Kinematically detected polar rings/disks in blue compact dwarf galaxies

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Abstract. Polar ring galaxies are systems with nearly orthogonally rotated components. We have found the gas on polar (or strongly inclined) orbits in two BCD galaxies using ionized gas velocity fields taken with a Fabry-Perot interferometer of the SAO RAS 6-m telescope. Our analysis shows that all ionized gas in Mrk 33 is concentrated in a compact disk (3 kpc in diameter) which rotates in the polar plane relative to the main stellar body. The gaseous disk in Mrk 370 has a more complex structure with a heavily warped innermost part. The presence of polar gaseous structures supports an idea that current the burst of star formation in these galaxies is due to the external gas accretion or merging. A possible fraction of polar structures among BCD galaxies seems to be very large (up to 10-15%).

1 Observations

The observations were made with a scanning Fabry-Perot interferometer (FPI) mounted within the multimode instrument SCORPIO \textsuperscript{1} at the prime focus of the Russian 6-m telescope. The spectral range was equal to 13Å and the spectral resolution was 0.8Å (about 35 km/s) for a 0.36Å sampling. The spectral interval was centered on the redshifted emission lines [NII],\textlambda 6583 (Mrk 33) and H\alpha (Mrk 370). The observational data were reduced using the IDL-based software package \textsuperscript{2}. The final spatial resolution was about 2 – 2.5\arcsec. We fitted emission line profiles to the Voigt function, the profile fitting results were used to construct the two-dimensional fields of the line-of-sight velocities of ionized gas, maps of velocity dispersion, and images in the corresponding emission lines.

2 Mrk 33

It is a blue compact galaxy with structural properties corresponding to a dust-lane \textsuperscript{3}. Perosian et al.\textsuperscript{4} have studied its circumnuclear ($r < 5\arcsec$) gas kinematics and concluded that the position angle (PA) of the kinematic major axis significantly differs from the photometric major axis of the galaxy. Our observational data allows us to study the ionized gas kinematics at larger distances from the nucleus - the [NII] emission was detected up to $r = 15\arcsec$. The velocity field of the ionized gas can be approximated by the model of a circular rotating thin disk. The major axis of this disk differs significantly from the major axis of the outer isophotes. The major axis position angle and inclination derived from the ionized gas velocity field are $PA = 163\pm 4^\circ$ and $i = 47\pm 5^\circ$, respectively. For the outer oblate spheroid we adopted the orientation parameters based on photometry analysis \textsuperscript{5}; $PA = 116^\circ$, $i = 59^\circ$.

These values imply two formal solutions for the relative inclination between the ionized gas disk and the host galaxy main plane: $\Delta i = 85\pm 6^\circ$ or $39\pm 6^\circ$. The former corresponds to the stable polar structure. Based on the low-resolution kinematic data in HI, Bravo-Alfaro et al. \textsuperscript{3} also suggested that Mrk 33 has recently captured gas in a close interaction or merger with an initially gas-rich companion. Our observations show that the inner polar ionized gas disk has a similar kinematics with the external HI structure. The orientation of the inner ($r < 10\arcsec$) optical isophotes is in a good agreement with the ionized gas disk position. This fact indicates that a significant fraction of stars was already formed from the gas on polar orbits, therefore the inner gaseous disk was stable for least several dynamical times (~ 10 Myr).

3 Mrk 370

Cairos et al. \textsuperscript{6} found that the current star formation with the age of 3–6 Myr took place in numerous knots in this luminous ($M_B = -17.20$) BCD galaxy. Our FPI data show that external emission knots rotate in a plane roughly coinciding with the stellar disk of the galaxy. At smaller radii ($r < 700 – 800$ pc), circular orbits in the ionized gas disk change orientation abruptly (see Fig. \textsuperscript{1}). The intrinsic orientation of the disk changes through $\Delta i = 55 – 70^\circ$ (it depends on the accepted outer disk inclination). We suppose that a coherent warped disk observed in Mrk 370 is a small-scale analogue of strongly twisted disks recently found in the galaxies NGC 2685 \textsuperscript{7} and NGC 3718 \textsuperscript{8}.

