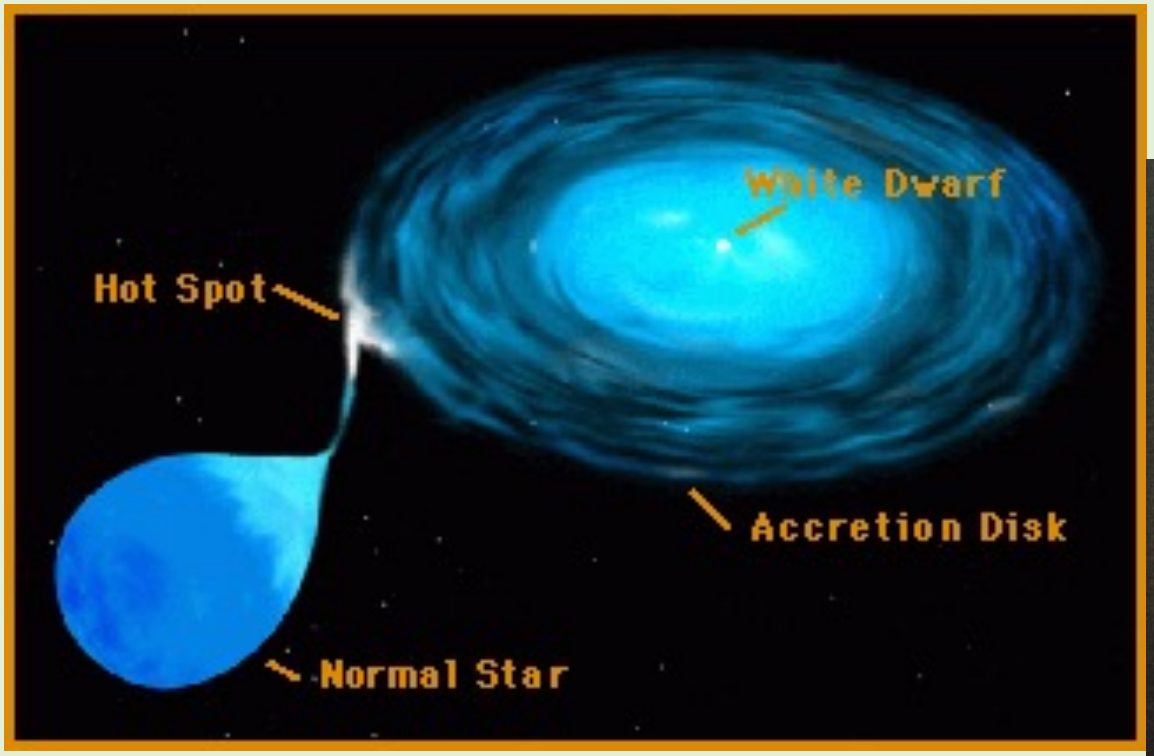
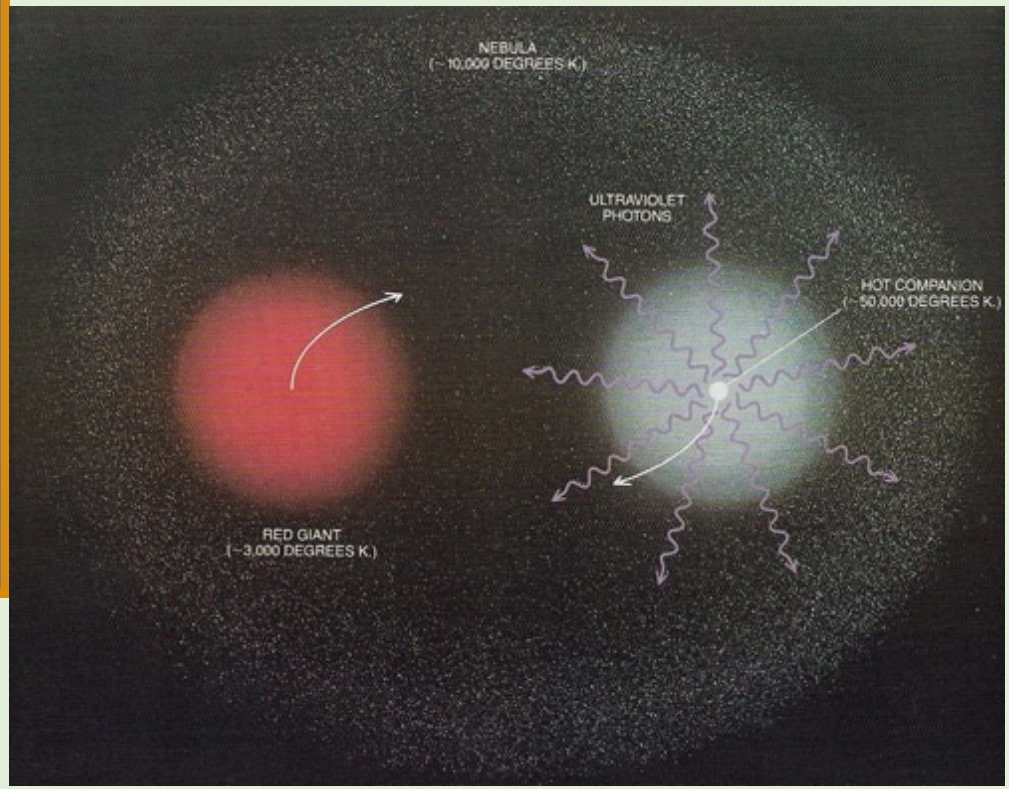
# Arcus and novae

