

Styx and Stones, Maybe Charon Too - Analog Nov 73

George Harper

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Nor was this the first prediction of a planet between Mars and Jupiter. Nearly two centuries earlier, around 1595, Johannes Kepler penned the unambiguous sentence: *Inter Jovem et Mortem planetum in-terposui*, or "Between Jupiter and Mars I interpose a planet."

Either way, the mathematical relationship expressed by Titius and the prediction by Kepler remained curiosities until the summer of 1781, when William Herschel proclaimed a new planet in the firmament, a planet which he named "Georgium Sidus" in honor of mad King George III, of Revolutionary War fame. With this discovery it was quickly realized the new planet fitted neatly into the next interval of the Titius Rule, at $4 + 96 = 196$.

Herschel's discovery refocused attention on the Titius Rule and incidentally, on a rather nasty but unfortunately somewhat typical situation which had arisen during the previous 15 years. The preeminent German astronomer of the time, one Johann Bode, had simply appropriated the Titius Rule and claimed it for his own despite the fact he had earlier explicitly acknowledged Titius' priority. As he had the wholehearted cooperation of the German astronomical fraternity the expropriation stuck and it is today generally known as the "Bode" Rule.

Ordinarily we wouldn't mention Bode here save for an unexpected irony. Bode was the astronomer who renamed Georgium Sidus, calling it Uranus. So, oddly enough, he got credit for the rule he stole and never received proper recognition for the planet he named! Maybe things come out even after all!

Still, the rule remained mostly a curiosity until New Year's eve, 1800-1801, when the astronomer-monk Giuseppe Piazzi discovered what he first believed to be a peculiar comet with an unusually circular orbit in a position roughly between Mars and Jupiter. But then Karl Friedrich Gauss proved it to be a small planet, orbiting at a distance of 27.7. The planetoid was later named Ceres and has since been proven to be the largest of the asteroids.

Once the asteroids were fitted into the 28 slot, the Titius Rule stood triumphantly confirmed. As of 1801 the solar system had a neat, complete look about it. Everything was in its place and all was right in the heavens. The *reason* for the rule might be obscure, but the *reality* was unquestioned.

Shortly after the discovery of Uranus, astronomers began to realize that the existence of the planet could have been predicted far in advance of its discovery. The period of Uranus is 84 years. The period of Saturn is only $29\frac{1}{2}$ years. This means that roughly every 40 years Saturn and Uranus come into conjunction. When Saturn starts to overtake Uranus it is accelerated by the gravitational attraction of the

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The actual effect of this is the precise *opposite* of what we should expect. The acceleration of Saturn toward Uranus translates itself into a higher orbit and a consequent reduction of speed in its motion about the sun. As it passes Uranus, the gravitational drag is converted into a lower orbit and an increase in speed. The fits and starts of Saturn had been observed for years without anyone ever suspecting the reason, but once the phenomenon was recognized, mathematicians commenced analyzing the motions of Uranus and Saturn to look for evidence of additional residuals which might indicate the presence of other planets.

They found them.

Adams in England and Leverrier in France arrived independently at the same conclusions. Adams was a bit ahead of his rival, but he made the mistake of turning his calculations over to the Astronomer Royal of England. And that worthy had better things to do with his time than worry about the calculations of some amateur. Leverrier had better luck, and on September 23, 1846, Neptune was discovered. Then a ripple of dismay began spreading through the ranks of astronomers. Rather than falling at 388 as the Titius Rule suggested, Neptune orbited at a scant 300, or over 800 million miles from where it belonged!

When Pluto was discovered, some 84

years later, the difficulty was compounded. Rather than orbiting at 772, as the Titius Rule predicts, it loops out in a highly eccentric orbit ranging from 290 to 420, and averaging 394. (See Table I.)

