Variability of Planetary Nebula Nuclei: pulsation, rotation, winds and binarity

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Variability of Planetary Nebula Nuclei (PNN) yields important constraints on the astrophysical properties of the stars, but also on the nebulae.

- The interior structure of *pulsating PNN* may be revealed applying the methods of asteroseismology, if multiperiodic pulsations are present. Indeed, there are several hot PNN that are known pulsators. They occupy the same instability strip as the pulsating DO white dwarfs (GW Vir stars), hence their periods are similar to those of pulsating white dwarf stars. The oscillations are multiperiodic, but the pulsation spectra are often temporally unstable, requiring essentially gap-free monitoring as provided by *Kepler*. Only one of these pulsating PNN could be asteroseismically sounded until now (Córsico et al. 2007, A&A 461, 1095). Enlarging this number would greatly aid the understanding of pre-white dwarf stars.

  A different group of PNN lies within the β Cephei instability strip. These objects are cooler than the ones previously described. Their pulsational variability has been theoretically predicted, but not yet observationally confirmed, perhaps due to camouflage by their strong winds. Detection of pulsation and perhaps a measurement of period changes (not necessarily with *Kepler* only) would measure their evolutionary speed and constrain their masses.

- *Rotationally variable* PNN allow to determine the spatial orientation of their rotation axes. This is important to understand the shape of the surrounding nebulae in 3D, and to assess the probability of the presence of a post common-envelope binary companion (see below). Previous *Kepler* data have enabled such a study (Handler et al. 2013, MNRAS 430, 2923).

- Variations in PNN *mass loss* are believed to be caused by the same mechanism as in main-sequence O stars: the presence Co-rotating Interaction Regions (CIRs) rooted close to or at the stellar photosphere. The formation of CIRs themselves may be due to magnetic fields, nonradial pulsations, or sub-surface convection. The photometric variations of these stars are dominated by irregular variations on time scales of hours, and effectively mask possible underlying periodic signals. Therefore, again, nearly gap-free and precise observations are required, and have successfully been obtained by *Kepler* (Handler et al. 2013, op. cit.).

- *Binarity* of PNN is one of the hot topics in PN research. In particular, it aids the understanding of Common-envelope (CE) evolution, and hence that of different types of post-CE binaries including Supernova Ia progenitors and low-mass X-ray binaries. Post-CE PNN can be readily detected through their light variability. Another important question is the formation of aspheric PN morphologies, thought to be due to close-binary PNN. However, the fraction of known close-binary PNN is much too low to explain these. *Kepler* observations would help to fix this number.

The possible boresights for Kepler Field 0 contain several PNN. We carefully selected only confirmed post-AGB central stars. These comprise one GW Vir pulsator (NGC 2371, Ciardullo & Bond 1996, AJ 111, 2332; highest priority, short cadence), one PNN with variable mass loss (NGC 2392, Handler 1996, IBVS 4283; high priority, long cadence), and nine other PNN that to our knowledge are as yet unstudied for variability (long cadence). The associated target list is ordered accordingly.