NGC 2261 are considered to be due to the movement of obscuring clouds in the near vicinity of the embedded stellar source which modulate the illumination escaping in the direction of NGC 2261 ("shadowplay" – Lightfoot, 1989).

The most prominent features on the HST images are the lack of a resolved stellar source to R Mon and the two spikes emanating from it. The eastern spike is present at all wavelengths in the images presented here from V to K band. It is clearly a dust feature or a tunnel of lower obscuration from R Mon into the nebula. The polarisation behaviour of these two spikes could prove useful in studying their origin. The NE spike, extended both in length and width, shows higher linear polarisation (25% at V integrated over its area) with a trend to increased polarisation outwards from R Mon. The NW spike, has lower polarisation (12% at V, and fairly constant along its length), is narrow (0.3″) and not visible in the H and K ADONIS images; Figs. 4, 5). The polarisation position angles of both features are quite consistent with illumination by R Mon. An interpretation of the lower polarisation (of the NW knot) could be in terms of the (single) scattering angle of the radiation from R Mon, reflected off the dust features towards the observer. The NE spike then is more tilted away from the observer than the NW spike. The features could be either 'tubes' relatively free of dust within the extended dust disk about R Mon or individual clumps. An extended cloud would reflect light at different angles giving rise to differing polarisation along its length whilst a radial feature should produce similar polarisation along its whole length (assuming single Mie scattering). However, Scarrott et al. (1989) have studied the polarisation behaviour of the disk around R Mon and suggest that scattering of polarised light and perhaps magnetically aligned grains may play a role. Detailed modelling is required to resolve these differing interpretations but the long wavelength coverage and comparable high resolution (0.2″) polarimetry offered by HST and ADONIS bring critical data to this problem.

Polarisation mapping has been applied to a great variety of astronomical sources: reflection nebulae around young stars, AGB stars, proto-planetary and planetary nebulae; to galactic scale extended emission-line regions in radio galaxies and normal and dusty galaxies; synchrotron sources in supernova remnants and quasars and AGN. Most studies have been at modest spatial resolution dictated by ground-based seeing. However, the application of adaptive optics to polarimetry brings a powerful tool to study the nearby regions of dusty sources enabling the study of dust structures around AGN, non-axially symmetric outflows near AGB stars and dust disks around young stars for example. NICMOS will also enable high-resolution polarimetry to be achieved in J and H bands. HST with WFPC2 allows high-resolution optical imaging in the optical and with the Advanced Camera for Surveys (ACS, see http://jhufos.phajhu.edu/ for details) installed into HST in 1999, even higher resolution polarimetry over a longer wavelength range (2500 to 8200 Å) will be achievable. Polarimetry brings critical data related to orientation that cannot be gained in other ways, and is therefore an important tool for deeper understanding of structures surrounded by dust.

5. Acknowledgements

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Proper Motion as a Tool to Identify the Optical Counterparts of Pulsars: the Case of PSR0656+14

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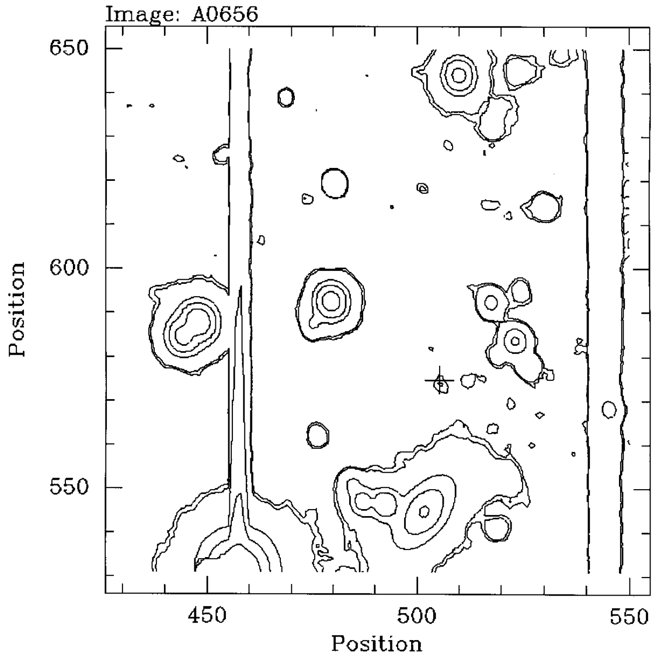
1. Introduction

