0.5 Arcsecond Images with the Danish 1.5 m Telescope on La Silla!

J. Andersen and B. Niss

The 2.4 m Space Telescope will achieve 0"1 resolution in 1984. But what is the best possible angular resolution from a ground-based observatory? Recently, fantastic long-exposure plates were obtained with the Danish 1.5 m telescope at La Silla, proving at the same time the excellent performance of this new telescope and the quality of the ESO site. Drs. Johannes Andersen and Birger Niss from the Copenhagen Observatory, Denmark, tell the exciting story.

In the last issue of the *Messenger*, the general features as well as the optical alignment, commissioning, and initial performance of the Danish 1.5 m telescope on La Silla were described. The conclusion, based mainly on laboratory tests and the accuracy achieved in the alignment, was that the image quality until then had been entirely limited by seeing, but confidence was expressed that the telescope would be "able to take advantage of even the nights of very best seeing".

Such prophecies are not uncommon in articles describing new telescopes. They are usually met with a benevolent scepticism of seasoned observers, who know by experience all the good excuses why the theoretically predicted image quality is (almost) never experienced in practice: Seeing, whether external or internal in the dome or telescope tube, and imperfect optical alignment, mechanical stability, and/or guiding, all combine to make images of one arcsecond or slightly less the best one hopes for in longer exposures, even if theoretical resolution is half that figure or better.

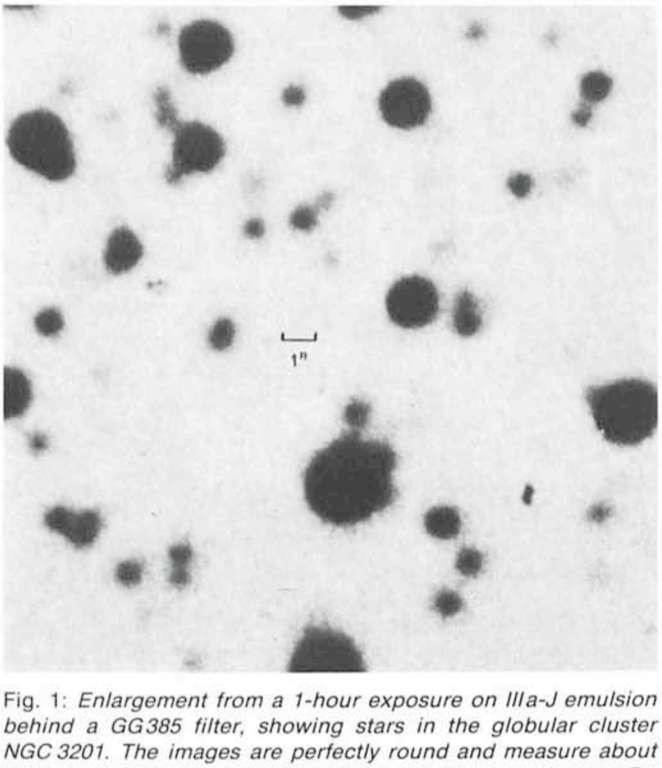

Fig. 1: *Enlargement from a 1-hour exposure on IIIa-J emulsion behind a GG385 filter, showing stars in the globular cluster NGC 3201. The images are perfectly round and measure about 0.5 arcsecond in diameter. Danish 1.5 m telescope; observer Dr. B. Niss, March 7, 1979. Average zenith distance 18°.*

The sanguine predictions for the Danish 1.5 m telescope were, however, confirmed before the ink on them was dry—with one startling reservation as will be discussed at the end of this note. In early March this year, one of us (B. N.) was continuing the observing programme in globular clusters described in *Messenger* No. 10, p. 14. Although the telescope was (and still is) in the testing phase, good cooperation from the equipment combined with a spell of excellent atmospheric conditions to produce a superb collection of plates. The image sizes range from 1" through several plates of 0"7–0"6 to the best one, a *one-hour* exposure on IIIa-J emulsion of NGC 3201, which shows images nicely circular—and of diameter 0"5 (30 microns) as measured on a projection micrometer! The figures show a reproduction of this plate and a PDS scan through one of the images.

This was an almost unbelievable result (J. A. was in fact only convinced by his own eyes looking through the micrometer eyepiece!). As mentioned in the previous article, the mirror acceptance tests indicated a geometrical energy concentration of 80 % in 0"45, to which must be added the diffraction disk of 0"2—and you already have the observed diameters! In fact, had these images been taken in a laboratory vacuum test tank, they would have been considered a most gratifying confirmation of the more indirect test methods. Obtaining such images in a long exposure with a real, moving telescope in a real dome and equally real atmosphere is an entirely different matter; however, not the least if one keeps in mind that asymmetries of 0"1–0"2 would have been plainly visible! This leads us to several pleasant conclusions:

- The optical test results supplied by Grubb Parsons were probably even on the conservative side;
- The optical alignment was in fact done to better than 0"1 of coma, as previously described, *and* it remained intact after four months of operation;
- The telescope tube and drives are of excellent mechanical quality;
- The autoguider and control system achieved a guiding accuracy of about 0"1 as specified, and, last but not least,
- Seeing, external *plus* internal, was significantly better than 0"5.

