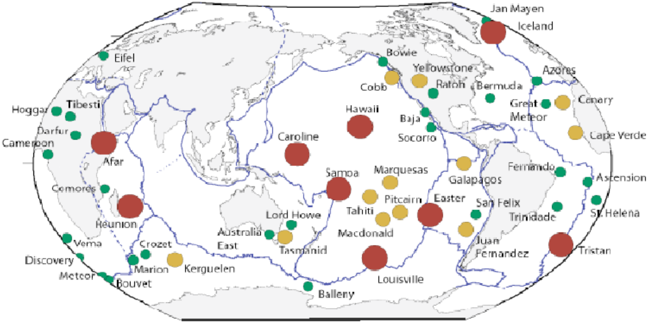
Wroclaw: Seminarium Instytutu Fizyki Teoretycznej

Something STRANGE is Flying Around

Jan Rafelski, Department of Physics, *The University of Arizona*

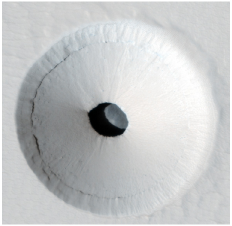


Are there compact ultra-dense objects (CUDOs) in the Universe? A few CUDO candidates are STRANGElet = fragments of neutron stars, dark matter bound objects, micro-black-hole. Could CUDOs have collided with solar system bodies and the Earth? If so: the high density of gravitating matter provides the distinct observable, the surface-penetrating puncture -- shot into, and even through, a moon or the planet. Only a fraction of the CUDO kinetic energy is damaging the entry/exit surface regions. For such exotic matter each planet or moon is a macroscopic detector accumulating signal over geological time scale. CUDOs maybe recognized by the coincident impactor hit with a singular high atmosphere volcanic eruption. Rocky objects in solar system accumulate impact scars for billions of years. Asteroid belt could harbor captured CUDOS.

12:15 Friday, December 15, 2017

CUDO=Compact UltraDense Object:

A new type of space bodies and meteors made of very dense matter: STRANGElet fragments of neutron stars, dark matter bound objects, micro-black-holes are a few discussed in literature. This talk discusses how their presence is manifest



Mars-hole Hirise#2560

kudos (from Greek kyddos, singular) =
honor; glory; acclaim; praise

kudo = back formation from kudos
construed as a plural

cud (Polish, pronounced c-ood) =
čudo (Slovak) = miracle

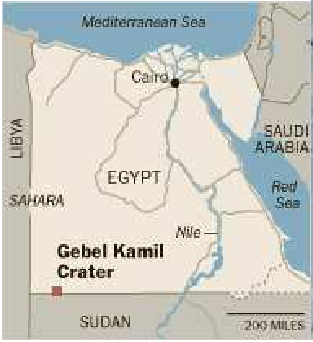
cudo (colloq. Polish) =
of surprising and exceptional character (gender related)

Nie ma CUDÓw, jest FIZIKA

Questions, questions:

1. Could CUDOs have collided with solar system bodies and the Earth? Yes. All (rocky) objects in the solar system are ‘detectors’ for CUDO impacts
2. What is CUDOs’ distinct observable? The surface-penetrating puncture and sometimes shot through. On rocky planets impact signatures are long-lived.
3. How is the ‘target’ damaged? Only a fraction of the kinetic energy damaging the solid surface on both entry/exit (partial stopping).
4. How can we distinguish CUDO from normal geological activity? Shot across the body creates a high energy high atmospheric eruption with specific signature on Earth. Old ‘t’ CUDO impacts look like no impactor craters, exits like hot spots or/and no explosion volcano.
5. Are there (self-interacting) dark matter meteor and asteroid-like bodies in the Universe? Maybe – will describe fascinating possibilities.

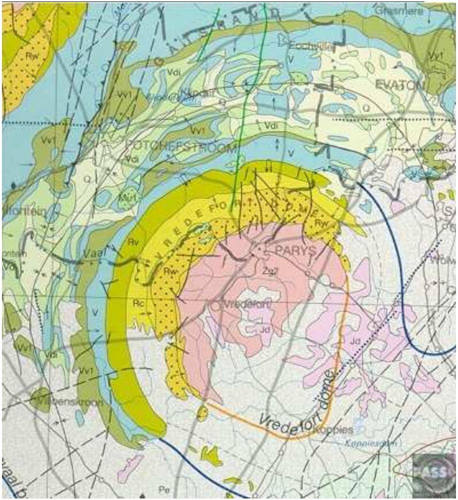
Normal meteor impact: visible impactor



Iron-nickel (20%) Gebel-Kamil: $22^0$01'06"N, $26^0$05'16"E East Uweinat Desert, Egypt: 44.8m in diameter, 15.8m deep meteorite crater: 1600 kg of iron meteorite shrapnel, 3400 kg >10 g pieces remained today. Upon hypervelocity impact, the 1.3 meters wide 5 to 10 tons meteorite was disrupted into thousands of fragments located up to 200 m from the crater rim, largest known fragment 83 kg. Dated to about 4,500 years, explored first 2009/10. A possible source of Egypt-Pharaoh Iron.

Where is the Meteorite that made the Arizona ‘Barringer’ Crater?

This is about 1 mile wide and 570 ft deep recent (50,000y old) crater where many tourists in Arizona visit. 110 years ago Daniel Barringer searched to profit from what he expected to be 2.510^6 tons of iron-nickel content of the meteorite. See what was found: a few (3!) meteorite fragments found in riverbeds many miles away. Short of a space ship crash site, of which remains were carefully removed, what is the causes for this gigantic hole in the ground? There are many other “missing meteorite” impacts



4.2. Where is the Meteorite?

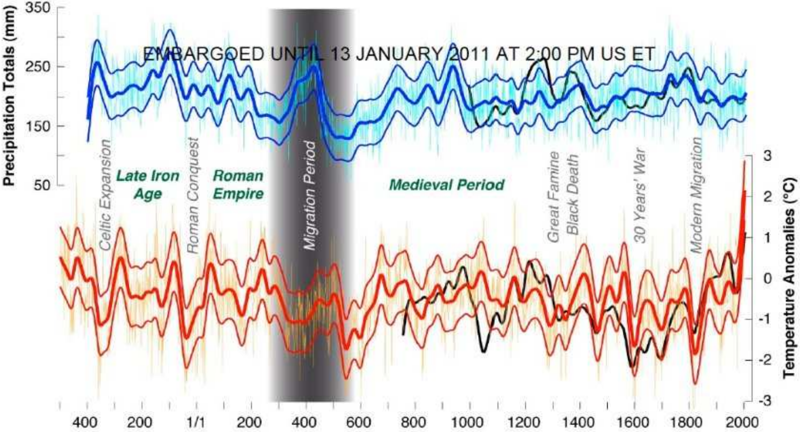
It is generally agreed now that the SIC was generated by a meteorite impact, and yet little evidence has been found of the signature of the impacting body. Highly siderophile elements (primarily PGE and particularly Ir) are a sensitive indicator of meteoritic influx (Peucker-Ehrenbrink and Ravizza, 2000) and impact (Evans et al., 1993). Siderophile element analysis has been outstandingly successful in identification of the world-wide chondritic signature of impact at the Cretaceous–Tertiary boundary (Ganapathy, 1980; Kastner et al., 1984; Evans et al., 1993), but this achievement has distracted attention from puzzling results at impact craters recognized by other criteria. Melt rocks from smaller craters often carry a signature of the impactor as, for example, at the 8.5 km Wanapitei Lake crater (Wolf et al., 1980; Grieve and Ber, 1994). In craters larger than ca. 30 km diam., however, melt rocks often show little or no PGE enrichment as at the 70 km Manicouagan, Quebec crater (Wolf et al., 1980). Nevertheless, the size distinction is not always clearcut since small craters such as the 1.8 km diameter Lonar, India, crater may be found with no meteoritic signature (Morgan, 1978), whereas the ≈70 km Morokweng, South Africa, crater has impact melts containing large amounts of siderophiles (Koeberl et al., 1997; Reimold and Koeberl, 1999).

