INSIGHTS FROM HIGH RESOLUTION (MULTI-BAND) SPECTROSCOPY

– AN APPLICATION TO CLASSICAL NOVAE –

ABSTRACT & RESULTS: USING HIGH RESOLUTION (HR) MULTI-WAVELENGTH SPECTROSCOPY WE INVESTIGATED THE EJECTA KINEMATIC FOR FEW RECENT BRIGHT CLASSICAL NOVAE (CNe) AND DERIVED A NUMBER OF THEIR PHYSICAL PARAMETERS, INCLUDING THE GEOMETRY. THE OBSERVABLE EJECTA ARE CONSISTENT WITH POLAR-CAPS/BICONICAL GEOMETRY AND DO NOT BEHAVE AS A WIND BUT ARE IN BALLISTIC EXPANSION (V~R).
USING HR MULTI-WAVELENGTH SPECTROSCOPY WE ALSO CONSTRAINED THE DUST LOCATION, SIZE, AND EVOLUTION IN DUST FORMING NOVAE. THE DUST IS NOT DESTROYED BY THE HIGH ENERGY RADIATION FROM THE UNVEILING HOT WHITE DWARF (WD) BUT SLOWLY DILUTES AND MIXES WITHIN THE CIRCUMSTELLAR ENVIRONMENT.

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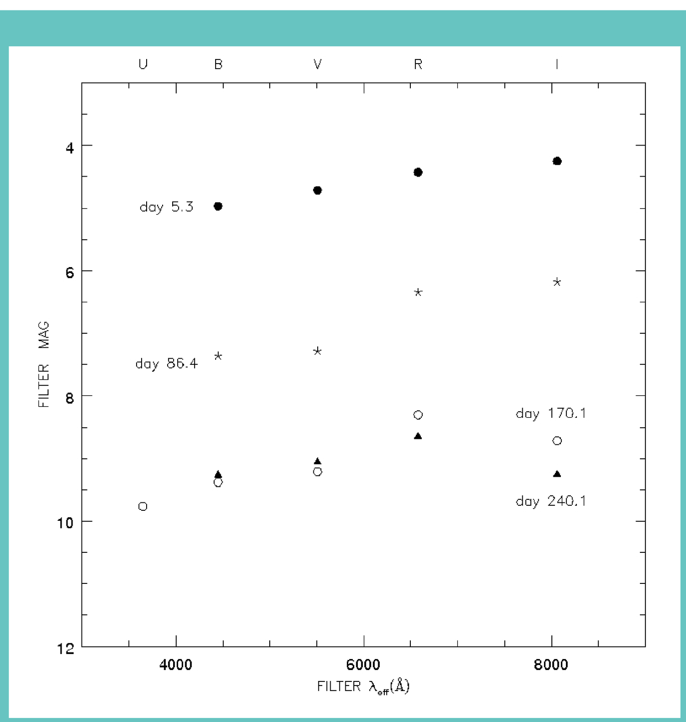
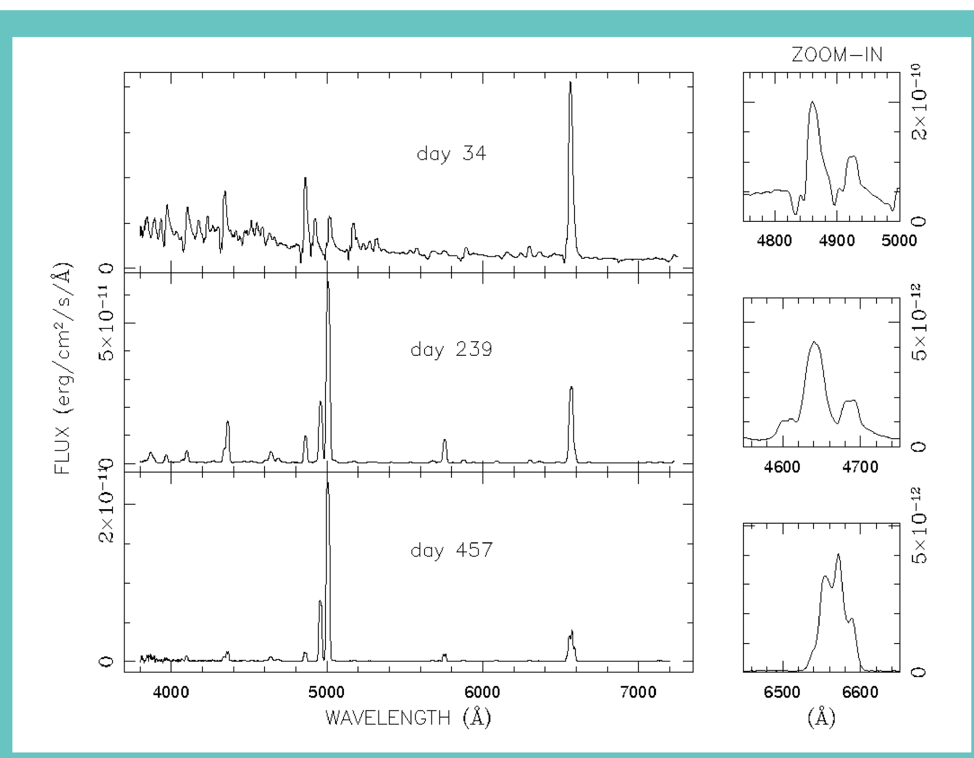
The figures below, unless otherwise specified, have been either created for this poster or extracted from one of the following publications:
Shore+ 2011, A&A, 533L8; De Gennaro Aquino+ 2014, A&A, 562,28; Shore+ 2016, A&A, 590, 123; Mason+ 2018, ApJ, 853, 27; Shore+ 2018, A&A in press / arXiv 1807.07174

