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ORIGINAL ARTICLE

The Planetary Nebula Luminosity Function at the dawn of Gaia

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Abstract The [O III] λ5007 Planetary Nebula Luminosity Function (PNLF) is an excellent extragalactic standard candle. In theory, the PNLF method should not work at all, since the luminosities of the brightest planetary nebulae (PNe) should be highly sensitive to the age of their host stellar population. Yet the method appears robust, as it consistently produces $\lesssim 10$ % distances to galaxies of all Hubble types, from the earliest ellipticals to the latest-type spirals and irregulars. It is therefore uniquely suited for cross-checking the results of other techniques and finding small offsets between the Population I and Population II distance ladders. We review the calibration of the method and show that the zero points provided by Cepheids and the Tip of the Red Giant Branch are in excellent agreement. We then compare the results of the PNLF with those from Surface Brightness Fluctuation measurements, and show that, although both techniques agree in a relative sense, the latter method yields distances that are ∼15 % larger than those from the PNLF. We trace this discrepancy back to the calibration galaxies and argue that, due to a small systematic error associated with internal reddening, the true distance scale likely falls between the extremes of the two methods. We also demonstrate how PNLF measurements in the early-type galaxies that have hosted Type Ia supernovae can help calibrate the SN Ia maximum magnitude-rate of decline relation. Finally, we discuss how the results from space missions such as Kepler and Gaia can help our understanding of the PNLF phenomenon and improve our knowledge of the physics of local planetary nebulae.

Keywords Distance scale · Galaxies: distances and redshifts · Planetary nebulae: general

1 Introduction

The [O III] λ5007 Planetary Nebulae Luminosity Function (PNLF) has been a reliable and precise extragalactic distance indicator for over ∼20 years (Jacoby 1989; Ciardullo et al. 1989a; Jacoby et al. 1992). During this time, the method has been applied to both elliptical (Jacoby et al. 1990) and spiral (Feldmeier et al. 1997) galaxies, to galactic spheroids (Ciardullo et al. 1989a; Jacoby et al. 1989; Hui et al. 1993) and disks (Feldmeier et al. 1997), and even to stars lost within the intergalactic environment of rich clusters (Feldmeier et al. 2004). In addition, PNLF observations are relatively easy: the method requires neither space-based observations nor heroically long integrations, and the photometric procedures needed to derive accurate distances are simple and straightforward. As a result, the PNLF is an integral part of the extragalactic distance ladder, and perhaps the best tool we have for examining systematic differences between Population I and Population II distance methods (see Fig. 1).

Of course, no technique is perfect. The PNLF is not well-suited for small galaxies which contain few planetary nebulae, nor can it reach to ∼100 Mpc, where the unperturbed Hubble Flow dominates. For all practical purposes, PNLF observations are limited to ∼20 Mpc (but see Gerhard et al. 2005 and Ventimiglia et al. 2011 for PN measurements in Coma and Hydra!). The technique also requires the use of a narrow-band [O III] λ5007 filter (FWHM ∼50 Å), whose properties in the converging beam of a telescope are well known. In this age of fast, extremely wide-field imagers, this can be a severe limitation, especially for systems where the

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