Marina Orio, May 2023




Nova in a cataclysmic variable

## Symbiotic nova

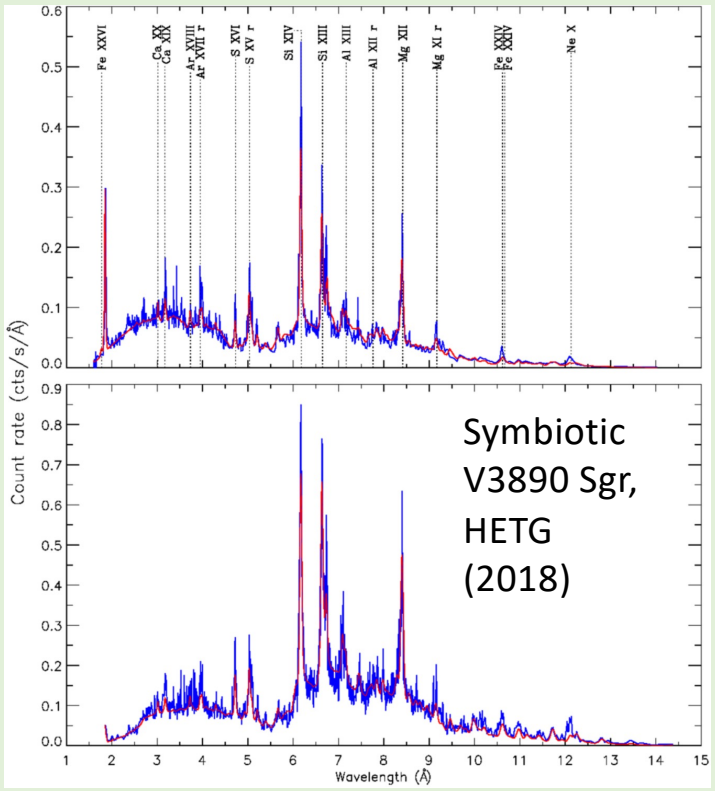



- All these interacting binaries are candidate progenitors of type Ia SNe either from single or from double degenerates
- Novae are fascinating astrophysical laboratories of many physical processes we need to understand better
- Novae enrich the interstellar medium of peculiar elements, important also in chemical evolution

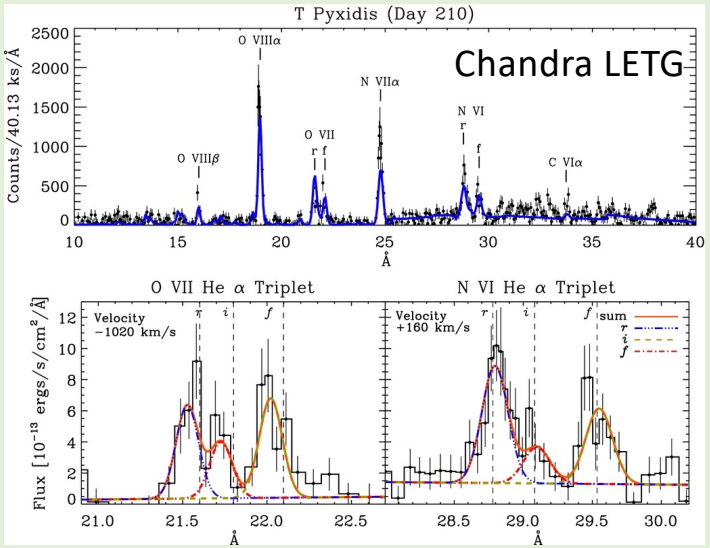
# Novae in outburst emit at all wavelengths

- Novae outbursts are initiated by a thermonuclear runaway on a white dwarf (WD) that has accreted a hydrogen rich layer from a companion, and ignited shell CNO burning in electron degenerate material
- The “explosion” may not eject any matter, but a radiation pressure driven super-wind, or mechanisms in the common envelope, may be responsible for the observed mass outflows at velocity of 1000-7000 km/s for weeks to many months
- Powerful shocks cause X-ray and secondary leptonic/hadronic gamma-ray emission (up to Cherenkov energy)
- X-rays in nova outflows: ~$10^{33\text{-}34}$ erg/s CV-type, $10^{36\text{-}37}$ erg/s symbiotics
- Copious UV/FUV/EUV fluxes, radio emission, IR flux (dust)…all observed
- Very soft X-rays from the WD as it shrinks again while shell burning is still ongoing (Eddington luminosity ~$10^{38}$ erg/s )

