3D distribution of metals in nova shells

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Summary

A nova eruption in a cataclysmic variable (CV) is a thermonuclear explosion on the surface of the white-dwarf primary once it has accreted a critical mass from its late-type companion. During the nova eruption, material is ejected into the interstellar medium, forming an expanding shell around the CV which can be observed once its angular size is sufficiently large to be resolved and separated from the inner binary.

The spectra of such shells are usually dominated by various emission lines including Hydrogen, Helium and forbidden metal lines. We have used GMOS and MUSE to observe several such nova shells. The IFU data allow to construct a full 3D-images of the expanding shell in the various emission lines (see right side).

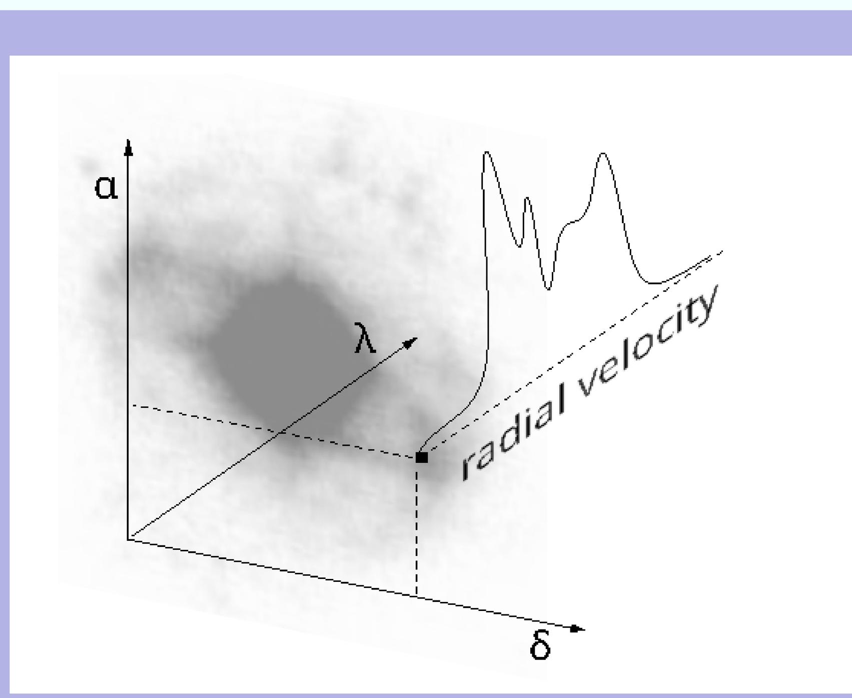
Creating the 3-D Image

For any of the various emission lines present in the spectra, the wavelength λ is transformed to radial velocity. For each spaxel the profile of each emission line therefore tansforms to a radial velocity distribution. Since the time since the nova eruption is known, the radial velocity distribution relates directly to the spatial distribution in z-direction.

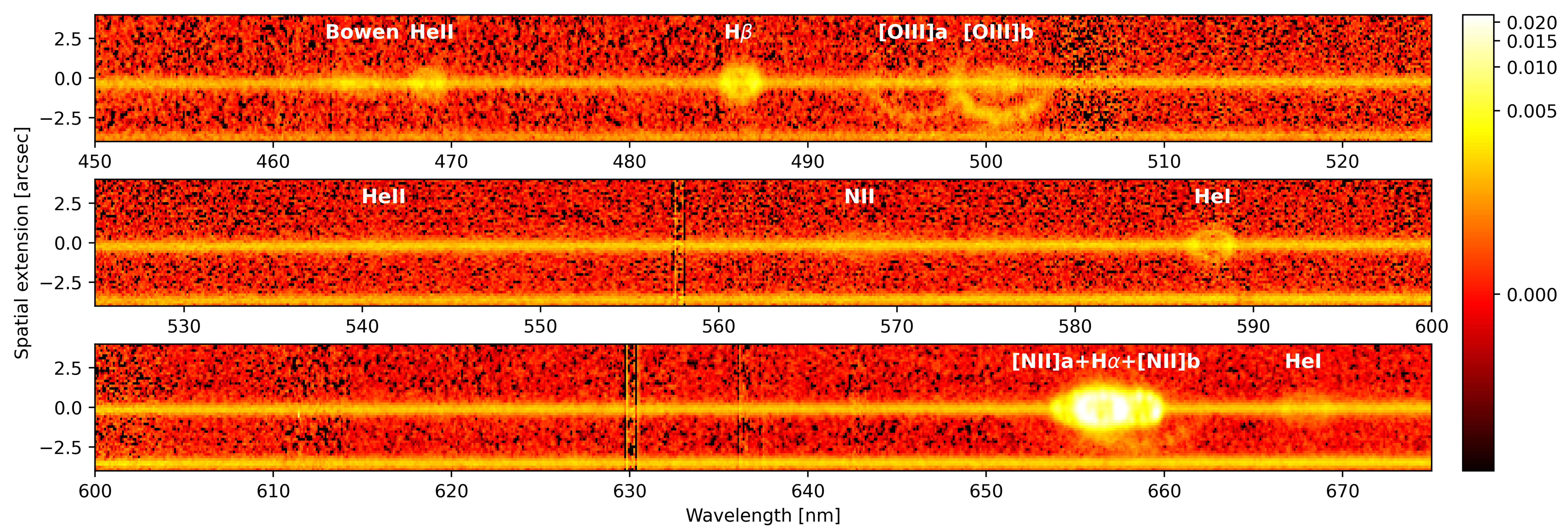
Using Gaia distances, the angular coordinates can be transformed into physical x,y-coordinates.

