Barred Galaxies
ASP Conference Series, Vol. 91, 1996
R. Buta, D. A. Crocker, and B. G. Elmegreen, eds.

Hydrodynamical Simulations of the Barred Spiral Galaxy NGC 1365

P. A. B. Lindblad and P. O. Lindblad

Stockholm Observatory, S-133 36 Saltsjöbaden, Sweden

E. Athanassoula

Observatoire de Marseille, 2 Place Le Verrier, F-13248 Marseille Cedex 4, France

1. Introduction

Several authors have explored the field of gas dynamics in barred systems. One of the aims of these investigations was to compare the model gaseous response, due to some assumed underlying stellar gravitational field, with observed gas density distribution and kinematics of barred galaxies. The gas is known to respond in a highly non-linear way, and therefore should give clues to dynamical parameters like the mass distribution, positions and existence of principal resonances and thereby the pattern speed.

2. Observations

High resolution HI data now exist for NGC 1365 (Jörsäter & van Moorsel 1995), and the kinematical HI data have been combined with optical long slit measurements to obtain the velocity field (Lindblad et al. 1995) used for extracting the rotation curve, representing the axisymmetric forces in NGC 1365, and for comparisons with models. A mosaic image of NGC 1365 in the J-band was used to compute the perturbing potential used in the models.

3. Conclusions from Hydrodynamical Simulations

We show that the density and velocity structure of a barred spiral galaxy may be reproduced with a rather simple model (see Figure 1). The bar and spiral potential shape, and the rotation curve outside $R > 120''$, have values directly from observations. For $R < 120''$ we use a rotation curve that is consistent with the observed optical slit velocities to the first order, when the perturbations of the bar have been taken into account. The pattern speed has a value that puts CR at a radius $R_{\rm CR} \sim 1.25 R_{\rm bar}$, in agreement with Athanassoula (1992).

The inner HI arms are reproduced in the models, where the model arms are driven by the forces associated with the ending of the bar, while both the outer HI arms and the offset dust lanes are explained as orbit crowding when crossing a resonance, consistent with viscous linear epicyclic theory (Lindblad & Lindblad 1994, Wada 1994). We can improve the fit by including a spiral potential, indicating massive spiral arms in NGC 1365. The observed motions

https://doi.org/10.1017/S0252921100050119 Published online by Cambridge University Press

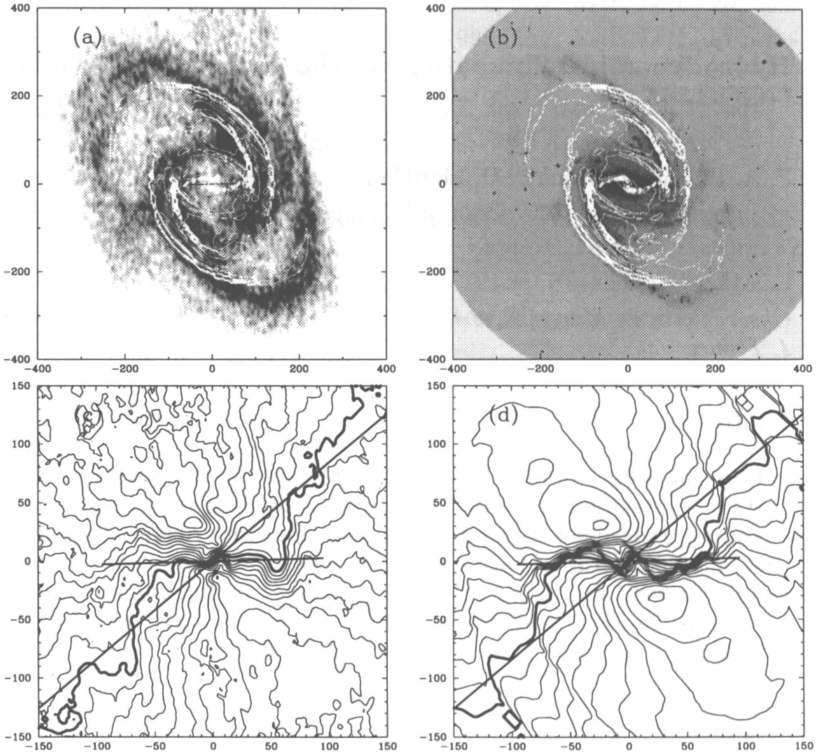

Figure 1. The bar + spiral model density contour map overlaid on the HI density map (**a**), the optical map (**b**). The observed, smoothed, velocity field inside $R < 150''$ (**c**), and the corresponding model velocity field (**d**), where the zero isovelocity contour is marked by the thick contour, and the galaxy minor axis and the bar major axis are marked by the straight lines.

in the bar region are consistent with the model streaming. We find that the star forming regions in our models resemble well those in NGC 1365, with star formation predominantly in the inner spiral arms and at the end of the bar. The full investigation is presented in Lindblad et al. (1995).

Acknowledgments. We would like to thank Steven Jörsäter and Gustav van Moorsel for letting us use their HI data, G.D. van Albada for making available to us his version of the FS2 code and Alice Quillen and Jay Frogel for letting us use their J-band image of NGC 1365.

References

Athanassoula, E. 1992, MNRAS, 259, 328 and 345
Jörsäter, S. & van Moorsel, G. 1995, AJ, 110, 2037

Lindblad, P. A. B., Lindblad, P. O., & Athanassoula, E. 1995, A&A, submitted
Lindblad, P. O. & Lindblad, P. A. B. 1994, in The Gaseous and Stellar Disks of the Galaxy, King I. R., San Francisco: AIP, 29
Lindblad, P. O., Hjelm, M., Högbom, J., Jörsäter, S., Lindblad, P. A. B., & Santos-Lleó, M. 1995, in preparation
Wada, K. 1994, PASJ, 46, 165

Discussion

A. Bosma: Did you calculate from your model a rotation curve in the same way S. Jörsäter did from the observations, and how well does it agree with the input rotation curve?

P.A.B. Lindblad: Yes we have, and the agreement is very good.

B. Elmegreen: What difference is there between the dust lanes in the spiral and the dust lanes in the bar which puts star formation in the former?

P.A.B. Lindblad: The shear is larger in the bar offset dust lanes, which inhibits star formation.

J. Sellwood: Your model places the OLR well inside the ends of the spiral arms. The termination of a spiral arm at its OLR is one of the few aspects of spiral structure that all theorists would agree! If your pattern speed cannot be lowered enough, or the outer rotation curve revised upwards, then it could be that the spirals have a different pattern speed from the bar.

P.A.B. Lindblad: The rotation curve in the outer parts is uncertain mainly due to warp effects. If we slightly modify the rotation curve, as to push the OLR further out, we can greatly improve the model fit in that region.

P. Teuben: Very nice sharp transition $x_2 \rightarrow x_1$ at ILR confirmed, but why so smooth across shock? Are the observations smoothed, or is there a problem with the models (having too sharp shocks)?

P.A.B. Lindblad: The velocity field is necessarily smoothed in the procedure of creation. When comparing slit spectra directly with the model velocities, the model velocity gradient across the dust lanes fits very nicely with the observed gradient.

Z. Tsvetanov: There are some weak spiral arms that do not come out of the end of the bar. Does your model reproduce these structures and, if yes, do they teach you something important?

P.A.B. Lindblad: There is a weak model arm, starting at the end of the bar, which we believe is created by the 4:1 resonance. It bears some resemblance to the observed arms, but the situation is not clear.