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Optical and near infrared multi-site follow up of the recurrent nova T Pyx

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Abstract. We report on the spectroscopic observations of the 2011 outburst of the Recurrent Nova T Pyx. The observations were obtained over the first two months of the outburst and they were made using two different high resolution echelle spectrographs: VLT-XSHOOTER and TNG-SARG. The first observation was obtained one day after the discovery of the outburst, so that we were able to follow the evolution of the nova from the very early emission before the maximum luminosity of the nova. Such early observation allowed us to detect the transition of the nova spectral emission from a He-N to a Fe II spectrum. The multiple absorptions observed in the P-Cyg profiles suggest the presence of a clumpy wind surrounding the white dwarf. The ejecta velocities are of the order of ∼ 1600-1800 km/s, similar to the velocities reported in the previous outburst in 1966. Further observations are planned in order to follow the late behavior of this peculiar recurrent nova.

1. Introduction

On 14 April 2011 T Pyx was observed to be in outburst by Linnolt (IAUC 9205), which reported an outburst of T Pyx at V = 13.0, late confirmed by Plummer and Pearce (CBET 2700). The 2011 outburst is the sixth recorded outburst for T Pyx. Before this, the recurrence time for T Pyx was assumed to be of the or-

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der of 20 years, so the lack of an outburst after the 1966 explosion increased the interest in this source. T Pyx is a moderately fast nova (Warner 1995), with a $t_3 \approx 65$ days, and a well-known orbital period of 1.83 hr (Uthas et al. 2010), which is the shortest period for a RN, less than the period gap for cataclysmic variables (Warner 1995). The value of the white dwarf mass is still debated: Uthas et al. (2010) obtained a value of the mass of $M_{WD} = 0.7 M\odot$, with a ratio $M_{WD}/M_{comp} = 0.2$ while other estimates (Contini & Prialnik 1997), have predicted a mass for the white dwarf near to the Chandrasekhar limit, $M_{WD} = 1.25 - 1.4 M\odot$, indicating T Pyx as a possible Sn Ia progenitor. This last hypothesis however was rejected in recent years by most accurate UV and X-ray observations (Gilmozzi & Selvelli 2007; Shara et al. 1997), where the authors argued that the main contributor to the Pyx quiescent spectrum is the accretion disc and not the possible supersoft state (SSS). In particular, it was found for T Pyx an ejected mass larger than the one that it should have accreted from the last outburst, excluding any possible Sn Ia destiny for T Pyx (Selvelli et al. 2008). Another important result was provided by the HST observation of the shells discovered around T Pyx (Shara et al. 1997; Schaefer 2010). They were resolved in a large number, thousands of knots, mainly H, O and N clumps, with a maximum velocity of 40 km/s, whose origin is to be searched in the shells ejected in previous outbursts. In particular the value of the velocity suggested that the main visible shell was originated in an outburst previous than the first (1890) recorded one. After 45 years from the last outburst, the 2011 event is a unique possibility to unveil some of the cited misteries about T Pyx.

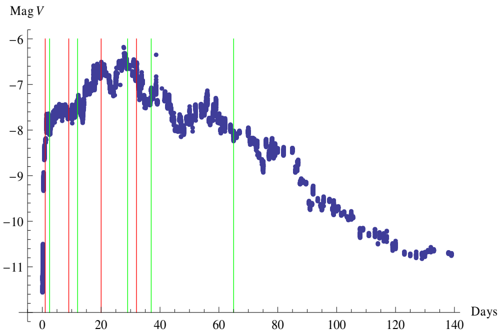

Fig. 1. Light curve of the 2011 outburst of T Pyx, obtained with the observations of the AAVSO members. The vertical lines correspond to our spectroscopic observations, as described in the text. Each color is associated with a given instrument: red lines for the SARG-TNG and green lines for XSHOOTER-VLT observations.

2. Spectroscopic observations

The light curve of the 2011 outburst is very similar to the 1966 outburst (Catchpole 1969), see Fig. 1: the emission rose rapidly to a halt, which we identify with the "shoulder" mentioned in Catchpole (1969), at about V = 7.5. Then, this initial halt was followed by a more gentle rise, and fall respectively, for several times until when the light curve started, after 40-50 days from the outburst, a phase of uniform decay with time. We obtained a first series of spectra immediately after the discovery of the outburst on 14 April, and a very large world-wide photometric follow-up was launched, together with proposed observations in different wavelenght ranges. Our work is based on the sample of spectra taken between 14 April and 17 June 2011 with two different telescopes, all equipped with high-resolution echelle spectrographs: the X-SHOOTER mounted on the 8 m VLT-UT2 and the SARG mounted on the 3.6 m TNG telescope.