Citation from Morgan et al 2003

Sudbury, Canada: Vredefort, South Africa; major mining districts of the world, where “something” called an impact seems to have pulled from the depth the Earth siderophile metals.

AD 536 Event

...is hotly contested: a comet or a giant volcano eruption (not found). The 6-month (time measurement resolution) dual event coincidence has probability 10^{-3}. Can be explained by dressed CUDO puncture and associated transport of material into upper atmosphere. Further milder weather fluctuations are also not well understood, see e.g. 1465 →



10 October 1465 Event

The massive volcano that scientists can't

BBC
By Zaria Gorvett
3 July 2017

It was the biggest eruption for 700 years but scientists still can't find the volcano responsible.

It was 10 October 1465 – the day of the hotly anticipated wedding of King Alfonso II of Naples. He was set to marry the sophisticated Ippolita Maria Sforza, a noblewoman from Milan, in a lavish ceremony.

Though it was the middle of the day, the Sun had **turned a deep azure**, plunging the city into eerie darkness.

This was just the beginning. In the months that followed, European weather went haywire. In Germany, it rained so heavily that corpses surfaced in cemeteries. In the town of Thorn, Poland, the inhabitants took to travelling the streets by boat. In the unrelenting rain, the castle cellars of Teutonic knights were flooded and whole villages were swept away.

Four years later, Europe was hit by a mini ice age.

The thing is, scientists can't find the volcano that did it. What's going on?

... produced an ash cloud which enveloped the Earth and led to the coolest decade for centuries.

“ *This is a true geological mystery, which has left geologists scratching their heads for decades*

That the ‘unknown eruption’ happened is undisputed – like most mega-eruptions, it vapourised vast quantities of sulphur-rich rock, which was blasted into the atmosphere and eventually snowed down on the poles as sulphuric acid. There it was locked into the ice, forming part of a natural record of geological activity that spans millennia. There's no other event capable of doing this, short of an asteroid impact.

High Density ($\times 10^{15+}$) = Strongly Interacting Gravity

We only turn the following 4 pages, those interested please consult these references:

Compact ultradense matter impactors
JR, Lance Labun, and Jeremiah Birrell, Phys.Rev.Lett. 110 (2013) 111102
http://prl.aps.org/abstract/PRL/v110/i11/e111102

Compact Ultradense Objects in the Solar System
JR, Christopher Dietl, LL; Acta Phys.Polon. B43 (2012) 12, 2251-2260
http://th-www.if.uj.edu.pl/acta/vol43/abs/v43p2251.htm

Planetary Impacts by Clustered Quark Matter Strangelets
LL and JR, Acta Phys.Polon.Supp. 5 (2012) 381-386
http://dx.doi.org/10.5506/APhysPolBSupp.5.381

Collisions: a) Tidal Forces

in PRL

Consider CUDO passing through normal density matter

Matter disrupted due to differential acceleration

$$a(r - L/2) - a(r + L/2) = a_{\rm tidal} = \frac{2GML}{r^3}$$

To compromise structural integrity,

$$\text{gravitational pressure} > \text{compressional strength}$$

$$\frac{F_{\rm tidal}}{\rm area} = \rho\, L\, a_{\rm tidal} > \rho\, c_s^2 \;\; \text{(bulk modulus)}$$

$\Rightarrow$ Material fails somewhere within Fracture length

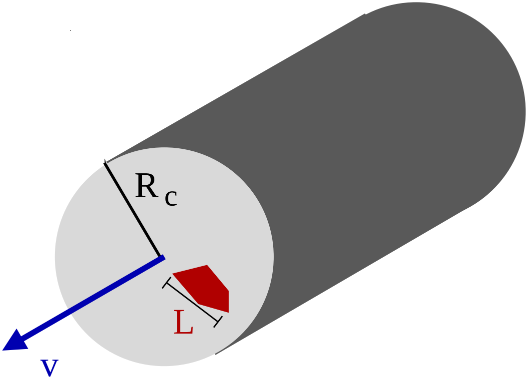
$$\frac{L}{R_c} = \sqrt{2}\frac{c_s}{v}\left(\frac{r}{R_c}\right)^{3/2}$$

$c_s =$ Bulk sound speed   Gravitational Capture radius $R_c := \frac{2GM}{v^2}$

Collisions: b) Fracture Length and Capture radius

Length scale: Gravitational capture radius $R_c = \frac{2GM}{v^2}$

$r < R_c$ material accreted to passing CUDO
$r > R_c$ material pulled in direction of motion, but left behind



In solid medium, material must be broken into pieces small enough to accrete

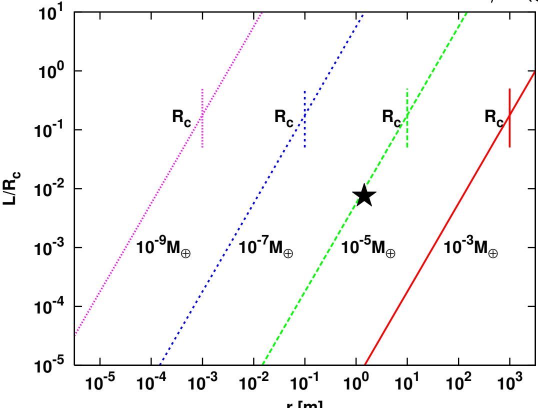
$$\frac{L}{R_c} = \sqrt{2}\frac{c_s}{v}\left(\frac{r}{R_c}\right)^{3/2} < 1$$

sound speed c_s representing bulk modulus (strength) of medium

Collisions: c) Accretion

CUDO velocity

- $v \sim 40\,\mathrm{km/s}$ (co-moving near solar system)
- $v \sim 200\,\mathrm{km/s}$ (galactic halo population)



