Ganymede: the surprisingly magnetic moon

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The largest moon in the solar system is Ganymede, at Jupiter. Ganymede was one of the moons examined by the Galileo spacecraft, which orbited Jupiter from 1995 to 2003. Ganymede is about 200 km larger in radius than the planet Mercury. Many structures have been found on its surface that are still a mystery. During the Galileo mission to Jupiter it was discovered that Ganymede possessed a weak magnetic field. This was very surprising to planetary scientists because in small objects like moons, it is generally thought that any intrinsic field should have long since ceased to exist. Planetary scientists rely on dynamo theory to explain how planetary magnetic fields are maintained for billions of years. But magnetic dynamo theory has technical problems and especially so with a moon like Ganymede. The question of how Ganymede could still possess a magnetic field was examined in a recent paper in the journal *Icarus* by researchers Bland, Showman and Tobie.[1]

In the study by Bland *et al.,* various scenarios were modeled regarding how a magnetic dynamo might explain Ganymede. A dynamo requires that there be a liquid core of a conducting material such as iron and the core must support convection currents. If there is an electric current in a core consisting of a moving conducting liquid, this may generate a magnetic field. The chief problem in a small body such as Ganymede is the small core. A small sphere cools faster than a large sphere, thus a moon tends to cool rapidly over time. The heat flux out of Ganymede's core should not be enough to keep convection operating in the core for over four billion years.

The rate of spin of the body also affects its ability to run a dynamo. Ganymede is in synchronous rotation around Jupiter with its orbital period and spin period matched at about 7.2 Earth days. This is a relatively slow spin rate for a moon, which is another difficulty for a dynamo in Ganymede. Bland *et al.* looked at various proposed models that would keep Ganymede's core hot enough and keep it with the right properties to allow it to still have a dynamo operating today. Every approach seemed to run into significant problems. The possibility of the moon being only about 6,000 years in age was not considered.

Another approach examined in the study by Bland *et al.* was what is called compositional convection, which is a different mechanism to explain how a dynamo could operate. In compositional convection, iron and possibly other metals would cool and condense to solid form at the top of the core and then sink to the center. In this process lighter materials such as sulfur would be driven out of the core. Thus a division of materials takes place, and when the metals condense, latent heat is released that is thought by some to be able to drive convection. This idea suffers from a significant problem that it happens at the bottom of the mantle, which is much cooler than the core. This means the heat generated by the process would be absorbed by the mantle and so it is doubtful that this process could drive a dynamo for billions of years.

Ganymede is in a three-way orbital resonance with Io and Europa. Io, Europa, Ganymede, and Callisto are the four so-called Galilean moons. Io is much closer to Jupiter than Ganymede and thus tidal heating is very significant in Io.[2] Io and Europa also experience some electrical effects as a result of Jupiter's very powerful magnetic field. Some researchers are attempting to argue that Jupiter has induced a magnetic field at Ganymede and Ganymede has no intrinsic field of its own. However, at the distance Ganymede lies in its orbit, Ganymede's intrinsic field is stronger than the field of Jupiter. Thus it is not likely that Jupiter would have induced Ganymede's field. The study by Bland *et al*. also examined scenarios in which the

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Jupiter's biggest moons, discovered by Galileo: from left to right, Io, Europa, Ganymede and Callisto.

orbits of Ganymede and neighboring moons changed over time so that in the past other orbital arrangements would cause tidal heating to be more significant than in the present for Ganymede. It was hoped this would generate enough heat in the interior of Ganymede to allow for a dynamo. These kind of scenarios are *ad hoc* and have no basis in real observations of the orbits of the Galilean moons. Even in scenarios of this kind, a dynamo in Ganymede would likely stop operating long before today. Rather, the orbital resonance that exists today including Io, Europa and Ganymede is likely a designed relationship put in place from Creation.[2]

In the model proposed by creationist Dr Russell Humphreys, God created planetary magnetic fields by initially aligning the spin magnetic moments of the protons in water molecules.[3] The cores of objects such as Earth and even moons would have been created initially as water, formed with the nuclear spins of the hydrogen atoms aligned. Then, some of the water was miraculously transmuted to other elements. In this way planet cores were formed and converted to being apparently composed of iron and iron sulfide as they are today. The initial alignment of the spins made a strong initial field. The atoms quickly randomized their spins after they were created. But by the time the spins became random a strong induced electrical current was in place that generates the field we measure today. This electrical current in the cores has undergone exponential decay to the present. This model from Humphreys has been very successful in explaining the magnetic fields of Earth,[4] our Moon,[3,5] and other planets in our solar system,[6] as well as recently being confirmed in measurements from Mercury.[7] Humphreys has also recently applied the idea beyond our solar system to stars and galaxies.[8]

