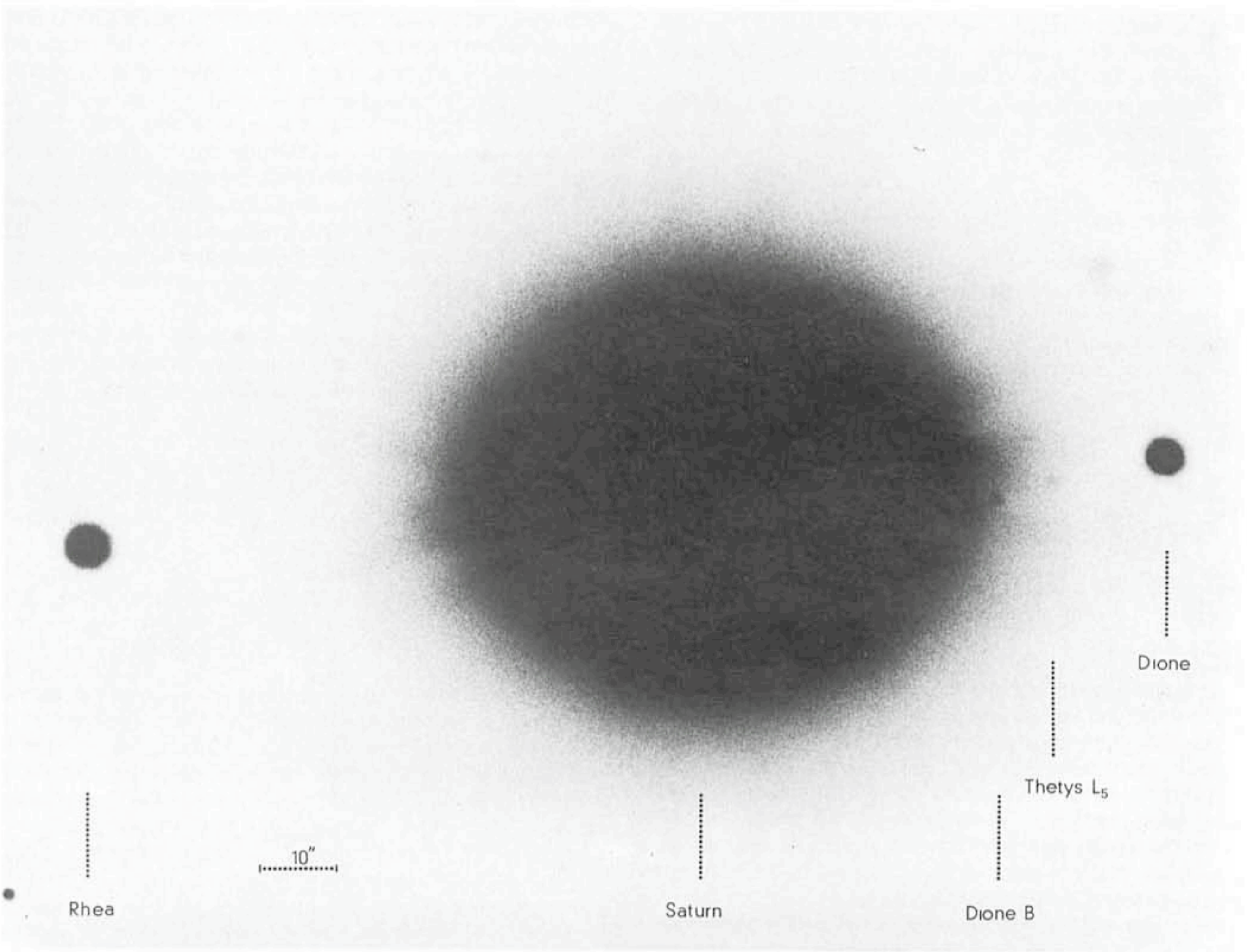

Fig. 1: *Dione B, moving on Dione's orbit, and Thetys L_5 object, moving on Thetys' orbit. 1981, Apr. 12, 03^h44^m UT, 8 mn exp. on III a-J plate. Voyager 2 observations give 50–60 km for their diameter.*

present a Laplacian near-commensurability which enhances the mutual gravitational effects and makes them observable. The only unknown parameter of the perturbations on the longitude of Miranda due to this near-commensurability is the mass product of Ariel and Umbriel. Thus we have a means to determine masses in the system of Uranus. At this time, it is the only one!

