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RESEARCH ARTICLE

EPOCH-ENDING METEORITE IMPACTS MAY EXPLAIN MIS-MATCH BETWEEN SOLAR DAY AND HUMAN CIRCADIAN DAY

***William W. McDaniel**

Department of Veterans Affairs, Hampton VA Hospital, Community Faculty,
Eastern Virginia Medical School, Norfolk, VA

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ABSTRACT

The circadian cycle of humans and other mammals is close to one hour longer than the 24 hour period from sunrise to sunrise. The meteorite strike(s) that occurred at the end of the Cretaceous era involved at least one very large body that struck our planet obliquely, apparently moving in the direction that it would have to have done to impart momentum to the rotation of Earth and decrease the period of the day. Working from current modelsfor estimating the mass of meteorites from crater dimensions, we found the largest estimate of the Chicxulub impactor to have been still three orders of magnitude too small to account for the difference between the solar day and the circadian cycle. The recently discovered Shiva crater in the floor of the Indian Ocean near Mumbai is much larger at 600km diameter. The orientation of the crater suggests its impact was also oblique, towards the northeast, and possibly as much as one half the mass necessary to have imparted momentum to the rotation of the Earth, and thus reduced the duration of the day by one hour. There were also cosmic impacts that coincided with the end-Permian extinction., and at least one of them was clearly moving eastward

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INTRODUCTION

We know that the free-running sleep-wake cycle does not match the planet's rotational period of twenty-four hours, and that the "clock is re-set" each day by a signal from the supra-chiasmatic nuclei (SCN) that coincides with the exposure of the eyes to the light of each new day (Fuller *et al*., 2006; Rosenthal *et al*., 1984; Czeisler *et al*., 1989). It seems quite remarkable that the period of the free-running sleep-wake cycle in mammals is between 24.2 and twenty-five hours depending on how it is measured (Sack *et al*., 2000; Czeisler, 2007), and that this is true among all mammalian species that have been examined (Czeisler, 2007; Reppert, 2002; Masuda, 2010). It seems obvious that animals native to a planet ought to have developed a sleep-wake cycle that matches the planet's cycle of light and darkness. When they do not, it might mean something important. It is not only students who find it difficult to get up earlier than accustomed, or to go to bed earlier. All shift-workers are familiar with this problem (Czeisler, 2007). Psychiatrists practicing in northern latitudes are now well-used to helping patients who are depressed only in the winter months by prescribing daily treatment with bright light (Czeisler, 2007).

These problems are both consequences of the dyssynchrony of our free-running cycle of sleep and wakefulness with the period of day and night. Why should there be a mis-match between the cycle and the period of the day? Let us assume that something happened to accelerate the planetary rotation, and so the period of the solar day. What force is sufficient to affect the angular momentum of the spinning planetary sphere? It is now well-accepted that a very large meteorite struck the Earth 66 million years ago and may account for the complete disappearance of the non-avian dinosaurs and many other species of both plants and animals (Morgan *et al*., 1997). There are many lines of evidence that this impact was by an asteroid or comet, including the rich content of iridium (Claeys *et al*., 2002) in the corresponding stratum. The pattern of deposition of ejecta from the crater suggests that the object struck obliquely from the west, at an angle of about 45 degrees (Wittmann *et al*., 2007). If so, it is possible that up to half of the energy of that impact could have been added to the angular momentum of the rotation of the Earth. Was it enough to account for a one-hour change in the length of the day?

METHODS

We surveyed the literature about the end-Cretaceous and end-Permian mass-extinctions. The geological discovery of the Chixculub crater and the evidence linking it to that extinction event—and the end of an age at the Cretaceous/Paleogene

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Corresponding author:* **William W. McDaniel,
Department of Veterans Affairs, Hampton VA Hospital, Community Faculty, Eastern Virginia Medical School, Norfolk, VA.

(K/Pg) boundary (Morgan *et al.*, 2002; Belcher *et al.*, 2009; Miller *et al.*, 2016), and the literature documenting evidence for a contemporaneous meteorite strike in the Indian ocean (Durand-Manterola, 2014; Chatterjee *et al.*, 2006). Using current estimates of the range of the mass and velocity of the impactor (Durand-Manterola, 2014), we calculated the force generated by the impact, and estimated its effect on the angular momentum of the rotation of planet Earth.

RESULTS

L = iw, i=2/5mr2, w=2(pi)/T, and Me-5.97x10 zillion kg

$R_e = 6.378\text{x}10^6\text{m}$

$T = 24\text{hr} = 8.64\text{x}10^4\text{sec}$

$L=4\pi(5.97\times10^{24}kg)(6.378\times10^{6}m)^2/5\times8.64\times10^{4}sec$
$= 7.061\text{x}10^{33}\text{kgm}^2/\text{sec}$ for 24hr and

$L = \frac{4\pi(5.97X10^{24}kg)(6.378\times10^{6})^{2}}{5\times9.0X10^{4}}$
$= 6.78\times10^{33}\text{kgm}^2/\text{sec}$ for 25hr period