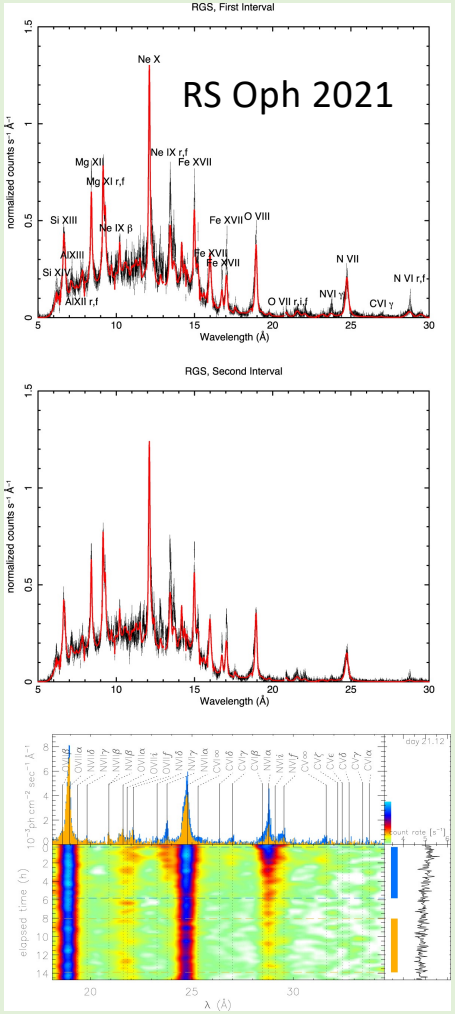
# A wide variety of X-ray spectra from the ejecta