We initiated the programme of observations of Miranda at Pic-du-Midi in 1976 with the collaboration of Guy Ratier. It began to provide us with useful positions of this satellite in the 1977 Uranus opposition. The observational conditions were not the best ones: Uranus had a declination of less than −16° and its zenith distance was at least 60° . . . We used a prism near the focal plane of the 1-m reflector to remove the effect of the atmospheric dispersion, too large for an accurate measurement at this zenith distance. The magnitude of Miranda is about 16.5 (and 6 for Uranus) and its period is 1.4 day. An exposure time longer than 6 minutes is not consistent with a good image because of the fast motion of this satellite with respect to the planet. The brightness of Uranus and its proximity of Miranda—between 6 and 8 arcseconds from the planetary edge—make a good seeing during the observations absolutely necessary. Moreover, this proximity constraints us to work with a sufficient focal length. These observational requirements were gathered on the Pic-du-Midi 1-m reflector on which regular observations of Miranda have been made on the 1977–78–79 Uranus oppositions. The 70 new positions of Miranda thus obtained (C. Veillet and G. Ratier [1980], *Astron. Astroph.* **89,** 342) made possible the search of the gravitational effect of Ariel and Umbriel on Miranda theoretically predicted by Greenberg (1976. *Icarus* **29,** 427). A complete determination of the orbit of Miranda provided us with a value of the mass product of Ariel and Umbriel $\mu_2\mu_3 = (1.10\pm0.25)\times10^{-10}$ (expressed in units of mass of the planet) by including this parameter in the calculation as an independent unknown.

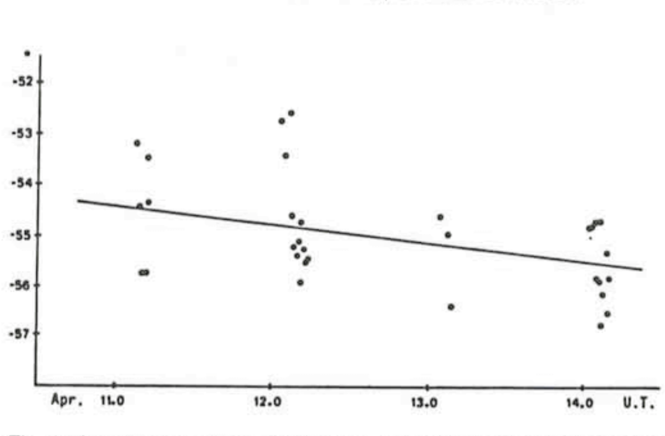

Fig. 2: *Angular separation of Thetys L_5 object from Thetys during the observing run. The slope is found to be* $(-0^\circ.38 \pm 0^\circ.15)$/day.

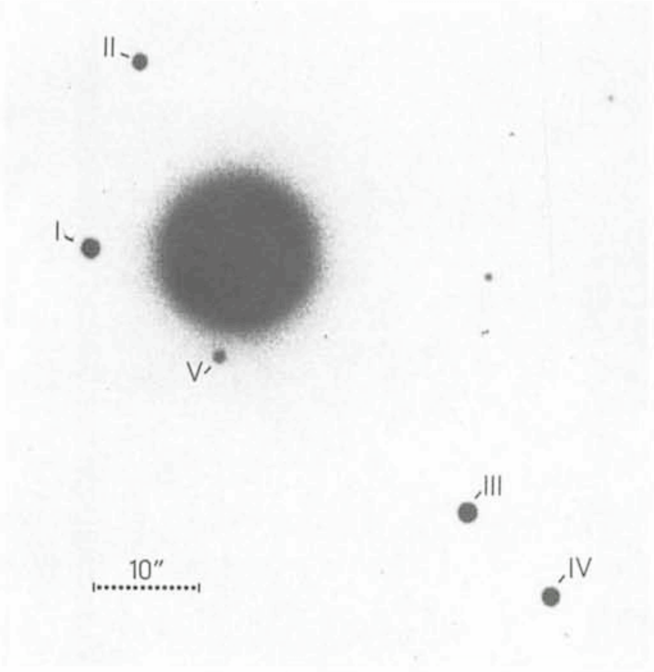

Fig. 3: *Uranus and its five satellites. I = Ariel – II = Umbriel – III = Titania – IV = Oberon – V = Miranda. 1981, 06, 07^h39^m UT, 4 mn exp. on III a-J plate.*

