

A new window into planet formation: kinematical studies of proto-planetary discs with ALMA

- Studying the properties of young planets in proto-planetary discs looking at how they modify the gas flow
- Developing and using new analysis tools on data coming from a revolutionary ALMA large programme on disc kinematics
- Weigh proto-planetary discs using their self-gravity

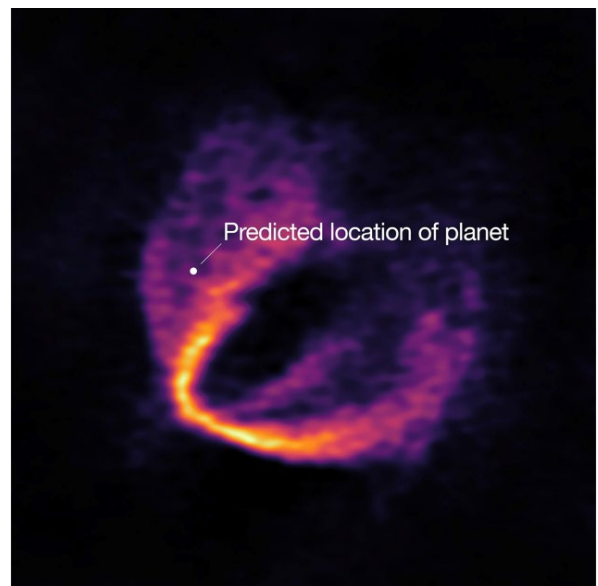
Level	PhD
First Supervisor	Giovanni Rosotti
Second Supervisor	Richard Alexander
Application Closing Date	19 January 2022
PhD Start date:	26 September 2022

Project Details:

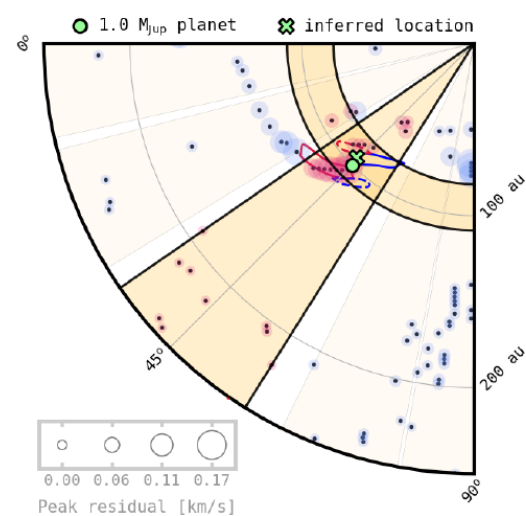
Proto-planetary discs are structures composed of dust and gas rotating around young stars – it is in these very discs that planets are formed. Thanks to the radio-telescope ALMA in Chile, we can now study in great detail the motion of the gas in these discs using the Doppler effect. The study of the gas kinematics is a new window into proto-planetary discs, enabling us to uncover properties which were previously impossible to measure. The most prominent example is spotting the signatures of young planets: we can use the gas kinematics to pinpoint where young planets are forming in the disc and “weigh” them. The supervisor is part of a team that was recently awarded a large programme on ALMA (150hr of telescope time) to study 15 discs using kinematics. This is an exciting opportunity for a PhD student to get involved in the collaboration and have access to new data of exquisite quality. The supervisor is particularly involved in the modelling side of the team and the student will be able to develop international collaborations with researchers all over the world (e.g., Munich, Milan, MIT, Monash, Santiago de Chile).

The study of kinematics is a very recent development in the field which started only three years ago and it is still uncharted territory; therefore, there is plenty of work to do in the collaboration and, depending on the student preferences, the project can be tuned in different directions. A common denominator across these different directions will be to be work at the interface between theory and observations, developing models to be applied to the upcoming ALMA data.

One possibility is developing 3D numerical simulations of planet-disc interaction to compare to the observations



A planet found by ALMA around the star HD163296



Disc Miner in action

and in this way extract the properties of the unseen planets. We will use radiative transfer modelling to generate synthetic observations and analyse them with the Disc Miner tool, which was developed to identify kinematical perturbations induced by the presence of planets. Disc Miner, developed in Munich and Milan as well as in Leicester, is an ongoing project and the student will be able to get involved in its further development – for example including the effect of disc warps, i.e. taking into account the fact that discs are not perfectly flat.

There is much more however that can be done in this area. The gas kinematics can also be used to constrain the mass of the disc through the influence of the disc self-gravity on the gas motion. Another possibility is studying how the mass is distributed in the disc: most of these discs are not smooth structures but exhibit prominent ring patterns and these leave behind distinct patterns in the kinematics. We will develop techniques to analyse the new observational data that will become available and test them against numerical simulations.

This is mostly a computational project and previous experience with Python is desirable, although not strictly necessary. During the course of the project the student will also learn how to analyse ALMA images and how to run simulations on supercomputers.

References:

- 1 Kinematic Evidence for an Embedded Protoplanet in a Circumstellar Disk - <https://ui.adsabs.harvard.edu/abs/2018ApJ...860L..13P/abstract>
- 2 The Disc Miner. I. A statistical framework to detect and quantify kinematical perturbations driven by young planets in discs - <https://ui.adsabs.harvard.edu/abs/2021A%26A...650A.179I/abstract>
- 3 Meridional flows in the disk around a young star - <https://ui.adsabs.harvard.edu/abs/2019Natur.574..378T/abstract>
- 4 The efficiency of dust trapping in ringed protoplanetary discs - <https://ui.adsabs.harvard.edu/abs/2020MNRAS.495..173R/abstract>
- 5 A Dynamical Measurement of the Disk Mass in Elias 227 - <https://ui.adsabs.harvard.edu/abs/2021ApJ...914L..27V/abstract>