Star formation history of the Galactic Bulge

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1 The Galactic Bulge

The Galactic Bulge is a predominantly old component of the Milky Way, with estimated age of 8–12 Gyr. It may represent an old spheroid, or be a pseudo bulge formed from heating of the inner disk.

Currently, 785 planetary nebulae (PNe) are known in the Galactic Bulge. They trace the end of stellar evolution, just before the star enters the white dwarf cooling track. The nebulae (Fig. 1) show expanding stellar ejecta, formed through extreme mass loss, and ionized by the heating central star. Planetary nebulae are the brightest and most easily observed phase of low-mass stellar evolution (Fig. 2).

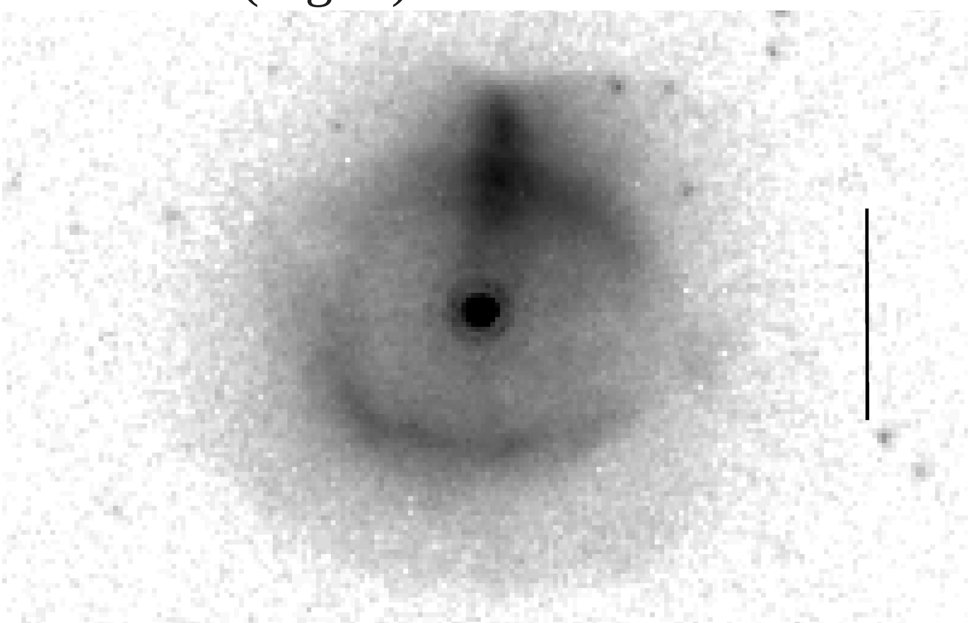

Figure 1: HST Hα image of one of the Bulge planetary nebulae, M2-29. Diameter is 4 arcsec.

2 Stellar masses

During the planetary nebulae evolution, the heating rate varies from 1K/yr for a mass of 0.56$M_\odot$ to > 100K/yr at 0.65$M_\odot$.

By measuring the expansion age of the nebula and the temperature of the star, we can measure the heating rate. This gives the mass to 0.02 $M_\odot$ accuracy.

2.1 Observations

We have observed 37 compact Bulge PNe using the HST (imaging) and the VLT (echelle spectroscopy).

- Stellar temperature is derived from photo-ionization models.
- Expansion velocity field is derived through echelle line profiles.
- Kinematic age is derived from velocity field and nebulae diameter.
- Heating rate is determined from kinematic age and stellar temperature.
- Stellar mass is derived from the heating rate and the Blöcker (1995) models.

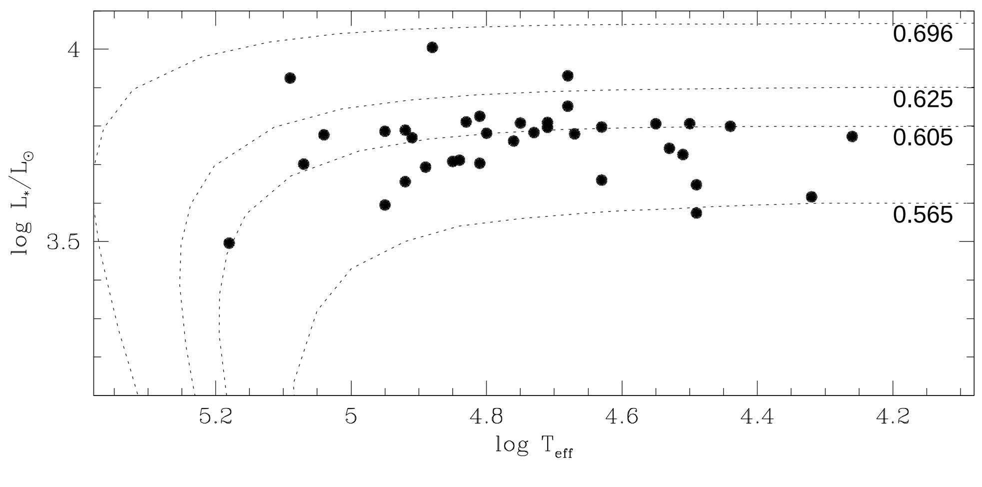

Figure 2: HR diagram with PN tracks for different final masses

The measured mass is that of the final stellar remnant, the later white dwarf.

