CHEMICAL ABUNDANCES FROM PLANETARY NEBULAE IN ELLIPTICAL GALAXIES

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1. The Planetary Nebula sample in early-type galaxies

Currently over 2000 Planetary Nebulae (PN) have been detected in Local Group E and S0 galaxies by on/off band [O III]5007Å CCD photometry. PN can currently be detected out to Fornax and Virgo clusters.

The magnitude of the brightest PN in the nearest elliptical galaxy (NGC 205) is m_{5007} 20.7 (Ciardullo et al, 1989); for NGC 5128 (Cen-A) it is 23.5 (Hui et al, 1993a) and $\geq$ 25.6 for Virgo ellipticals (Jacoby et al, 1990). Given the relation between m_{5007} and line flux:
$m_{5007} = -2.5 \log F_{5007} - 13.74$
the typical Hβ fluxes are $\leq 1.5 \times 10^{-16}$ ergs cm^{-2} s^{-1} for NGC 5128 PN and $\leq 2.5 \times 10^{-17}$ for Virgo PN. Obtaining spectra of these faint emisison lines is clearly a challenge. The only PN spectra studied in Local Group galaxies are 1 PN in M32 (NGC 221) (Log F(Hβ)=-14.9; Jenner et al, 1979) and recently 15 in NGC 205 (Jacoby et al, 1995). None of the spectra are of high quality and the T_e diagnostic line [O III]4363Å was not detected. There is evidence of possible high N abundance in the M32 PN.

2. PN as astrophysical probes in early-type galaxies

The observational study of PN in early type galaxies can provide a number of useful tools:

1. as distance indicators from fitting of the PN Luminosity Function
2. as tracers of the kinematics and the galaxy potential(eg Hui et al, 1993a)
3. as tracers of the chemical abundance gradient

I. Appenzeller (ed.), Highlights of Astronomy, Vol. 10, 483–485.

https://doi.org/10.1017/S1539299600011837 Published online by Cambridge University Press

4. to study the effect of age and metallicity on a PN population
5. to determine the nature of the most luminous PN in a galaxy
6. to study the luminosity evolution of a PN population

Here only the third point will be discussed, although touching on the fourth and fifth.

3. PN as Abundance Tracers in early-type Galaxies

In early-type galaxies abundances of the stellar population are derived from the line of sight integrated properties of the starlight. The strength of absorption lines and molecular bands (eg. Fe I, Mg_2, Ti O and CN) or broadband colours are measured to provide abundances. However stellar indicators are subject to contributions from stars all over the HR diagram, which can have a range in metallicity and age. Early-type galaxies generally become bluer with increasing radius and the absorption line strengths usually decrease outward. The colour and line strength variations are interpreted by an outwardly–decreasing metallicity (eg. Pelletier et al, 1990).

Planetary nebulae can also be used as abundance tracers in a way comparable to H II regions in spiral galaxies, if abundant elements can be found which are not strongly affected by AGB and post-AGB nucleosynthetic processing:
O/H – the galactic O/H gradient from PN (eg. Maciel & Köppen, 1994) matches well that of H II regions (-0.07 dex per kpc).
He/H – the helium abundance gradient for the Type II PN in the Galaxy is very similar to that for the H II regions (eg. Peimbert & Serrano, 1980), and similarly for the Magellanic Clouds, when account is taken of collision excitation of He I (Clegg, 1987).
N/H – the situation is less clear, but the gradient may be similar to O/H or steeper. However some N may be of secondary origin during the AGB and this would lead to discrepances with H II regions.
Richer (1993) has shown that for LMC and SMC PN there is almost no dependence of mean O abundance on the cutoff luminosity implying that dependable abundances can be derived from the few brightest (Type II) PN in a galaxy. **The brightest PN have a similar status as abundance indicators to H II regions in spirals.**

By measuring eg. O/H abundances from PN at a variety of R_e the abundance gradient can be inferred. The available range in R_e is much greater than accessible to absorption line studies and comparable to that covered by deep photometric studies ($\leq$4 R_e). Measuring abundances of PN provides a **unique** way to determine the abundance spread of the old stellar population in elliptical galaxies. Arimoto & Yoshii (1987) suggest from synthesis models that [Fe/H] varies over a range of at least 3 in a giant elliptical – PN can be used to test this and hence probe the star formation history of ellipticals

The effect of higher than solar metallicity environments, typical of early-type galaxies, on PN evolution can also be studied. It is known that there is a dependence of [O III] luminosity on O abundance; by determining directly the O abundance of a few planetaries in a galaxy the PN luminosity function can be corrected for abundances much different from the Local Group calibrators (Dopita et al, 1992).

4. Observational prospects

For NGC 5128 (Centaurus-A), the brightest PN have [O III] 5007Å flux of $\sim 8\times10^{-16}$ ergs cm^{-2} s^{-1}. In order to determine reliable abundances, a temperature sensitive line such as [O III]4363Å needs to be detected. For a typical temperature of 1.1×10^{4}K, then in order to derive reliable abundances (a 25% error on 4363Å produces a ~25% error on O/H at this T_e), the 4363Å line with a strength of $\leq 7\times10^{-18}$ ergs cm^{-2} s^{-1} must be measured. Such deep emission line spectroscopy is possible with long exposures (~5-10 hours), long slits, PN without strong local galaxy continuum, good seeing and dark sky for optimal sky subtraction. But in order to study the abundance gradient some 20-30 PN at a range of galactocentric radii must be observed. This calls for object multiplexing but not with fibres since sky subtraction is critical and inferior to a slit. There are 28 PN brighter than m_{5007} of 24.0 in NGC 5128 (Hui et al, 1993b) which are within the reach of a dedicated 4m class programme, but more extensive coverage requires a multi-object spectrograph on an 8-10m telescope

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