NOVAE WITH X-RAY GRATINGS: WHY AND HOW

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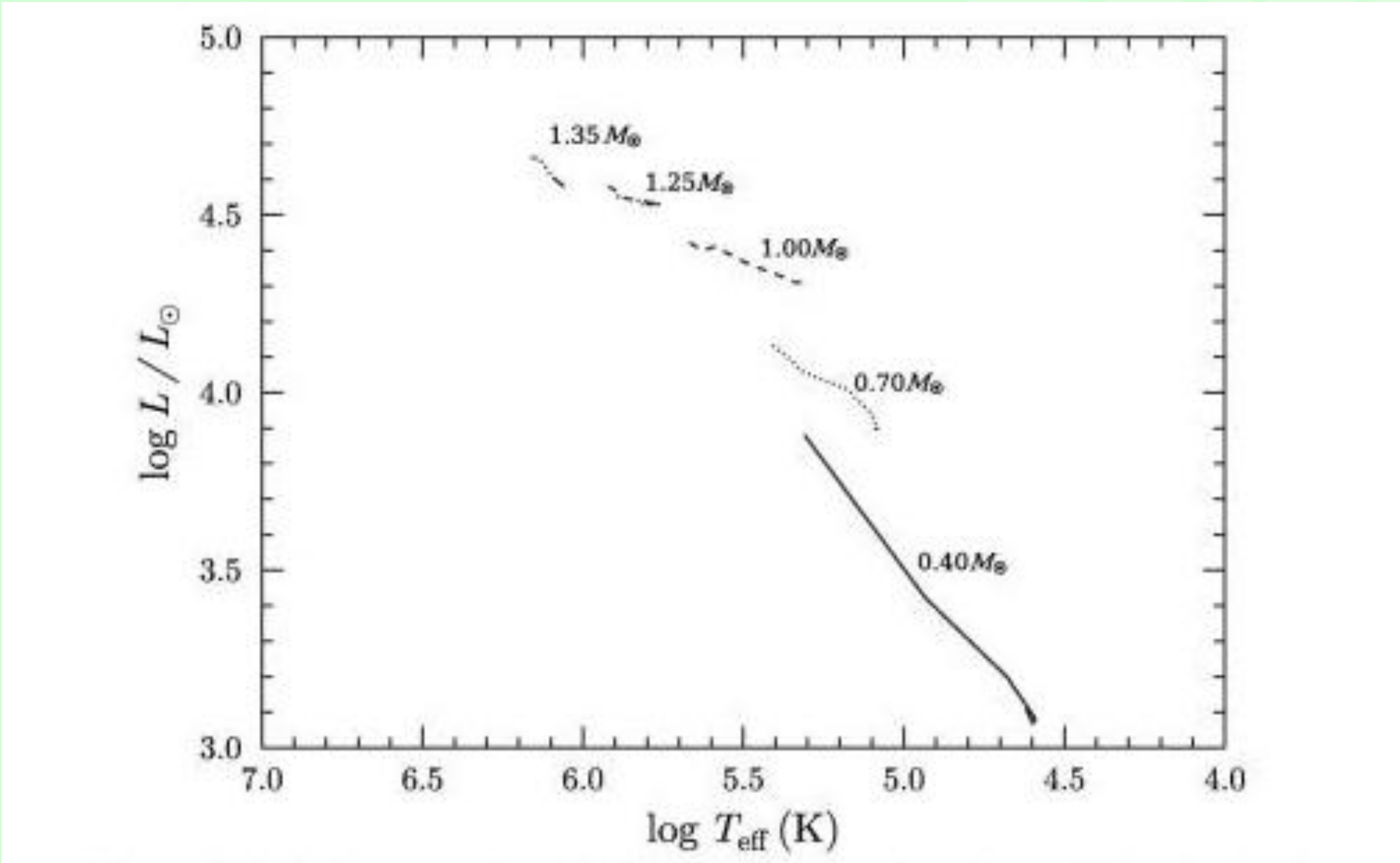
ASKING FOR THE COURTESY OF THE AUDIENCE (AND A BIRTHDAY PRESENT):

Please take note of comments and questions and intervene at the end, I will leave time!

From Starrfield et al. 2012: importance of measuring WD temperature as outburst ends



=> Translates into an M(WD) vs. T_{eff} plot

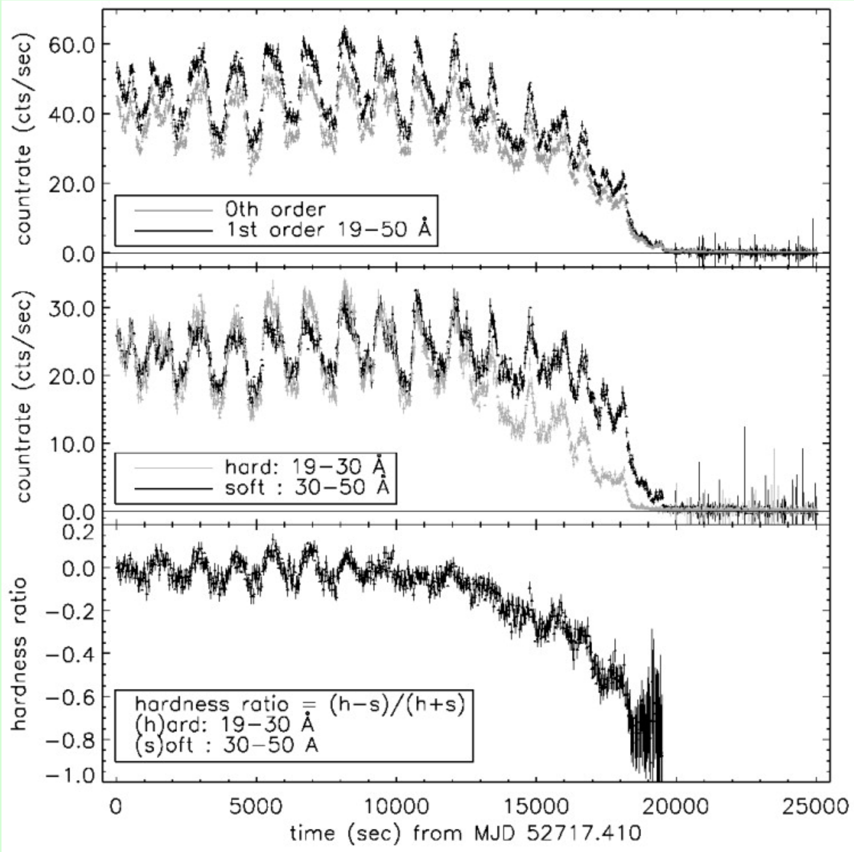
Program of X-ray gratings observations of luminous novae

- Novae become supersoft X-ray sources around the time the "nova wind" ends => the shell becomes thin to the very soft X-rays
- The SSS allows to probe hydrogen burning in shell above burning layer: measure WD abundances, effective gravity, T_{eff} (a proxy for the mass)
- Program started 13 years ago, in full swing for 10 years and greatly helped by advent of Swift as pathfinder
- 11(12) Galactic novae in outburst, 2 (4) LMC novae observed with X-ray gratings. 6 were RN (3 with numerous recorded outbursts). . Also 5 grating spectra of non-nova supersoft sources. Initial aims: observe continuum AND absorption features
- The first huge surprise were strong, prominent emission lines from the ejecta in the very "soft" range….(H-like and He-like). They complicate the spectral analysis. Some novae exhibit almost only an emission line spectrum. The copious X-ray emission from the ejecta (up to 10^{36} erg/s) can even be very hard.

