Meta Research Bulletin

Volume 17, Number 1 *August 1, 2008*

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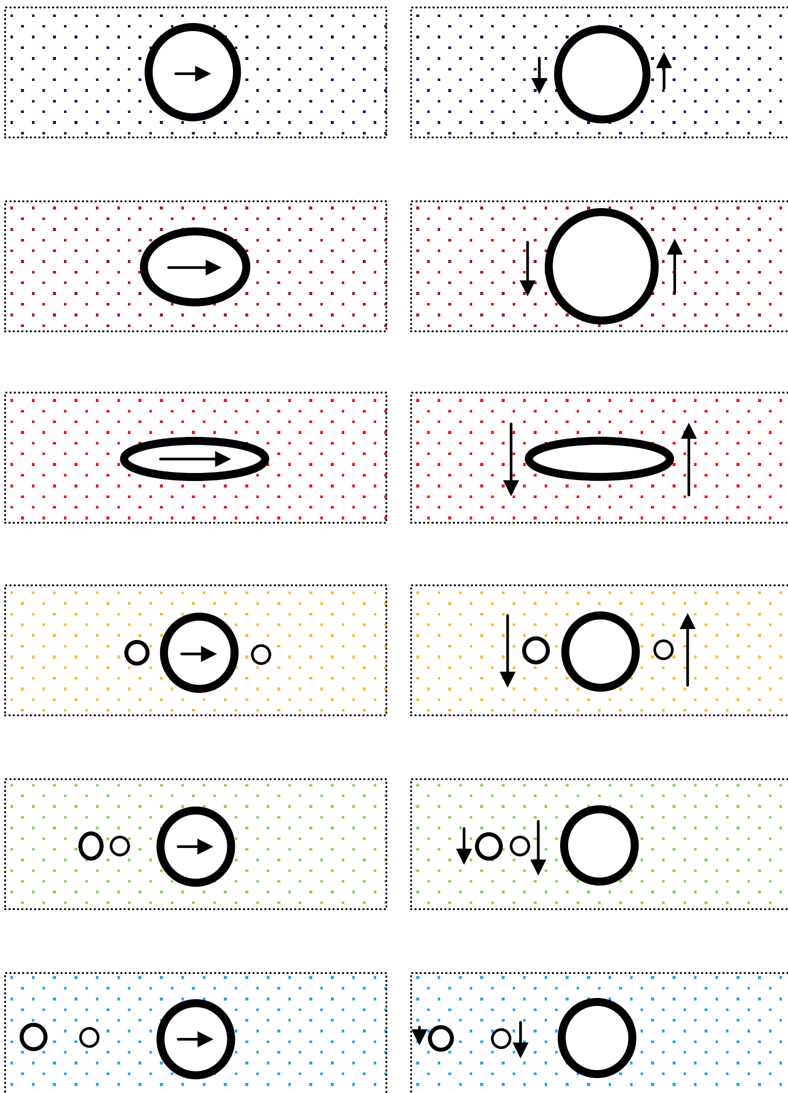

ISSN 1086-6590

IN THIS ISSUE

- ⊕ NO, you did not fail to receive the March 15 or June 15 issues of this Bulletin. Neither issue was published. See our lead story about changes in our publication schedule, necessitated by our other activities, primarily the CCC2 conference. This is the first MRB issue of 2008.
- ⊕ The cover is a schematic of the fission theory for formation of planets and major moons. The left column is the sequence of events viewed in-plane, and the right column is the same sequence viewed from above.
- ⊕ This is your final opportunity to sign-up for our international "Crisis in Cosmology – 2" (CCC2) conference from 2008 September 7-11 in Port Angeles, WA. Both participant and observer spaces remain available as of this writing, but may not remain so for very long. See http://www.cosmology.info/2008conference/.
- ⊕ The major article of this issue is a comprehensive development of the fission theory for the origin of all major planets and moons of both our solar system and other stellar systems. An outline of this model was first published in MRB in 1997, and appeared in the second edition of "Dark Matter, Missing Planets and New Comets" in 1999. But this new article fills in the details of the mechanism and compares and contrasts this model with the mainstream model in more detail. The fission model is then applied to explaining the origin of traditional solar system bodies, newly discovered solar system and extra-solar planetary bodies, and now-exploded former planets and moons of the solar system. Between the fission hypothesis for how these major bodies begin, and the exploded planet hypothesis for how they end, Meta Science now provides a fairly complete basis for understanding the evolving nature of our solar system over its 4.6 billion years of existence.
- ⊕ Our third article is an updating of an article first published in these pages in 1995. It clarifies a common mis-application of the equivalence principle, and shows why gravitational and inertial masses for a single body are not necessarily equal even approximately, despite alleged verification of their equality to more than a dozen significant figures.
- ⊕ There is again much to report in our regular feature, *Meta Science in the News*. However, we have limited this feature to four items this time in the interest of getting this very late issue out now. (It would otherwise have slipped to October because of the September CCC2 conference.) In this issue, we report about the failure of Gravity Probe B, NASA's "official" stamp of approval for the discovery of water on Mars, Google's new Knols project as a viable replacement for the failed Wikipedia model for recording encyclopedia-worthy information, and the latest news in the debate about the origin of the Mars hemispheric dichotomy.

The MRB Publishing Schedule

You did not fail to receive the expected March 15 and June 15 issues of the Meta Research Bulletin – neither exists. This is the first issue of 2008. The publishing delay was caused largely by your editor's involvement as chairman of the Local Organizing Committee for "Crisis in Cosmology 2" (CCC2), an international meeting that seeks to bring to public attention how much trouble the Big Bang theory is in and what our best options are for an alternative cosmology. The meeting organization brings together the personnel and resources of four organizations: the Alternative Cosmology Group (ACG), the International Academy for Cosmological Studies (IACS), The Virtual Institute of Rational Astrophysics (VIRA), and Meta Research, Inc. (MRI).

I'm hoping that many Meta Research members can attend the conference, either as participants or as Observers. The dates are 2008 Sept. 7-11, and the location is Port Angeles, WA, nestled between the Straits of Juan de Fuca and Hurricane Ridge on the Olympic Peninsula, just 15 miles from the editor's new location in Sequim, WA. Many of the world's leading experts on cosmology in general and alternative cosmologies in particular will be presenting at the conference. Papers have been accepted from scientists working in 14 different countries, and registrations have been received from six other countries. Detailed information on attending and an overview of the program, discussion Panel topics, and accepted papers may be viewed at http://www.cosmology.info/2008conference/.

The success of the conference in displacing the Big Bang in favor of a more viable and sensible cosmology seems a worthy investment of time and resources by Meta Research. However, the consumption of available time by conference preparations is the main reason we missed our first two publication dates this year – the first time one has been missed in the Meta Research Bulletin's sixteen years of existence. Yet this might not be a one-time anomaly. If Meta Science is going to win the attention of mainstream scientists and the science-interested public, we will need to make similar investments in projects related to our other main themes: the origin and nature of gravity; faster-than-light communication and propagation in forward time; the fission model for the origin of planets and moons; the exploded planet hypothesis; the amazing Mars anomalies; the principles of physics and Scientific Method; and the many other aspects of Meta Science.

Our Bulletin is our primary vehicle for communicating new frontiers research with our supporting Members. It is now reaching a wider audience than ever because of being open access on-line. So we plan to keep it going strong. However, considering the realities of astronomy, such as that new discoveries and events of interest occur on schedules we have no control over, it is more realistic to have a less rigid publication schedule. In addition, postal rates for print edition subscribers have gone up again.

So beginning with the present issue, this Bulletin will be published as often as time and contents permit, but on a variable schedule. Because that may sometimes be less often than quarterly, each issue may be longer on average than the quarterly issues. Our target for the future will be three issues per year, but with as many or more *pages of content than the previous four issues per year. That will save mailing and printing time and costs as well as postage costs. Subscriptions and Memberships will last through three Bulletin issues, even if that takes longer than a calendar year. This means everyone will receive as much or more content as before, but spread out over more time and on a less predictable schedule. And our publication dates will no longer always be on the 15th of the month, so Bulletin cover dates will vary.*

Please feel free to write <tomvf@metaresearch.org> with your suggestions and concerns. We are always happy to hear from our Members and Supporters.

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"It is very often easier to get forgiveness than permission." – Jim Batka

Our Original Solar System – a 21st Century Perspective

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Abstract. The primeval solar nebula hypothesis, the mainstream theory of solar system formation for over 200 years and a product of inductive reasoning, is wrong. It cannot explain much of what we know about the solar system today, and has failed to make useful substantive predictions. Rather, each new discovery requires a new explanation for how it can fit into the theory. By contrast, deductive reasoning leads us to fission theory as the logical origin of today's major planets and non-asteroidal moons, with the exploded planet hypothesis accounting for small solar system bodies. In the decade since this model was formulated deductively, it has made several significant and successful predictions, led to explanations lacking in paradoxes, pointed to previously unrecognized patterns, and given us insights about planets and moons that no longer exist.

The primeval solar nebula hypothesis

The primeval solar nebula hypothesis (PSNH) is the mainstream theory of solar system formation in the field of astronomy today. It is a modern variant of a theory put forward by Pierre Laplace in 1796 – so variant that Laplace would hardly recognize it. In PSNH, the Sun, its major planets and their natural moons all formed from the cooling and condensing of a rotating cloud of interstellar gas and dust. As a large blob formed somewhere inside this cloud, matter began to fall toward it, causing the cloud to spin up and flatten. The large blob continued to grow and eventually became the Sun. Then the largest of the other revolving lumps in this nebula condensed into major planets. These in turn attracted more gas and dust to fall toward the planets, and began to revolve around them. The largest clumps therein grew into the natural moons of the planets. Jupiter's gravity prevented formation of a planet in the main asteroid belt, where asteroids are found. And the formation of Uranus and Neptune pumped up the orbits of many smaller icy bodies, leading to the Trans-Neptunian Objects (TNOs) and the Oort cloud of comets 1000 times farther away from the Sun.

The problems with this theory are many, requiring continual help from *ad hoc* helper hypotheses. First, interstellar gas and dust clouds don't have significant rotation, so it is difficult to get such a cloud to flatten. It is now usually recognized that something like the blast wave from a supernova explosion is needed to flatten the cloud. Today, the Sun contains over 99% of the solar system's mass, yet surprisingly only 1% of its angular (rotational) momentum. The PSNH theory proposes magnetic forces between Sun and planets to explain this puzzle, but details consistent with today's solar system have been lacking. Even more serious, attempts to explain the dominance of prograde orbital motion and rotation for planets and moons have been entirely unsuccessful.

Mathematical modeling of PSNH homed in on computer models that produced solar-system-like outcomes. But newly discovered exoplanetary systems around other stars have found many Jupiter-sized planets near their parent stars, which these models forbid; and many high-eccentricity orbits, which are supposed to be rare. Jupiter's gravity creates a zone of enhanced stability in the main asteroid belt, the exact opposite of being a force disrupting planetesimal formation. Moreover, small bodies with mutually similar solar orbits cannot accrete because gravitational forces make them librate and avoid collisions; whereas small bodies with dissimilar orbits tend to collide destructively because of high relative speeds. The sharpness of the observed "Oort cloud" property of comets orbits has proved difficult to reconcile with the model's expectation of a much broader distribution of mean distances from the Sun. The presence of argon and nitrogen found by the *Galileo* spacecraft in Jupiter's atmosphere is inconsistent with the expected temperatures at Jupiter's formation distance from the Sun. James Maxwell showed that the shear forces from a disk with differential rotation would have prevented the condensation of individual planets. Sir James Jeans studied the breakup of spinning bodies from centrifugal forces and also concluded that formation of the solar system from a single co-rotating gaseous cloud was not dynamically possible. (Britannica Online 2008)

It seems safe to say that, but for all the history, textbooks, papers, funding, careers, and reputations at stake, the field would readily embrace a viable alternative model free of all these problems. Amazingly, such a model now exists.

