Revista Mexicana de Astronomía y Astrofísica Serie de Conferencias, 60, 73-74, (2026)

OPEN ACCESS https://doi.org/10.22201/ia.14052059p.2026.60.71

Three-Dimensional Modeling of Supersonic Gas Accretion and Ionized Envelope Dynamics in Jupiter-like Planets

M. Montesinos[1,2,3], J. Garrido-Deutelmoser[4], N. Cuello[5], J. Cuadra[6], A. Bayo[7], J. Olofsson[8], M. R. Schreiber[3], M. Sucerquia[9], M. P. Ronco[10] and O. M. Guilera[10]

[1]*Escuela de Ciencias, Universidad Viña del Mar.*
[2]*Millennium Nucleus for Planet Formation, NPF.*
[3]*Dpt. de Física, Universidad Técnica Federico Santa María.*
[4]*Instituto de Astrofísica, PUC, Chile.*
[5]*Univ. Grenoble Alpes, CNRS, IPAG.*
[6]*Departamento de Ciencias, Facultad de Artes Liberales, Universidad Adolfo Ibáñez.*
[7]*European Southern Observatory.*
[8]*Max Planck Institute for Astronomy.*
[9]*Instituto de Física y Astronomía, Fac. de Ciencias, U. de Valparaíso.*
[10]*Instituto de Astrofísica de La Plata.*

Keywords: *disk: circumplanetary disk, hydrodynamics: simulations, planets: planet feedback, planets: planet formation*

Corresponding author: mmontesinos@gmail.com

We explore gas giant accretion in protoplanetary disks using 3D hydrodynamical simulations of a Jupiter-mass planet. Our model incorporates a non-isothermal energy equation for gas and radiation energy diffusion, enhanced by a novel radiative feedback mechanism from the planet. Key findings demonstrate supersonic gas accretion forming an ionized envelope around the planet, with its extent (0.2-0.4 of the Hill radius) influenced by radiative feedback. This ionization radius serves as a critical boundary for accretion dynamics, impacting the calculation of accretion rates and $H\alpha$ emission luminosities. We show that radiative feedback significantly increases accretion rates, especially inside the ionization radius. Accretion luminosities at this radius are substantially lower than at the Hill radius, providing new perspectives for interpreting current non-detections of $H\alpha$ emissions in planet formation.

We conducted FARGO 3D (Benítez-Llambay & Masset, 2016) numerical simulations to examine the evolution of Jupiter-like planets in a viscous disk, taking into account both gas and radiation energy transport and the radiative feedback of planets (Montesinos et al., 2015). A key discovery is the formation of an ionized envelope around these planets, characterized by an ionization radius that also marks the stopping point of supersonic gas accretion (Figure 1). This radius, fluctuating between 0.2 and 0.4 times the Hill radius, is significantly impacted by the inclusion of radiative feedback.

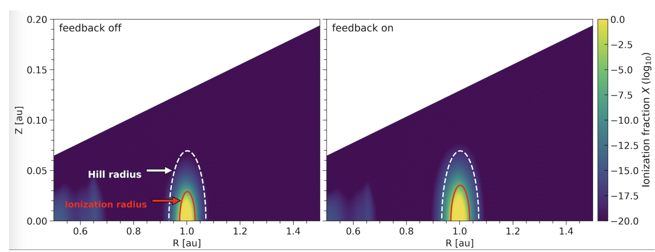

Figure 1. Representation of the ionization envelope around the planet, in Hill units, at the final stage of the models. This is for scenarios with and without radiative feedback, defined by ionization parameter values $X \geq 0.5$.

We observed that the radiative feedback enhances the accretion rate with a subsequent expansion of the ionization radius when the feedback is active (Figure 2). Comparing the accretion rates at the Hill sphere and the ionization radius, we found that a much smaller fraction of gas passing through the Hill sphere actually contributes to the envelope or reaches the planet's surface.

This study suggests that computing the accretion rate at the ionization radius, rather than at the Hill radius, is more effective for determining the luminosity associated with $H\alpha$ emissions. Our findings imply that the accretion

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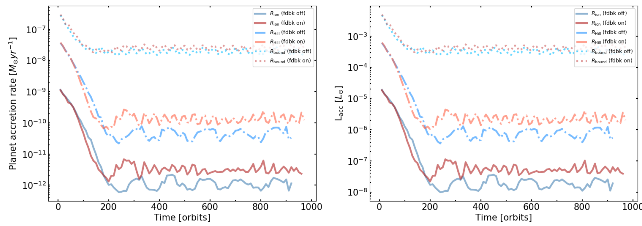

Figure 2. Planet accretion rate for models with and without feedback computed at different radii: ionization radius R_{ion}, Hill radius R_{Hill}, and bound radius R_{bound}.

luminosity, and thus the $H\alpha$ luminosity, computed at the ionization radius is considerably smaller than previously assumed, based on calculations at the Hill radius. This has important implications for interpreting the non-detections of $H\alpha$ emissions in several protoplanetary disks (Zurlo et al., 2020) as indicators of ongoing planet formation.

References

Benítez-Llambay, P., & Masset, F. S. 2016, ApJS, 223, 11, doi: 10.3847/0067-0049/223/1/11

Montesinos, M., Cuadra, J., Perez, S., Baruteau, C., & Casassus, S. 2015, ApJ, 806, 253, doi: 10.1088/0004-637X/806/2/253

Zurlo, A., Cugno, G., Montesinos, M., et al. 2020, A&A, 633, A119, doi: 10.1051/0004-6361/201936891

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