Something STRANGE is flying around

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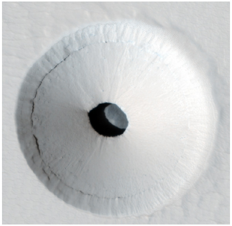
CUDO=Compact UltraDense Object:

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)

Some of our arguments are published

Work by other groups will be cited in text

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

Properties of Dark Compact Ultra Dense Objects
Christopher Dietl, LL, and JR, Phys.Lett. B709 (2012) 123-127
http://dx.doi.org/10.1016/j.physletb.2012.02.015

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

Traveling Through the Universe: Back in Time to the Quark-Gluon Plasma Era
JRi and Jeremiah Birrell, J. Phys. G in press.
http://arxiv.org/abs/arXiv:1311.0075 [nucl-th]

Are there‘dark’ matter meteor and asteroid-like bodies in the Universe?

Could CUDOs have collided with solar system bodies and the Earth?

CUDOs’ high density of gravitating matter provides the distinct observable, the surface-penetrating puncture: shot through

Only a fraction of the kinetic energy damaging the solid surface.

One slide on asteroids of high density

Contents lists available at SciVerse ScienceDirect

Planetary and Space Science

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ELSEVIER

Density of asteroids

Planetary and Space Science 73 (2012) 98–118

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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±13.10g/cc; & 675 Ludmilla 73.99±15.05 – worth exploring/mining in coming decades . . . not public for commercial reasons.

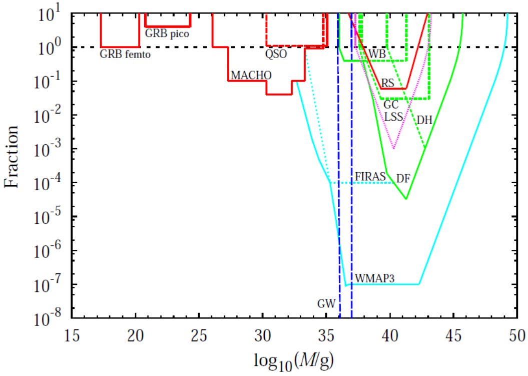
Impacts: THE EARTH, ALL ROCKY PLANETS ARE DETECTORS

1. All objects in solar system are detectors for impacts
   (rate enhanced by gravitational focusing)
2. On rocky planets impact signatures are long-lived
   $\Rightarrow$ Detectors integrate over geologic timescales (Gyr)
3. Easy to access signatures: impacts on Earth! However, these impacts are also geologically unstable and subject to weathering. Only recent events carry clear signatures and can be discussed. May offer guidance what to look for at a distance

Planetary mass objects not withing the resolution of direct astronomical observation can be constrained by gravitational microlensing, [B.J. Carr,PRD,81 04019 (2010)]

Microlensing constraints on invisible clumps of matter

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



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

Examples

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

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.

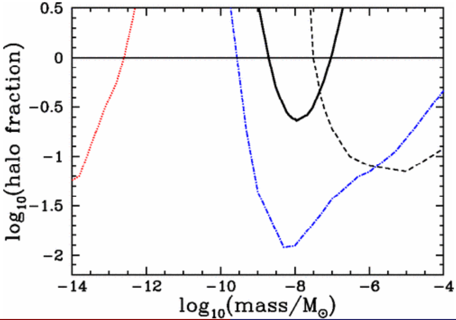


Figure 2

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 $0.3\ \mathrm{GeV\ cm^{-3}}$.

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: $\frac{E/A(3\text{ flavors})}{E/A(2\text{ flavors})} < 1$

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)]

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 <u>not</u> contribute to BBN limit on Ω_b

2. Strange stars

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

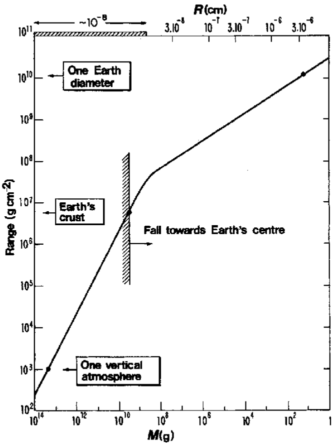
Strangelet meteorites= 'Nuclearites' considered before:

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

What happens for heavier impactors?