Strip material from target:

$$\frac{L}{R_c} = \sqrt{2}\frac{c_s}{v}\left(\frac{r}{R_c}\right)^{3/2} < 1$$

Earth mantle: $c_s \simeq 8\,\mathrm{km/s}$

Example: $10^{-5} M_{\mathrm{Earth}}$

$R = 1\,\mathrm{m}$

$r < R_c$ material separated from bulk and accreted to CUDO

$r > R_c$ material pulled in direction of motion, but left behind

Collisions: d) Stopping, Other Characteristics

Entrainment of Material

Captured matter acquires CUDO velocity $\Rightarrow$ reduces kinetic energy

$\frac{\Delta E}{E} = 0.01 \left(\frac{40\,\mathrm{km/s}}{v}\right)^4 \frac{M}{M_{\mathrm{Earth}}}$ Objects $M < 10^{-4} M_{\mathrm{Earth}}$ not stopped

$\Rightarrow$ Two surface punctures! Entry and Exit signatures

Drag from Normal matter interactions

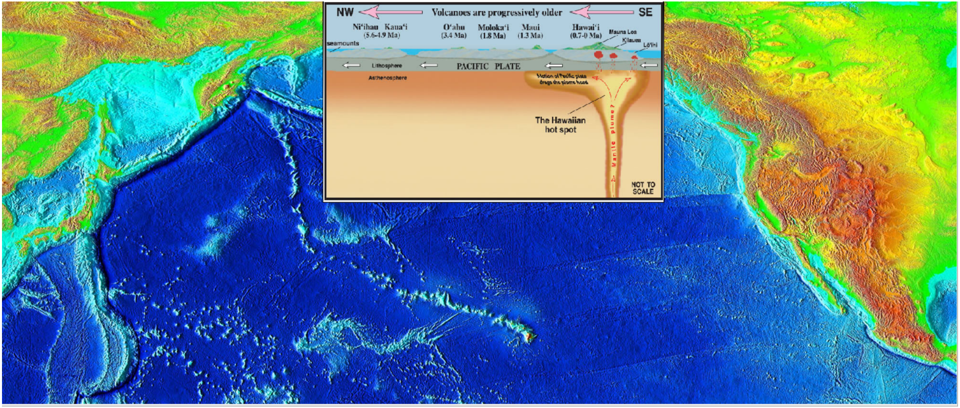
- Molten $T \sim 10^5\,\mathrm{K}$ shocked material
- Mixing of nearby entrained and nearly-entrained material

Pulling debris stream along behind CUDO

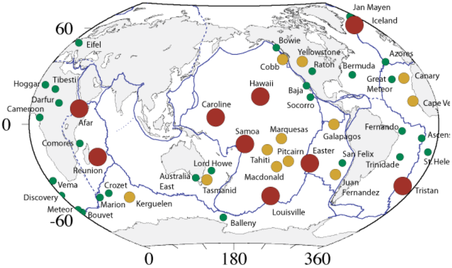
- Matter from previous collisions can “dress” CUDO,
  giving appearance of normal (but overdense) meteor
- Fraction remains bound to impacted planet,
  but re-distributed inside and above surface

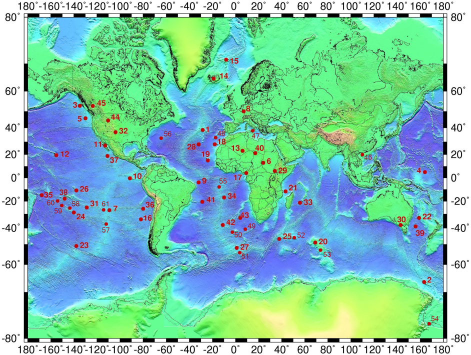
Earth puncture could leave a lasting damage that cures slowly

Hawaii is a ‘hot-spot’: the central pacific plate moving NW over the deep hot spot giving birth to chain of 20+ islands (edge from India hitting Asia!)



Hotspot=Mantleplume? =Shot-In/Out?





Global distribution of the 61 hotspots listed in `https://en.wikipedia.org/wiki/Hotspot_(geology)`; Eurasian Plate:
Eifel hotspot (8) $50^0$12'N $6^0$42'E, w= 1 az= $082^0 \pm 8^0$ rate= 12 $\pm$2 mm/yr
Iceland hotspot (14) $64^0$24'N $17^0$18'W Azores hotspot (1) $37^0$54'N $26^0$00'W
Jan Mayen hotspot (15) 71^0N 9^0W Hainan hotspot (46) 20^0N 110^0E, az= $000^0 \pm 15^0$
`http://www.mantleplumes.org/Hawaii.html`: The Emperor and Hawaiian Volcanic Chains: How well do they fit the plume hypothesis? by G. R. Foulger & Don L. Anderson

Hot Spots provide lasting Earth reference frame

The Geological Society of America
Special Paper 430 2007

Plate velocities in the hotspot reference frame

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We present a table giving the "present-day" (average over most recent ~5 m.y.) azimuths of tracks for fifty-seven hotspots, distributed on all major plates. Estimates of the azimuth errors and the present-day rates for those tracks with age control are also given. An electronic supplement contains a discussion of each track and references to the data sources. Using this table, the best global solution for plates moving in a fixed hotspot reference frame has the Pacific plate rotating about a pole at 59.33°N, 85.10°W with a rate that gives a velocity at this pole's equator of 89.20 mm/yr (–0.8029 °/m.y.). Errors in this pole location and rate are on the order of ±2°N, ±4°W, and ±3 mm/yr, respectively. The motions of other plates are related to this through the NUVEL-1A model.

Have you been to a Hot Spot?

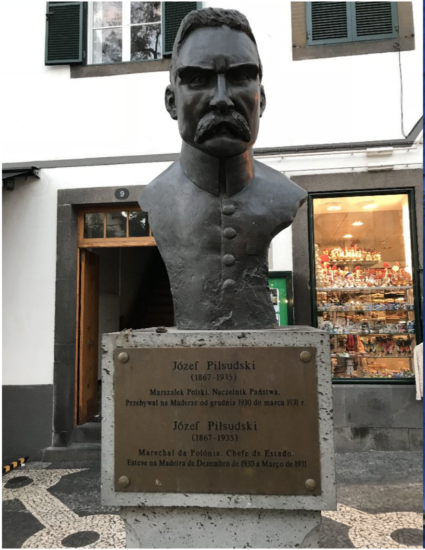
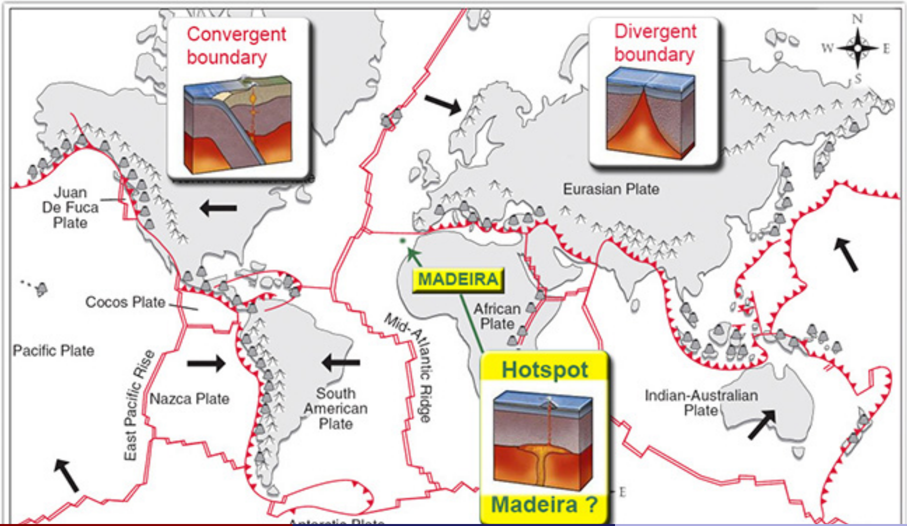