Competing theories

Ironically, the original Laplace "nebular hypothesis", before it had to be manipulated in so many ways, contains the kernel of a model that actually works. Laplace had the proto-Sun's atmosphere extending beyond the distance at which any planets form. Next, he assumed the Sun would cool and contract as it radiated away its heat. Contraction would force speed-up of the various atmospheric layers. At each layer where gravity and centrifugal force balance, collisions would deposit a ring of material in the Sun's equatorial plane. Each such ring would then coalesce into a planet. Moons would form by a similar process around planets.

We now know that rings do not coalesce, but will instead disperse to the maximum extent possible so that collisions are minimized or avoided altogether. But modern ideas agree that the early proto-Sun was a very extensive body and might easily have extended well beyond Neptune's orbit. Laplace simply did not have knowledge of how such a body would behave as it continued to accrete more infalling gas and dust. If he had, he would have been led directly to the fission model.

Historically, however, the next step by opponents of the PSNH went in a different direction. Thomas Chamberlin and Jeans proposed a catastrophic tidal theory in which a passing star drew away solar material that eventually condensed into the planets. But this required an extremely low-probability encounter event and did not solve most of the other objections to PSNH; and it introduced a few new objections of its own. It was soon abandoned.

The fission model as it exists today was elucidated in Van Flandern (1997b) and Van Flandern (1999) with a minor update in Van Flandern (2004). The following section will give the most detailed description of the specifics of the model yet developed by any author.

The fission model for planet formation

Summary: A supernova sends out a blast wave, which flattens an interstellar cloud. Gravitational collapse of the flattened cloud forms one or more proto-stars, which contract and spin-up as they accrete gas and dust. Spin makes the proto-star's shape oblate, and faster spin makes it prolate, This leads to overspin and finally fission, forming planets.

1. A nebula gets flattened by a shock wave.

We start with a nebula, a three-dimensional cloud of gas and dust, of the type seen frequently throughout our Galaxy, often created by matter from previous generations of exploded stars. Such nebulas are normally too large and dispersed for collapse from self-gravitation before other factors change the nebula. One such factor is likely to be the shock wave from a nearby supernova explosion. This must eventually happen, and tends to compress the nebula in the direction of travel of the blast wave, creating a pancake shape. (See Appendix A for more details on why it flattens the nebula.) This greatly increases the density of the gas and dust everywhere in the nebula, making gravitational collapse easier and faster. Gravity will ensure that the randomly densest regions will collapse first. The original gas cloud is flattened rather than scattered because all its molecules of whatever mass are quickly given roughly the same speed as the supernova blast wave at just the time when the blast wave passes. As a result, most of the cloud's molecules end up with a similar distance from the supernova and velocity through space when the blast wave dissipates. The densest concentrations of molecules are then the sites for potential star formation in a new generation cluster.

2. Gravity and collisions make dense regions denser and hotter, eventually forming a proto-star.

Because the individual gas and dust molecules have small, random motions of their own, they do not simply fall straight toward the nearest high-density anomaly. But their motion is modified somewhat toward that direction, which causes them to further increase the density of an already over-dense region as they pursue a low orbit around it. Of course, the lower such particles dip into the over-dense region, the greater is the probability of a collision with another particle. Head-on collisions lowering one or both particle velocities relative to other velocities in the over-dense region, and heating both particles, would be common. (See Appendix B for the meaning of "heat" for small particles.) These collisions tend on average to drop particles into still lower orbits with even greater collision probabilities. The end result of cascading collisions is to form a proto-star, with highest particle density and heat in the center, gradually tapering off in density and heat with distance until it blends smoothly into the average density of the surrounding pancake nebula.

3. As central density further increases, the proto-star becomes a liquid.

Note that collisions far from the center of a forming proto-star are still mostly disruptive because of high relative speeds. Particles in such collisions tend to bounce rather than stick; and tend to break apart particles that may have already stuck together. Only near the center can densities get so high that particles are forced into continuous contact and a contiguous mass begins to form. If a secondary density concentration started to form elsewhere, continuous high-speed bombardment from particles orbiting the primary would most likely dissipate it before its density could approach that of a contiguous mass. But in the center, the cloud of gas and dust with free molecules becomes a liquid by virtue of having contiguous molecules in contact, able to vibrate but not to move independent of their neighbors. Meanwhile, farther from the center, planetary formation and even moon formation have little chance of occurring in the manner envisioned in the PSNH because collisions are mostly destructive and tend to heat things up. (See Appendix C for more on the distinction between solid, liquid, and gaseous phases.)

4. The proto-star and its atmosphere contract and start to spin as accretion continues.

Continuing our deductive reasoning to see where it leads, gravity would continue to attract particles from the larger nebula, and random collisions would tend to bring down particles already in a vast extended atmosphere around the forming proto-star. Particles falling from greater distances would increase their radial and transverse speeds, but acquire relatively little motion normal to the pancake-shaped nebula. Purely by chance, the net number of collisions resulting in clockwise (CW) motion of the colliding particles may outnumber the net number producing counterclockwise (CCW) motion; or vice versa. Because we can view the pancake from either side, we are free to choose the side consistent with the astronomers' convention that the resulting dominant motion will be CCW as seen from above, which is then "north" by definition. The forming proto-star and its extended atmosphere develop a unique spin.

5. The net motion in the proto-star atmosphere sets up rotation with speed increasing inward.

As soon as the proto-star's atmosphere acquires a dominant rotation direction, however slight, collisions between particles going the "wrong way" (CW) will be more frequent than collisions between "right way" (CCW) particles. So CW particles tend to get corrected into CCW particles. At the same time, average speeds are being lowered by collisions, causing further contraction and heating of the atmosphere and liquid proto-Sun. But as particle orbits lower, their average speeds must increase to conserve angular momentum. The farther inward the gravity-controlled particle drops, the faster will be the CCW motion it encounters. So the proto-star and its atmosphere take on a preferred rotation direction, and the particles gradually sort themselves out by eliminating velocity-cancelling CW particles and particles with radial motions. This will get all particles moving at appropriate speeds for stable, near-circular orbits at their own distance from the proto-star center. This is the case except at small distances where the density has become high enough to cause friction to dominate gravity in controlling particle motions. Near the center, the forming contiguous liquid grows in size.

6. Continued contraction increases spin, then gravity and cohesion compete to find a new equilibrium.

Layers in the proto-star and its atmosphere at different distances rotate at different rates, as is necessary to balance gravitational and centrifugal forces and keep the shape stable. But the continuing accretion induces further contraction, which forces further spin-up to conserve angular momentum. This process creates a stability problem. Angular momentum is proportional to the product of distance and orbital velocity. To conserve it, a distance decrease must be accompanied by a corresponding velocity increase, which will then be inversely proportional to distance; i.e., at ¼ the distance the velocity will be 4 times as great. However, to maintain an equilibrium between the central gravitational force and the centrifugal force at that distance, as required for orbits to remain circular, the velocity must be inversely proportional to the square root of distance; i.e., at ¼ the distance the circular velocity will be twice as great. These two conditions are incompatible. A contraction that conserves angular momentum will force the rotation rate to be too high for that distance. This cohesion vs. gravity competition, or "cograv effect" for short, resolves in one of the following ways:

- For the central parts of the proto-star, the molecules are already in contact, so cohesive forces override gravitational forces and the liquid body simply spins faster and the shape deforms to the extent that cohesion allows.
- For the sparse outer parts of the proto-star atmosphere, gravity still dominates, so all the molecules at each distance are forced to rise to the distance where gravity and centrifugal force again balance. In brief, while the proto-star is contracting and driving mass inward toward its center, the angular momentum of the arriving molecules is being driven outward and away from the center where there is relatively little mass. (Here we see the beginning of the resolution of the famous angular momentum paradox – why the Sun with most of the mass has only ~1% of the solar system's angular momentum.)
- For intermediate parts of the proto-star atmosphere, both processes operate. Centrifugal force tries to drive the molecules and their angular momentum outward, slowing orbital speeds; whereas collisions create pseudo-cohesive forces that make the atmosphere spin faster than its natural orbital speed for any given distance.

7. Excess spin forces a body to become oblate. More spin makes it prolate.

Although the nebula was flattened by a shock wave, it is not perfectly flat and still has some thickness much larger than the dimensions of a star. So our small, accreting, central proto-star initially takes on a spherical shape when gravity dominates. As this becomes a coherent liquid body (even with differential rotation at different depths and different latitudes), it is forced to spin up by further contraction and accretion, just as a twirling ice skater will spin up if she pulls in her arms. After more contraction and spin-up, the equator is forced to bulge outward by centrifugal forces, while the polar regions tend to drop closer to the center to fill the void left by the expanded equator material. In short, the shape of the proto-star changes from spherical to oblate (mildly flattened). The same phenomenon, increasing oblateness, is happening to the extended atmosphere, noting only that its outer regions were never very spherical to begin with. With still more contraction and spin-up, the bulging equator will tend to bulge out faster on opposite sides along some particular axis, becoming football-shaped or lemon-shaped. Parts of the equator away from this axis will tend to flow toward the axis to compensate for density reductions along the axis when the original material there is stretched along the expanded axis. In short, the shape becomes prolate, also called a "Maclaurin spheroid".

8. Overspin causes twin proto-planets to fission from a proto-star.

If a prolate-shaped body reaches overspin – the state where centrifugal forces exceed the combination of gravitational and cohesive forces near the outer ends of the long axis – the end of the larger and more extended bulging lobe will break off. Its speed is somewhat above orbital speed for its distance from the proto-star, so it continues its previous motion, but now in a slightly higher (and slower) orbit around the proto-star instead of attached to it. Meanwhile, the opposite bulging lobe was itself close to breaking off because of the symmetry of the prolate shape. When the first lobe breaks off, the stretched remaining portions of the proto-star just below the broken lobe are pulled sharply back into the proto-star by gravity. That downward vertical momentum sends a pressure wave all the way through the proto-star sufficient to break off most of the opposite lobe. But because the opposite lobe had started to relax when the proto-star suddenly became smaller, not as much of the proto-star breaks off as it did for the larger lobe. Empirically, in our solar system, the opposite lobe has close to 86% of the mass of the larger lobe. (Van Flandern 2007a: Appendix I) And the second lobe to break off will also have a closer (and faster) orbit around the changed, smaller proto-star than the first lobe. In other respects, the two fissioned lobes are destined to become twin proto-planets, with the outer one always being the more massive of the pair. And the proto-star left behind has shed mass and momentum, and is no longer in an overspin state for its new, smaller radius.

9. Proto-planets become hydrogen-dominated gas giants, helium-class gaseous planets, or terrestrial-class solid planets.

Details for how proto-planets evolve into solar system planets and how that differs from the evolution of moons will be discussed below. For now, we note here that a solar-type star is dominantly hydrogen, so all fissioned proto-planets start their existence as dominantly hydrogen bodies as well. If they are massive enough for their gravity to retain hydrogen, the lightest and potentially fastest element, the proto-planet will become a hydrogen-dominated gas giant planet. If a proto-planet is not massive enough to retain hydrogen, but is massive enough to retain helium, the hydrogen escapes and the result is a helium-class gaseous planet. It the proto-planet is less massive than that and most helium escapes too, the planet will likely become a terrestrial-class solid planet containing mainly elements heavier than helium, which astronomers like to refer to collectively as "metals".