We leave the many possibilities offered by such images to the reader's imagination, but a quick comparison with previous electronographic work indicates that had one of our McMullan cameras been on the telescope that night, we would have been able to detect and measure stars of magnitude between 26 and 27! We do not suggest that such nights are the rule, even on La Silla, but nor do they belong entirely in the realm of dreams.

If one insists in being ungrateful, than it should be said that our mirrors, which we always considered excellent, did *not* in the end live up to those "nights of very best seeing". Rather unexpectedly, the resolution seems ultimately to be limited by residual optical (mostly zonal) aberrations, even at this very low level. It will be interesting to see whether the CAT optics, made by the same manufacturer under even tighter specifications, will produce still better images under optimum conditions.

Being far from ungrateful, however, we wish to conclude by paying tribute once again to those responsible for this achievement: to the firm of Grubb Parsons for their outstanding optical and mechanical craftsmanship, to the ESO Optics Group for their invaluable help in testing and aligning the optics, and to the ESO Controls Group and the workshops of Copenhagen University Observatory for the successful combination of control system and autoguider.

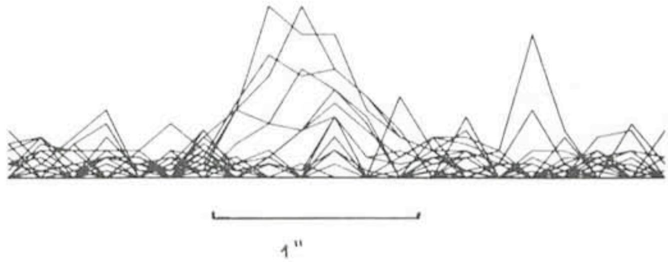

Fig. 2: *A scan through one of the images in figure 1, made with the PDS microdensitometer at the Lund Observatory through a 10 × 10 micron square aperture.*

The Problem of Star Formation—and what Ten Nights of Sub-millimetre Observations with the VLT Could Contribute to its Solution

P. G. Mezger

Astronomical observations are regularly carried out over the whole electromagnetic spectrum, from γ-rays to low-frequency radio waves. There are few unexplored "holes", but one of these—in the neighbourhood of 1 mm—is exactly where we expect most of the radiation from stars during their early stages of formation. The VLT would be ideally suited for ground-based observations in the sub-millimetre range, because of its large surface and good angular resolution. Dr. Peter Mezger of the Max Planck Institute for Radioastronomy in Bonn explains how the VLT can make a very important contribution to the study of stellar formation.

Sub-millimetre Observations, Star Formation and the VLT

The transformation of gas into condensed objects, either ordinary main-sequence stars with masses ~0.1–100 $M_\odot$ or perhaps also much heavier supermassive stars, is one of the most fundamental processes in the Universe. Star formation plays a leading role in the formation of galaxies, in the chemical evolution of the interstellar matter (i.e. its enrichment with elements heavier than ^{4}He) and may well be related to some of the phenomena associated with radio galaxies and quasars.

In spite of a wealth of radio and IR observations related to both dense molecular clouds (out of which protostars form) and pre-main-sequence evolutionary stages of massive stars, the basic process of the formation of protostars out of the interstellar matter is far from being understood, even in a qualitative way. The reason is that the formation of protostars occurs at very low temperatures of the interstellar gas (typically ~10 K) and that the outer shell of the contracting protostar remains at such low temperatures until nuclear burning starts at its centre. Thus the Planck curve for 10 K (shown as dash-dotted curve in Figure 1) is an upper limit for the intensity of both continuum and line TE radiation emitted by dense molecular clouds and protostars in their early evolutionary stages. This curve peaks at ~500 μm (= 0.5 mm). In Figure 1 is also shown the transparency (heavy curve) of the atmosphere for an amount of 1.3 mm of precipitable water, conditions as they prevail at an altitude of ~3,000 m for about 30 % of the clear nights. One recognizes a number of atmospheric windows whose transparency decreases with decreasing wavelength. Below ~300 μm the atmosphere is practically opaque. The wavelength range between 1.8 mm and 300 μm, although accessible for ground-based observations with a telescope placed at a very high and dry site, is largely unexplored. This is due to both a lack of sensitive radiometers and of radio telescopes with a sufficient surface accuracy of its reflector.

Promising developments of both coherent radiometers (for spectroscopy) and incoherent radiometers (bolometers for broadband continuum observations) for the sub-millimetre wavelength range are in progress in various laboratories in Europe and the US. But even the second generation of mm-telescopes, now being planned or under construction, are only marginally usable for sub-millimetre observations. The reason is that the quality of a telescope for coherent detection is determined by the rms deviation of its reflector surface from a best-fit paraboloid, and this in turn is determined by the surface accuracy of the reflector panels, the accuracy with which these panels can be adjusted, and by the design of the reflector back-up structure. Most mm-telescopes in operation today have rms deviations $\sigma \gtrsim 100$ μm. For the new large mm-telescopes one anticipates rms deviations in the range $90 \gtrsim \sigma/\mu m \gtrsim 50$, which degrade the telescope characteristics (such as gain, aperture, and beam efficiency) according to exp