Optical study of the peculiar Supernova Remnant VRO 42.05.01 (G 166.0+4.3)

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Abstract

We present optical 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 and high-resolution imaging were 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 and modeling, we provide new significant information on (a) it's formation and evolutionary history, (b) the interaction between the SNR and the surrounding medium.

Observations

Imaging

- Wide field: VRO was observed with the 0.3m telescope at Skinakas Obs., Greece, 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 used with the Hα+[N II], and [O III] filters (E.T.=1800s).

[Imaging observing runs in: 2001, 2005, 2014, 2017]

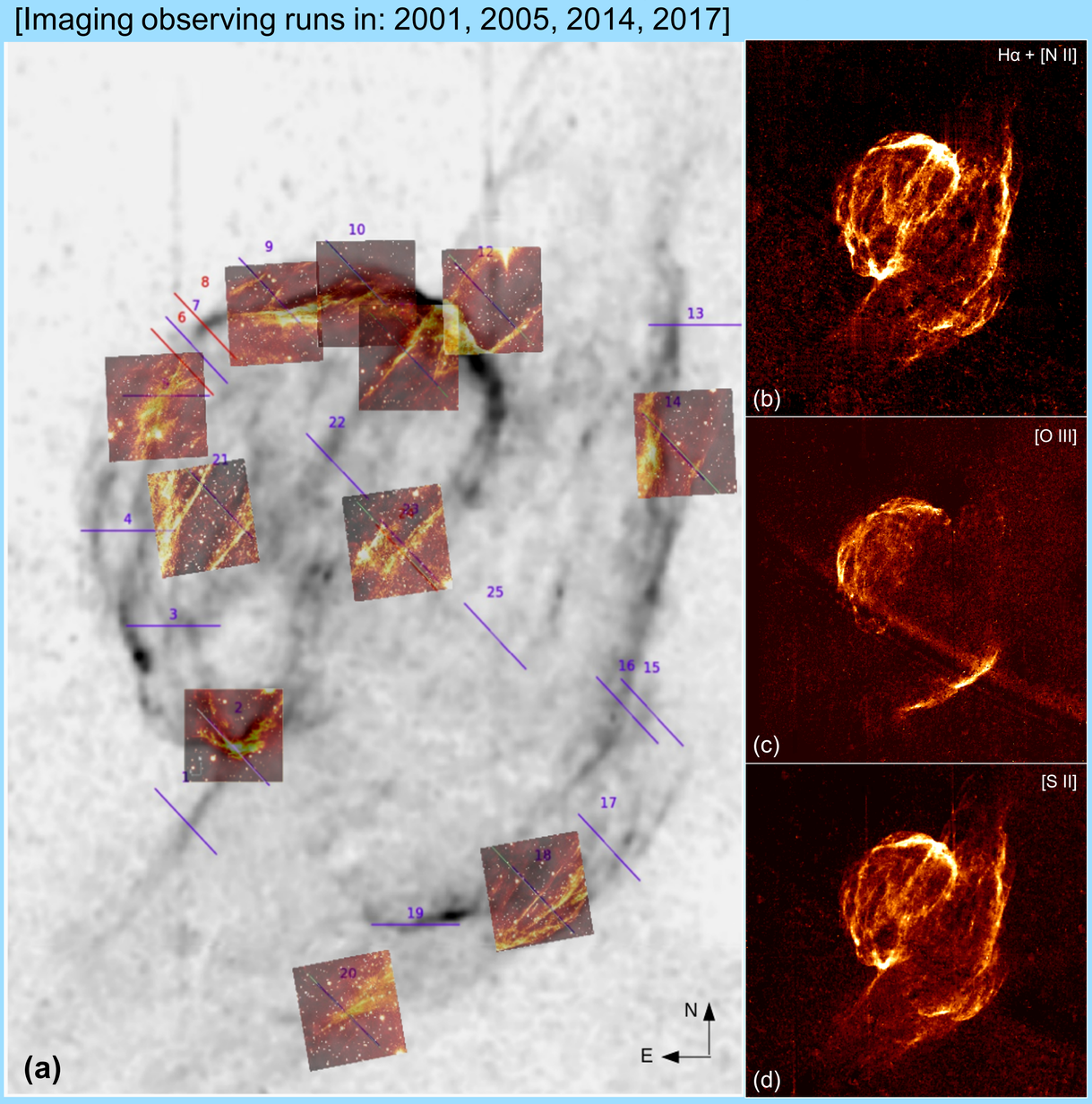

Fig. 1. (a): The Hα+[N II] image of VRO. Color high-res images (5'x5') obtained with the 2.3m Aristarchos telescope in selected areas are also shown. **(b),(c), (d):** The Hα+[N II] , [O III] , [S II] of the wide-field image of VRO, respectively.

Spectroscopy

- Low resolution: The 1.3 m telescope at Skinakas Obs. was used to obtain long-slit spectra (E.T.=3600s). 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 SPM Obs., Mexico was used to obtain echelle spectra (E.T.=1800s) with the MES-SPM, using a slit 300μm wide (=3.9" and 20 km/s).

