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Helical Structures in Seyfert Galaxies

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Abstract. Seyfert galaxies with Z-shaped emission filaments in the Narrow Line Region (NLR) are considered. We assume that observable Z-shaped structures and the velocity pattern of the NLR may be explained as tri-dimensional helical waves in the ionization cone.

1. Introduction

Numerous emission-line images of Seyfert galaxies show the existence of cone-like NLRs with broad opening angles and spatial sizes from 10 pc to 18 kpc (Wilson & Tsvetanov 1994). These galaxies also have highly collimated, elongated radio structures (radio-jets) coinciding with the cone axis (Wilson & Tsvetanov 1994; Nagar et al. 1999). An ordered Z-shaped emission pattern is a frequent feature in the NLR. We found more then 20 such objects on published emission-line images of nearby Seyferts. There is no common point of view on the origin of such regular structures in the NLR. Different models were proposed for individual objects: a bent bipolar outflow (Mulchaey et al. 1992), a strongly collimated precessing twin-jet (Veilleux, Tully, & Bland-Hawtorn 1993), a system of inclined gaseous disks (Morse et al. 1998), etc.

2. Kinematic Features of the Z-Shaped NLR

A sample of galaxies with Z-shaped NLRs were observed at the 6 m telescope. The scanning Fabry-Perot Interferometer and integral field spectrograph MPFS were used for study of the 2D kinematics of stars and ionized gas. Some systems of gas clouds with velocity differences more than $100 \div 200\,\mathrm{km\,s^{-1}}$ are present on the line of sight in the central regions of the cones, but the outer emission filaments have only one component of the emission lines. The gas velocity fields are strongly non-circular in comparison with the stellar fields. A large gradient in the line-of-sight gas velocities appears as a Z-shaped spiral. We note that similar features are also observed in the velocity fields of other Sy galaxies (see references in Moiseev et al. 2000) and these could be evidence for a common Z-shaped pattern.

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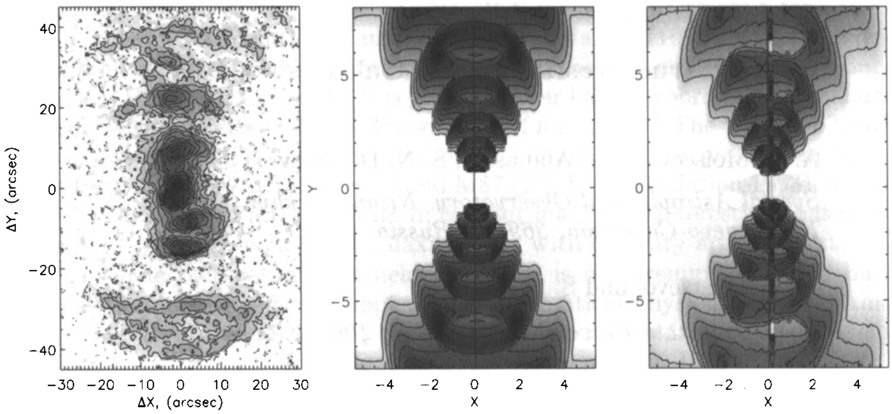

Figure 1. [OIII] image of NGC 5252 obtained at the 6 m telescope (*left*) and contours of the model luminosity for pinch (*middle*) and for helical (*right*) shock wave modes.

3. Non-Linear Simulations

We suggest that the Z-shaped spiral filaments in NLRs have a common wave origin and are generated by a hydrodynamic instability due to the velocity break between the galactic interstellar medium and outflowing gas from the central AGN. A collimated radio jet corresponds to the direction of outflow and matches with the cone's axis. A linear analysis shows that jets are unstable relative to waveguide-resonance development of pinch and helical internal gravity waves. Development of the instabilities leads to creation of a set of shock waves in the ambient medium. Our 2D and 3D non-linear hydrodynamic simulations show that the shock waves penetrate outward from the jet boundaries to the ambient medium. The resulting shock-wave structure covers a broad cone with opening angle $30° - 80°$ and appears in the sky-plane as a NLR with a bright emission pattern (Fig. 1). Pinch (axisymmetric) and helical modes of the shock waves develop in the NLR. Helical wave modes provide the Z-shaped emission structures which are observed in the ionized cones.

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