Up to now, about 1% of Isolated Neutron Stars (INS) have been observed in the optical domain (Caraveo, 1996). From an observational point of view, INSs are challenging targets owing to their intrinsic faintness. Young ($\tau \lesssim 10^4$ yrs) pulsars like the Crab, PSR 0540-69 and Vela are relatively bright, powered by magnetospheric processes, and easily identified through the detection of optical pulsations. However, such magnetospheric emission fades away rapidly in the optical domain, giving way to the star's surface thermal emission. It is the case of the so-called "Middle-Aged" ($\tau \sim 10^5$ yrs) Isolated Neutron Stars (MINSs) that, with a temperature T $\approx 10^5$–10^6 K, can be detected at optical wavelengths as thermal emitters. However, since neutron stars are extremely compact objects (10 km in radius), the optical luminosity of MINSs turns out to be very faint, preventing the timing of their optical emission.

Thus, for MINSs the optical identification generally relies on the positional coincidence with a candidate as well as on its peculiar colours. This is how the candidate counterparts of Geminga (Bignami et al, 1987), PSR 1509-58 (Caraveo et al., 1994b), PSR 0656 +14 (Caraveo et al., 1994a) and PSR 1055-52 (Mignani et al., 1997a; Mignani et al., 1997b) were singled out. However, for some of the closer objects (d ≤ 500 pc) other, independent, pieces of evidence can be collected.

Isolated Neutron Stars are known to be high-velocity objects (Lyne and Lorimer, 1994; Caraveo, 1993), moving in the sky with transverse velocities $v_T \sim$ 100–400 km/s. A tentative optical identification can thus be confirmed, or, at least made much more compelling, by measuring the proper motion, if any, of the optical counterpart. Indeed, this is how the optical identification of Geminga was confirmed by Bignami et al. (1993). In the case of a radio pulsar, with known



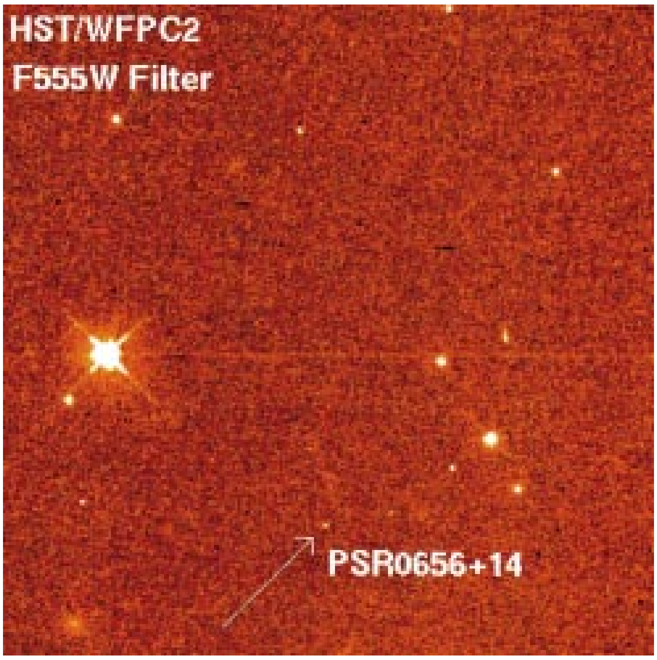


Figure 1: (a) Image of the field of PSR 0656 +14 taken in 1991 with the NTT/EMMI (from Caraveo et al., 1994a); the proposed optical counterpart is marked by a cross. (b) Image of the same region, taken in January 1996 with the WFPC2 onboard HST. The proposed optical counterpart of the pulsar is indicated by an arrow. The image size is about 35 × 35 arcsec.

proper motion, this would indeed secure the optical identification with a degree of confidence comparable to that obtained through detection of pulsed emission.

This strategy gains much more power when exploiting the high precision positioning of the target, presently achievable with the imaging facilities onboard HST and, in the near future, with the VLT.