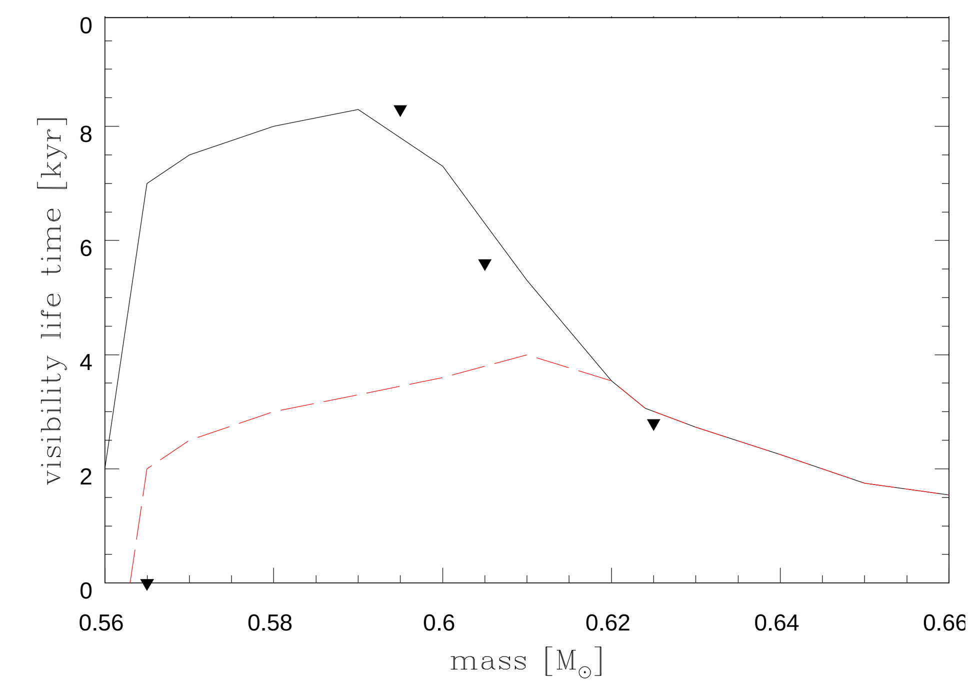

Figure 3: Observable life time of PNe as function of stellar mass. Solid line is for all PNe; dashed line is for compact PNe as observed with the HST

PN observable life times as function of mass are shown in Fig. 3. The observed mass distribution is divided by this function.

Stars less massive than 0.56 $M_\odot$ cannot be detected through PNe studies (Fig. 3)

After correcting for visibility bias, we find a constant distribution from the lowest mass up to 0.6 $M_\odot$, plus a well-defined peak at 0.61$M_\odot$, and a few higher-mass stars. The higher mass stars could present foreground confusion (expected 10% of the sample).

After division and scaling to the total number of PNe in the Bulge, the distribution of Fig. 4 measures the stellar death rate.

Correcting for spatial incompleteness, we predict a total Bulge population of 2000 PNe, and a stellar death rate of 0.3 yr^{-1}.

