Near-Infrared Study of the Pulsar Wind Nebula in G21.5-0.9

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1. INTRODUCTION

G21.5-0.9 is a composite-type supernova remnant. Its complex structure is well visible in the X-ray image taken with the Chandra observatory (Fig. 1) where not only the pulsar wind nebula is present but also the non-thermal halo that surrounds it. To the north of the PWN the "North Spur" is situated, while in the middle of the PWN the compact nebula can be found (Slane et al. 2000). This amazing structure changes when looking at the object in different energy bands; in the radio domain only the PWN is detected (e.g. Bietenholz & Bartel 2007). In the highest energies, where the H.E.S.S. telescope operates, G21.5-0.9 is seen as a point source (Djannati-Atai et al. 2007). Recently, a pulsar J1833-1034 inside the compact core of G21.5-0.9 has been discovered with radio telescopes (Gupta et al. 2005; Camilo et al. 2006), soon followed by its detection in the γ-rays by the Fermi space telescope (Caliandro 2009).

This PWN is heavily obscured in the optical band where the interstellar extinction is estimated to $A_V=10$ (Gorenstein 1975), based on the measured X-ray absorption column ($N_H=2.24\times10^{22}$ cm^{-2}; Slane et al. 2000). Observations of such object in the near-infrared band where the extinction is as small as $A_{1.6\mu m}=2$ give the possibility to detect line emission from shocked supernova ejecta and filaments in the nebula. Its intrinsic polarisation can also be used to observe the synchrotron emission originating from relativistic particles propagating in the magnetic field of the nebula.

Here we present the preliminary results of the NIR observations of G21.5-0.9 performed with ISAAC camera at the VLT. Data reduction and analysis was performed using the IDL Astronomy Library and the IRAF software.

