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The NTT Provides the Deepest Look Into Space

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The ESO New Technology Telescope on La Silla has again proven its extraordinary abilities. It has now produced the "deepest" view into the distant regions of the Universe ever obtained with ground- or space-based telescopes.

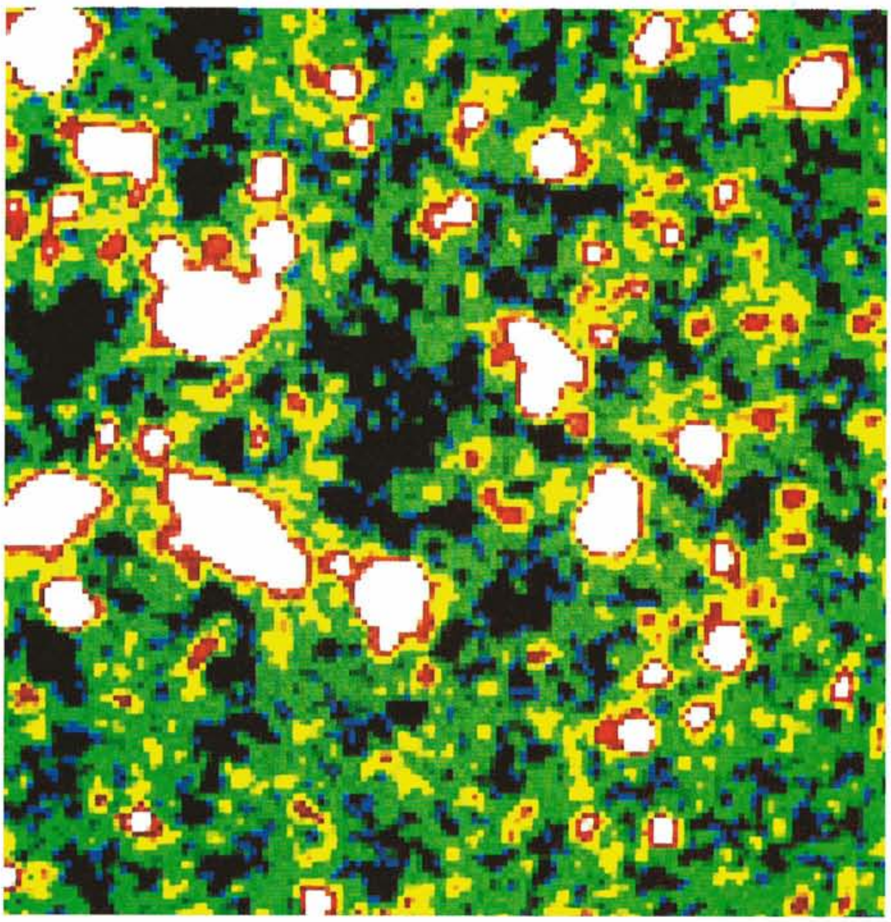

Figure 1: *This picture is a reproduction of a 1.1 × 1.1 arcmin portion of a composite image of forty-one 10-minute exposures in the V band of a field at high galactic latitude in the constellation of Sextans (R.A. 10^h 45^m; Decl. $-0°$ 14′).*

The individual images were obtained with the EMMI imager/spectrograph at the Nasmyth focus of the ESO 3.5-m New Technology Telescope using a 1000 × 1000 pixel Thomson CCD. This combination gave a full field of 7.6 × 7.6 arcmin and a pixel size of 0.44 arcsec. The average seeing during these exposures was 1.0 arcsec.

The telescope was offset between the individual exposures so that the sky background could be used to flat-field the frame. This procedure also removed the effects of cosmic rays and blemishes in the CCD.

More than 97 % of the objects seen in this sub-field are galaxies. For the brighter galaxies, there is good agreement between the galaxy counts of Tyson (1988, Astron. J., ***96,*** *1) and the NTT counts for the brighter galaxies. However, the limiting magnitude for this image is ~ 1 mag fainter than for previous work. A magnitude sequence of a few of the galaxies is shown on the accompanying map on page 2.*

This V-image represents the deepest image that has ever been published.