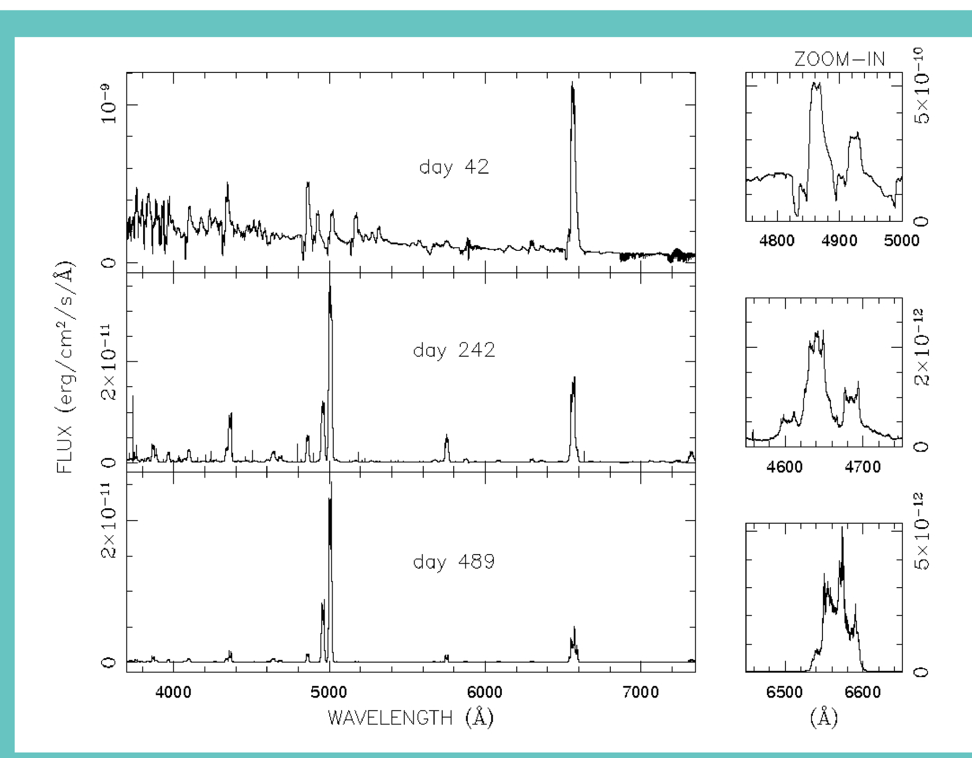
HR SPECTROSCOPY: DOES IT REALLY MATTER? WHAT A DIFFERENCE CAN IT MAKE?



