plates. And indeed, the application of this low-noise, high-contrast spectroscopic emulsion allowed, for the first time, the identification of a very weak He I λ4471 line in the spectrum of an O3-star. This is demonstrated by figure 1, which shows three spectrograms (12 Å/mm dispersion) of the O3-star HD 93250 at this wavelength. The fourth tracing is the superposition of the three spectrograms.

According to our theoretical non-LTE calculation, the red neutral helium line λ5876 should be at least twice as strong as λ4471. We therefore took some red spectrograms of HD 93250, which, as expected, allowed us to identify λ5876.

The detection of these neutral helium lines makes it possible to determine more precisely the effective temperature and the gravity and, from these, the radius, luminosity and mass. To do so, we carried out detailed non-LTE calculations. The fit of the line spectrum of neutral and ionized helium as well as of hydrogen (fitting the profiles, not only the equivalent widths, see figure 2) yields $T_{eff} = 52500$ K, log g = 3.95 (cgs) and normal helium abundance. The position in the (log g, log T_{eff})-diagram, when compared with evolutionary tracks (also including mass-loss), indicates that HD 93250 is a very massive object with more than 120 $M_\odot$ (see fig. 3). This is supported by the distance of HD 93250 (3000 ± 400 pc), which is obtained from its membership in the very young open cluster Tr 16 (Feinstein et al., 1973, *Astron. Astrophys. Suppl.* **12,** 331). By comparison with the flux of our final non-LTE model, we then obtain $R \approx 19\ R_\odot$,

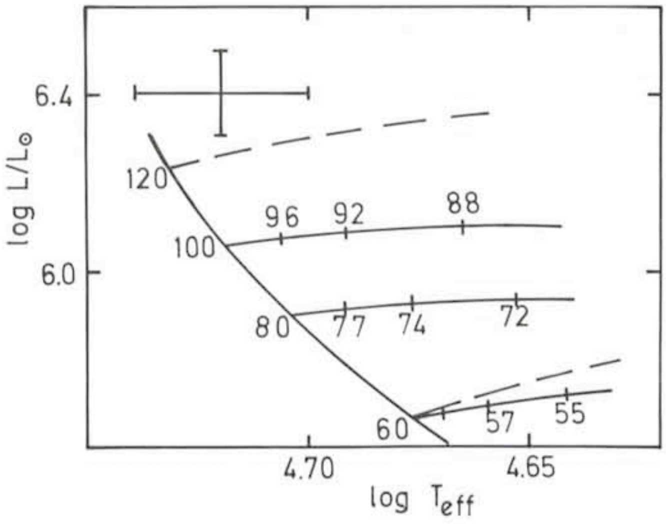

Fig. 4: *Position of HD 93250 in the HRD. The evolutionary tracks are the same as in figure 3.*

$\log L/L_\odot \approx 6.4$ (see fig. 4). If we compute the mass from the gravity and the radius, we obtain $M/M_\odot \approx 120$.

So, even when taking into account realistic errors for all of these quantities, it appears unavoidable to conclude that HD 93250 is in fact a main-sequence star, more than *one hundred* times heavier than the Sun!

The International Ultraviolet Explorer (IUE)

A. Heck, F. Beeckmans, P. Benvenuti, A. Cassatella, J. Clavel, F. Macchetto, M.V. Penston, P.L. Selvelli, and D. Stickland.

European and American astronomers received a beautiful new telescope when the International Ultraviolet Explorer was launched earlier this year in a collaboration between NASA, ESA and SRC. IUE is the first space telescope to be operated like a telescope on the ground, by "visiting" astronomers together with observatory staff members. Dr. André Heck, together with the VILSPA Observatory staff based at the ESA Villafranca Satellite Tracking Station, ESTEC and the UK IUE Project, informs us about the satellite and the fantastic observations that have been made with it. During one session, simultaneous observations were made with the IUE and with three ESO telescopes at La Silla.