Main open problems to solve

- Physical mechanism of continuum and emission lines from the shell: importance of shocks vs. photoionization. Learn about mass outflow and ejecta conditions.
- Variability discovered thanks to much longer exposures. Must now understand the variability of the hot WD observed in supersoft X-rays (Irradiation? Magnetic fields? Non continuous mass ejection episodes?)
- Is there a conspicuous residual wind after the main nova wind has ceased, and can we rely on the WD peak atmospheric temperature as a proxy for the WD mass? (Expanding atmosphere would be cooler and have lower effective gravity than quasi-static atmosphere of the same luminosity)

Aperiodic variability: deep dip

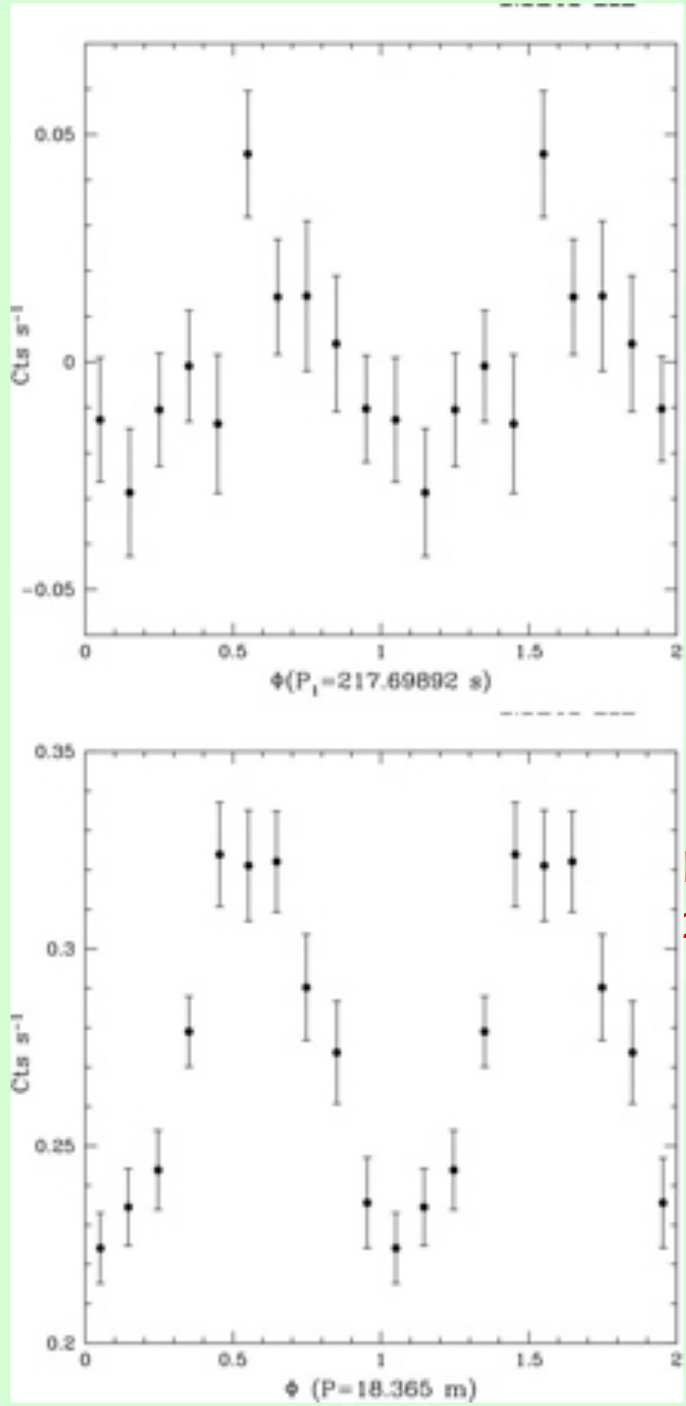


V4743 Sgr

New large mass ejection months after optical maximum?

Periodic variability

- ~half hour periods (e.g. previous slide): non-radial g-mode oscillations?
- Period due to the WD rotation (V4743 Sgr seems to show both)
- In RS Oph, KT Eri, and perhaps V1974 Cyg, periods of ~30 sec are observed: very short WD spin. Is the WD spun up by accretion? Why observed in the SSS?
- Orbital variability: hours (up to 1.5 days) Are the magnetic fields playing a role in this variability?
- Flares repeated at each orbital period: are they common?



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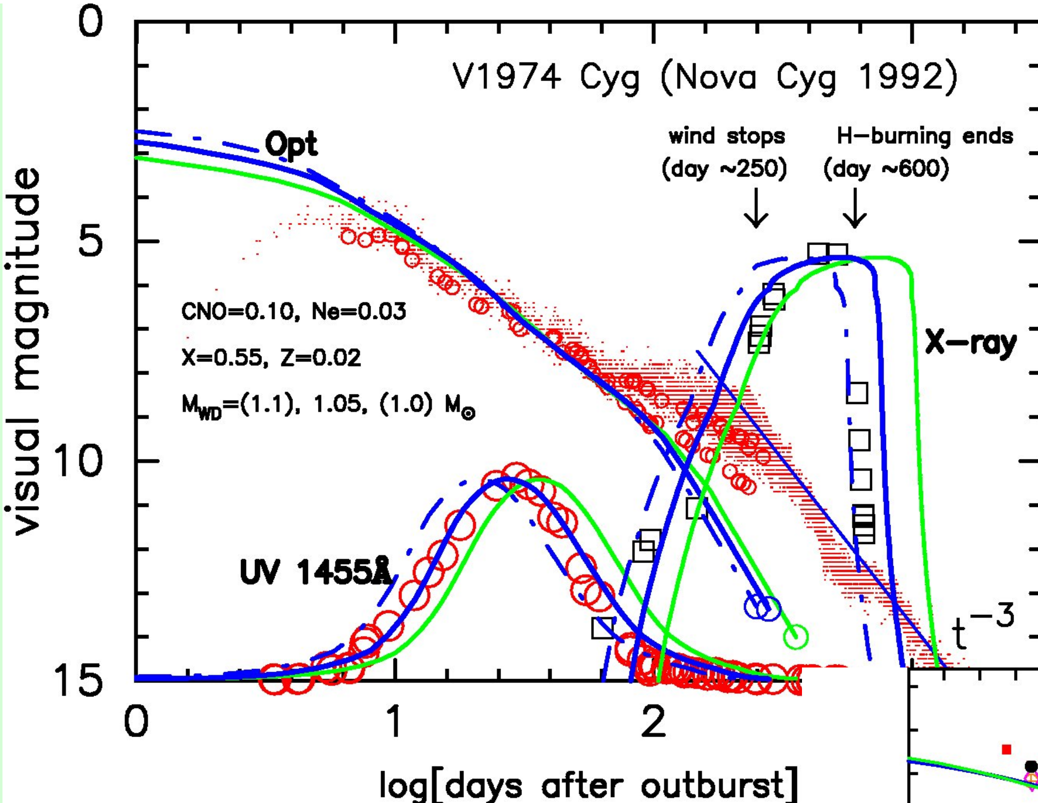
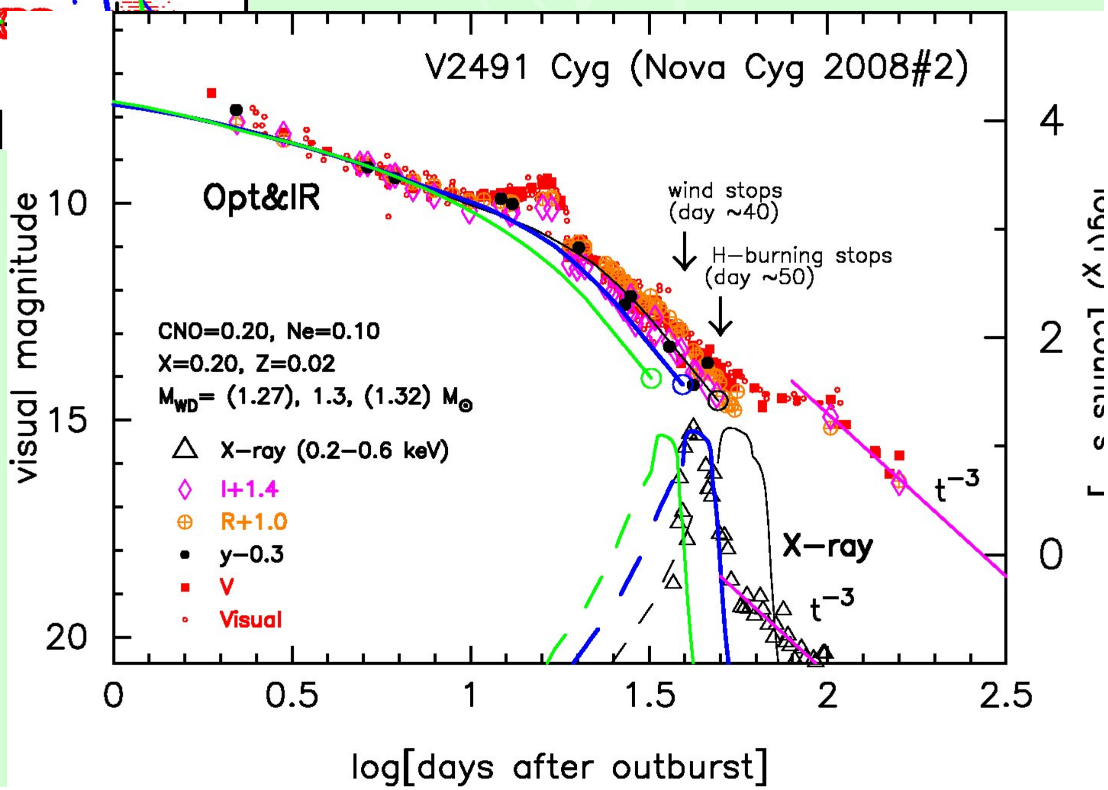


