PLANETARY SCIENCE: A NEW DISCIPLINE?

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Planets are individuals formed by stochastic processes. They resist generalizations and pigeonholes. Their study needs a new discipline between the historical approach of the geological sciences and the mathematical sophistication of astrophysics.

The discovery of over 100 planets orbiting stars other than the Sun has brought the question of planetary origin and evolution into sharp focus, following on from 40 years of exploration of our own system of planets. The detailed study of planets in fact is a very late development in science and required the prior development of many other disciplines. Thus classical physics was well established by Newton, with the publication of the Principia in 1687. Biology was set upon the right track by Darwin in 1859 when he published The Origin of Species. Chemistry closely followed with the formulation of the Periodic Table of the Elements by Mendeleev in 1869. The fundamental nature of atoms was established nearly a century ago in 1911 by Rutherford.

The Hertzsprung-Russell diagram, fundamental to astrophysics, dates from 1913 and the OBAFGKM (with a recent LT addition that spoils the mnemonic) classification of stars from about the same time, while the origin of the chemical elements was understood following the work of the Burbidges, Willy Fowler and Fred Hoyle in 1956.

But it was not until 1963 that Fred Vine and Drum Matthews, following on 200 years of detailed geological work, hit upon the driving mechanism of plate tectonics responsible for the architecture of the surface of the Earth. The origin of the Moon was finally clarified in 1984 by Al Cameron while the problem of the origin and evolution of the planets in the solar system is slowly being clearer.

A major problem in trying to understand planets is that, unlike stars, they are individuals that refuse to be placed into neat pigeonholes. Thus while stars are relatively uniform in composition, and differ mostly in mass, planets in our system are assembled randomly from the left-over debris in disks, and so resemble the products of a junkyard. Thus there is no equivalent of a Hertzsprung-Russell diagram or of the stellar classification for planets.

So there is a philosophical difference between dealing with stars and planets that requires a new type of scientist with a distinct mindset, somewhere in between the mathematical approach of astrophysics and the historical approach of the geological sciences with a dash of chemistry and physics thrown in.

The problem is typified at present by the two competing theories for the formation of the extra-solar planets: top-down or bottom up. The giant planets in our own system have non-solar compositions and appear to have formed by gravitational collapse of gas around cores, surviving examples of which being Uranus and Neptune. “Metals” are clearly a requirement in our system and the correlation between the existence of extra-solar planets with the metallicity of their associated stars supports the bottom-up model.

The existence of earth-like planets elsewhere, like astrobiology, cannot be addressed directly at present in the absence of examples. Information from our own system reveals that, apart from the obvious requirements for metals, orbits of low eccentricity and avoidance of giant planet migration into the inner nebula, rocky planet formation was essentially stochastic.

Not only do the terrestrial planets lack the gas and ice components of the solar nebula, but they are also depleted in elements volatile below about 1000K, including biologically significant elements. Formation from differentiated planetesimals has also resulted in differences in planetary compositions for the major elements (e.g., Mg/Si and Al/Si) from the primordial CI abundances. Earth and Venus, unlike Mars and Mercury, are close in density, bulk composition and heat production, but the geological histories of these "twin" planets have been wildly different. So the problem of forming planets elsewhere would seem to depend on the repetition in detail of the essentially random processes of planetary accretion and subsequent geological evolution that has characterized the formation of planets in our solar system.