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The Planet Migration Hypothesis – Saving The Paradigm

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Introduction

Over the past two decades, the planet migration hypothesis has become a "hot" topic for planetologists, so much so that one researcher in this budding field of inquiry was confident to conclude that "…one thing is certain: the idea that planets can change their orbits dramatically is here to stay."(1) Further, commenting on one particular planet migration simulation study, another researcher viewed it as providing "…additional evidence that the solar system has been, and remains, a much more active and chaotic place than envisioned by researchers a quarter-century ago."(2)

This subject was briefly discussed in a previous paper with respect to the current conventional idea that Uranus and Neptune had formed closer to the proto-Sun in the primordial nebula and migrated - by unspecified forces – to their present positions at some distant time in the past.(3) It was stated therein that the idea of migrating planets or, in a more general sense, the intrinsically dynamic nature of the Solar System, is generally consistent with the transformation hypothesis. This paper will expand on the cursory remarks made in that paper in order to provide a greater understanding of the motivations that led to the creation of the planet migration hypothesis.

The Need For Migrating Planets

Due to the detection of extra solar planets ("exoplanets") and the Kuiper Belt of our own Solar System, a state of discomfort developed amongst conventional planetologists. The combination of gas giant planets orbiting closely around their host stars ("hot Jupiters") – many of whose semi-major axes barely approach 1 astronomical unit - and the growing number of Pluto-like objects that have been detected inhabiting the Kuiper Belt had placed into question the efficacy of the conventional Solar System-formation paradigm.

The problem - when the constraints of the conventional Solar System-formation paradigm are considered, a paradigm rooted by general consensus in the planetesimal version of the nebular or derivative hypothesis – resides in the obvious inconsistency existing between the relatively long semi-major axes of our own gas giant planets and the relatively short semi-major axes of these hot Jupiter exoplanets. Compounding the problem further was accounting for the existence of the growing number of Kuiper Belt objects being detected in that distant region of space beyond the orbit of Neptune. These small, rocky objects should not have formed way out there.

Since its discovery in 1930, Pluto's presence as the ninth and final "planet" had – up until its recent demotion to "dwarf planet" status - posed a challenge to the various attempts made thitherto to account for its formation within the constraints of the derivative paradigm. As it was generally conceived, the paradigm envisioned the formation of small rocky planets close to the Sun with formations of large gas giant planets at much greater distances. But, with Tombaugh's discovery of a small rocky planet residing at the greatest distance from the Sun, beyond the giant planet zone, it became clear that something was seriously amiss with the nebular hypothesis. Pluto should not have been there.

Therefore, in order to explain how Pluto had gotten there, and thereby save the integrity of the paradigm, it became fashionable to view it as one of Neptune's moons that had subsequently – by some unspecified mechanism – broken free of the giant planet's gravitational influence and had migrated outward to its current orbital distance from the Sun. The paradigm was temporarily saved by this quick fix. But, six decades later, the further discovery of other so-called trans-Neptunian objects ("TNOs") once again imperiled the integrity of the paradigm. The mounting discoveries of these TNOs, along with the discoveries of the short orbital period exoplanets now called for a more vigorous approach to save the paradigm from total disrepute. Enter the planet migration hypothesis.

The General Features Of The Planet Migration Hypothesis

Computer-simulated models depicting planet migration generally have four common features:

The first feature incorporates the notion that all of the migrations occurred in the early history of the Solar System, when the abundance of material in the primordial nebula was at its peak, and the planet-accreting process was in full swing. This planet-forming material included already-existing small bodies or planetesimals, as well as particles of dust and gases.(5) The generally proposed timescale of the migration process involving the gas and ice giants – although its duration varies according to the simulation model being used – is on the order of 10^8 years and ended some 3.8 to 4 billion years ago.

The second feature is characterized by the almost exclusive focus these models place on the migrations of the gas (Jupiter, Saturn) and ice (Uranus, Neptune) giant planets, although some of them consider the roles small, rocky planets played in the production of the "final" configuration of the Solar System, as well.(4) It is obvious that this preoccupation with the gas and ice giant planets was motivated by the discoveries of the hot Jupiter planets orbiting other stars.

