An Optical Counterpart of SgrA* at the Galactic Centre?

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The nature of the very Galactic Centre is still mysterious: It could be a cluster of seemingly normal young luminous stars, or a somewhat massive black hole surrounded by an accretion disk (see Genzel and Townes, 1987, *Ann. Rev. Astron. Astrophys.* **25,** 377) – or even something more exotic. The characteristic feature of the innermost region is the coincidence within 2″ (i.e. 0.1 pc) of the unresolved nonthermal radio source Sgr A* with the peak of the diffuse infrared stellar light distribution. The fact that there is no discrete infrared counterpart to Sgr A* adds to the curiosity as to the relation of Sgr A* with the Galactic Nucleus. A detailed optical study of the region and the candidate sources is hindered by the enormous foreground extinction reaching 30 mag in the visual. However, by pushing as red as CCD's practically allow (i.e. near 1 μm), one can reduce the extinction to about 14 mag and at the same time increase the detectability for intrinsically blue sources – ultimately with the hope of detecting a "hot" counterpart for Sgr A*.

On July 24, 1990 we used the 3.5-m NTT telescope on La Silla to image the Galactic Centre region through a Gunn z filter (ESO # 417, cut on 920 nm, long pass) using EFOSC 2 with a Thomson chip, 1024 by 1024 pixels, image scale 0.3 arcsec/pixel, and a sensitivity of 6% at 950 nm. The total response produces a bandpass of 100 nm centred at 950 nm with a peak throughput of 3.3%. However, since the bandpass is nominally open in the red, albeit with very low throughput, the effective wavelength may be shifted towards or even beyond 1 μm. This is because the high absolute values of the extinction encountered towards the Galactic Centre (A_V up to 30 mag) imply very high differential reddening effects, which may easily overwhelm the decrease in the CCD response.

The seeing was mediocre but, more importantly, very stable (1″.05 FWHM). With this seeing we oversampled the PSF by a factor of 3. We obtained five frames with an exposure time of 40 min each and random 10–20% field centre offsets, plus dome and sky flat fields. Careful alignment including a resampling by another factor 4, and rejection of detector defects and cosmics, gave us a coadded 200 min effective exposure. A 10″ by 12″ window from the summed frame is shown in Figure 1. The two brightest sources are IRR1 and IRR2 of 17.6 mag at 980 nm (Henry et al., 1984, *Ap. J.* **285,** L27). The limiting magnitude of the image is 24 mag at 950 nm (sky level 25000 e^- per original pixel; 125000 e^- for IRR1 and IRR2). This is the deepest sub-1 μm) CCD image ever obtained of the Galactic Centre region.

Given the high signal-to-noise ratio, we were able to apply image deconvolution techniques on far-red images of the Galactic Centre region for the first time. We used the Lucy algorithm of iterative deconvolution (Lucy, 1974, *A.J.* **79,** 745), implemented into the IDL environment by H.-M. Adorf (ST-ECF). The largest field size treated was 512 by 512 image elements, corresponding to 36″ by 36″. The gain in resolution obtained after 50 iterations was a factor 2.5 (i.e. 0″.4 FWHM for point sources). During deconvolution, the image of the star IRR2 (the upper left one of the two bright objects in Fig. 1) remained very circular and unresolved, while IRR1 (the bright star in the centre) became elongated from SE to NW. A slight indication of this can also be seen in the original. Figure 2 shows the sharpened frame, modified by subtraction of a scaled unresolved stellar image from the centre of gravity position of IRR1.