See Bejko (2001) for a brief animation of a simple fission.

How solar system planets fit into the fission model

The solar system presently consists of eight major planets and three dwarf planets. But the distinctions between major planets, dwarf planets, and moons, or between asteroids and comets, are somewhat arbitrary and based on broad, general criteria. Marginal cases exist that can be argued either way. Pluto for example only recently lost its "major planet" status. And it has been argued that Pluto and its large moon Charon are escaped moons of Neptune. (Harrington and Van Flandern 1979; Van Flandern 1991)

In the inner solar system, Van Flandern and Harrington (1976) argued that much of what we know about Mercury and Venus tells us that Mercury is an escaped Moon of Venus. More recently, Van Flandern (1997a) suggested that Mars is a former moon of Bellona (formerly called "Planet V"), the now-exploded planet originally in an orbit at the distance of Mars from the Sun. The Mercury *Messenger* spacecraft will evaluate predictions made by the former hypothesis (see Van Flandern 2007c), while new evidence has already been supportive of the latter hypothesis. (Van Flandern 2007a and 2007b) These identity reassignments, as we will see, fit perfectly with the fission model for solar system origin even though they were deduced from entirely unrelated considerations long before the modern fission model had been formulated by anyone. For example, the idea of major planets occurring in twin pairs is completely missing from the first (1993) edition of my book about the solar system, although it appears prominently in the second (1999) edition, after I came to realize the implications of the fission hypothesis. (Van Flandern 1999)

If we accept these planet/moon identifications for the moment, it is interesting to look at what is left by way of true, major planets in the original solar system. First we have Venus and Earth, both rather similar in mass, composition, solar distance, and number of original significant moons (if our premise about Mercury is correct). If the exploded planet hypothesis is accepted, then Bellona (now-exploded parent planet of Mars in a similar orbit to Mars and associated with S-type asteroids in the inner asteroid belt) and Planet K (now-exploded planet associated with C-type asteroids in the outer – and more massive – asteroid belt) would have been another pair, similar in that they both met the conditions leading to explosion. Following the asteroidal gap, we have the two largest gas giants, Jupiter and Saturn, likewise with similar composition and numerous moons, and with masses and solar distances more similar to one another than to any other existing planet. (We will deal with the mass difference later.)

Next out we have another pair of twins, Uranus and Neptune, with similar masses, compositions, and solar distances. Their number of original significant moons would likewise have been similar if the conjecture about the origin of Pluto and perhaps also Charon as former Neptunian moons is correct. Next we have another asteroid belt, called the "trans-Neptunian objects" (TNOs), beyond the orbit of Neptune near where another planet might have been expected. And intriguingly, we now have evidence that the TNOs might come in an inner and an outer belt too, just as the main belt asteroids do. Three TNOs have been discovered much farther out, with orbits that could not have shared an origin with the inner TNOs. Could these two sets of asteroids be the remnants of yet another original pair of twin planets?

One aspect of this picture is striking: a tendency for these planets to occur in pairs. Two of these pairs are similar enough for the respective planets to occasionally be called "twins": Venus-Earth and Uranus-Neptune. And each pair is notably and strikingly dissimilar to its adjoining pair or pairs. Now there is no particular reason under the PSNH of planetary formation why this should be so. The nebula from which the planets allegedly condensed should have been rather homogeneous in most respects and planet masses should have had a smooth radial gradient with solar distance. By contrast, the fission model not only expects this feature, it demands it, at least for hydrogen-dominated single stars such as our Sun. Similar remarks with respect to both models apply to the distribution of angular momentum in the solar system: the PSNH is surprised, whereas the fission model requires outward migration of angular momentum through fissioning (the cograv effect).

The fission hypothesis would also solve the mystery of the dominance of prograde rotation for these original planets, since they would have shared in the proto-Sun's prograde rotation at the outset. By contrast, Lissauer (1992) summarizes this puzzle from a PSNH perspective: "Almost all the previous calculations were wrong … If you accrete planets from a uniform disk of planetesimals, the observed prograde rotation just can't be explained." Planets that accreted from collisions should have random rotations and pole orientations depending on the random directions of the most significant accreting impacts.

There are some basic similarities between the solar fission hypothesis for origin of the planets, and the more traditional accretion from the primeval solar nebula. In both cases, an extended gas and dust cloud contracts, and a concentration toward the center eventually becomes dense and hot enough to be classified as a star. Once that happens, the extended cloud of gas and dust, stabilized in size, forms a rapidly rotating disk well-outside the inner parts of the proto-Sun where nuclear fusion may be starting to take place. The core collapses gravitationally from the inside out, with internal heat stabilizing the configuration. The disk will tend to continually spin up the central star. But the fission model notes that the central proto-star cannot continue to accrete matter from the rapidly rotating disk without occasionally flinging a significant fraction of it back out. In PSNH, the mechanism for outward mass transfer is still debated, with some astronomers favoring polar outflow models and others favoring outflows that originate in the nebular disk (Shu 1992).

However, it would be incorrect to think of the disk as comprised of numerous discrete globules that can collide and accrete, as the PSNH requires. Recall that two bodies in similar orbits around a central mass will go into a state of libration and avoid collisions. (Van Flandern 1999: chapter 6) The Trojan asteroids in Jupiter's orbit, for example, always avoid collision with Jupiter by librating. All planetary rings are additional examples. Ring particles are not normally colliding with one another unless the ring is disturbed. Around a relatively massive primary, the more similar any two orbits are, the more nearly impossible collision between the bodies in those orbits becomes. So the accretion feature of PSNH has very little dynamical basis because the collisions that are allowed (orbits dissimilar by more than the size of the gravitational sphere of influence of the larger orbiter) are normally destructive rather than accretive. This problem alone makes PSNH a dubious proposition.

In fission theory, the initial spin of the proto-planets would be that of the surface of the proto-Sun, and therefore always prograde. Subsequent tidal evolution will evolve each twin proto-planet outward (because the tidal bulge on the proto-Sun leads the proto-planet), with the more massive of the two evolving outward faster (because it raises the larger bulge). Although such tidal forces are negligible in the solar system today, they would have been substantial during the proto-Sun stage, also called its "T Tauri" phase. Soon after fissioning, the proto-planets would have been within a few solar radii, assuring very large tidal forces. (Note: At any given distance, each doubling of the solar radius, or halving of the solar distance, increases such tidal forces by roughly two orders of magnitude.) Moreover, the proto-planets would have much larger masses before shedding much of their hydrogen than they have today, so mutual tides between twin proto-planets would also be large and significant for subsequent orbital evolution.

Tidal evolution of the mean distance of the proto-planets caused by the Sun and by each other would typically proceed toward a stable configuration, wherein each planet has a circular, co-planar orbit with some simple relation to the orbital period of the next planet in. Once a stable configuration was achieved, further orbital evolution would cease. Examination of configurations stable to tidal evolution is a non-trivial subject, touched on briefly later. One simple example would be the outer planet having double the orbital period of the inner one (period ratio of 2-to-1). Another common period ratio would be 5-to-3 because of the interaction of spin periods with mutual tides and orbital periods with solar-induced tides. A few other stable configurations exist too.

Special case: The LHB planets

Our picture of the solar system is just what the fission hypothesis requires, with one glaring exception: Jupiter and Saturn do not conform to the expectation of a twin pair with an 86% mass ratio and Saturn having the larger mass of the two. In a previous exposition (Van Flandern 1997b), we conjectured hypothetical Planets A and B in two different configurations that might account for this, assuming that Jupiter's mass was greatly enhanced by absorbing much of the debris when those two planets exploded. Indeed, we may be confident of the former existence of additional, large, early members of the planetary system because of the "late heavy bombardment" (LHB) event. Here is a brief synopsis of that evidence.

From studies of lunar rocks it is now known that the Moon, and presumably the entire solar system with it, underwent a "late heavy bombardment" of unknown origin not long after the major planets formed. The following relevant descriptions of the event are from Weissman (1989):

- "[The LHB] occurs relatively late in the accretionary history of the terrestrial planets, at a time when the vast majority of that zone's planetesimals are already expected to have either impacted on the proto-planets, or been dynamically ejected from the inner planets region."

- “It appears that a flux of impactors flooded the terrestrial planets region at this point in the solar system’s history, and is preserved in the cratering record of the heavily cratered terrain on each planet.”
- “An essential requirement of any explanation for the late heavy bombardment is that the impactors be ‘stored’ somewhere in the solar system until they are suddenly unleashed about 4.0 Gyr ago.”
- “A plausible explanation for the late heavy bombardment remains something of a mystery.”
- “... it seems likely that the late heavy bombardment is not the tail-off of planetary accretion but rather is a late pulse superimposed on the tail-off. Nor is there any reason to suppose that it was the only such pulse; it may have been preceded by several others which are not easily discernible from it in the cratering record.”

So the LHB was a real solar system event. And it would be most readily explained as the explosion of one or more massive planets in early solar system history, presumably very massive, hydrogen-dominated planets like Jupiter and Saturn. That would mean we are missing a pair of planets in the middle of the solar system. But were they a twin pair? Helium-class twin planets have shown a tendency to explode (see later discussion), but they are too limited in mass. The other explosion mechanism apparently operating is triggered by tidal stress. (Van Flandern 2007a) Massive planets in twin pairs would be susceptible to extreme tidal stresses. But once the larger twin had induced the smaller to explode, there would be no mechanism to explode the survivor. Therefore, we conclude it is most likely that Jupiter and Saturn are the surviving halves of former twin pairs, and are therefore not themselves an original twin pair.

It follows that both Jupiter and its presumed twin companion (“Planet LHB-A”) would have been subject to enormous tidal stresses over a prolonged period because they were so massive, having retained a major fraction of their hydrogen; and because they would have made many close approaches before tidal forces could separate them. Eventually, the combined tidal forces of the Sun and Jupiter triggered an explosion in LHB-A. Although Saturn is three times less massive than Jupiter, it is still five times more massive than Neptune, the next largest surviving planet. So under this scenario, Saturn would have been the outer and more massive member of another twin pair with a companion (“Planet LHB-B”). Saturn, like Jupiter, then became a single planet by eliminating its twin. This would have been the earlier and less massive of the inferred two LHB explosion events.

It is true that this scenario may appear to be circular reasoning to the skeptical mind. Jupiter and Saturn do not fit the fission theory’s requirements; so instead of falsifying the theory, we propose that each must have disposed of a companion, thereby conveniently making the hypothesis correct. However, the LHB exists and was not invented to save this theory, and is consistent with the existence of one or two more early planets that exploded. Furthermore, the fission theory clearly does require strong tidal interactions between twin planets soon after fissioning, which implies there must exist some fissioned mass limit above which the tidal interactions would be fatally disruptive. Neither of these is an "add-on helper hypothesis", motivated just to save the theory. Both are requirements of the original hypothesis.

Moreover, this particular solution to the Jupiter-Saturn "exception" has the bonus feature that it explains why many "hot Jupiter" exoplanets found recently around other stars are single planets and not twins. Apparently, only the smaller gas giant planet pairs (such as Uranus & Neptune) can survive the tidal strain of numerous close approaches to another gas giant soon after fission.