The Satellite

The IUE satellite, launched successfully on January 26, 1978, is a joint undertaking on the part of NASA, the United Kingdom Science Research Council (SRC) and the European Space Agency (ESA). It has been developed as a general facility for observing the ultraviolet spectra of astronomical sources over the wavelength range from about 1150 Å to 3200 Å. NASA provided the spacecraft plus the optical and mechanical portions of the scientific instrument, while the SRC provided the television cameras used to record the spectroscopic data. ESA's contribution has been the deployable solar-cell array and the operation of the European ground station at Villafranca del Castillo, near Madrid in Spain. A second ground station is located at NASA's Goddard Space Flight Center, Greenbelt, U.S.A.

The scientific aims of the project, unchanged since the earliest studies of its feasibility, are:

- to obtain high-resolution spectra ($R \sim 10^4$) of stars of all spectral types in order to determine their physical characteristics more precisely;
- to study gas streams in and around some binary systems;
- to observe faint stars, galaxies and quasars at low resolution ($R \sim 250$) and to interpret these spectra by reference to high-resolution spectra;
- to observe the spectra of planets and comets as these objects become accessible;
- to make repeated observations of objects known or newly found to show variable spectra;
- to define the modifications of starlight caused by interstellar dust and gas more precisely.

The scientific aims of IUE are achieved by both high-resolution spectra (~0.2 Å) of bright objects and low-resolution spectra (~8 Å) of fainter objects. Determining the equivalent widths of faint lines used to measure chemical abundance, or the profiles of stronger lines used to study gas motions, requires a spectral resolution of at least 0.2 Å.