The new picture reaches magnitude 29 and shows enormous numbers of extremely faint and remote galaxies whose images almost completely fill the field of view.

A Magnitude Sequence in the NTT Picture

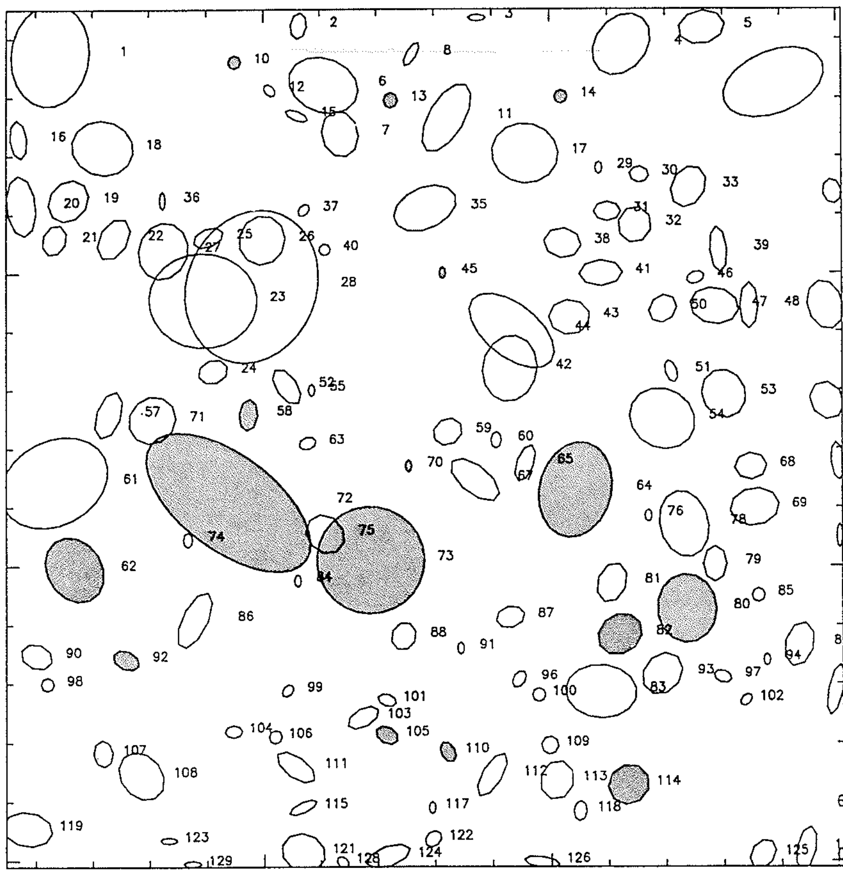

Figure 2: *This map identifies some of the galaxies which are seen in the deep NTT frame on the front page. The computer-drawn ellipses reflect their sizes and shapes. Note that the identifying numbers are located to the right of the objects they refer to.*

The following sequence of measured V-magnitudes illustrates the extraordinary depth of this picture: V = 20.3 (galaxy no. 72), 21.1 (73), 21.5 (64), 23.0 (62), 23.4 (80), 24.9 (114), 26.3 (58), 26.8 (92), 27.5 (105), 27.7 (110), 28.0 (13), 28.4 (10), 29.0 (70), 29.1 (45).

The Observations

Beginning in March 1991, and together with Yuzuru Yoshii of the National Astronomical Observatory in Tokyo and Joseph Silk of University of California, Berkeley, we have embarked upon an observing programme with the NTT aimed at detecting and measuring extremely faint galaxies.

To avoid problems with bright objects in the field, we pointed the NTT towards an "empty field" in Sextans. Previous observations had shown that no objects brighter than about magnitude 20 were visible in this direction. As will be seen, this first attempt has been highly successful.

Using a Thomson high-quality CCD detector in the ESO Multi-Mode Instrument (EMMI) at one of the NTT Nasmyth foci, Bruce Peterson took forty-one exposures of this field, totalling 6 hours 50 minutes. The individual pictures were registered and co-added to produce a combined image of which a small part (about 2% of the total area) is reproduced on the photo on the front page of this issue of *The Messenger.*

Characteristics of the Picture

It has been known for some time that on very deep sky exposures, most recorded objects fainter than about magnitude 24 are galaxies, rather than individual stars. In simple terms, this is because, as we look further and further out in space, we see more and more galaxies, while there is only a limited number of foreground stars in the Milky Way.

