ANALYSIS OF A PLANET IN A MIRA WIND

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Abstract

The possibility of planets orbiting variable stars poses the question of how the planets might interact with the variable star's outward-flowing wind and if these interactions might be observable. Computational modeling of planetary objects orbiting these stars is being used to help determine hydrodynamic characteristics of the winds.

1. Introduction

Willson and Struck (2001) suggested that a planetary object located in a Mira wind might be detectable through the wake created by the planet interacting with the wind and/or through planetary accretion disc dynamics. This could explain anomalous features in the light curves of stars such as AM Cyg and X CrB (de Laverny *et al.* 1998). These stars showed a periodic "bump" in the light curve which may occur due to reversal of the accretion disc around the planet (dynamics of this process will be discussed in Section 2). The bumps in the light curves appeared at the same phase and with the same magnitude, showing that the phenomenon has repeatable occurrences. The periodicity of a planet orbiting such a star and releasing observable energy might also be a repeatable occurrence. The hydrodynamic modeling of the process is being used to determine the structures formed in such a process and if these structures may be able to release enough energy to account for the bumps in the light curves. Figure 1 shows a bump in the light curve of the star AM Cyg. The bump occurs approximately at a phase of 0.35.

2. Discussion

Figure 2 shows the initial setup of the hydrodynamic model. Physical aspects of the winds (referred to as particles) are in accordance with previous research (Bowen 1988). The lower boundary pulsates (shock fronts given off by a Mira) while the upper boundary flows outward, at about the same speed as the pulsating wind.

The model has two main goals. First, it tries to demonstrate the possibility of particles accreting around the planet and if these accreting particles store enough energy for a light burst. Second, the model tries to determine the wake structure and its lasting effects in the wind.

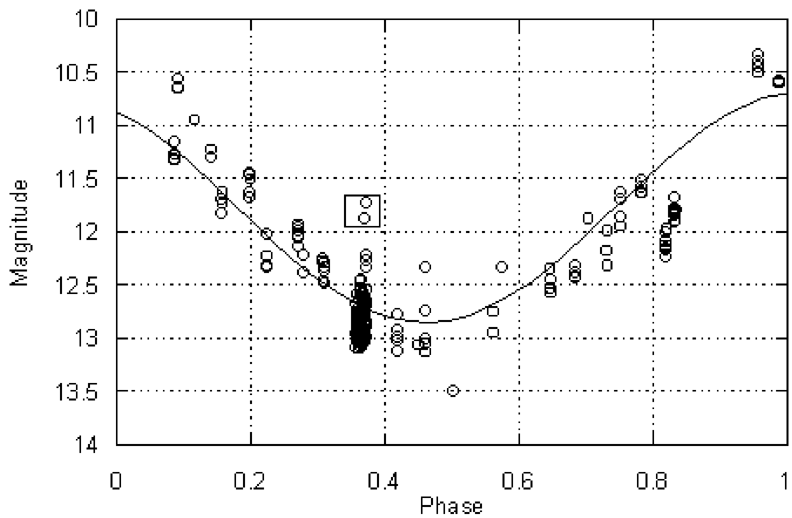

Figure 1. Light curve of the star AM Cyg. Hipparcos data were used to construct the curve. The data in this graph are folded over 3.5 cycles with a period of 360.1 days. The curve through the data shows the light curve through the folding of 4 periods. (The "bump" possibly indicating presence of a planet may be seen at phase 0.35 (bump is represented by boxed data). (Figure courtesy of Joshua Drake.)

Figure 2. Setup of computational code, showing key features such as: center of gravity (CG) of the star, boundaries, particles, and planet. The units along the axes are in AUs and the planet is being viewed from above as it travels through its orbital plane.

The accretion dynamics that could lead to energy release requires explanation. In the previous models of the wind (Bowen 1988 and Figure 2) it can be seen that the particles within a certain radial distance of the star flow inward and outward with a fairly constant period. Outward motion is caused by the pulsational shocks created in Mira stars, and inward motion comes from the star's gravity pulling the particles back. As the particles flow outward from the star, their interaction with the planet swirls particles around the planet in one direction (for the sake of discussion, say that it is clockwise to begin with, viewing the star-planet system from above). So as the particles flow outward the planet is gathering particles around it in a clockwise fashion. Once gravity manages to reverse the particles' outward motion, they stream back towards the planet and the accreting material, coming in contact with these accreted materials. Some of the accreted material that is swirling around the planet will have velocity opposite to that of the particles flowing back in, and the colliding interaction of these particles will lead to a cancellation of angular momentum, leading to infall, and releasing energy, possibly through a burst of light (see Willson and Struck 2001; Struck, Cohanim, and Willson 2002). This process has not been analyzed yet because the model is still being refined, and a good model is needed before any analysis is to be done.

