GIANT IMPACT BASINS TRACE THE ANCEINT EQUATOR OF MARS Jafar Arkani-Hamed (Earth and Planetary Sciences, McGill University, Canada, jafar@eps.mcgill.ca)

Introduction: There are many lines of evidence that the rotation axis of Mars has moved relative to its body [1, 2, 3, 4, 5]. The formation of Tharsis bulge has displaced a huge amount of mass inside and on the surface of the planet, and caused polar wander of Mars. Theoretical modeling of the polar wander of Mars showed that the rotation axis of Mars could have moved by as much as 70 degrees within a geologically short time period [6]. In this paper I estimate the polar wander of Mars on the basis of the locations of 5 giant impact basins Argyre, Hellas, Isidis, Thaumasia, and Utopia, and show that they are located on a great circle that most likely traced the equator of Mars at the time of impacts. The projectiles were fragments of a large asteroid that broke apart when entered the Roche limit of the planet. I also estimate the mass of the asteroid.

The Ancient Equator of Mars: I investigate 5 giant impact basins of Mars, Argyre, Hellas, Isidis, Thaumasia and Utopia. The centers of the basins are determined using the global Bouguer anomaly map (Figure Top), on the premise that a giant impact allowed the mantle to uplift through isostatic compensation in a short time period and introduce strong density perturbations in the crust, giving rise to the significant positive Bouguer anomaly associated with the basin. The circular shape of the uplift probably better delineates the impact site. The black dot at latitude -30 and longitude 175 is the pole of the great circle fitted to all 5 basins.

The five giant impact basins are located on a single great circle. Figure (Bottom) shows the Bouguer anomaly map of Mars with the equator defined by the great circle fitted to all five basins. All impact basins centers are located within a maximum latitude of λ_{max} = 8 degrees in this figure. The five basins do not trace a small circle at appreciable latitude. The latitude of the small circle fitted to the basin centers is less than 3 degrees.

To investigate the statistical significance of the estimated great circle fitted to the basins, I examined the probability that 5 randomly distributed impacts occurred within a given angle from a great circle. For a maximum λ_{max} = 8 degrees the probability that the 5 giant basins on Mars are produced by randomly distributed impactors is 0.27%. Excluding Thaumasia basin increases the probability to 1.5%.

The five giant basins are essentially coplanar and are located on a great circle, indicating that the projectiles that created the basins were also coplanar. It is quite unlikely that the projectiles were individual asteroids with orbital planes that just happened to coincide with the same great circle. It is possible that a heliocentric asteroid captured by Mars was fragmented when entered the Roche limit of Mars, and the large fragments followed more or less the same orbital plane of the original asteroid before impacting on Mars. The fact that the giant basins are on a great circle makes it quite unlikely that the orbital plane of the asteroid had an appreciable inclination relative to the existing equator of Mars.

It is of course possible that a projectile approaching Mars at a high inclination impacts near the equator. But it is unlikely that 5 projectiles on a highly inclined orbit all impact near the equator. To illustrate this point, I explore the probability that a projectile approaching Mars on an orbital plane with an inclination α fragmented and 5 large pieces produced 5 basins lying within (+-)λ_{max} latitude from the equator at the time of impacts. While the fragments were on their rout to impact, Mars was rotating about its axis. Therefore, 5 pieces impacted on Mars at random longitudes, but within (+-) α latitudes, depending on the impact time. The probability that a fragment impacted within (+-)λ_{max} latitude band equals to 1 when $\alpha =< \lambda_{max}$ and equals to $(\sin\lambda_{max} / \sin\alpha)$ when $\alpha > \lambda_{max}$. Assuming that impact times, i.e. the impact longitudes, were random, the probability that all 5 fragments impacted within the λ_{max} latitude band equals to 1 when $\alpha =< \lambda_{max}$ and equals to $(\sin\lambda_{max}/\sin\alpha)^5$ otherwise.

The Size of the Original Asteroid: Here I estimate the size of the original asteroid, using the surface topography and gravity of the basins [7]. The total mass of the projectiles, ~9.8×10^{20} kg, is ~1.5×10^{-3} times the mass of Mars.

Conclusions: The 5 giant impact basins of Mars, Argyre, Hellas, Isidis, Thomasia and Utopia are located essentially on a single great circle, within the error limits of their impact sites. The basins are most likely produced by fragments of a large heliocentric asteroid that broke apart as it entered the Roche limit of Mars. The asteroid was ~9.8×10^{20} kg, ~1.5×10^{-3} times the mass of Mars.

References: [1] Arkani-Hamed, J. (2001) *GRL, 28*, 3409-3412. [2] Hood, L.L., and A. Zakharian (2001) *JGR*, *106*, 14601-14619. [3] Melosh H.J. (1908) *Icarus, 73*, 745-751. [4] Murray, B.C., and M.C. Malin (1973) *Science, 197*, 997-1000. [5] Schultz, P.H. and A.B. Lutz-Garihan (1982) *JGR, 87*, A84-A96. [6] .Spada, G. et al. (1996) *JGR, 101*, 2253-2266. [7] Mohit, P.S., and J. Arkani-Hamed (2004) *Icarus, 168*, 305-317.