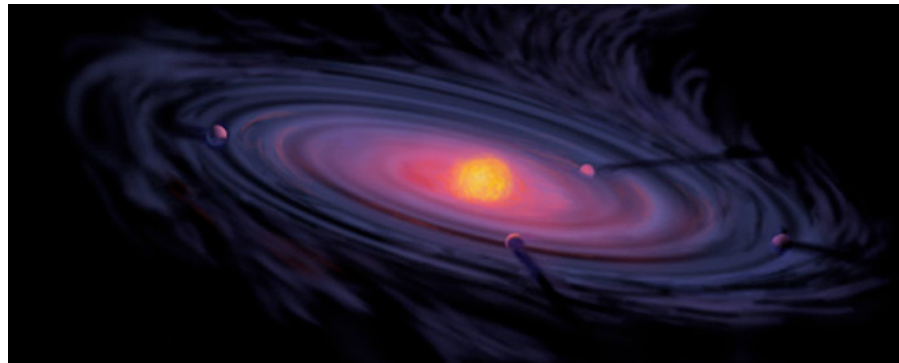


Accretion and Planetary System Formation

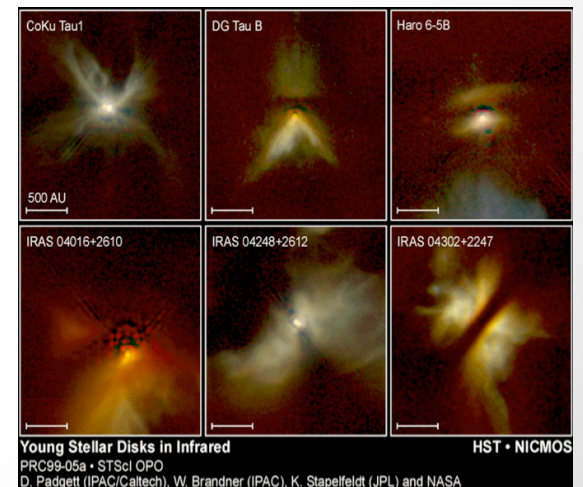
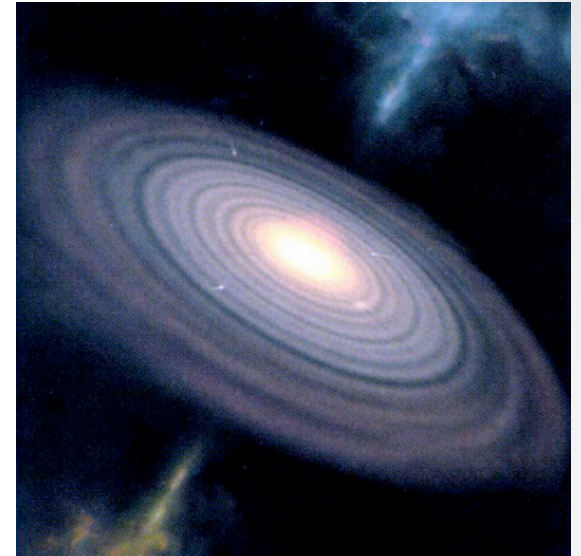


Rebecca G. Martin

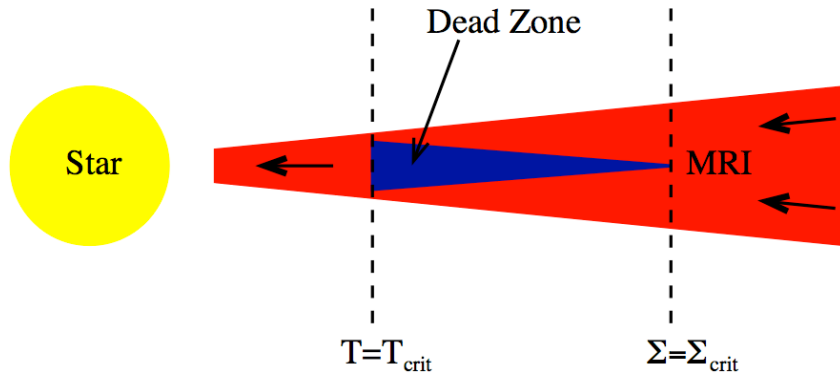
Sagan Fellow from Autumn 2012
University of Colorado, Boulder

Protoplanetary Discs

- Low mass stars form from a molecular cloud that collapses to form a protostar and an accretion disc. The disc is thought to be the site of planet formation.
- Understanding angular momentum transport within these discs is fundamental to explaining the formation of planets and satellites. Viscosity (driven by turbulence) carries angular momentum outwards allowing material to accrete on to the central object.
- The magneto-rotational instability (MRI) drives turbulence if the gas is sufficiently ionised (Balbus & Hawley 1991). Self gravity drives a second type of turbulence if the disc is massive enough.
- Because of a low ionisation fraction, protoplanetary discs may have a dead zone at the mid-plane, a region with no turbulence (Gammie 1996). The surface layers of the disc may be ionised by cosmic rays and remain turbulent.
- A dead zone causes a build up of material in the disc and the accretion flow cannot be steady.