2. PSR 0656 +14: A Middle-Aged Neutron Star

PSR 0656 +14 is one of the INSs still waiting for a confirmation of the optical identification. It is a "Middle-Aged" ($\tau \sim 10^5$ yrs) radio (P = 385 ms) as well as a soft X-ray pulsar (Finley et al., 1992) with a thermal spectrum consistent with the surface temperature ($T \leq 8 \times 10^5$ K) expected on the basis of its age (Becker, 1996). Recently, PSR 0656 +14 has been tentatively observed as γ-ray pulsars by EGRET (Ramanamurthy et al., 1996). It is thus, with PSR1055-52, a pulsar of the "Geminga class" (Mignani et al., 1997a). PSR 0656 +14 is also characterised by a ~ 70 mas/yr proper motion (Thompson and Cordova, 1994) towards SE (position angle ~ 114°), corresponding to a transverse velocity $V_T \sim 250$ km/s at the assumed radio distance (760 pc).

Images of the field were obtained at ESO in 1989 and 1991 and a probable optical identification of PSR 0656 +14 was proposed by Caraveo et al. (1994a). A faint ($m_V \sim 25$) point source was detected in both observations, coincident, within a few tenths of arcsec, with the pulsar's radio co-ordinates (see Fig. 1a). This object was later tentatively associated by Pavlov et al. (1996) with a point source detected with the HST/FOC. However, the data presently available do not provide a firm optical identification of PSR 0656 +14. Since the object's faintness renders extremely difficult the search for optical pulsations, the optical identification must rely on the *a priori* knowledge of the pulsar's proper motion. We, thus, needed a new, high-resolution image, containing enough reference stars to allow very accurate relative astrometry to unveil, if at all present, its expected angular displacement (~ 0.5 arcsec in 7 years). As shown for the measure of Geminga's parallax (Caraveo et al., 1996) the WFPC2, operated in the PC mode, is presently the ideal instrument to measure tiny angular displacements since it offers a high angular resolution (0.0455″/px) coupled with a 35 × 35 arcsec field of view.

3. The Observations

As a starting point to measure the object's proper motion, we used our 1989 and 1991 ESO images, dating back sufficiently to provide the required time baseline. The observations were performed with the 3.6-m and with the NTT, respectively, using EFOSC2 and EMMI (see Table 1 for details). These images also provided a useful reference to plan the upcoming HST observations.

The target was observed in January 1996 with the PC, equipped with the wide band F555W filter (λ = 5252 Å; Δλ = 1222.5 Å) i.e. the one closer to the Johnson's V which was used to obtain our 1989/1991 images. The final image (Fig. 1b) clearly confirms the previous 3.6-m/NTT detection of Caraveo et al. (1994a). The object magnitude was computed to be 25.1 ± 0.1, consistent with our previous ground-based measurements, but with a considerably smaller error. We then computed the centroids for our target and for the reference stars in the field, fitting their profiles with a 3-D gaussian using different centring areas. This procedure yielded the stars' relative co-ordinates with a precision of a few hundredths of a PC pixel (0.0455 arcsec). We have then compared the present position of PSR 0656 +14 with the ones corresponding to our ESO 1989 and 1991 observations rebinned and tilted to match the PC reference frame. While

TABLE 1: Ground-based plus HST observations of PSR 0656 +14 used for the measure of the proper motion.

Date	Telescope	Filter	Pixel size	Seeing	Exposure time
1989.01	3.6-m/EFOSC2	V	0.675″	1.5″	60 min
1991.01	NTT/EMMI-RED	V	0.44″	1.0″	70 min
1996.01	HST/WFPC	F555W	0.0455″	—	103 min