The first series of spectra, Fig. 2, are characterized by several emission lines, where it is possible to note the presence of the Balmer and Helium and Nitrogen lines. In particular, the emission at 4640Å of the blend He II - N II is stronger than the Hβ line, indicating an He-N spectrum for this very early emission of T Pyx, following the Williams et al. spectral classification (Williams et al. 1991). We noted also the presence of the Ca H and K lines. It is remarkable to note that it is very difficult to have very early spectra of novae, so these first spectra are very useful in particular to study the initial fireball phase of the nova expansion

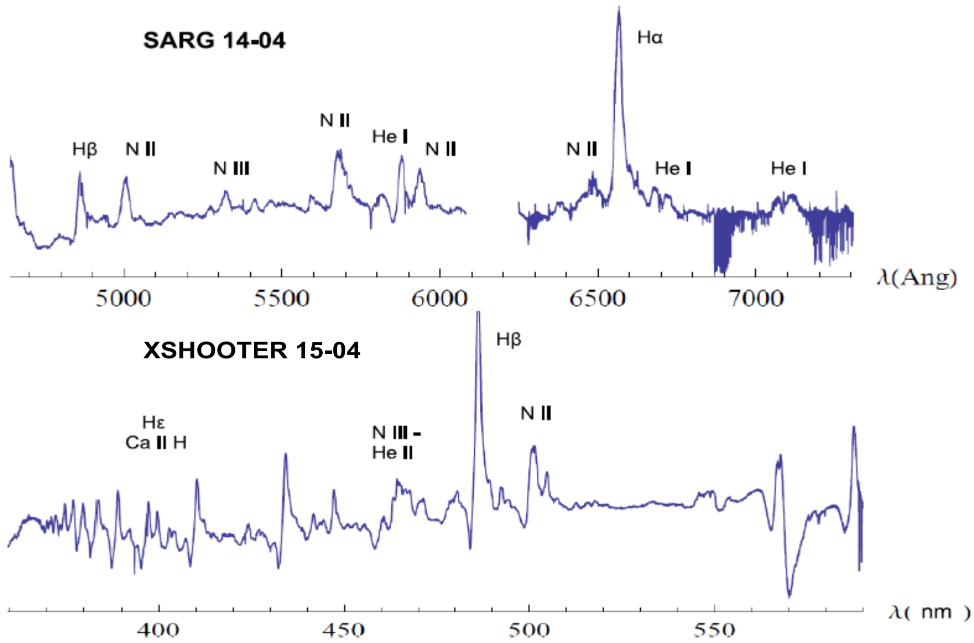

Fig. 2. T Pyx spectra obtained the nights of 14 April with SARG (upper panel) and 15 April with X-SHOOTER (lower panel). The observed features, in particular the He and N lines, mark T Pyx as a He-N nova.

(Ederoclite et al. in prep., Williams et al. in prep.).

In the spectrum obtained on 3 May, 18 days after the first series of spectra, we observed the oresence of Fe II lines and the appearance of P-Cygni profiles in the Balmer and Fe lines, while the He-N blend looked very dim. These characteristics observed in this spectrum clearly mark T Pyx as a Fe II nova.

In the days approaching the maximum, which was around the 6 of May, the evolution of the spectrum was clearly evident, with Fe lines increasing in intensity, and an evolving structure of the P-Cyg profiles, see Fig. 3. We have also noted the presence also of O and Mg emission in the far visible spectrum, which are quite common in Fe novae spectra. Particularly evident is the evolution of the Ca and Fe lines in the days around the maximum.

In the post-maximum spectra, we started to see a further evolution of Fe lines, which started to dim relatively to the Balmer lines. Also the P-Cyg profiles were almost absent for these features and, in particular, in the spectrum of the 17 June, see Fig. 4, we have seen an evolving structure around 4640Å which in the spectrum of the 17 June was clearly evident. Our possible interpretation of this feature is that it is due to a He-N blend. A similar emission was visible at 5005Å, which in this case we have associated to the N II line. Several structures were also seen in the far visible range, where it is evident the emission of the O line.

2.1. Radial velocities and P-Cyg profiles

The presence of P-Cyg profiles, 8 days after the outburst, allowed us to obtain estimates of the radial velocities of the absorbing systems surrounding the white dwarf. For our purposes we have considered the absorption systems observed in the Hβ line, as done in the work of Catchpole (1969) for the 1966 outburst. A sim-

