RevMexAA (Serie de Conferencias), **40**, 251–252 (2011)

SEVERAL WAYS TO BRIGHTNESS

M. G. Richer[1]

RESUMEN

Las luminosidades máximas, los cocientes de abundancias químicas y la cinemática interna de las cáscaras nebulares de nebulosas planetarias extragalácticas brillantes no dependen fuertemente de las características de las poblaciones estelares progenitoras en una galaxia. Esta falta de variación sugiere que las nebulosas planetarias más brillantes tienen estrellas progenitoras similares en todas las galaxias, un resultado inesperado teóricamente dada las metalicidades y las historias de formación estelar. Sin embargo, existen diferencias pequeñas y consistentes en cuanto a las luminosidades y la cinemática que sí dependen de las propiedades de las poblaciones estelares en las galaxias huéspedes y de la metalicidad en particular. Estas diferencias sugieren que necesariamente observamos las nebulosas planetarias en distintas galaxias en distintos estados evolutivos, corresponden las pertenecientes a las galaxias elípticas y los bulbos de espirales a fases más tempranas. Entonces, deben existir múltiples vías para la producción de las nebulosas planetarias intrínsecamente más brillantes.

ABSTRACT

The maximum luminosity, the chemical abundance ratios, and the internal kinematics of the nebular shells of bright extragalactic planetary nebulae are all rather insensitive to the underlying stellar populations in any given galaxy. These similarities argue that the brightest planetary nebulae arise from similar progenitor stars, but this is not necessarily expected theoretically given the metallicities and star formation histories of their host galaxies. However, there are consistent, if small, differences in luminosity and kinematics that do depend upon the host galaxy's stellar populations, notably its metallicity. These differences imply that we necessarily observe the brightest planetary nebulae in different galaxies in different evolutionary stages, with the brightest planetary nebulae from elliptical galaxies and the bulges of spirals being observed in an earlier stage. Therefore, there must exist multiple evolutionary pathways to produce the intrinsically brightest planetary nebulae.

Key Words: planetary nebulae — stars: evolution

Planetary nebulae are the penultimate evolutionary phase for stars of low and intermediate masses, during which the progenitor star's outer envelope is driven off into space through the action of the wind and radiation from the remnant pre-white dwarf (e.g., Kwok et al. 1978). The distribution of luminosities for bright extragalactic planetary nebulae has a maximum luminosity that is insensitive to the host galaxy's stellar populations (e.g., Ciardullo et al. 1991; Merrett et al. 2006). Typically, the chemical abundance ratios observed in bright extragalactic planetary nebulae are similar (Richer & McCall 2008; Magrini & Gonçalves 2009; Bressolin et al. 2010), implying that the masses of their progenitor stars are similar, independent of whether the host galaxy is actively forming stars or not. Finally, the kinematics of the nebular shells in these bright planetary nebulae also similar, implying similar energy injection and, perhaps, masses for the progenitor stars. It is not clear that these similarities are expected theoretically, given the differences in stellar populations among galaxies (Perinotto et al. 2004; Schönberner et al. 2010).

In detail, the luminosities depend upon the metallicity of the progenitor stellar population (Ciardullo et al. 2002). Figure 1 compares the bright planetary nebulae in the LMC and the bulge of the Milky Way and similarly indicates that the kinematics of the nebular shell also depend upon metallicity, with smaller line widths at the lower metallicity of the LMC, in spite of its potentially larger progenitor masses. Presumably, the lower initial expansion velocity of the envelopes of the stellar progenitors at lower metallicity is responsible (Marshall et al. 2004), even though these nebular envelopes are expected to suffer greater acceleration (Schönberner et al. 2010). Similar differences were found within the disc of M31 (Richer et al. 2010). Apart from the line width distributions at a given evolutionary stage (Figure 1, right), the distribution of evolutionary stages differs between the LMC and the Milky

[1]Instituto de Astronomía, Universidad Nacional Autónoma de México, Apdo. Postal 877, 22800 Ensenada, Baja California, Mexico (richer@astrosen.unam.mx).

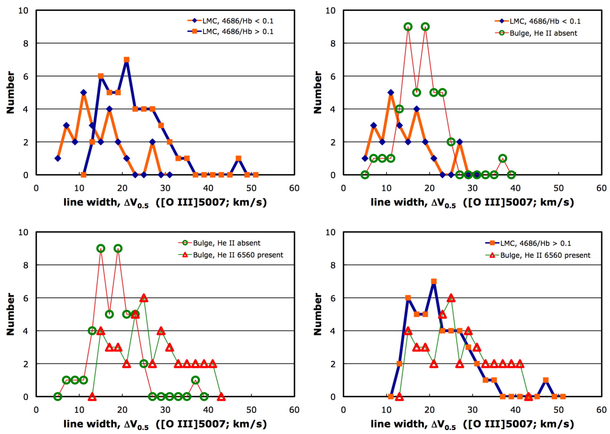

Fig. 1. On the left, the distributions of line widths are shown for bright planetary nebulae in the LMC (top; Dopita et al. 1985) and Milky Way bulge (bottom; Richer et al. 2008). On the right, the distributions of line widths are shown for young (top) and evolved (bottom) planetary nebulae in both environments. For both young and evolved planetary nebulae, the line widths are shifted to larger values in the Milky Way. The criteria to define young and evolved planetary nebulae in the LMC and Milky Way are equivalent.