Planet	Dist. (au)	Period (yr)	Mass (⊕)
Venus+Merc	0.7	0.6	0.9
Earth+Moon	1.0	1.0	1.0
Bellona (V)	1.6	2.0	2.4
K	2.5	4.0	2.8
LHB-A	3.7	7.1	273
Jupiter	5.2	11.9	318
LHB-B	6.8	17.7	82
Saturn	9.5	29.5	95
Uranus	19	84	15
Neptune	30	165	17
T	43	280	2.4
X	68	560	2.8

Table I. The original solar system as inferred from the planetary fission theory. Most planets have original periods in a 2-to-1 or 5-to-3 ratio with the next planet in.

With the Jupiter/Saturn case resolved in this way, and considering other arguments made some time ago about which planets are escaped moons and which asteroid belts represent exploded planets, we can now see the original solar system as composed of six twin-pair proto-planets, with the inner member of each pair being originally 86% of the mass of the outer in each pair. See Table I. If Byl and Ovenden (1975) are correct that Jupiter's mass has apparently increased by roughly 40% since its asteroidal moons were captured, then those asteroidal moons predated the main asteroid belt. This would also imply that the masses shown in the Table for LHB-A and Jupiter, and probably also LHB-B and Saturn, should all be factored by the factor 5/7 to get their original masses.

Application of fission theory to the formation of planets

After each planet pair is formed by fission, it will be some time before the proto-Sun and its extended atmosphere reach another overspin as they continue to contract. By that time the Sun will be hotter, more massive, and smaller from accretion and contraction. So the next pair of planets will fission under rather different conditions, forming another pair of planets similar to each other but dissimilar from all previous pairs.

Each gaseous twin proto-planet initially orbits close to the surface of the parent star. Tidal interactions initially drive the pair outward, with the more massive outer member of the pair driven faster because of its greater mass, which causes it to raise larger tides. The direction is outward because the parent star, while reduced in radius and no longer over-spinning for its reduced size, nonetheless spins faster than the orbital speed of either proto-planet; so the tidal bulges raised on the star by each proto-planet are tidally dragged ahead by the parent star's rotation, which then acts to accelerate the proto-planet that raised it. Differential rotation inside the star has the same effect because rotation gets faster with depth. So even though the star is gaseous, which tends to diminish longitudinal tides, radial tides in the star are still quite active on the proto-planets. (Van Flandern 1999: chapter 12) And the magnitude of these tidal forces is quite large because they are a strong function of the ratio of star-radius to planet-distance, a ratio initially near unity. As time goes on, the strength of tidal forces drops off rapidly because it depends roughly on the seventh power of the radius-to-distance ratio, which is shrinking both because the proto-planet is evolving outward and because the star is continuing to contract.

Once the proto-planets are away from the star's surface and separated from one another, the star's tidal forces would eventually drive the inner planet outward faster than the outer one because the forces are a stronger function of distance than of mass, and the inner planet is closer to the star. However, the initial orbits of the two proto-planets produce close approaches to each other whenever the inner planet passes the outer one. Mutual tides raised during these encounters raise tidal bulges dragged in the direction of rotation on each planet. Because that rotation is prograde (imparted by the star's own rotation), the bulge on the inner planet raised by the outer one operates to accelerate the outer planet and move its orbit outward. At the same time, the tidal bulge on the outer planet raised by the inner one decelerates the inner planer, opposing the Sun's tendency to accelerate it and slowing its outward movement, perhaps even moving it slowly inward. See Figure 1. So these mutual tidal forces operate to ensure that the orbits of the two planets continue to separate.

Commonly, direct gravitational perturbations of proto-planets on each other can increase orbital eccentricities and instability. However, certain orbital period ratios cause perturbations to average zero, enhancing stability. The unstable period ratios that increase eccentricity can result in close approaches again, and a return to large mutual tidal forces that drive the orbits apart. By contrast, stable orbital period ratios keep perturbations to a minimum, and therefore are long-lasting dynamical configurations.

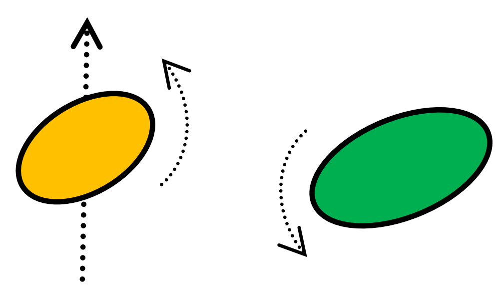

Figure 1. Tidal bulges raised by two passing, rotating planets. The Sun is to the left.

For example, the simplest stable configuration occurs when one orbital period is exactly double the other, a "resonance" with a 2-to-1 period ratio. This occurs when the distance ratio is ~0.63 or ~1.59. Another stable configuration (apparently shared by Venus and Earth before Venus shed its moon Mercury, an event that slightly disrupted the configuration) is a 5-to-3 period ratio. This is because Venus would make exactly 2.5 revolutions in the time Earth took to make 1.5 revolutions, so close approaches would occur on alternate sides of the orbits but always at the same spots along both orbits, causing the mutual perturbations to average to zero. As mutual tidal forces drive planet orbits away from one another, the strength of the tides would diminish. However, the frequency of conjunctions (one planet passing by the other at any distance) would increase because of a greater difference in orbital periods. So tidal evolution would continue until a combination of sufficiently weakened tidal forces and a stable (resonant) dynamical configuration occurred.

These processes can account for the origin of a dozen major planets. Later, we will examine how it can account for major moons as well. Fission theory does not need to explain asteroids and comets, which arise mostly from exploded moons or exploded terrestrial planets. (Van Flandern 2007b) Ordinarily, the explosion of a gaseous planet would leave no solid debris. But it would tend to impact, add mass to, and destabilize any moons in its vicinity, possibly causing them to explode at a later date.

Looking beyond Neptune, we note what may be another asteroid belt, possibly the remnants of an exploded planet in the outer solar system, in the form of tens of thousands of large fragments in Pluto-like orbits. This is often referred to as the "Kuiper Belt", although it apparently has little or nothing to do with the comets that either Kuiper or more recent astronomers predicted (Van Flandern 1995). We designate the hypothetical original pre-explosion planet as "Planet T", since we prefer to follow the convention of calling the asteroids in that region TNOs (for Trans-Neptunian Objects).

Recently, three additional asteroids have been discovered even farther out, with orbits that cannot reach that of Planet T. This is suggestive of yet another asteroid belt, much the way the main asteroid belt between Mars and Jupiter has an outer ("C-type") portion and an inner ("S-type") portion, corresponding to the explosion of twin parent planets K and V, respectively. Future observations will determine if this is indeed a second outer asteroid belt. Certainly, fission theory would lead us to expect that Planet T had a twin companion. We designate it "Planet X" because it would have been the tenth major planet but for all this revised solar system history. ("X" is the Roman numeral for "ten", and "V" is the Roman numeral for "five".) At one time, hypothetical Planet X was considered the most likely source of unmodeled perturbations on the gas giant planets and certain comets. (Van Flandern 1999: chapter 18). But the failure of searches for it combined with this latest finding of more asteroids at that rough distance and suggestions that the original masses were in the "helium-class" range all indicate that Planet X, like helium-class planets V, K, and T, is now exploded.

In our first publication of the modern fission theory (Van Flandern 1997b), we noted the existence of the TNOs and commented: "Certainly, [this] prediction of a *second* planetesimal belt beyond Neptune, if fulfilled, would be a strong point in favor of the fission theory for the origin of planets." Now that a second TNO asteroid belt appears to exist, the prediction takes on added significance.

So that fills out the original solar system to distances much beyond which passing stars would make planet orbits relatively unstable over billions of years. It is sobering to realize that, if our deductions are valid, fully half of the solar system's original planets may have perished in explosions over the past 4.5 billion years. Planets are apparently even more ephemeral than stars, and some of the events we call "novas" may turn out to be explosions of planets orbiting the visible star.

Generalizing this scenario's methodology, the largest TNOs are probably escaped former moons of Planets T and X. And something similar can be said about former "Planet K" in the outer main asteroid belt. The largest asteroid (now a "dwarf planet") Ceres would also have been a former moon, and its twin moon probably met the same kind of fate (explosion) as Body C. So when close-up spacecraft views of Ceres become available, we expect they will show a hemispheric dichotomy and other explosion-related similarities to Mars. The lack of atmosphere would probably mean hard, melting or vaporizing impacts leaving lava-like deposits all over one hemisphere, but with no obvious source volcanoes for that hemisphere.

Terrestrial and helium-class planets

For twin planets Earth and Venus, fission theory indicates that tidal evolution to a 5-to-3 orbital period resonance occurred between the two. Further simple tidal evolution between Venus and its fissioned moon Mercury indicates that the escape of Mercury from Venus occurred about 500 million years later. The present-day circular orbital speed of Venus is 35.02 km/s, but would have originally needed to be 35.32 km/s to be in the 5-to-3 resonant orbit with Earth (orbital period 7.2 months). However, when Mercury was still a moon of Venus, its tidal escape would have been through the L1 Lagrange point on the line from Venus to the Sun. As that happens, Mercury's relative satellite orbital momentum at escape from Venus is opposite its solar orbital motion. (This is for the same reason that our Moon's relative velocity is opposite to Earth solar orbital velocity at New Moon phase.) This means Mercury's escape would have caused a small forward impulse to Venus, giving Venus more angular momentum but ultimately less orbital speed. Then the strong mutual tides between Venus and Mercury during the early post-escape period would separate the orbits further, giving Venus even a bit more angular momentum and a bit less orbital speed. The inferred drop in Venus's orbital speed from 35.32 (theoretical) to 35.02 km/s (observed) is an entirely reasonable amount for these two processes, supporting the starting conjecture that Venus and Earth were indeed in a resonant 5-to-3 orbital period-lock in the early solar system.

Analogously, as terrestrial proto-planets were shedding their abundant original (hydrogen and helium) light gases, the bulk of that mass would likewise preferentially escape through the L1 point. So the escaping mass leaves terrestrial planets with a net gain in orbital momentum, and tends to amplify separation of twin planet orbits. This is another mechanism driving them farther from the Sun and apart from one another. The same early-mass-loss process for proto-Venus would have accelerated the tidal escape of Mercury and the rate of recession of our Moon from Earth. The latter would have allowed proto-Earth, which would become fairly molten again following the Moon's fission because of the close Moon's strong tidal pumping, to cool and solidify again sooner than simple dynamical models predicted. Our Moon failed to escape Earth orbit because it is much less massive than Venus's former moon Mercury, so the tidal forces our Moon raised were always smaller than the ones Mercury raised on Venus – one reason why Venus was so much more volcanically active than Earth long ago.

We note that no corresponding action pushes a new twin pair into resonance with any pre-existing planet unless the new pair is fissioned while the old pair is still evolving. So resonances may never occur between one twin planet pair and the next. However, major moons of gas giant planets apparently do have 2-to-1 resonances between twin pairs, suggesting they fission on a much shorter time scale and/or take longer to evolve. This is consistent with tidal forces between proto-planets and their moons being stronger than tidal forces between proto-Sun and its planets because the strength of tidal forces depends more strongly on mutual distance than on mass.

In overview, fission theory indicates twelve original major planets, of which six survive. For each twin pair, the more massive proto-planet (the outermost) would produce intense tidal stresses on the smaller (innermost) at times of closest approach shortly after fission from the enlarged proto-Sun. This means these giant twin planets would never get the chance to evolve into resonance before the smaller was induced to explode by the larger one. This also explains why many Jupiter-sized exoplanets (around other stars) apparently have no twin companion.

