THE SHKLOVSKY PARADOX

DAVID BUCKLEY
Department of Physics, East Stroudsburg University of Pennsylvania
Department of Physics & Astronomy, Univ. of Massachusetts, Amherst
and
STEPHEN E. SCHNEIDER and DAVID VAN BLERKOM
Department of Physics & Astronomy, Univ. of Massachusetts, Amherst

ABSTRACT. Shklovsky estimated distances to planetary nebulae (PNs) based on an assumed constant ionized mass and the relationship between flux and radius under the assumption of a constant density, fully ionized shell. He found that a mass of $\sim$0.2 $M_\odot$ yielded the best results. Estimates of the ionized masses of PNs with independently determined distances also rarely exceed a few tenths of a solar mass. This is surprising since many PNs are thought to derive from high mass progenitors (up to 8 $M_\odot$). Recent optical work (Plait and Soker, 1990) and our own computer simulations show that this simple mass estimation method may severely underestimate the total ionized mass. This is because of a halo of lower density ionized material which often contributes only a small fraction of the PN luminosity even though it may contain many times the mass of the dense inner shell. The precipitous drop in surface brightness (both optical and radio) beyond the inner part of the ionized shell also lead to underestimates of the PN's actual ionized radius. Since the evolution of PNs is driven by the expansion of the nebular shell coupled with the evolution of the nucleus (PNN), we ran several simulations using a simple momentum conserving two-wind model as well as employing density profiles derived by more sophisticated energy conserving models, with a wide range of wind parameters and using two different models of PNN evolution. From our simulations (assuming a 4 $M_\odot$ progenitor) we derive an apparent "Shklovsky Mass" – defined as the ionized mass that would be derived from the observationally determined fluxes and radii of our model PNs. While the total ionized masses and Strömgren radii of the model PNs varied widely depending on the PNN and wind parameters, the derived Shklovsky mass consistently remained below one solar mass. This result is almost independent of the total ionized mass or the mass of the progenitor envelope and is fairly insensitive to the wind parameters chosen as input to the models. The observed spread of masses (based on an error analysis of the work of Gathier, 1987) is similar to the mass dispersion in our models for PNs of moderate age. This may explain why the Shklovsky distance method has been found to agree well with kinematic distances (Schneider and Terzian, 1983) even though the fundamental assumptions may be inappropriate for the nebula as a whole.

References

Gathier, R. (1987) Astr. Astrophys. Suppl., **71**, 245.
Plait, P. and Soker, N. (1990) Astron. J., **99**, 1883.
Schneider, S. and Terzian, Y. (1983) Astrophys. J., **274**, L61.

https://doi.org/10.1017/S007418090017041X Published online by Cambridge University Press