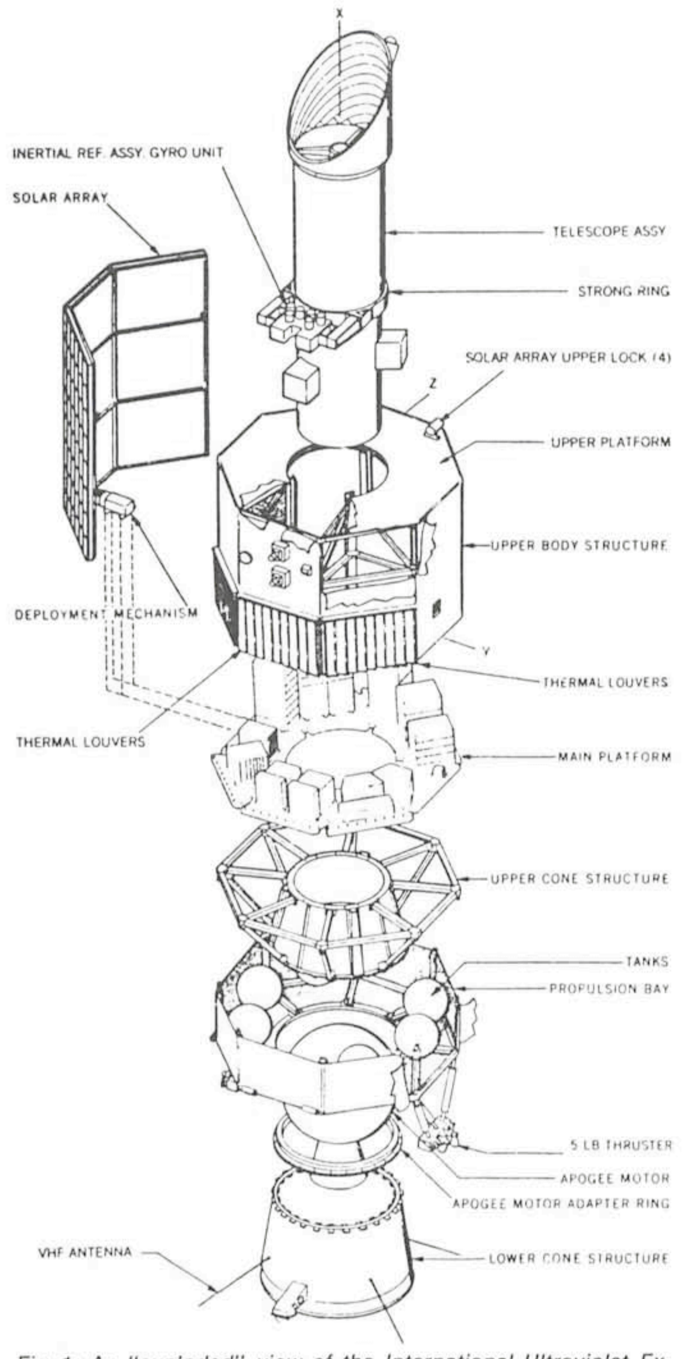

Fig. 1: *An "exploded" view of the International Ultraviolet Explorer Satellite.*

Low-dispersion spectroscopy, on the other hand, serves primarily in the observation of faint sources. The observing programmes calling for this capability either do not require high resolution for analysis or they involve sources with intrinsically broad spectral features. The emphasis is placed on limiting magnitude rather than resolving power. The desire to record complete ultraviolet spectra rather than selected spectral regions dictates the use of spectrographs able to record a spectral image, rather than spectrum scanners.

The IUE scientific instrument consists of a telescope, an offset star tracker used for fine guidance, echelle spectrographs and television cameras. The optical characteristics of the Ritchey-Chretien-type telescope are given by the following table:

IUE Telescope Parameters

Figure	Ritchey-Chretien
Clear aperture	45 cm
Central obscuration (baffled)	22 cm
Primary focal length	125 cm
Effective focal length	675 cm
Focal ratio	50 cm
Mirror separation	102.7 cm
Back focal distance	17.5 cm
Plate scale	30.6 arc sec/mm
Image quality	3 arc sec
Field of view	16 arc min

The acquisition field of view of 16 arcmin is mapped by the fine error sensor in order to identify the target and an eventual guide star, which can be as faint as the 14th magnitude. The fine error sensor, in combination with the gyro package, maintains ~1 arcsec guidance for as long as is required.

The two spectrographs (optical data in the following table) can be operated in a low-dispersion mode (low-dispersion grating only) or in a high-dispersion mode by addition of a high-dispersion echelle grating in place of a plane mirror. They are physically separated and correspond to the following wavelength ranges:

Short wavelength spectrograph 1150 to 2000 Å
Long wavelength spectrograph 1800 to 3200 Å

IUE Spectrograph Optics

Optical Element	Short-Wavelength Spectrograph	Long-Wavelength Spectrograph
Offset mirrors	none	two 45° flats
Collimator radius	189 cm	189 cm
Low-dispersion mirror	flat	flat
Echelle grating		
frequency	101.9 mm^{-1}	63.2 mm^{-1}
blaze angle	45.5 degrees	48.1 degrees
off-normal angle	10.2 degrees	10.2 degrees
Spherical grating		
frequency	313.0 mm^{-1}	200.0 mm^{-1}
radius	137 cm	137 cm
Camera select mirror	45° flat	45° flat
High-dispersion resolving power	10^4	10^4
Low-dispersion resolution	8 Å	8 Å

The detectors are SEC Vidicon cameras. Each spectrograph has two apertures: a 3 arc sec circle and a 10 x 20 arc sec rectangle.

The Orbit

By being in a synchronous orbit such that it can be in continuous contact with the two operations centres, at Goddard Space Flight Center and Villafranca, IUE differs conceptually from previous orbiting observatories, which communicated with ground stations only intermittently and so had to be self-contained, automated systems that acquired data while not under direct ground control. In the case of IUE, control and performance monitoring is exercised continually from the ground. The telescope field is displayed to the observer, who can identify his target star and direct the course of the observation essentially in real time. The "observatory", therefore, consists of the ground control centre where the astronomer views the television monitors, and the optical and electronic instrumentation in orbit at synchronous altitude.

