

The Transformation of Gas Giant Planets into Rocky Planets

Anthony J. Abruzzo M.Phil
ajabruzzo@optonline.net
Huntington, New York, USA

Introduction

This is the fifth in a series of papers whose purpose has been to introduce and explore the implications of the transformation hypothesis. In brief, the transformation hypothesis views planets as the end products rather than the by-products of stellar evolution. Put more simply, stars evolve into planets.(1) Although the subject of this paper has already been touched upon in the previous papers, its purpose is to examine further the processes that transform gas giant planets into rocky planets and highlight an external mechanism to which some gas giants are subjected that accelerates this transformation process.

Gas Giant Planet Cores

There is virtual agreement amongst conventional planetary scientists that the Solar System's gas giant planets have solid cores. These solid cores – “solid” and “rocky” are synonymous terms - are composed of iron, nickel and silicates. The presumption of the existence of these solid cores is based on the accretion model used to explain how the gas giant planets formed. According to this model, the rocky cores formed from the accretion of heavier material in the original proto-solar nebulous cloud of gas and dust and acted as the seeds around which the lighter material - primarily hydrogen and helium – became gravitationally bound.

Although the transformation hypothesis rejects this accretion model of gas giant formation - as it is a mechanism associated with the general features of the derivative hypothesis - it does recognize the existence of their solid cores. However, the essential difference between the derivative hypothesis and the transformation hypothesis is that the latter views the formation of planetary cores as an intrinsic outcome of stellar evolution. A previous paper had alluded not only to the likelihood that core formation is already well under way during the brown dwarf star stage of stellar evolution, but that core formation may even occur earlier while stellar objects are in their “active” energy producing stage.(2)

In this regard, I should mention the theory of Oliver Manuel who argues that the Sun has an iron core. Without going into the details of his theory, the general idea is that the Sun and the Solar System formed from an already existing stellar object that went supernova. The Sun formed around the solid iron core remnant of this titanic explosion. The inner planets formed from the heavier elements residing in the inner regions of the supernova's debris field whereas the gas giant planets formed from lighter elements propelled further out in the explosion.(3)

Manuel's rejection of the standard solar model, which, amongst other things, views the Sun as a sphere of mostly hydrogen plasma, clearly places his solid iron core theory beyond the fringe of conventional astrophysical theory. However, the idea that stellar objects may in fact harbor solid cores is not inconsistent with the transformation hypothesis. On the other hand, his account of the Solar System's formation from a supernova event must be rejected since it is, in its own peculiar way, a species of the derivative hypothesis.

The point here is that the Earth and the Moon, both of which were once stellar objects, do indeed have solid cores. This conclusion is based on empirical evidence derived from seismological data. Since there is nothing particularly special about these two objects, it is assumed that the other planets have solid cores, as well. Since the transformation hypothesis views planets as a later stage of stellar evolution, the formation of their solid cores must be an intrinsic aspect of this evolutionary process. The question is when did the solid cores of planets begin to form? If the standard solar model is rejected, it is not outside the realm of possibility to contemplate that solid cores begin to form simultaneously with the formation of stellar objects. However, this subject requires a separate treatment since it challenges the very foundation upon which current conventional stellar theory is built. Thus, let us step gingerly out of this minefield and proceed to the transformation of gas giant planets into rocky planets.

It is generally assumed that the bulk of the mass constituting the gas giant planets in our Solar System is contained in their outer layers, whereas the rocky cores represent but a small fraction of this total. With respect to Jupiter and Saturn – what planetary scientists refer to as “gas” giants as opposed to Uranus and Neptune, to which they refer as “ice” giants - this mass includes outer gaseous atmospheres of primarily hydrogen and helium and inner layers of liquid hydrogen and possibly a small amount of liquid helium under high pressure. It is believed that the bulk of their outer mass is concentrated in the liquid “mantles” that exist between the outer gaseous atmospheres and the rocky cores. The model for the ice giants Uranus and Neptune, on the other hand, substitute icy mantles at relatively lower pressures, rather than the liquid hydrogen/helium gas giant mix, consisting of frozen water and ammonia.

