Formation and Nature of Giant Planets

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The observed properties of giant planets, models of their evolution, and observations of protoplanetary disks all provide constraints on the formation of gas giant planets. The four largest planets in our Solar System contain considerable quantities of hydrogen and helium, which could not have condensed into solid planetesimals within the protoplanetary disk. Jupiter and Saturn are mostly hydrogen and helium, but have larger (fractional) abundances of heavier elements than does the Sun. Neptune and Uranus are primarily composed of heavier elements. All of the more than two dozen (transiting) extrasolar giant planets with well determined masses and radii also must contain substantial amounts of these light gases. But one of them, HD 149026 b, which is slightly more massive than is Saturn, appears to have comparable quantities of light gases and heavy elements. And another, the small planet GJ 436 b, seems quite similar to Neptune and Uranus in both mass and abundances of light gases.

Spacecraft flybys and observations of satellite orbits provide estimates of the gravitational moments of the giant planets in our Solar System, which in turn provide information on the internal distribution of matter within Jupiter, Saturn, Uranus and Neptune. Atmospheric thermal structure and heat flow measurements constrain the interior temperatures of planets. Internal processes may cause giant planets to become more compositionally differentiated or alternatively more homogeneous; high-pressure laboratory experiments provide data useful for modeling these processes.

The preponderance of evidence supports the core nucleated gas accretion model of formation of the giant planets. According to this model, giant planets begin their growth by the accumulation of small solid bodies, as do terrestrial planets. However, unlike terrestrial planets, the growing giant planet cores become massive enough that they are able to accumulate substantial amounts of gas before the protoplanetary disk dissipates. The primary questions regarding the core nucleated growth model is under what conditions planets with small cores/total heavy element abundances can accrete gaseous envelopes within the lifetimes of gaseous protoplanetary disks.