Like this, any pixel $(\alpha, \delta, \lambda)$ is transformed into (x,y,z) and the full 3D-images of the expanding shell can be constructed for the various emission lines.

(Celedon et al. 2023)

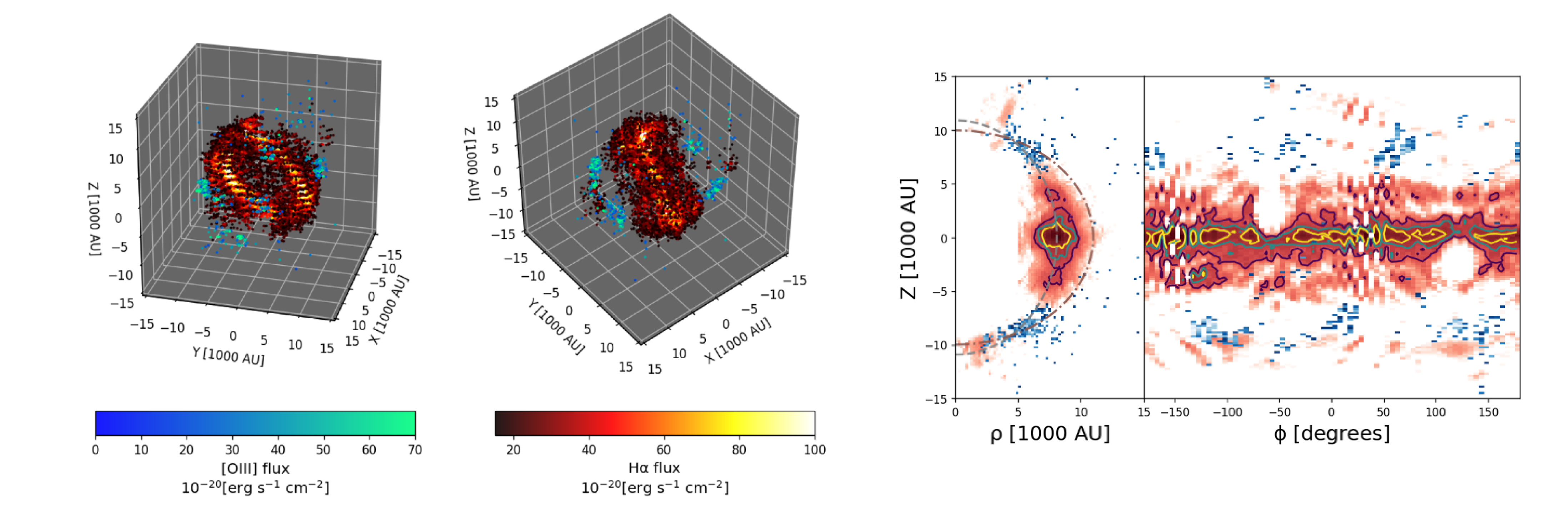


The optical spectrum of nova V1425 Aql



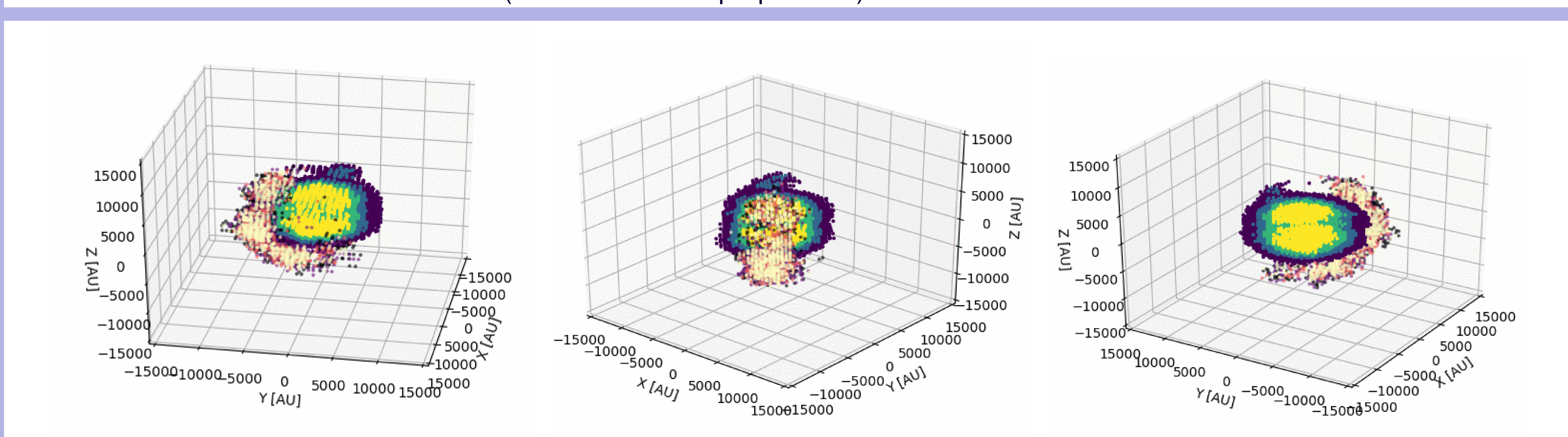
Sky-subtracted GMOS spectrum taken on 2018-09-05 at Gemini-South with grating B600+G5323 and a 1 arcsec slit. The spectral resolution is 0.45 nm. The spatial axis goes from south-west to north-east at an angle of 223.3°. The binary is visible in continuum and the Bowen blend. The other emission lines mainly originate in the ejecta. A significant contribution from the binary is expected for Hα, but cannot be confirmed due to strong blending with the [NII] lines. For brevity, we designate the blue and red components of the [NII] and [OIII] doublets with 'a' and 'b', respectively. Two different ejecta are identified: an inner one – visible both in allowed and forbidden lines – and an outer one – visible exclusively in forbidden emission. The outer shell is limited to the south-west side of the slit (Tappert et al. 2023).