VERY LOW RESOLUTION (R~5):
The analysis is limited to the spectral energy distributions (SEDs). The presence of emissions and absorptions prevents drawing any unambiguous conclusions. [photometry (nova Sgr 2015b) courtesy of AAVSO]



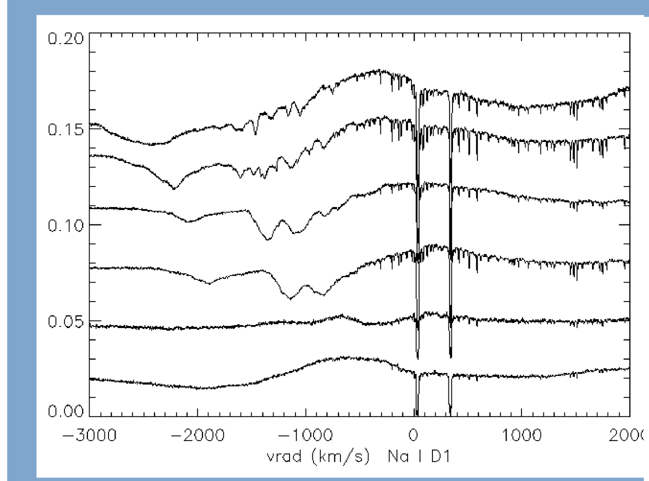
LOW/MED RESOLUTION (R~1500):
Continuum and lines can be analyzed separately. Asymmetries and Gaussian like single or multiple components can be identified. Absorptions might look like P-Cyg profiles from a wind. [spectra (nova Cen 2013) courtesy of ARAS]

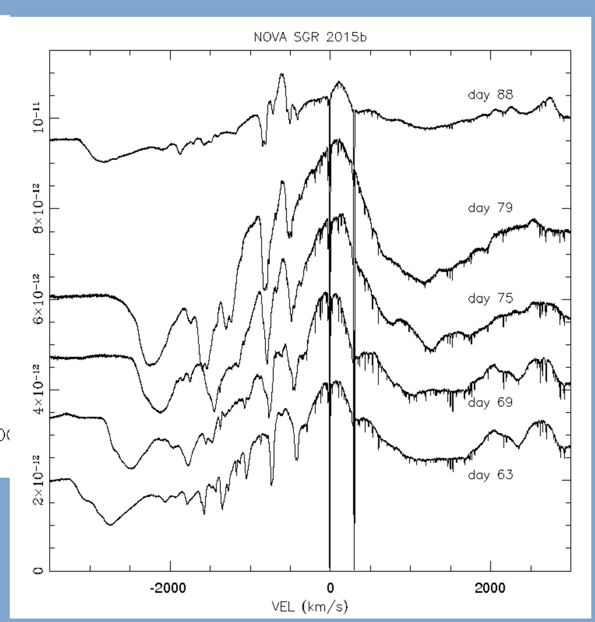


HIGH RESOLUTION (R>40000):
Continuum and lines can be analyzed separately. Emission and absorption profiles breaks into ensembles of narrow components. Absorptions are dissimilar from a wind P-Cyg profile. DIBs and interstellar absorptions can be used as well.

THE OBSERVATIONAL FACTS AND OUR INTERPRETATION:

The early decline forward- or backward-motion of the the narrow absorptions is APPARENT (BOTTOM PANELS).

