Isaac Newton Institute for Mathematical Sciences

Dynamics of Discs and Planets

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Ever since the discovery in 1995 of an object with half the mass of Jupiter in a four-day orbit around the star 51 Pegasi, it has been clear that the dynamics of extrasolar planetary systems can be quite different from that of our solar system. More than 260 extrasolar planets have now been found, including at least 25 systems with multiple planets, some in resonant configurations. Their diversity must originate in the properties of the protoplanetary disc of dusty gas out of which they form, the dynamics of the formation of the planetary core within that disc, and the subsequent interaction of the planet with the surrounding disc, with other planets, and with the central star.

Over the past decade, there has been significant progress on the theoretical aspects of the planet formation process. Two viable models of planet formation have been explored, through core accretion (i.e., growth of dust into planets by sticking in dust-dust collisions) and through gravitational instability in the disc. Several ways in which planet-disc interactions can lead to planet migration have also been identified which may explain the proximity of the 51 Peg planet to its star. However, many of the stages of the planet formation process remain poorly understood, such as how km-sized planetesimals form, and how the final planetary system architecture is determined.

Recent advances in both observational and computational capabilities mean that this is an exciting time for extrasolar planetary science. Our knowledge of the physical nature of proto-planetary discs is increasing dramatically owing both to observations of the gaseous and dusty components of the protoplanetary discs of pre-main sequence stars and to computational modelling of their (magneto-) hydrodynamics. The outcome of planet formation is also becoming more tightly constrained, through the rapidly growing number of systems known to have either extrasolar planets or planetesimal belts analogous to the asteroid and Kuiper belts. Along with discoveries of planetesimals and dwarf planets in the Kuiper belt beyond Neptune, which are leading to a revision in our understanding of the formation and evolution of the outer solar system, there is now a wide array of phenomena seen in all systems which is opening up new areas of celestial mechanics and astrophysical fluid dynamics.

The goal of this programme is to provide a firm theoretical basis for our understanding of extrasolar planetary systems and their formation in protoplanetary discs. It aims to achieve this by bringing together world-leading researchers in disciplines including accretion disc theory, planet formation, planet-disc interaction and solar system dynamics, to focus on the three themes of (1) the formation and evolution of protoplanetary discs, (2) the formation of planetesimals and planets within protoplanetary discs, and (3) the dynamics of planetary systems in later phases.

Artist's impression of the planetary system around the star Vega (copyright 2004 Hardy/UKATC). Information on this planetary system is inferred from the structure of the star's dust disc which includes signatures of past and present dynamical interactions between planets, planetesimals and dust.