From Kato et al, 2012



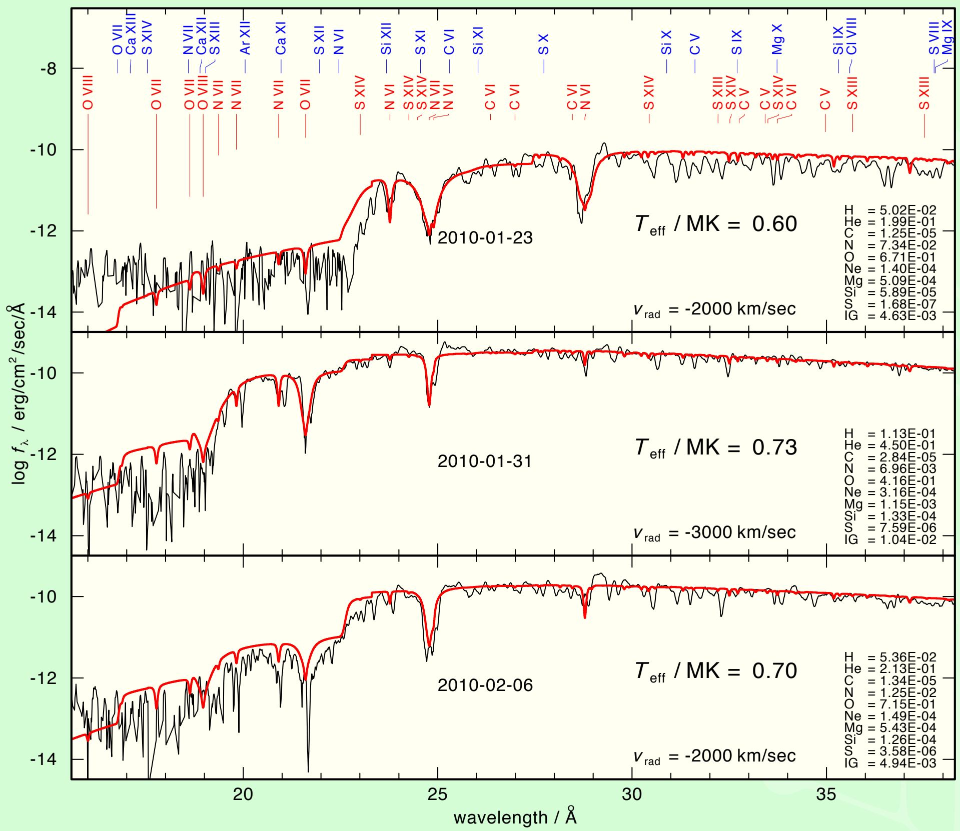
General understanding that by the time nebular lines are prominent and the SSS appears, the nova wind ceases

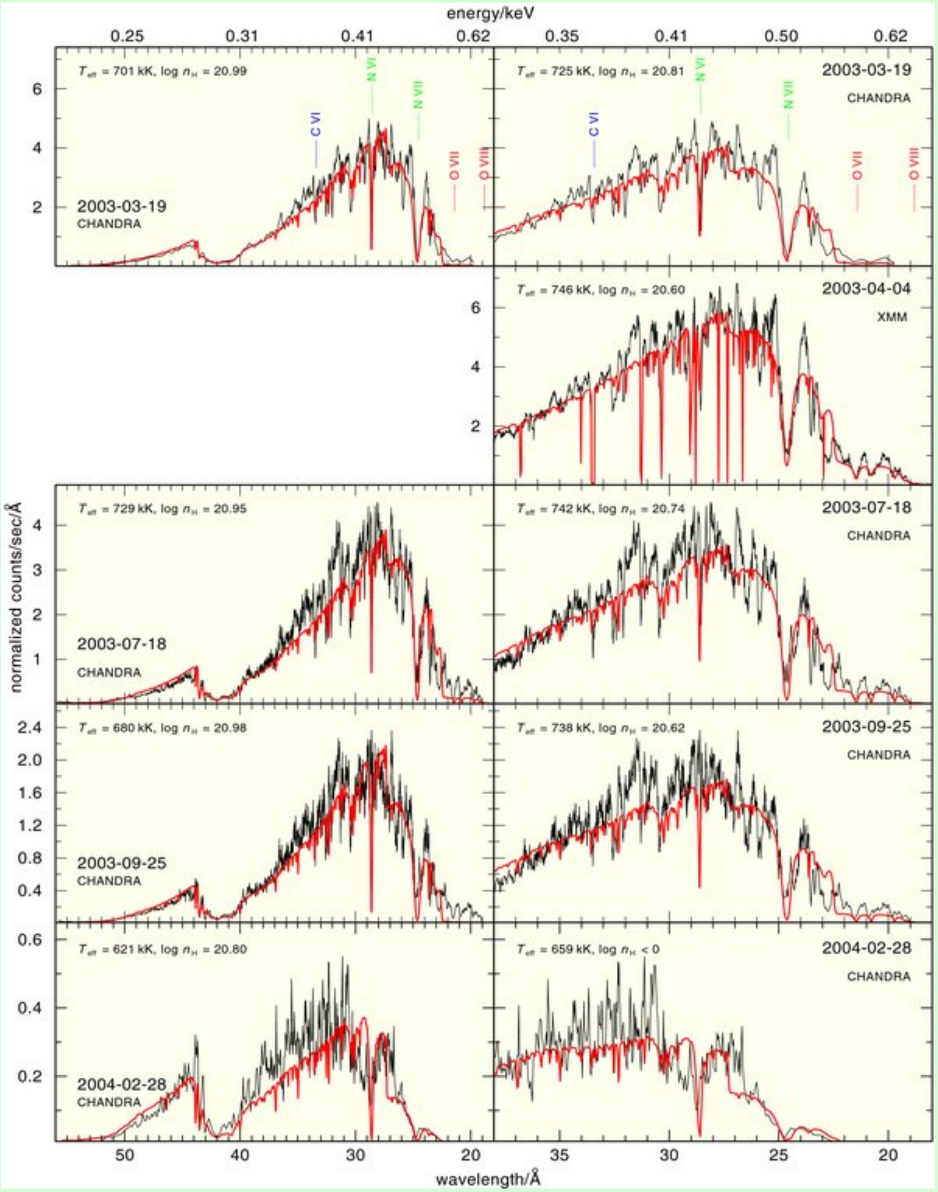
Note that the WD is very compact again when SSS is observed.

How to model the WD atmosphere?

- A blackbody is not a good fit to the continuum because at very high temperature the luminosity is overestimated by at least an order of magnitude (the opposite can be true at much lower T_{eff})
- Two basic classes of atmospheric models: static and wind
- The static models give an excellent fit to the absorption features, abundances and T_{eff} in agreement with the theoretical models
- The wind models *may be* motivated by the blue shift of the absorption lines (~2000 km/s)
- The wind models have shown that, IF there still is mass loss exceeding mdot=10^{-8} $M_{\odot}$ yr^{-1}, the wind has the effect of reducing T_{eff} and log(g) for a given luminosity. This is, of course, a big "IF"… many observational facts seem to indicate that mass loss ceases almost completely.
- In the wind models, there is a "mass degeneration" so m_{WD} cannot result from the fit.
- Emission lines are produced mostly in the outer shell, often in shocked material. We seem to have no "real" P-Cyg profiles to derive residual mass loss rates.