In other words, after Uranus the whole system goes to pot! One result of this has been an effort by some astronomers to call the whole rule a fluke. "Pure coincidence," they scoff... but even in their scoffing we sense a certain uneasiness; as if there is a lurking fear there is unfathomed significance to the old rule after all.

The fear seems justified when we turn to look at the satellite systems circling some of the outer planets. Take Uranus,

for instance. Here we find five beautiful satellites, all in perfect equatorial orbit about the planet, and all with very nearly zero eccentricities. If we apply the Titius Rule here, we find an excellent approximation save for a moderately considerable discrepancy with the innermost satellite, Miranda, and a massive discordancy with the outermost, Oberon. (See Table II.)

When we consider the five inner, regular satellites of Jupiter, also listed in Table II, we again arrive at an interesting approximation of the rule. Barnard's Satellite and Io are definitely too close to their primary, but Ganymede and Callisto are squarely on the mark. The more distant satellites, being highly

eccentric and inclined in orbit, are considered to be later acquisitions and thus not subject to the rule. A substantial improvement in the accuracy of the Titius Rule is achieved if we postulate that whenever a given condition is fulfilled at the outer edges of the system, the planets or satellites out there will tend to condense at half intervals. The precise nature of this condition is unimportant at the moment, but as a guess we may hazard it is somehow related to the density of Matter per unit volume of space. But even if the reason is obscure, the fact of the improvement is real.

Neptune and Pluto fall neatly into place in the solar system, and Oberon

fits just as neatly into the pattern of Uranus' satellites. (See Table III.)

It may be objected that the failure of the Saturn satellites to conform invalidates the hypothesis, but we may counter by observing that the Saturn family is exceptional in more ways than just this one. For instance, how do we account for the fact Mimas and Enceladus have abnormally low densities, being only 0.5 and 0.7 that of water respectively? Tethys, the fourth satellite out, has a density of 1.2, and we can show that the small size of the Kirkwood gaps in Saturn's rings precludes - a density greater than 0.4

for Janus, the newly discovered innermost satellite of Saturn. In fact, not

until the fifth satellite, Dione, do we begin to develop ‘normal’ satellite densities. (See Table IV.)

Conventionally, astronomers draw a distinction between “terrestrial” and “jovian” planets and satellites, calling Saturn’s inner family “jovian.” It seems likely this is an artificial distinction, especially since Jupiter has no “jovian” satellites and we find no evidence of a pattern in the placement of these satellites around other planets. It seems more probable the same factors which contributed to the formation of the ring system also messed up the Titius Rule and created a whole set of underdense satellites with anomalous orbits.

Admittedly, the argument is not

overwhelmingly convincing, but with so many peculiarities in and around Saturn, we need not be surprised when the Titius Rule also goes by the wayside. It is simply one more oddity in the system.

So in summary, it looks as if the Titius Rule contains elements of reality and represents something more than simple coincidence. Granting this much, if a tenth planet should exist in our solar system we would expect to find it wandering in orbit at around 58 astronomical units. An eleventh planet would probably fall somewhere around 77.2 a.u. Further, as the formula for naming planets is already fairly well established, we can go ahead and name a tenth planet “Styx” and an eleventh

“Charon” without doing violence to tradition.

This is fine as far as it goes, but there is a fly in the ointment... Pluto. Considering the true value for Neptune and the half intervals of the modified Titius Rule, Pluto is exactly where it belongs. But this is almost the *only* thing right about the planet. Everything else is wrong. Its orbit is too eccentric, its mass is too small, its composition and density evidently wrong, and the rotational period faulty. In short, astronomers would probably much prefer that Pluto were not around. But unfortunately, it is there, and we have no convenient way of ignoring the planet. So we must try to explain it. The matter begins in 1915,

when Percival Lowell published an expertly developed mathematical analysis of observed deviations in the orbit of Uranus. From these he deduced the existence of a planet beyond Neptune and arrived at a probable location.