How solar system moons fit into the fission hypothesis

The fission hypothesis is a very general mechanism, and explains the formation of all major moons as well as all major planets. The formation process for major moons is quite similar to that for planets, with one major exception: The proto-Sun is accreting mass and gaining spin angular momentum as it does so; whereas proto-planets are losing mass (they can't hold all their light gases) and shedding spin angular momentum. This difference results in the larger of any fissioned twin pair of moons being the inner one, and causes the operating tidal forces to move moons inward instead of outward. Both of those circumstances are opposite to the behavior of fissioned planets.

Another difference is that proto-stars are all liquid or gaseous, whereas some proto-planets are solid. When a rotating parent body that is solid or has substantial material strength, such as proto-Earth or proto-Venus, spins fast enough to fission, normally just the weaker of the two globules at either end of the prolate major axis will fission, and the rest of the body will snap back to a smaller, rounder shape with a slower spin. The spinning parent body gives away a substantial part of its angular momentum to the fissioned globule. So only a single moon results, and enough angular momentum is lost that the planet is unlikely to achieve overspin a second time. Therefore we note that gaseous and liquid bodies would produce twin pairs by fissioning, whereas solid bodies would normally produce single moons.

Traditionally, it has been objected that tidal friction between a fissioned companion body and its gaseous parent ought to be negligible because the gaseous parent can reshape itself quickly so that any tidal bulge has no lag or lead, and therefore transfers no angular momentum to the companion body. If this were the whole story for tides, frictional forces would be negligible even right after fission, so they could not produce orbit evolution. However, as explained in Van Flandern (1999: chapter 6), it is not the usual longitudinal tidal forces described in most textbooks that are effective for gaseous parent bodies. Those would indeed be negligible for tidal evolution purposes. Rather, it is latitudinal and radial tidal forces that matter. For example, a proto-planet causes the proto-Sun to bulge outward, and a proto-moon does the same to its parent proto-planet.

But the gaseous parent is rotating differentially with depth. For the proto-Sun, rotation is slower toward its center and faster toward its surface. So as the proto-Sun bulges outward, part of its slower mass is raised into layers with faster rotation, thereby causing a leading tidal bulge. Likewise, gravitational tugs toward the equator of the proto-Sun from a proto-planet also typically force mass into a latitude band with faster rotation resulting in a leading bulge. Either process would transfer the excess angular momentum acquired by the bulge to the proto-planet that raised it, resulting in outward orbital evolution for the proto-planet. The situation is just the reverse for the fissioning of proto-moons from a proto-planet because rotation for a body shedding mass will be faster toward the center and slower toward the surface. Hence, a tidal bulge is forced to slow as it is pulled to higher levels or lower latitudes. This results in inward orbital evolution for the proto-moon that raised the bulge.

Now consider a gaseous proto-planet as the parent body. It will cool and contract rapidly once away from the proto-Sun, both because it has no internal heat source and because it is losing mass. Proto-Sun contraction is much slower because it is accreting mass and heating up. But the proto-planet would be continuously shedding its light gases as it contracts, and this mass-shedding carries away spin angular momentum. The gaseous proto-planet, like the proto-Sun, will acquire differential rotation; but for a proto-planet shedding mass, the fastest rotation would occur toward its core (where it is hottest) and the slowest rotation toward its cooler surface. Just like a proto-star, as the proto-planet contracts, it must spin up to conserve angular momentum. So the proto-planet can likewise reach an overspin condition. If the proto-planet is gaseous, a pair of moons will be spawned by the fission process. But unlike the solar case, the slower differential rotation of the parent at its surface will cause a tidal bulge lag, which will cause the fissioned moons to lose angular momentum and spiral slowly inward. The more massive moon will raise the larger tides and evolve inward the fastest.

Obviously, the proto-planet must continue to contract faster than its moons evolve inward, or the result would be a cataclysmic merging that would destabilize the rotation of the proto-planet and tip it over about 90 degrees to minimize its new moments of inertia. Perhaps that is exactly what happened to Uranus, whose spin axis is tipped over by 98 degrees and whose remaining natural moons are relatively small for the planet's size. Having derived this mechanism deductively from the fission hypothesis, rather than conjecturing it inductively to explain observations, we might even be justified to consider it as a mechanism to explain other phenomena too. For example, in the very last stages of proto-Sun evolution, if the proto-Sun accreted the last of the solar nebula and briefly expanded rather than contracting, it might have merged with the "last" fissioned proto-planet pair – a hypothetical pair that fissioned not far from the present Sun's surface but never had the chance to evolve outward. The mass difference of these proto-planets to the proto-Sun would be too great to cause a tilt as large as 90 degrees. However, their merger would tilt the proto-Sun somewhat. Today, the Sun has a heretofore unexplained tilt of 7 degrees to the mean plane of the rest of the planets, perhaps caused by re-merging with this hypothetical last fissioned planet pair. A mass merging with a spinning body that is not elongated in a Maclaurin spheroid shape will produce some degree of rotational instability as the spin axis seeks to maximize the new moments of inertia.

The remainder of the process is very similar to the proposed formation of the Moon by fission from an over-spinning Earth (Van Flandern 1999: chapter 14). See Binder (1984) for a diagram and description of this process as it applies to the fission of the Moon.

Application of fission theory to the formation of moons

Tidal theory predicts that the large, regular moons of the gas giant planets will occur in twin pairs, with the more massive always being the inner of the two. How does that prediction compare to reality? The results are in Table II. Masses are in units of 10^{-5} of the primary's mass, distances are in multiples of the primary's radius, and periods are in days. We have included Pluto and Charon as if they are escaped former moons of Neptune, as suggested by Harrington and Van Flandern (1979). The more recently discovered dwarf planet Eris and two of the largest TNOs also now make an appearance. These are all probably former moons. We have compared them to Neptune for lack of better knowledge about which planet was their actual parent.

The table points up some interesting patterns among these major planetary satellites. With Saturn's large moon Triton excepted, these do indeed tend to occur in pairs, and the inner member of each pair is always the more massive, just as the fission theory predicts. This alternating sequence of satellite masses had not, to this author's knowledge, been recognized, much less considered significant, before the fission theory pointed it out.

Jupiter and Uranus have the most regular and apparently undisturbed large satellite systems: circular and co-planar orbits, orbit-synchronized spins, with orbital periods roughly double that of the next moon in. (The small moons are presumed to be captured asteroids.) Correspondingly, the patterns of these moons contain no exceptions to the requirements of the fission theory. The closest any of these moon pairs come to an exception would the larger-than-average mass ratios for the two Jovian pairs, which is larger than the expected 86% mass ratio rule given by fission theory. However, quoting from Van Flandern (2007a):

Primary	Moon	Mas	Dis	Perio
Jupiter	Io	4.7	5.9	1.8
Jupiter	Europa	2.5	9.4	3.6
Jupiter	Ganymed	7.8	15.0	7.2
Jupiter	Callisto	5.7	26.3	16.7
Saturn	Titan	23.8	20.3	15.9
Uranus	Ariel	1.6	7.5	2.5
Uranus	Umbriel	1.4	10.4	4.1
Uranus	Titania	4.1	17.1	8.7
Uranus	Oberon	3.5	22.8	13.5
Neptune	Triton	20.9	14.3	5.9
Neptune	Eris	18.5	?	?
Neptune	Pluto	14.6	?	6.4?
Neptune	2006	4.7	?	?
Neptune	Makemak	4.3	?	?
Neptune	Charon	3.2	?	?

Table II. Moons of gas giant planets with mass at least 1.0×10^{-5} of the parent planet mass. Distances are in multiples of parent radius, orbital periods in days.

It is almost certainly not a coincidence that the four major moons of Jupiter are likewise a modest exception to the mass ratio that applies elsewhere. Indeed, Jupiter is almost certainly accreting mass even today faster than any other planet. So if its original mass was modified substantially by the Planet LHB-A & LHB-B explosions, it follows that its major moons would likewise accrete extra mass. If so, then the innermost of each moon pair would accrete more because it has faster orbital speed, is more massive to start with, and lies closer to Jupiter. And this is the direction in which the observed discrepancies lie for both Jovian pairs, with the discrepancy being larger for the inner pair as the same idea would predict.

Neptune, of course, has a highly disrupted satellite system. But the close physical and chemical resemblance between Pluto and Triton has been noted by many astronomers, making a common origin as moons of Neptune not at all unlikely. Our task is merely to find the right “twin” for each. Preliminary mass estimates for Eris (still uncertain by at least several percent) suggest that Triton is closer to the nominal 86% ratio with Eris than Pluto is. If so, then Pluto’s mate has yet to be discovered, or met the same kind of explosion fate as Bellona, the hypothetical twin of Mars. TNOs 2006 EL_{61} and 2005 FY_9 (“Makemake”) are probably another twin pair of former moons ejected from Planet T when it exploded. If Planet T was helium class, as we have conjectured, then it probably was of order 20% of the mass of Neptune. So the relative mass figures for moons of Planet T should then be multiplied up by a factor of about five.

Neptune’s moon Nereid, Uranus’s moon Miranda, and all of Saturn’s moons except Titan have far less than the “one part in 100,000” lower mass limit we adopt here for any major moon relative to its own parent planet. They are here considered to be either asteroids or explosion by-products of larger icy moons. Pluto’s present-day moon Charon may have been another former moon of Planet T, joining Pluto in an exchange of moons when Planet T had a close encounter with Neptune. Its partner was most likely ejected into independent solar orbit. This would parallel the history of Pluto. If so, it awaits discovery as probably the largest of the still-undiscovered TNOs.

Among the gas giant planets, Saturn is the main surprise. Its many moons have rather unevenly spaced orbits with several huge gaps, interspersed with rings of material. It seemed evident that the Saturnian moons are not in their original orbits even well before this analysis. Now we see yet another criterion that underscores that disturbed condition: Of Saturn’s eight original, presumably non-asteroidal moons, only Titan is as large as 10^{-5} of Saturn’s mass. Titan weighs in at 23.8×10^{-5} of Saturn, making it the second most massive moon in the solar system, behind only Ganymede. The next largest Saturnian moon, Rhea, is roughly 50 times smaller in mass. Most of the others range from a few times 10^{-6} to a few times 10^{-8} of Saturn’s mass.

These features imply some sort of disruption event. The obvious possibility is the explosion of former Planet LHB-B when its orbit was inside, but still relatively close to, Saturn’s orbit, back near the solar system’s beginnings. The explosion would have been triggered when the two planets were close. Large chunks of mass from the exploded gas giant planet could have impacted hard enough to alter the orbits of then-existing moons, and accreted enough added mass on other moons to induce them to become unstable and later explode. The most notable example would have been the twin companion to Titan. Some of the debris from these secondary explosions would have impacted Saturn or escaped the planet. But other debris would have survived in the form of small, icy moons; and tidal forces (still quite strong at those early dates) would have tended to circularize or regularize their orbits again.

