Speckle Interferometry

A. Labeyrie

Radio astronomers have for many years employed interferometric techniques to resolve the finest details in celestial radio sources. One of the first to use similar methods in optical astronomy was Dr. Antoine Labeyrie who is now constructing an interferometric optical telescope at the CERGA Observatory, near Nice in France. He sees the VLT as an array of 2–4-metre telescopes which deliver coherent light beams to a central "coudé" laboratory. With this instrument Dr. Labeyrie hopes to study the surfaces of individual stars and binary systems. It may even be possible to resolve optically the nearest quasars.

Building giant eyes is perhaps part of the normal evolutionary fate for advanced civilizations. Eye size must be a measure of how advanced the civilization is.

At this time, the main technical problem for a 25-metre equivalent telescope is to decrease the cost per square metre for mirror elements of astronomical quality. Two approaches are currently investigated, namely replication and diamond turning, and these promise considerable gains over traditional mirror figuring techniques.

Thus, the problem of what to observe with giant telescopes is certainly relevant at this time. However, in the same way as the builders of Palomar could not prophesy that their telescope would spend most of its time looking at QSO's, the extrapolations made at this time will prove obsolete as new types of mysterious objects are discovered.

The Multi-element Telescope

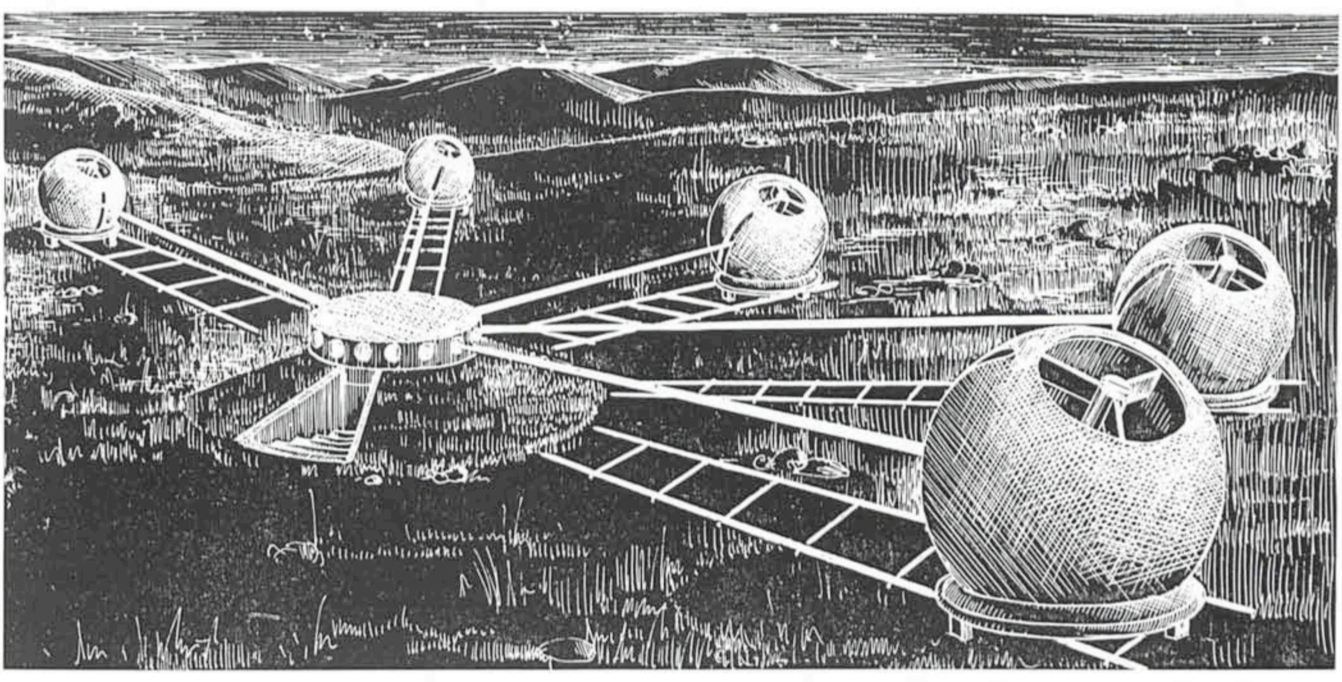
I deliberately assume that the telescope is *coherent*. There is so much more science to do, for a negligible cost increase, with a coherent telescope that I simply cannot imagine any advantage in favour of a non-coherent machine. Achieving coherence is simply a matter of adding micrometric drives, under micro-computer control, and this is now a simple and well-established technique.

Then, let us think in terms of a coherent array incorporating many telescopes. 150 2-metre or 36 4-metre mirrors are equivalent in luminosity to a 25-metre dish, but the resolution can be far superior with a "diluted" array spanning up to several hundred metres. The figure below shows my preferred configuration, the simplest, having a minimum number of coudé flats, and most compatible with future extension and modifications. Coherence only implies that the component telescopes are driven slowly along their radial tracks during observations. As explained elsewhere (1), the ring has to be elliptical with variable eccentricity. In the central laboratory, all the coudé beams converge into a single image. Observable stellar details range in size from 20 down to perhaps 0.1 millisecond of arc.

It is likely that active-optics devices (2) will be available for diffraction-limited images, but only on bright objects.