Two significant scientific advantages of the synchronous orbit are that the astronomer has physical access to the observatory, whereby he can participate directly in the telescope control loop, and the observing circumstances develop at the diurnal rate so that plans and real-time decisions can be made in an effective and orderly manner. Also, the earth subtends an angle of 17° as seen by the telescope, and the area of sky available at any given time is much greater than from lower orbits or from the ground. Moreover, the region of the celestial sphere periodically occulted by the earth is also greatly reduced. As a result, in most parts of the sky, long exposures or the monitoring of variable phenomena need not be periodically interrupted because of earth occultations.

Pointing within 43° of the sun is prohibited. Pointing within 15° of the anti-sun requires special planning to avoid telescope defocus problems. Pointing within 25° of the earth may be restricted during image readout because of antenna null problems, but observations in this region are permissible.

In exchange for its contribution to the project, Europe has been allotted eight hours of satellite observing time per day, shared equally between ESA and SRC.

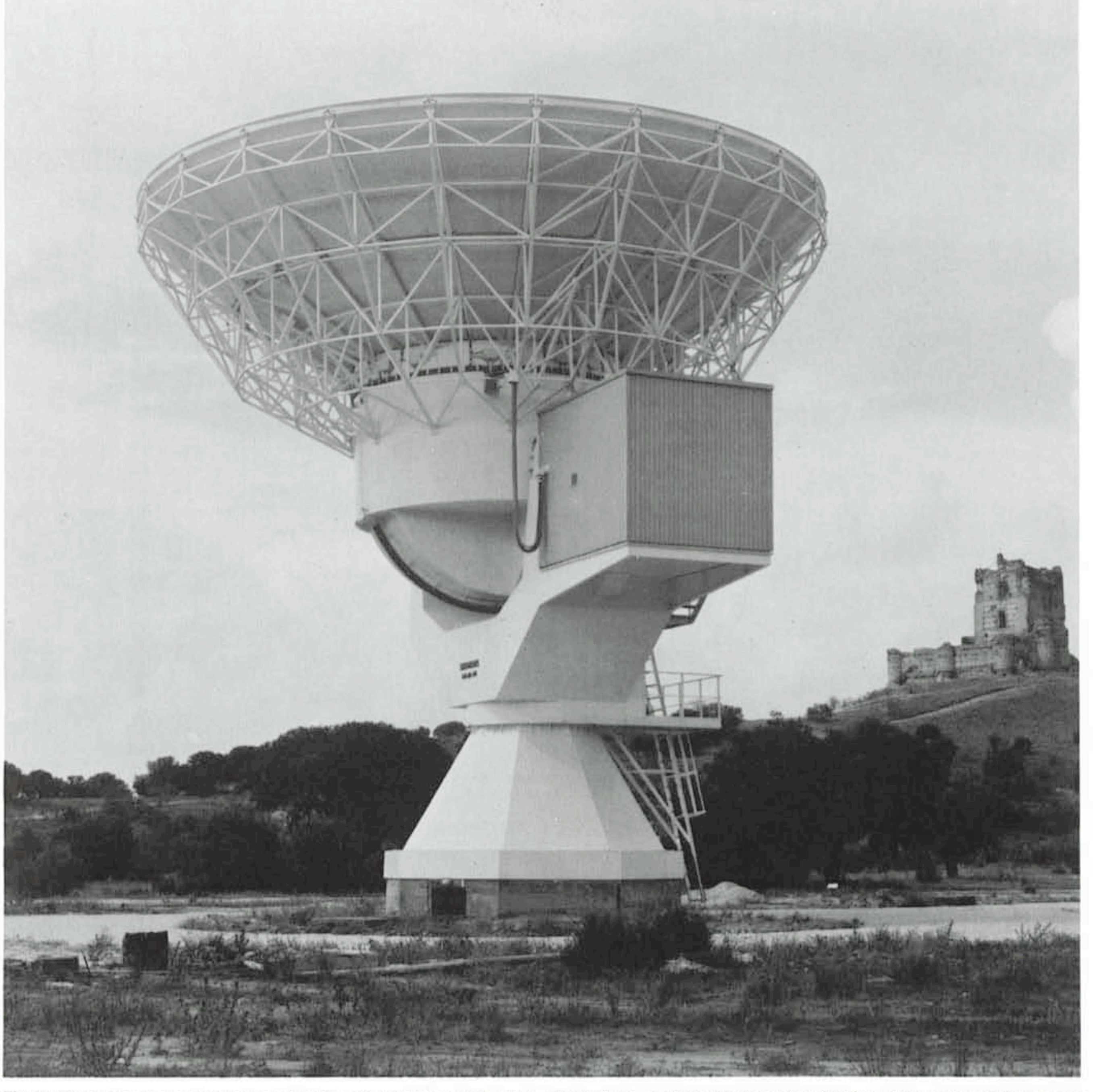

Fig. 2: *The antenna used for the collection of data from IUE at the ESA Villafranca Satellite Tracking Station. Like some other famous observatories, the facilities lie close to a distinguished castle!*