Rauch static models: example of KT Eri





Van Rossum:

T_{eff} =550 K, log(g)=8.18

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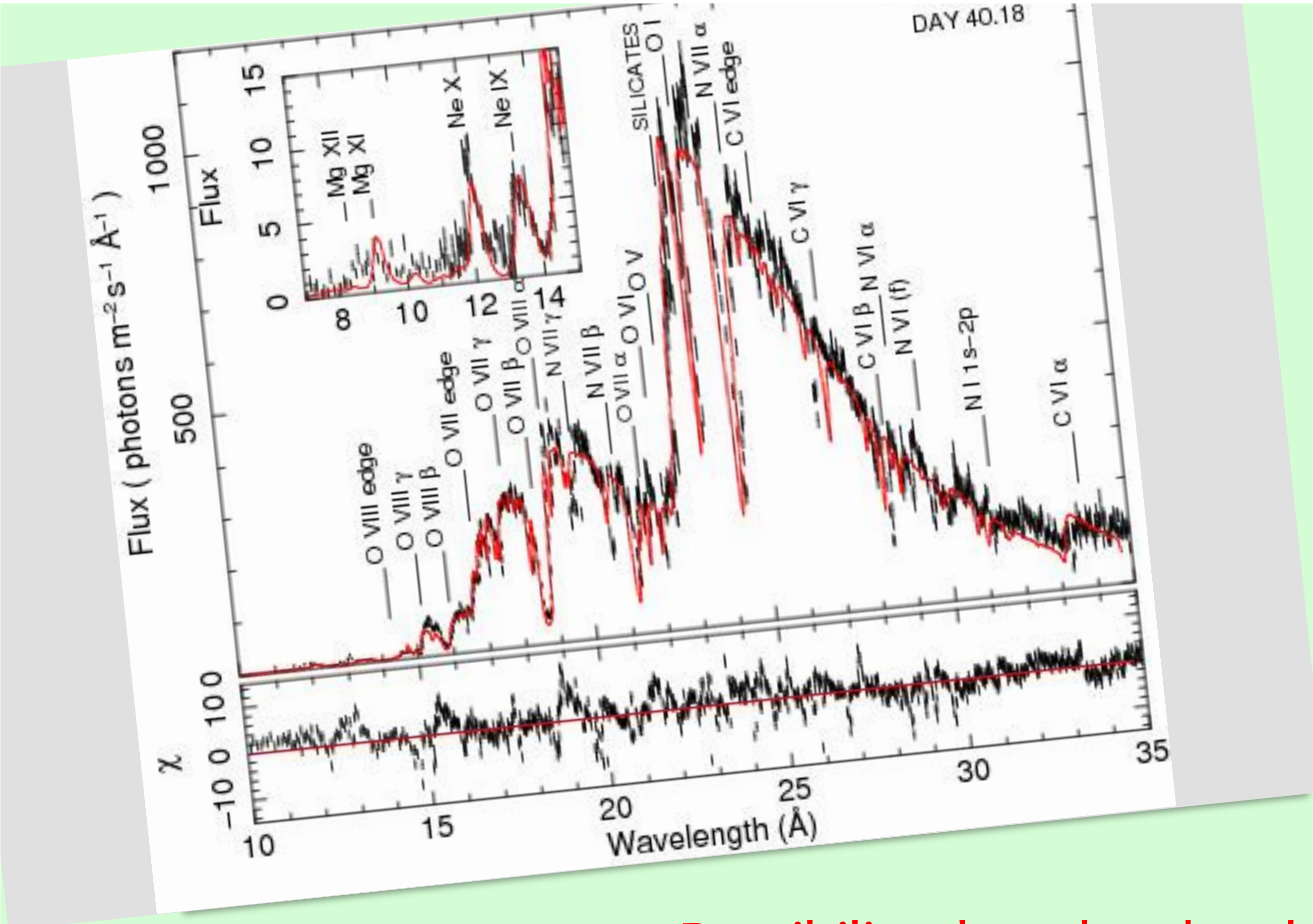
T_{eff} =550 K, log(g)=8.44

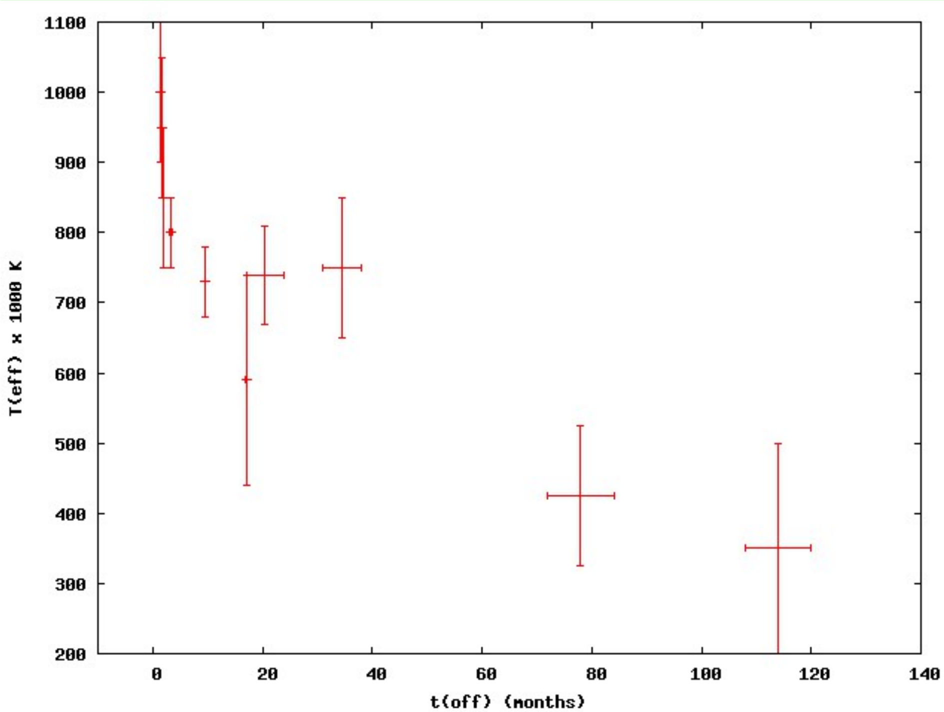
T_{eff} =475 K, log(g)=8.48

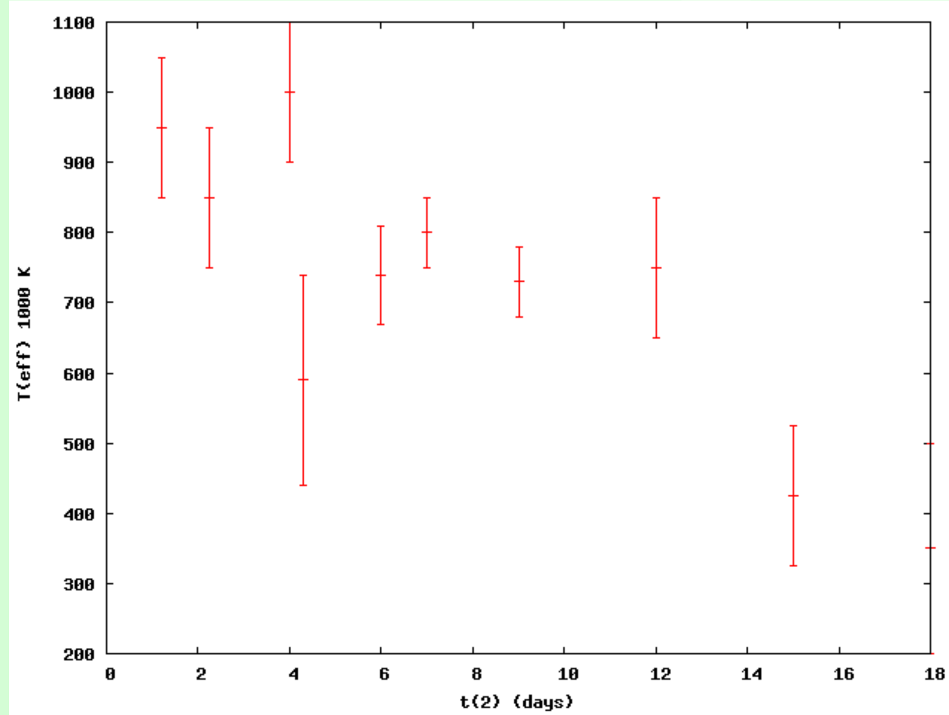


Possibility that also the absorption

originates in shock-ionized, thin outer shells?