In order to get a more accurate determination of the nodal and apsidal precession period, as well as a smaller error on the value of the mass product of Ariel and Umbriel, we decided to extend the observations on the Danish-ESO 1.5-m reflector. Its aperture and focal length are very suitable indeed for such a work and the La Silla location offers Uranus at the zenith to the observer! A first observing run by Guy Ratier in 1980 gave only a few plates of Miranda on half a night. The other nights were under wind and rain... However these observations were good enough to incite us to come again. It was lucky for us that we did: I obtained on eight nights from April 6 to 14 1988 about 80 positions of Miranda, more than in three years at Pic-du-Midi!

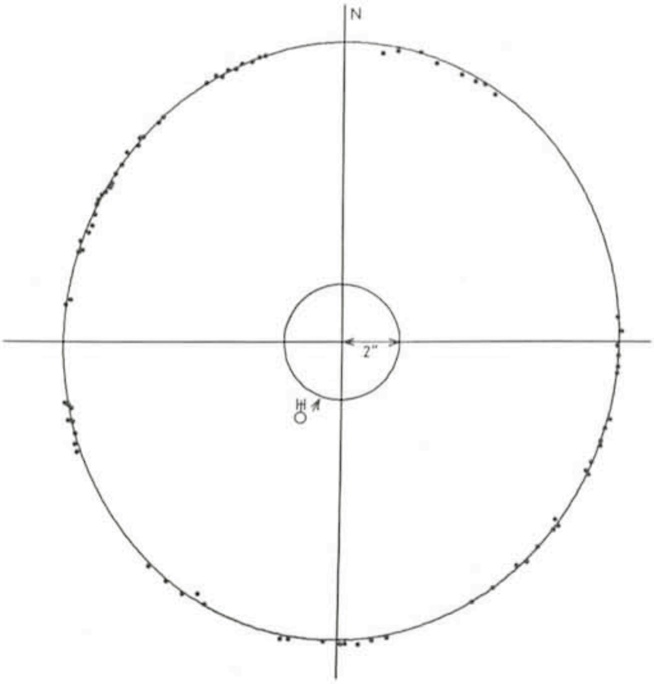

Fig. 4: *Observed positions of Miranda on the sky during the observing run (1981, April 6–14). The standard deviation of the 81 residuals in apparent distance from the plotted ellipse is 0.081 arcsecond.*

Fig. 3 shows a print of a typical plate obtained at La Silla. The diffraction cross is avoided in the same way as for the Saturn plates: Too often Miranda has the bad idea to be just behind one of their arms at the epoch of observation! Four minutes were sufficient to record this satellite well separated from the overexposed image of the planet. Measurements on a Zeiss measuring machine and a reduction using the four other satellites to determine the parameters of the field give the position of Miranda with respect to Uranus (too big on the plate to be measured directly). Fig. 4 shows the results of the 1981 observations. The pair Uranus-Miranda is seen as a double star with a separation between 8 and 10 arcseconds, and a magnitude difference about 10 between them. The high interest of these observations is that for the first time the apparent orbit of Miranda is "frozen", ruling out both nodal and apsidal precessions the periods of which are too long (18 and 16 years) to be taken into account on a week. The best ellipse fitting the observed positions is plotted on Fig. 4. Their parameters will permit an accurate determination of the inclination and longitude of the node on the equator of Uranus, assumed to be the orbital plane of Ariel and Umbriel. It will be possible to propose a set of new orbital parameters and to improve the value of the mass product of Ariel and Umbriel. The calculations are not yet achieved and will be published in the next few weeks.

Neptune

We shall end our visit of the outer planets with Neptune, an unfortunate body which has not filled the first pages of the astronomical news for more than 30 years. It was at the time of the discovery of Nereid in 1949 by Kuiper, a very faint (mg = 19) and eccentric (e = 0.756) object orbiting around its planet with a period of about 360 days. No rings up to now, no spacecraft in the next few years ... and no published positions of Nereid since 1969! Van Biesbroeck and Kuiper have provided all available positions and their distribution is shown on Fig. 5. It is only in 1974 that Rose (*Astron. J.* **79,** 489) used these data to determine the elements of a Keplerian orbit. One year later, Mignard studied an analytical theory of the motion of this satellite including the perturbations due to the gravitational effect of the Sun on a very eccentric orbit (F. Mignard [1975], *Astron. Astrophys.* **43,** 359). But he didn't try to link this theory to the observations. In order to determine the mean elements of Mignard's work and to check the validity of this theoretical orbit, we initiated in 1981 a programme of observation of Nereid

