[6] E. Aubourg et al., in preparation.
[7] J. Berger et al., *Astron. Astrophys. Suppl. Ser.* **87** (1991) 389; J. Guibert and O. Moreau, *The Messenger* **64** (1991) 69.
[8] L. Vigroux et al., IAU *Working Group on Wide-Field Imaging Newsletter* **3** (Royal Observatory, Edinburgh, February 1993); L. Vigroux et al., *The Messenger* **71** (March 1993) 44.

First Optical Identification of an Extragalactic Pulsar

The recent identification of the optical image of a pulsar in the Large Magellanic Cloud is a fine illustration of astronomy as a high-tech international science. It is the first extragalactic pulsar to be so identified and only the third radio pulsar, after those in the Crab and Vela nebulae in the Milky Way, for which this has been possible.

The conclusive observations were made in early 1993 by astronomers from Ireland, Denmark and ESO[1] with TRIFFID[2], a new, powerful instrument of their own design, used together with the ESO MAMA[3] detector system and attached to the 3.5-metre New Technology Telescope (NTT) at the ESO La Silla observatory in Chile. Earlier observations by Italian astronomers with the same telescope were crucial for the success of this research project.

A Spinning Neutron Star in the Large Magellanic Cloud

The Large Magellanic Cloud (LMC), a satellite galaxy to the Milky Way galaxy in which we live, is one of the most studied objects in the sky. In addition to several millions of stars it also contains a great number of nebulae of gas and dust. Some of these have been found to be the remains of gigantic supernova explosions in the past when heavy stars in the LMC became unstable and blew up. The most recent happened as late as in February 1987, when Supernova 1987A became the first naked-eye supernova in 400 years.

One of these nebulae has a circular shape with a diameter of about 6 arcseconds; it is believed to be the remnants of the penultimate LMC supernova which exploded some 760 ± 50 years ago; this age is deduced from the expansion rate of the nebula. In 1984, a group of American astronomers studied the data from the Einstein X-ray satellite observatory and found that pulsed X-rays are emitted from the direction of this nebula. The measured pulsation frequency is unusually high and has now been refined to 19.838 Hz (pulses per second).

This is explained by the presence of a pulsar somewhere inside the nebula, that is an extremely compact neutron star which weighs as much as the Sun, but has a diameter of 10–15 kilometres only. It was created by enormous pressures during the supernova explosion. The observed pulses indicate that it is now spinning around its axis once every 0.05 seconds. The nebula in which it is imbedded contains the rest of the material that was thrown out during the explosion.

The new object received the designation PSR 0540-693 (the numbers indicate its approximate position in the sky). Because of its many similarities with the Crab pulsar and nebula, it has also been nicknamed the Crab Twin.

Due to the large distance to the LMC, of the order of 160,000 light-years, it has not been possible, until recently, to measure the very faint radio emission from this pulsar with southern radio telescopes. The X-ray observations only fix the pulsar position within a circle with a diameter of about 4 arcseconds (the "X-ray error circle"), and since detailed radio observations cannot be made of this faint radio source, it is impossible to determine the position of PSR 0540-693 with sufficient accuracy to permit identification of its optical image. Variations of the optical emission with the above X-ray frequency were measured in the mid-1980's from the general area of the nebula, but the image sharpness achievable with the astronomical telescopes available at the time did not allow the detection of a star-like object inside the relatively bright nebula.

Narrowing Down the Choice

This was the situation in early 1992 when a group of Italian astronomers[4] obtained images of the field around PSR 0540-693 with the ESO NTT.

Thanks to excellent weather conditions, the remarkable optical quality of the NTT and the fine performance of the ESO SUSI high-resolution CCD camera, they were able to record the most detailed images ever made of this region. Although the comparatively strong light from the nebula tends to "wash out" any details within its confines, they detected for the first time the presence of two star-like objects inside the nebula. Both were much fainter than the nebula itself; they are located in the south-west area of the nebula (near the edge of the X-ray error circle) and are separated by about 1.3 arcseconds. (See the photo on page 28).

Because all of the exposures necessarily lasted much longer than the 0.05 second pulse interval, these observations did not permit to decide if any of the two had a variable light intensity and might therefore be the pulsar. Still, when the Italian astronomers published their new results[5], they remarked that the northernmost of the two objects was more likely to be the pulsar; this image was somewhat more star-like (sharper) than the other one and a jet-like symmetrical structure appeared to be exactly centered on it.

[1] The group consists of Andy Shaerer, Mike Redfern and Peter O'Kane from the University College Galway (Ireland), Holger Pedersen from the Copenhagen University Observatory (Denmark) and Martin Cullum from ESO.

[2] TRIFFID = TRansputer Instrument For Fast Image Deconvolution. This image sharpening camera was built by the University College Galway in collaboration with the Dunsink Observatory of the Dublin Institute for Advanced Studies (DIAS). The construction of TRIFFID and the observational programme which lead to the identification of the pulsar were funded by EOLAS, the Irish Science & Technology Agency.

[3] MAMA = Multi-Anode Microchannel Array.

[4] This group consisted of Patrizia Caraveo, Giovanni Bignami, Sandro Mereghetti from the Istituto di Fisica Cosmica del CNR and Marco Mombelli from the Dipartimento di Fisica, Università degli Studi, Milan, Italy.

[5] In *The Messenger* (No. **68**, page 30; 1992) and the *Astrophysical Journal* (Vol. **395**, page L103; 1992).

New ESO Publications

SCIENTIFIC REPORT No. 12: "Second Catalogue of Stars Measured in the Long-Term Photometry of Variables Project (1986–1990).

OPERATING MANUAL No. 17: "Remote Control of the 3.5 m New Technology Telescope at the European Southern Observatory – User Guide."