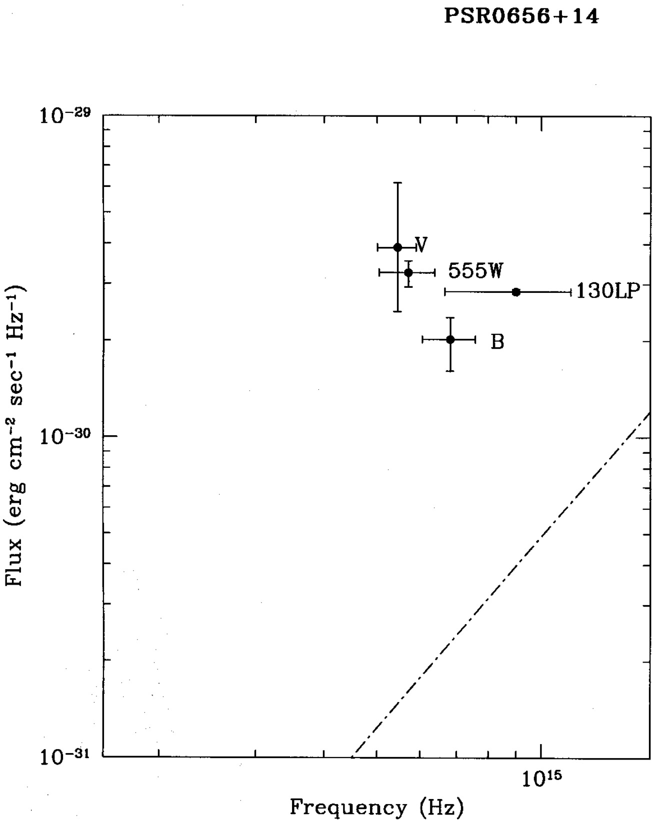


Figure 2: Colours of PSR 0656 +14 compared with the Rayleigh-Jeans extrapolation of the soft X-ray spectrum ($T \sim 8 \cdot 10^5$ K) as observed by the ROSAT/PSPC (Finley et al., 1992). The optical/UV fluxes have been corrected for the interstellar extinction using the N_H best fitting the ROSAT data ($N_H \sim 10^{20}$ cm^{-2}) and correspond to the original detection in the V band (Caraveo et al, 1994a), to the HST observation in the 555W filter (see text), to the FOC observation of Pavlov et al. (1996) in the 130LP filter and to the B photometry of Shrearer et al. (1996). The points are at least 2 magnitudes above the expectations.

the position of the reference stars does not change noticeably, a trend is recognisable for the proposed candidate.

Unfortunately, the factor of ten difference in the pixel size between the ESO images and the PC one translates into a large error of the object relative position as computed in the 1989 and 1991 frames, thus making it difficult to reliably compute its displacement. After fitting the object positions at different epochs, we obtain a value $\mu = 0.107 \pm 0.044$ arcsec/yr with a corresponding position angle of 112° ± 9° to be compared with the radio values obtained by Thompson and Cordova (1994). Although not statistically compelling, a hint of proper motion is certainly present in our data.

4. Conclusions

Proper motion appears to be a powerful tool to secure optical identifications of candidate counterparts of INSs, as successfully shown for Geminga (Bignami et al., 1993). Its application is straightforward, just relying on deep, high-quality imaging.

Following this strategy, we have used our ESO 3.6-m/NTT images plus a more recent HST/PC one, to measure the proper motion of the candidate counterpart of PSR 0656 +14. Although promising, this case is not settled yet. The significant uncertainty makes the present result tantalising but certainly far from being conclusive. Of course, new high-resolution observations, could easily say the final word. Again, these could be obtained with the PC or, from the ground, using the VLT.

A firm optical identification of PSR 0656 +14 would be important to establish its emission mechanism in the optical domain and, thus, to complete the multiwavelength phenomenology of this source. The multicolour data presently available (Pavlov et al., 1996; Mignani et al., 1997a), are not easily compatible with the Rayleigh-Jeans extrapolation of the soft X-ray Planckian, even considering the spectral distortion induced by an atmosphere around the neutron star (Meyer et al., 1994). New, as yet unpublished FOC observations in the B/UV (Pavlov, 1996, private communication) seem to confirm this finding which appears to be further substantiated by the possible detection of optical pulsations (Shrearer et al., 1996), accounting for almost 100% of the flux in the B band (B ~ 25.9) More colours of the counterpart are needed to understand the optical behaviour of the source. Now that the FOC has explored the B side of the spectrum, it is mandatory to concentrate on the Red part seeking for an R or I detection. NTT time has been granted for this project and the observations are currently underway.

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On the Nature of the High-Redshift Universe

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One of the most debated arguments of recent astronomy is the understanding of the physical conditions of the Intergalactic Medium (IGM) at high redshift since it represents a unique probe of the young Universe. The state of the diffuse matter, the formation and distribution of the first collapsed objects, their nature and evolution with redshift are all open questions strongly related to the origin of the Universe. The most distant and powerful sources, the quasars, offer the opportunity to explore this side of the Universe.

The optical part of high redshift quasar spectra ($z > 2$) manifests the presence of a high number of Lyα absorption lines due to neutral hydrogen. For very