Detecting Triaxiality and Figure Rotation in Gaseous Elliptical Galaxies

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Abstract: We discuss the possibility of detecting triaxiality and figure rotation in elliptical galaxies with extended edge-on gaseous disks, using the method developed by Kuijken & Merrifield (1995) to detect bars in edge-on spiral galaxies.

1 Introduction

The ellipticity of most (giant) elliptical galaxies is not due to rotational flattening and is generally explained by velocity dispersion anisotropies, which means that most ellipticals are probably triaxial. This view is supported by other properties of many elliptical galaxies (e.g. isophotal twist and minor axis rotation). While it is accepted that many ellipticals are triaxial, the question of whether their figure rotates (tumbles) remains open and almost untouched. From a theoretical point of view, rotating triaxial models have been constructed to study the orbital configuration and stability in those systems. On the other hand, there are few observational results concerning figure rotation in triaxial ellipticals. Figure rotation has a profound effect on the dynamics of triaxial systems, so it is important to find a way to attack this problem from an observational point of view.

We propose here that the innovative approach developed by Kuijken & Merrifield (1995) for the study of barred spiral galaxies could be used as well to study the properties of ellipticals. They have shown that it is possible to identify a bar in an edge-on spiral galaxy from kinematical observations alone. We argue that their method could be used to detect figure rotation in trixial elliptical galaxies possessing an extended gaseous disk seen edge-on.

2 Detecting Triaxiality and Figure Rotation:

Spiral Galaxies

Kuijken & Merrifield (1995) have shown that, due to the particular dynamics of a barred disk, the gas in an edge-on barred system will have a characteristic two-dimensional line-of-sight velocity distribution (LOSVD, or position-velocity diagram), markedly different from gas in near-circular motion in an axisymmetric disk. The orbits in a non-axisymmetric disk potential are elongated. In a barred disk, resonances occur between circular motions and the bar pattern speed; with increasing radius, the orbits change their orientation at each principal resonance (inner Lindblad resonance, corotation, outer Lindblad resonance). Because the gas is forced onto closed non-overlapping, non-self-intersecting orbits, a region around those resonances will be gas-depleted, creating gaps in the projected LOSVD (compared to an axisymmetric disk) and giving rise to a characteristic "figure-of-eight" (double-peaked profiles, see the bottom diagram of Fig. 1 for a striking example). This feature is a signature of the non-axisymmetric potential in the disk.

In spiral galaxies, where we know the triaxial potential of bars rotates, this method can be used to detect if a bar is present in an edge-on system. The bars in spirals are rapidly rotating and often the inner Lindblad resonance is not present. The major resonance is then corotation, far out in the disk. Because most spiral galaxies have extended gaseous disks (particularly the late-type systems), this method can potentially be applied to a large number of objects.

3 Detecting Triaxiality and Figure Rotation:

Elliptical Galaxies

We believe that the method of Kuijken & Merrifield (1995) can be used directly to detect if the figures of triaxial elliptical galaxies are rotating.

Resonances depend only on the figure rotation and the form of the potential, and the potential of a rotating triaxial elliptical galaxy is very much like that of a bar. Still, for the method to work, the presence of a gaseous disk is required. While most ellipticals are gas-poor, a significant fraction of them do in fact possess a gaseous disk, which in some examples is relatively extended. The question remains whether these disks extend far enough in radius, out to the resonances, for the method to be useful. We argue that they do. Because the bars in spiral galaxies are rapidly rotating, the method requires that the gas extends out at least to the corotation radius. On the other hand, the tumbling of the figure in triaxial ellipticals is believed to be slow. If this is correct, an inner Lindblad resonance (occuring at small radius) should be present in the disk, and a relatively extended gaseous disk may well reach that far.

From this argument, we suggest that it may be possible to detect figure rotation (and triaxiality) in elliptical galaxies possessing an edge-on gaseous disk, by looking for the "figure-of-eight" signature in the inner parts of their observed gas line-of-sight velocity distribution (LOSVD).

4 Comments

Before claiming detections of triaxiality and figure rotation, one needs to consider whether other structural or dynamical components in an axisymmetric or non-rotating triaxial galaxy could give rise to a feature similar to the "figure-of-eight" in the gas LOSVD.

