Major-axis velocity profiles of galactic bars

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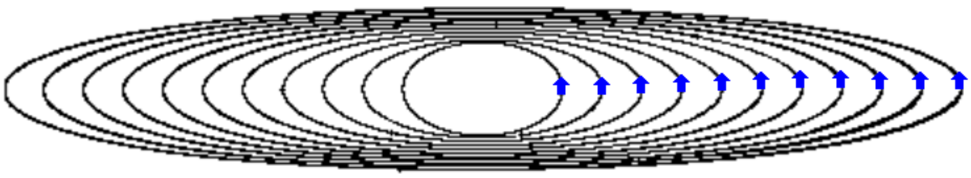
Galactic bars are often assumed to have "solid body rotation" because the major axis velocity profile observed in many bars is linearly rising.

In simple power-law fields the gravitational acceleration towards the centre varies in proportion to the distance **d** from the centre raised to some power **x**. A field may be described by its value of **x**. For example the (x=-2) field is the "inverse square" keplerian field.

The assumption that bars have solid-body rotation is equivalent to saying that the field in the bar region is the (x=1) field, also known as the simple harmonic oscillator field. If the orbital streamlines of the bar are assumed to be all of the same ellipticity, then indeed only the (x=1) field produces a linearly rising major axis velocity profile.

However in [1] it was shown that a galactic bar will have an ellipticity profile in which each orbital streamline is slightly more elliptical than the orbital streamline immediately inside it. This ellipticity profile is precisely tuned to produce exactly the same precession rate for every streamline.

Therefore this paper calculates the major axis velocity profile of a galactic bar in which the orbital streamlines have the exact ellipticity profile which produces co-precession of all the streamlines. The field chosen first for illustration is the (x=2) field. This produces the surprising result that the major axis velocity profile is linearly rising.



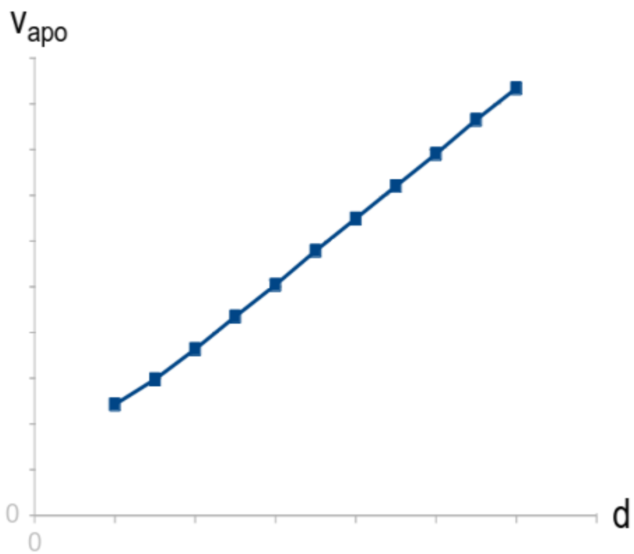


Figure 1

Major axis velocity profile of a galactic bar in the (x=2) field

A similar result is obtained for the (x=1.5) field, in which a bar, with an ellipticity profile tuned to produce co-precession of all streamlines, also produces a linearly rising major axis velocity profile.