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

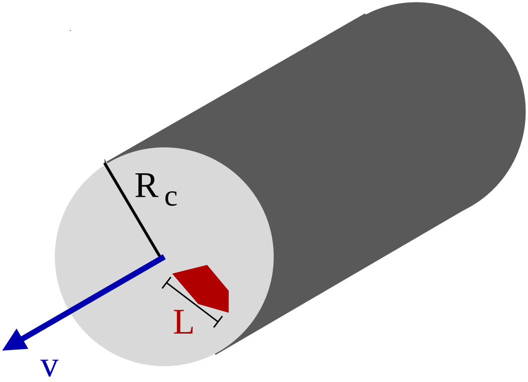
$$\frac{L}{R_c} = \sqrt{2}\frac{c_s}{v}\left(\frac{r}{R_c}\right)^{3/2}$$

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

Collisions: b) Fracture Length and Capture radius

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

$r < R_c$ 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

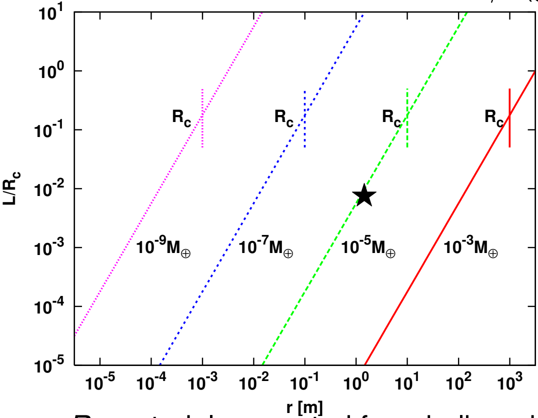
$$\frac{L}{R_c} = \sqrt{2}\frac{c_s}{v}\left(\frac{r}{R_c}\right)^{3/2} < 1$$

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

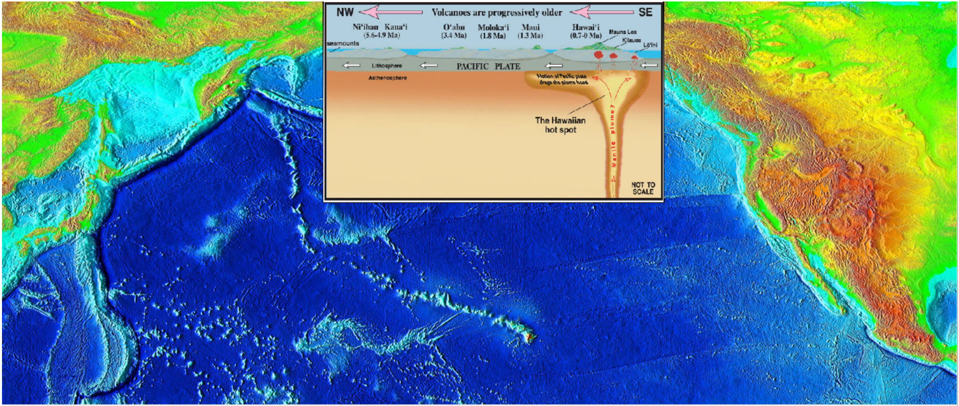
- Matter from previous collisions can “dress” CUDO,
  giving appearance of normal (but overdense) meteor
- Fraction remains bound to impacted planet,
  but re-distributed inside and above surface

STRANGElet impacts offer possible explanation of

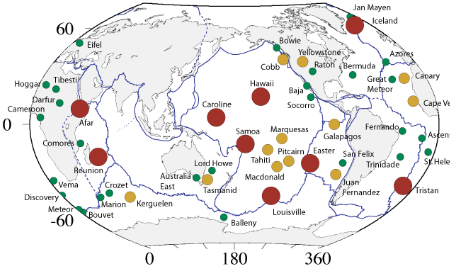
1. Hot spots;
2. Impacts without impactors;
3. Comet Ison survives (2013) grazing collision; Comet Lovejoy (2011/2) C/2011 W3 grazes within Roche limit the solar corona and survives the passage only to explode later
4. 10 million tons of spherules 12.8kyears ago altered climate and are not of ‘conventional origin
5. Climatic excursion 536-545A.D. Ice Cores indicate ‘explosive’ volcanic origin, no impact wound and upper atmosphere material needed was initially interpreted as a 500m cometary impact.