But this was not the first effort to seek out a transneptunian planet. As early as 1834, Hansen indicated a belief that a single planet would not account for the residuals in the orbit of Uranus. In 1880, Todd made a systematic search using the 26-inch refractor at the U.S. Naval Observatory. There were others too, but these were probably first in their respective areas. Hansen first suggested the planet, Todd first sought for it, and Lowell first arrived at a mathematical

prediction. When Pluto was finally discovered, in March of 1930, it turned out to be within six degrees of Lowell's predicted position. This is phenomenally good mathematics, and the likelihood of coincidence is negligible. But even as the discovery was being announced, astronomers at the Lowell Observatory were hedging their comments. If Lowell's mathematics were correct, Pluto had to have a mass 6.6 times that of Earth; that is, assuming the distance at which it was actually found. This led to problems, for the planet appeared to be about the size of Mars, or roughly .25 the volume of Earth. This would imply a density of 147.0 for Pluto as contrasted to Earth's density of 5.52, which would

make Pluto consist mainly of collapsed matter!

Unfortunately, this creates its own problems. It happens Pluto's orbit is the most eccentric of any planet in the system. At its point of nearest approach to the sun, on May 5, 1989, it will actually be located *within* Neptune's orbit! As Pluto is highly inclined, there is no danger of collision with Neptune, but it is a lead-pipe cinch any planet with 6.6 Earth masses coming that close to Neptune would perturb it mightily over the ages, both in terms of orbital ellipticity and inclination. And what do we find? We find Neptune to be second *least* perturbed of any planet in the solar system, with an eccentricity of 0.0087.

Venus is slightly better, with an e of 0.0068, while Earth is just behind, with an e of 0.0167, roughly twice as great. Uranus is a distant fourth, with an e six times larger than Neptune's. This datum alone causes all other arguments to pale to insignificance. There is simply no way Pluto can wind up with a highly considerable mass. The assumption of .10 Earth mass for Pluto seems about right, and it is difficult to concede any more.

If we accept all this, it means Lowell's mathematics were accidental. The mass of Pluto turns out to be so

-inconsiderable there is no way it could give results of the magnitude postulated. Taken at face value, the

whole discovery becomes a fluke... or so goes the argument today.

Taken by itself, the matter could easily be dismissed. After all, Pluto is still in the right place so far as the Titius Rule is concerned. If more planets are to be found we should expect to find them at 58.0 and 77.2

a.u., so it really makes little difference if Pluto turns out to be smaller than we anticipated. This would appear to be a clear and concise conclusion.

But there is a problem. In Pluto we have a tiny planet with an orbit intersecting that of a major planet. The question inevitably arises, how “stable can such orbit be? Is there perhaps a point in time where the two would have

to bump?

Computer simulations fail to reveal such a point, but as they can only be projected a few millions of years into the past and future, this is inconclusive. Much can happen in four billion years which wouldn't even be hinted at in the course of a few million. Thus, there is a distinct possibility of collision, either in the past or the future.

A collision in the future is simply an interesting possibility. Almost certainly the last, enfeebled descendants of humanity will have long since perished ere this time comes. And there is no conceivable connection with our problem at the moment. Whether or not Pluto collides with Neptune is irrelevant

so far as the Titius Rule is concerned.

But there is an unexpected relevancy when we look to the distant past. There is a distinct possibility Pluto is not-properly a planet at all, that it is instead an escaped satellite of Neptune! And if so, then we don't really have a planet to put into the 38.8 a.u. slot.

Impressive evidence supports the thesis. First is the fact that Pluto's probable radius of 2,650 kilometers is on the same order as Titan, Ganymede or Callisto. It is only slightly larger than the 2,000-kilo-1 meter radius of Neptune's major satellite, Triton. The size is therefore about right for a satellite. Then comes another peculiarity, the rotation period of the planet. Being so far from

the sun, tidal effects would be negligible and any planet would retain its aboriginal spin unchanged over eons of time. Thus Jupiter spins once every 9 hours, 50 minutes. Saturn takes 10 hours, 14 minutes, Uranus 10 hours, 49

minutes, and Neptune 15 hours, 40 minutes. Then comes Pluto with an absurd period of 6.39 days!