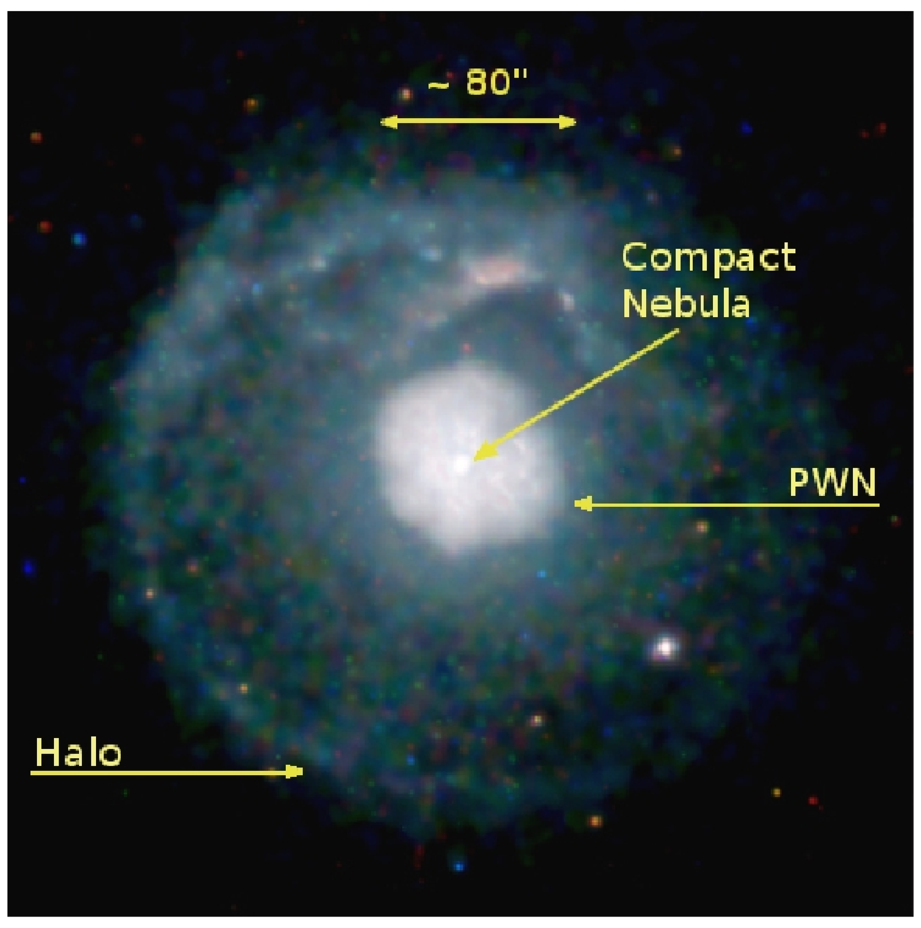

Fig. 1. The Chandra X-ray image of SNR G21.5-0.9 (adapted from Matheson & Safi-Harb 2005). In the centre the bright PWN is visible. It is surrounded by the limb-brightened halo. To the north of the PWN bright emission blob is present – it is called the North Spur. In the middle of the PWN the compact nebula is detected.

2. NARROW-BAND IMAGING

The imaging was performed in the [FeII] 1.64μm line filter and also in the 1.71μm continuum filter. The 1.71μm was taken in order to subtract the stars from the [FeII] image and thus to minimise their influence on the faint extended emission expected from G21.5-0.9 in the [FeII] line (Fig. 2, left panel).

In the [FeII] image after the subtraction of the continuum an extended limb-brightened emission becomes apparent. Its size and orientation corresponds well with the size of the PWN seen in the X-rays and in the radio (Fig. 2, right panel). The most probable interpretation of the emission seen in the [FeII] line is that it originates from the ejecta thrown into space during supernova explosion that are being shocked by the PWN front shock propagating in the surrounding medium. In order to further study the dynamics and the composition of the ejecta and also to learn the evolutionary stage of the PWN a follow-up NIR spectroscopic observations are being taken with the TNG telescope on La Palma.