Difference in Angular momentum is $2.3\times10^{32}\text{kgm}^2/\text{sec}$

If largest estimate based on crater size is accurate (Durand-Manterola, 2014), the impactor mass was 5×10^{17}kg, and had a radius of $2.4\text{x}10^4$m and if a comet, itsimpact velocity was about $7\text{x}10^4$m/sec, then angular momentum of the impactor would be expressed as $L_b = mvr_e = 5\text{x}10^{17}\text{kg x}7\text{x}10^4\text{m/sec x }6.378\text{x}10^6\text{m} =2.23\text{x}10^{29}\text{ kgm}^2/\text{sec}$. We know the angle of impact was 45 degrees from vertical, and horizontal vector was due east, so one half of this energy would have been directed in the direction of the planet's rotation (Durand-Manterola, 2014). By current estimates of the size of the meteorite that excavated the Chicxulub crater, it would not by itself have been large enough to alter the length of the day. For it to alone alter the length of the day by one hour the mass required would have been $5\text{x}10^{20}$ kg (this assumes impact velocity of a comet—70,000km/sec).

The putative Shiva crater in the floor of the Indian Ocean west of Mumbai is larger at 600km. More recently discovered, it is not as well studied, but it is thought that the responsible meteorite struck the planet obliquely around the same time as the Chicxulub impactor, travelling from southwest to northeast. It is thought to have been responsible for initiating the movement of the Indian plate northeast into the Asian plate, towards the collision that has raised the Himalayas (18, 19). At 600km mean diameter it is more than twice the largest estimate of the Chicxulub crater. The impactor size was estimated by Chatterjee as under 24km because the crust was not ruptured, and its mass as being no more than 10^{17}kg, for the same reason (19). The fourth model proposed by Durand-Manterola and Cordero-Tercero (17) to describe the Chicxulub impactor from the dimensions of the crater is the only one useful with the scant data we currently have about the Shiva impact. It predicts the impactor mass as a function of impactor velocity.

$M=2E/V^2$

Given a spherical impactor with radius r, then the mass is expressed as

$$m = \frac{4}{3}\pi r^3 \rho_i$$

If ρ_i is the density of the impactor, then the mass that excavated a 600km crater must have a mass in the range between $1.36\text{x}10^{20}$ kg for a chondrite as dense as normal weight concrete (2400kg/m^3), and $4.47\text{x}10^{20}$kg if iron with a density of 7478kg/m^3. The model thus predicts a greater mass than the 10^{17}kg predicted by Chatterjee, but the larger extreme value is very close to half the mass calculated for a comet to alter the momentum of the planet so that the duration of the solar day is shortened by one hour. As this is an absolute upper limit of the range of mass for the Shiva impactor, it must be admitted that the known end-Cretaceous impacts cannot account for the discrepancy between the solar day and the mammalian free-running circadian rhythm. Until recently, it was thought that the extreme volcanism represented by the Siberian Traps accounted for the end-Permian mass-extinction. There is now evidence for a possible meteorite crater west of Australia that was dated to 250 million years ago

DISCUSSION

The symmetrical distribution of crater ejecta and iridium throughout the world has puzzled geologists studying the Chixculub crater, but is better explained if there were two or more impacts. The symmetrical distribution of iridium suggests that the Chicxulub and Shiva impactors were fragments of the same body separated by impact or by the Earth's gravity, and so striking at different times, and different parts of the planet (Miller *et al.*, 2010; Lerbekmo, 2014). Chatterjee had proposed an upper limit to the mass of the impactor of 10^{17}kg because the crust was not pierced by the impact. There are recent models (Elkins-Tanton, 2005) that suggest the possibility of a large impact deforming the crust so that a nearby magma plume might then erupt nearby, and not necessarily through the crater itself. The enormous lava flows whose remnants remain as the Deccan traps east of Mumbai might be an example of just such an event. While it was long thought that there were no impact events associated with the much larger mass extinction at the end of the Permian, a 600km crater has been discovered under the ice of Wilkes Land, Antarctica (Von Frese, 2009). Similarly, the Bedout High on the ocean floor off NW Australia has features that have led some to conclude that it represents the remnant of a large impact crater (Becker *et al.*, 2004). While there has been some controversy about the latter (Von Frese, 2009), it seems certain that both Antarctica and Australia moved east and south from Gondwanaland (Becker *et al.*, 2004). While much less is known about end-Permian impacts, this is likely to mean those impacts could have imparted angular momentum to the rotation of the planet. The degree of this is confounded by the fact that even at the end of the Permian, both impact craters were thought to be closer to the pole than to the equator. The present location of the Australian continent far to the east of late-Permian Africa is probably good evidence for an impactor also moving eastward. The somewhat less eastward position of Africa and Eurasia may suggest other impacts that have yet to be discovered or are obscured by sediments or plate tectonics. The fossil record demonstrates the very earliest of the mammals appeared during the Permian period, as did the earliest reptiles. Among terrestrial invertebrates, several orders of insects first appeared during the Permian, including the hemiptera and orthoptera, both of which demonstrate a free-running circadian cycle very near 25 hours. (Settembrini, 1984; Tomioka, 1984)

Conclusion

The anomalous dys-synchrony of the solar day and the mammalian (human) circadian cycle is thought to be contributory to seasonal affective disorder and sleep phase advance disorder. It may be explained by meteorite impact, but not by the end-Cretaceous impacts alone. It is possible that end-Permian impacts also contributed.

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