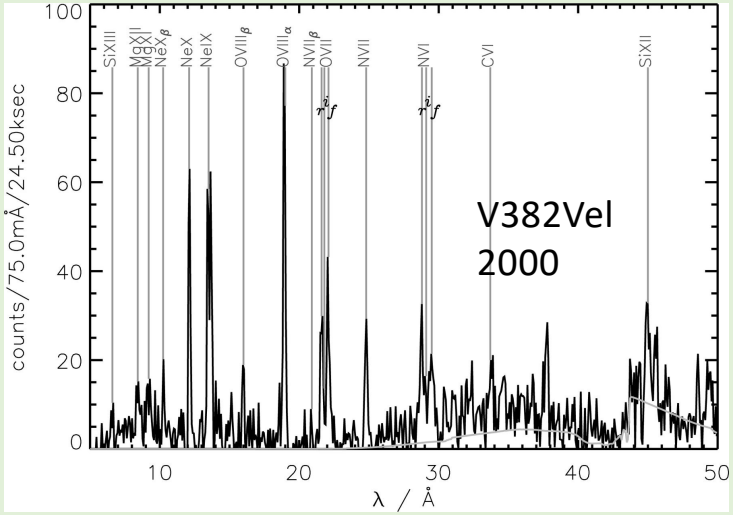

Orio et al. 2020



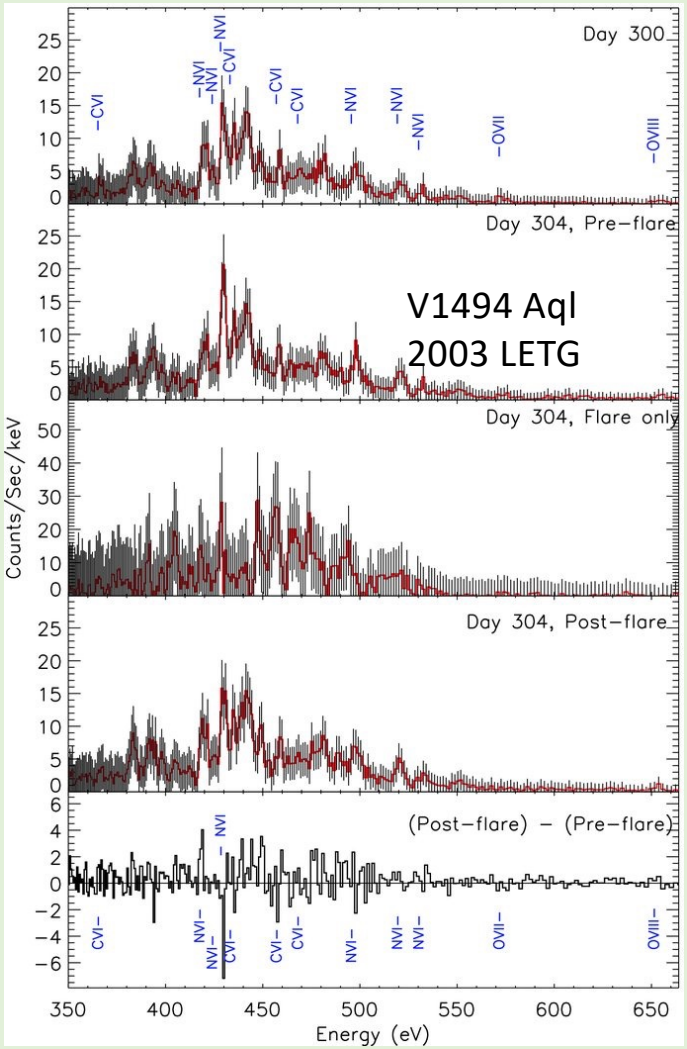

Tofflemire et al. 2013



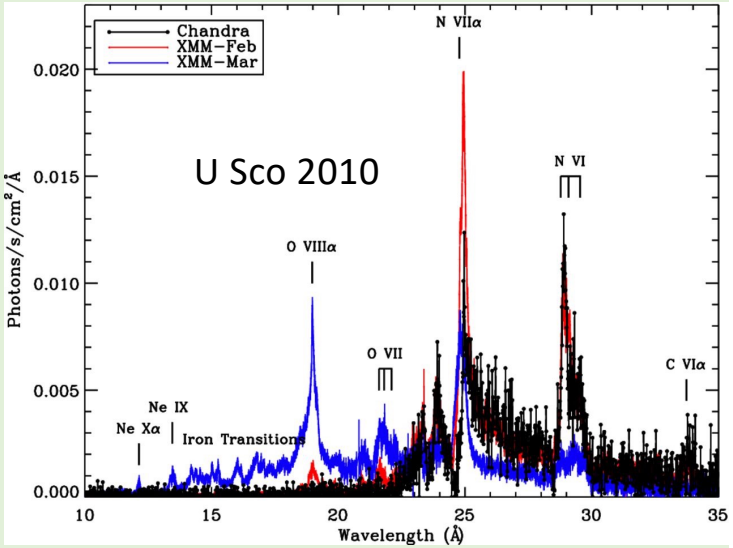

Orio et al. 2022




Ness et al. 2005

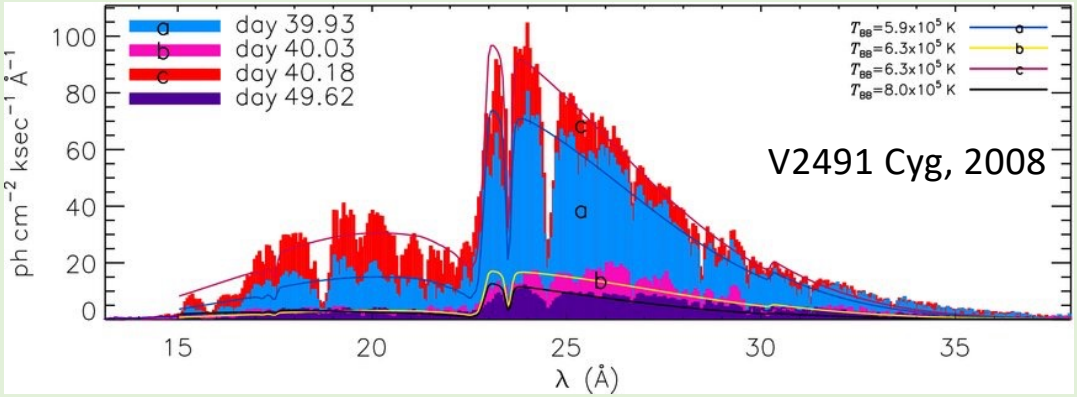



Rohrbach et al. 2009



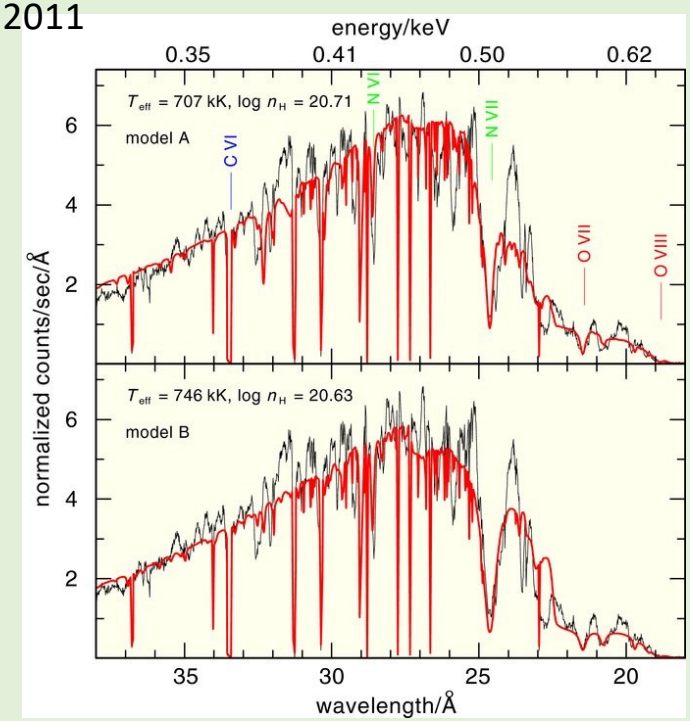