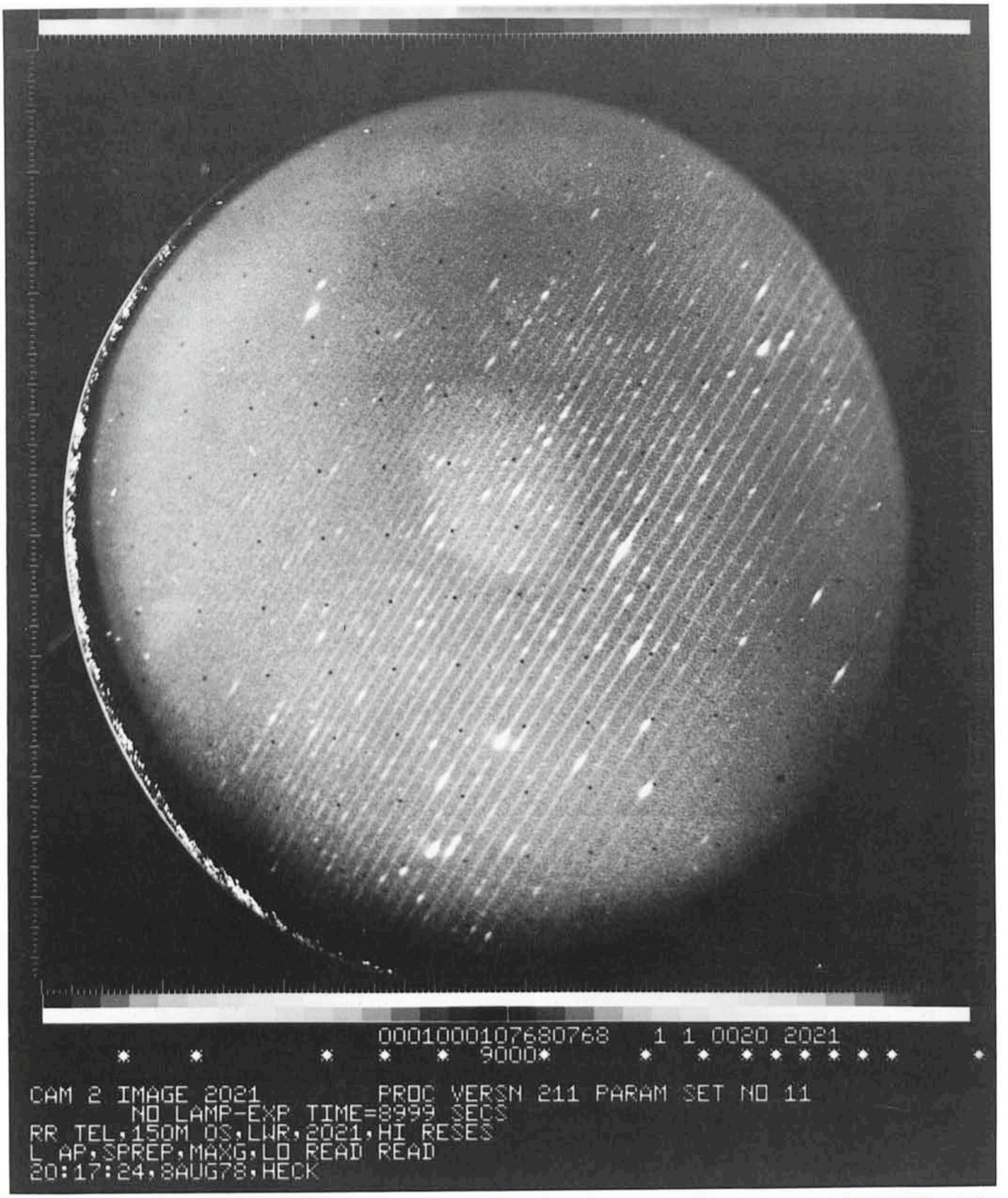

Fig. 3: *The "long-wavelength", high-dispersion UV echelle spectrum of the slow nova RR Tel. This spectrum contains over 300 emission lines!*

Observing with the IUE

To ensure that the observers visiting the ground stations are able to make maximum use of the satellite observing time available to them, a small group of resident astronomers are available to provide assistance and to guide and train visiting scientists, many of whom are astronomers from universities, conventional observatories and other institutes.

During his shift, the observer directs the activities of the spacecraft and scientific-instrument operators and a data-reduction specialist. An observing sequence starts with the observer requesting that the telescope be slewed to the coordinates of his first target. After the slews have been accomplished, a fine-error-sensor image is commanded, resulting in a display on the television monitor of the positions of all stars brighter than a predetermined magnitude. The observer can then compare this display with a finder chart, identify his target star and designate a suitable guide star.

When the target image is in the correct aperture, the spectrograph camera high voltage is commanded *on* to start the exposure. During exposure, the guidance quality is monitored on the ground by examining the signal from the fine-error sensor. At the end of the exposure, the tube high voltage is turned off, and the camera commanded to read out the image.

The telescope may be held on target until the observer has had an opportunity to examine the data. About 20 minutes after the end of the exposure, the raw spectrum from the television camera can be displayed on an television monitor to see if the observation should be repeated or if the subsequent observing schedule should be modified in some way. When the observer determines that useful data have been obtained, the spectral image is stored for full processing and the observing session continues.