Photo by Prof. Dr. José Luis da Silva, University of Madeira

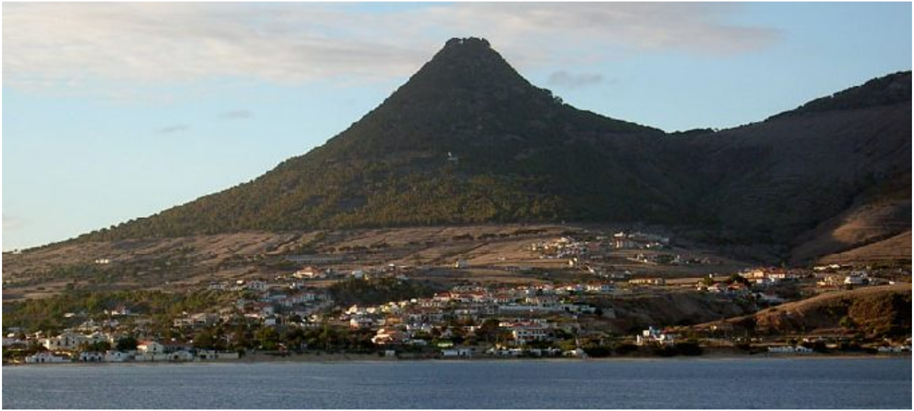
Islands formed between 5-15 million years ago

Madeira Island is top of a massive shield volcano that rises about 6 km from the floor of the Atlantic Ocean well away from the edge of African plate and Euroasian plate – it is a popular and geological hot-spot.



In my experience this is worth a CUDO trip

Where CUDO? Visit the oldest Island: Porto Santo



Two CUDO structure candidates

1. Stable fragments of nuclear matter called strangelets
2. Dark matter starlets (self-interacting DM or not)

CUDO matter Example: Strangelets: *uds*-symmetric matter in bulk

Strangelet = piece of $n_u \simeq n_d \simeq n_s$ matter, large baryon number A

Simple argument for (meta)stability

Chemical equilibrium:

$$\mu_d = \mu_u = \mu_s$$

Charge neutrality:

$$\frac{2}{3}n_u - \frac{1}{3}n_d - \frac{1}{3}n_s = 0$$

Compute thermodynamic potentials $\Omega_{u,d} = -\frac{\mu_{u,d}^4}{4\pi^2}$

with massive strange quark $m_s > 0$

$$\Omega_s = -\frac{\mu_s^4}{4\pi^2}\left(\sqrt{1-x^2}(1-\frac{5}{2}x^2) + \frac{3}{2}x^4\ln(x^{-1} + \sqrt{x^{-2}-1})\right) \quad x = m_s/\mu_s$$

Third fermi sea reduces Energy/baryon: $\frac{E/A(3\text{ flavors})}{E/A(2\text{ flavors})} < 1$

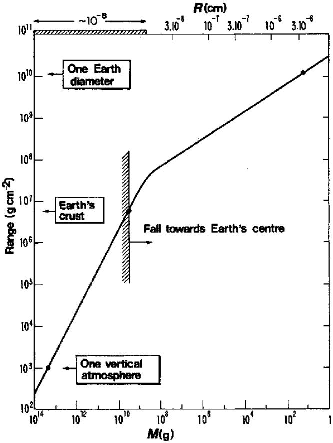
Strangelet meteorites= 'Nuclearites' considered before:

CUDO impacts on Earth have been considered before:

de Rujula & Glashow, Nature (1984) Proposed searching for

1. tracks preserved in mica
2. visible light emission
3. large scale scintillators
4. Seismic waves

continued: Herrin et al, PRD, **53** (1996) & **73** (2006), AMS (ongoing), Lunar Soil Search, PRL (2009)



► all but (1) above require *real time* observation of impact, and we do not think this is realistic.

Sources of Strangelets

1. Cosmological

First order phase transition to hadronic vacuum [Witten,PRD,30(1984)]

Objects $A < 10^{55}$ evaporate at $T \simeq 50\,\mathrm{MeV}$ [Alcock & Farhi,PRD,32(1985)]

Strangeness enriched at surface $\rightarrow$ reduced emissivity of nucleons

$$** \ \text{Quasi-equilibrium } A \sim 10^{46} \Leftrightarrow M \simeq 10^{19}\,\mathrm{kg} = 10^{-5} M_{\mathrm{Earth}} \ **$$

[Madsen,PRD,34(1986) & 43(1991)]

- Large objects $A \gtrsim 10^{23}\Omega^3_{\mathrm{nug}} h^6 f_N^3$ consistent with BBN
- Quark matter in nuggets does not contribute to BBN limit on Ω_b

2. Strange stars

Collisions eject fragments [Madsen,JPG,28(2002) & Bauswein,PRL,103(2009)]

Example of Strangelet Mass and Size Scales

Strangelet = piece of $n_u \simeq n_d \simeq n_s$ matter, large baryon number A

Madsen astro-ph/9809032, astro-ph/0612740

$$10^{30} < A < 10^{56} \quad \Leftrightarrow \quad \begin{cases} 10^4\,\mathrm{kg} < M < 10^{29}\,\mathrm{kg} \\ 10^{-20} < M/M_{\mathrm{Earth}} < 10^5 \end{cases}$$

- Constant density: $M \sim R^3$
- Density scale set by nuclear length $R_{\mathrm{nuc}} \sim 1\,\mathrm{fm}$
  (10^5 reduction relative to normal matter atomic length $R_{\mathrm{atom}} \sim 1$Å)

Normal matter asteroid	SQM "asteroid"
$M \sim 10^{-5} M_{\mathrm{Earth}}$	$M \sim 10^{-5} M_{\mathrm{Earth}}$
$R \sim 100\,\mathrm{km}$	$R \sim 1\,\mathrm{m}$

Compactness and high density $\rho_{\mathrm{nuc}} \sim 10^{15} \rho_{\mathrm{atomic}}$ mean...