To our surprise, two faint sources (20-21 mag) were hidden behind the seeing disk of IRR1. We designated the slightly fainter SE object GZ-A and the brighter NW component GZ-B. It is remarkable that GZ-A and GZ-B coincide with the position of Sgr A* (indicated by the white cross in Fig. 2) to within 0″.3 and 0″.5, respectively. Transformation of the absolute radio position of Sgr A* onto our frame (with an r.m.s. error of 0″.5) was achieved through the 950 nm counterparts of a dozen previously known 2-μm sources, most of which have been detected here for the first time. Among these are IRS7 (the object due north of Sgr A* near the upper boundary of Fig. 2) with a total of 2000 e^- recorded,

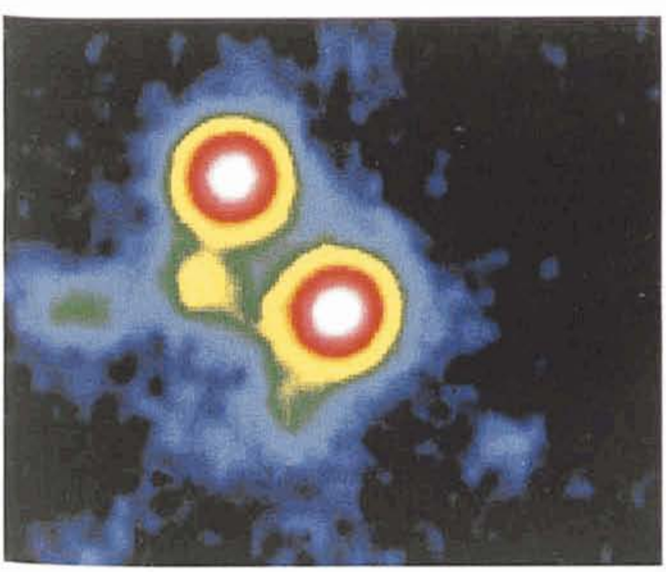

Figure 1.

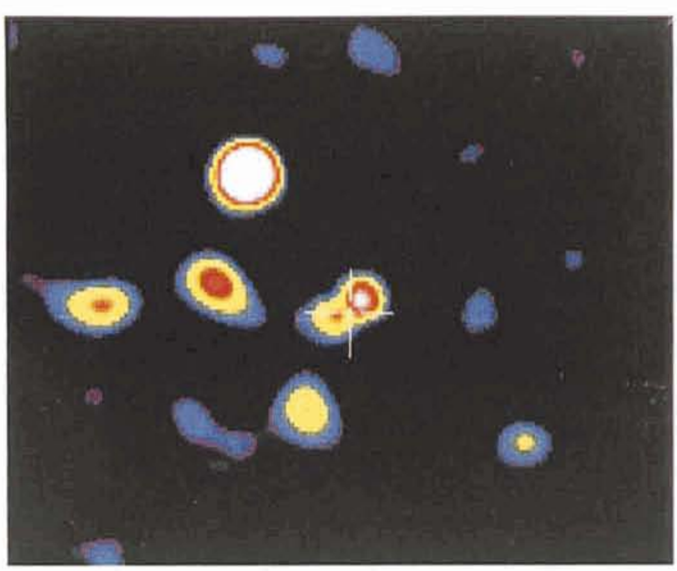

Figure 2.

as well as IRS9, IRS13, IRS21, IRS29, IRS35 (cf. Tollestrup et al., 1989, *A.J.* **98,** 204). GZ-B may be identical with IRS16NW, while GZ-A seems to have no prominent 2-μm counterpart.

Because of the near coincidence of GZ-A and GZ-B with Sgr A*, it may well be that the two sources are indeed in the Galactic Centre. If this is the case, the observed magnitudes could be consistent with either a group of young stars or the optical radiation from an accretion disk around a black hole. The estimated luminosity in both cases would be of order $5 \cdot 10^6 L_\odot$ A nonthermal origin of the radiation, in particular for GZ-A, cannot be excluded either. Also the possibility of chance alignment with faint foreground objects or a physical companion of IRR1 cannot be rejected at present. Clearly, these new objects are interesting enough to deserve further detailed observations: high angular resolution imaging at different wavelengths, spectroscopy and perhaps even polarimetry.