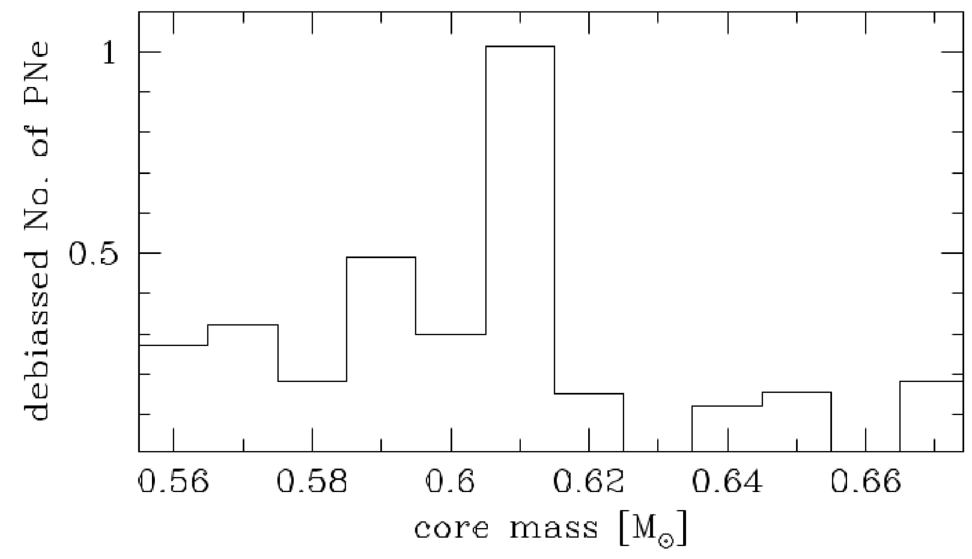

Figure 4: Central star masses for the Bulge PNe

2.2 Initial stellar masses

The initial-final mass relation is not well calibrated for old populations. To find initial masses and ages, we assume that

- The lowest mass central stars have ages of 10 Gyr. Older populations (globular clusters) have few PNe.
- The dominant population is < 7 Gyr (McWilliam & Zoccali 2010) and formed within 0.5 Gyr (Fulbright et al. 2007).
- The initial-final mass relation is linear.

For each initial mass, the relation between stellar birth rate and stellar death rate are determined from the FRANEC isochrones (Maraston 1998).

3 Star formation history

We derive a constant star formation rate, lasting ∼ 2 Gyr, followed by a shorter-lived peak. The star formation rates are

- 4 $M_\odot\,yr^{-1}$ during first 2 Gyr
- 8 $M_\odot\,yr^{-1}$ during the 0.5 Gyr peak
- < 1 $M_\odot\,yr^{-1}$ afterwards.

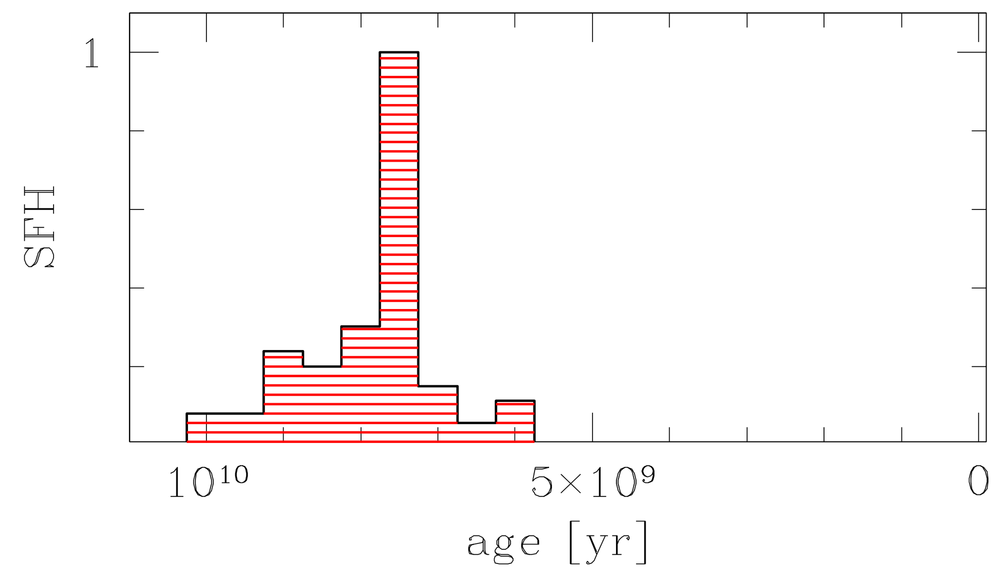

Figure 5: Star formation history (arbitrary units) derived from the Bulge PNe

The Bulge and thick disk have approximately the same age. The thick disk may have formed during a minor merger (Wyse 2009). Under this assumption, we would conclude

- Minor merger took place 7– 8 Gyr ago;
- Star formation peak traces gas falling into the Bulge during the merger;
- Older star formation traces pre-existing stars scattered into the Bulge.

4 Conclusion

PNe indicate the Bulge population formed during an extended phase of star formation of a few Gyr, followed by a short-lived burst of star formation. The exact ages are subject to revision. Whether these stars formed in-situ in the Bulge is not proven by these observations.

References

Blöcker, T. 1995, A&A, 299, 755

Fulbright, J. P., McWilliam, A., & Rich, R. M. 2007, ApJ, 661, 1152

Maraston, C. 1998, MNRAS, 300, 872

McWilliam, A., & Zoccali, M. 2010, ApJ, 724, 1491

Wyse, R. F. G. 2009, IAU Symposium 258, The Ages of Stars, E.E. Mamajuk, D.R. Soderblom, & R.F.G. Wyse, eds., p.11