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Pulsations in the Nucleus of Planetary Nebula IC 418?

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Abstract. IC 418 belongs to the group of about a dozen planetary nebulae with central stars that show irregular spectroscopic and photometric variations. Recent theoretical results provide arguments that this group may constitute a new class of pulsators. We present new photometric observations of the nucleus of IC 418 showing variations with a timescale of about 1/4 day. We discuss two possible explanations of the observed phenomena: pulsational instability and an unstable wind.

1. Introduction

The planetary nebula IC 418 contains the relatively bright ($V = 10^m$) nucleus HD 35914, classified as O7f. HD 35914 is a prototype star of a recently proposed class of variable PNN (planetary nebula nuclei). This group include nuclei of He 2-131, He 2-138, PB 8, NGC 2392, IC 4593, NGC 6826, NGC 6543, Hu 2-1, IC 3568, NGC 40, IC 2149. The common characteristics of these objects are:

- presence of a compact, bright nebula
- effective temperature between 27000 and 50000 K
- spectral type mostly between O4f and O7f
- presence of strong stellar wind
- short-term radial velocity variations
- photometric variability of low amplitude over timescales of several hours
- observed variations are not strictly periodic.

Photometric variations of PNN are usually due to either hemispheric heating and/or eclipses produced in binaries or nonradial g-mode pulsations present in extremely hot pre-white dwarfs. IC 418 - like PNN constitute a separate class, still waiting for a complete observational and theoretical description.

In an exploratory investigation of the linear stability of envelopes of post-AGB stars Gautschy (1993) used new stellar opacity tables and observational constraints to model the nucleus of IC 418. It turned out that instability of the fundamental radial pulsation is possible in this star. From his modal diagram one can find that the theoretical period of pulsations of HD 35914 should be in the range from $0.^d15$ to $0.^d32$.

2. Observations and a search for periodicity

We analyzed the differential photometry of HD 35914 obtained at Mt. Suhora Observatory in 1989 (on 2 consecutive nights) as well as observations obtained by Jerzykiewicz (1994) at the South African Astronomical Observatory in 1991 (3 consecutive nights). The maximum range of variations of the central star together with the surrounding nebula reached $0.^{m}053$ in the U filter.

We examined the observations for the presence of periodicities by means of Fourier analysis. For observations from 1991 the dominant spike in the power spectrum appears at frequency corresponding to the period of about 6^{h}, which is consistent with a period found by Mendez et al. (1983) in their investigation of photospheric radial velocities (cf. also Handler et al., 1995). However, the results for our observations from 1989 do not confirm this frequency, although they also show variations on a timescale of several hours (Kuczawska et al. 1995).

3. Discussion

No single period can fit all of our observational runs, implying that we have to do with either multimodal or irregular phenomenon. Apart from pulsational instability driven by the κ-mechanism (Gautschy 1993) a key role in the observed variations may also play a fact that all IC 418 - like PNN show strong observational evidence of mass outflow via a radiatively driven stellar wind. Such an outflow can be highly unstable against even small changes in photospheric parameters, as it has been demonstrated by theoretical models (Owocki et al. 1988, Rybicki et al. 1990, Pauldrach & Puls 1990). The source of the initial fluctuation can be stellar pulsations. In accordance with such models, the photometric variations of the nucleus of IC 418 could be at least partially ascribed to the changes in optical thickness caused by the formation and propagation of dense shells or clumps above photospheric level. The analogous continuum light variations have been observed for WR stars (Drissen et al. 1989).

Longer series of continuous data are obviously needed to determine whether the nucleus of IC 418 along with similar PNN constitute a new class of pulsators.

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