Clearly, something had to slow it down, and that can only have been some sort of tidal effect operating somewhere. The only visible way of providing a drag of this magnitude is to assume Pluto was once a satellite of Neptune in a 6.39-day orbit. Then the period would be synchronous with the rotation and our problem would be solved.

Perhaps the most impressive bit of evidence in support of this thesis is Neptune's major moon, Triton. It looks quite normal, as moons go. The radius of 2,000 kilometers is a bit large, but not exceptionally so. The eccentricity of the orbit is zero to four decimal places, which makes it as nearly perfect as possible. The period about Neptune is a nice 5.87 days and its orbital distance from the planet is 353,600 kilometers.

But now comes the clinker... Triton travels *backward* in its orbit around Neptune!

Admittedly, there are a few other satellites which go the wrong way around their primaries. Jupiter has four

retrograde satellites, having radii of 11.0, 28.0/31.2 and 10.0 kilometers respectively. Their eccentricities are all greater than 0.13, or at least 13,000 times greater than Triton while their diameters are on the order of 1,000 times less.

Saturn adds one more to the collection. Little Phoebe is a moonlet with a diameter of 150 kilometers and an e of 0.166. It is also nearest of the other retrogrades to its primary, being a mere 13 million kilometers from Saturn, or some 30 times further out than Triton.

In short, the other retrogrades are small, highly eccentric in orbit and very distant from their primaries. Current belief is they were all captured at some

time in the past. But the possibility of Triton having been captured is so slight as to be virtually nonexistent. We are therefore left with the inadmissible conclusion it must have formed *in situ* around Neptune only traveling backward in orbit. Clearly, there is a need for an alternative choice.

R. A. Lyttleton of Cambridge University put it all together. He began with the assumption that Pluto was originally a satellite of Neptune in 6.39-day orbit some 500,000 kilometers distant. Triton was also a regular satellite of Neptune in normal orbit at perhaps 600,000 kilometers. Gravitational interaction caused the two satellites to converge until eventually

Triton and Pluto whipped about one another in near collision, with Triton winding up in a lower, circular, retrograde orbit about Neptune while Pluto was cast off as a runaway satellite.

The orbit of the ex-satellite would naturally reflect its point of origin so we would expect it to have a perihelion close to Neptune's orbit. Further, as Triton and Pluto would have a common birth in their present configuration, we would also expect them to have similar inclinations in their respective orbits. And sure enough, Pluto has an exceptionally high $17^{\circ}.13$ inclination, far higher than any other planet in the system. Triton matches this with an inclination of $20^{\circ}00' \pm 2^{\circ}.3$. Subtract

Uranus' own inclination of $1^{\circ}.77$ and we arrive at a relative value of $18^{\circ}.33 \pm 2^{\circ}.3$ for Triton; phenomenally close to Pluto. Lastly, nothing in all this would change the angular momentum of Pluto itself, so the new planet would continue to possess a 6.39-day rotation period as a memento of its dependence on Neptune. All in all, this is a convincing argument. Everything winds up being - explained in terms of simple, easily understandable mechanics. If correct, Pluto does not belong as the ninth planet. It simply chanced to get there by accident. And if this is the case, then for there to be planets at 58.0 and 77.2 would imply the existence of some planet other *I than Pluto at*

approximately the • mean orbital distance of Pluto! It would have to be this as yet undiscovered planet which fills the Titius Rule slot at 38.8. This is not an impossible requirement. The sidereal period of a planet in orbit at 38.8 is in the neighborhood of 250 years. In the 42 years since discovery we have observed Pluto over only 1/6 of a single orbit. There is therefore *a* distinct possibility another planet i could exist in the same approximate orbit as Pluto without our having discovered it. There are, after all, some thousands of minorj planets in the asteroid belt, so another planet at 38.8 is by no means out of the question. The chance are it would not be more than twice Pluto's diameter or

it would have shown up in the extensive planet searches sponsored by the Lowell Observatory, but this would still make it nearly terrestrial in size and mass, so it would be no mean object.