Although the existence of the outer gaseous envelopes is beyond dispute, the presumed compositions of the gas giant and ice giant mantles have yet to be confirmed by direct observation. It will be recalled that when the Galileo descent probe entered Jupiter's atmosphere in December 1995, it only penetrated to a depth of 600 kilometers before it stopped transmitting data about an hour later. According to a current model of the radius

of Jupiter's atmosphere – approximately 10,000 km - the probe only descended about 6% into it. Therefore, while the Galileo decent probe was a great technical achievement, Jupiter's interior composition, as well as the interior compositions of the other gas/ice giants, is still virtually unknown.

The masses of these solid cores are also a subject of much speculation. Very recently, a computer simulation derived a solid core mass for Jupiter that ranges between 14 and 18 Earth masses.(4) Taking the middle of this range, the modeled core mass works out to 9.6×10^{25} kg. Earlier Jupiter core mass models were roughly half of this new range. Similar modeling techniques estimate Saturn's core mass to be 8 Earth masses, while the core masses for the lighter ice giants Uranus and Neptune are roughly equivalent to 1 Earth mass – 6×10^{24} kg. Although these core masses are speculative, they are consistent with the high-end range of Solar System and exoplanet rocky planet masses that include Earth, Venus and a planet orbiting a small red star in the constellation Aquarius, named Gliese 876. This exoplanet's mass has been determined to be about 7.5X the Earth's mass. As such, it is comparable in mass to the estimated core mass of Saturn.

It should be clear to the discerning reader that what separates gas giant planets from rocky planets are their massive outer gaseous and liquid layers. A gas giant planet stripped of its outer gaseous and liquid layers would be indistinguishable from a rocky planet. Indeed, it would be a rocky planet. Therefore, understanding the transformation of a gas or ice giant planet into a rocky planet requires an understanding of the physical processes or mechanisms through which these outer layers dissipate over time.

Primary and Secondary Atmospheres

The primary cause of atmosphere dissipation is due to the continuing mass loss stellar objects undergo as they age. The first paper in this series suggested that proton decay and, perhaps, some other as yet unknown mass-reducing process are the main mechanisms by which stellar objects transform into sub-stellar objects. Thus, mass loss is the dominant function of the aging process. The aging process could also be expressed as a function of energy loss, but the use of mass loss as a function of age is better suited to an inquiry into the evolution of stellar objects.

If we focus on the non-stellar objects in our Solar System that have atmospheres, it is possible to interpret the various chemical compositions they have as functions of their masses and, therefore, their relative ages. Due to their relative massiveness, the gas and ice giants still retain considerable quantities of the lightest elements, hydrogen and helium. As these large objects continue to reduce in mass, however, these lighter elements will eventually escape into interplanetary space. And, as the loss of mass continues, the gas and ice giants' gravitational grip on heavier elements will also loosen and they, too, will dissipate into space.

As a general rule, the mass of an object will determine the chemical composition of its atmosphere. The more massive objects, like the gas and ice giants, are able to retain the light elements, as well as heavier gases like methane and ammonia, but as they lose mass, the light elements are lost whereas the heavier gases are still retained. The less massive rocky planets, on the other hand – keeping in mind that they are at a more advanced stage of evolution – are only able to retain heavier gases. Thus, Earth’s atmosphere retains nitrogen and oxygen. Venus has a heavy shroud of carbon dioxide and nitrogen while Mars barely retains a thin membrane composed mostly of carbon dioxide mixed with a small amount of nitrogen.

Several dwarf planets also have atmospheres. Saturn’s large moon Titan has an atmosphere composed almost wholly of nitrogen. Neptune’s moon Triton is wrapped in a thin crust of frozen nitrogen. A tenuous shell of oxygen has been detected on Jupiter’s Europa and the presence of nitrogen has been confirmed on demoted Pluto. Even Saturn’s tiny moon Enceladus has a wispy atmosphere consisting largely of water vapor. However, this water vapor is vented from its interior and is not retained for long. Jupiter’s moon Io, too, has an atmosphere consisting mostly of sulfur dioxide. But, like Enceladus, this material is expelled from the planet’s interior into space.