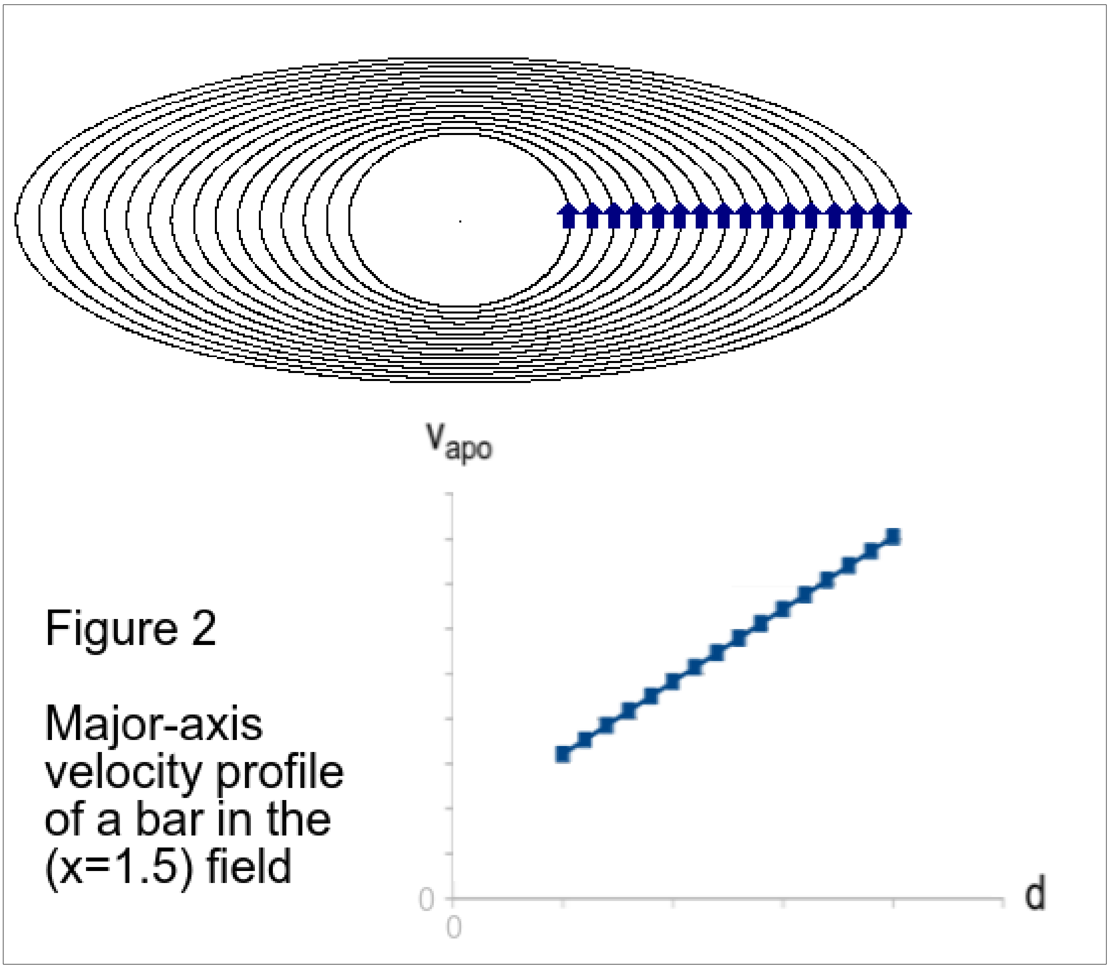
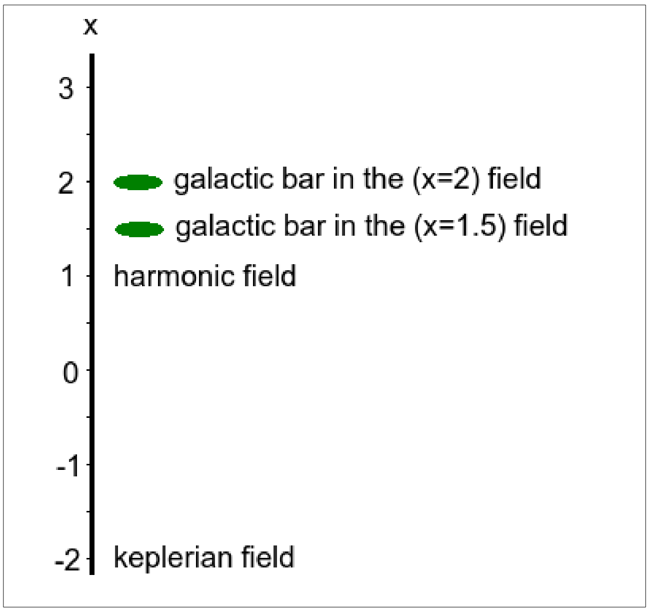


Figure 2

Major-axis velocity profile of a bar in the (x=1.5) field

In figure 3 the fields of the two example bars are are illustrated relative to the keplerian (inverse square) field and the harmonic (solid body rotation) field.



Conclusion

Galactic bars constructed in simple power-law fields in the range (x>1) have linearly rising major-axis velocity profiles.

This surprising result is a consequence of the precisely tuned ellipticity profile (streamline ellipticity increases with streamline size) which produces co-precession of all the streamlines. Specific examples are illustrated for the (x=2) and the (x=1.5) fields.

The widespread view, that a linearly rising major axis velocity profile indicates the (x=1) field, also known as the “solid body rotation” field or “simple harmonic oscillator” field, is based on an implicit assumption that all streamlines have the same ellipticity, and therefore is likely to be incorrect.

In a bar, streamline ellipticity increases with streamline size, therefore an observed linearly rising major axis velocity profile means that the field is not the (x=1) field, but is a field in the range (x>1).

Bars with observed linearly rising major axis velocity profiles are consistent with power law fields significantly beyond the (x=1) field, as demonstrated by the bars in the (x=1.5) and (x=2) fields presented above.

It is remarkable that in simple power law fields in the range (x>1), the ellipticity profile which produces co-precession throughout the bar also produces a linear relationship between apocentre velocities and apocentre distances, and it would be interesting to know whether there is an analytical explanation for this numerical result.

References

[1] Edgeworth S.
Galactic bars in power-law fields
www.orbsi.uk/space/research/se/pdf/galactic-bars-in-power-law-fields.pdf