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PRESENTACIÓN MURAL

The Paradigm of SAURON vs. the Ring of NGC 7742 and Other Kinematic Mirages

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Abstract. In the last ten years several scenarios have been explored to explain kinematically decoupled cores (KDCs) in early type galaxies. Among them are large fractions of merging events and the subsequent missing satellite problem, dwarf-spheroidals harassment, giant-ellipticals formation and evolution, and dark matter cusp effects. We show that the phenomenon of core counter rotation can also be explained by a warping of the equatorial plane defined by the observed stellar rotation. Once an instability has led to a warped inner disk core, the perturbed orbits can maintain a common orientation due to rigid body-like rotation at the central region. We found that warp angles not larger than 30 degrees could explain fast and low rotators of the "Sauron paradigm" in a unified scenario requiring the smallest angular momentum difference between the outer disk and its KDC, including the paradigmatic case of the counter-rotating ring of NGC 7742. We propose that these "kinematic mirages" cannot be neglected and therefore caution should be taken when considering the KDC statistics under the galaxy formation and evolution scenarios.

Resumen.
Varios escenarios se han explorado en los últimos 10 años para explicar los núcleos cinématicamente desacoplados (KDCs) en galaxias de tipo temprano, mayormente involucrando grandes números de eventos de fusión en la vida de una galaxia, interacciones fuertes con enanas esferoidales, efectos de la cúspide del halo de materia oscura, etc. Mostramos aquí que el fenómeno de contra-rotación de los núcleos se puede explicar también por un alabeo del plano ecuatorial definido por la rotación estelar observada. La solución que proponemos requiere una mínima diferencia de momento angular entre el disco estelar externo y el KDC, y se ejemplifica con el caso del anillo circumnuclear 'contra-rotante' de NGC 7742. Basta con ángulos de alabeo no mayores que 30 grados para generar un 'espejismo' cinemático que podría explicar las familias de rotadores 'rápidos' y 'lentos' en el llamado 'paradigma de Sauron' por lo que algunas de sus implicaciones como el problema de los 'satélites faltantes', deben ser consideradas con precaución a la hora de extenderlas a los escenarios de formación y evolución de galaxias.

1. Introduction

More than twenty years ago, Efstathiou, Ellis & Carter (1982) reported for the first time the discovery of a counter-rotating core in the elliptical galaxy NGC 5813. In the same year, Bender (1988) had found that four out of seven slowly rotating large ellipticals presented fast rotating or counter-rotating cores. Then Balcells & Quinn (1990) modeled numerically a merger between a large elliptical and a small companion, with the caveat that the smaller of the two merging galaxies has to have a core dense enough to survive the tidal stripping, dynamical friction, and to arrive intact to the center of the main elliptical. Two new results further challenged this scenario: the discovery of KDCs in a disturbing number of dwarf ellipticals with $M_B > -19$ (e.g. de Rijcke et al. 2004); and the striking similarity in the stellar content of the KDCs and the host galaxy (e.g. Emsellen et al. 2004). The also proposed harassment produced by the fly-by encounters with other galaxies can explain the counter-rotating core of NGC 770 (Geha et al. 2005) but cannot explain the origin of the counter-rotating core of the nucleated galaxy VCC 510 in the Virgo cluster. With $M_B \approx -15.7$, it is the smallest dwarf known to show a counter-rotating core (Thomas et al. 2006). Cases like VCC510 should not be expected more than once every 400 galaxies in a Hubble time. There is no unified scenario for the KDC phenomenon, but a consensus seems to exist about the existence of decoupled central structures, on scales from tens of parsecs to as much as two kiloparsecs, in a variety of galaxies with brightness between $-22 < M_B < -16$. The data table of the 28 objects studied is available upon request to the authors.

