A Deep Optical Study of the Supernova Remnant G 166.0+4.3 (VRO)

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Abstract

We present the first CCD images of the VRO 42.05.01 (G 166.0+4.3) supernova remnant in Hα+[N II], [O III] 5007 and [S II] at a moderate angular resolution. Low and high-dispersion spectroscopy was also performed at selected areas around this extended remnant. Diagnostic diagrams of the line intensities from the present spectra and the new kinematical observations both confirm the supernova origin. Taking into account our results (i.e. shock velocities, morphological characteristics etc.) together with observations of other wavelengths (i.e. radio), we provide significant information on the interaction between this SNR and the surrounding Interstellar medium (ISM).

Introduction

VRO 42.05.01 is a known SNR (van den Bergh 1960; Fesen et al. 1983, 1985) but because of its large size, it was never studied in detail. It is classified as a shell-type SNR, with a spectral index of ~0.37 (Green 2014). Its angular size is 55'x35' and using HI measurements the distance of the remnant was calculated at 4.5 kpc (Landecker et al. 1989). Our group performed many imaging and spectroscopic observations in order to study this SNR in detail in high angular resolution (see for similar work Boumis et al. 2005, 2008, 2009, Alikakos et al. 2012).

Observations & First Results

Imaging: Wide field: VRO was observed with the 0.3m telescope at Skinakas Obs., Greece in 2001, 2005, using the Hα+[N II], [S II]] and [O III] filters (E.T.=2400s). **High resolution:** The 2.3m Aristarchos telescope at Helmos Obs., Greece was use in 2011, 2015, with the Hα+[N II], and [O III] filters (E.T.=1800s). **Spectroscopy: Low resolution:** The 1.3 m telescope at Skinakas Obs. was used to obtain long-slit spectra (E.T.=3600s) in 2009, 2010. The data were taken with 1300 lines/mm grating covering the range 4750Å - 6815Å. The slit width was 7.7" and its length 7.9'. **High resolution:** The 2.1m telescope at San Pedro Martir (SPM) Obs. (Mexico) was used to obtain echelle spectra i(E.T.=1800s) in 2010, 2011 with the MES-SPM spectrometer, using a slit 300μm wide (=3.9" and 20 km/s).

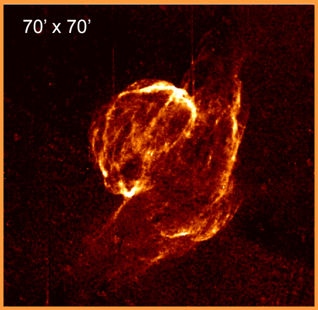


Fig. 1: The Hα+[N II] image of VRO.

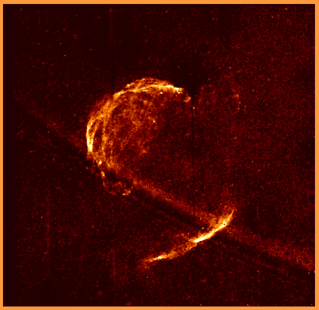


Fig. 2: The [O III] image of VRO.

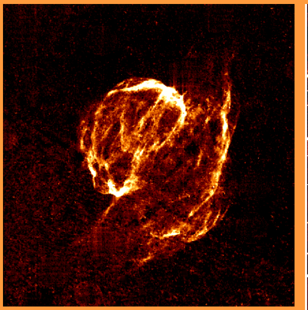
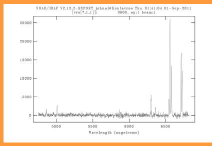


Fig. 3: The [S II] image of VRO.



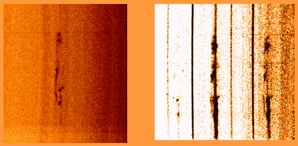


Fig. 5 (left): Typical low-res spectrum.

Fig. 6 (middle/right): [O III] and Hα+ [N II] high-res spectra at the same position, where the velocity features can be clearly seen.

The low ionization images generally show strong filamentary structures, which are very well correlated with the radio emission and they are the remnant's outer edge. Strong filamentary emission has also been discovered in the medium ionization [O III] line. Both the calibrated images and the long-slit spectra suggest that the detected emission results from shock heated gas since the [S II]/Hα ratio exceeds the empirical SNR criterion value of 0.4. The morphological differences between the low and medium ionization lines provide evidence for significant inhomogeneities and density variations in the ambient medium. We have also determined the electron density to be below 240 cm^{-3}, by measuring the density sensitive line ratio of [S II] λλ6717/6731. The strong [O III] emission detected suggests shock velocities greater than 100 km/s (Cox & Raymond 1985) which was also found in the high resolution spectra.The remnant under investigation has not been studied in detail in the optical band (only the work of Fesen et al. 1983; 1985 presented images and spectra of selected areas), therefore, the current stage of its evolution is still unknown. In a forthcoming paper for VRO (Boumis et al. 2016, in preparation), imaging, low resolution and kinematical data will be presented for a first time, as well as diagnostics diagrams of the line intensities, which allow us to provide more information about its morphology and dynamics. Finally, the multiwavelength correlation will also be discussed and will give us a better indication about its evolutionary stage and its interaction with the ISM.

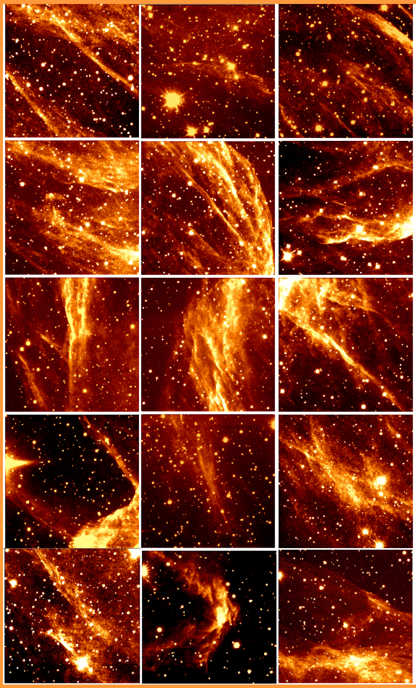


Fig. 4: High-resolution Hα+[N II] images (5'x5') obtained with the 2.3m Aristarchos telescope in selected areas, where low and high resolution spectra were taken.

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