More than 97% of the objects in the frame are galaxies. The brightest ones, of about magnitude 21–25, can clearly be seen to have different shapes and can be accordingly classified. Thanks to the good angular resolution, it is possible to see that some of the fainter images are more or less elongated. This may be due to the galaxy type or to the inclination.

Calibration exposures were made on the same nights and we determined that the limiting magnitude of the frame is fainter than magnitude 29. This is more than one magnitude, i.e. at least 2.5 times, fainter than any other image obtained so far by any optical telescope, on the ground as well as in space. We have indicated a magnitude sequence on the drawing.

The frame shows enormous numbers of faint galaxies whose images to a large extent overlap each other. As a matter of fact, it is not even certain that there is any place where we are able to see the sky background. Already this simple observation is of great cosmological significance: the number of galaxies still appears to be increasing at these very faint magnitudes. It seems that we have not yet reached a point where we begin to look through the system of galaxies, as we can look through the stars in the Milky Way system.

A single frame, however, cannot with certainty discern between relatively nearby dwarf galaxies, very distant "normal" galaxies, or extremely remote superluminous galaxies. If some of the faintest images here seen belong to dwarf galaxies like the Magellanic Clouds, then their redshifts are likely to be 0.5 to 0.7, corresponding to look-back times of 38–48% of the age of the Universe. Those which are normal galaxies like the Milky Way will have redshifts of the order of 3–3.5 and the look-back time would be 88–91%. However, if any of them are brighter than the Milky Way Galaxy, then their distances would be even larger.

Follow-up Observations

A number of follow-up observations are now being undertaken.

First of all, reasonably accurate colours of most of the observed galaxies will be measured. With the NTT, this will be possible for those which are brighter than magnitude 28. An R-frame similar to the V-frame shown here has already been obtained; a comparison may enable us to cast some light on the ages of the galaxies observed.

The NTT will also be able to obtain spectra of the galaxies brighter than about magnitude 24. This will make possible the measurement of their redshifts, i.e. their velocities and cosmological distances.

The differentiation between relatively nearby dwarf galaxies and much more distant normal galaxies will also be possible by means of continued observations of the same sky field. Dwarf galaxies at redshift 0.5 would be close enough for individual supernovae to be observed in large numbers. Contrarily, supernovae in normal galaxies at redshift 3 or more would be too faint to be observed. A comparison of pictures obtained at different times will tell whether short-lived supernovae are seen or not, and therefore immediately give important information about the nature of the objects seen.

This NTT picture has given us a tantalizing, first glimpse of what can be done with the new and improved observational means which are now at our disposal. It has given us a unique look into regions of the Universe, so remote in space and time that they have never before been explored.

This is the type of work that will be at the frontline of optical observational cosmology during the coming years.

HST – the First Year

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At the end of April, the Hubble Space Telescope completed its first year in orbit. With a projected lifetime, however, of some fifteen years, the observational programme of the spacecraft is just beginning. After the announcement in June 1990 of the spherical aberration in the primary mirror, the first assessment by astronomers tended to relegate the observatory to the role of a "large IUE with some UV imaging".

Now that the science verification phase of the commissioning process is nearing completion and the Guaranteed Time and General Observer programmes have started, it is a good time to assess what we have learned so far and try to paint a somewhat more realistic picture of the current capabilities of the instruments as they will be until the optical correctors are installed late in 1993 (current estimate).

In our eagerness to examine and assess the first real observations with the cameras and the spectrographs, it is perhaps too easy to overlook the tremendous complexity of the spacecraft and the ground operation and so to underestimate the achievement that the by now regular observing schedule represents. In the early months of the year, many of the pointing and target acquisition problems were overcome and by April, when revised pointing control software was installed in the on-board computers, the rate of successful completion of planned observations had become encouragingly high.

