International Journal of Astrobiology 5 (4): 325–326 (2006) Printed in the United Kingdom
doi:10.1017/S1473550406003065 First published online 19 September 2006

The galactic habitable zone in barred galaxies

M. Sundin

Department of Physics, Gothenburg University, S-412 96 Gothenburg, Sweden
e-mail: maria.sundin@physics.gu.se

Abstract: One of the criteria for the concept of a galactic habitable zone (GHZ) is that the pattern speed of the stars in the GHZ should be close to the pattern speed of the spiral arms. Another criteria is that the stars in it should have a high enough metallicity. In a barred galaxy, the GHZ will be more complicated to define since the bar can change stellar orbits. Many disc galaxies, including the Milky Way, are barred galaxies. The stars in the bar move in a number of fairly complicated orbits. However, the bar will also influence the orbits of stars in the whole galaxy. Stars passing close to the bar can either gain or lose angular momentum, due to a positive or negative torque by the bar. Some stars will therefore be captured by the bar while some stars eventually may reach the escape velocity from the galaxy. The bar will hence be able to relocate stars, and stars with low or high metallicity could be found far away from their original orbits. The ordinary evolution of a bar is to grow in length out to the co-rotation radius for the pattern speed of the bar. As the galaxy ages, and the bar grows in length, the bar will influence a larger part of the galaxy. The effect of moving stars inwards or outwards is greatest just outside the bar, and this region can eventually lose a high percentage of the stars.

Received 6 July 2006, accepted 28 July 2006

Key words: barred galaxies, galactic habitable zone, Milky Way, stellar orbits transfer of angular momentum.

Introduction

The concept of a habitable zone around a star is well known in astrobiology as the zone where a planet with liquid water on the surface could exist. The existence of a galactic habitable zone (GHZ) in the Milky Way has been proposed (Gonzales 2001). The two most important criteria discussed (Gonzales 2001; Lineweaver 2004) so far for the GHZ are as follows.

(1) A high enough metallicity allowing terrestrial planets to form. This rules out the outer parts of the disc where the metallicity is low due to slow star formation. The metallicity should on the other hand not be too high as this could favour the creation of hot-Jupiters instead of terrestrial planets.
(2) An environment free of hazardous radiation. This means that the speed of the star should be close to the pattern speed of the spiral arms, thus avoiding many spiral arm crossings. The spiral arms and the galactic centre are regions of extreme UV, X-ray and gamma radiation.

These two criteria indicate the GHZ in the Milky Way being a narrow annular region at approximately the same distance from the galactic centre as the Sun. The main foci in the criteria have been on the chemical evolution of the galaxy, and on what we know of the evolution of life. I suggest that it is also important to include stellar dynamics.

Since the beginning of the 1990s there has been growing evidence of the Milky Way being a barred galaxy (Gerhard 2002). New results from the Spitzer Space Telescope (Benjamin *et al.* 2005) indicate the Galactic bar being a larger feature than previously thought. Their results indicate that the bar is 27 000 light years long. So far, however, the existence and influence of the bar in the Milky Way on the GHZ has not been discussed. In this paper, it is proposed that it is essential to take the bar into account and that the GHZ will be much harder to define in the Milky Way due to the existence of the bar. Both of the above criteria will be influenced. In a barred galaxy the transfer of angular momentum between the bar and the stars will occur. One way to transfer angular momentum (Lerner *et al.* 1999) will be discussed in this paper. Further research will be needed to complete the picture. The discussion presented is general and relevant for all barred galaxies, not only the Milky Way.

Stellar orbits in barred galaxies

In the Hubble classification of galaxies we have two different kinds of disc galaxies, i.e. spiral galaxies and barred (spiral) galaxies. Research on barred galaxies has been performed using observations, theory and numerical simulations. The bar is built by stars moving on a number of different orbits, the most common examples being elongated orbits belonging to the x1-family (Contopoulos & Grosbol 1989). It is also possible for stars to move between the bar and the disc, especially if the barred galaxy is perturbed (Sundin 1991). Knowledge of the orbital structure of the bar is very important for the understanding of how angular momentum can be exchanged in a barred galaxy.