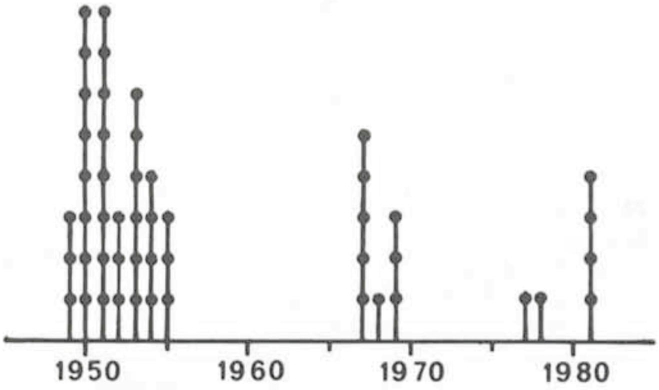

Fig. 5: *Plot of the number of Nereid observations (50) versus time. Each dot is one position.*

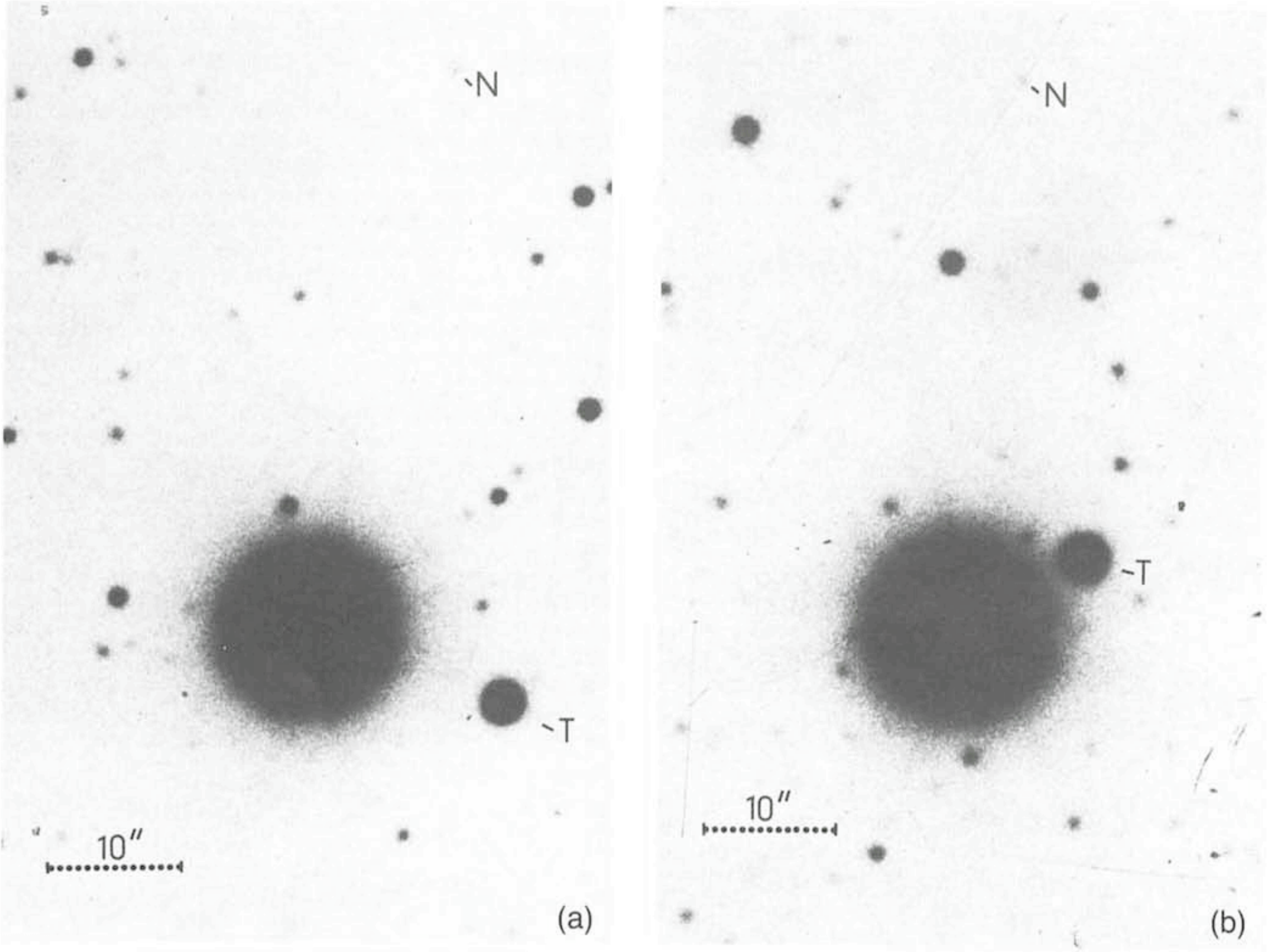

Fig. 6: *Neptune, Triton (T) and Nereid (N). (a) 1981, Apr. 06, 08^{h}40^m UT; (b) 1981, Apr. 11, 08^{h}40^m UT – 40 mn, exp. on III a-J plate. North is up.*

which provided us with four accurate positions. We still used the Danish-ESO 1.5-m reflector. Exposure times of 20 and 40 minutes permitted to record images of Nereid good enough to be measured. Fig. 6 shows prints of two plates taken on two different nights. The motion of Nereid relative to the planet is clearly seen (about 1.8″/day at this epoch).

All the plates have been measured and reduced on an Optronics at ESO (Garching). From a Schmidt plate taken approximatively at the same time for this purpose and reduced with the reference stars of Perth 70, about 15 stars are measured and their coordinates determined. The reduction of the plate showing Nereid is made using these secondary stars. The position of Nereid is available by direct measurement with a sufficient accuracy (0.1 arcsecond) because of the circular image of the planet and the circular circles on the reticle of the Optronics.

Six years after his first paper, Mignard published a second one (F. Mignard [1981], *Astron. J.* **86,** 1728) in August 1981 in which he determined the mean elements of his theory but only by using the old observations (1949–69). Thus our work was no more devoted to a first determination of mean elements, but to a check of the previous orbits and a redetermination of