Pinto et al. (2012) neglect emission and attribute absorption to shocks in outer shell: interesting possibility, but must be in addition to nova atmosphere…



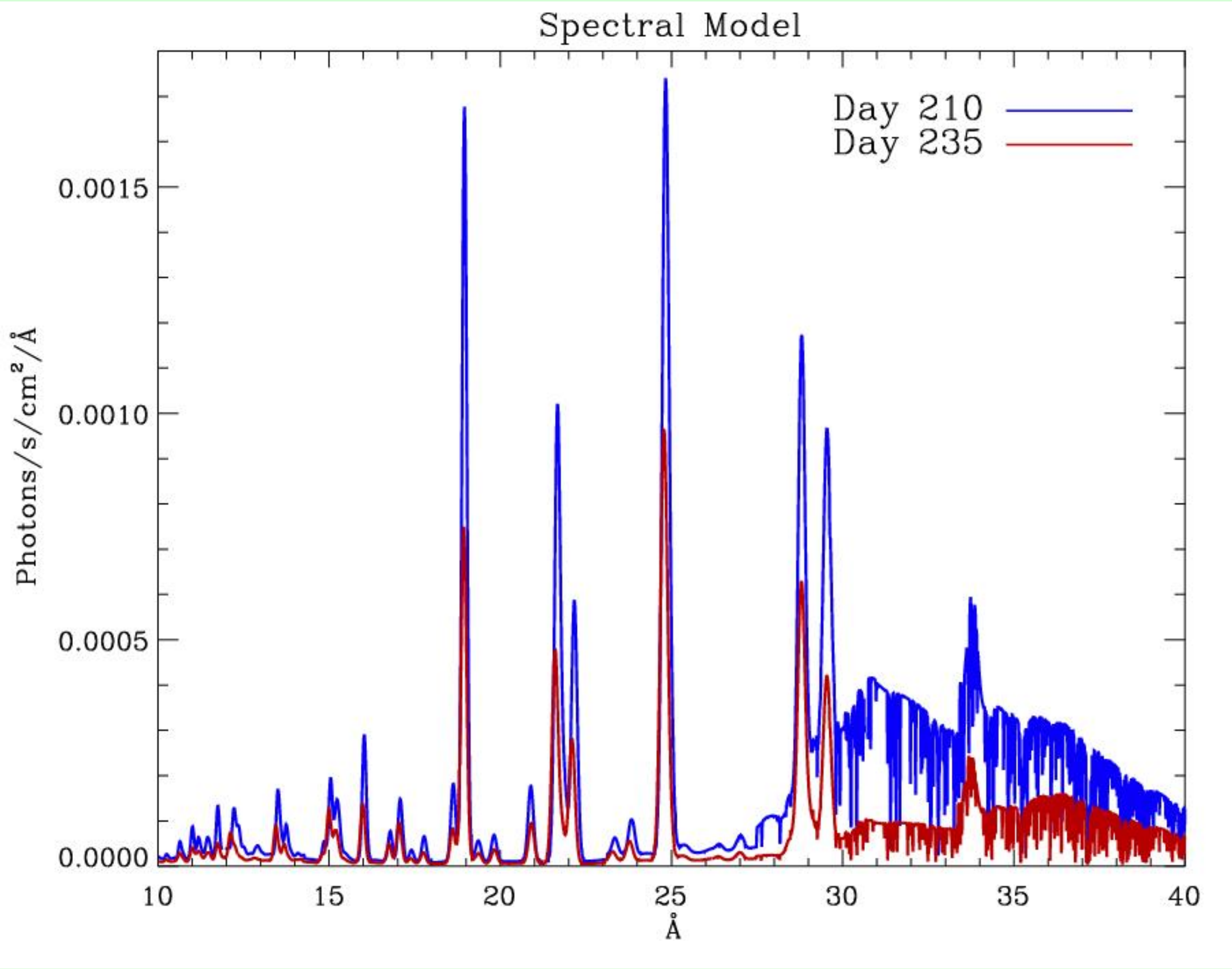


Peak effective temperature obtained with Rauch's models' fits shows expected dependence on t(turn-off) and t_2. The spread with respect to a linear relationship is expected to be due to mdot,

PLAN: try an evaluate modt for the novae in the plot as they return to quiescence. We should be able to use T_{eff} as a proxy for the mass: very important!

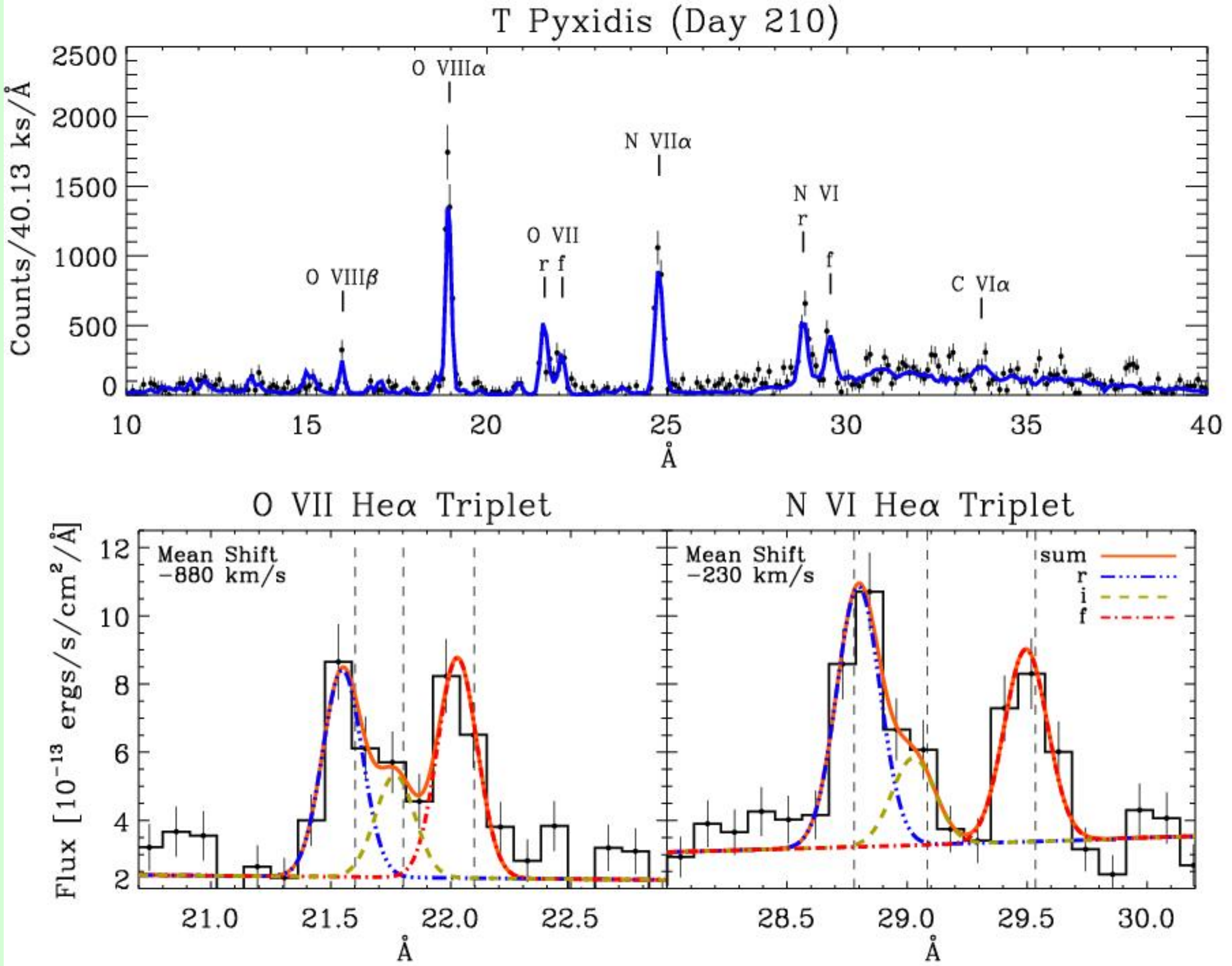
Will show now that T Pyx does not fall "well" in these plots