Orio et al. 2013

# The supersoft X-ray phase

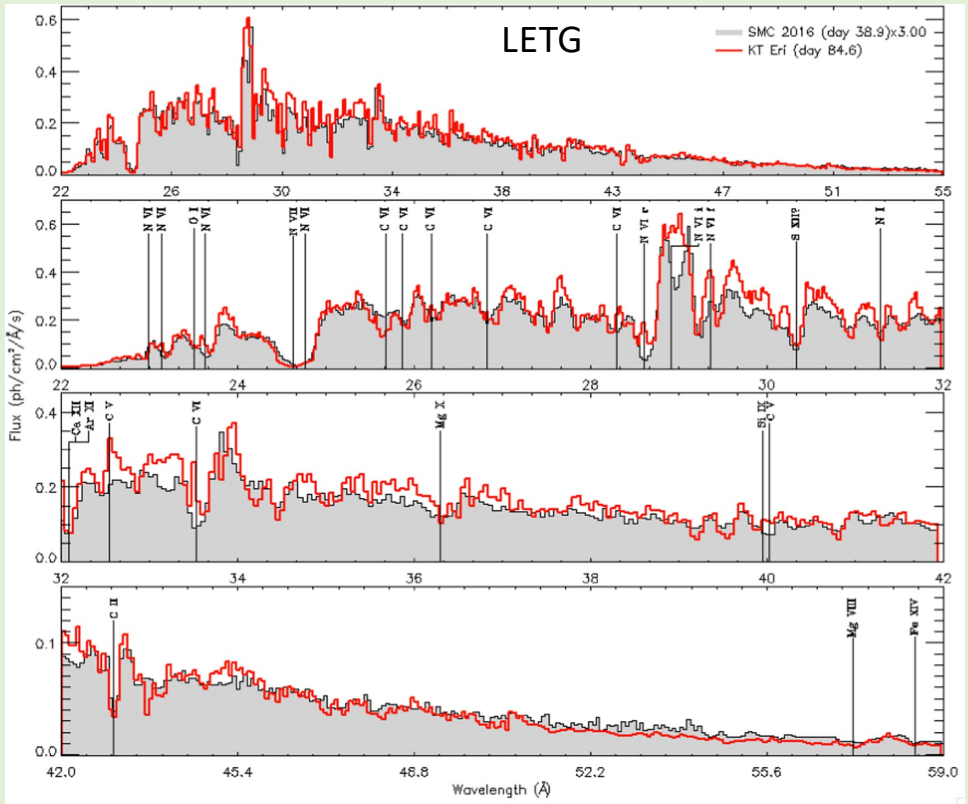



V2491 Cyg, 2008

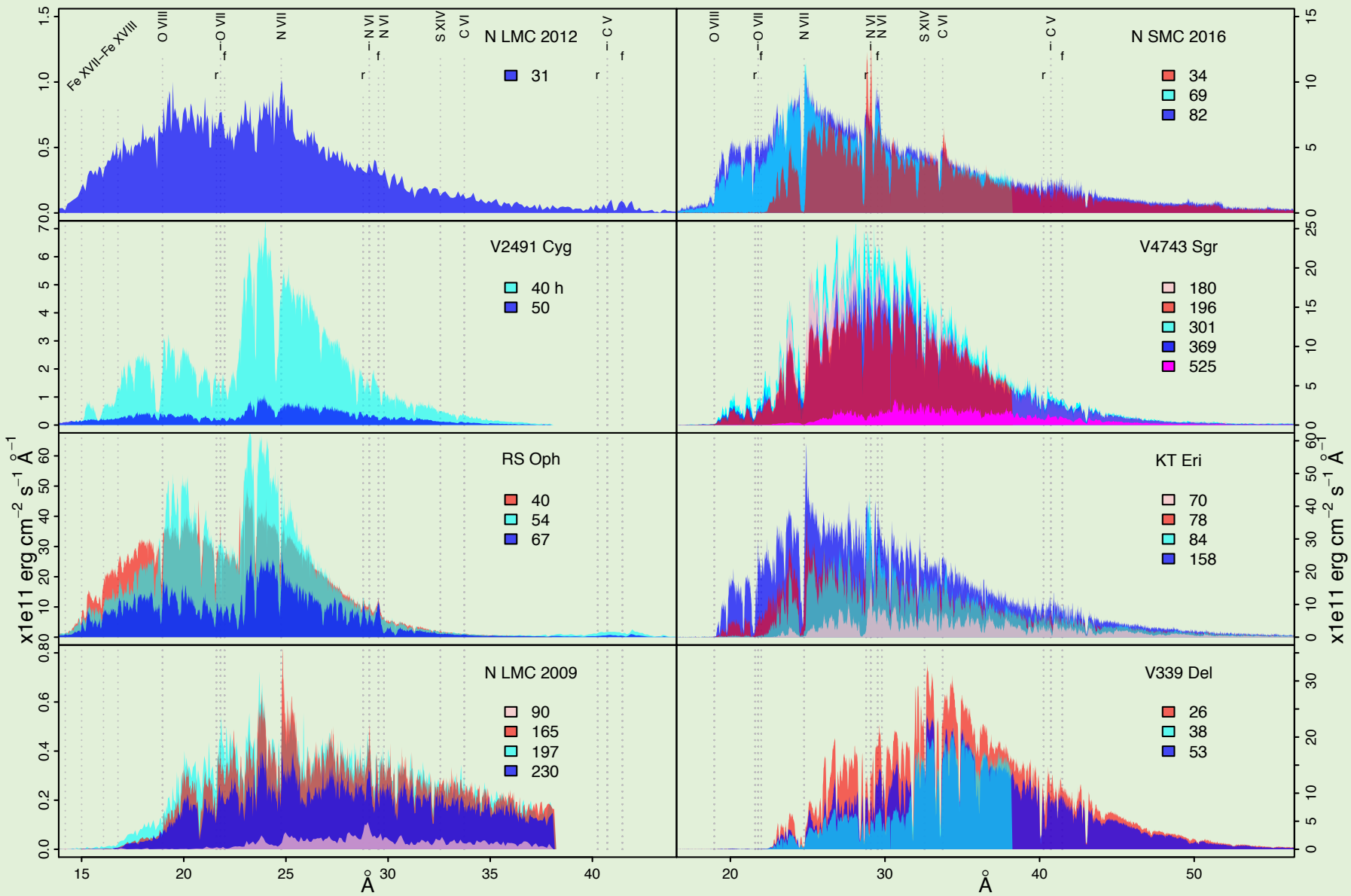
Ness et al. 2011




V4743 Sgr, LETG, 2002-2003 Rauch et Al. 2010

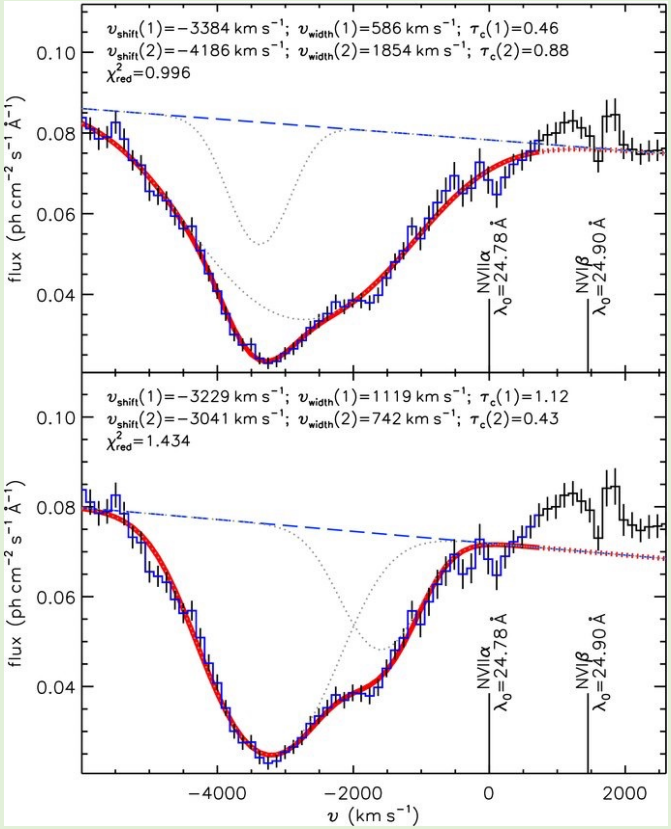



Orio et al. 2018



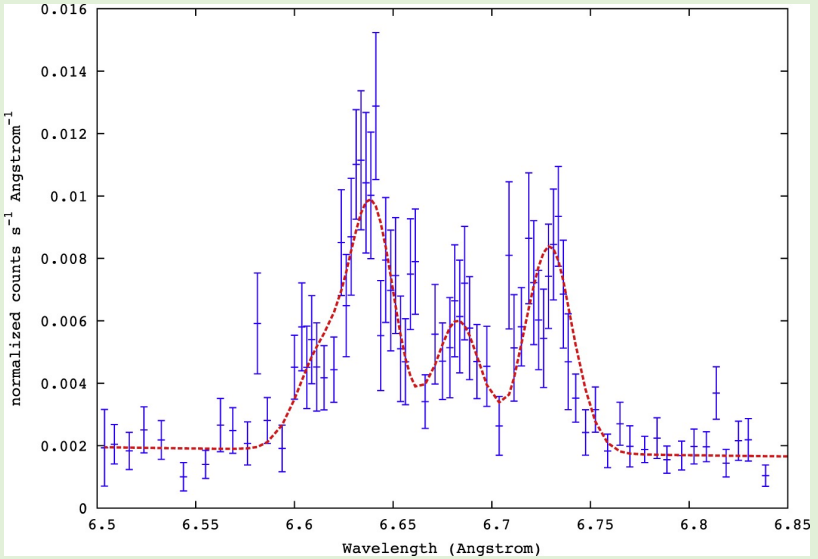

The squares show post maximum days

# Some reasons for which we want high spectral resolution




SSS: We would like to measure weaker lines overlapping with strong ones (not only in absorption) (Ness et al 2011).

Only ARCUS spectral resolution can prove which approach is suitable to draw conclusions from models



