Decoupled gas kinematics in isolated early-type disc galaxies

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Abstract. We have studied a sample of completely isolated galaxies by means of long-slit spectroscopy at the 6-m telescope. We have found that 7 of 12 (58 ± 14%) galaxies have revealed a presence of large-scale ionized-gas component which angular momentum is mostly different from stellar one: 5 of 7 (71 ± 17%) show a visible counterrotation. The diagnostic diagram demonstrates a wide range of gas excitation mechanism. We have estimated the gas oxygen abundance in the cases where excitation mechanism by young stars dominates and have found that ionized gas has a subsolar metallicity. We concluded that cold-gas accretion from primordial cosmological filaments is unlikely for these objects, while external accretion from dwarf gas-rich satellites is more suitable.

1. Introduction

Evolutionary history of galaxies through cosmic time is thought to be strongly controlled by a number of internal and external physical processes. Consideration of isolated galaxies makes possible to constrain a diversity of processes and to exclude some of them: gravitational tides, major mergers, ram pressure stripping in hot intracluster/intragroup medium.

We have compiled our sample of isolated lenticular galaxies basing on the approach recently developed by the team of Karachentsev, Makarov, and co-authors. They have developed a group-finding algorithm that takes into account individual characteristics of galaxies in order to associate galaxies in pairs, triplets and groups in the Local Supercluster and its surroundings (see details in\textsuperscript{Makarov & Karachentsev (2011)} and references therein). We have carried out spectroscopic observations of 12 strictly isolated galaxies with isolation index \( II > 2.5 \) and average value of \( \bar{II} = 12: \) IC 875, IC 1502, NGC 16, NGC 2350, NGC 3098, NGC 3248, NGC 6615, NGC 6654, NGC 6798, NGC 7351, UGC 4551, UGC 9519.
2. Observations and data analysing

We have observed spectroscopically the sample of lenticular galaxies using the multimode focal reducer SCORPIO-2 (Afanasiev & Moiseev 2011) mounted at the 6-m Russian telescope. Long-slit spectra along major axes of galaxies were acquired with a spectral resolution FWHM≈4Å in wavelength range from 3900 to 7000Å.

To derive information about stellar and ionized gas kinematics we firstly fitted the stellar absorption-line spectra by the PEGASE.HR high resolution stellar population models (Le Borgne et al. 2004) convolved with a parametric line-of-sight velocity distribution (LOSVD) by applying NBürsts full spectral fitting technique (Chilingarian et al. 2007). After that we subtracted the stellar absorption-line model spectra from the observed spectrum to obtain pure emission-line spectrum, and then fitted it with Gaussians pre-convolved with instrumental resolution. Kinematical profiles for stars and ionized gas in a few most striking examples (NGC 2350, NGC 6798, UGC 9519) are presented in Fig. 1. To identify the dominant source of the gas ionization, we plot our emission line measurements onto the classical diagnostic BPT-diagram (Baldwin et al. 1981) (see Fig. 2).

For the cases when the emission-line measurements reveal excitation dominated by young stars, we determine oxygen abundance of ionized gas using NS-calibration proposed by Pilyugin & Mattsson (2011).

3. Results and Discussion

We have found that 7 of 12 (58 ± 14%) lenticular isolated galaxies studied by us reveal a presence of extended ionized-gas discs which rotation is mostly decoupled from the stellar kinematics: in 5 of 7 (71 ± 17%) – NGC 3248, NGC 6798, NGC 7351, UGC 4551, UGC 9519 – the gas demonstrates visible counterrotation. Previously, Davis et al. (2011) studied three galaxies of our list using their IFU data; they mentioned kinematical misalignment of stars and ionized gas in these galaxies.

Davis et al. (2011) noted a dependence of gas kinematics in the early-type galaxies (mostly S0s in the ATLAS-3D sample) on their environment: dense environment provided tight coincidence between gas and star kinematics while in more sparse environments the fraction of decoupled gaseous kinematics grew. Our isolated lenticular galaxies represent an extreme point in this dependency, and the fraction of decoupled gas kinematics exceeds 50 per cent.

The decoupled kinematics is a clear evidence for external origin of the gas component. Our galaxies are isolated so they cannot acquire their gas from neighbours of comparable mass/luminosity; the sources of cold gas accretion may be dwarf satellite merging or perhaps cosmological gas filaments. Our measurements of oxygen abundance for 3 objects indicate that gas metallicity is subsolar, but not very low. NGC 6798 has a starforming ring at $r = \pm 30$ arcsec where $12 + \log O/H = 8.4 - 8.5$ dex. Oxygen abundance at the distance $7'' - 8''$ in the NGC 7351 has value of 8.2 dex, while at the center 8.45 dex. Such gas metallicities are more consistent with the gas accretion from dwarf satellites where the gas could be enriched by metals than with accretion from cosmic filaments.

We probably have found some traces of dichotomy in the ionized-gas excitation related to geometry of a gaseous system. When the gas is accreted smoothly in the plane of a stellar disc, there are more possibilities to conserve its coolness with following...
Figure 1. Kinematical profiles of stars (black points) and ionized gas (color points) of NGC 2350, NGC 6798, UGC 9519. Hα measurements are shown by red colour, [N II] – magenta. The low velocity dispersions falling below the possibility of being measured with our spectral resolution are indicated as 5 km s⁻¹ velocity dispersions.

ignition of star formation (SF). The location of emission-line ratio measurements in the SF region of the BPT diagram supposes that the young stars radiation contributes there the dominant source of gas ionization. Our observational data indicate that in the galaxies where the gas is probably confined to the disc planes (NGC 2350, NGC 6798, NGC 7351, the very outer part of NGC 6654) the excitation by young stars is preferable. Shocks or post-AGB stars are the main agent of gas excitation in the remaining galaxies (NGC 3248, UGC 4551, UGC 9519) whose velocity profiles possess asymmetries and complex features which are probably resulted from gas motions in inclined planes.

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Figure 2. Excitation diagnostic diagrams comparing the emission-line ratios: \([\text{NII}] / \text{H}\alpha\) vs. \([\text{OIII}] / \text{H}\beta\). The colour of the points codes the distance from the galaxy centers. The symbols correspond to different galaxies. The distribution of the measurements of the line ratios for galaxies from the SDSS survey with high signal-to-noise ratios (S/N > 3 in every line) are shown by gray colour. The black curves, which separate the areas with the AGN/LINER excitations (to the right) from areas with the star-formation-induced excitation (to the left from these curves), are taken from [Kaufrmann et al. (2003)](2003) (dash-dotted curve) and from [Kewley et al. (2006)](2006) (solid curve).