Humphrey's model of planetary magnetic fields is a versatile model that works well for a wide variety of types of bodies. In the dynamo theory, the field depends on factors such as the spin rate, the size of the liquid core (if it has a core), and how much heat is present to drive convection in the core. In Humphreys' model, the magnetic field does not have to align with the spin axis of the body (if the core is solid) and the core does not have to be hot enough to be liquid. These could be possibilities for various moons in the solar system. Thus Humphreys approach can explain a wide range of cases, from Jupiter (very large with a rapid spin) to moons. In Ganymede, the core is particularly small, only about 700 km in radius. Possible heat sources are radioactive decay and tidal heating. Radioactive decay in an old age view would not provide significant heat in the present if the moon is 4.5 billion years old but could have provided heat in the past. Tidal heating was examined in the recent study and found to not be very significant because of Ganymede's distance from Jupiter. Thus, from an old age perspective researchers have found no explanation for how Ganymede's core could still be hot enough to be able to support dynamo convection. In a young age view based on Humphrey's model, the magnetic field could still be exponentially decaying from Creation and fluid convection in the core is not a requirement. Ganymede's magnetic field magnitude at its equator has decayed to its present measured value of approximately 750 nanotesla (nT). By Humphrey's approach, Mercury and our Moon exhibit relatively rapid decay of their magnetic fields which argues for a young age. Ganymede's field is likely to be similar.

There is another interesting possible structure in Ganymede that could affect its magnetic field. Planetary scientists suspect that Ganymede has a layer of liquid salt water some distance below the crust.[9] This has been proposed to explain some of the interesting surface formations on Ganymede. However, a salt water layer is potentially an electrical conductor. So, scientists have considered whether the water layer could contribute to Ganymede's magnetic field. A water solution, if there were an electrical current in it, would not likely produce a dynamo because very rapid fluid motion would be required. A water convection dynamo would probably not be stable, if it were even possible. However, it is possible that a water layer could cause some minor variations in Ganymede's magnetic field. In a young age approach such as that from Russ Humphreys, the difficulties of dynamo theory are avoided and Ganymede fits into a biblical view of history.

References

1. Bland, M.T., Showman, A.P. and Tobie, G., The production of Ganymede's magnetic field, *Icarus* **198**:384–399, 2008.
2. Spencer, W.R., Tidal Dissipation and the Age of Io, *Proceedings of the Fifth International Conference on Creationism*, Creation Science Fellowship of Pittsburgh, PA, pp 585–595, 2003.
3. Humphreys, D.R., The creation of planetary magnetic fields, *Creation Research Society Quarterly* **21**:3, December 1984.
4. Humphreys, D.R., Physical mechanism for reversals of the earth's magnetic field during the Flood, *Proceedings of the Second International Conference on Creationism*, Creation Science Fellowship of Pittsburgh, PA, pp 129–142, 1990.
5. Spencer, W.R., Our solar system: balancing biblical and scientific considerations, *Proceedings of the Sixth International Conference on Creationism*, Creation Science Fellowship of Pittsburgh, PA, and the Institute for Creation Research, pp 293–306, 2008.
6. Humphreys, D.R., Good news from Neptune: the Voyager 2 magnetic measurements, *Creation Research Society Quarterly* **27**(1), June 1990.
7. Humphreys, D.R., Mercury's magnetic field is young, *Journal of Creation* **22**(3):8–9, 2008.
8. Humphreys, D.R., The creation of cosmic magnetic fields, *Proceedings of the Sixth International Conference on Creationism*, Creation Science Fellowship of Pittsburg, PA, and the Institute for Creation Research, pp. 213–230, 2008.
9. See NASA press release of December 16, 2000, Solar System's Largest Moon Likely Has a Hidden Ocean, <www.jpl.nasa.gov/news/releases/2000/aguganymederoundup.html> or for an article with photos, see <www.astrobio.net/news/index.php?name=News&file=article&sid=93>.