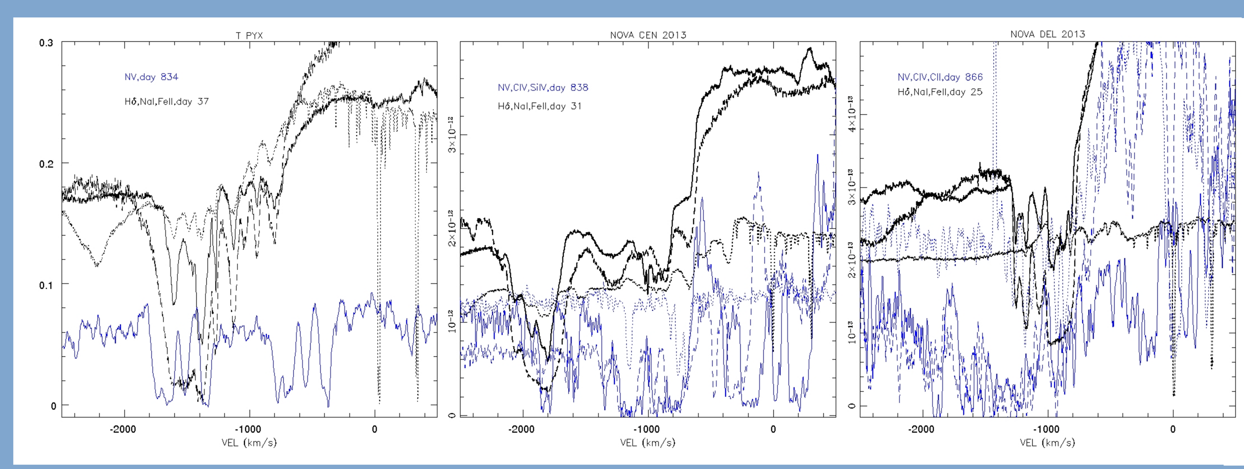




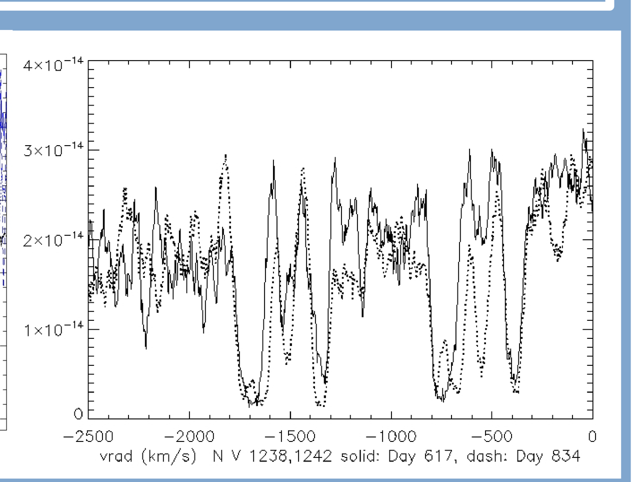
TOP: T Pyx NaI D evolution between day 2 and day 47 after discovery/outburst. Time increases from bottom to top.
RIGHT: Nova Sgr 2015b NaI evolution. Nova age in the Figure itself.

BALLISTIC EXPANSION
v~r
each structure within the ejecta moves with constant velocity and the velocity gradient across the ejecta is constant: further out portions move faster than the inner components.

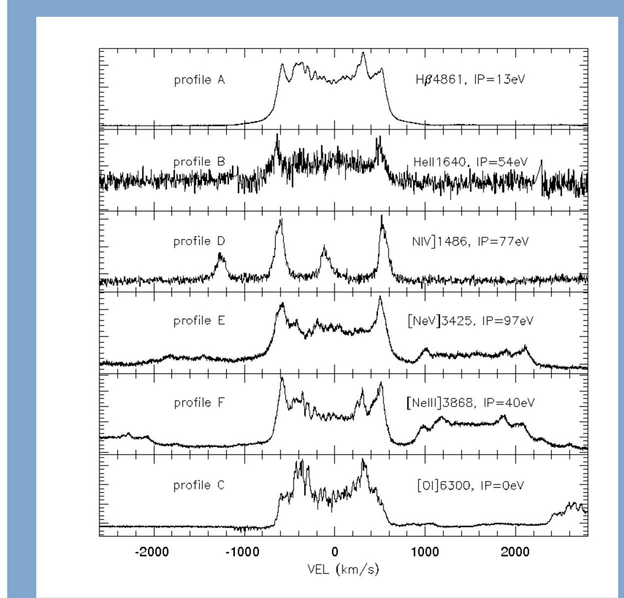
The narrow absorptions do not move in velocity space: clusters of absorptions that were visible in a velocity range in a given transition at early epochs, are visible in THE SAME VELOCITY RANGE in a resonant transition of a high ionization potential energy ion, years after outburst (BOTTOM). The absorptions in the nebular spectra remain still across time (BOTTOM RIGHT).



Comparison, in the velocity space, of the absorption structures at early decline (black lines) and late nebular phase (blue lines). Line identifications are marked in the figure itself.



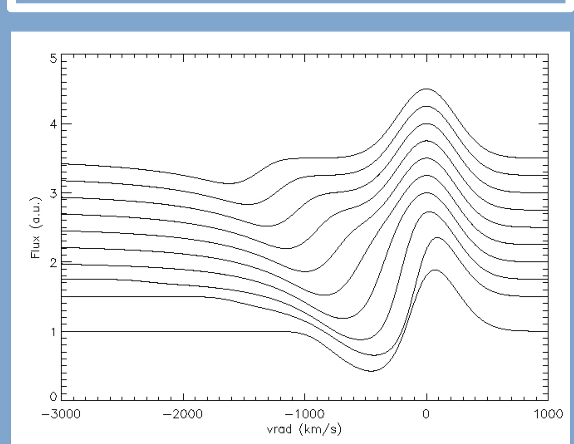
T PYX NV (λλ1238,1242 Å) absorptions at two late epochs (day 617 and 834)

