First 3D Morpho-Kinematic model of Supernova Remnants. The case of VRO 42.05.01 (G 166.0+4.3) S. Derlopa, P. Boumis, A. Chiotellis, W. Steffen, S. Akras



Figure 1: The $H\alpha + [N II]$ wide-field image of VRO 42.05.01 (Boumis et al., 2019)

Peculiar morphology

 It occurred close to contact discontinuity of two interstellar media with different properties (Pineault et al., 1985; Landecker et al, 1989)

 No physical proof of an interaction between VRO and non-homogeneous surrounding medium (Arias et al., 2019a)

 Model of Chiotellis et al., 2019 → interaction with a wind bubble formed by a supersonically moving mass losing progenitor star.



Figure 2: The 2D density contours of the wind bubble formed by the RSG wind (a) and of the wind bubble evolution during the Wolf-Rayet progenitor's phase (b, c, and d).



Figure 3: The 2D density contours of the SNR evolution within the wind bubble of Fig. 2d.

Chiotellis et al., 2019

In this work ...

1st 3D Morpho-Kinematic model for SNRs (up to now: MHD models and 3D velocity maps)

Difficulties

→ Extended sources => great amount of data

 \rightarrow Asymmetries => complexity in morphology and kinematics.

 \rightarrow Low central emission – optical emission tangent to the observer => radial velocities ~0

Observations

<u>Imaging</u>

Skinakas Observatory (0.3m telescope)
Helmos Observatory (2.3m telescope)

<u>Spectroscopy</u>

San Pedro Martir Observatory (2.1m telescope)

The software SHAPE

Input: Hα + [N II] images, Position-Velocity (PV) diagrams





Figure 3. PV observational (in H α emission line) and synthetic diagrams of six different regions of VRO. For description see Section 5.



Figure 1. Fig. 1a shows the VRO in H α +[N II] 6548, 6584 Å emission lines. The blue labelled lines represent the slits' positions where high resolution spectra were obtained. In Fig.1b the 3D model of VRO is demonstrated, where its three components are labelled, and Fig.1c illustrates the 3D model in mesh-grid representation overlaid upon the H α +[N II] image, without the slits' positions. The different colours correspond to the distinct components of the remnant with respect to their morphology and kinematics. The black arrows point to the direction of expansion of the green region and the "hat" component of VRO. The three coloured dots illustrate the geometrical centre of each component, which coincides with the centre of each component's velocity field too.



Figure 2. 3D model of VRO in mesh-grid representation, as seen from different angles rotated through x, y and z axis. For colour description see Fig.1. An animation of the 3D model can be found in the supporting materials of this paper.



https://drive.google.com/file/d/1_bqPMgrDej5G19hBWmZePVW5U_Refk9o/view

Results

• VRO is tilted by $\sim 3^{\circ} - 5^{\circ}$ • V_{sys} = -17±13 km/s V_{shell} = 115±5 km/s V_{upper_shell} = 155±15 km/s V_{wing} = 115±5 km/s • $V_{hat} = 90 \pm 20 \text{ km/s}$



Results



Shock breakout

SN vs Wind Bubbledensity wall

High CS densitiesstagnation point