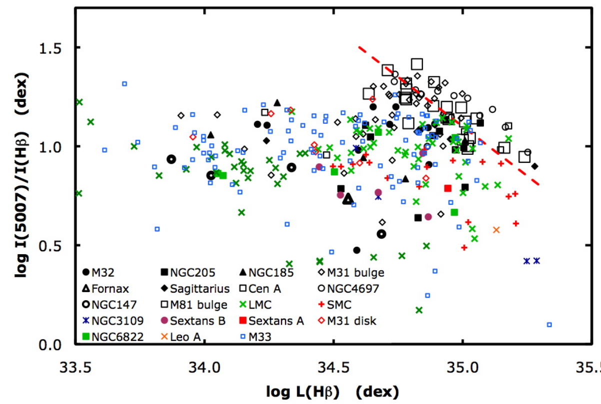

Fig. 2. The [O III]λ5007/Hβ ratio is plotted as a function of Hβ luminosity for extragalactic planetary nebulae with large [O III]λ5007 luminosities (for references, see Richer et al. 2010). Symbols in color represent galaxies with ongoing star formation; black symbols represent galaxies where star formation has ceased. The dashed line indicates a constant [O III]λ5007 luminosity. For these planetary nebulae, the Hβ luminosities decrease, on average, with time. The distribution of points differ for bright planetary nebulae in galaxies with and without star formation, indicating different evolutionary pathways.

Way (Figure 1, left), with the LMC having a larger fraction of evolved objects.

For planetary nebulae that are near their peak luminosity in [O III]λ5007, the Hβ luminosity is expected to decrease monotonically with time (Schönberner et al. 2007). Figure 2 presents the ratio of [O III]λ5007 to Hβ as a function of the Hβ luminosity. Bright planetary nebulae in galaxies with and without star formation occupy different loci in this plot, implying that their temporal evolution differs. In particular, the early evolution of bright planetary nebulae in galaxies without star formation appears to occur at a constant [O III]λ5007 luminosity, whereas the [O III]λ5007 and Hβ luminosities of their counterparts in galaxies without star formation are more closely correlated throughout their evolution. Since the planetary nebulae in galaxies with star formation typically have hotter central stars (Figure 1; Stasińska et al. 1998), they should be more evolved than their counterparts in elliptical galaxies and the bulges of spirals (they are also of lower metallicity).

Given that both the nebular shells and central stars of the brightest planetary nebulae are in different evolutionary stages in different galaxies, there must exist multiple pathways to produce the intrinsically brightest planetary nebulae.

REFERENCES

Bressolin, F., Stasińska, G., Vílchez, J. M., Simon, J. D., & Rokolowsky, E. 2010, MNRAS, 404, 1679

Ciardullo, R., Feldmeier, J. J., Jacoby, G. H., Kuzio de Naray, R., Laychak, M. B., & Durrell, D. R. 2002, ApJ, 577, 31

Ciardullo, R., Jacoby, G. H., & Harris, W. E. 1991, ApJ, 383, 487

Dopita, M. A., Ford, H. C., Lawrence, C. J., & Webster, B. L. 1985, ApJ, 296, 390

Kwok, S., Purton, C. R., & Fitzgerald, P. M. 1978, ApJ, 219, 125

Magrini, L., & Gonçalves, D. R. 2009, MNRAS, 398, 208

Marshall, J. R., van Loon, J. Th., Matsuura, M., Wood, P. R., Zijlstra, A. A., & Whitelock, P. A. 2004, MNRAS, 355, 1348

Merrett, H. R., et al. 2006, MNRAS, 369, 120

Perinotto, M., Schönberner, D., Steffen, M., & Calonaci, C. 2004, A&A, 414, 993

Richer, M. G., López, J. A., Pereyra, M., Riesgo, H., & García-Díaz, Ma. T. 2008, ApJ, 689, 203

Richer, M. G., & McCall, M. L. 2008, ApJ, 684, 1190

Richer, M. G., et al. 2010, RevMexAA, 46, 191

Schönberner, D., Jacob, R., Sandin, C., & Steffen, M. 2010, A&A, 523, A86

Schönberner, D., Jacob, R., Steffen, M., & Sandin, C. 2007, A&A, 473, 467

Stasińska, G., Richer, M. G., & McCall, M. L. 1998, A&A, 336, 667