Exploring other Solar Systems

Scientific Context and Questions

Over the past two decades, astronomers have learned that the processes that give birth to stars are also likely to give birth to other planetary systems. Observations carried out with the Infrared Astronomy Satellite, the Hubble Space Telescope and on the ground reveal disks of orbiting gas and dust having size similar to the solar system and mass comparable with that of the planets, asteroids and comets now orbiting the sun.

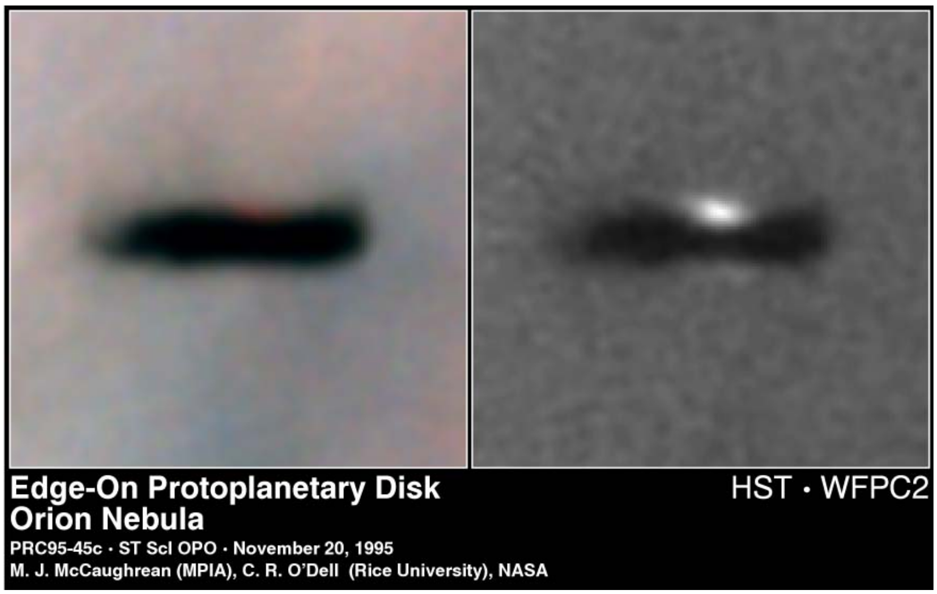

Figure 1: Disks of solar system size and mass observed by the Hubble Space Telescope against the bright background of the Orion Nebula

That some of these disks indeed form planets is now known with certainty, thanks to the pioneering observations of several groups in the US and Europe. As of this writing, more than 100 extra-solar planetary systems are known. Perhaps most surprising is the diversity of these systems: few resemble our solar system. What accounts for the diversity of planetary architectures that we observe? How and when do giant planets like Jupiter form? How frequently do terrestrial planets similar to our own Earth and its near neighbors Venus and Mars form? How many are located in favorable locations for life? How many enjoy the protection offered by our own Jupiter which both shields our planet from an untoward number of collisions with asteroids, while redirecting icy comets to transport the water which gave rise to life-bearing oceans?

Answers to these questions are within grasp. Over the next decade, continued ground-based observations will increase the number of planetary systems by several fold, both extending the sample of exo-solar systems and exploring domains of planetary separations heretofore beyond the reach of the past decade's studies. In space, both the Kepler satellite (which will detect planets as they eclipse their parent stars), and the Space Interferometry Mission (which will have the sensitivity to discover through orbiting earths around nearby stars via their effects on the apparent motions of their parent stars) are expected to advance our understanding of planetary demographics.