- gravity relevant in interactions: $g_{\mathrm{surf}} = \dfrac{GM}{R^2} = \dfrac{4\pi G}{3}\rho R$
- Matter cannot support a strangelet: "punctures the Earth"

[see e.g. DeRujula/Glashow, Nature,312(1984), Herrin et al,PRD,53(1996) & 73(2006)]

Dark Matter is Matter

From standard cosmology, fractions of **N**on-**B**aryonic and **B**aryonic gravitating matter show $4/5$ of gravitating matter not identified: ‘dark’

Bullet Cluster, Abell 520, etc show
– Separation of luminous matter and gravity source
$\Rightarrow$ evidence of independent dynamics
$\Rightarrow$ small self-interaction

Many candidate particles could mean *many components* of unseen ‘dark’ matter, some could cluster **form a halo of dark matter asteroids?**

Dark Matter Probably Self-Interacting

https://physics.aps.org/synopsis-for/10.1103/PhysRevLett.119.111102

Synopsis: Self-Interacting Dark Matter Scores Again

Dark matter that interacts with itself provides a better description of the speeds of stars in galaxies than dark matter that doesn't self-interact.

ESA/Hubble & NASA

Physics

September 13, 2017

Self-Interacting Dark Matter Can Explain Diverse Galactic Rotation Curves

Ayuki Kamada, Manoj Kaplinghat, Andrew B. Pace, and Hai-Bo Yu

Phys. Rev. Lett. 119, 111102 (2017)

Published September 13, 2017

Self-interacting dark matter—a hypothetical form of dark matter made of particles that interact with one another—is a problem fixer in cosmology. On galactic and smaller scales, it can fix discrepancies between observations and predictions of the standard cosmological model, which instead considers "cold" dark matter that doesn't interact with itself. And it does so while leaving intact the standard model's success on larger scales. Manoj Kaplinghat from the University of California at Irvine, Hai-Bo Yu from the University of California at Riverside, and colleagues now show that self-interacting dark matter can also explain the diversity of galaxy rotation curves—graphs of the speeds of stars in a galaxy versus their distance from the galaxy's center.

Primordial DM Meteor Possible – Qualitative Consideration

High mass/energy scale help with early-universe formation:

a)Becoming non-relativistic at an earlier time, dark matter has a density proportionally higher at the time when gravity can begin to work on local density fluctuations

b)CUDO comprises $10^{11} - 10^{19}$ fewer particles $\Rightarrow$ requires smaller correlation volume contributing

c)Dark particle-particle gravitational interaction $10^{6} - 10^{10}$ times larger.

d)Normal (SM) matter in same correlation volume easily ejected carrying away energy and angular momentum (Auger process)

High surface acceleration CUDOs stable against gravitational disruption (especially in collisions with normal matter objects) $\Rightarrow$ persist into present era

Maybe a new elementary particle

LIMITS ON DARK MATTER PARTICLE MASS

Beyond the standard model particles: mass limit pushed up by CERN-LHC and now electron dipole moment to 1000's of proton mass:

In most suggested extensions of the standard model, a measurable d_e implies the existence of heavy new particles with masses roughly proportional to $1/\sqrt{|d_e|}$. Their *CP*-violating interactions with electrons and other leptons could also account for the cosmological matter–antimatter asymmetry.

A d_e of 10^{-26} e·cm would have suggested that the new particles have masses of a few hundred GeV. That's precisely the energy scale of electroweak symmetry breaking, where SUSY models originally anticipated the appearance of "sleptons," supersymmetric boson partners of the leptons.

But now we learn that d_e is even smaller than 10^{-28} e·cm. "That's a very significant tightening of constraints on the new physics," says theorist Maxim Pospelov (University of Victoria, British Columbia). "It seems to disengage the anticipated *CP*-violating leptonic interactions from the electroweak scale. It pushes the new particles firmly into multi-TeV territory inaccessible to the next generation of sub-TeV electron–positron colliders." Their discovery at CERN's Large Hadron Collider remains an open question.

REFERENCES

GO TO SECTION...

1. J. J. Hudson *et al.*, *Nature* **473**, 493 (2011). http://dx.doi.org/10.1038/nature10104
2. J. Baron *et al.* (ACME collaboration), *Science* **343**, 269 (2014). http://dx.doi.org/10.1126/science.1248213

DOI: http://dx.doi.org/10.1063/PT.3.2334

We consider two types of DM CUDOs

Analogous to compact objects composed of SM matter:

Narain et al, PRD **74** (2006), Dietl et al, PLB **709** (2012)

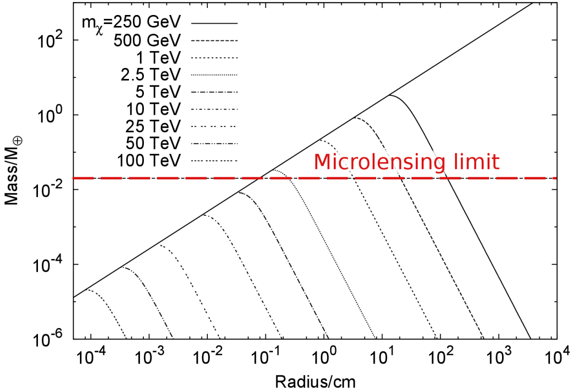
Fundamental fermion	Composite
mass $m_\chi \gtrsim 1\,\mathrm{TeV}$	**B**ag model vacuum pressure $B \gtrsim (1\,\mathrm{TeV})^4$
supported by pressure of degenerate fermi gas	self-bound by interactions
analogy to white dwarf, neutron star	analogy to quark-star, strangelet

Solve for equilibrium configuration in Oppenheimer-Volkoff equations

TeV-scale Fundamental Fermi particle

$M_{\oplus} = 6\ 10^{24}$ kg
$= $ Earth mass

$M_{\max} \propto m_{\chi}{}^{-2}$



★ upper end of curve are objects stable and robust in collisions

EROS Collaboration, Astron.Astrophys. **469** (2007)

Dietl et al, PLB **709** (2012)

Character of Gravit Bound Objects: Scaling Solution

If we have only m, M_{Pl} and need only 1 equation of state $p(\rho)$

Dimensionless...

1) pressure, density

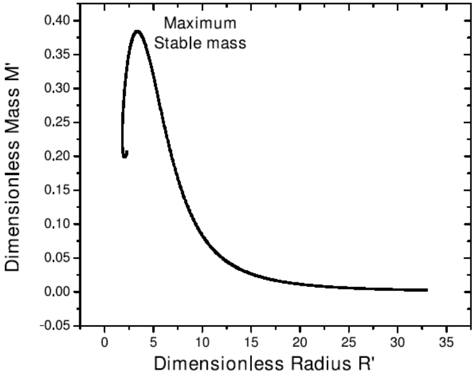
$$\widetilde{p}(\widetilde{\rho}) = m^{-4}\, p\big(\rho m^{-4}\big)$$

2) total mass of solution

$$\widetilde{M} = M\frac{m^2}{M_{\mathrm{Pl}}^3}$$

3) surface radius of solution

$$\widetilde{R} = R\frac{m^2}{M_{\mathrm{Pl}}}$$



[Narain, Schaffner-Bielich, Mishutsin, PRD **74** (2006)]

TOV equations now dimensionless – Solve once!