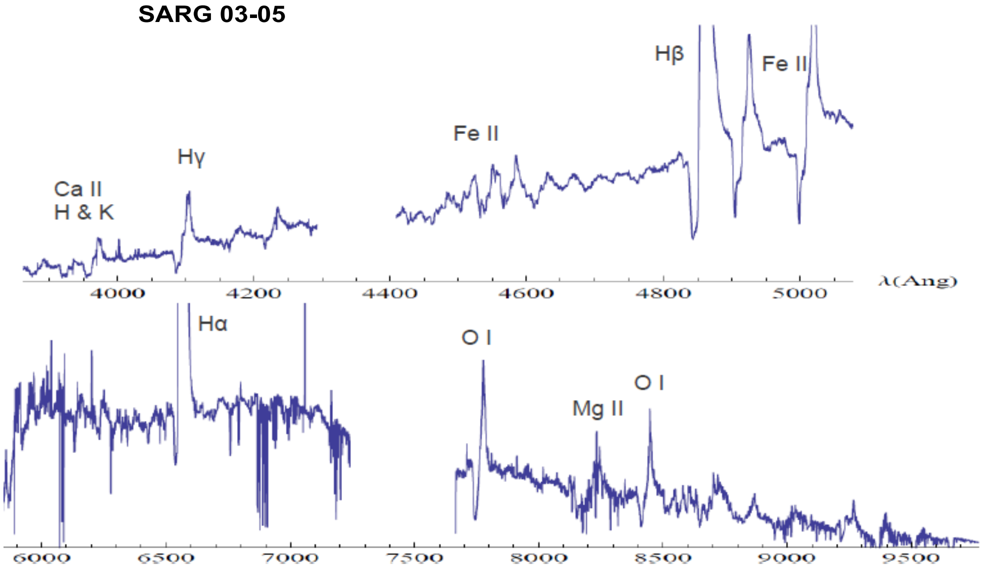

Fig. 3. T Pyx spectrum obtained the night of 3 May with SARG. It is clearly evident the apearance of Fe II lines, while the He-N blend at 4640Å is very dim.

Table 1. Heliocentric velocities of Hβ absorption systems (km/s)

14/04		n.a.		
23/04		−1272	−1132	−797
06/05			−1186	−821
15/05		−1388	−1209	−890
30/05	−1982	−1696	−1141	−896
17/06	−1942	−1712	−1263	

ilar analysis was done in Shore et al. (2011), where the authors have considered the absorbing components in the P-Cyg profiles oh the Hα line (see also ATEL 3306 and 3376). The results of our analysis is reported in Table 1, where we have observed in the late spectra the presence of absorbing systems with larger radial velocity than the early spectra. They are in agreement with the analysis of Shore et al. (2011) and with other recent nova observations, see e.g. Ederoclite et al. (2006). In particular, we observe an evolution of the Hβ profile, which became flat-topped after ~ 45 days from the outburst, see Fig. 5. A more complete and definitive analysis of this dataset, and its extension, will be presented in a future work.

3. Discussions and perspectives

We have presented a preliminar analysis of the extensive spectroscopic dataset of the 2011 outburst of the RN T Pyx. We have observed a transition in the T Pyx spectral emission from a He-N to a Fe II spectrum, while the last spectrum obtained 2 months after the outburst shows permitted lines of both He, N and Fe. Oxygen lines are also detected. However, due to sun constraints, we were not able to observe T Pyx in the last 3 months, but when T Pyx becomes visible again, we will continue our monitoring program.

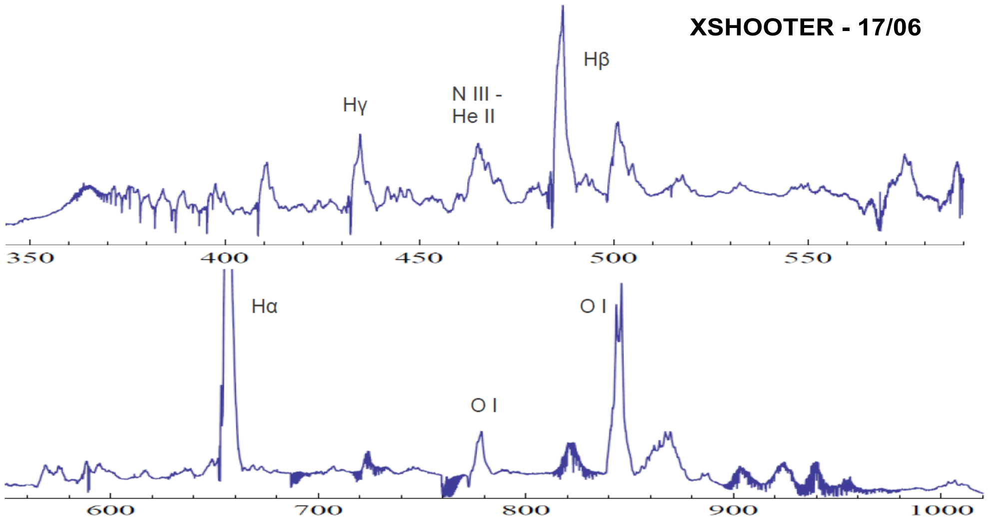

Fig. 4. T Pyx spectrum obtained the night of 17 June with XSHOOTER.

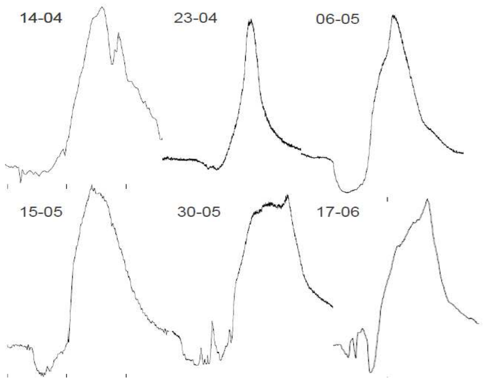

Fig. 5. Relative intensity profiles of Hβ during our observations. Note also the evolution of the P-Cyg profiles.

4. Discussion

KIM PAGE's comment: Just to let you know, Swift should be observing T Pyx every single days for the next 6 weeks or so, so we should be able to follow the super-soft X-ray emission in detailand yet a good light curve.

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