T Pyx: “not so hot”, yet short lived

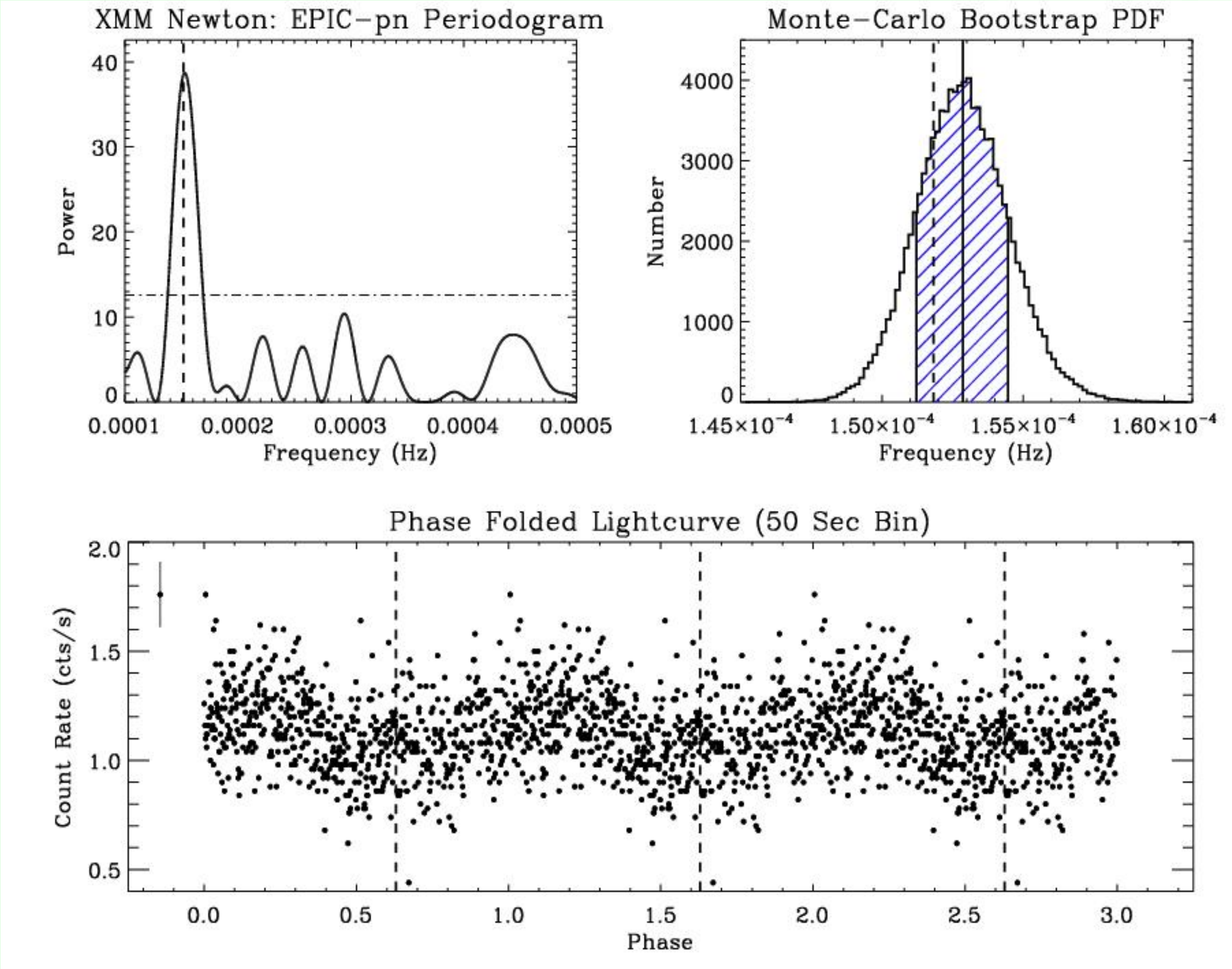


T Pyx:
The spectra are consistent with large intrinsic absorption and with T_{eff} <=500,000K, turn off between day 210 and 235.
Only case that does not fit the picture.

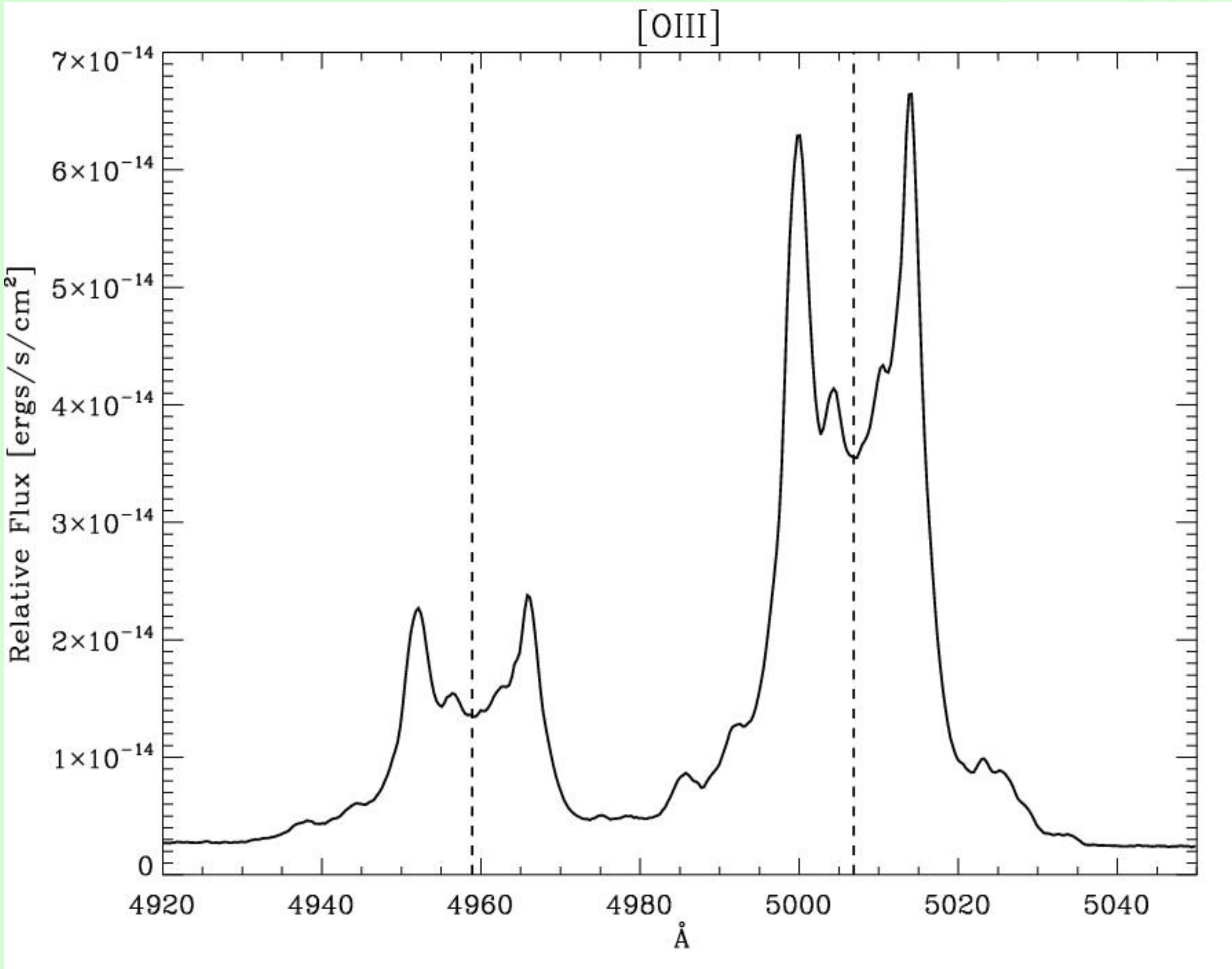
T Pyx: Chandra spectrum: evidence of shocked ejecta