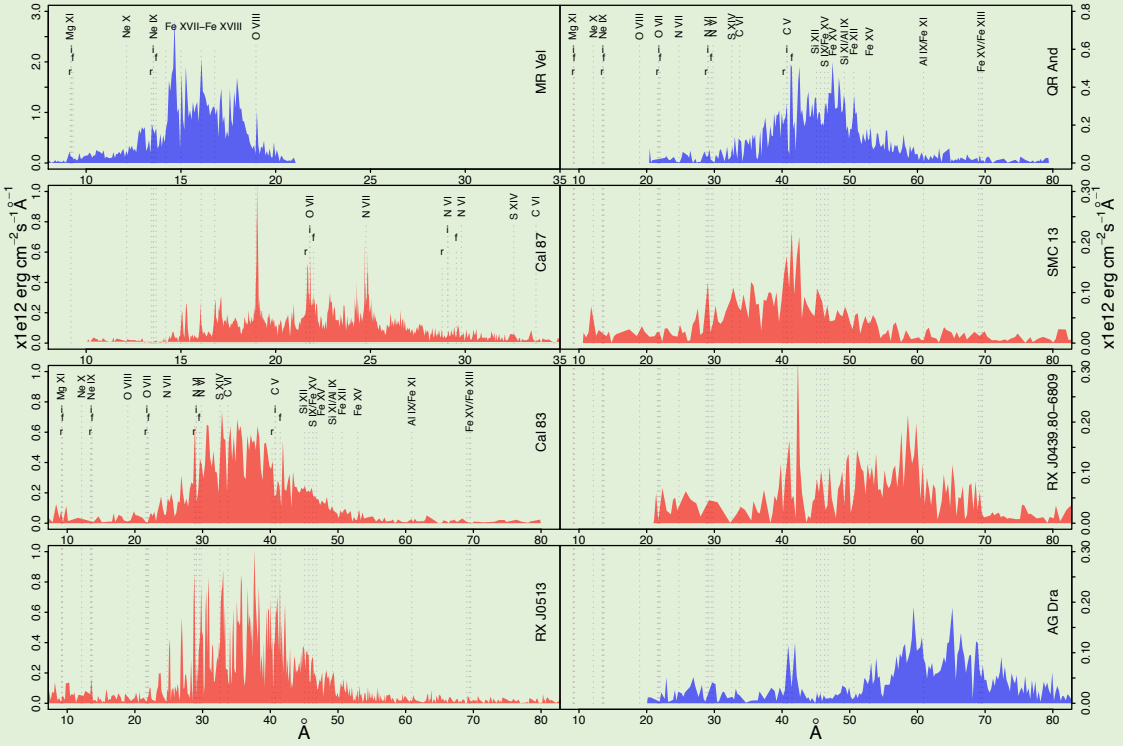

Outflows and shocks: Measure more line ratios and with much higher precision (Orio et al. 2020)

# X-ray line and line ratios as diagnostics

- High spectral resolution is the key to obtain accurate plasma temperature, electron density and chemical yields of different elements
- Many novae seem to occur on rare ONe WDs, distinguishable because of the Ne/Mg line fluxes and the flux in other lines of elements produced in "super-hot" CNO cycle side reactions, like the much discussed Al
- Massive CO WDs are very interesting as "single degenerate" SN Ia progenitors
- Ratios of flux in H-like lines and He-like triplets is the first indications of non-equilibrium plasma – but can be obtained with a multi-temperature plasma
- $(f+i)/r < 4$ in He-like lines generally indication of shock ionization
- f/i ratio indication of electron density (Gabriel & Jordan 1969; Bautista & Kallman 2000; Porquet et al. 2010)

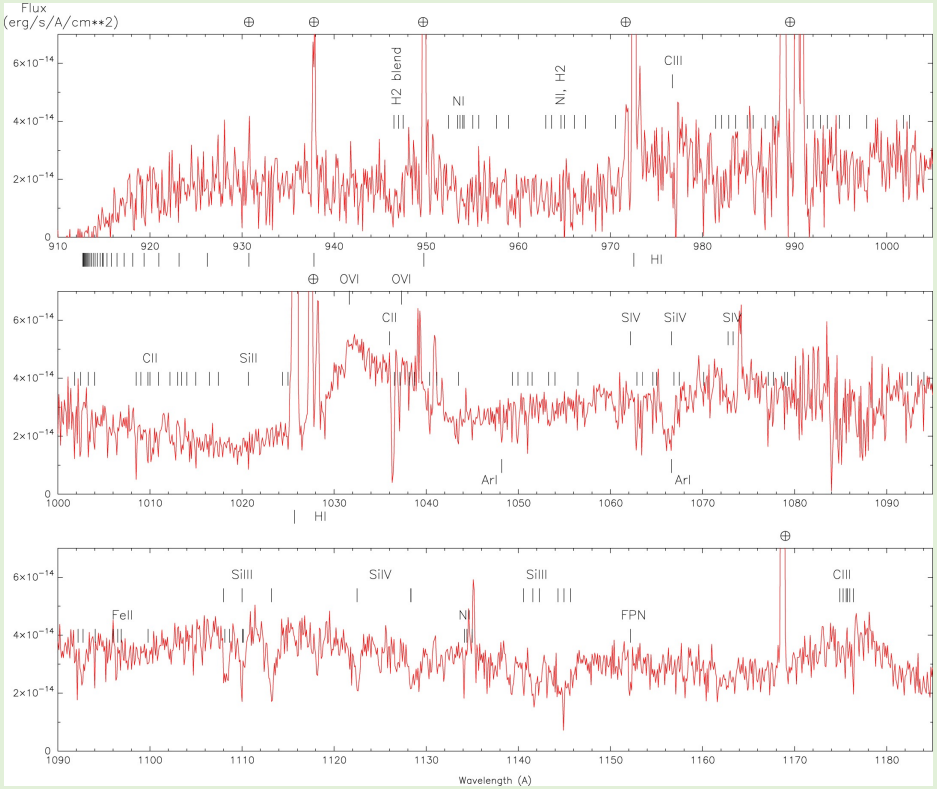
# Not only novae in outburst…

- Quiescent accreting binaries have rich X-ray emission line spectra from which white dwarf mass and mass accretion rates can be quite precisely estimated
- “Non-ejecting novae” and other shell burning white dwarfs have intricate, rich luminous supersoft X-ray spectra with many lines longwards of 40 Angstrom, in emission and in absorption, as shown here on the right