Still frames of the model are shown in Figure 3. These frames show the swirling of particles in both clockwise and counterclockwise directions. Shock fronts and wake structures are also well defined.

The wake structure of the planet might play a role in observed SiO maser emission. As particles stream around the planet, many of them are not caught by the planet, but instead swing around and collide with others. These collisions effectively slow down the particles, and the collisions, along with overall cooling of the wake particles, may help energize the maser (see Struck 1988).

3. Conclusion

With the refinement of the model, analysis will show if either of the two main processes (accretion and wake structure) or both would be enough to explain the bumps in the light curve. The models may also have further implications in the study of how planetary nebulae form through possible interactions with planetary wakes.

The future of the models may include entire orbits (instead of just a quarter of the orbit which is shown here), planets traveling in elliptical orbits, as well as multiple planet systems. These future models may give better insight into accretion patterns as well as the light output that could be generated by multiple planets and their wakes interacting in the particle wind.

4. Acknowledgements

Special thanks to Joshua Drake of Iowa State University for providing the plot of the light curve in Figure 2.

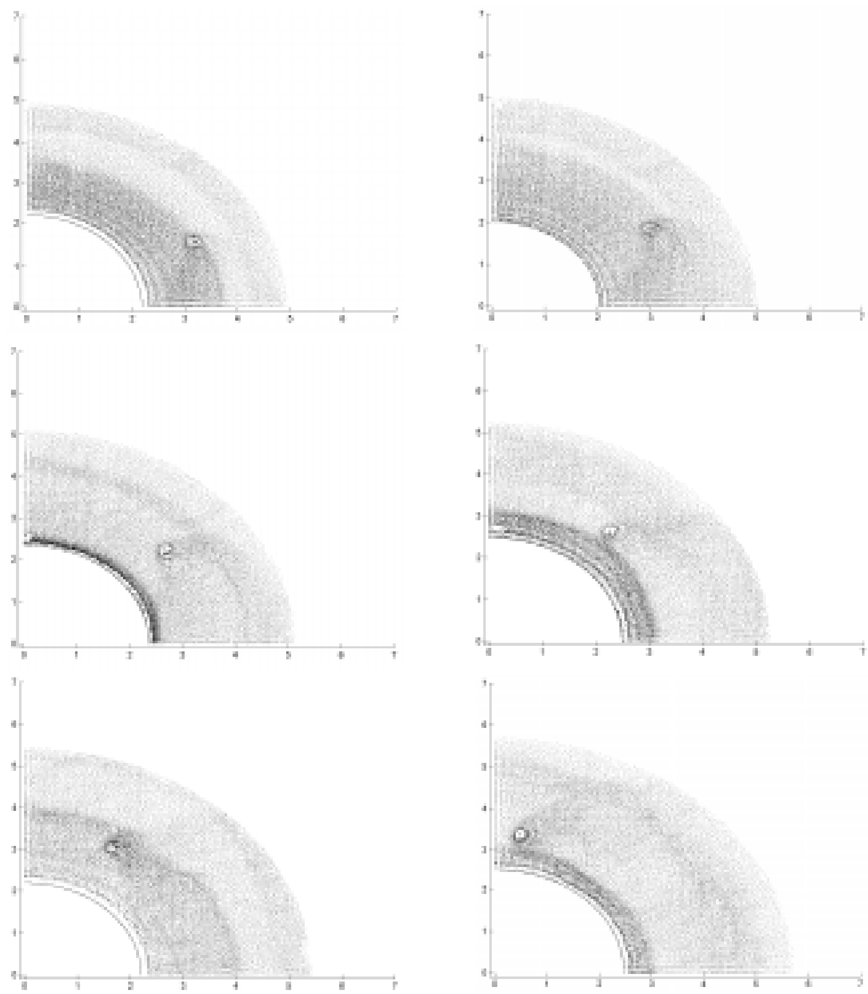

Figure 3. Simulation frames showing swirling patterns around planet, shocks, and wake structures.

References

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