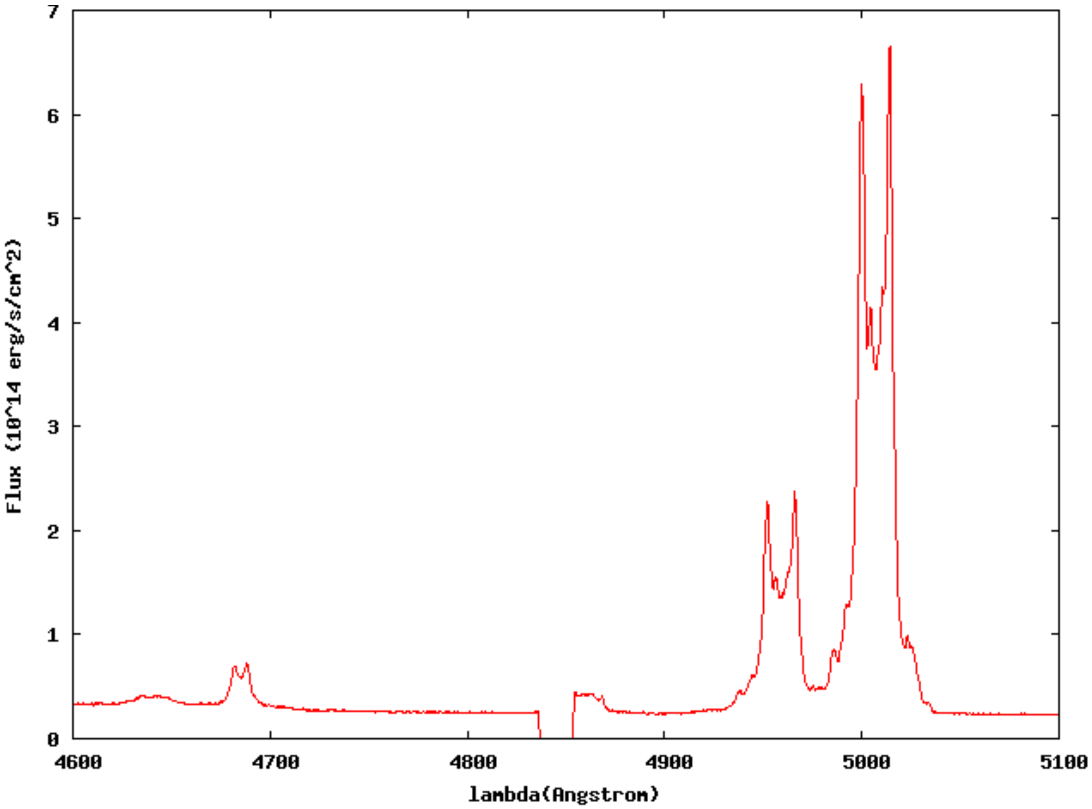
SSS X-ray clear modulation with orbital (?) period in nearly face-on system



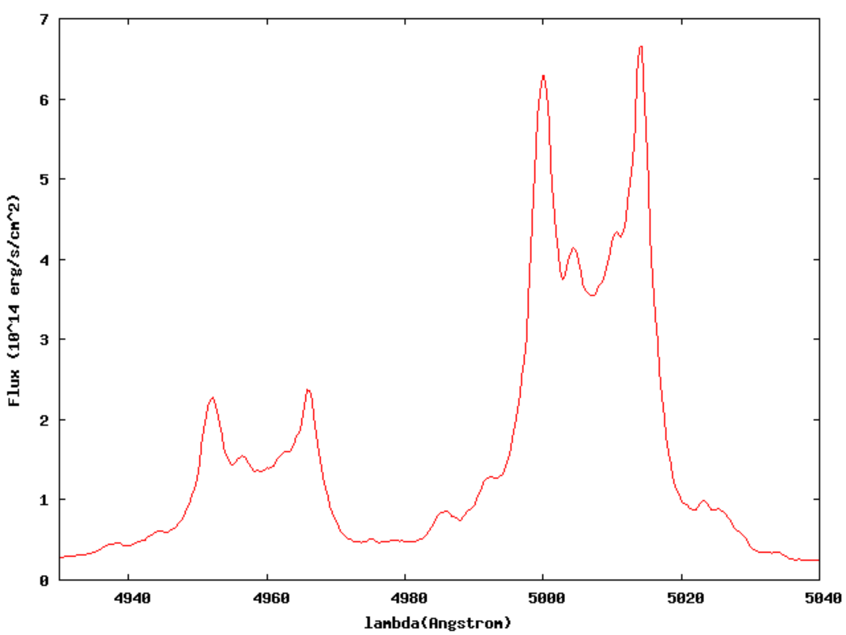
T Pyx: huge nebular lines in optical spectrum

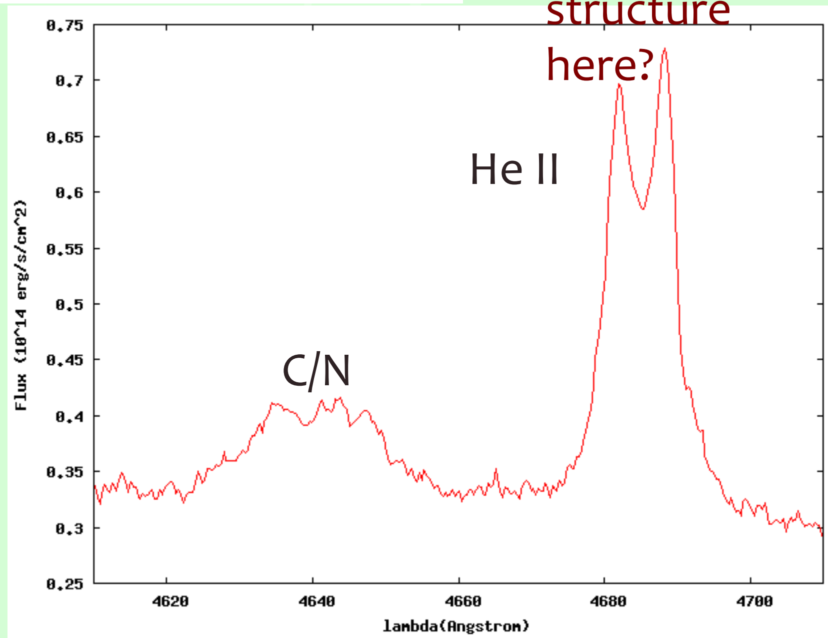


SALT observations of T Pyx December 2012



Why double Peaked structure here?