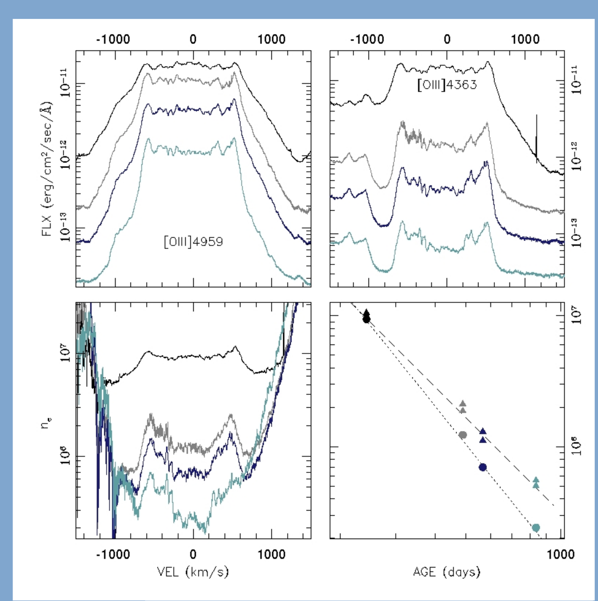


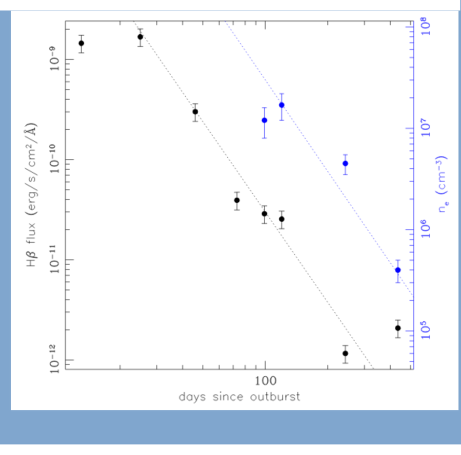
The line profiles vary with the ion and allow mapping the ionization state of the gas across the ejecta

In the FIGURE ABOVE: a selection of line profiles from nova Cen 2013 spectrum, 836 days after outburst.

The apparent motion of the absorptions during early decline is consistent with a recombination front propagating through the ejecta as they expand with time. It can be mimicked by assuming a constant mass ejecta with a r^{-3} density dependence and in ballistic expansion (BOTTOM PANEL).



