Why Galaxies Care About AGB Stars:
A Continuing Challenge through Cosmic Time
Proceedings IAU Symposium No. 343, 2019
F. Kerschbaum, M. Groenewegen & H. Olofsson, eds.

doi:10.1017/S1743921318007937

Near IR and visual polarimetry of the Planetary Nebula M2-9

Silvana G. Navarro[1], Omar Serrano[2], Abraham Luna[2], Rangaswami Devaraj[2], Luis J. Corral[1], Julio Ramírez Vélez[3] and David Hiriart[3]

[1]Instituto de Astronomía y Meteorología, Universidad de Guadalajara, 44130 Guadalajara, Jal., México
emails: silvana@astro.iam.udg.mx, lcorral@astro.iam.udg.mx

[2]Instituto Nacional de Astrofísica Óptica y Electrónica, 72840 Puebla, Pue., México
emails: arthas@inaoep.mx, aluna@inaoep.mx

[3]Instituto de Astronomía, sede Ensenada, Universidad Nacional Autónoma de México, Ensenada Baja California, México
emails: jramirez@astro.unam.mx, hiriart@astro.unam.mx

Abstract. Bipolar and more complex morphologies observed in planetary nebulae have been explained by two principal hypotheses: by the existence of a companion producing a circumstellar disk, by the effects of a magnetic field, or by a combination of both. The polarimetric analysis of these objects could give information about the presence of dust grains aligned with any preferential direction, due to a magnetic field or to the action of radiative torques (RAT). We performed polarimetric observations of some planetary nebulae in order to detect linear polarization and (in the best scenario) to detect the signature of an accretion disk in these objects. We observed in the visual region with POLIMA at the San Pedro Mártir observatory, and with POLICAN the NIR polarimeter in the Guillermo Haro observatory. We present the result of these observations in one of these objects: the PN M2-9.

Keywords. Polarization, stars: magnetic fields, ISM: Planetary Nebulae: individual: M2-9

1. Introduction

Polarization due to dust scattering is a useful tool to determine the geometry of extended envelopes in symbiotic systems and proto-planetary nebulae (Scarrott & Scarrott 1995, Gledhill 2005). It is also used to trace the circumstellar disk and jets/outflows present in such objects. M2-9 is a widely studied bipolar PN, it shows two coaxial shells and a series of bright filaments and knots, symmetrically located on both lobes, which have been explained by a lighthouse effect. Their apparent motion has been shown by Corradi *et al.* (2011). Recently, Castro-Carrizo *et al.* (2012), resolved two ring-shaped structures at the center of this object *giving evidence of their binary nature.*

2. Observations

M2-9 was included in an observation program of PNe using POLIMA polarimeter on the 84 cm telescope located in San Pedro Mártir observatory on July 2012. We used two narrow filters: Hα ($\lambda = 6564$ Å, $\delta\lambda = 72$ Å) and H6819 ($\lambda = 6819$ Å, $\delta\lambda = 86$ Å). The spatial resolution, with a 2x2 binning, is 0.528 arcsec/pix. We present the Hα polarization map to compare with those obtained at the IR. At these wavelengths, we use POLICAN, the IR polarimeter at the Guillermo Haro observatory at Cananea (Devaraj *et al.* 2018).