[Spectroscopic observing runs in: 2009, 2010, 2011, 2014, 2016, 2017]

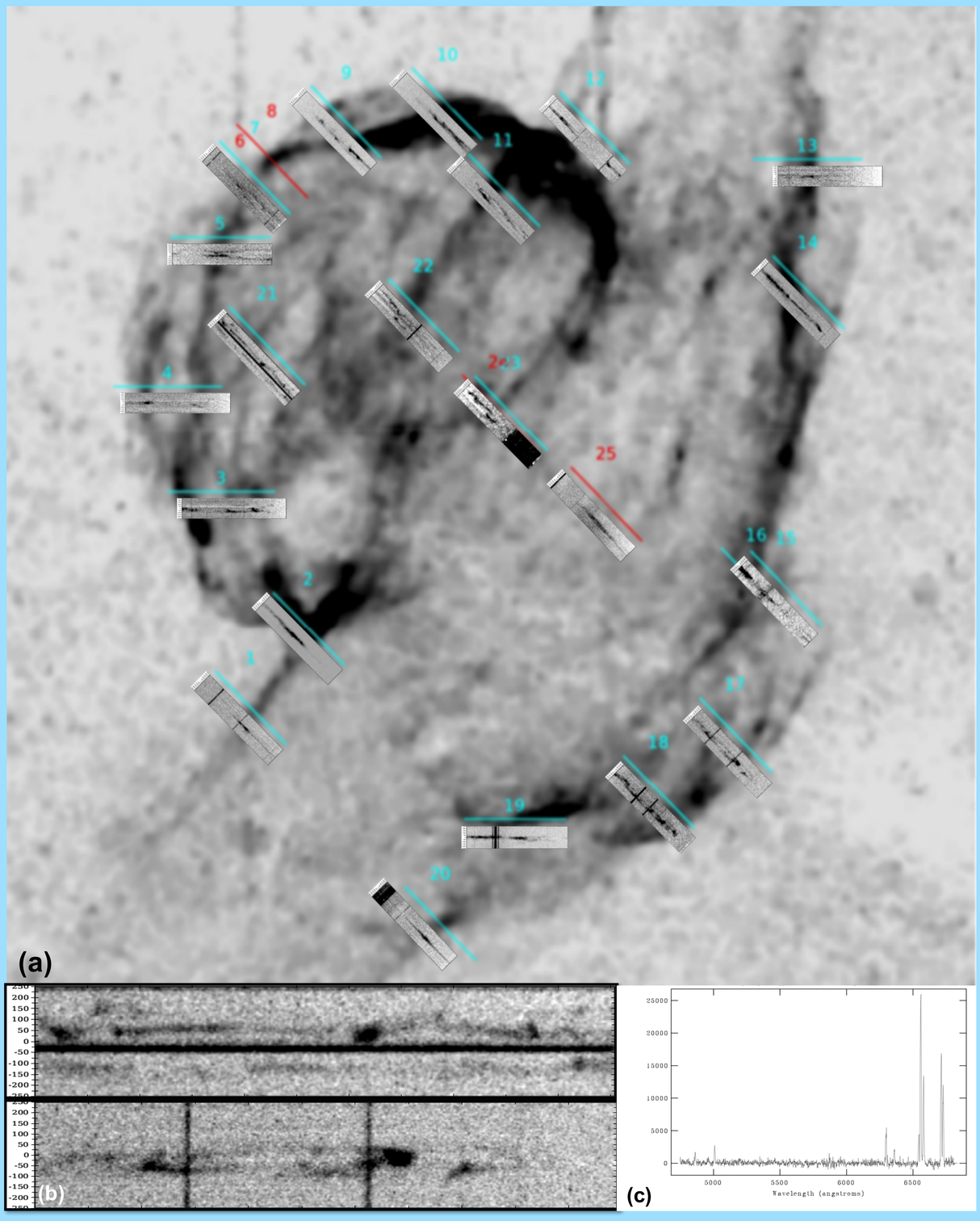

Fig. 2. (a): The Hα+[N II] image of VRO. PV diagrams of High-res MES-SPM spectra are also shown next to each slit position. **(b):** An example of high-resolution MES-SPM spectra (slits 17 and 21). **(c):** A typical low resolution spectrum.

Results

•All observed filamentary structures result by emission from shock heated gas since the [S II]/Hα > 0.4 and thus, we interpret they belong to the SNR.

• The ratio of [S II] λλ6717/6731 shows that the SNR is characterised by low electron densities (n_e < 240 cm^{-3}) indicating that VRO is expanding into a non-dense ambient medium.

•The strong [O III] emission suggests shock velocities > 100 km/s (Cox & Raymond 1985) which were also found in many high-res spectra (Fig. 2b).

•The morphological differences between the low and medium ionization lines indicate ambient medium inhomogeneities and expansion velocities variations where the hemi-spherical part of the SNR ('shell') is expanding faster than its bow-shaped counterpart ('wing'). Such a result contradicts with the current models of VRO which suggests that the shell is expanding in a much denser environment than the wing (e.g. Pineault et. al 1987) .

• In a series of forthcoming papers for VRO (see also posters S10.4, S10.5) we attempt to give insight into the unknown origin of VRO suggesting a supersonically moving and mass-losing progenitor star.

References

Boumis P., Akras S., Leonidaki I., Chiotellis A. et al., 2016, Proc. of SNRI conf,id.15

Cox D.P. & Raymond J.C., 1985, ApJ, 298, 651

Fesen R.A, Gull T.R., Ketelsen D.A., 1983, ApJS, 51, 337

Fesen R.A., Blair W. P., Kirshner R.P., 1985, ApJ, 292, 29

Pineault, S., Landecker, T. L., & Routldge, D. 1987, ApJ, 315, 580