The most obvious candidate is a ring embedded in an axisymmetric gaseous disk. The superposition of the apparent solid-body rotation curve of an edge-on ring and an intrinsically more-or-less flat rotation curve would produce a double-peaked gas LOSVD, qualitatively similar to the gross features of the distribution shown in Fig. 1 (bottom) for NGC 5746. We note, however, that the LOSVD for NGC 5746 is in detail much more complex than this simple picture would allow. Merrifield (1996: Figure 3) has shown that the LOSVD signature expected from an edge-on gaseous disk in a rotating triaxial potential can be similarly complex, depending on the viewing angle. It would be difficult to reproduce this level of complexity by simply adding or subtracting a dynamical component to an axisymmetric disk. The same may well apply to the velocity distribution created by selectively populating certain periodic orbit families in non-rotating triaxial systems.

5 Observational Examples

Although we have not yet applied the method to elliptical galaxies, we illustrate the kind of gas LOSVD signature one might expect from a rotating triaxial galaxy with an edge-on gaseous disk, by showing observations of the almost edge-on (barred) spiral galaxies NGC 5746 (Fig. 1) and IC 5096 (Fig. 2). Fig. 1 & 2 show the ionised gas LOSVD along the major axis of the galaxies (obtained from optical long-slit spectroscopy), accompanied by Digitized Sky Survey images on the same scale. The line-splitting giving rise to the "figure-of-eight" is obvious in both cases and indicates that a bar is present in the disk of the galaxies. A more detailed comparison with models indicates that the bar in IC 5096 is probably seen almost end-on while the NGC 5746 bar is seen more side-on.

As part of an ongoing study of spiral galaxies with boxy/peanut-shaped bulges, we have observed the "figure-of-eight" signature in every system (6 up to now) where the line emission was sufficiently extended, supporting the hypothesis that these boxy/peanut systems are edge-on barred spirals.

We expect rotating triaxial elliptical galaxies to display the "figure-of-eight" gas LOSVD, analogous to what is seen in the inner parts of Fig. 1 and Fig. 2 (bottom diagrams). The detection of triaxiality and figure rotation in elliptical galaxies should therefore be straightforward if a sufficiently extended gaseous disk is present.

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References

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Figure 1. Structure and kinematics of NGC 5746.

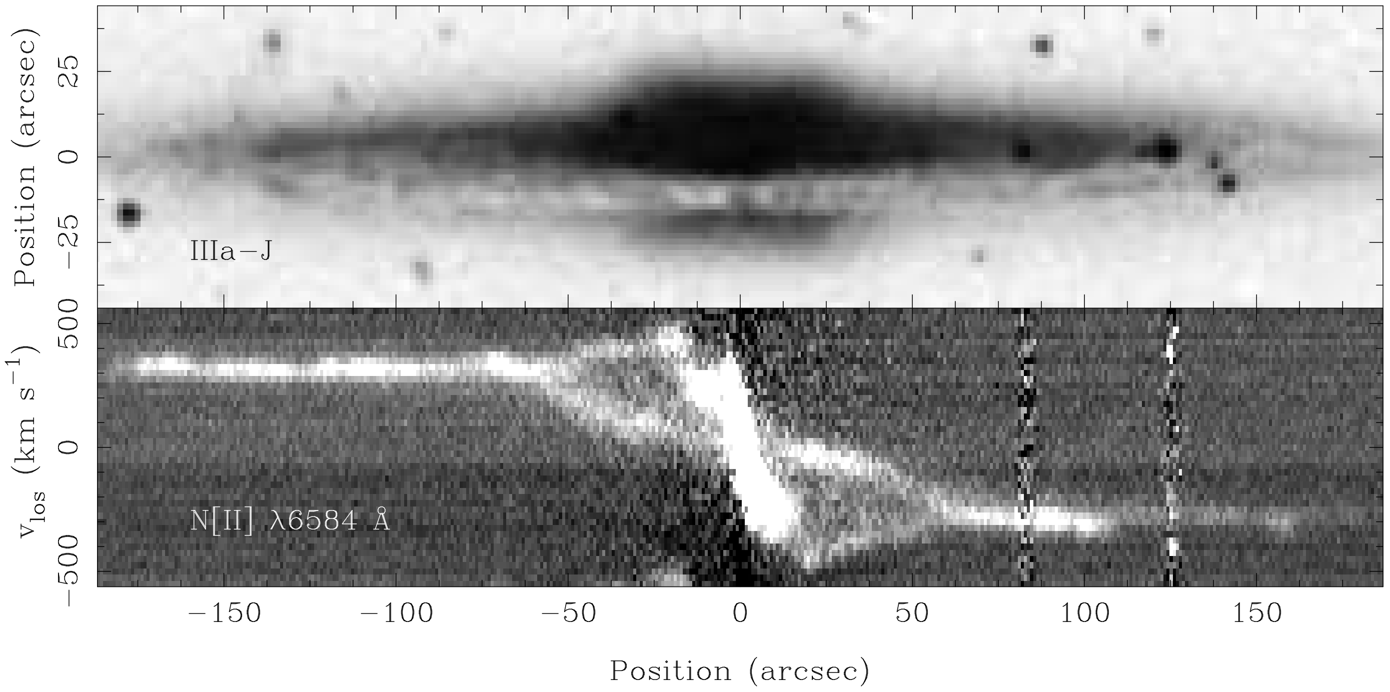
Figure 2. Structure and kinematics of IC 5096.