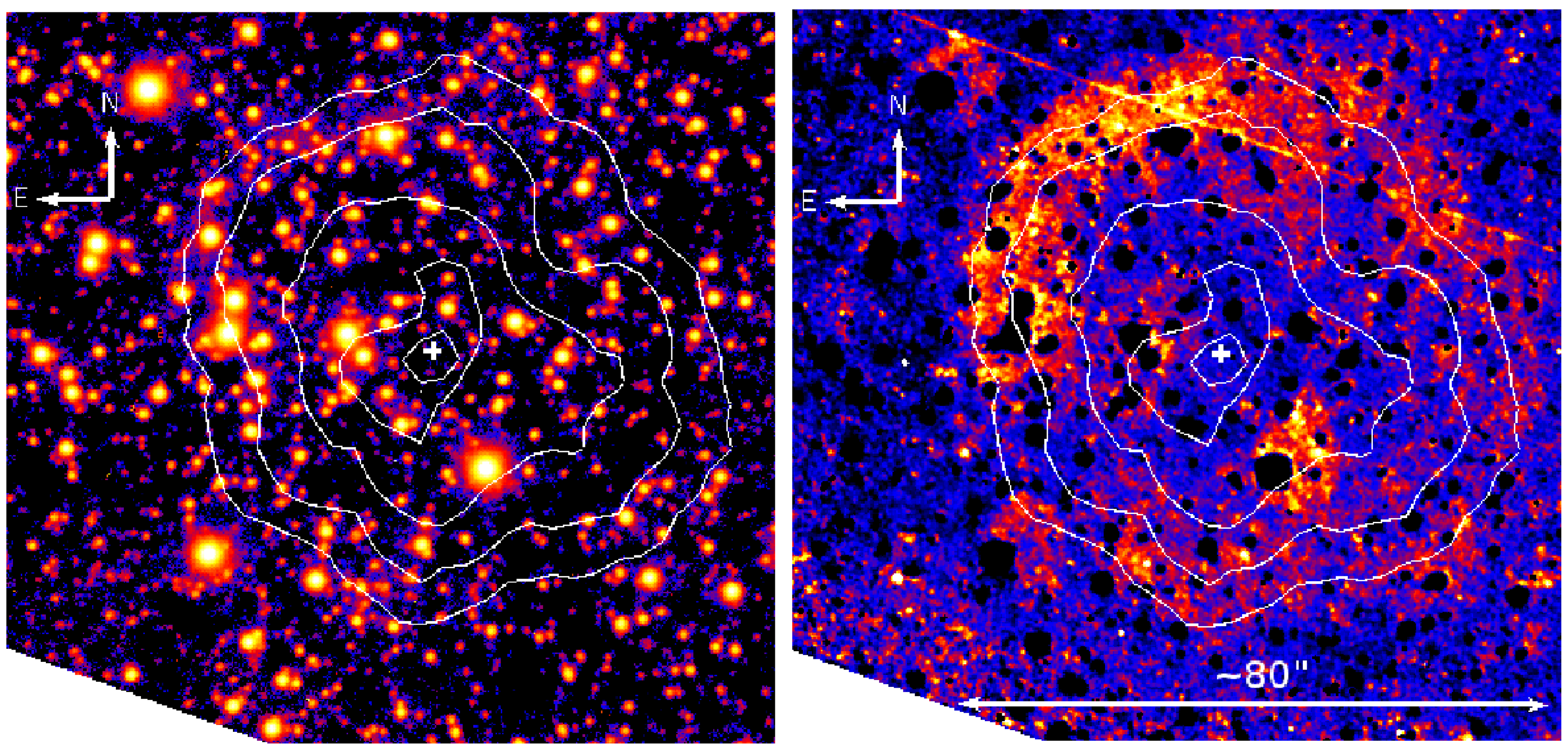

Fig. 2. *Left panel:* sky image in the [FeII] 1.64μm line. The ACIS/Chandra contours are superimposed on it. The cross marks the position of the pulsar. *Right panel:* image of the same field of view as in the left panel. The image presented here is the [FeII] image after the subtraction of the image taken in 1.71μm continuum filter. Clearly visible is the extended limb-brightened line emission that is coincident with the PWN seen in the X-rays (contours: ACIS/Chandra). The cross marks the position of the pulsar.

3. POLARIMETRY

Polarimetry was carried out in the K band (2.2μm). The Stokes parameters needed for the determination of the linear polarization were measured. Moreover, in order to cross-check the polarimetry of G21.5-0.9 and to ascertain the level of instrumental polarization polarized standard stars were observed and analysed.

The map of polarization degree covering the central part of the PWN is presented in the left panel of Fig. 3. Only small blob of polarized emission is visible. Its size and position correspond well with the position of the compact nebula detected in the X-rays by Chandra. The measurements of polarization degree and polarization position angle are strongly affected by stars. Thus, the linear polarization vectors were calculated only for the emission where there was no star contamination or the contamination was small (Fig. 3, right panel). The orientation and the magnitude of these vectors across the emission blob suggest that the polarized emission originates in the pulsar wind termination region which has the shape of a torus where the regular toroidal magnetic field is present. Such picture supports the results of modelling of such a torus in G21.5-0.9 carried out by Ng&Romani (2008).