Thus, conventional planetary science categorizes atmospheres into two general classes consisting of primary and secondary formations. The transformation hypothesis also recognizes this classification but rejects the explanation given for their formations. In the conventional scheme, dominated by the derivative paradigm, all of the planets that accreted from the proto-solar disk possessed primary atmospheres consisting almost wholly of hydrogen with smaller amounts of helium, ammonia and methane. Due to their relatively small masses and proximities to the Sun, however, the inner rocky planets lost their primary atmospheres while the heavier more distant Jovian giants were able to retain theirs.

The secondary atmospheres, characteristic of rocky planets and formed from outgassing by tectonic and volcanic processes, consist of an array of elements and compounds including water vapor, carbon dioxide, nitrogen, oxygen, sulfur dioxide and methane. Since the planets’ cores are hot, the secondary atmospheres that result from this outgassing are already in the process of formation while they are still enshrouded in their primary atmospheres. Although the evidence for the mixing of the two atmospheric components is still inconclusive, it is likely that the colorful atmospheric band features of Jupiter and to a lesser extent Saturn are caused by outgassed sulfur, carbon, phosphorus and nitrogen compounds that have mixed with the upper layers of hydrogen and helium.

An External Atmosphere Dissipation Mechanism

Since post-stellar objects eventually lose their extensive atmospheres, a brief discussion of a known external mechanism whereby such losses occur is appropriate. Data derived from Earth orbiting satellites and deep space probes sent to the outer planets have shown the denuding effect the solar wind has on planet atmospheres. The action of this energetic stream of charged particles ejected by the Sun has been found to literally “cook

off” the gases of Earth’s upper atmosphere, even though its magnetic field provides some protection. Mercury, Mars and Venus, on the other hand, lacking strong magnetic fields, receive the full “corrosive” effect of the solar wind, although the continual upwelling of volcanic gases from Venus’ interior apparently replenishes that increment of its atmosphere that is lost to interplanetary space.(5)

However, in the case of the gas and ice giants – keeping in mind their relative youth with respect to the more ancient ages of the rocky planets – the strong magnetic fields and robust volcanic activity emanating from their hot interiors combine to dampen the solar wind’s corrosive cooking off action of their atmospheres. But, in the fullness of time, even their thick atmospheres will ultimately thin out – losing much of their mass in the process - and expose their rocky surfaces to whomever is around the neighborhood to bear witness at that distant future time.

An extreme example of a gas giant planet losing its atmosphere to its host star’s corrosive winds is HD 209458b, orbiting the G-type star HD 209458 near 51 Pegasi. Discovered in 1999, this “hot Jupiter,” referred to as “Osiris,” has a very close orbital period of a mere 3.5 days to its host star, is estimated to be slightly larger in dimension than Jupiter but less massive and has a core mass roughly ten times the mass of Earth. The temperature of its atmosphere is estimated at 1,000 degrees Celsius. It is believed that the loss rate of atmospheric hydrogen may be as great as 5×10^9 kg/sec.(6) Assuming that this rate of mass loss is accurate, a quick calculation shows that over the course of one billion years it will lose about 1.6×10^{26} kg. This mass loss is roughly 60% more than Neptune’s entire mass of 1.02×10^{26} kg. It is instructive to quote the concluding remarks of the exoplanet researchers whose paper is cited in footnote 6.