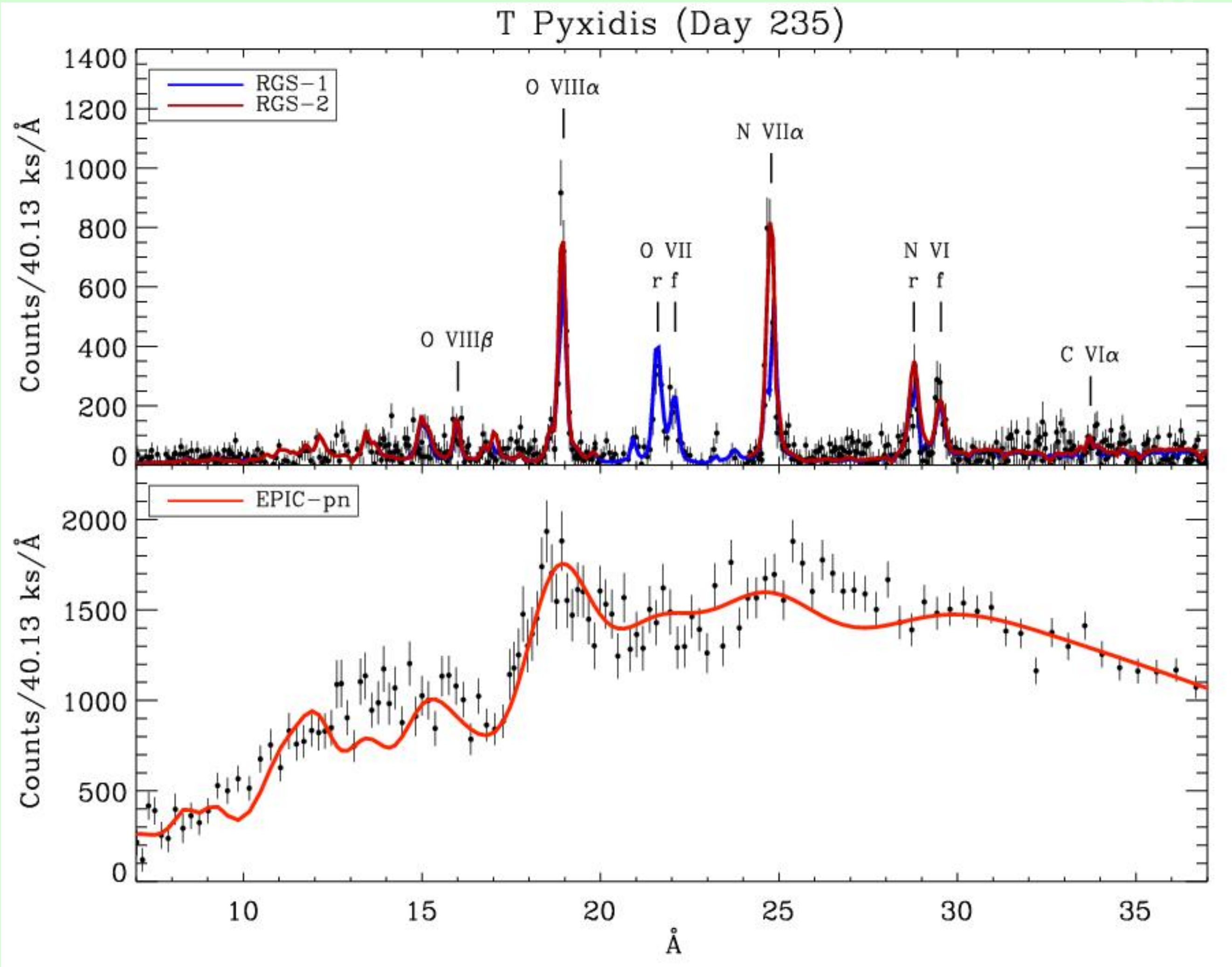




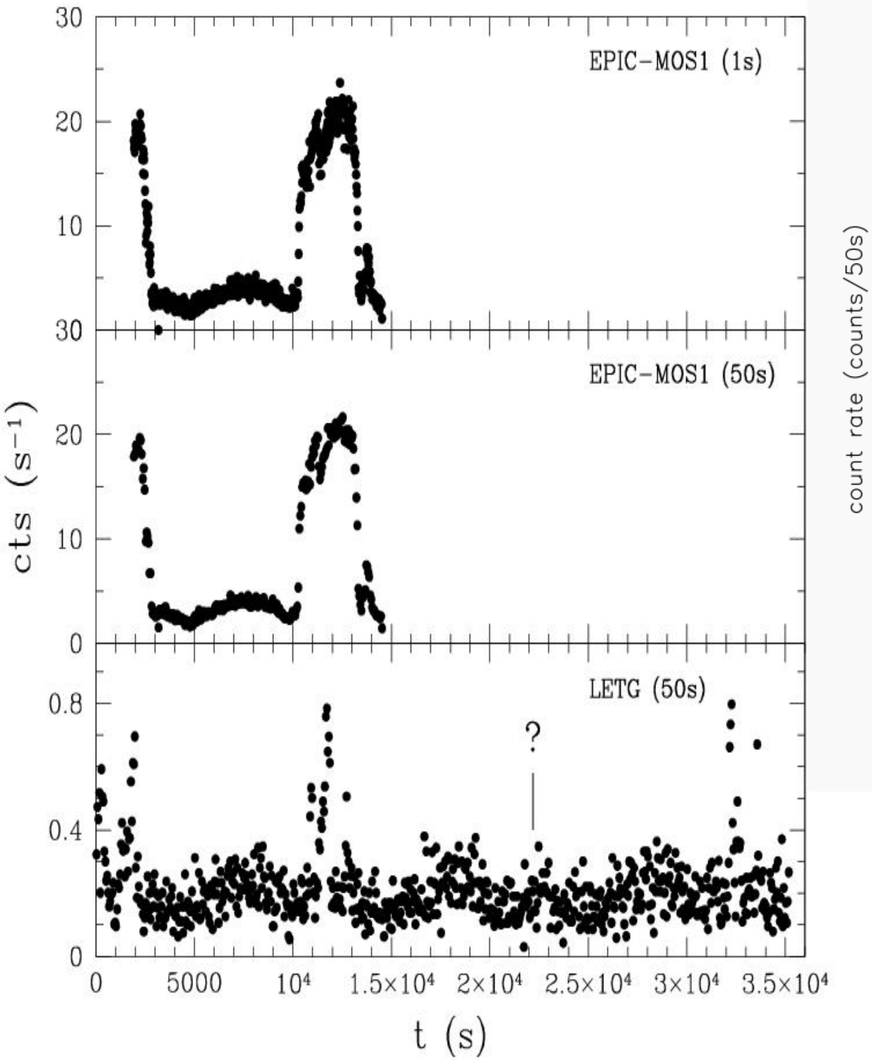
Conclusions

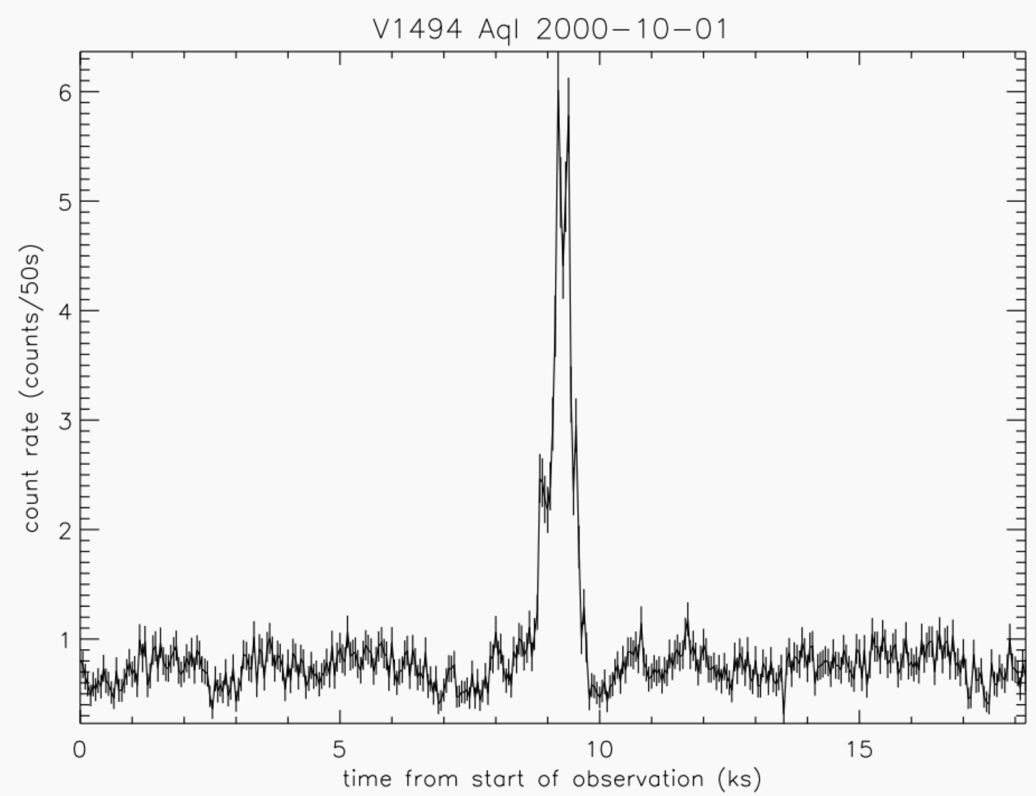
- Great importance of X-ray observations to probe mass outflow and WD mass and abundances
- Use of T_{eff} as a proxy for the mass(WD) "fully" possible if residual mdot not conspicuous. Trend of T_{eff} with outburst parameters should always be true (even with van Rossum WT models)
- X-ray gratings best way to test models and parameters' space
- Importance of X-rays monitoring + high S/N grating observations
- Models' results well tested, but… T Pyx does not fit the picture
- Must understand WD continuum variability, a "disturbing" indication of non-spherical effect and more complex physics, e.g. magnetic accretion onto the poles of the WD: non thermally homogeneous atmosphere?
- Some of this complex physics surely effects T Pyx
- What if this nova is ejecting also, and especially, mass accreted BEFORE this series of RN outbursts?
- What physical would inhibit a single "full" outburst in T Pyx?

T Pyx: XMM-Newton spectrum



V5116 Sgr vs V1494 Aql





5 times lower emission measure at minimum (T <10% higher, N(H) same?). Phenomenon repeated for months

"Stunted" flare of V5116 Sgr lasting about 1000 s, with rise time ~200 s, seen once in (almost) every orbital phase => was it the same phenomenon driving the "flare" on V1494 Aql?