PROFILE OF A KEY PROGRAMME

Optical Identification Content of the ROSAT All Sky Survey

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On June 1, 1990 the X-ray satellite ROSAT was launched from Cape Canaveral on a Delta II rocket (Fig. 1). The project is a collaboration between Germany, the United States and the United Kingdom with the Max Planck Institute for Extraterrestrial Physics (MPE) as the leading scientific institution. During the first 6 months of the mission, ROSAT is performing the *first all-sky survey* made with an imaging X-ray telescope. The data rights for this survey lie with MPE.

Among the instruments on board ROSAT (Fig. 2) is the Positional Sensitive Proportional Counter (PSPC) which will be used for the all-sky survey. This imaging detector has a low resolution ($\Delta E/E = 0.4$) spectral capability over the soft X-ray energy range from 01.–2 keV. This energy range is considerably softer than that of the Einstein Observatory, so that one might confidently expect different proportions of different known classes of X-ray sources to be detected and, of course, even new classes of objects.

On the basis of the Einstein Observatory Extended Medium Sensitivity Survey (EMSS) one would expect to detect ≈ 100,000 X-ray sources over the whole sky. This will enable the acquisition of X-ray data for large samples of various classes of astronomical objects, in particular stars, AGN and clusters of galaxies. Obviously, one cannot hope in the foreseeable future to optically identify 100,000 sources. Our proposal aims at defining and observing a viable sub-sample of the ROSAT survey in order to completely identify the X-ray sources in that sample.

During the all-sky survey, ROSAT will scan along great circles of constant ecliptic longitude roughly perpendicular to the position of the sun. As the sun moves along the ecliptic, the scan path of the satellite follows and after a period of 6 months the whole sky will be covered. The exposure time varies from ≈ 600 seconds near the ecliptic to 30,000 seconds near the ecliptic poles. Other effects mainly involving background radiation and hydrogen column density will modify this sensitivity for detecting sources in a predictable manner. Figure 3 shows a small part of the survey, a strip of $\approx 6^\circ \times 13^\circ$ centred at $\alpha = 5^h30^m$, $\delta = -57^\circ$, accumulated from five days of data from August 9 to August 14. The area shown consists of 26 square degrees on the sky and therefore represents ¼ of the ESO Key Project Field II. The bright source in the lower right hand corner is LMC X-3. So far 34 sources have been detected in this section of the all-sky survey. For weak sources (< 20 counts) a 90% confidence error radius < 1 arcmin is expected, while for strong sources this radius would be 30–40 arcsec.

The average X-ray flux limit of the ROSAT survey will be roughly 3×10^{-13} erg/cm^{2}s.The results of the identification process will provide the basis for statistical studies of the X-ray properties of stars, quasars, AGN, BL Lac objects and clusters of galaxies. In particular, log N-logS and X-ray luminosity functions will be determined. This unbiased sample will also serve to calibrate all other samples selected from the all-sky survey. The existence of the Parkes and Australia Telescope radio surveys will permit correlations with radio properties.

Our sub-sample covers an area of 575 square degrees divided into 4 regions from which, on the basis of the EMSS at high galactic latitudes, we would expect to detect ≈ 380 extragalactic objects and ≈ 610 stellar objects in our Galaxy. With 380 objects, we will have the basis for statistical studies of the proportions of quasars, AGN, BL Lac objects and clusters of galaxies. Since the areas have been defined partly because of optical work planned or in progress by others (e.g. objective prism surveys, multi-colour surveys at low N_H column density, and other multi-colour surveys) there is also the possibility of comparing samples made using completely different criteria. For example, the proportion of X-ray quiet to X-ray loud AGN is of some interest both from the point of view of physical properties of AGN themselves and from the point of view of cosmology. Another important and topical question is that of the large scale structure and distribution of extragalactic sources. Equally important will be the follow-up programme of individual objects that emerge as a result of the particular energy range of this survey.

Among the stars, again using the EMSS as a guide, we might expect the