CLOSE BINARY (AND PULSATING) NUCLEI
OF PLANETARY NEBULAE

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Close-binary central stars of planetary nebulae are of interest to participants in this Colloquium because of recent suggestions that the cataclysmic binaries, containing a white dwarf and a lower-main-sequence star, may be descended from such objects (e.g. Paczynski 1976; Ritter 1976; Webbink 1978; Meyer and Meyer-Hofmeister 1978; Livio, Salzman, and Shaviv 1979). The proposed scenario is that a binary system of initially large separation (P = 1-10 yr) forms a "common-envelope" binary after the primary has evolved to the red-giant stage and developed a degenerate core. The secondary star spirals inward inside the red-giant envelope, eventually transferring enough angular momentum to the envelope to eject it. The result is a close binary containing the hot degenerate core of the red giant and a cool main-sequence companion, surrounded by the ejected envelope, which is ionized by the hotter star. Much later, when the cool companion begins to evolve, it will start to transfer matter to the hot star (by now a white dwarf), and cataclysmic activity ensues.

Considerable support for such a scenario comes from the writer's discovery (Bond 1976) that the eclipsing binary UU Sagittae is identical with the central star of the planetary nebula Abell 63. Subsequent investigations (Miller, Krzeminski, and Priedhorsky 1976; Bond, Liller, and Mannery 1978) have shown the orbital period to be 11^h10^m. The eclipses of the O-type primary are total and are due to a secondary star that is inferred to be a K-type dwarf. The hemisphere of the K star facing the hot star is heated to about 10000 K, producing a "hump" about 0.25 mag high near phase 0.5 of the light curve.

Because of the importance of such systems to our understanding of the origin of cataclysmic binaries (and planetary nebulae), the writer has undertaken a program of photometric monitoring of planetary-nebula central stars, with the collaboration of Dr. A. D. Grauer of the University of Arkansas at Little Rock. The observations to date have been made with an 0.9-m reflector at Kitt Peak National Observatory.

Photometry seems to be the most efficient means for detecting binary central stars like UU Sge, because the heated hemisphere of the hypothetical cool star will produce a periodic hump in the light curve, even if the orbital plane is insufficiently inclined for actual eclipses. Only systems viewed nearly pole-on would fail to show any photometric variations.

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Extensive photometric data are now in hand for seven central stars. Six of them have shown no variations in excess of ±0.01 mag, and are listed below. These observations were all made through the B filter of the UBV system.

Name	Hours of monitoring	Nights
Abell 30	8.4	8
Abell 36	2.4	5
Abell 39	2.3	5
Abell 78	4.3	3
NGC 1514	5.8	5
PHL 932	4.4	3

The four Abell objects were all suspected of variability by their discoverer (Abell 1966 and private communication), but appear constant in our work where a nearby comparison star is frequently measured. The central star of NGC 1514 has a composite spectrum dominated by an A-type star (Greenstein 1972) and has been suspected of variability (Kohoutek 1966). Although Greenstein found a constant radial velocity on his coude spectrograms, a velocity variation with a period of 0.4 day was reported by Acker (1976). We do not question the composite nature of the spectrum, but the constant luminosity that we observe strongly suggests that the central star of NGC 1514 either is not a close binary (otherwise the A star would have a heated hemisphere), or must be viewed pole-on. Significant radial-velocity variations would not be expected in either case. PHL 932 is the central star of a high-latitude, low-surface-brightness nebula discovered by Arp and Scargle (1967).

Our material shows that some planetary-nebula nuclei are almost certainly not close binaries. Therefore it seems that there are (at least) two mechanisms that produce planetary nebulae: the binary-star interaction described above that created UU Sge, and a single-star mechanism.

Our most unexpected discovery has been that the central star of K1-2 is a pulsating variable. This planetary nebula, and the variability of its central star, were discovered by Kohoutek (1964). The variability was confirmed by Liller and Shao (1968). We obtained photometry of K1-2 on nine nights in 1978 November and December, and 1979 February, using the 0.9-m telescope at Kitt Peak and a crystal copper-sulfate filter in front of an S-20 photomultiplier.

K1-2 was found to vary from 16.4 to 17.8 blue magnitude. The most-likely period seems to be 0.6707 day, which is also consistent with a series of magnitude estimates on plates from the Harvard collection by W. Liller (private communication). The light curve is a one-cycle sinusoid, and is almost certainly due to pulsation rather than orbital motion in a binary system.

Several pulsating variables located on the left-hand side of the H-R diagram have been discovered in recent years, including the DB white dwarf PG 1159-035 (P = 8 min; Carleton, McGraw, Angel, and Starrfield, unpublished), the helium star BD +13°3224 ($P = 2^h35^m$; Landolt 1975), and now the central star of K1-2 ($P = 16^h05^m$). The pulsation mechanism for these objects remains obscure, although one suggestion involving the CNO ionization zone that might apply to K1-2 has been made by Stothers (1977). In at least the first two objects, the mechanism cannot involve hydrogen.

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