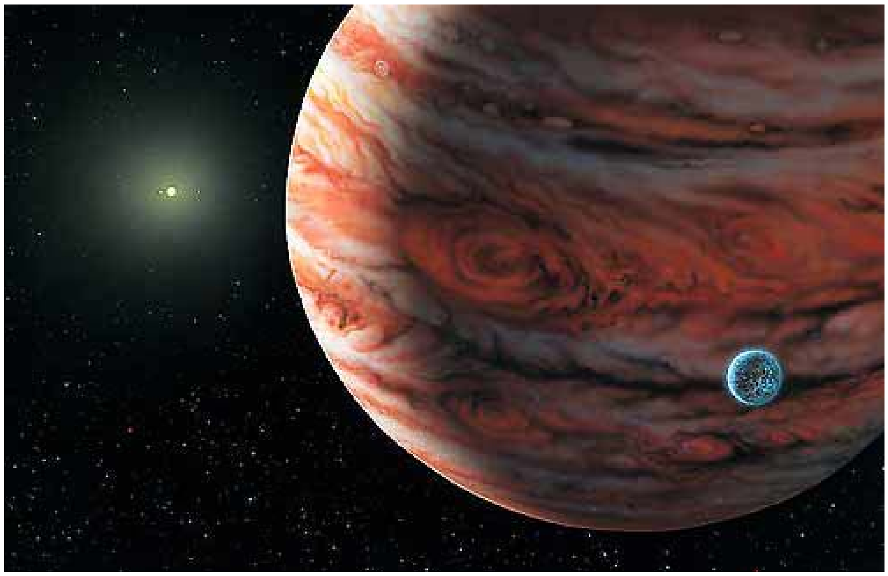

Figure 2: Artists conception of the planetary system orbiting the nearby star 55 Cancri as seen from near the location of a Jupiter-like planet located at a distance from this star close to that of Jupiter from our own Sun. GSMT will be able to analyze the light from this planet, determine its chemical composition and infer the mechanism by which it formed

The role of GSMT

While other ground- and space- based tools will infer the presence of planetary systems by indirect means, the enormous sensitivity and unsurpassed image quality of GSMT will provide the means of observing mature extrasolar planets directly. Young Jupiter-like planets can be imaged around stars out to the nearest star-forming regions, more than 200 light years away. GSMT will be able to analyze their spectra and determine their chemical composition – a key to understanding whether they were built up in a manner similar to our own Jupiter (by collisions among solid body), or by a very different mechanisms (gas gathered together quickly in favorable regions of the disk).

More mature planets can be imaged and analyzed around near-neighbors of the sun, out to distances of 30-60 light years. If there are planets similar to Venus or Earth orbiting stars located closer than 20 light years from earth, GSMT may be able to image them – thus providing for the first time direct evidence of planets similar to our own.

GSMT will also have the light gathering power to peer into the disks surrounding just-born stars, to learn whether planetary systems begin to shape within the first few million years of a sun's life. While light from the planets themselves will be too weak to see against the bright emission arising from the disk, their presence can be revealed through observations 'gaps' created by the effects of a forming planet's gravity on orbiting gas and dust. From these observations, we can determine when and where giant planets form, and whether their location is benign or hostile to the development of life-bearing planets.

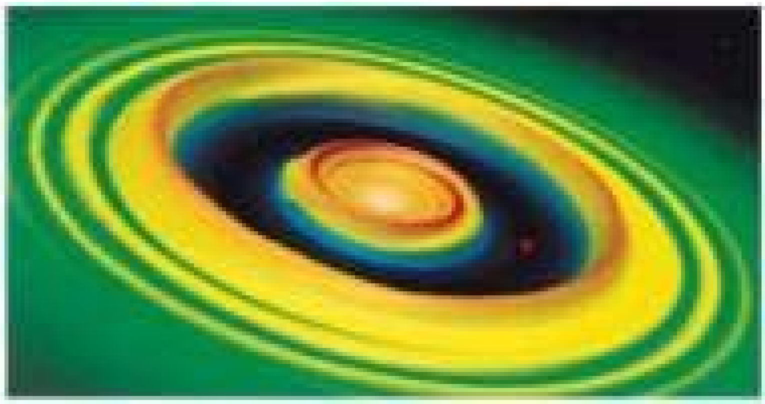

Figure 3: An aritist conception of a 'gap' opened up by the gravitational effects of a planet forming within a disk of gas and dust orbiting a newborn sun. The location of these gaps can be inferred by exploiting the light gathering power of GSMT to feed a sensitive infrared spectrograph capable of 'deconstructing' the shape of the disk.