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Ionization and Recombination Timescale and the Impact on the Analysis of the PNe of VLTP progenitors

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The old planetary nebulae around the very late helium flash central stars (VLTP) V4334 Sgr and V605 Aql and the late helium flash (LTP) star FG Sge were used in the past to derive, due to the lack of any other kind of information, the physical properties of the objects before their outbursts. The argument there was the long recombination time scale for such thin media. Schönberner (2008) denotes these results as “fiction”. He argues that the ionization time scale, far below the recombination time scale, dominates the old nebula as well. But as both processes are far from equilibrium and not independent from each other, as shown here a more complex coupled analysis is required.

Ionization and Recombination Timescale and the Impact on the Analysis of the PNe of VLTP Progenitors

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The old planetary nebulae around the very late helium flash stars (VLTP) V4334 Sgr and V605 Aql and the late helium flash (LTP) star FG Sge were used in the past to derive, due to the lack of any other kind of information, the physical properties of the objects, especially L_{pre} and T_{pre} before outburst (Pollacco, 1999, MNRAS, 304, 127; Kerber et al. 1999, A&A 344, L79, Lechner & Kimeswenger, 2004, A&A, 426, L145). The argument there was the long recombination time scale for such thin media. Schönberner (2008, ASPC, 391, 139) denotes these results as "fiction". He argues that the ionization time scale, far below the recombination time scale, dominates the old nebula. But in a "reaction chain", where the input of the later process depends on the product of the first one, just the reverse applies.

$$n_e \alpha_A^{HI} = \frac{1}{t_{REC}} << \frac{1}{t_{ION}} = \frac{1}{4\pi r^2} \int_{\nu_{HI}}^{\infty} \frac{L_\nu}{h\nu} e^{-\tau_\nu} a_\nu^{HI} d\nu$$

Schönberner:

$$\frac{1}{t_{TOTAL}} = \frac{1}{t_{ION}} + \frac{1}{t_{REC}} \quad \Rightarrow \; t_{TOTAL} \cong t_{ION}$$

The "reaction chain":

$$t_{TOTAL} = t_{REC} + t_{ION} \quad \Rightarrow t_{TOTAL} \cong t_{REC}$$

Schönberner's access would imply, as the ionization time scale is a few months only, that the nebula around V4334 Sgr should have mostly vanished during the cold outburst in 1996 and should undergo steady fast evolution since 2004. Moreover the nebula around V605 Aql is now 90 years after the outburst in the state of a re-ionized shell. Both is not observed.

As the figures on the right show, the objects are assumed to undergo a rapid loss in luminosity just after the flash. This phase is like "switching off" the central star. But as recombination and re-ionization processes are far from equilibrium and not independent, a complex coupled analysis is required.

The radiative recombination of O III gives the shortest timescale of a few tenths of years only. As discussed already in Lechner & Kimeswenger (2004), this ion is coupled via the Bowen fluorescence to Helium. This process removes energy from ionized Helium in the nebula during the recombination.

The frequent heavy elements (C, N, O, Ne, Mg, S, Ar) are twice ionized in such a nebula before the flash. The recombination photons to the single ionized state exceed 13.6 eV. For N, O, Ne and Ar this even applies for the transition to the neutral state. Thus only forbidden lines are contributing significantly to additional cooling beside the processes included into the α_A of the isolated ion.

Thus their fluxes give a good quantitative estimate for the change of the recombination time scale. While O III recombines within 10-30 years, strongly depending on the density, the other ions are hardly influenced. Once O III → O II has taken place, the cooling of Helium via the Bowen mechanism stops also. Calculations showed that thus the total Helium recombination does not change much.

I found that the O recombination fakes via the ratio of $[OIII]_{5007,4363}$ / $[OII]_{3727/29}$ a wrong Oxygen abundance and thus the parameters L_{pre} and T_{pre} too are to high about 20 and 5 % respectively.

In case of the older flash V605 Aql re-ionization UV radiation leaking through the bipolar lobes (Kimeswenger et al., 2008, ASPC, 391, 177) "reduce" the effect. As a the nebula in fact shows a different geometry axis in $[O\ III]_{5007}$ than in H_α this indeed might be a signature (orientation of the dust torus). We intend to investigate this by spectra in different directions.

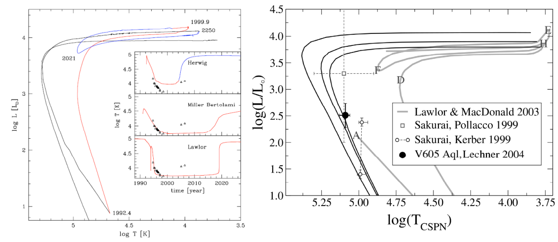

Fig.1: Left: The flash model of Herwig (2001, ApJ, 554, L71) inserted to a HRD (from van Hoof et al., 2007, A&A 471, L9) . Right: The flash model of Lawlor & MacDonald (2003, ApJ, 583, 913) together with CLOUDY model results of the old PNe (from Lechner & Kimeswenger, 2004).

Static modelling with CLOUDY during the track through the HRD (using ATLAS model atmospheres) near the hot high luminosity point 2 to 5 years after the flash showed, that a strong pumping of [O III] and [Ne III] lines, far above those found in the spectra, starting at L = 4000 $L_\odot$ occurs, if the temperature exceeds 55 kK. This limit might move slightly, if we use different stellar surface abundances (Armsdorfer et al. 2003, IAUS, 209, 511). As shown by Kimeswenger & Koller (2002, Ap&SS, 279, 149) for V4334 Sgr with ISO data there was no strong dust shell during this phase blocking the UV.

Conclusions:

The Parameters of the pre flash stars obtained by static photo-ionizing models of the old nebula reveal the history of the objects rather well. Small corrections to slightly lower luminosities and temperatures and thus to higher ages have to be applied.

The missing strong "re-ignition" of [O III] during the HRD path a few years after the flash (pos. D in fig. 1) makes the track of Herwig (2001) (> 55 kK) very unlikely. The object was most likely cooler at that time.

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Calculations were performed with version 08.00 of CLOUDY, last described by Ferland et al. (1998, PASP, 110, 761)

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