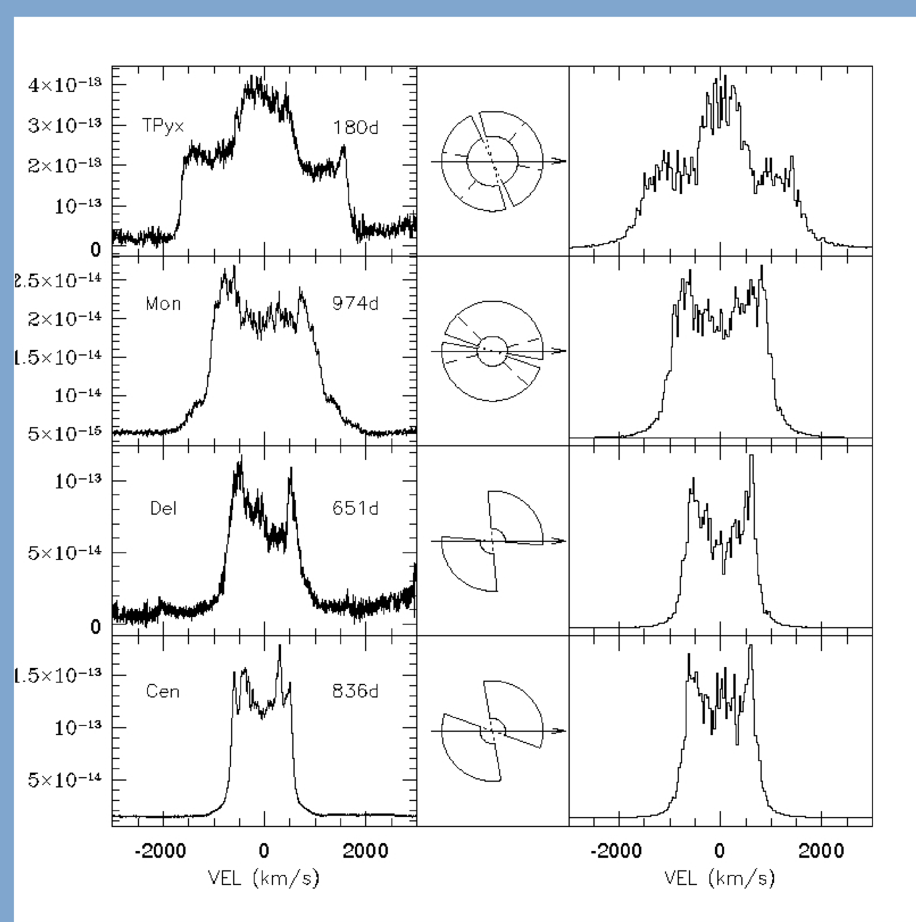




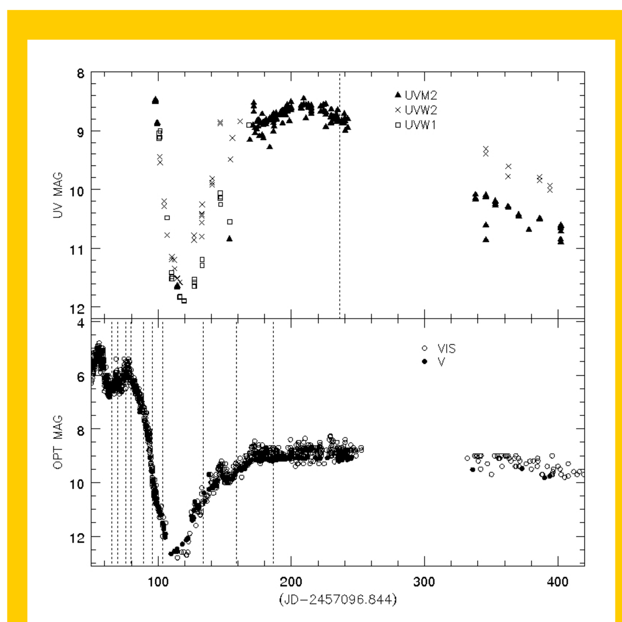
The figures on the RIGHT show flux and N_e evolution with time for nova Del 2013, and [OIII] line profiles, N_e in velocity space and N_e evolution with time for nova Cen 2013

Line flux and electron density in late nebular spectra decline as t^{-3} as for optically thin gas that is dominated by recombination processes. The electron density can be computed for individual resolution elements and the same decline patter verified. THIS IS ALSO CONSISTENT WITH A GAS IN BALLISTIC EXPANSION

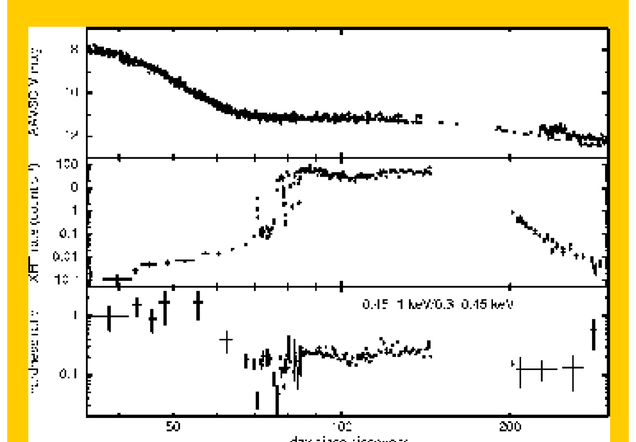
The observed global line profiles can be mimicked adopting clumps in ballistic expansion and confined within a biconical shape and with density distribution proportional to r^{-3}. (RIGHT PANEL)