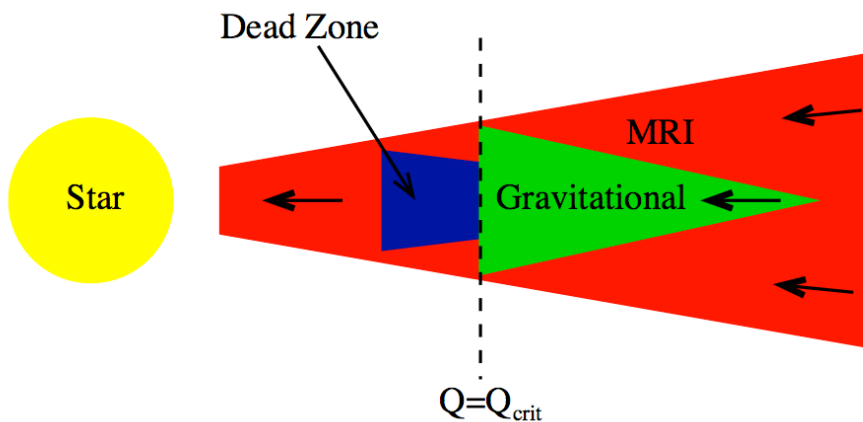
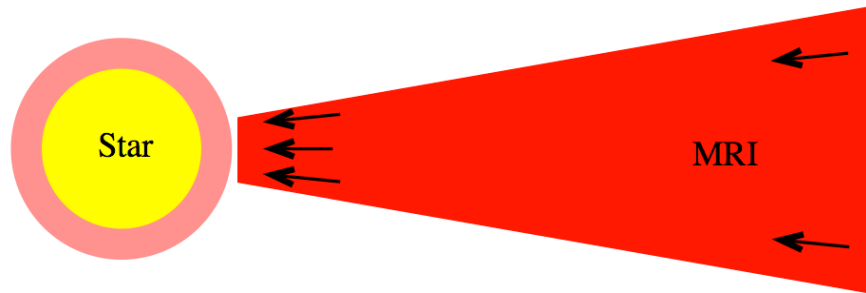


The Gravo-Magneto Disc Instability



The disc empties, cools and the dead zone reforms.

Mass builds up and the outer parts of the dead zone become self gravitating.



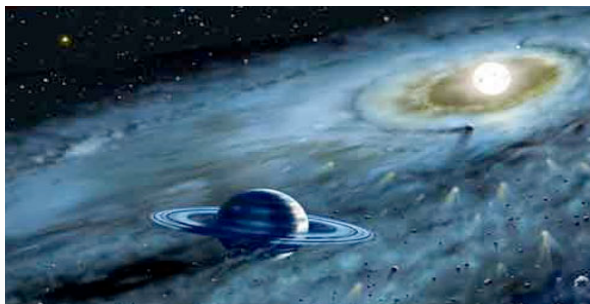
The dead zone is heated by self gravity and the MRI is triggered causing an accretion outburst.

Planet Formation

- Planets likely form after the infall accretion rate on to the disc has dropped and there is not sufficient mass for the gravo-magneto instability to operate. However, there may still be a dead zone.
- Planets may form in the dead zone of a protoplanetary disc because solids settle to the mid-plane there.
- Planetary migration is slowed in a dead zone, because the viscosity is smaller. This allows more time for planets to grow.
- The inner edge of the dead zone can trap planets and prevent further migration. This may allow planets to survive after the disc has dispersed.

Giant Planet Formation

- When a planet with a mass greater than Neptune forms in a circumstellar disc, it opens a gap in the disc. Material continues to flow on to the planet and a circumplanetary disc forms (Lubow et al. 1999). Much of the mass of a gas giant is accumulated through the disc.
- The circumplanetary disc is also unstable to the gravo-magneto instability and thus the mass of the planet grows in large accretion outbursts. These outbursts may aid planet detection during the early formation stages.



Satellite Formation

- Circumplanetary discs are thought to be a site of satellite formation. A dead zone in these discs may help satellite formation and prevent them from falling on to the planet, allowing them to remain after the disc has dispersed.
- All of the satellites of Jupiter and Saturn are very close to their planet compared with the size of the circumplanetary disc (Martin & Lubow 2011b). A fully turbulent circumplanetary disc offers no explanation for their locations but a dead zone may help to solve this problem.
- By first understanding satellite formation within our solar system we can develop theories that can be tested on extra solar systems.



During my time as a Sagan Fellow I will use analytic and numerical methods in gas dynamics to study accretion disc dynamics and the theory of planet and satellite formation and survival processes.