When we start talking about the likelihood of such a planet, that becomes a different matter. The extensive searches by Tombaugh make it appear unlikely, but he by no means blinked all segments of the heavens, so there is a reasonable possibility such a planet might exist. If it is as small or smaller than Pluto, and at a distance of 38.8 a.u., there is a good chance it would have been missed even on a direct search. (Pluto was about 34 a.u. from the sun when it was discovered; a planet of the

same size at 39

a.u. would be 450 million miles more distant and only about half as bright.) But this isn't the point. We have no right to postulate extra planets just for the fun of it. There should be some real reason or we are simply playing games and it becomes an exercise in airy speculation. So we must ask if there is some empiric reason to postulate one or more extra planets at and beyond Pluto. This is a difficult question to answer. For example, it is entirely possible to explain away the disturbances in Uranus' orbit in terms of inaccurate early observations mated to highly accurate later ones. Thus the residuals Lowell used would all be imaginary and

there would be no significance to the mathematical results he achieved. We could even argue there was a positive emotional push for astronomers of the last century to interpret any vagrant residual as evidence of more distant, undiscovered planets. The successes of Herschel, Adams and Leverrier testified to the honors awaiting the discoverer of a new planet, and ambitious astronomers were eagerly seeking ways of joining the select group. This is the argument being advanced today by those who feel Lowell's calculations were merely a lucky chance. We admit the strength of the argument. But we must also note that the modern pressure is in precisely-the opposite direction. The young

mathematician of today scurries around in the mathematics of Lowell and others, picking up a residual here, another residual there, and tacks them all together in the presence of “uncertainties,” and finally pronounces that he can explain Lowell’s “error.”

Of course, all he has done is assume that all errors accumulated over the years were “positive” with no

“negative” errors to balance. This is highly unlikely. The thought of competent observers over a stretch of two centuries all making the same sort of error in total ignorance of each other boggles the imagination. It just isn’t likely. Lowell’s computations retain a definite attraction. No matter how cavalierly dismissed,

there remains a powerful suspicion he said something worth listening to. And if so, at least one more planet must exist beyond Neptune.

Recent items in *Sky and Telescope* (November 1972, page 297) and *Computer Decisions* (June 1972, page 4) relate to the hypothesis of Joseph L. Brady and Edna Carpenter, of the University of California's Lawrence Radiation Laboratory, who postulate a planet of 300 Earth masses orbiting at 59.9 a.u. and inclined 120° from the ecliptic. They derive these values from observed discrepancies in the return of Halley's Comet as reported from A.D. 295 to the present.

Unfortunately, a direct scan and blink

comparison of the predicted location fails to disclose a planet. Further, rediscussion of the apparitions of Halley's Comet tends to throw doubt on the dates adopted by Brady, so here again it looks like a standoff.

But there is still another line of argument; one used by Brady but still not made explicit by him. This argument derives from the theory of comet "families." Going back a bit, the best evidence today suggests that the entire solar system is englobed by a cometary "halo," consisting of some 50 million comets in slow orbit about the sun at distances ranging from 30,000 to 50,000 a.u. This works out to perhaps one cometary mass for each volume of space

equal to a sphere with a radius the size of Earth's orbit about the sun.

Occasionally one of these bodies interacts with another and both are perturbed out of their circular orbit. If the perturbation is less than escape velocity for the system, both bodies are fated ultimately to plunge inward toward the sun in a long, elliptical orbit. Generally these orbits are so eccentric the comet will have a period running into the millions of years.