3D-images of nova shells

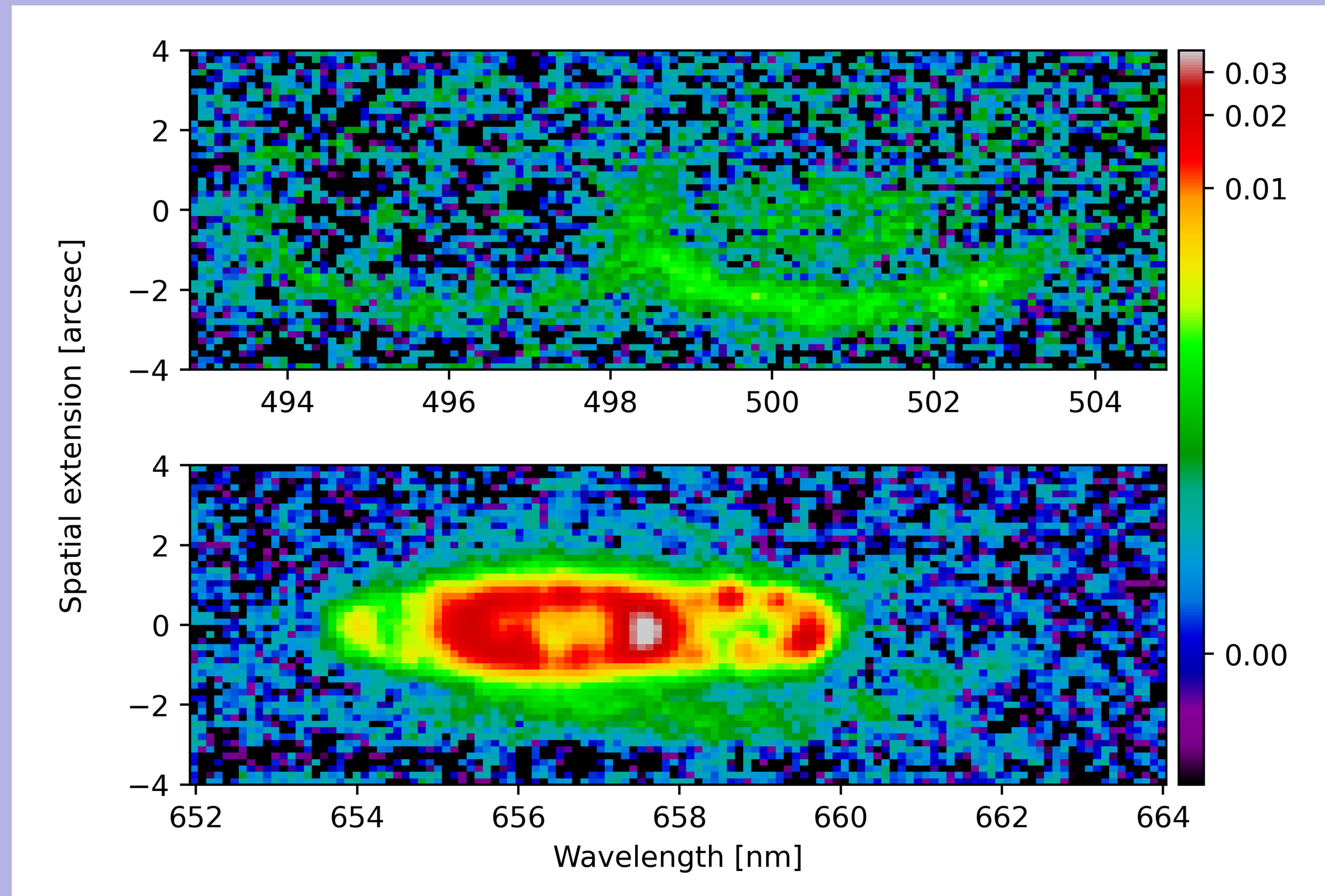


Above is the 3D-image of RR Pic; the data were taken with MUSE on 2021-12-12 in WFM-NOAO-N mode. One can see an equatorial ring in Hα, and a perpendicular bipolar loop in [OIII]. On the right a projection of the shell in cylindrical coordinates is plotted which highlights this distribution (Celedon et al. 2023)

Below is the 3D-image of V1425 Aql in the spectral ranges around Hα+[NII] (blue to yellow colours) and [OIII] (red to beige). The data were taken with MUSE-data on 2021-07-31 and 2021-05-08 in WFM-AO-NE mode. The data reveal the outer ejecta as an arc-like structure towards the south-west (Celedon et al. in preparation).



V1425 Aql: densities and temperature



Subtracting the stellar continuum reveals the different forbidden line ratios of the two ejecta, [OIII] being more prominent in the outer shell shell. Already 820 d after the nova eruption, Lyke et al. (2001) find two classes of material with two different densities and velocities. Extrapolating the density to the time of our observations (8624 d), we find $n_i = 1.37 - 3.01\,10^3 \mathrm{cm}^{-3}$ and $n_o = 0.23\,10^3 \mathrm{cm}^{-3}$ for the electron density of the inner and outer ejecta. Since we only have upper limits for [OIII] λ436.3 nm and [NII] λ575.5 nm, we derive upper limits for the temperatures $T_i < 5000\mathrm{K}$ and $T_o < 7500\mathrm{K}$.

References

Celedon L., Schmidtobreick L., Tappert C., Selmann F., 2023, A&A in press
Lyke J.E., Gehrz R.D., Woodward C.E., et al. 2001, AJ, 122, 3305
Tappert C., Celedon L., Schmidtobreick L., 2023, A&A 679, 40