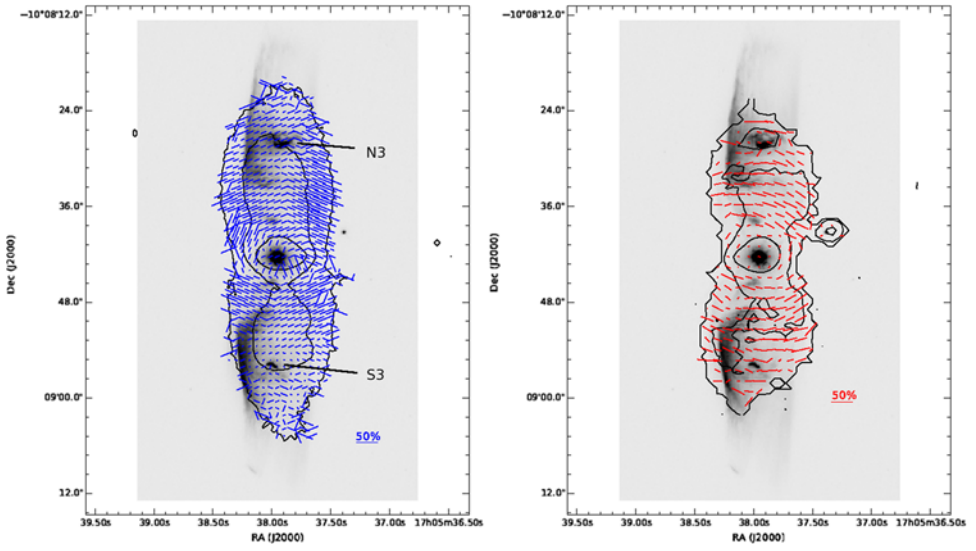

Figure 1. Left: Polarization vectors in Hα superimposed over the HST image of M2-9 at Hα. Right: Polarization vectors in the H band superimposed over the same HST image.

We obtained polarimetric images in the J and H bands in March 2017. The polarimeter, attached to the IR camera CANICA provides a spatial resolution of 0.32 arcsec/pix (0.64 arcsec/pix with a binning of 2x2). The observations were made in commissioning time with a seeing of 1.2 arcsec.

3. Results and analysis

3.1. *Polarization of M2-9 in Hα*

In this object, a high degree of polarization is detected, especially in the regions near the border, as we expect from scattered light coming from the lobes. In general, the direction of the polarization vectors is nearly perpendicular to the radiation from the central object, in accord with the grain alignment produced by radiative torques (RAT, Lazarian & Hoang 2007). Although at the position of the bright knots observed in the north and south lobes (N3 and S3 in Fig. 1), the percentage of polarization is lower. In these regions, there are indications of shocked material that produce such bright knots (Schwarz *et al.* 1997) and dominate over the scattered light in these regions. In the Hα polarization map (Fig. 1) at the central waist of the object, a thin region with higher polarization is observed. This could be an indication of the presence of dust in the core of the object as was shown by the observations of Lykou *et al.* (2011) in the NIR and Castro-Carrizo *et al.* (2012) in the ^{12}CO J=2-1 line.

3.2. *NIR Polarimetry of M2-9*

In the H band, M2-9 shows considerable polarization levels. As in Hα, the observed polarization angle is, in general, perpendicular to the radiation from the central object. In this case, only in one of the knots (at the north from the central object) the polarization is notoriously less important. At the central region, the polarization is minimum, and the thin region with a greater polarization level is not detected.

https://doi.org/10.1017/S1743921318007937 Published online by Cambridge University Press

References

Castro-Carrizo A., Neri R., Bujabarral V., Chesneau O., Cox P. & Bachiller R. 2012, *A&A*, 545, A1

Corradi, R.L.M., Balick, B., & Santander-García M. 2011 *A&A*, 529, A43

Devaraj, R., Luna, A., Carrasco, L., Vazquez-Rodríguez, M. A., Maya, Y. D., Tánori, J. G. & Serrano-Bernal E. O. 2018, *PASP* 130, 987

Gledhill, T.M., 2005, *MNRAS*, 356, 883

Lazarian, A. & Hoang, T. 2007, *MNRAS*, 378, 910

Lykou, F., Chesneau, O., Zijlstra, A. A., Castro-Carrizo, A. A., Legdec, E., Balick, B. & Smith, N. 2011, *A&A*, 527, A105

Scarrott, S.M. & Scarrott, R.M.J. 1995, *MNRAS*, 277, 277

Schwarz, H. E., Aspin, C., Corradi, R. L. M. & Reipurth, B. 1997, *A&A*, 319, 267