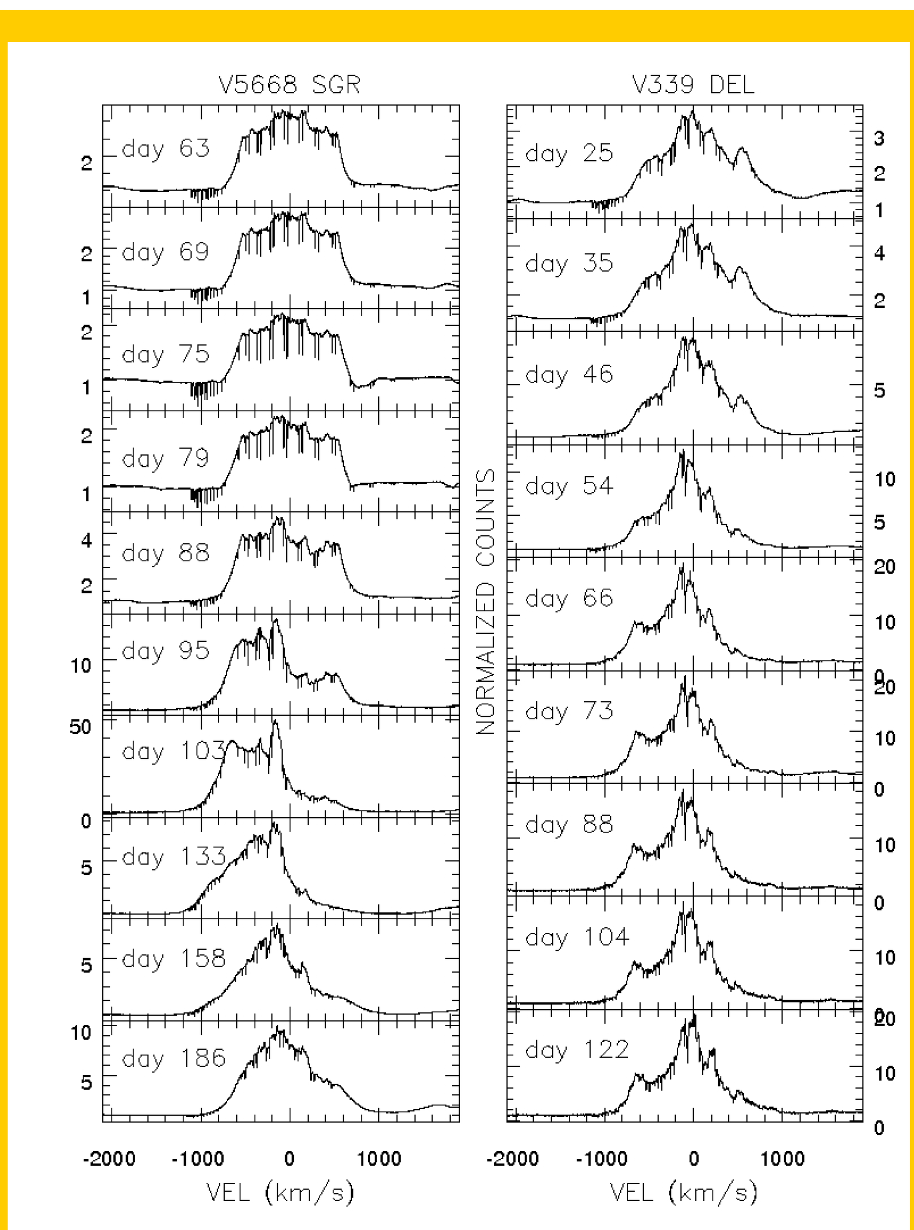


IN CASE OF DUST:



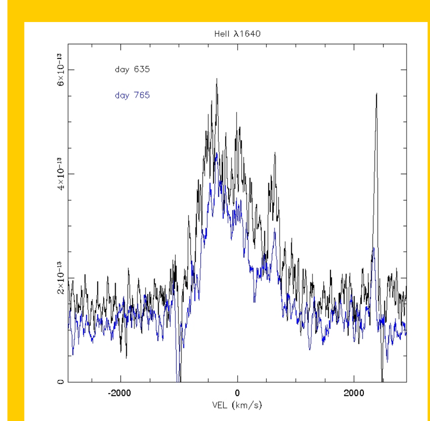
TOP: UV and optical light curves of nova Sgr2015b (v5668 Sgr).
BOTTOM: Optical and X-ray light curves of nova Del 2013 (V339 Del).