The third feature takes into account the interactions within the primordial solar disk between the accreting planets and the swarms of planetesimals surrounding them. All of these strictly gravitationally based interactions cause the transfer of orbital energy within and amongst this ensemble of bodies. These transfers of orbital energy produce, in turn, the dynamical effects that result in the migrations of both the gas and ice giants and the planetesimals from their "initial" orbital positions. The ice giants migrated out, while the gas giants took a sunward direction, and the space in which all of these planets resided was swept clean of plantesimals.

Some of the planetesimals were sent sunward, producing the so-called "Late Heavy Bombardment" that pummeled the rocky inner planets, including the Moon. Others were propelled out to the Kuiper Belt, the more distant scattered disk and even the Oort Cloud, the latter zone representing the Solar System's extreme boundary. Once there, some of this planetesimal material coalesced into the dwarf planets that are now being discovered with great regularity. Needless to say, it was a period in the Solar System's history that is best characterized as "chaotic."

However, there is virtually no mention of any electromagnetic phenomena in operation during this general migration process that may have also played some role in ultimately producing the configuration of the Solar System, as we know it today. This total lack of consideration should immediately raise red flags for anyone who accepts the indisputable fact that the universe contains plasma-induced electromagnetic forces that affect solid matter as greatly, if not even more greatly than do gravitational forces.

And, the fourth feature – the only one that has an empirical basis - promotes the idea that the orbital period resonances now existing between several adjacent planets and dwarf planets – what are referred to as "mean motion resonances," and which are viewed as having produced the abiding "stability" in the system - indicate that such migrations actually occurred. In other words, these migrations must have occurred, otherwise the observed period resonances of the orbits would not have obtained. Illustrative of these orbital period relationships, the following resonance ratios play the largest roles in computer-simulated migration models that seek to derive the present stable constitution of the Solar System from a primordial condition of instability.

Neptune/Pluto – 3/2, i.e. 165yrs.X 3 (495yrs.) = 248yrs. X 2 (496yrs.)(6)
Uranus/Neptune – 2/1, i.e., 84yrs. X 2 (168yrs.) = 165yrs. X 1 (165yrs.)
Jupiter/Saturn - 5/2, i.e., 11.9yrs X 5 (59.5yrs.) = 29.5yrs. X 2 (59yrs)

These simple low integer ratios represent the number of revolutions completed by each pair in the same time interval. So, in the time it takes Neptune to complete 3 circuits around the Sun, Pluto will make 2 and so forth. However, the reader should note that, in the three examples given, the actual orbital periods depart from the strict equality of the resonance ratios by amounts varying from 6 months to three years. But these discrepancies are considered insignificant and, over time, do not adversely affect the overall orbital stabilities of the resonant pairs. Thus, according to this conventional view, the chaos initially produced by the interactions of the giant planets and the planetesimals has now been reduced to order with the development of these orbital resonances.

Further Comments On Mean Motion Orbital Resonances

When the dynamical interactions of the Solar System's numerous bodies are taken into consideration with respect to the existence of mean motion orbital resonances amongst them, a surprisingly large number can be found. A number of the moons of Jupiter and Saturn exhibit resonant relationships. There are also mean motion resonances between some asteroids and Jupiter. And, the motions of Mercury and Venus closely approach a 5/2 resonant relationship. This latter near-resonant relationship can be interpreted in several ways. It may point to a former resonant condition between the two planets that is now diverging. Or, it could represent a converging resonance that will reach exact parity at some future time. Finally, it could simply signify a stable condition where the question of divergence or convergence is purely academic.