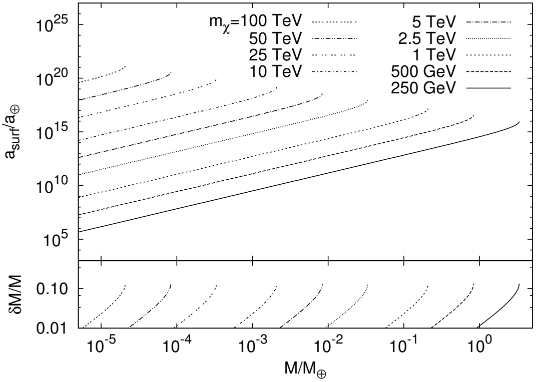
NOT the whole story: check stability against perturbation

Oppenheimer/Serber 1936

Gravitational Stability and Tidal Force

Compact: Size of object comparable to gradient of gravitational field

$\Rightarrow$ Tidal force important $\quad a_{\rm tidal} = \frac{2GM}{r^2}\frac{L}{r} = a_{\rm surf}\frac{R^2_{\rm surf}}{r^2}\frac{2L}{r}$



$a_\oplus = 9.8\mathrm{m/s}^2$
$= $ Earth surface

- Tidal acceleration pulls apart atoms in solids: $a_{\rm surf} > 3.5\ 10^{15} a_\oplus$

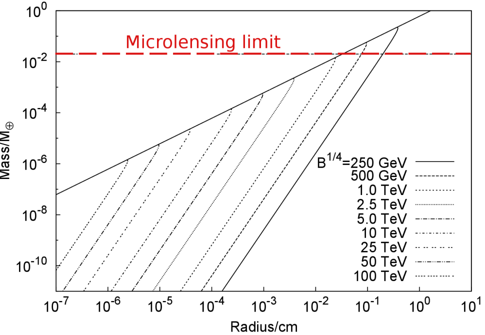
Dietl et al, PLB **709** (2012)

CUDOs not stopped by impact with normal density (visible) matter

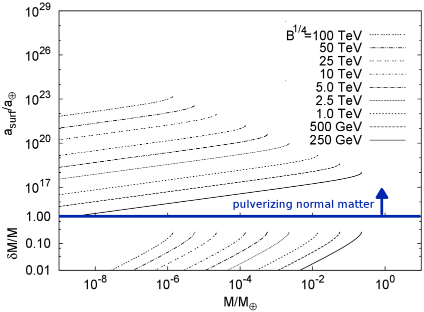
Composite with TeV confinement energy

$M_{\oplus} = 6\,10^{24}\ \mathrm{kg}$ = Earth mass

B = bag model vacuum pressure



Dietl et al, PLB **709** (2012)



$$M_{\max} \propto (B^{1/4})^{-2}$$

EROS Collaboration, Astron.Astrophys. **469** (2007)

Tidal force destructive for

$$a_{\rm surf} > 3.5\,10^{15} a_{\oplus}$$

Summary: Fundamental Fermi vs. Composite/Bag

Fundamental fermion	Composite particle
mass $m_\chi \gtrsim 1\ \mathrm{TeV}$	vacuum pressure $B \gtrsim (1\ \mathrm{TeV})^4$
$M_{\max} = 0.209 \left(\frac{1\ \mathrm{TeV}}{m_\chi}\right)^2 M_\oplus$	$M_{\max} = 0.014 \left(\frac{1\ \mathrm{TeV}}{B^{1/4}}\right)^2 M_\oplus$
$R = 0.809 \left(\frac{1\ \mathrm{TeV}}{m_\chi}\right)^2 \mathrm{cm}$	$R = 0.023 \left(\frac{1\ \mathrm{TeV}}{B^{1/4}}\right)^2\ \mathrm{cm}$

$$M_\oplus = 6\ 10^{24}\ \mathrm{kg} = \text{Earth's mass}$$

★ Due to high mass scale, common $M <$ Earth mass, $R < 1$ cm

$\Rightarrow$ Highly compact and not too heavy

Scaling solution $\Rightarrow$ gravitational binding also scales!

$\Rightarrow$ as stable as white dwarf/neutron star solutions with SM particles

Last: Is something ‘strange’ flying around?

On asteroids of high density

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Planetary and Space Science

journal homepage: www.elsevier.com/locate/pss

Density of asteroids

Planetary and Space Science 73 (2012) 98–118

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ARTICLE INFO

Article history:
Received 23 August 2011
Received in revised form
1 March 2012
Accepted 6 March 2012
Available online 3 April 2012

ABSTRACT

The small bodies of our solar system are the remnants of the early stages of planetary formation. A considerable amount of information regarding the processes that occurred during the accretion of the early planetesimals is still present among this population. A review of our current knowledge of the density of small bodies is presented here. Density is indeed a fundamental property for the understanding of their composition and internal structure. Intrinsic physical properties of small bodies are

Table 1
Compilation of the average mass (M) and volume-equivalent diameter (ϕ) estimates (see Appendixes A–C), and resulting bulk density (ρ) and macroporosity ($\mathcal{P}$) for 287 objects, with their associated uncertainties. For each object, the dynamical class is listed (Dyn.), together with the taxonomic class (Tax., for asteroids only) and associated meteorite (Met.). The density estimates are ranked A E, owing to the level of confidence at which they are determined (see text). Unrealistic density estimates are marked with a cross (✗) and uncertainties on the macroporosity larger than 100% are listed as ∞. **References**: (1) Clark et al. (2010), (2) Ockert-Bell et al. (2010), and (3) Fornasier et al. (2011). An electronic version of this table is available at https://genoide.imcce.fr/tools/public/densities.php.

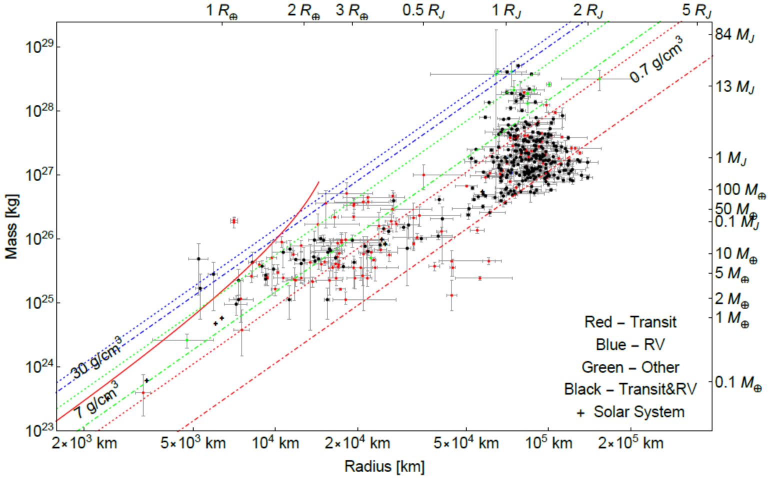
Designation		Classification			Masses (kg)			Diameter (km)			Density		Porosity		Rank
#	Name	Dyn.	Tax.	Met.	M	δM	Fig.	ϕ	$\delta\phi$	Fig.	ρ	$\delta\rho$	$\mathcal{P}$	$\delta\mathcal{P}$	
1	Ceres	MBA	C	CM	9.44	$\pm 0.06 \times 10^{20}$	A.1	944.79	± 22.99	B.1	2.13	± 0.15	4	± 1	A
2	Pallas	MBA	B	CK[1]	2.04	$\pm 0.04 \times 10^{20}$	A.2	514.41	± 19.12	B.2	2.86	± 0.32	0	± 11	A
3	Juno	MBA	Sq	OC	2.73	$\pm 0.29 \times 10^{19}$	A.3	241.79	± 10.58	B.3	3.68	± 0.62	0	± 16	A
4	Vesta	MBA	V	HED	2.63	$\pm 0.05 \times 10^{20}$	A.4	519.33	± 6.84	B.4	3.58	± 0.15	0	± 4	A
5	Astraea	MBA	S	OC	2.64	$\pm 0.44 \times 10^{18}$	A.5	113.41	± 3.53	B.5	3.45	± 0.66	0	± 19	B
33	Polyhymnia	MBA	S	OC	6.20	$\pm 0.74 \times 10^{18}$		53.98	± 0.91		75.28	± 9.71	0	± 12	✗
34	Circe	MBA	Ch	CM	3.66	$\pm 0.03 \times 10^{18}$	A.31	113.02	± 4.90	B.32	4.83	± 0.63	0	± 13	✗