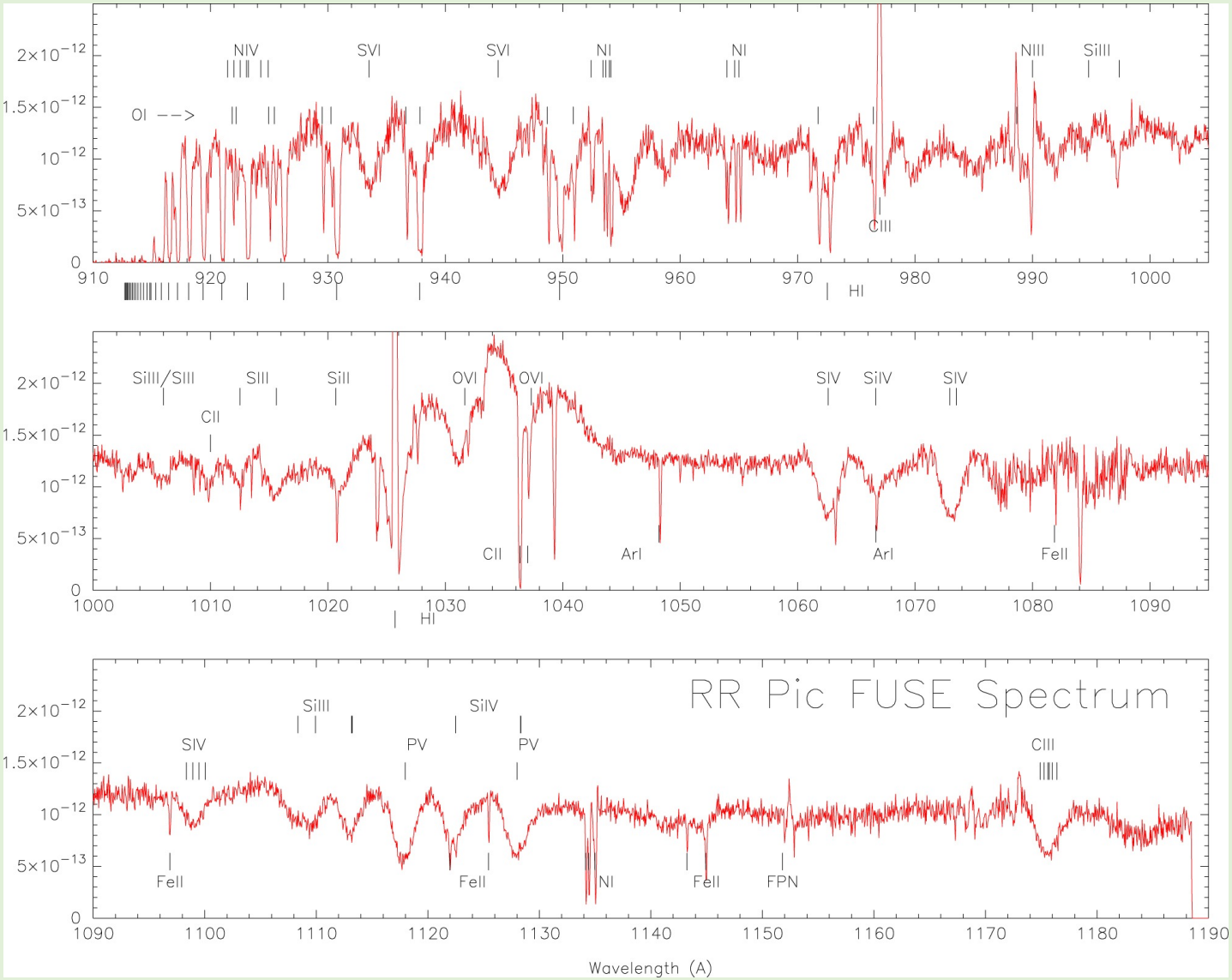


# The FUV spectra

- The continuum flux will be very high at peak UV stage in a nova outburst. Unabsorbed, >~$10^{-6}$ erg/cm$^2$/s at distance a few kpc, but absorption is high
- COS, FUSE and the Hopkins UV Telescope studied mainly accreting white dwarf binaries
- Are most novae in outburst too luminous or was there a TOO time problem?
- For accreting WDs, accurate model exist to derive WD $T_{eff}$ and mass accretion rate (e.g. Sion+Godon)
- 2 novae in outburst observed with HUT, rapidly varying emission lines, Lyman and Werner molecular bands used to derive hydrogen column density (Greeley et al. 1995)




Quiescent dwarf nova ER Uma, Guzman et al. 2019




Quiescent nova RR Pic, Sion et al. 2017

# Some (preliminary) conclusions

- Simultaneous X-ray and UV spectra will give much more accurate N(H) measurements
- Great improvement with higher spectral X-ray resolution (line profiles, line ratios…) will allow much more accurate temperature, electron density, WD mass and chemical yields measurements
- We will “reach” more extragalactic novae in the Local Group, at different metallicity environments
- Both FUV and X-ray spectra are also extremely useful to study accretion and nuclear burning in quiescent WD binaries