Effect of Wind-Driven Accretion on Planetary Migration

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Introduction

Can wind-driven accretion modify planetary migration?

In 2D simulations, we establish a simplified model of wind-driven accretion in protoplanetary discs. We test the effect of different wind strengths on the semi-major axis of planets in a gaseous, non-viscous disc.

Wind-Driven Accretion

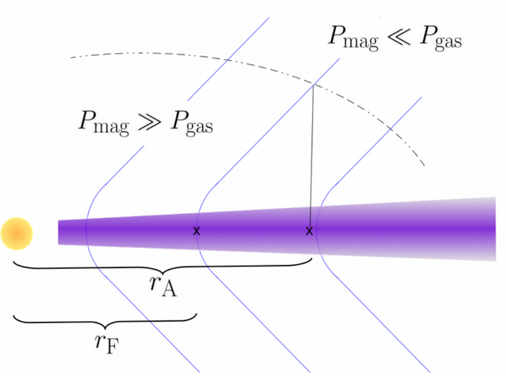

Figure: Configuration of the magnetic field for wind-driven accretion.

Wind-driven accretion is an alternative theory for the viscous accretion of gas.[1] Magnetic field lines emerge from the disc with an angle and corotate with the same angular freqency as on the point where they emerge from. Charged particles can be launched, moving along a field line and accelerate in the process. They extract angular momentum from the disc which means that particles in the disc drift inwards.

Results

In a non-viscous disc without wind-driven accretion, we expect and observe an opening of a gap, but no migration of the planet.

With wind-driven accretion, the planet migrates and the direction depends on the wind strength.

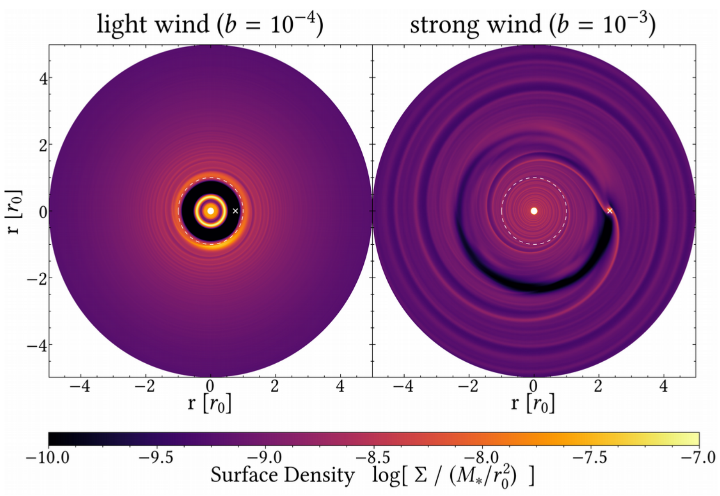

Figure: Surface densities in simulations with a Saturn-like planet in a non-viscous disc with wind-driven accretion. Both panels show the distribution after 1000 orbits. The white x marks the current position, the dashed ring the initial position of the planet and r_0 = 5.2 AU. The lever arm is r_A/r_F = 1.5 in both simulations.

With light winds, the planet migrates **inwards.** It opens a gap in the surface density and migrates with the gap edges due to the inward drift of the gas.

The planet migrates **outwards** with strong winds. In this case, it opens only a partial gap. This occurs due to the horseshoe streamlines in the co-rotation region which cause a mass excess in front of the planet (see Figure on the right). This excess accelerates the planet and drives it outwards.

Simulation

We use FARGO3D[2] and implement the effect of the magnetic field as radial drift of the gas:

$$v_{r,\mathrm{wind}} = -\frac{\Omega_K r}{\pi}\, b \left[\left(\frac{r_A}{r_F}\right)^2 - 1 \right]$$

with Ω_K as Keplerian velocity, b as measure for the mass outflow (in percent per orbit) and r_A/r_F as lever arm of the magnetic field.

Outward Migration

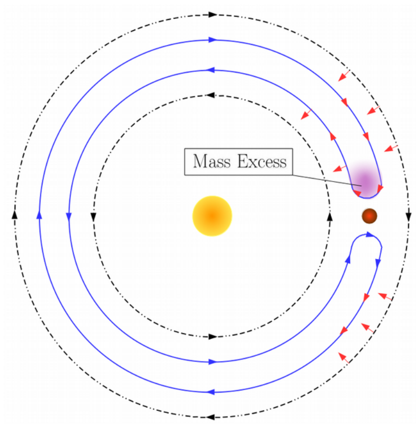

Figure: Schematic representation of the horseshoe streamlines (blue) with a radial inward drift of the gas (red arrows) in the planet's moving frame.
For a detailed explanation of this figure, watch this video.

Conclusions

Wind-driven accretion can cause inward or outward migration of planets.

As the viscosity in discs is found to be much lower than assumed so far, this theory can become an important explanation for migration.

Publication

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"The authors compare the efficiency of the wind-driven accretion process with respect to the viscous accretion process in protoplanetary disks. They show that for the co-orbital region, this wind-driven process always injects mass from the outer edge of the co-orbital region and removes mass from the inner edge, while the viscous process does not. As a consequence, wind-driven accretion may strongly alter our formation scenarios." - from aanda.org

References

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Questions?

Please ask me anytime.
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About Me

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