EBERHARD KARLS UNIVERSITÄT TÜBINGEN

MATHEMATISCH-NATURWISSENSCHAFTLICHE FAKULTÄT

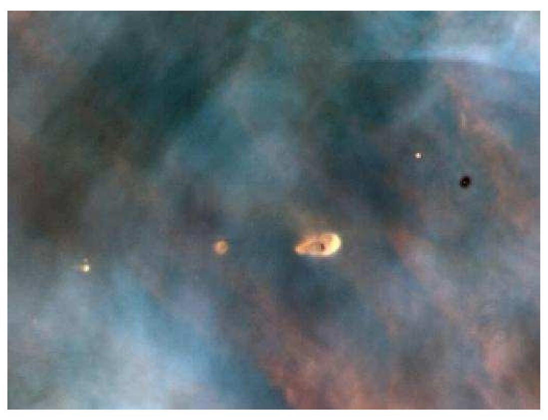
Computational Physics – CPT

Kley, Haghighipour, Stute, Schäfer, T. Müller, Seizinger, Hertfelder, Stoll, Dürmann, M. Müller, Thun, Riecker, Wehner

Institut für Astronomie und Astrophysik

Theory of Accretion Discs

Our research focusses on the physical structure and dynamics of accretion discs. Examples include circumstellar discs around T-Tauri stars, consisting mainly of gas and also a small amount of interstellar dust. In accretion discs the gas rotates with nearly Keplerian velocity around the host star, spirals slowly inwards and is accreted onto the central star. In our group we study various aspects of accretion disc physics:



HST view of the Orion nebula showing five young stars of which four are surrounded by protoplanetary discs (Courtesy: NASA).

Turbulence

It causes the gas to lose energy and angular momentum, and therefore drives the accretion process. The physical source of the turbulence is still unclear, but magnetorotational instability (MRI) is the most likely mechanism.

Thermodynamics

It governs the thermal structure of the disc. The temperature in the disc follows from an equilibrium between turbulent dissipation, pdV-work and radiative cooling. It determines the disc thickness in the vertical direction at a given location.

Self-gravity

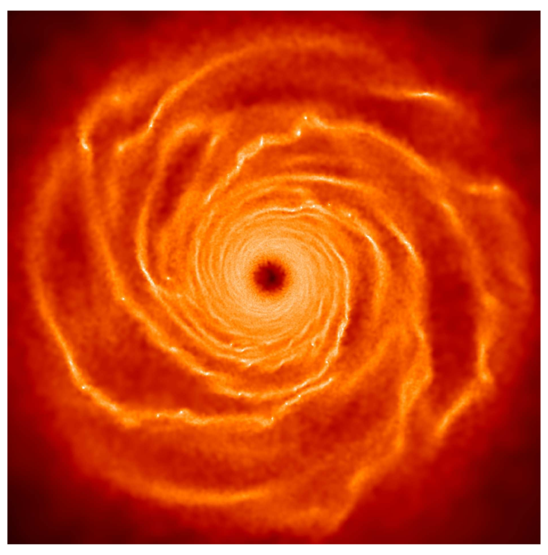
It plays an important role in very massive discs. Depending on the efficiency of cooling, gravitational instabilities can occur and cause the disc to develop spiral arms or even to fragment.

Companion stars

A companion can influence the evolution of the disc by tidal forces and may cause the disc to become eccentric.

Planet Formation

Planet formation has been an area which has been studied in great detail with respect to the Solar System. The discovery of hundreds of extra-solar planets since the mid-1990s has put the field into a much larger context. A revision of the major aspects of classical planet formation theory is required. In our group we study various aspects of planet formation within the sequential accretion and gravitational instability scenario.



Simulated image of a self-gravitating disc undergoing fragmentation.

Dust properties

In the very beginning, planetesimal growth depends strongly on the material properties of the constituent dust particles. Using laboratory data for dusty material we perform ab initio simulations to calculate the continuum properties of dust agglomerates.

Early dust growth

The initial particle growth in the protoplanetary disc requires sticking upon individual collisions. Present models encounter great difficulties in growing particles beyond a decimeter due to destructive collisions. Using new data and methods we perform simulations to calculate the statistical outcome of collisions.

Migration

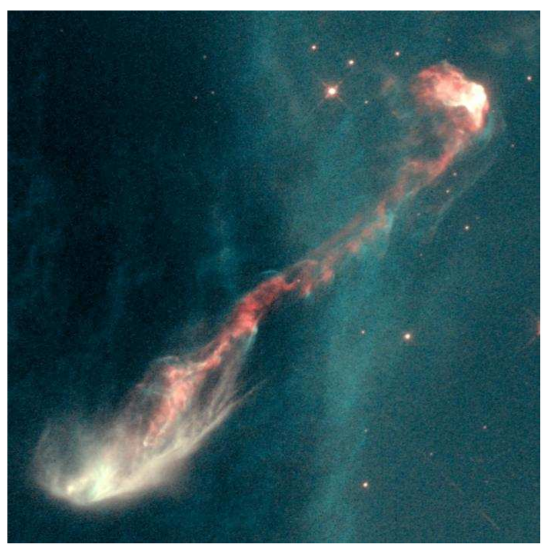
Planet-disc interactions cause a change in the orbital elements of embedded planets. For smaller planets of a few earth masses, the theoretically obtained migration rates are much too fast to match the observations. We perform detailed models of fully radiative discs with embedded planets to study this important phase.

Gravitational Instability

An alternative formation scenario for planet formation, at least a very large distances from the star, is provided through direct fragmentation of an initially unstable massive protoplanetary disc. We perform simulations to understand the efficiacy of such a process.

Astrophysical Jets

Astrophysical jets are ubiquitous, occurring in a variety of objects on very different size and mass scales. They can be produced by pre-main sequence stars in young stellar objects, by post-AGB stars in pre-planetary and planetary nebulae, by white dwarfs in supersoft X-ray sources and symbiotic stars, by neutron stars in X-ray binaries, by stellar black holes in black hole X-ray binaries and by supermassive black holes in the case of active galactic nuclei. However, there are still many open questions.



HST view of the Protostellar Jet HH 47 (Courtesy: NASA).

The propagation of jets

How does the jet travel through the interstellar/intergalactic medium? We model the kinematics of jets and their sub-structure (e.g. knots), the emission from radiative shocks in jets and the morphology of jets.

The formation of jets

Jets are formed by large-scale magnetic fields threading an underlying accretion disc. We solve the equations of magnetohydrodynamics (MHD) numerically and investigate analytical self-similar solutions.

The interplay between accretion and jet ejection

How does the formation of jets depend on accretion states? Why are jets formed in one class of objects, but not in another? What are neccessary conditions for jet formation?

We investigate jets with analytical models, numerical simulations and observations with several space telescopes.

Poster presented at
Waves and Particles: Multi-Messengers from the Universe
AG Annual Meeting, 24.-27.09.2013, Tübingen, Germany

University of Tübingen · Faculty of Science
Kepler Center for Astro and Particle Physics
Institute for Astronomy and Astrophysics