2. Some Results

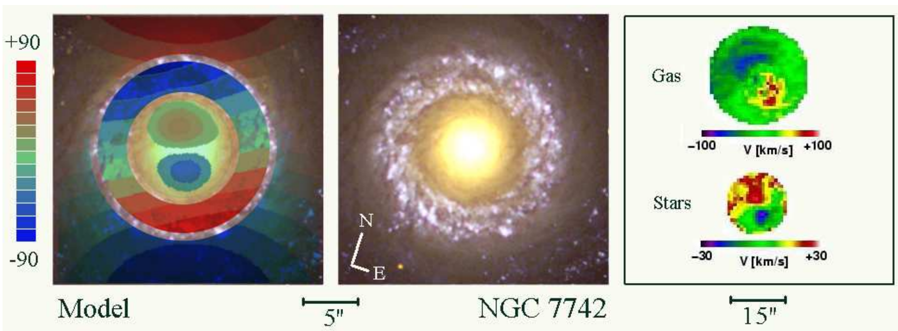

Figure 1. The most evident example of the proposed scenario: the well known counter-rotating gaseous circumnuclear ring of NGC 7742 (SAURON+WHT, de Zeeuw et al. 2002). Left: example of small tilt model for the gaseous disk, with $i_g = +10°$, $PA_g = 40°$, and for the stellar radial velocity field $i_s = -5°$, $PA_s = 30°$, assuming a seeing of $1.5''$. Center: Hubble Heritage optical composite image of NGC 7742. Right: Observed radial velocity fields. Note that the ring has an almost circular projection on the sky plane, suggesting the face-on configuration.

The geometry and projected kinematics of a global disk with a warped external region have been extensively discussed in literature. In the most common rotation curve case, where approximately $\Omega \propto 1/R$, slow and fast bending waves are produced on the warp (Binney & Tremaine 1991). We deal here with a rather new aspect of this phenomenon, the warping of the inner disk. Hitherto, it has not been realized that this type of warping can survive for a long time in the region with a rigid body-like rotation curve. It can be easily shown that in these regions the epiciclic and vertical frequencies are approximately constant and a set of orbits in a plane would preserve their identity (radial lines of particles remain aligned), eventually precessing as a whole. That makes a substantial difference to the external warping case and allows us to present the problem as that of a sharp warping which physically separates the central part of the equatorial plane of a rotating ellipsoidal galaxy, which we will simply call the disk. Since in the Sauron paradigm literature no distinction has been made heretofore between disk galaxies or galaxies with a strong spheroid, we will in general refer to disk warps or tilts in the stellar rotation equatorial plane. **Sauron's Counter Rotating Ring:** A clear example is the radial velocity field of the circumnuclear ring of gas in NGC 7742, studied by de Zeeuw et al (2002, their Figure 13). The authors propose that the ring counter-rotates with respect to the stellar component inside the radius of the ring. Notwithstanding, this otherwise normal galaxy is face-on (the circumnuclear ring is indeed circular in appearance in the HST imagery) and the amplitude of the stellar velocities is modest. Fig. 1 shows a simple kinematic model constructed from a typical Hα rotation curve for a circumnuclear ring, co-rotating and tilted just 15° with respect to the stellar disk. The gas rotation velocity has moderate values and this small tilt of the gaseous ring would explain the apparent counter rotation between the gas and the stellar velocity field. There is no need for a very complex chemical history as proposed by Mazzuca et al. (2006), and a dynamically unstable configuration like the rotation of the gaseous clouds against the stellar streams in the equatorial plane of the galaxy. Most probably, we are just facing a "kinematic mirage" from an otherwise normal circumnuclear ring. **Two extreme cases:** The best source of examples is provided by the most complete sample of early type galaxies for which 3D spectroscopy has been performed using the SAURON instrument (Bacon et al. 2001). We developed a simple kinematic model for NGC 4382, which is one of the paradigmatic and extreme objects in the sample. This galaxy's central region, first observed with SAURON (Emsellem et al. 2004), and later at higher resolution with OASIS (McDermid et al. 2004), presents a counter-rotating KDC with a small rotation amplitude ($\sim 30\,\mathrm{km/s}$). The model radial velocity field was constructed with a Plummer spheroidal mass component fitted to the global observed radial velocity field up to $20''$ with a small inclination. Allowing for an abrupt but small change of inclination and line of nodes for radii smaller than $2''$, we were able to reproduce the observed radial velocity field, see Fig. 2. Another well known case is that of NGC 770 observed at the Gemini North Telescope with GMOS (Geha et al. 2005). This is a dwarf elliptical galaxy and a satellite of NGC 772, as mentioned in Section 1, the cannibalism origin seems statistically implausible for this small galaxy. Geha et al. (2005) propose that the dwarf satellite has engulfed a smaller dwarf companion which only changed the rotation sense in the center and no other property of the stellar population. Moreover, surface photometry by Geha et al. (2005) shows a change in the photometric major axis at the KDC outer radius, but their spectra do not show a change in the chemical properties of the underlying stellar population, within the observational uncertainties. This is more consistent with a strong warp in the stellar disk ($\leq 65°$) in the example model presented in Fig. 2. This warp could be originated by tidal perturbations in the same way external warps are created in galaxy interactions, even with a relatively small perturbation and angular momentum exchange, as has been shown by observations and numerical modeling (e.g. Díaz et al. 2000).