One of the most interesting developments would have been bringing a major moon close enough to Saturn to allow tidal forces, operating over billions of years, to gradually bring it inside the Roche "break-up" limit. The consequence would be the formation of Saturn's spectacular icy rings – a unique feature of our solar system. (Other planetary rings are much smaller, fainter, and composed of finer and darker asteroid-like material.) Present estimates are that these icy rings of Saturn are less than 100 million years old because older rings would have been disrupted by micrometeoroid impacts. But when newer data is analyzed, it may turn out that only the smallest debris was eliminated. The rings probably now consist of small bodies with a sharp cut-off on the small-mass side because of the micrometeoroids, and a sharp cut-off on the large-mass side imposed by the Roche limit tidal forces for a bodies with the strength of ice. If so, then rings considerably older than 2% of the age of the solar system are still a possibility for Saturn.

Conclusions

If we make allowance for special cases that have most probably been altered from their original condition since the solar system's beginning, as judged by lines of evidence existing before this analysis began, we may conclude that the undisturbed solar system members provide a spectacularly good match to the predictions of the tidal fission theory. That includes major planets and large, regular moons. And we have used the model to make several predictions along the way.

But a scientific theory must be falsifiable as well as make successful predictions. So we conclude with the obvious prediction that all these same conclusions about the formation of planets and moons must apply equally well to exoplanets orbiting other stars, and to their moons. The most easily discovered exoplanets will be the Jupiter-sized ones, and those will tend to be singles because of inducing explosion in their companions. And indeed, we already know that lots of hot Jupiter exoplanets exist -- a big surprise to the mainstream PSNH theory. But if exoplanets do occur commonly as twins, that fact would not be immediately evident in the earliest observations because exoplanets cannot normally be seen, but only inferred to exist from other data.

With data of that indirect type, it would be very difficult to recognize that a signal is caused by two bodies, and the first inference one draws will usually be the existence of one body on an eccentric orbit. If two bodies have already established a period resonance with one another, it will be even more difficult to recognize that two separate planets are involved because it will act even more like one planet on an eccentric orbit. The wobble of the parent star will generally make it appear that there is a single orbit of high eccentricity, when in reality the data reflects the beating of two near-resonance periods. However, unless the resonance is exact, a longer span of data will reveal the dual nature of the orbiting planets. We predict that many of the discoveries of extra-solar planets recently announced will follow that course as the span of observations lengthens in the coming years, and as more Neptune-to-Earth-sized exoplanets are discovered.

Even more to the point, the standard model and fission theory make opposite predictions about the direction of tidal evolution. The surprising (to the standard model) number of "hot Jupiters" close to their parent star must be driven inward by tidal forces in the standard model, but driven outward by tidal forces in the fission model. This direction of orbital evolution is slow in a human lifetime, so this measurement is difficult. But perhaps a case will be found where the spin of the star and the orbit of the planet can be shown to be in the same direction, with the star spinning faster than the planet's orbital period. That would be indirect proof that the direction of tidal evolution was outward.

Appendix A – Why a supernova flattens a nebula

Most interstellar nebulas are made primarily of hydrogen atoms. The blast wave consists mainly of ions -- protons and electrons -- traveling at high speed. So the numerous impulses to each nebula atom from the blast wave ions are statistically fairly similar.

Suppose we have two atoms, A and B, at rest with respect to each other and at different distances from the supernova. Let the blast wave encounter A first, and accelerate A to nearly the blast wave speed. Sometime later the blast wave encounters B and accelerates B to the same high speed. So A & B end up with no relative speed, but nearly at the same distance from the supernova. Their radial separation will have been "flattened". In fact, some flattening must occur even if the acceleration were limited to much less than the blast wave speed because A is accelerated sooner than B.

A second factor is "speed flattening". Suppose atoms A and B have no radial motion relative to the supernova, but atom B has a small speed σ relative to atom A in the direction perpendicular to the supernova. If a blast wave from the supernova applies a radial speed of S to both atoms, then the speed of A will be increased from zero to S. However, the final speed of B will become $\sqrt{S^2+\sigma^2}$ because these two speeds are at right angles. If S is large compared to σ, then (by expanding the square root) atom B's final speed is approximately $S+\sigma^2/2S$. So the speed difference between A and B is just $\sigma^2/2S$, which is equal to $\sigma(\sigma/2S)$. This is obviously much less than the initial speed difference σ if $S \gg \sigma$. So the cloud atoms end up with smaller relative speeds than they started with. And this means they will have a greater tendency to collapse under the influence of gravity.

Appendix B – The meaning of "heat" for small particles

When something small hits something big and gets absorbed instead of rebounding, usually some of the impactor's kinetic energy gets absorbed and redistributed into the molecular vibration speeds in the larger body. We call this adding heat and causing an increase in the temperature of the larger body, even though we cannot directly measure the change in molecular vibration speeds. The added heat resulting from an asteroid hitting the Earth would be obvious. If instead, a globular cluster hits a galaxy, that would cause an increased average speed of both the galaxy's and the cluster's interacting stars near the site of impact.

On a quantum scale, the same principles apply even though we have no way to observe heat activity at that level. When molecules impact one another, they vibrate faster. When ions impact one another, the extra "speed" must be deposited in the constituents making up the ion, or else in the elysium* atmosphere surrounding it. "Heat" must always manifest itself as increased speed, but we cannot yet hope to directly observe constituents of ions with existing instrumentation. We can just say with confidence that the colliding "dust" particles of whatever type in a nebula will get hotter.

Appendix C – Solid vs. liquid vs. gaseous phases

In the universe, conservation of momentum is fundamental and absolute because substance and motion can be neither created from nothing nor vanish into nothing. The conservation of energy is also usually true. But energy is harder to track because we can't observe where it goes if large bodies break off pieces too small and/or too fast to observe. And conversely, when small, fast entities are absorbed by a larger one, their absorbed motion often takes the form of heat or vibration and becomes unobservable.

Far out in the collapsing interstellar cloud, we call its low-density contents a gas. The denser, closer regions tend to be hotter because of more frequent collisions. This heat is manifested in either translational speeds or vibration speeds of molecules, or perhaps similar motions on the quantum level. The same kind of heat gradient occurs in planetary atmospheres, which retain heat better at lower altitudes.

In a region where the particle density becomes so great that the individual particles (of whatever size) have little freedom to move independently, but can only vibrate and continuously bang into nearby neighbors, the gas can become a liquid. The transition occurs when there is no more room for translational motion so molecules have limited ability to migrate, and heat is entirely by vibration. If the density increases further without corresponding heat increase, or if heat is lost, the

* "Elysium" is the hypothetical material medium surrounding an ion giving rise to its charge: excess elysium for a positive charge and an elysium deficit for a negative charge.

molecules may become locked in place, unable to move except in a shared motion with their locked neighbors, in which case we have a solid.

Appendix D – The origin of spin

Inhomogeneities (density variations) in the original nebula and in the supernova blast wave that invades it will create matter concentrations in the flattened nebula. The same inhomogeneities produce small, random torques, leaving each matter concentration with some small net spin. Then the matter concentration gravitationally attracts atoms from the surrounding nebula, and begins to grow in size. Let's track what happens to a single atom falling at random into such a matter concentration destined to become a proto-star.

The falling atom starts out in the newly flattened nebula as an independent agent with its own small random motion. If it did not collide with anything along the way, it would simply pick up speed as it fell, and its trajectory would be an elliptical orbit around (or through) the matter concentration. The farther it falls toward the center of the mass concentration, the more speed it will pick up, slowing again only after it passes the pericenter of its elliptical orbit.

Now suppose the atom A strikes another identical atom B already in the matter concentration and participating in its small net spin. The most probable place for the strike to occur is near the pericenter of A's orbit, where the mass concentration is densest and the existing net spin is fastest. If A catches up to B and strikes it from behind, the relative speed of the two atoms is minimal, and A's linear momentum simply adds angular momentum (spin) to the matter concentration by joining it and by accelerating the forward motion of B. However, if A strikes B head-on, the relative speed is maximal, and a larger fraction of A's linear momentum is converted to heat (vibration). The two atoms lose orbital speed, but that causes them to drop to a lower orbit, picking up speed again as they drop. Subsequent encounters assure that each atom will take on the speed and direction appropriate for its distance from the center of the matter concentration, which is then the only way it can avoid continuing collisional encounters.

The net result of a new atom joining a matter concentration can range from adding all its linear momentum to the angular momentum of the concentration at one extreme, or to subtracting part of its linear momentum from the angular momentum of the concentration at the other extreme. So on average, accretion of new atoms adds angular momentum (spin) to a matter concentration and heats it up at the same time. Accreting bodies will continue to spin up until the source for accretion is exhausted, or until the accreting body reaches overspin and fissions.

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"Many things do not happen as they ought. Most things do not happen at all. It is for the conscientious historian to correct these defects." – Herodotus

Are Gravitational and Inertial Masses Equal?

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Abstract. Conventional thinking about the difference, or lack thereof, between gravitational and inertial masses is wrong. The two may differ by an indefinitely large amount. Eötvös-type experiments claiming to show equality to very great precision are actually null experiments, showing nothing.

Introduction

A distinction is not usually made between a body's gravitational mass and its inertial mass because experiments have shown them to be equal to very high precision. Some forms of the so-called "Eötvös experiment" suggest this equality holds to better than 13 significant figures. However, in principle, these two concepts need not be identical because they behave differently and are measured differently.

In this article we will re-examine the basic concepts involved, and question the conclusion that gravitational and inertial mass have been shown to be equal. We will further question that they need be even approximately equal in certain cases of astrophysical and dynamical interest. We propose that an anomaly now seen in the motion of certain artificial satellites may be caused by this inequality.

Definitions

A test particle is a body small enough that its own mass may be neglected and assumed to be zero. The inertial mass of a body is a measure of its resistance to acceleration, and is generally determined by applying a known laboratory force to the body to see how fast it accelerates in response to that force. The gravitational mass of a body is a measure of the strength of the gravitational field it generates, and how strongly that body attracts other bodies toward itself. The surest way to determine gravitational mass is by observing the accelerations of test particles moving in the body's gravitational influence. For example, observations of artificial satellites of the Earth are used to determine Earth's gravitational mass. For small planets, the gravitational mass of the star they orbit is given simply by a^3/P^2, where a is the planet's mean distance in astronomical units (Sun-to-Earth = 1 au), and P is its orbital period in years.

Relativity viewpoint

In the theory of general relativity, the "principle of equivalence" suggests that the local effects of uniform acceleration and of a gravitational field are identical, and that an enclosed observer could not distinguish between them. For example, an observer unable to look out a window could not tell if he was a rest on the Earth or accelerating at 1 g through isolated space, because both would feel the same.

In general relativity, this equivalence is used to suggest that gravitational force is merely test particles following the curvature of "spacetime" induced by a source mass. It is said that "mass tells space how to curve, and space tells bodies how to move." As a consequence, if that is indeed true, then gravitational and inertial masses should have an exact equality because they are intimately related.

Goal

However, we will argue here that the apparent exactitude of this equality arose from inadvertently blurring an important distinction, and need not in fact be the case. We will conclude that the equality of gravitational and inertial masses has really been established only to about five significant figures for laboratory masses; and that it need not hold even to one significant figure in certain astrophysical cases such as neutron stars.

Background

Galileo's Tower of Pisa experiment showed that, neglecting non-gravitational forces such as air drag, all bodies fall at the same rate regardless of mass; i.e., heavy bodies do not fall faster than light bodies. The key point of the experiment is that it doesn't matter what the gravitational mass or the inertial mass of the small body is -- all masses small enough that they do not affect the Earth appreciably fall with the same acceleration. So the gravitational acceleration A_a of body A having mass m_a, and the gravitational acceleration A_b of body B having mass m_b, both at the same height in the Earth's gravitational field, are given by $A_a = A_b = GM/R^2$, where G = gravitational constant, M = mass of Earth, and R = distance of each body from the Earth's center. The surprise in Galileo's experiment was that neither the gravitational mass nor the inertial mass of the falling body appears in the formula for its own acceleration.

