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Inner polar disks in early-type spiral galaxies

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Abstract. We measured a remarkable gas velocity gradient along the minor axis of a number of early-type spiral galaxies. This phenomenon suggests the presence of a kinematically-decoupled component in orthogonal rotation with respect to the galaxy disk which we named *inner polar disk*. If this is the case a second event has taken place in the history of the galaxy. Alternatively the gas velocity gradient is the result of non-circular motions induced by the potential of a triaxial bulge.

Key words. galaxies: kinematics and dynamics – galaxies: structure

1. Introduction

By looking at all the kinematical data available in literature for the S0's and spirals of the RSA catalog, we realized that $\sim 60\%$ of unbarred galaxies shows an unexpected gas velocity gradient along their minor axis. This phenomenon is observed all along the Hubble sequence of disk galaxies, but it is particularly frequent in S0'a and Sa spirals. To investigate this issue we measured the ionized-gas and stellar kinematics along the major and minor axis of a sample of 10 early-type spiral galaxies. We found a minor-axis velocity gradient of the gaseous component in 8 of them. In NGC 4984, NGC 7213, and NGC 7377 such a velocity gradient is due to the warped structure of the disk. We focused our attention to the remaining 5 galaxies for which the rotation along minor axis is confined in the innermost regions. They are NGC 2855, NGC 3885, NGC 4225, NGC 4586, and NGC 7049 (Fig. 1).

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2. Gas motion in a triaxial bulge

Since the minor axis rotation is confined in the central bulge-dominated region and the shape of bulges is generally triaxial (Bertola et al. 1991) we are left with two possible scenarios:
Non-circular motions: In a non-axisymmetric potential gas in equilibrium moves onto closed elliptical orbits which become nearly circular as soon as we move at larger radii (de Zeeuw & Franx 1989; Gerhard et al. 1989). In this scenario, the minor-axis velocity gradient observed in the innermost regions of the galaxy are generated by non-circular motions induced by triaxiality: there is no kinematical decoupling between the inner and the outer gas and both components are rotating in the same equilibrium plane. No central velocity plateau is predicted along the major axis (see Corsini et al. 2003 for details) and this is the case of NGC 3885, NGC 4224 and NGC 4586.

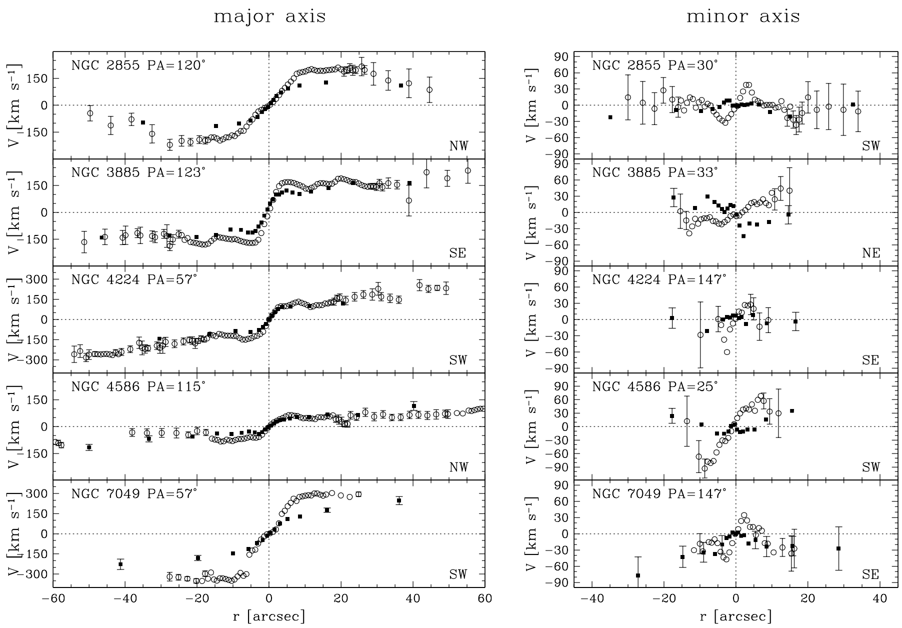

Fig. 1. Stellar (filled squares) and ionized-gas (open circles) velocity curves measured along major (left panels) and minor (right panels) axis of NGC 2855, NGC 3885, NGC 4224, NGC 4586, NGC 7049.

Intrinsic decoupling: There is a kinematically-decoupled gaseous structure settled in the equilibrium plane orthogonal to the intrinsic major axis of the triaxial bulge. Such a gas forms a disk, which is confined in the central region of the galaxy and it is in orthogonal rotation respect to the main disk of the galaxy. In the region characterized by the presence of the decoupled component, we expect to observe a zero-velocity plateau along the disk major axis (or at least a remarkable decreasing of the velocity gradient) as observed in NGC 2855 (see also Corsini et al. 2002) and NGC 7049. This particular behavior was observed in NGC 4698 for both the gaseous and stellar component (Bertola et al. 1999). HST observations confirmed the presence of a nuclear stellar disk in orthogonal rotation (Pizzella et al. 2002).

In NGC 2855 and NGC 7049 the origin of the orthogonally-rotating gaseous structure, which we named *inner polar disk*, can be explained with the occurrence of a second event during the galaxy lifetime. This phenomena suggests that even galaxies with an apparently undisturbed morphology may unveil signs of acquisition phenomena, which can be evidenced only by detailed studies of their kinematics.

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