But if the circumstances are just right, at some point on its inward plunge or outward return to the depths of space the comet will be perturbed by one of the planets, such as Jupiter. When this happens, the period of the comet is

shortened and it becomes a reflection of the period of the perturbing planet. Thus we have the jovian “family” of comets, having periods of 10 years or less, a Saturn “family” with periods ranging from 10 to 20 years, a Uranus family of 20 to 40 years, and a Neptune family of 40 to 100

years. According to Table V, 39 comets belong to the jovian family, six to the Saturn family, three to Uranus and five to Neptune. *Then there are two others with periods which appear consistent with a planet at 58.0 a.u.!*

Actually, we can probably add three more comets to the 58.0 family. These are Swift-Tuttle, found in 1862, with a period of 119.6 years, Barnard (2),

found in 1880, with a period of 128.3 years, and Mellish, discovered in 1917, with a period of 145.3 years. The comets on Table V have all been observed; through more than one apparition and so have fairly reliable orbits established, but these three have been observed only once apiece and have somewhat doubtful orbits. It is unlikely that any of these three has had its orbit so badly misjudged as to be completely out of the area, so we can probably feel fairly safe in attributing five comets to the 58.0 a.u. family.

But like almost everything in astronomy, we can argue with the conclusions. Objectors to the idea of comet families point to the high

inclinations of such objects as Halley's Comet and argue that Neptune could not possibly be of significance in modifying the orbit. They maintain that the real culprit for virtually all periodic comets is Jupiter. They further maintain that blocking off decades of time and claiming some sort of mysterious connection with the planets is mere numerology.

On the balance, this is one place where the argument of the objectors is clearly the stronger of the two. There is no doubt that the theory of comet families is correct -as stated, but the application should almost certainly be restricted to comets on approximately the same plane as the planets influencing

them. Halley's Comet, for instance, passes within 4.6 a.u. of Jupiter, but it never comes within 25 a.u. of Neptune. Clearly, the influence of Jupiter will be vastly the greater of the two. For that matter, the influence of the Earth and Venus, and perhaps even lowly Mercury, would outweigh that of Neptune. So to think that Neptune is somehow responsible for the orbit is to miss the whole point of the matter. To this point the question of additional planets seems inconclusive, with the balance apparently leaning against the prospect. However, there is one line of reasoning which has not to my knowledge been advanced elsewhere but which I feel is highly suggestive.

The existing model of the solar system calls for a region of planets extending outward from the sun to Pluto, or roughly 40 a.u. Then we have a blank region until we enter the realm of the comet halo between 30,000 to 50,000 a.u. Being generous, let us postulate a halo doubled in size including all the space between 10,000 to 50,000 a.u. This still leaves a conspicuous gap in the region between 40 to 10,000

a.u., or possibly even between 40 to 30,000 a.u.

To suggest this is all void space would be, I suspect, wholly incorrect. It would be almost impossible to explain such a void by any mechanical means. If we postulate a comet halo, pushing the

solar system out to 50,000 a.u., then we must be prepared to accept responsibility for explaining vast expanses of emptiness if and as they occur. In short, if the solar system ends at 40 a.u., or 50 or 60 a.u., for that matter, then we are free of the need to explain why the region immediately beyond it is empty. But if we accept the halo, we must also accept the implications of our reasoning and be prepared to talk-about the gap between the planets and the halo.

So far as the comet halo is concerned, the evidence for its existence is nearly conclusive. Only two or three comets ever observed had orbits which were hyperbolic, and even these were just

barely so. If comets were coming in from outside the system, a clear majority would have hyperbolic orbits, and most of those would be wide hyperbolas, not just marginally so as we find them in our few examples. This is as nearly conclusive as we can hope to get under the circumstances. I know of no contemporary astronomer who seriously doubts the existence of the halo.