Routine data processing, defined as those calculations that require special knowledge of IUE but that do not require astronomical interpretation of the data, is done by the observatory staff. These tasks include noise and distortion removal, wavelength determination to an accuracy comparable with the spectral resolution and photometric calibration.

The standard outputs of the data processing are magnetic tapes, plots and photographic representation of the images.

In about six months of observation at the date of writing, numerous important results have been obtained with IUE in various fields of astronomy.

To the end of September 1978, 57 groups of guest observers from 11 different countries have come to VILSPA and taken 878 spectral images on IUE (some containing more than one spectrum). An average of 7 images per day was obtained in September—a marked improvement over the first scientific target in Commissioning which took 24 hours to observe! These image numbers closely approximate the 33 per cent expected from Europe's one-third time on the satellite. IUE has shown its versatility by obtaining from Villafranca ultraviolet spectra of planets, the interplanetary medium, stars of all spectral types from O to M as well as Wolf-Rayet, symbiotic, nova-like, X-ray emitting and T Tauri stars, planetary nebulae, supernova remnants, galaxies—including in particular Seyfert and radio galaxies—BL Lac objects and quasars. IUE has proven capable, in long exposures, of detecting and obtaining useful spectroscopic information on an 11th magnitude Seyfert nucleus in high dispersion and a quasar of almost 18th magnitude in low dispersion.