33 Polyhymnia: $\rho = 75.28 \pm 9.71$g/cc. Other with high probability above $\rho_{\mathrm{Au-U}} = 20$g/cc: 152 Atala 47.92$\pm$13.10g/cc; & 675 Ludmilla 73.99$\pm$15.05 – worth exploring/mining in coming decades . . . not public for commercial reasons.

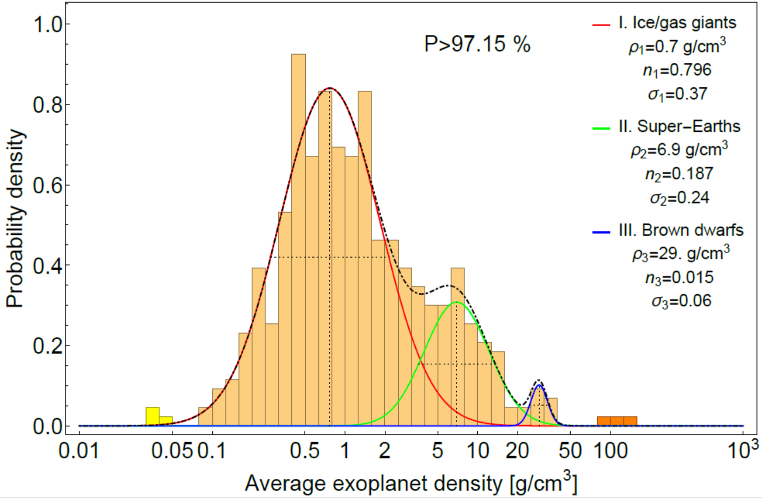
On exoplanets of high density

arXiv:1612.03556v1 [astro-ph.EP] 12 Dec 2016

Classification of exoplanets according to density



On exoplanets of high density

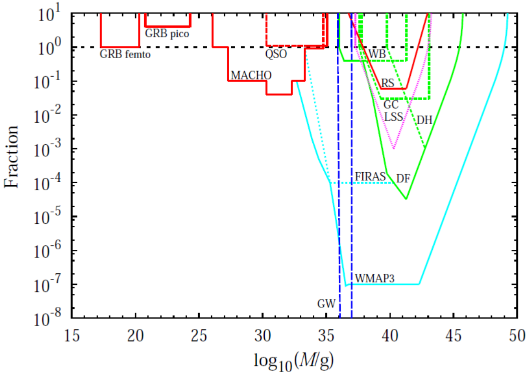


Microlensing constraints on invisible clumps of matter

MACHOs = **M**assive **C**ompact **H**alo **O**bjects
sought by gravitational microlensing surveys (MACHO, EROS, OGLE)

Examples

failed stars (brown dwarfs)
supermassive planets
neutrino stars
Bose stars
black holes



B.J. Carr et al PRD **81** 04019 (2010);
$M_{\rm Sun} = 2 \times 10^{33}$g, $M_{\rm Earth} == 6 \times 10^{27}$g,

Update of Carr's results

of Kepler Source Microlensing Data

Kim Griest, Agnieszka M. Cieplak, and Matthew J. Lehner
Phys. Rev. Lett. **111**, 181302 – Published 31 October 2013

ABSTRACT

We present new limits on the allowed masses of a dark matter (DM) halo consisting of primordial black holes (PBH) (or any other massive compact halo object). We analyze two years of data from the Kepler satellite, searching for short-duration bumps caused by gravitational microlensing. After removing background events consisting of variable stars, flare events, and comets or asteroids moving through the Kepler field, we find no microlensing candidates. We measure the efficiency of our selection criteria by adding millions of simulated microlensing lensing events into the Kepler light curves. We find that PBH DM with masses in the range $2 \times 10^{-9} M_{\odot}$ to $10^{-7} M_{\odot}$ cannot make up the entirety of the DM in the Milky Way. At the low-mass end, this decreases the allowed mass range by more than an order of magnitude.

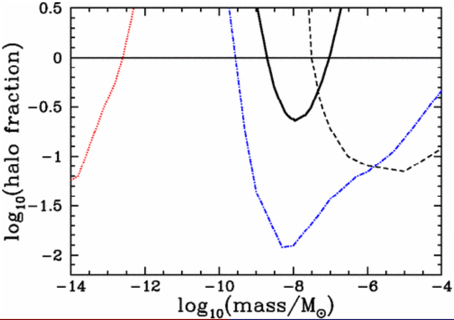
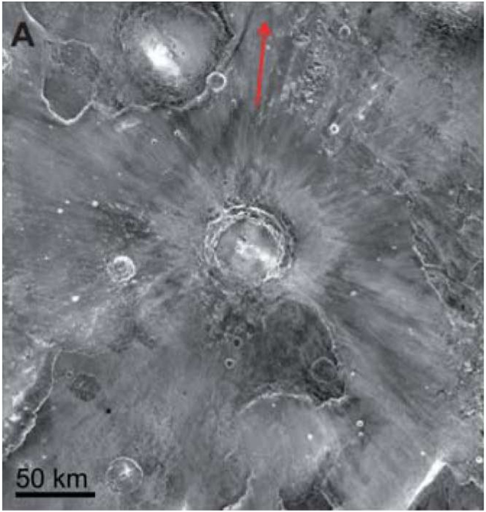


Figure 2

Upper limits (95% C.L.) on PBH DM from nonobservation of PBH microlensing in two years of Kepler data. The solid black line is our new limit, the dashed black line is the previous best limit (Ref. 11), the blue dot-dash line is the theoretical limit from Paper II, and the red dotted line is the femtolensing limit from Ref. 32. The black horizontal line indicates a halo density of $0.3\ \mathrm{GeV\ cm^{-3}}$.