Mutual acceleration

Technically, of course, there is a very slight difference in relative acceleration because the Earth is forced to fall toward each small body also, and would fall slightly faster toward the larger small body. However, the magnitude of Earth's acceleration would typically be many orders of magnitude smaller than the acceleration of the small body toward the Earth, and may therefore be safely neglected for all practical purposes. More to the point, if Earth and a falling body are isolated from all other forces and their motions are measured in an inertial coordinate system, then the absolute acceleration toward Earth of the falling body at a given distance would be exactly the same regardless of its own mass, because the acceleration of Earth toward the falling body would not be included in the measurement. This would be true even if the falling body's mass were greater than Earth's.

Newton's law of gravity

As long as we stick to gravity and accelerations, experiments tell us that all bodies fall at the same rate regardless of their own mass (gravitational or inertial), density, chemical composition, temperature, or any other physical property. Newton's Universal Law of Gravitation as used in practice should therefore say that every body accelerates every other body by an amount directly proportional to its own mass and inversely proportional to the square of the distance between them. The mass of the body being acted upon is irrelevant. Using the word "force" in the universal law as usually stated when the observable phenomenon is normally acceleration and not force has led to considerable confusion, as we will see.

It is also noteworthy that we need never compute forces as such, even when solving the most complex dynamical systems, as long as only gravity is involved. The Newtonian and Einstein equations used in celestial mechanics give the accelerations of bodies directly, not through the intermediary of forces. What we are saying here is that there was no value in introducing the inertial mass m of the accelerating body into the universal gravitational law of gravitation by using Newton's second law of motion $F = mA$, because doing so made the universal law about unobservable force F instead of about observable acceleration A.

Historical point

In Newton's original formulation, where the Sun was still taken as the center of the universe, he considered that the Sun had finite gravitational mass but infinite inertial mass so that it did not move. Only at the last moment, literally while his famous paper on motion was in proof, did he get the inspiration that the Sun must move too in response to the planets. So he hastily modified his Universal Law of Gravitation to its now-very-familiar form involving the product of the masses, and combined it with his second law of motion to give an expression for gravitational force instead of acceleration. This modification seemed conceptually easier at the time since it made gravity seem more like the other forces of nature. However, the subsequent consequences of that choice have been unfortunate.

Standard formulas

Summarizing this point using formulas, let subscript a refer to falling body A in the gravitational field of a source having gravitational mass M. (Later, we will use subscript b to refer to falling body B.) Newton started with $A_a = GM/R^2$ (his original universal law of gravitation). To emphasize the reciprocity of gravity (both bodies affect each other), Newton then invoked his second law of motion in the form $A_a = F_a/m_a$. Combining these two formulas, he rewrote the universal law in terms of the force on body A instead of its acceleration:

$$F_a = \frac{GMm_a}{R^2}$$

And this is the familiar form usually presented in textbooks, in which the product of two masses appears instead of just the single active mass M.

Essence of argument

It is clear from this historical context that, whereas M is a gravitational mass by definition, m_a must be identified with the inertial mass of body A, not its gravitational mass, because it comes from Newton's second law of motion $F = m\,A$, the law that *defines* inertial mass. This requirement cannot be avoided if the acceleration of a body is to be independent of its own mass. And this is the key point of this article -- If a distinction is made between gravitational and inertial masses, then Newton's Universal Law of Gravitation in standard form involves the product of a gravitational and an inertial mass, and not the product of two gravitational masses that is usually assumed.

We will return to the question of the symmetry of the universal law below under "Action and reaction".

The Eötvös experiment

This is an experiment designed to test for any difference between the gravitational and inertial masses of a body. The original form of the experiment, named after its inventor, involved two bodies, each made of different materials, determined by weight to have equal gravitational masses. The two are then suspended from a torsion balance. If the inertial masses of the two bodies were unequal, the balance would have experienced a torque from the rotating Earth (except near the equator) because the gravitational accelerations and centrifugal accelerations would have been unequal. The absence of such a torque establishes the equality of the gravitational and inertial masses to some precision that depends on the precise experimental design. At least, that is the theory behind the experiment.

It will be readily seen that, if our reasoning up to now has been valid, Eötvös tests like the one described are really comparing two different manifestations of inertial mass. The passive gravitational accelerations of the two bodies toward the Earth are going to be the same even if the two masses start out quite unequal. (Of course, the point of suspension for the torsion balance would change, but no torque would result from the Earth's spin.) Nothing in the experiment senses the active gravitational mass of either body -- how strongly either mass attracts other bodies. The customary interpretation of the experiment assumes that both masses in Newton's Universal Law of Gravitation are gravitational masses; whereas we have argued that only the Earth's mass is gravitational, while that of the small body is inertial.

Example

Suppose we have two small bodies in the Earth's field: body A has inertial mass mi_a and body B has inertial mass mi_b. To exaggerate the point, let us assume that the gravitational masses of A and B are, respectively, $mg_a = mi_a$ and $mg_b = 0.1\ mi_b$; i.e., body A is normal and body B has an inertial mass 10 times its own gravitational mass. Next, let F_a and F_b be the force exerted on bodies a and b, respectively, by the Earth; and let A_a and A_b be the respective resulting accelerations. GM = gravitational constant times the (gravitational) mass of the Earth, and R = distance of both test bodies from the Earth's center. We will equate forces in the usual way using "force equals (inertial) mass times acceleration" and Newton's Universal Law of Gravitation. Then in the customary interpretation that both masses in Newton's law of gravity are gravitational masses, we would write:

$$F_a = mi_a\, A_a = GM\, mg_a / R^2$$
$$F_b = mi_b\, A_b = GM\, mg_b / R^2$$

But as pointed out earlier, in all experiments involving gravity and celestial bodies, we measure accelerations, but not forces. So in practice in astronomy we use the above equations in the form:

$$A_a = GM\, (mg_a / mi_a) / R^2$$
$$A_b = GM\, (mg_b / mi_b) / R^2$$

Of course, if gravitational and inertial masses are equal for each body, then $A_a = A_b$, since the mass ratio in parentheses would be unity. This holds true even if the two small masses (mi_a and mi_b) are quite different from one another, as long as they are both negligible compared to the Earth.

But in the example we will study here, first using conventional assumptions, $mg_b = 0.1\ mi_b$, so $A_b = 0.1\ A_a$. One body falls faster than the other. This difference in acceleration is what the Eötvös-type experiments fail to detect, leading to the conclusion that gravitational and inertial masses are equal. In the tightest experiments, this equality is said to be established to better than 13 significant figures.

However, we have argued above that this reasoning is incorrect. To discuss the same point from another perspective, we must make a new distinction. Let the "active gravitational mass" of a body be a measure of the gravitational *acceleration* that body produces on another; and let the "passive gravitational mass" of a body be a measure of the gravitational *force* that body produces on another. So in the equations, if mi = inertial mass, mg = active gravitational mass, and mp = passive gravitational mass, then Newton's universal law tells us that $F = GM\ mp / R^2$. The force of one body on another depends on its own active gravitational mass and the other's passive gravitational mass.

With the above active/passive distinction in place, our acceleration formulas for bodies A and B now become:

$$A_a = GM\ (mp_a / mi_a) / R^2$$
$$A_b = GM\ (mp_b / mi_b) / R^2$$

Now comes the crucial step. The preceding formulas look similar to the ones originally derived. But what compels the identification of passive gravitational mass mp with active gravitational mass mg? In point of fact, since only accelerations and not forces are observed, the identification of passive gravitational mass with inertial mass is equally allowed. And we know the remarkable fact that heavy and light bodies accelerate at the same rate when the motivating force is gravity, which seems to require that $mp_a = mi_a$ and $mp_b = mi_b$ in the above formulas. If we adopt this to see its effect, we arrive at this final form:

$$A_a = GM / R^2$$
$$A_b = GM / R^2$$

which are the Newtonian equations as actually used in practical celestial mechanics, and as verified by observations. But now, bodies A and B must fall at equal rates even though *by starting assumption) the active gravitational mass and the inertial mass of body B differ by a factor of 10 (or any factor). Eötvös-type experiments are simply not sensitive to this inequality of active gravitational and inertial masses.

A better test

So if Eötvös experiments don’t do so, how could we succeed in testing for the inequality of active gravitational and inertial masses in a body? Such a test would necessarily involve a non-gravitational force because all orbital motions depend only on active gravitational masses, and are independent of inertial masses, when gravity is the only force acting. In the laboratory, we can independently measure both a small body's resistance to acceleration from application of a known mechanical force, and the acceleration that same small body induces in nearby test particles. By doing so, gravitational and inertial masses can be compared to about a part in 100,000. Obviously, viewed in this light, we have not yet established the equality of gravitational and inertial masses of bodies to very much precision at all. There's plenty of experimental room for the existence of a gravitational shielding effect, for example, wherein the intervention of one very dense body between two others partly shields the active gravitational effect the outside bodies would otherwise have on one another. Indeed, if density is a factor in gravitational shielding, laboratory studies may be highly misleading. Deviations between gravitational and inertial messes may become indefinitely large in super-dense bodies.

Action and reaction

In the general case where active and passive gravitational masses are unequal, the action and reaction forces will likewise be unequal. In we rewrite our preceding example to designate the larger mass as gravitational, we get:

$$F_b = G\, Mg\, mi_b / R^2$$

for the force of the Earth on body B. However, the reaction force of body B back on the Earth would be:

$$F_e = G\, Mi\, mg_b / R^2$$

Where subscript *e* designates Earth and *Mi* is the inertial mass of the Earth, here presumed equal to *Mg*. Since by hypothesis $mg_b = 0.1\ mi_b$, it follows that the two forces also differ by a factor of 10. How are we to interpret this?

First, it is evident that Newton's third law, that action and reaction forces must be equal, cannot hold true in cases where active gravitational and inertial masses are unequal. However, since the observable accelerations are not affected by this, it follows that the failure of the third law does not alter the motion of purely dynamical systems (where only gravity acts) in any way. In particular, the center of mass of such systems still remains fixed or in uniform, linear motion.

The same cannot be said for the "center of force", however. We define "center of force" in exactly the same way as "center of mass", except that we use inertial mass in place of gravitational mass for all bodies in the system. If body B is in an elliptical orbit around body A, and if the center of mass of the A-B system is fixed at the origin of coordinates, then the center of force describes a miniature ellipse with the same period and eccentricity as the large bodies around the center of mass, remaining always on the line connecting A and B.

In the astronomical literature, where *mp* is identified with *mg* instead of *mi*, there is discussion of a "self-force" in systems wherein gravitational and inertial mass are considered as possibly unequal. "Self force" results in an actual motion of the center of mass of a dynamical system, with its accompanying violation of conservation of energy for the whole system. This is obviously unphysical, and is a further argument that any real gravitational shielding effect in nature is surely not of this type.

One example of such a paper is: D.F. Bartlett & D. Van Buren, "Equivalence of active and passive gravitational mass using the Moon", Phys.Rev.Lett. 57:21-24 (1986). In it, the authors use the absence of an observed self-force to confirm the equality of gravitational and inertial masses in the Earth-Moon system, and by implication for the elements iron and aluminum, to a precision of better than 11 decimal places. In this paper we argue that all such conclusions are not well-founded and should be reconsidered. Certainly this circumstance is not the fault of the authors, who simply followed conventional interpretations.