A passage of a star close to one of the two edges of the bar can lead to a positive or negative transfer of angular momentum from the bar to the star (Lerner *et al.* 1999). The sign of the transfer of angular momentum is dependent on the position of the star relative to the bar at the time of closest approach. The star can either be subject to a positive or negative torque by the bar, leading to either a positive or negative transfer of angular momentum. Repeated passages of a star close to the bar's edges hence leads to several changes in the angular momentum of the star. This will cause the orbits of the star to change. Several positive transfers of angular momentum can eventually lead to the star gaining the escape velocity to leave the galaxy. Among the conclusions (Lerner *et al.* 1999) are that the stars which are born close to the centre of the galaxy usually end up in the bar. Stars born in the outer parts of the galaxy remain there on fairly circular orbits. In the annular region just outside of the bar the stars are heavily perturbed and they end up spread over the whole of the disc or they may escape the galaxy. Thus, high metallicity stars could be found in all parts of a barred galaxy.

The normal evolution of a bar is to grow out to the co-rotation region between the pattern speed of the bar and the stars. In barred galaxies where the pattern speed of the bar coincides with the pattern speed of the spiral arms, the stars in the region normally viewed as the GHZ, according to criterion (2), will be very perturbed. Many of the stars will move on elongated orbits leading to greater chances of passing the spiral arms.

Conclusions

Until we know more about the bar in the Milky Way, for example the exact length, shape, pattern speed and mass distribution, it is hard to say exactly how it influences the other parts of the galaxy. For all barred galaxies there is a chance of finding high metallicity stars all over the galaxy, and some stars originally co-rotating with the spiral arms will start moving on elongated orbits leading to spiral arm passages. Thus, both criteria in the introduction to this paper will have to be reconsidered. The author suggests that it is probably impossible to identify a well-defined GHZ in most galaxies. What could be done instead is, for example, to determine the probability of finding stars suitable for life for each part of the galaxy.

Future work

The components of a barred galaxy are the thin and thick disc, the bar, the bulge, the spiral arms and the halo. Barred galaxies can also be very different in length, mass, mass distribution, pattern speed and shape, as well as having dissimilar galactic components. There is a number of ways that angular momentum and energy can be redistributed in a galaxy (Athanassoula 2003). The interactions of galaxies will also lead to large changes of angular momentum and energy. For the moment, the Milky Way is merging with the Sagittarius dwarf (Majewski *et al.* 2003). Also, the gas and dust of the interstellar medium will be involved in the exchange. Future work will have to be done on all these components to gain a full understanding of the GHZ.

It would, of course, also be interesting to investigate the possibility of finding regions suitable for life in elliptical, lenticular, irregular and active galaxies.

References

Athanassoula, E. (2003). *Mon. Not. R. Asron. Soc.* **341**, 1179–1198.
Benjamin, R.A. *et al.* (2005). *Astrophys. J.* **630**, L149–L152.
Contopoulos, G. & Grosbol, P. (1989). *Astron. Astrophys. Rev.* **1**, 261.
Gerhard, O. (2002). *The Dynamics, Structure & History of Galaxies* (*ASP Conference Proceedings*, vol. 273), ed. Da Costa, G.S. & Jerjen, H. Astronomical Society of the Pacific, San Francisco, CA; p. 73.
Gonzales, G., Brownlee, D. & Ward, P. (2001). *Icarus* **152**, 185.
Lerner, M.S., Sundin, M. & Thomasson, M. (1999). *Astron. Astrophys.* **344**, 483–493.
Lineweaver, C.H., Fenner, Y. & Gibson, B.K. (2004). *Science* **303**, 59–62.
Majewski, S.R., Skrutskie, M.F., Weinberg, M.D. & Ostheimer, J.C. (2003). *Astrophys. J.* **559**, 1082–1115.
Sundin, M. & Sundelius, B. (1991). *Astron. Astrophys.* **245**, L5–L8.