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Where does the huge orbital a.m. of solar and exoplanets come from? Evidence in both arenas that they get it during nebula-borne construction, the property of new insight on the physics of gravitation

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Abstract

The present solar planetary system is replete with dynamical constraints on how it was built, and further constraint is provided by accumulating exoplanet observations. In this regard, the most securely determined and far-reaching dynamical constraint of all - the high orbital angular momenta of the planets, relative to solar rotation - has been recognized for nearly a century [1-5], but has proven to be the very elusive to explain within the currently prevailing variants of the Kant-Laplace solar nebula paradigm. One of the most recent, the 'Nice' model, see [6], lacks systematic treatment of the prograde directions of planetary spins and satellite orbits. My purpose here is to underline the significance of these and other failures by working through the various planetary system features at issue, and then to outline a possible way ahead.

The mean specific orbital angular momentum (a.m.) of the solar planetary materials is ~$1.3x10^5$ times the rotational a.m. of solar material. Individual planetary a.m. arises from the prevailing Keplerian velocity pattern; the question is how they got there. Sparse exoplanet data on central-body rotation show no sign that the star's rotation is anywhere near fast enough to remove this huge disparity of a.m. So we seek to resolve this problem by recognizing that nebular action during planet formation was the only agent available for such 'partition' of a.m. Such action, by whatever means, requires completion of planetary growth within the period of nebular presence, so that their growth materials also be equipped with the appropriate a.m. This limitation accords with two constraints from meteorites:- accretion onto asteroids continued until ~4563Ma (but no later), and relationships between very short-life isotopes require that they were imported very soon (1Ma?) after their production in a stellar explosion [7]. So the >50Ma timescales of the Nice model, to provide for orbit migration in the presence of much other material, seem to be ruled out.

The near-circular orbits of all except Mercury are indeed consistent with completion in the presence of nebular gas-drag. But planetary growth by randomly directed impact would not systematically increase their orbit size and a.m.

So where and how were the SS protoplanets nucleated and achieve their growth? This introduces the matter of planetary spin directions. Mercury's spin is probably irrelevant, having suffered a late giant impact (tilted and highly eccentric orbit, 2/3rds of its mantle missing) [8,9]. Of the 7 other planets all are prograde except Venus, whose very slow retrograde spin might be due to retrograde-capturing large amounts of the Mercury impact debris, another 2.7% of which may have built the Moon. The 98deg inclination of Uranus does not render it 'retrograde'. Restoring it by that angle makes its satellite pattern like those of the other three Giant Planets (GP). Moreover, Uranus' orbit is now as circular as its GP brethren, so the impact which tilted its axis must have been quite early, giving time for subsequent circularization by nebular action. So we are looking for a nebula-present mode of planetary construction which leads to a systematically prograde spin result. Such systematic behaviour hints strongly at gravitational nucleation.

Note at once that in a Keplerian disc the vorticity is retrograde. The only place where prograde vorticity would be available in a plasma-rich protoplanetary disc is very close to the Sun and due to quasi-equatorial magnetic coupling. This point immediately strikes a chord with the exoplanet scene. There, ~23% of all those found are grouped around an orbital distance of ~10 solar radii. The proportion has changed little as the numbers grew, despite changes in detection methods. It is not a matter of ease of detection, but of why they are there at all, when Mercury, our closest-in planet, is at 83 solar radii. Some have sought to explain this as the result of **inward** migration due to gas drag, but that overlooks the problem of how they had the higher a.m. of being in a bigger orbit to start with. (The same objection applies to the treatment [6] of Jupiter as a source of a.m. for exchanges.)

Evidently, the SS planets must have derived their prograde spins from being nucleated - perhaps successively - in close-to-Sun positions, screened from it by nebular opacity, then enlarging their orbits and increasing their a.m. The close-in exoplanets that we can see are exposed to us and to their star by departure of the nebular agent that would have continued to push them outward, so they may eventually vanish by evaporation. As did any inside Mercury?

The remaining dynamical question is how to preserve, during protoplanet growth and outward progress to its present orbital distance, the prograde spin that each acquired by close-in nucleation. The answer, affirmed by the systematically prograde orbits of the inner 56 satellites of the Giant Planets, is that those are the residual part of a tidal capture population [10], the retrograde members having spiralled inward and built up the interiors of those planets. A dynamically balanced population of tidal captures during outward motion will leave the protoplanet with its original spin direction, but slower. To achieve efficient tidal capture the need for nebular gas-drag assistance during the first pass further confirms that, bar the Mercury impact, the entire planetary construction process was accomplished within a nebula-present timescale - a not-unreasonable result in view of the big capture cross-section thereby offered.

This timescale (~5Ma?) rules out the supposed formation of planetary cores by percolation of molten iron, thought to require >30Ma, but is consistent with the nebula-present mode of so doing [11,12], with the further great benefit of providing the otherwise-obscure source of the abundant SS water [12], including that subsequently carried out to the cometary belts. So the substantial detection of water in an exoplanet may have similar significance.

In summary, the very high orbital angular momenta of planets, w.r.t. their star, demands a scenario in which the motion of materials in the protoplanetary disc is **outward**. (A recent image of the Beta Pictoris young exoplanet system is persuasive visual evidence of such a flow pattern.) If a frame for doing that can be provided, the other features discussed above could all fit in, replacing the Kant-Laplace paradigm and its problems.

To meet this demand, I will outline a 2-stage scenario [9,13] which embodies my finding that the Newtonian gravity field of a body is inevitably accompanied by a radial electric field, the Gravity-Electric (G-E) field, provisionally extrapolated from [14] at ~30V/m at the solar surface. In essence, when the ion plasma-rich protoplanetary disc was present, this field would provide outward force on these materials, **creating** a.m., none of it coming from the Sun/star. Final expulsion of the disc materials - a process portrayed in the Beta Pic image - allows the non-ionized elements of the system to adjust to the Keplerian state which now prevails. Evidently, the G-E field is the essential agent for the high a.m. of planetary orbits. Without it, the only planets anywhere would be close-in and ephemeral.

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