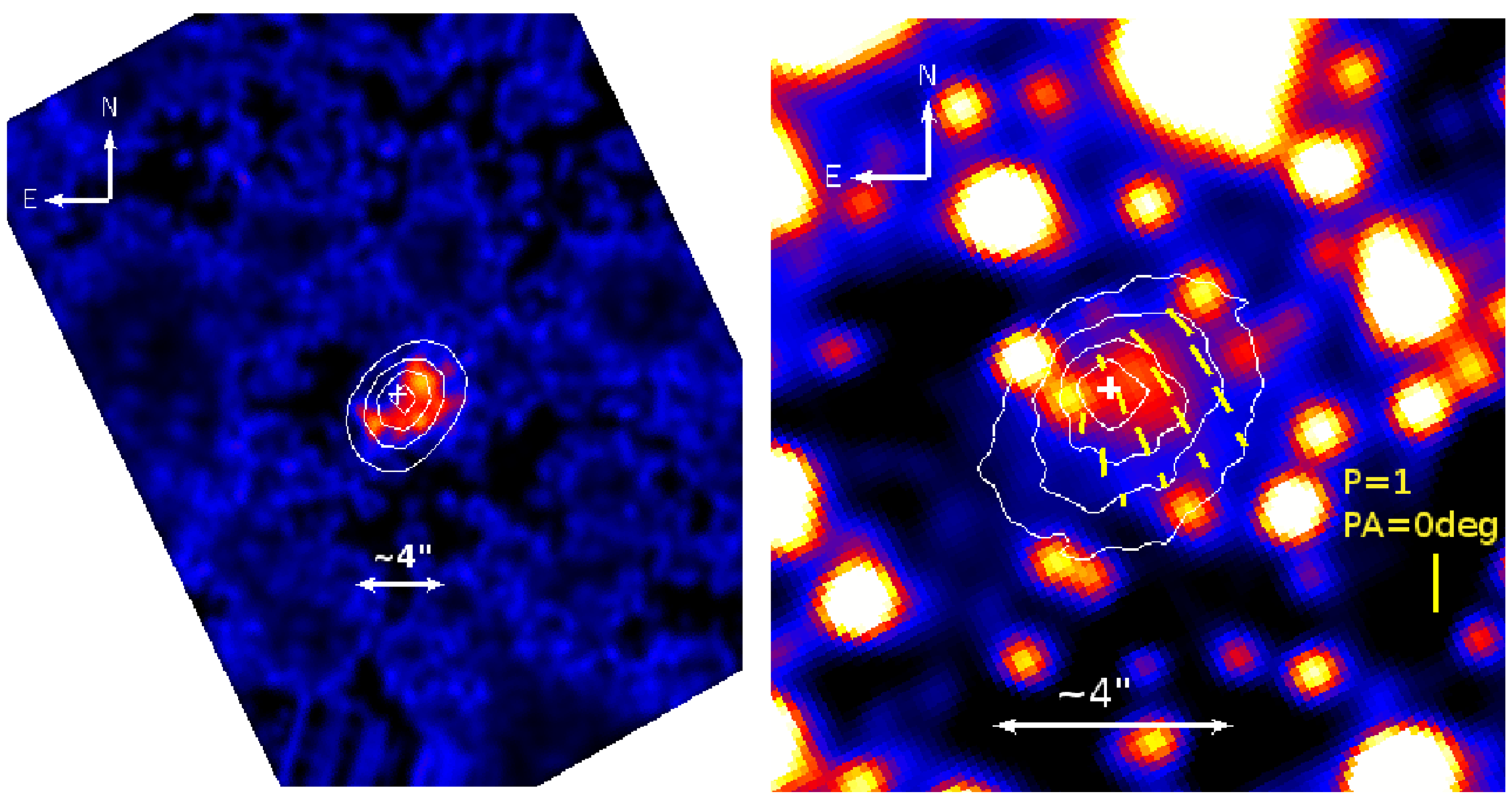

Fig. 3. *Left panel:* map of linear polarization fraction. In the middle the blob of highly linearly polarized light is visible. The emission is coincident with the compact core of the PWN seen in the X-rays by ACIS/Chandra (depicted with white contours). The cross marks the position of the pulsar J1833-1034. *Right panel:* total intensity image zoomed on the emission blob. Yellow lines represent the linear polarization vectors with their length proportional to the polarization degree (see description in the image). Contours represent the compact core of the PWN seen by HRC/Chandra; the cross marks the PSR position.

4. SUMMARY

The ejecta compressed by the PWN front shock are detected in the [FeII] line emission. The polarimetry of G21.5-0.9 yields information on the magnetic field structure in the pulsar wind termination region. The NIR observations of PWNe that are heavily obscured in the optical may bring valuable information on the structure, dynamics and evolution of these objects.

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