Instead of conclusions - a few riddles in pictures

Mojave Crater on Mars, source of all Mars impactors on Earth.
Candidate for CUDO exit. Note rayed structure.

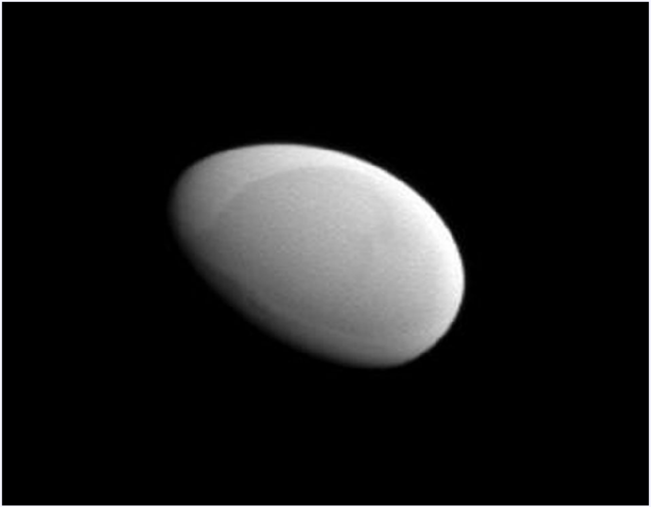


Do you like diamonds?

Kimberley Open pit mine - made by a 'supersonic gas ejection'

Discover the cosmos! Each day a different image or photograph of our fascinating universe is featured, along with a brief explanation written by a professional astronomer.

2012 November 6

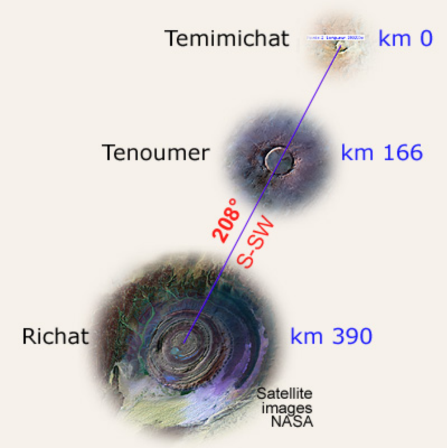


Methone: Smooth Egg Moon of Saturn
Image Credit: Cassini Imaging Team, ISS, JPL, ESA, NASA

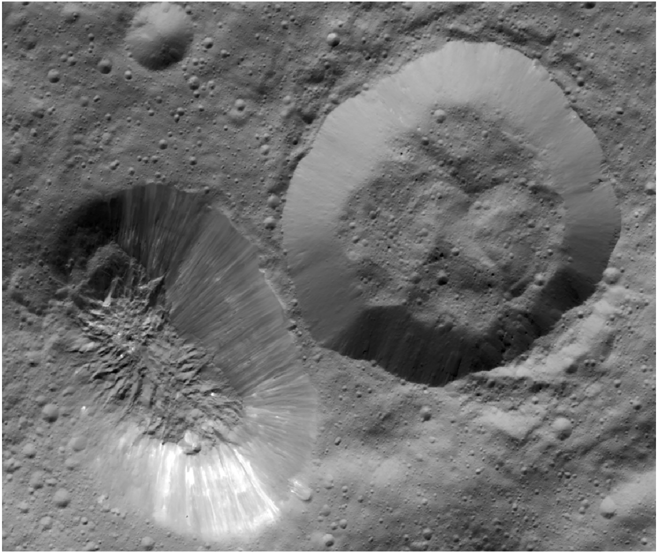
Explanation: Why is this moon shaped like a smooth egg? The robotic Cassini spacecraft completed the first flyby ever of Saturn's small moon Methone in May and discovered that the moon has no obvious craters. Craters, usually caused by impacts, have been seen on every moon, asteroid, and comet nucleus ever imaged in detail -- until now. Even the Earth and Titan have craters. The smoothness and egg like shape of the 3 kilometer diameter moon might be caused by Methone's surface being able to shift -- something that might occur were the moon coated by a deep pile of sub-visual rubble. If so, the most similar objects in our Solar System would include Saturn's moons Telesto, Pandora, Calypso, as well as asteroid Itokawa, all of which show sections that are unusually smooth. Methone is not entirely featureless, though, as some surface sections appear darker than others. Although flybys of Methone are difficult, interest in the nature and history of this unusual moon is sure to continue.

Kenntucky Mamouth Cave: “Center-of-the-Earth”

Richat three impacts
Surface grazing CUDOs bounce like stone on water?

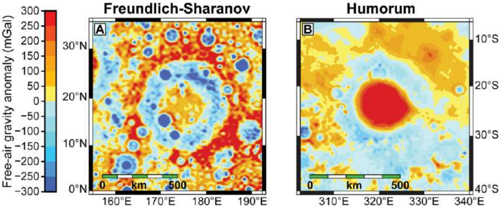


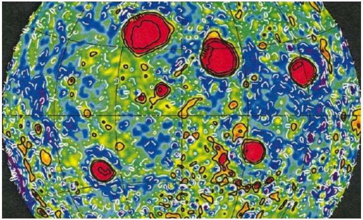
Ahuna Mons anomalie on CERES: Man made mining pit or CUDO uplifted & turned fragment?

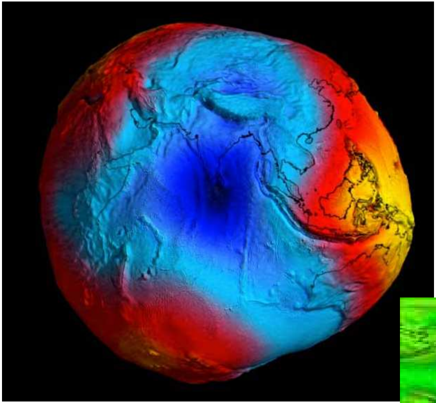


Remote Sensing: MASCONS

MASCONs (mass concentration): Lunar mascons appear due to old impacts, but how such strong anomalies were created/preserved is debated. Is excess mass due to denser lava material filling the crater or due to upwelling of denser iron-rich mantle material to the crust? Mascons make the Moon the most gravitationally lumpy body known in the solar system, anomaly is 0.5%. Mascons also exist on Mars, none have been found on Venus or Earth – as of 2001; those two larger planets, however, have had an active tectonic (geological) past that has drawn their crusts down into their interiors several times in the past few billion years, homogenizing the distribution of mass. Forward to 2012/2013: High-resolution gravity GRAIL mission show that gravitational fields resembling a bull's-eye pattern: a center of strong, or positive, gravity surrounded by alternating rings of negative and positive gravity.
http://web.mit.edu/newsoffice/2013/an-answer-to-why-lunar-gravity-is-so-uneven-0530.html







What made this?

The **G**ravity Field and Steady-State **O**cean **C**irculation **E**xplorer (GOCE) produced geoid view of Earth showing a spherical impact-like depression South-West off the India coast.

In India there is a large lava flow region called “Deccan Traps” dating to 65 million years ago - was this the Dinosaur killer? Geologists argue about that.