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Search for mass-ejections from late He-shell flash stars

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H-deficient post-AGB stars are the result of a (very) late thermal pulse (VLTP). The particular time of the He-shell flash determines the amount of H remaining in the stellar envelope.

In case of a VLTP, H is mixed downward by the He-shell ignition and begins to burn as soon as it reaches depths hot enough. These so-called H-ingestion flashes cause excessively-high convective velocities, and it is possible that H-deficient blobs shoot out from the He-shell flash convection zone. In a LTP, no such large convection velocities are possible. The detection of H-deficient knots around H-deficient post-AGB stars allow to constrain the evolutionary scenario of these stars.

We report on *HST* and VLT imaging of H-deficient PG 1159 stars.

Search for Mass-Ejections from Late He-Shell Flash Stars

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H-deficient post-AGB stars are the result of a (very) late thermal pulse (VLTP). The particular time of the He-shell flash determines the amount of H remaining in the stellar envelope. In case of a VLTP (star already at the white-dwarf cooling track, nuclear burning ceased), H is mixed downward by the He-shell ignition and begins to burn as soon as it reaches depths hot enough. These so-called H-ingestion flashes cause excessively high convective velocities, and it is possible that H-deficient blobs shoot out from the He-shell flash convection zone. In a LTP (after descend from the AGB, at still high luminosity), no such large convection velocities are possible. The detection of H-deficient knots around H-deficient post-AGB stars would allow to constrain the evolutionary scenario of these stars.

Model Predictions

The modeling of a VLTP is particularly challenging because of the violent convective/reactive processes. H, mixed downward by the He-shell ignition, begins to burn as soon as it reaches depths hot enough. It occurs a so-called Hydrogen-Ingestion Flash (Herwig et al. 2006). Up to now this complex process is simulated only with parameterized, quasi-static 1D models, but it seems clear that hydrodynamical simulations will give different results concerning the course of burning and mixing of material. We have recently begun 3D hydro-simulations for convective/reactive flows relevant for evolutionary calculations of a VLTP. Since such simulations in the context of pAGB-evolution are the very first steps to describe the physics in a more realistic manner, we are seeking for observational benchmarks. One such benchmark is the observed surface abundance pattern of H-deficient pAGB stars mentioned above. Another complementary benchmark is the influence of a He-shell flash on the circumstellar environment. It is based on the discovery of H-deficient nebular knots in the close vicinity of two H-deficient central stars, Abell 30 and Abell 78 (e.g. Borkowski at al. 1993), being [WC]/PG1159 transition-type objects. The knots recede from the stars with about 200 km/s, which is much higher than the escape velocity from an AGB star (about 20 km/s), but much lower than the escape velocity from the compact central stars (about 4000 km/s, that is roughly the terminal velocity of their radiatively driven winds). The knots are located in the innermost parts of the (otherwise H-rich) PN (Fig. 1). It is unclear how the clumps of H-deficient material have left the star.

We hypothesize that the H-deficient knots were expelled immediately after the onset of the VLTP. Our hydrodynamical models show that material can exceed the escape velocity while the star is on its way back from the white dwarf to the AGB stage. This can explain the intermediate velocity of the knots. The local confinement of the high convective velocities can explain the non-spherical clumpy mass-loss. Fig. 2 is a snapshot of our simulations. We see a blob rising with about 10000 km/s and forming a shock at the leading edge. The corresponding energy generation clearly shows that we see a detonation here. We are not be too concerned about the fact that 10000 km/s is much more than what is observed for the blob velocities in Abell 30/78. As explained with Fig. 2, our models are still immature, and the only thing they motivate is that H-deficient blobs shooting out from the He-shell flash convection during a HIF seems possible.

Observations

We employed WFPC2@HST with filter F502N to observe the vicinity of the central stars of Longmore 4, NGC 246, K 1-16, RX J2117.1+3412, and PG 1144+005 (exposure times 1200 - 2300 s). In addition, we used NACO@VLT with filters Ks and NB1.08 to image Longmore 4, NGC 246, PG 1159-035, HE 1429-1209, and PG 1144+005 (exposure times 3600 s).
The HST observation were performed from June 2007 to January 2008. The VLT images were obtained from April to June 2007. We used IRAF for the elimination of cosmic-ray features and to add multiple observations in order to increase the S/N ratio.

Results

The search was entirely negative. Neither radial structures nor any weak emission were detected.

Explanations?

Our negative result is as yet unexplained. It is unlikely that all of our objects experienced a LTP.

References
Borkowski et al. 1993, ApJ, 415, L47
Borkowski et al. 1995, ApJ, 449, L143
Herwig et al. 2006, ApJ, 642, 1057

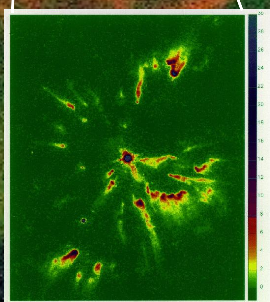

Figure 1. [O III] 5007Å WFPC2 image of A 30 (from Borkowski et al. 1995). The FOV is 15.2" × 18.5". The intensity scale is cts/px.

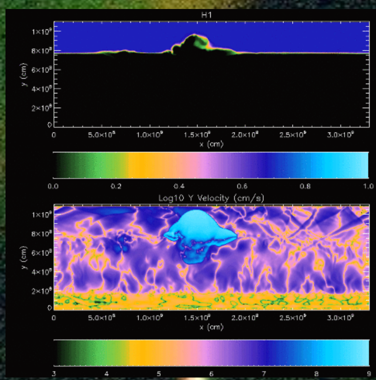

Figure 2. Snapshot from a hydrodynamical simulation of a hydrogen-ingestion flash (HIF) triggered by a late He-shell flash. Top panel: A H-free blob starts to rise driven by the rapid energy release from burning due to H ingestion (displayed is the chemical stratification). The lower boundary of the H-rich zone is the upper boundary of the He-shell flash convection. The lower boundary of the He-shell flash convection can be seen in the lower panel that shows the vertical velocity. The marked jump in the lower half of the box represents the bottom of the He-shell flash convection zone. The velocity plot clearly shows a blob with about 10000 km/s rising to the top, and forming a shock at the leading edge. At this point, we have to classify the present simulation as a toy model because there are many things that are not realistic enough, including some scaling of energy generation rates, as well as details about the flame treatment, turbulent mixing, the setup itself, 2D and boundary effects. Nevertheless, all of these simplifications are not so major as to not take this preliminary result as a possibility that we can not exclude that H-deficient blobs around H-deficient post-VLTP stars (= PG1159 stars) can have their origin in these convective burning events that define the VLTP.

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Background image of PN A66 30: http://fuse.pha.jhu.edu/~wpb/abell30