“Giant gaseous exoplanets with small initial masses may evolve into volatile-rich large terrestrial planets (Kuchner 2003; Lammer et al. 2003b). This process could explain the observed paucity of massive close-in exoplanets (Patzold & Rauer 2002). The remnant cores of giant exoplanets orbiting close to their host stars may be detectable for the first time with the new generation of space observatories such as *Convection and Rotation (COROT)* or *Kepler*. In conclusion, our study shows that thermal escape at close orbital distance, once claimed to be negligible, is a major loss process that should be included in any realistic model of the mass and radius evolution of close-in exoplanets.”(7)

Conclusion

The Osiris data provides preliminary empirical evidence for a process at work that over time can reduce or transform a gas giant planet – in this case, a “hot Jupiter” in close proximity to its host star – into a rocky remnant. And, while other mass-reducing mechanisms also play a role in the transformation of planets with extensive gaseous envelopes into smaller rocky planets, it seems reasonable to conclude that the transforming process is accelerated when the large atmosphere of a planet in close proximity to its host star is subjected to the scouring effects of its corrosive irradiations. Also, it is reasonable to assume that a forming secondary atmosphere under the

hydrogen-dominated primary atmosphere on Osiris would not survive the denuding effects of HD 209458's winds either. For that matter, as Osiris loses mass its orbit will shrink accordingly and it will probably be destroyed when it passes within the Roche limit of its host star.

Since Earth Venus and Mars have secondary atmospheres, it is reasonable to opine that they may not have been subjected to the withering assault to which Osiris is currently being subjected. However, our knowledge of their histories is too vague to draw any certain conclusions. Mercury is more problematic. Its close proximity to the Sun and the absence of virtually any atmospheric components suggests that it has fallen victim to the solar winds. On the other hand, Mercury may have lost its atmospheres by other means. As one of the more ancient objects in the system, it may have arrived at its current position without any atmosphere.

It is regrettable that the rudimentary state of our knowledge of the Solar System precludes a more rigorous treatment of the foregoing subject. And, although this shortcoming, in a historical sense, has not deterred speculation – some good, but a great deal more not so good – it should be governed and, thereby, restrained by the limitations the empirical data imposes on us. However, our knowledge of the Solar System will certainly increase as we continue to acquire more data. We must be patient, though. In this regard, I should mention that the New Horizons satellite now heading towards an encounter with Pluto is not scheduled to arrive at that distant icy world until July 2015. Therefore, as with so many other unknown aspects of the Solar System, we can only speculate and wait for Pluto to be revealed to us. And, at that time, some of our questions will be answered and a host of new ones will be raised.

Footnotes

1. The reader is urged to read the first paper in this series, “Are Planets the End Products rather than the By-Products of Stellar Evolution?,” *The General Science Journal*, August 15, 2008. It lays out the general framework of the transformation hypothesis.
2. Abruzzo, Anthony, J., “Brown Dwarf Stars – The ‘Missing Link, ’” *The General Science Journal*, November 20, 2008
3. Dr. Manuel's papers pertaining to his theory of a solid iron Sun can be found on his website, omatumr.com
4. Militzer, B., Hubbard, W.B., Vorberger, J., Tamblyn, I., Bonev, S.A., “A Massive Core in Jupiter Predicted from First-Principles Simulations,” *The Astrophysical Journal Letters*, Vol. 688, No. 1, pp L45-L48, November 20, 2008
5. On October 27, at the 2008, Huntsville Plasma Workshop, planetary scientist David Brain of UC Berkeley gave a presentation that described how the solar wind might rip away large chunks of the already tenuous Martian atmosphere due

to the peculiar configurations of the planet's magnetic field. This view is in contradistinction to the previously held views that Mars either lost most of its atmosphere to a cataclysmic event or to the continuous and gentle erosive effect of the solar wind over time. An article describing Brain's theory can be found at, science.nasa.gov/headlines/y2008/21nov_plasmoids.htm

6. Lammer, H., Selsis, F., Ribas, I., Guinan, E.F., Bauer, S.J., and Weiss, W.W., "Atmospheric Loss of Exoplanets Resulting from Stellar X-Ray and Extreme-Ultraviolet Heating," *The Astrophysical Journal*, 598, pp L121-L124, December 1, 2003

7. Ibid., p L124

Copyright: Users may copy, distribute and display verbatim copies of the above paper only if they give the author credit, and may not produce derivative work based on it without the author's permission.