their parameters by adding our new observations. Fig. 7 shows the mean value and standard deviation of the residuals on both the rectangular apparent coordinates of Nereid derived from the previous and the new orbits. The improvement obtained with the new determinations is apparent. The mean elements of the new determination, as well as current osculating elements for the present epoch, will soon be available (a paper has been submitted for publication in *Astronomy and Astrophysics).* The mass of Neptune inferred from the new disturbed orbit is $m^{-1} = 19383 \pm 110$, in good agreement with the values found with other techniques and a good improvement to Neptune masses derived from the previous orbits. However, the residuals of the 1981 plates present systematic errors and it is impossible to

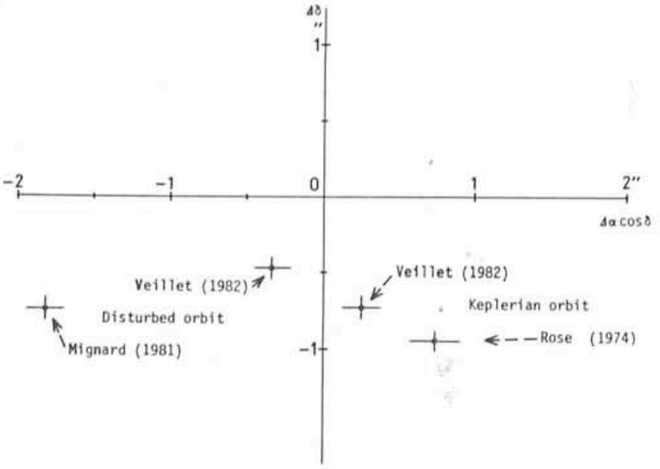

Fig. 7: *Mean value and standard deviation of the residuals in the rectangular apparent coordinates of Nereid from the previous and new orbits for the 1981 observations.*

rule them out. The weight of the old observations, the quality of which is not as good as the new ones, is too important. The standard deviation of the residuals is more than 1 arcsecond after complete calculation and it is difficult to choose which old plate has to be removed without seeing it. . . . The only solution is to get more plates of Nereid in order to increase the number of recent good positions. Observations are planned at both ESO and CFH observatories in 1982. Potential observers are also required: For such a work, it is important to diversify the source of available data.