4 Summary

In both studied galaxies the ionized gas in the circumnuclear region ($r < 1 – 2$ kpc) rotates in the plane which is

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orthogonal (or significantly inclined) to their stellar disks. Similar circumnuclear polar disks where recently found in more than 30 nearby galaxies (see [9] for references and discussion). Though a detailed process of the inner polar disk formation is still an open question [9], the most likely formation mechanism is the same with classical polar ring galaxies (PRG) – merging or accretion of external gas clouds with a specific direction of orbital momentum [10]. It is considered that PRGs are rare objects – according to [11], only 0.5–5% of S0 galaxies possess polar rings and this percentage is significantly smaller for late-type galaxies. However, a possible fraction of polar structures among BCD galaxies seems to be larger (up to 10-15%). For instance, 5 galaxies out of 28 nearby luminous BCDG in the sample by Cairós et al. [12] possess polar structures: Mrk 33, Mrk 370, Mrk 314 [13], II Zw 71 [14] and III Zw 102 [15]. Therefore the current burst of star formation in these galaxies can be connect with the same interaction event (accretion or merging) which also transported gas clouds on polar orbits.

Fig. 1. Mrk 370, the maps derived from FPI data cube: Hα monochromatic image, velocity field of the ionized gas, a titled-ring model of the circular rotation of the warped disk and the residual velocity map (observations minus model).

Based on the observations collected with the 6-m telescope of the Special Astrophysical Observatory of the Russian Academy of Sciences, which is operated under the financial support of the Science Department of Russia (registration number 01-43). This work was supported by the Russian Foundation for Basic Research (projects no. 09-02-00870) and by the ‘Dynasty’ Fund. I am very grateful to the Organizing Committee for their support of my stay in Lyon during this Meeting.

References

1. V.L. Afanasiev, A.V. Moiseev, Astronomy Letters 31, 194 (2005), arXiv:astro-ph/0502095
2. A.V. Moiseev, O.V. Egorov, Astrophysical Bulletin 63, 181 (2008), arXiv:0805.2367
3. H. Bravo-Alfaro, E. Brinks, A.J. Baker, F. Walter, D. Kunth, Astron. Journal 127, 264 (2004)
4. A.R. Petrovian, T. Maksymian, G. Comte, D. Kunth, S. Dodonov, Astron. and Astroph. 391, 487 (2002)
5. R. Amorín, J.A. Aguerri, C. Muñoz-Tuñón, L.M. Cairós, Astron. and Astroph. 501, 75 (2009)
6. L.M. Cairós, N. Caon, B. García-Lorenzo, J.M. Vilchez, C. Muñoz-Tuñón, Astron. Journal 577, 164 (2002)
7. G.I.G. Józsa, T.A. Oosterloo, R. Morganti, U. Klein, T. Erben, Astron. and Astroph. 494, 489 (2009)
8. L.S. Sparke, G. van Moorsel, U.J. Schwarz, M. Vogelaar, Astron. Journal 137, 3976 (2009)
9. A. Moiseev, O. Sil’chenko, I. Katkov, in Hunting for the dark: the hidden side of galaxy formation, edited by V. P. Debattista & C. C. Popescu (2010), Vol. 1240 of AIP Conference Series, pp. 251–252
10. F. Bournaud, F. Combes, Astron. and Astroph. 401, 817 (2003)
11. B.C. Whitmore, R.A. Lucas, D.B. McElroy, T.Y. Steinman-Cameron, P.D. Sackett, R.P. Olling, Astron. Journal 100, 1489 (1990)
12. L.M. Cairós, J.M. Vilchez, J.N. González-Pérez, J. Iglesias-Páramo, N. Caon, Astroph. Journal Suppl. 133, 321 (2001)
13. L.V. Shalyapina, A.V. Moiseev, V.A. Yakovleva, V.A. Hagen-Thorn, O.Y. Barsunova, Astronomy Letters 30, 583 (2004), arXiv:astro-ph/0411457
14. A.L. Cox, L.S. Sparke, A.M. Watson, G. van Moorsel, Astron. Journal 121, 692 (2001)
15. A.V. Moiseev, Astrophysical Bulletin 63, 201 (2008), arXiv:0808.1696