Figure 1. & 2.:

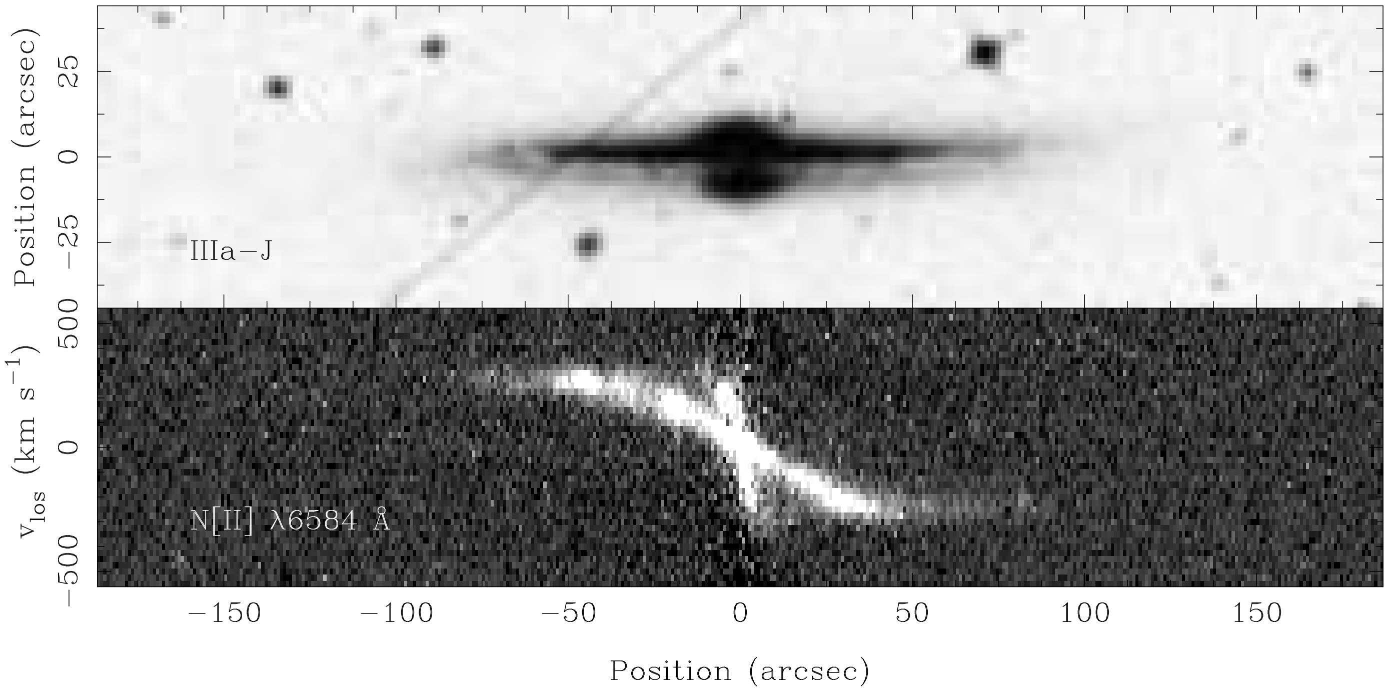
Top: Blue image of the galaxy (DSS).

Bottom: Line-of-sight velocity distribution (LOSVD) of the ionised gas ([N II] λ6584 Å) along the major axis of the galaxy.

Note: The complex structures in the LOSVD's are caused by the orbital properties of the gas in the potential of a rotating bar. The "figures-of-eight" are the characteristic signature of a rotating triaxial potential on an edge-on gaseous disk.



IIIa−J
N[II] λ6584 Å
Position (arcsec)
v_{los} (km s^{-1})
Position (arcsec)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N[II] λ6584 Å
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v_{los} (km s^{-1})
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50
100
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Position (arcsec)