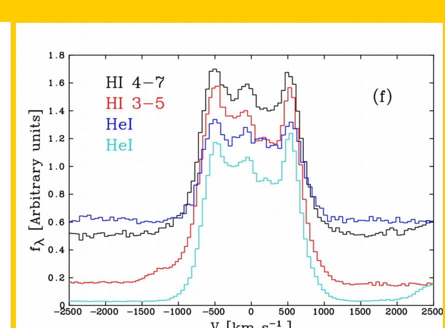




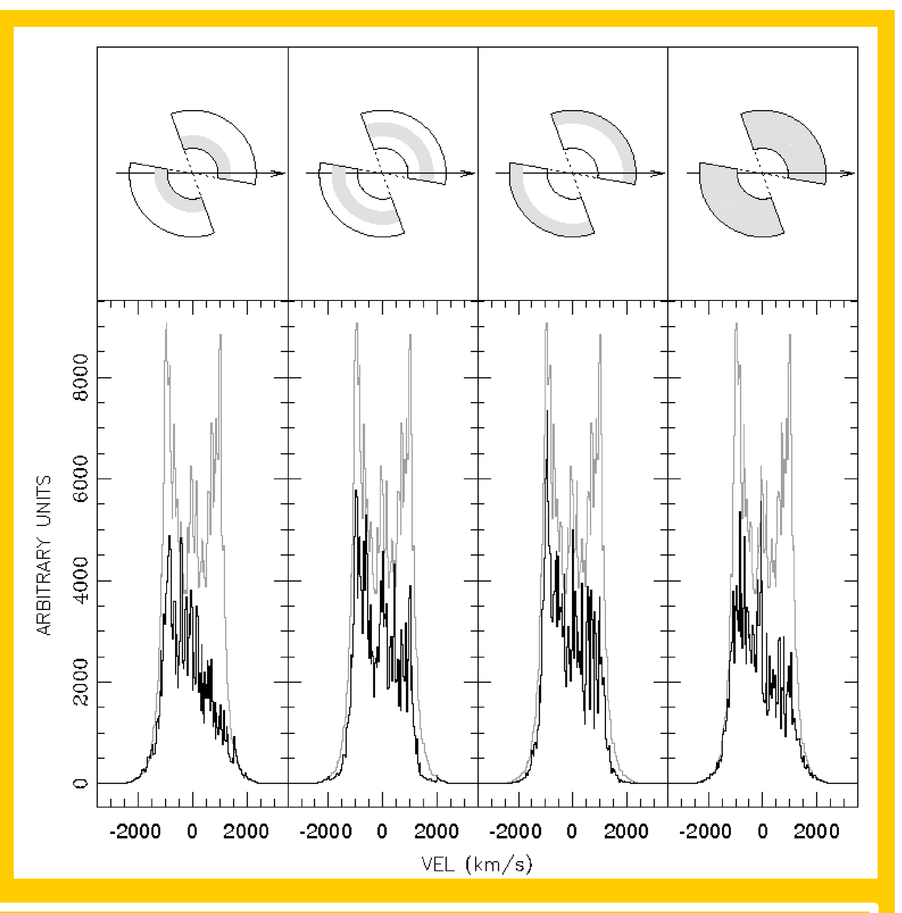
_ Dust forms when the ejecta start unveiling the WD (x-ray flux increases and softens)
_ Dust shades portion of the ejecta. It might cause sudden dimming in the optical and UV light curve. It causes asymmetries in the line profile: the red portion weakens (LEFT PANEL) and the line flux barycenter shifts blueward (this has noted already in Low Resolution spectra of Super Novae).
_ The dust optical depth is lower in the NIR than at optical and UV wavelengths. Hence, in presence of dust, line profiles might appear symmetric in the NIR but asymmetric in the UV (BOTTOM PANEL).
_ The persistence of the asymmetry well after the end of the super soft source phase indicates that the dust has survived the strong high energy radiation.

LEFT: Line profile evolution of the optically thin [OI] λ6300Å line during the dust forming event in V5668 Sgr and V339 Del
BOTTOM: Comparison of the H and He line profiles in the UV-optical and the NIR spectra of V339 Del at day >635 and 683 after outburst respectively.





NIR profiles figure from Evans+ MNRAS 2017, 466, 4221



Dust effects on the line profile can be consistently reproduced by our simulation: where the dust forms will affect differently the resulting line profile (TOP FIG.). The degree of asymmetry as measured from the blue/red line peak ratio allows estimates of the dust optical depth. The degree of asymmetry across wave-bands (together with the continuum slope) allows constraining the dust absorption coefficient and therefore the grain size. These together with the derived geometry and dust location allow computing the dust mass (independently of the distance).