This means we must be prepared to discuss the “empty” space between 40 and 10,000 or more a.u. For my part, I postulate that this region is occupied by literally hundreds of thousands, or even millions of minor asteroids and planetoids possessing radii on the order of 150 to 1,500 kilometers with a few

having radii up to roughly 3,000 kilometers and perhaps five or six with radii ranging upwards of 10,000

kilometers. Inclinations and orbits are random in the same sense that comets in the halo appear to possess random inclinations and orbits. There is so much space out there, and motions are so slow, that no systematic scouring has occurred and conditions remain nearly primeval. Several arguments lead to this hypothesis. A fairly clear line of evidence indicates that planets condense from clouds which contain substantial amounts of particulate matter. A glance at the scarred faces of the moon and Mars is more than adequate to establish this argument and a view of the asteroid

belt provides added proof if needed. To suggest that all this particulate matter was confined within a region of some 40 a.u., while simultaneously assuming the comets occupied all space beyond would appear more nearly an article of faith than reason.

Secondly, suppose Lyttleton's hypothesis of the origin of Pluto is correct. If so, this reduces the size of the system to around 30 a.u. and forces the correlary assumption that at this distance there was enough particulate matter to form the nucleus for the condensation of Neptune, Triton, Pluto, and tiny Nereid (radius 150 kilometers) which was obviously a capture from further out. To argue that Nereid was the last such item

left over and there is now nothing until we get out to the comet halo requires a truly titanic act of faith on our parts.

A third line of reason goes back to Brady and Lowell. If we postulate a very considerable amount of random particulate matter beyond Neptune, then we can arrive at perturbations which give us a vector solution whenever we try to resolve them down to a single object. The discordant mass of Pluto becomes readily understandable as constituting an appreciable fraction of the masses acting on Uranus, but not necessarily the only remaining mass. And Brady's Saturn-sized mass at 58.0 a.u., which is otherwise invisible to telescopes, becomes simply another

vector solution. It is a sum of forces rather than an actual object, so naturally there is nothing there to be seen.

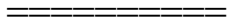
A more remote argument comes from the “lost mass” of the galaxy. The physical mechanics of the galaxy require a mass of matter fully 20 percent greater than that we can observe or infer. Such material presumably exists in the form of black bodies: singularities, sub-dwarf stars, planets, free gases, comets, et cetera. We add all this together and still arrive at a shortage of roughly 10 percent. There is just that much mass missing somewhere.

Conventionally we find our solar system depicted as consisting of a sun and nine planets plus some

miscellaneous objects such as comets, asteroids and satellites. The miscellaneous objects combined would not equal the mass of Earth and the sum of all the dark objects of the system is less than one percent of the mass of the sun. Postulating the existence of the intermediate belt between the inner system and the comet halo changes all this. An aggregate mass several times that of Jupiter could easily exist in this area without being detected, providing it was broken up into enough small fragments. A hundred thousand lunar-sized planetoids would equal 26 Jupiters in mass and would more than adequately account for the "lost mass" of the galaxy, at least so far as our one system is

concerned. If this construction were typical of all solar systems, the “lost mass” question ceases to be a problem. So now the matter is turned around. When we began we were talking about the prospects of another planet or two out beyond Pluto. But instead of one or two it turns out the real argument is for the existence of thousands, or hundreds of thousands of planets and asteroids, some of which are in all likelihood approximately the size of Earth.

Styx there is, and Charon too, and stones without number. It's a big, big solar system!



ABOUT THE AUTHOR

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George Harper has trekked into the Caura River country of Venezuela, instructed in arctic survival in northern Alaska, guided a survey party in southwest Alaska, and roamed the southern Yucatan searching out the homeland of the Mayas. He was an air route traffic controller with the FAA, then quit to serve a brief stint as director of a small observatory. In the process he taught courses in astronomy at several local colleges and still teaches on occasion at Tacoma Community College. On the astronomy scene, he has a rather

detailed study under way touching on some of the unresolved fundamentals of the universe, such as what is mass, or how is an impulse transmitted through mass.