Resolving the Stars

Now, what shall we observe? The first obvious thing is nearby stars, of which maps can be made. This shows limb-



darkening, certain bright coronas, star spots, stellar rotation, oblateness. According to the few results of speckle interferometry at Palomar, cool stars appear to be accurately spherical. There must be exceptions, particularly among the fast-rotating hot stars. Features resembling Saturn's rings are expected around Be stars, but these were not resolved at Palomar. Are there dots or channels on Betelgeuse, Antarès and Aldebaran? Are Mira stars changing their size or shape as they pulsate? How about observing the pulsations of Cepheids?

Close binaries provide inexhaustible supplies of spectacular observations. How much atmosphere is there between Algol A and B? Accurate stellar masses can be obtained in many cases from observed orbits and radial velocities.

A major gain of information arises from the fact that spectra will become sharper. This is a consequence of improved spatial resolution: In conventional spectrographs the mixing of spectral features produced by different regions of the star widens the observed line profiles. The kind of highly informative spectral and spatial data heretofore obtained on the sun, including spectroheliograms showing detailed atmospheric motions, will also be obtained on the 30 or 100 largest stars. This means nightmares for model-atmosphere experts, and headaches for their computers!

Quasars, Pulsars and X-ray Binaries

Active optics cannot cancel atmospheric effects at stellar magnitudes fainter than 10 or 12, but some less appealing interferometric methods still remain applicable down to $m_v = 15$ or more. These methods can answer some critical questions in cosmology. A speckle-interferometer measurement of 3C 273 suggests a source smaller than 0".020. Something mysterious happens there, and we do not even know how small the source really is. The bright nuclei of many galaxies also deserve a closer look.

Optical pulsars, particularly the Crab object, are of course worth a look even though neutron-star models predict non-resolvable dimensions for the central object. Indeed, nebulosity near the object might exist and exhibit patterns resembling a searchlight beam in clouds.

Among the X-ray emitting binaries which are believed to incorporate a black hole, certain orbital dimensions can be resolved with the instrument. For the detection of circumstellar planets by direct-imaging means, a single space telescope of 2.5-metre size is more likely to succeed than a large ground-based array. This is because the problem is one of scattered light, not resolution. An additional limitation has to do with faint objects of complicated morphology, such as globular clusters or stars in galaxy images: owing to some basic noise effects in interferometry, these objects are also relevant to space telescopes and arrays.

References

1. A. Labeyrie, *Ann. Rev. Astron. Astrophys.* (1978).
2. J. W. Hardy, *Optical Telescopes of the Future,* Proceedings of ESO Conference, p. 455.

Instrumentation Schedule

Following the proposal of the Users Committee, we shall start with this edition of the *Messenger* to publish regularly our time schedule for the major instruments which are being developed at ESO in Geneva. These instruments are constructed for use on the 3.6 m telescope. The target dates indicate the date of "first light". This means that the instruments will have passed at that date the test procedures in Geneva and on La Silla as far as optical-mechanical and electronical tests are concerned. "First light" is the date of the first trial on the sky. It should be understood that it will take half a year more before the instrument goes into regular use.

It can be assumed as a normal rule that the instruments have a half-year assembly and test period in Geneva followed by a three-month period for shipment and installation before the target date. The detail design gets frozen already one year and a half before the target date.

In order to learn more about these instruments, questions and proposals may be addressed to the astronomer or to the engineer indicated in brackets. For some of the instruments, a description can also be found in the *Messenger* as indicated.

Triplet Adaptor (M. Tarenghi, M. Ziebell). Target date: May 1979. The components are:
- two 3-lens correctors for prime focus
- an adaptor with tv for acquisition and guiding
- a remote-controlled shutter and changer for 4 filters
- a remote-controlled changer for 8 plates (3 magazines); plate size is 240 x 240 mm.

More details will be published in the next *Messenger.*

4 cm Mc Mullan Camera (W. Richter). Target date: October 1979.
- Electronographic camera as developed by Mc Mullan. Can be used behind triplet adaptor in prime focus.

Coudé Echelle Scanner (CES) (D. Enard, J. Melnick). Target date: end 1979.
- Instrument to record very high resolution digital spectra (up to 100,000) on a 1876-channel-DIGICON detector. Double-pass scanning mode permitting calibrations on bright objects with very clean instrumental profile.

For more details see *Messenger* No. 11.

Infrared Top-End (R. Grip, P. Salinari). Target date: start 1980.
- Wobbling secondary mirror with f/35 in Cassegrain focus, new telescope top-ring which puts radiating material away from light beam.

For more details see *Messenger* No. 13.

Coudé Auxiliary Telescope (CAT) (T. Andersen, M. Dennefeld). Target date: mid 1980.
- 1.5 m spectroscopic telescope feeding CES of the 3.6 m telescope. Three-mirror alt-alt telescope with f/120 (f/32 after focal reducer). Dall-Kirkham optics with spherical secondary. Direct drive servos without gear.

For more details see *Messenger* No. 10.

Cassegrain Echelle Spectrograph (CASPEC) (M. le Luyer, M. Ulrich). Target date: end 1980.
- Instrument with resolution of 15,000, 30,000 and 60,000 with an SEC-Vidicon detector. Data-reduction process not yet defined in detail.

W. Richter