Joint IUE-ESO Observations of RR Tel

In particular, interesting joint observations from space and ground were performed on June 20, 1978 by astronomers observing from the ESO site at La Silla and from the European Space Agency Villafranca Satellite Tracking Station (Vilspa) in Spain.

At the latter station, the real-time operation shift on the International Ultraviolet Explorer (IUE) satellite was available for the resident astronomer's programme. As André Heck was observing at that time with the 50 cm at La Silla (photometry in Strömgren and Crawford systems), it was decided to perform simultaneous spectrophotometric observations of the slow nova RR Telescopii. Thanks to the collaboration of J. Surdej and N. Cramer respectively, the star was also observed at the coudé focus of the 1.5 m ESO telescope (two spectra at 20 Å/mm—one in the blue region, one in the red region) and at the 40 cm Swiss telescope (photometry in Geneva system). The observer at Vilspa was P. L. Selvelli. Further UV observations were performed later at Vilspa by other resident staff.

The spectra, covering both UV and visible ranges, are quite exciting and contain about four hundred emission lines. They are presently being reduced, as are the photometric observations which are primarily useful for monitoring possible variations. All the Vilspa Observatory staff are participating in the reduction and the discussion of the data.

RR Tel was extensively observed and studied by the late A. D. Thackeray and it is hoped that the combination of visible and UV data will improve our understanding of the complex nature of this object. At the time of writing, we have confirmed its binary nature as the optical data show a late-type star whereas the continuum energy distribution is consistent with a B-type star. Emission lines identified so far include species up to about the fourth stage of ionization. The presence of some lines from highly excited levels may indicate the presence of hot gas of up to 260,000 K.

This example of joint observations from ground and space is a forerunner of what will most probably be very common in the future.

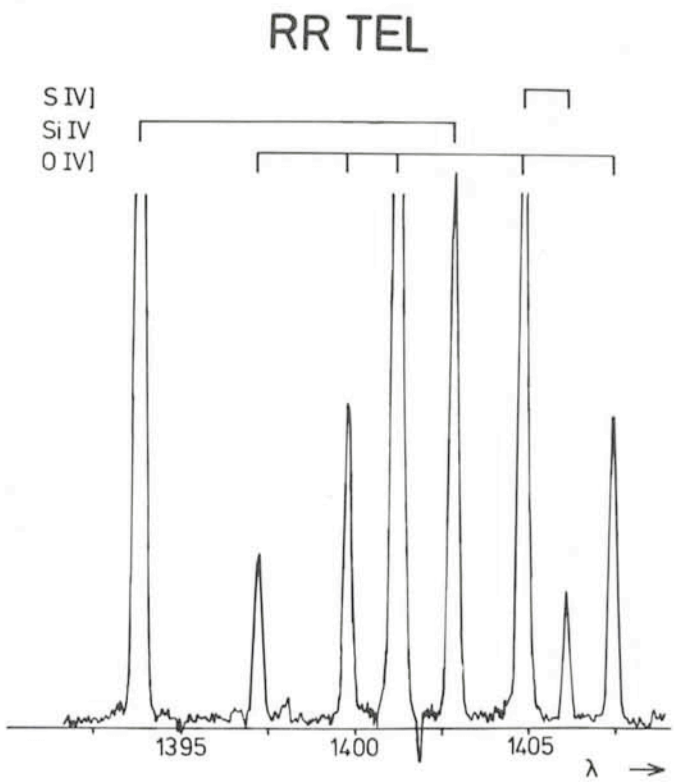

Fig. 4: *A tracing of a portion of the "short-wavelength" UV spectrum of the slow nova RR Tel, showing the group of strong lines from O IV], Si IV and S IV] near 1400 Å.*