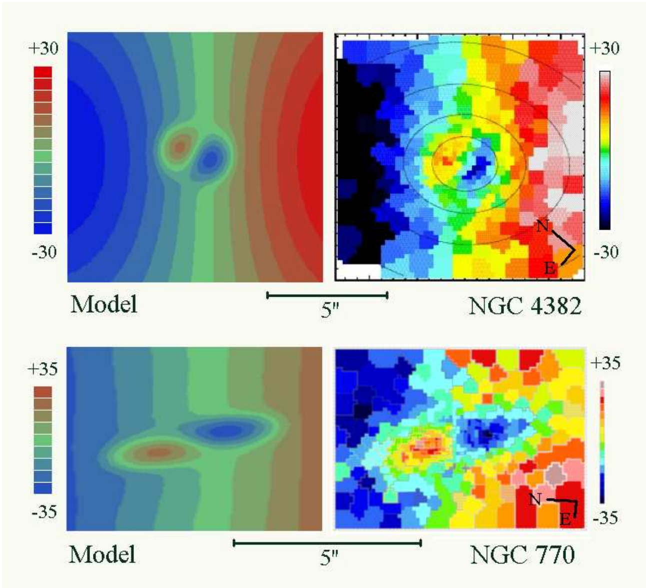

Figure 2. Up: small warp model, with $i_o = +10°$, $PA_o = 45°$, and for radii $r < 2''$, $i_i = -10°$, $PA_i = 25°$, seeing of $0.5''$; and the observed radial velocity of the "paradigm" object NGC 4382 (OASIS, Mc Dermid et al. 2004). Down: large warp model, with $i_o = -10°$, $PA_o = 0°$, and for radii $r < 2.5''$, $i_i = +60°$, $PA_i = 15°$, seeing of $0.7''$; and the observed radial velocity of the dwarf elliptical NGC 770 (GMOS+Gemini, Geha et al. 2005).

References

Bacon, R., et al., 2001, MNRAS, 326, 23
Balcells & Quinn 1990, ApJ, 361, 381
Bender, R. 1988, A&A, Lett 202, L5
Binney, J., & Tremaine, S. 1991, Galactic Dynamics, pp. 406 & 599 (Princeton U.P.)
De Rijcke, S. Dejonghe, H., Zeilinger, W., Hau, G. 2004, A&A, 426, 53
De Zeeuw, T., et al., 2002, MNRAS, 329, 513
Díaz, R., Rodrigues, I., Dottori, H., Carranza, G. 2000, AJ, 119, 111
Efstathiou, G., Ellis, R., Carter, D. 1982, MNRAS, 201, 975
Emsellem, E., et al., 2004, MNRAS, 352, 721
Geha, M., Guhathakurta, P., van der Marel, R. 2005, AJ, 129, 2627
Mazzuca, L., Sarzi, M., Knapen, J., Veilleux, S., Swaters, R. 2006, ApJ, 649, L79
McDermid, R., et al., 2006, MNRAS, 373, 906
Thomas, D., et al., 2006, A&A, 445, L19