There is another type of mean motion orbital relationship involving more than two bodies called the "Laplacian resonance." A good example of this type of resonance can be found existing between Jupiter's first three spherical moons – Io, Europa and Ganymede – where the relationship is 4:2:1. Thus, it takes Io four orbits and Europa two orbits, respectively, to equal one orbit of Ganymede. Again, the actual orbital periods do not conform precisely to unitary 4/1 or 2/1 integral resonances. E.g., Io takes 1.769138 days to complete one orbit around Jupiter. A multiple of four orbits yields 7.076552 days. Ganymede, on the other hand, requires a longer period of 7.154553 days to complete one orbit around Jupiter. The difference amounts to 1 hour and 52 minutes. In the case of the 2/1 resonance between Europa and Ganymede, the real time difference is slightly less at 1 hour and 15 minutes.

It is clear that when Laplacian resonances are involved, it is conceivable that besides divergence or convergence, there is the possibility that a combination of both conditions may be at work. Or, as in the case of Mercury and Venus, the question may be moot. It is important to point out, however, that, depending on the specific circumstances of the interacting bodies in question, the stability or instability of mean motion orbital resonances obtaining amongst bodies can also be influenced by the orbital dynamics of bodies outside of these systems of resonance. Thus, for the sake of argument, if Earth were to develop an anomalous orbital motion, it could affect Venus' orbit, which, in turn, could affect Mercury's orbit, and be the primary cause of either greater divergence or convergence between the latter two planets' orbits. And, given all of the bodies in the Solar System, the possibility of such hypothetical events actually occurring cannot easily be dismissed.

In addition to the many examples of mean motion orbital resonances between adjacent bodies that occur in the Solar System, resonances can also be found amongst nonadjacent bodies. To cite just four, there is an almost exact 21/1 relationship between Jupiter's orbit and Pluto's orbit, an equally close-to-unity 3/1 ratio between the orbits of Uranus and Pluto, a 3/1 relationship between the orbits of Venus and Mars, and a 19/1 resonance between the orbits of Mercury and the dwarf planet Ceres.

Further, there are resonant relationships that include orbital parameters other than the mean periods of bodies. These relationships can be found between the axial tilts of planets, the eccentricity of their orbits compared to their orbital inclinations or their semi-major axes, and one or two others. The conclusions drawn from these types of resonances are, like the mean motion orbital type, assumption-laden and merely speculative with respect to their long-range predictions. When viewed in a conventional light, all of these conclusions, however, are meant to serve the dual purpose of providing support for the sagging derivative hypothesis and promote the idea that the Solar System's chaotic history lies billions of years in the past, and that it is now essentially stable - the admission of a few minor instabilities, notwithstanding.

Conclusion

While the observed resonances existing amongst the various bodies in the Solar System, with one or two exceptions, are empirically verifiable, there is no theoretical justification to use them as the foundation upon which a "new and improved" derivative hypothesis can be erected. And, since the resonances, at least those obtaining with respect to the gas and ice giants, stand on the shaky footing of the planetesimal mechanism, for which there is no empirical evidence, the planet migration hypothesis reveals itself as merely another "epicycle" whose sole purpose is to save the appearances, which, in this case, is how the nebular or derivative hypothesis adequately accounts for the Solar System's formation and current constitution.

Indeed, some of the more candid researchers in this field view their work as nothing more than imaginative exercises that seek to account for some elements of the Solar System's initial formation and further evolution to its present overall configuration. In fact, one particular research team that has done work on the formation and migrations of the gas and ice giant planets actually includes "Fairy Tale" in the title of one of its papers.(7) In the introduction to this paper, the team unabashedly observes, "Our model…contains elements that are probably wrong in detail. However, large portions of it may be correct and it illustrates the lengths to which we must go in order to understand the formation of these planets."(8) Implicit in this statement is the team's adherence to the underlying paradigm of the planetesimal-type derivative hypothesis.

