K2 Observations of Central Stars of Planetary Nebulae

Investigators: Howard E. Bond & Robin Ciardullo (heb11@psu.edu, rbc@astro.psu.edu)
Investigator Institution: Dept. of Astronomy & Astrophysics, Pennsylvania State University

As a low- or intermediate-mass star nears the end of its life, it leaves the asymptotic giant branch by ejecting its outer layers, evolving across the HR diagram, and photoionizing the ejected envelope to produce a planetary nebula (PN). Thus studies of planetary-nebula nuclei (PNNi) provide important information on the final fates of stars like our Sun.

Beginning in the late 1980's, we pioneered studies of variability of PNNi using digital detectors on ground-based telescopes (e.g., Bond & Ciardullo 1989; Bond et al. 1996; Ciardullo & Bond 1996). We found that there is a wealth of photometric variability of PNNi, including these:

• **Close binaries**: An appreciable fraction, about 10–20%, of randomly chosen PNNi prove to be close binaries (e.g., Bond 2000; Miszalski et al. 2009) with periods of a fraction of a day to a few days. These are the "smoking guns" that prove the existence of a common-envelope phase in binary-star evolution. In this scenario, one component of an initially wide binary swallows a companion, which then spirals down inside the envelope and finally ejects it, exposing the hot core of the primary and ionizing the ejecta. These studies have had a major impact on the field, establishing that binary interactions are a major formation channel of PNe as well as producing their complex shapes. Variability sometimes exceeding 1 mag can be seen in the closest binaries because of heating effects, even if the system does not eclipse. However, as the orbital period increases to several days, this "reflection effect" declines to very small values and is very difficult to detect from a single ground site.

• **Pulsators**: We discovered several members of a class of short-period pulsating PNNi. These are hydrogen-deficient stars, pulsating in nonradial g-modes with amplitudes as large as $\sim$0.1 mag. Follow-up asteroseismological studies have allowed mode identification, mass determinations, and potentially the real-time detection of stellar evolution through changes in the pulsation periods as the PNN cools. *Kepler* has a real advantage here because of its ability to attain a long time-series.

• **"Irregular" variables**: The least-understood class of PNN variables are those that slowly vary by as much as 0.1 mag on a timescale of hours. They are particularly difficult to observe from single sites on the ground, but they may be related to variability in the stellar-wind outflows. *Kepler* observations over several months would provide a wealth of new information on this phenomenon.

We propose photometric monitoring of PNNi in the K2 field, and of similar objects should the *Kepler* program progress around the zodiac. There are 4 PNNi in the nominal K2 field (the first 4 in the accompanying target list), two of which are members of the hydrogen-deficient class and candidate pulsators. There are 7 more candidate PNNi out to a radius of 12 degrees from the nominal center, comprising the remainder of our proposed target list (including NGC 2371, a known pulsator found in our 1996 survey, and K 2-2, which we suspected of binarity but were unable to confirm). A one-minute cadence would be desirable for the pulsator candidates, and 30 min would be used for the rest.

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