Possible non-null observation

From our considerations here, it follows that we have not yet experimentally established the exact equality of gravitational and inertial masses even for small laboratory masses. The precision of measurement of active gravitational masses limits the precision of this equality to about five decimal places. Masses of astronomical size might have inequalities far larger than laboratory masses because of the possible role of internal gravitational shielding. Astronomical bodies of great density, such as neutron stars, could in principle have gravitational and inertial masses differing by indefinitely large amounts. Any self-shielding within such a dense body would reduce its effective gravitational mass by not allowing all “gravitons” to freely penetrate the body. Meanwhile, its inertial mass would be unaffected by its density.

Borrowing an analogy used by J.C. Maxwell, consider a swarm of bees as an analog for a small body, which in both cases is mostly empty space. The inertia of the swarm is proportional to the total number of bees because any change in the momentum of some bees must be propagated to all the others for the swarm to remain coherent. By contrast, the number of visible bees, which determines how much sunlight the swarm could block if the swarm flew in front of the Sun, may be much smaller than the total number of bees because, if the swarm is dense enough, many bees will be flying behind or in the shadow of other bees. Gravitons may have a problem acting on all matter elements in a super-dense body for the same reason. This is what is meant by “gravitational shielding”.

Certain long-standing astronomical mysteries, such as the observed deficit of solar neutrino output, might also be due to this cause -- more inertial mass (matter content) in the Sun than can be detected by measuring its external gravity field because of internal gravitational shielding. And it might be the case that certain artificial Earth satellites experience partial shielding of the Sun’s gravitational perturbations whenever they enter the Earth’s shadow. Anomalous motions are in fact seen in the Lageos and GPS satellites during eclipse seasons for these satellites. Possible explanations in terms of radiation pressure and charge drag have not proved entirely satisfactory.

Conclusion

For any kind of non-gravitational force applied to a body, the resulting acceleration depends on the mass of the body. In the case of a gravitational force, the resulting acceleration is independent of the affected body's own mass. If we review tests of the equality of gravitational and inertial mass of bodies, this fundamental difference between gravitational and non-gravitational forces in nature has not been respected in the interpretation of those tests. This has resulted in a degree of confidence in the equality of gravitational and inertial masses that has apparently been greatly over-estimated.

The principle of equivalence in general relativity still holds in this new interpretation because active gravitational masses completely determine the dynamical motions of celestial bodies. Inertial masses do not play a role except when non-gravitational forces become significant. However, this new interpretation raises considerable doubt that the equivalence principle has anything to do with space-time geometry – a conclusion already reached in neutron interferometer experiments. [D.M. Greenberger and A.W. Overhauser, Rev.Mod.Phys. 51:43 (1979)]

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"Give a man a fire and you keep him warm for a day. Set a man on fire and you keep him warm for the rest of his life." – Anonymous

Meta Science in the News

Gravity Probe B failure

A NASA space probe to test "frame-dragging", one of the more subtle effects predicted by general relativity, has been plagued by systematic errors. It has now been announced that it failed to achieve useful results, and further funding has been canceled. See story at http://space.newscientist.com/article/dn13938-gravity-probe-b-scores-f-in-nasa-review.html.

Phoenix Lander confirms Mars water, conditions right for life

Water has been discovered on Mars many times previously. The first such proposal may have been a "geyser" seen on Mars by astronomer Leonard Martin in 1980, and publicized by Vince DiPietro of SPSR. See http://www.lauralee.com/jpl.htm. Evidence of an ice lake spotted by Kent Steadman first appeared in MRB in 1999. ESA found definite evidence of water several ago from their *Mars Express* spacecraft. MRB editorialized about the lack of water confirmation by NASA in 2005. MRB also carried Gilbert Levin's 2007 article about evidence for ice in the tracks left by the *Opportunity* rover. See http://metaresearch.org/publications/bulletin/2007issues/0615/Mrb07b.asp.

Now, NASA's new Phoenix lander has confirmed that ice seen by the lander in early images taken near Mars' northern polar region is definitely water ice, not carbon dioxide ice. In short, the discovery of water has been made "official" by a NASA stamp of approval more than a quarter century after it was first made.

NASA plans an additional announcement shortly about conditions on Mars being very favorable to life. Unfortunately, the Phoenix spacecraft did not contain a life-detection experiment, so only this indirect (conditions favorable to life) result is possible. By contrast, the two *Viking* landers in 1976 contained three life-detection experiments each. However, the discovery of life now would undercut the justifications for several future missions, in which much has already been invested by Caltech's Jet Propulsion Laboratory (which builds and operates all robotic spacecraft for NASA). So we must all wait (perhaps another generation?!) for results about life on Mars when living microbial organisms have already been detected. More than that, strong pictorial evidence from orbit exists for plant life; and the landers have found some evidence for fossils as well. Official recognition for artifacts isn't even on the radar screen yet. Many of us may not live to see that important finding declared "official".

Google makes viable alternative to Wikipedia available

Google knols are authoritative articles about specific topics, written by people who know about those subjects, and now available to everyone. The web contains vast amounts of information, but not everything worth knowing is on the web. An enormous amount of information resides in people's heads: millions of people know useful things and billions more could benefit from that knowledge. Knol will encourage these people to contribute their knowledge online and make it accessible to everyone.

The key principle behind Knol is authorship. Every knol will have an author (or group of authors) who put their name behind their content. It's their knol, their voice, their opinion. Google expects that there will be multiple knols on the same subject, and that is a good idea. With Knol, Google is introducing a new method for authors to work together called "moderated collaboration." With this feature, any reader can make suggested edits to a knol which the author may then choose to accept, reject, or modify before these contributions become visible to the public. This allows authors to accept suggestions from everyone in the world while remaining in control of their content. After all, their name is associated with it!

Knols include strong community tools which allow for many modes of interaction between readers and authors. People can submit comments, rate, or write a review of a knol. Everyone knows something. See what people are writing about, then tell the world what you know: http://knol.google.com. [This gets around the principal failure of Wikipedia, that any group with a vested interest or any individual with an ax to grind can vandalize any article. It has become impossible to determine what is reliable and what is junk in Wikipedia. – Ed.]

Why Mars has two unlike hemispheres

Mars has two opposite hemispheres. The southern has a thick crust (3-20 km) and is saturated with craters. The northern has a smooth, flat, 1-km crust -- the flattest in the solar system -- and is mostly devoid of craters.

Conventional thinking has always been that "saturated with craters" is the normal condition for planetary surfaces, so conventional theories revolve around what happened to the northern hemisphere to make it so different. In late June, a set of papers appeared in Nature magazine supporting the notion that a giant impactor blasted away the northern hemisphere and all its craters. However, the exploded planet hypothesis (EPH) promoted by Meta Science says it's just the opposite: Martian sands and winds eroded away all the old craters all over the planet (as happened on Earth). Then the former planet that Mars orbited exploded 65 million years ago, and peppered one side of Mars with "young" craters, leaving the other side virtually untouched. (The date estimates of billions of years ago in the conventional model are based on crater counts, so they are meaningless in this context.)

The EPH scenario fits with the totality of evidence (over 20 observed anomalies) about Mars history (90-degree pole change, loss of most atmosphere, Xe-129 anomaly implying an explosion, etc.). Two of them in particular rule out any variant of the giant impact theory. One is that the northern hemisphere was found to have had a large number of eroded, sub-surface craters and would have been wiped out by any such giant impact. The other is that lobate scarps from numerous impactors hitting Mars tangentially near the dichotomy boundary have left streaks and scarps (piled-up terrain at the ends of trenches dug by grazing impacts) that can only be explained by numerous northward-going impactors.

http://www.nature.com/news/2008/080625/full/news.2008.916.html
http://www.nature.com/nature/journal/v453/n7199/full/4531191a.html

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"Your seat cushions can be used for flotation; and, in the event of an emergency water landing, please paddle to shore and take them with our compliments." – Part of a takeoff briefing heard on an airline

GENERAL INFORMATION

Pertinent articles and discussion of published articles, especially those related to Meta Science, are welcome. The preferred format is Microsoft Word. Appropriateness for this Bulletin is at the discretion of the editor; but if accepted by referees, articles will be published without significant editing of content. A response by the editor or a referee may then also be published. The first author is shown any such response and offered the opportunity to adjust his contribution in the light of the response. If time permits, this process is iterated until all parties are satisfied. Until the publication deadline, authors have the option to defer publication to a later issue to complete this process.

MEMBERSHIPS-SUBSCRIPTIONS-BOOKS-CDS

Beginning in 2007, the electronic version of this Bulletin is open access. Our research is not normally eligible for government funding, so we rely on Member contributions to support the organization. Memberships (which are primarily contributions to the research) come in three levels: Supporting Member ($25/year), Sustaining Members ($50/yr), and Patron Members (≥$100/yr). A "year" of Membership now lasts for three issues of the Bulletin, however long it takes to publish three issues. Membership and other contributions to Meta Research, a 501(c)(3) organization, are tax deductible in the United States. Members are notified of new Bulletins and other publications by email, and have access to the Members Only area of our Message Board. A printed version of the Bulletin is separately available to anyone via mail on a subscription basis for $19 for 3 issues for U.S. and Canada addresses and $24 for three issues mailed to other countries.

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- A CD containing all 15 MRB volumes (60 issues) from 1992-2006 (before issues became open-access and available on the web) is also planned, and will be announced at a later date.

Payment methods include mailed checks, credit cards (Visa/MasterCard/Discover/American Express, include expiration date and security code); and on-line payments via PayPal.com (to <tomvf@metaresearch.org>). You can also pay for Memberships or make purchases, including back issues of MRB, at our secure on-line store at http://metaresearch.org/home/store/advanced/default.asp.

META RESEARCH

Meta Research, Inc. is a scientific non-profit 501(c)(3) corporation run by a 7-member Board of Directors. It was founded in 1991 in response to the broad problem of getting support to do research on promising but unpopular alternative ideas in astronomy that have trouble getting funded from the usual sources. The organization supports and encourages research or observations in connection with astronomical theories that are in accord with observations and experiment, add insight or understanding, and make testable predictions; but that are not otherwise supported solely because they lie outside of the mainstream of the field of Astronomy.

The name "Meta" (pronounced with a short "e") comes from the dictionary meaning of that prefix: "later or more highly organized or specialized form of; more comprehensive; transcending; used with the name of a discipline to designate a new but related discipline designed to deal critically with the original one."

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Our office hours are 9 a.m. to 6 p.m. Pacific Time. Our expeditions are led by Meta Research astronomers. For eclipses, we go to near the edge of the path of totality, where the view is most spectacular. Plans for future expeditions are on hold. Check the "Expeditions" tab at our web site or go directly to http://eclipseedge.org to learn of such plans, which may develop on short notice because of unexpected astronomical developments.

AUTHOR INFORMATION

The Meta Research Bulletin (*MRB*) is published four times a year, in the last two weeks of March, June, September, and December. The publisher is Meta Research, Inc. The editor-in-chief and author of all articles not otherwise credited is astronomer Tom Van Flandern tomvf@metaresearch.org. Editing assistance is provided by John Bailey JBailey@ida.org. The print edition editor is Blaine Pugsley gbntpugsley@q.com. Articles in this Bulletin are considered to have the same status as preprints. Permission to reprint articles will usually be given upon request as long as the source is acknowledged.

TABLE OF CONTENTS