

The LAMOST spectroscopic survey of planetary nebulae in M31 and M33

Maosheng Xiang¹, Xiaowei Liu², Meng Zhang², Haibo Yuan³ and Zhiying Huo¹

¹National Astronomical Observatories, Chinese Academy of Science, China
email: msxiang@nao.cas.cn

²Department of Astronomy, Peking University, China email: x.liu@pku.edu.cn

³Department of Astronomy, Beijing Normal University, China

Abstract. We present LAMOST observations and radial velocity measurements of about 1500 planetary nebulae (PNe) in M31 and M33. Most of the PNe are previously known, but 36 of them are newly discovered in the outskirts of M31, and the furthest one has a projected distance larger than 50 kpc away from the galaxy center. Eighteen objects in the area of M33 are probably newly discovered PNe, and quite a few of them are associated with previously known clusters. For all the 1500 PNe, homogeneous radial velocities are measured from the LAMOST spectra, with a typical uncertainty of a few km s⁻¹.

Keywords. planetary nebulae: general; galaxies: kinematics and dynamics

1. Introduction

The Guo Shoujing telescope (LAMOST) collects low resolution ($R \sim 1800$) fibre spectra of 4000 objects simultaneously in a sky area of 20 square degrees. The large number of fibres and wide field of view make it particularly suitable to search for planetary nebulae (PNe) as well as other special objects (e.g. supergiants, H II regions, globular clusters) in the M31 and M33 galaxies. PNe exhibit prominent emission lines (e.g. [O III] $\lambda 5007$, H α $\lambda 6563$), thus can be easily detected and identified. Thousands of PNe and candidates in the area of M31 and M33 have been targeted by LAMOST in both the commissioning (9/2009 - 9/2011) and the survey stage (10/2011 - 6/2017). The main scientific goals include (1) Validating wavelength calibration of LAMOST spectra; (2) Searching for new PNe, especially in the out skirts of the galaxies; (3) Obtaining accurate and homogeneous measurements of radial velocities and emission line fluxes of a large sample of PNe to study stellar populations, kinematics and chemistry of M31 and M33. With the commissioning data, Yuan *et al.* (2010) discovered 36 PNe in the outskirts of M31. In this work, we present results from observations carried out in the survey stage.

2. PN identifications and radial velocity measurements

A cross-identification with the emission line object catalog of Merrett *et al.* (2006) yields 1756 observations of 1351 common objects. Comparison of [O III] $\lambda 5007$ magnitudes deduced from the LAMOST spectra with those of Merrett *et al.* shows good correlation, indicating that flux calibration of LAMOST spectra is reliable. The differences in [O III] magnitudes of individual PNe have a mean and standard deviation of 0.17 and 0.58 mag, respectively. Based on those common objects, a criterion is defined in the $F(5007)/F(4861) - [\text{O III}]$ magnitude plane to distinguish PNe and contaminations from other emission line objects, e.g. H II regions.

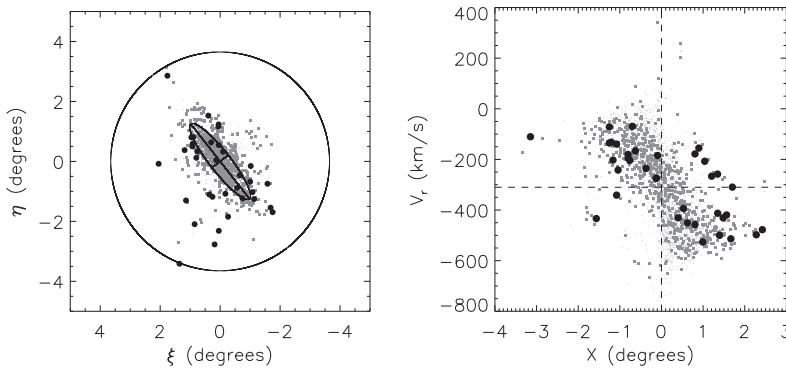


Figure 1. Left: Spatial distribution (Left) and P-V digram (Right) for newly discovered (black) and previously known (grey) PNe of M31. Previously known PNe that have LAMOST observation are shown with squares, while those do not have LAMOST observations are shown with small dots. For the left panel, the circle corresponds a projected distance of 50 kpc to the M31 center. The ellipse has a semi-major radius of 95.3 arcmin, an inclination angle of $77.^{\circ}5$ and a position angle of $38.^{\circ}1$. For the right panel, the abscissa is the projected position along the major axis of M31. The horizontal dashed line denotes a radial velocity of -310 km s^{-1} .

After inspecting literatures and the SIMBAD database, we confirm that 36 PNe are newly discovered around M31. Their spatial distribution and locations in the position-velocity (P-V) diagram are shown in Figure 1. Two of the newly discovered PNe have moderate continuum in their spectra, for which one is possibly contaminated by a nearby Wolf-Rayet star, and the other is associated with globular cluster candidate. The furthest newly discovered PN has a projected distance larger than 50 kpc away from the M31 center, and probably associated with the giant stellar stream. In the sky area of M33, eighteen objects are probably PNe newly discovered, 5 of them are isolated with very weak continuum in their spectra, while the other 13 are associated with previously known globular clusters or Wolf-Rayet stars.

A comparison of radial velocities deduced from $[\text{O III}] \lambda 5007$ lines of LAMOST spectra with those of Merrett *et al.* yields a mean difference of -10.0 km s^{-1} , and a standard deviation of 20.3 km s^{-1} . While a comparison with Halliday *et al.* (2006) yields a mean difference of -3.2 km s^{-1} and a standard deviation of 7.0 km s^{-1} . For objects with $[\text{O III}]$ magnitudes brighter than 23 mag, the standard deviation reduces to 5.0 km s^{-1} . Radial velocities for ~ 1500 PNe in M31 and M33 are deduced from LAMOST spectra, with a typical uncertainty of a few km s^{-1} . Fluxes of prominent emission lines of those PNe are also measured.

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