An engineering assessment of the spacecraft reveals both good news and some cause for concern. The new NiH2 batteries, specified at a late stage in the project, are performing well and the solar arrays are exceeding expectations in their power output. This means that the extra power can be used to minimize the thermal cycling of the scientific instruments and so help to extend their lifetime. Also, the thermal behaviour of the spacecraft as a whole is excellent and imposes no additional operational restrictions on the observing programmes. Communications with the ground, both direct and via the TDRS system, are no problem with a bit-error-rate some thousand times better than the minimum specification. The data management is also operating well, although a failed memory unit (one of six, four of which are currently used) caused the HST to enter a deep sleep – "hardware sunpoint safemode" state – recently. A five-day recovery process was completed just in time to intercept the observing schedule for some GHRS observations of the flare star AD Leo coordinated with a variety of ground- and space-based observatories.

After an equivocal start, the pointing performance has been improved to a level where most target acquisitions are successful. The spacecraft motions induced by the solar arrays during terminator transitions mean that the "jitter" does not meet specifications although large parts of the orbit are extremely quiet (~ 5 milliarcseconds rms). Noisy periods, which would degrade certain observations, can be rendered benign

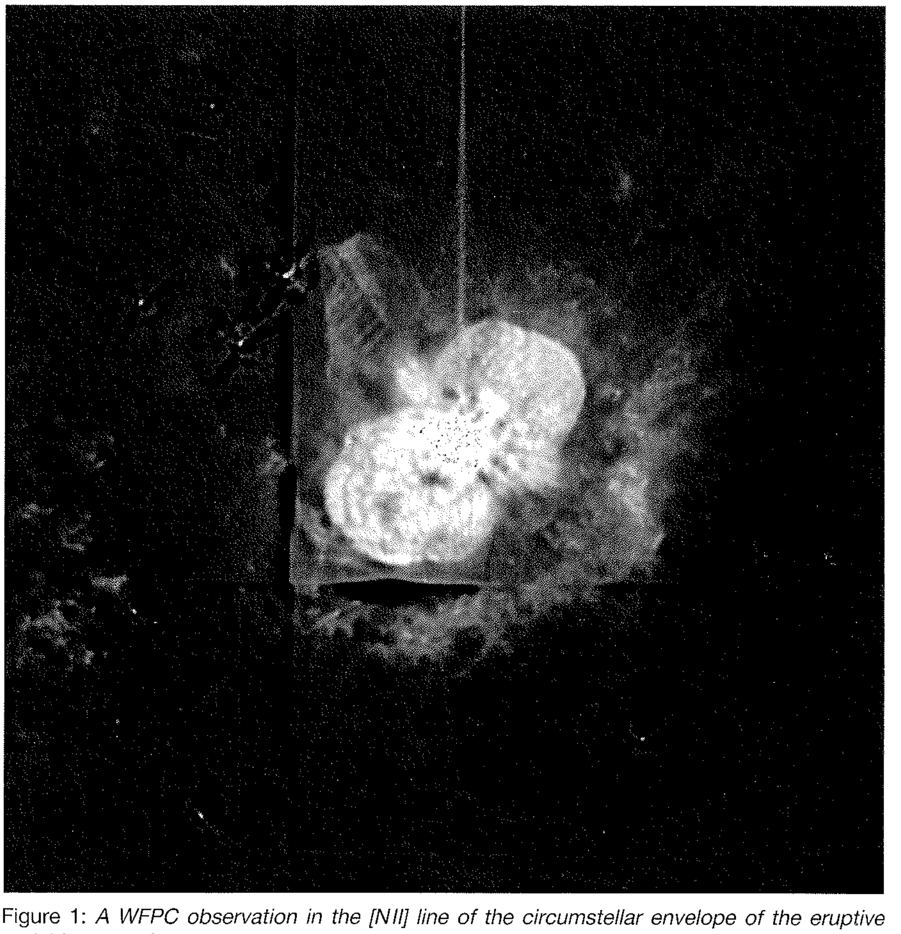

Figure 1: *A WFPC observation in the [NII] line of the circumstellar envelope of the eruptive variable star η Car. The restored image is a composite from four CCDs and shows structures down to 10 A.U. in size. (Credit: J. Hester/CalTech and NASA.)*