In general, the planetesimal version of the derivative hypothesis is the unquestioned premise from which all of the planet migration hypotheses spring. It is obvious that without the formation of these small, solid bodies from the dust and gas of the primordial disk surrounding the proto-Sun, not only would no planet migrations have occurred, but also no planets would have formed. The entire edifice is based on the presumed existence of planetesimals.(9) And, it is so firmly entrenched as a premise beyond dispute that a perusal of the relevant literature will yield a diversity of opinions bearing on the possible mechanisms operative during the planetesimal formation process itself.(10)

However, no amount of patching and tinkering can save this paradigm from its inherent flaws. Nonetheless, one wonders to what lengths the advocates of the derivative hypothesis would go to save appearances if an Earth-like planet were discovered orbiting the Sun in the far reaches of the Kuiper Belt or further out in the scattered disk? Such a discovery – certainly within the realm of possibility – would surely result in the production of new and "enhanced" computer-simulated "fairy tales" seeking to explain why and how such a large object could exist so far from the Sun, within the context of the planetesimal paradigm.(11)

Summing up, it is clear that the planet migration hypothesis fails as a building element in the Solar System's "final" architecture because it is incorporated into the derivative hypothesis, which views the Solar System as having formed from one unitary evolutionary process. The transformation hypothesis, on the other hand, views the Solar "System" as essentially a work in progress, wherein the architecture is continually subject to change. Sometimes these changes are gradual and virtually unnoticeable, while at other times, they are abrupt and "catastrophic." Conventional planetology will remain trapped in its theoretical dead end until this reality is grasped and accepted.

Footnotes:

1) Malhotra, Renu, "Migrating Planets," *Scientific American* 281(3), p. 63, September 1999

2) Lissauer, Jack, NASA Ames Research Center, quoted by Ron Cowan in, "Roaming giants: did migrating planets shape the solar system," *The Free Library*, May 28, 2005

3) Abruzzo, Anthony, "The Formation and Age of the Solar System," *The General Science Journal*," October 27, 2008, pp 4-5

4) A good example of this type of modeling, as it would apply to all solar systems, can be found here: Mandell, Avi, M., Sigurdsson, "Survival of the Terrestrial Planets in the Presence of giant Planet Migration," *The Astrophysical Journal*, 599: L111-L114, 2003 December 20

5) There is no definitive definition of a "planetesimal," but it is generally agreed that 10 kilometers would constitute an upper limit on their size. They are, of course, solid objects, and meteors – even comets – are often classed as species of planetesimals.

6) It is interesting to note that since Neptune was only discovered in 1846, it will not return to its point of discovery until August 10, 2011. Thus, one could say that its orbital period is still "hypothetical," although no significant anomalies have been detected in its motion. In Pluto's case, however, the opportunity to verify its hypothetical orbit of 248 years will not come until 2178.

7) Levison, Harold, F., Thommes, Edward, Duncan, Martin, J., Dones, Luke, "A Fairy Tale About the Formation of Uranus and Neptune and the Lunar Late

Heavy Bombardment." This paper can be found on the internet at, plutoportal.net/~hal/pdf/fairytale.pdf

8) Ibid

9) Some researchers have claimed to have detected planetesimals, but the "evidence" is indirect and the data upon which their conclusions are based – the analysis of certain spectral lines in the spectra of young stars – are open to alternative interpretations. E.g., see Chakraborty, Abhijit, Ge, Jian, Mahadevan, Suvrath, "Evidence of Planetesimal Infall onto the Very Young Herbig Be Star LkHa 234," *The Astrophysical Journal*, 606:L69-L72, 2004 May 1

10) Two typical examples of this type of analysis are, Youdin, Andrew, N., Chiang, Eugene, I., "Particle Pileups and Planetesimal Formation," *The Astrophysical Journal*, 601: 1109-1119, 2004 February 1; Futo, P., Gucsik, A., "Compaction and Sticking of Planetesimals Due to Porosity," 40th Lunar and Planetary Science Conference, (2009). This paper can be found at lpi.usra.edu/meetings/lpsc2009/pdf/1008.pdf

11) Such a discovery has already been anticipated and modeled, following the conventional planetesimal/gas giant interaction mechanism discussed above. As such, the model suffers from the shortcomings inherent in this "fairy tale" mechanism. See, Lykawka, Patryk, S., Mukai, Tadashi, "An Outer Planet beyond Pluto and the Origin of the Trans-Neptunian Belt Architecture," *The Astrophysical Journal*, 135: 1161-1200, 2008 March 4