Conclusion

This observing run at La Silla for studying the motion of faint satellites of outer planets has been very fruitful. We have obtained many results showing that both the site and the instrument are well suitable for accurate astrometric observations of faint objects. It would be very useful to get more positions of the satellites moving on the orbits of Thetys and Dione in order to precise their libration motion. The observations of the Uranian and Neptunian system have also to be carried on to reach a better accuracy in the determination of the orbital elements of their satellites. We plan to make again such a work with the Danish-ESO 1.5-m reflector in May and to extend the programme to the CFH 3.6-m reflector in March this year (1982).

PERSONNEL MOVEMENTS

STAFF

Arrivals

Europe

UNDEN, Christiane (B), Secretary, 8.2.1982

Departures

Europe

JANSSON, Jill (S), Secretary, 30.4.1982

FELLOWS

Arrivals

Europe

PERRIER, Christian (F), 15.2.1982 (transfer from Chile)
KOTANYI, Christopher (B), 15.2.1982
ROSA, Michael (D), 1.3.1982

ASSOCIATES

Chile

BEZANGER, Christian (F), Coopérant, 20.1.1982
DUFLOT, Christophe (F), Coopérant, 20.1.1982

EXPERIENCES WITH THE 40-MM MCMULLAN CAMERA AT THE 3.6-M TELESCOPE

Absolute B,V Photometry of cD Galaxies

Edwin Valentijn, ESO

The ESO 40-mm electronographic McMullan camera was delivered for general use at the 3.6-m telescope in April 1980 and has been used since then at regular intervals. A description of the camera, which can be mounted on both triplet correctors of the 3.6-m telescope, has been given in the *Messenger* No. 17.

The McMullan Camera Compared to the CCD

In 2-dimensional photometry the McMullan camera is a unique instrument, since it combines a relatively large field of view (12′ diameter at the 3.6-m telescope) with a relatively high sensitivity (detected quantum efficiency [DQE] ~10–20%). Therefore, the camera is a sort of intermediate system between the normal photographic plate (DQE ~2%, field diameter 1° at the 3.6-m) and the CCDs (DQE 40–90%, field 4′ × 2.5′). If one expresses the data rate of the cameras in terms of field of view and sensitivity, then the 40-mm McMullan camera has a 2.5 times higher rate compared to the present ESO CCD. The new ESO 80-mm McMullan camera, which will be installed in the near future, will exceed the CCD data rate by a factor of 10. The electronographic camera is UV sensitive, in contrast to the CCDs which are red sensitive. Another advantage of the electronographic camera is its supposed linear response, i.e. the density (D) on the plate relates linearly to the intensity of the exposed light: $m = C - 2.5 \log D$, m is the magnitude of the object and the so-called zeropoint (C), is a constant representing the total sensitivity of the camera plus telescope. For a proper working tube it was found that the gain of the system does not change (< 0.5%) over periods of a few nights. This property is important for doing absolute photometry and is better than the CCDs which can have much faster gain variations. A major drawback of the McMullan camera was that the only available nuclear emulsions from Ilford (uncoated high speed G5, and fine grain L4) were actually not manufactured for astronomy. These plates showed a lot of artifacts and non-uniformities. Besides this, it is very difficult to keep the large 3.6-m dome free of dust, which leads to dust particles on the filters, entrance window and mica window of the camera. I suspect that this was one of the main reasons why the 3.6-m McMullan camera was never taken seriously enough and only a few observers have tried the system. As a result they had to work with an untested system which came straight from the factory and ran into all sorts of instrumental troubles which occurred during their observing run. Most of these problems could have been avoided if more test time had been devoted to the instrument. Thus, the more or less bad reputation of the 3.6-m McMullan camera became self-fulfilling, in contrast to the electronographic camera used on the Danish 1.5-m telescope, where substantial testing has been done and the camera is often used with much more satisfaction. In a recent run, I have tested a new Kodak nuclear emulsion (fine grain SO-647) which was actually developed for astronomical specifications. The Kodak plates are supercoated and were found to be almost free of artifacts and very uniform. The introduction of this much more satisfactory emulsion makes the electronographic camera an up-to-the-mark instrument, unique in 2-dimensional astronomy because of its high data rate. One profits the most from the typical McMullan camera characteristics in doing 2-dimensional photometry of 2′–8′ sized objects.