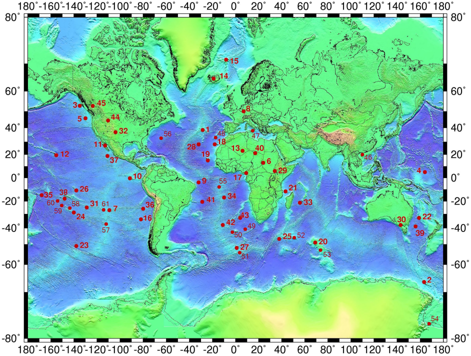
and much more as we will see in quick slide show at the end of talk (in lieu of summary).

1) Hawaii is a known hot-spot (geology and tourism experts agree)



Hotspot=Mantleplume? =Shot-In/Out?





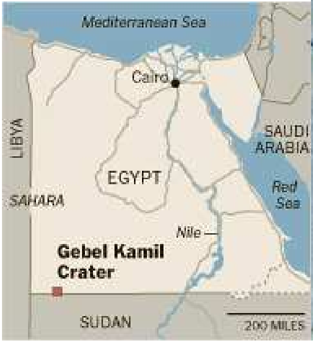
Global distribution of the 61 hotspots listed in `https://en.wikipedia.org/wiki/Hotspot_(geology)`; Eurasian Plate:
Eifel hotspot (8) 50^{0}12'N 6^{0}42'E, w= 1 az= 082^0 $\pm$8^0 rate= 12 $\pm$2 mm/yr
Iceland hotspot (14) 64^{0}24'N 17^{0}18'W Azores hotspot (1) 37^{0}54'N 26^{0}00'W
Jan Mayen hotspot (15) 71^{0}N 9^{0}W Hainan hotspot (46) 20^{0}N 110^{0}E, 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

Where is the Meteorite that made the 'Barringer" Meteor Crater?

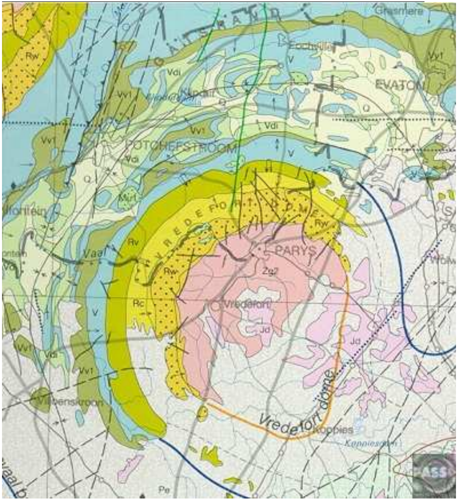
This is about 1 mile wide and 570 ft deep recent (50,000y old) crater where many tourists in Arizona visit. 110 years ago Daniel Barringer searched to profit from what he expected to be 2.510^6 tons of iron-nickel content of the meteorite. See what was found: a few (3!) meteorite fragments found in riverbeds 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? Normal impact example: Egypt-Pharaoh Iron came from a recently rediscovered Kamil crater in the South-West Egypt border desert.

There are many other missing meteorite impacts

Comparison: Normal impact with visible impactor



Iron meteorite Gebel-Kamil: 22^{0}01'06"N, 26^{0}05'16"E East Uweinat Desert, Egypt: A total of about 1600 kg of iron meteorite shrapnel (thousands of pieces), ranging in mass from < 1 to 35,000 g, plus a single 83 kg individual completely covered with well developed regmaglypts, was found in and around the 45 m diameter (148 ft) Kamil impact crater by an Italian-Egyptian geophysical team in February 2009 and February 2010.



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.

Comet stability = a CUDO seed?

Examples: Comet Lovejoy C/2011 W3 (and similar ISON C/2012 S1)

The Astrophysical Journal, 757:127 (33pp), 2012 October 1 doi:10.1088/0004-637X/757/2/127

COMET C/2011 W3 (LOVEJOY): ORBIT DETERMINATION, OUTBURSTS, DISINTEGRATION OF NUCLEUS, DUST-TAIL MORPHOLOGY, AND RELATIONSHIP TO NEW CLUSTER OF BRIGHT SUNGRAZERS

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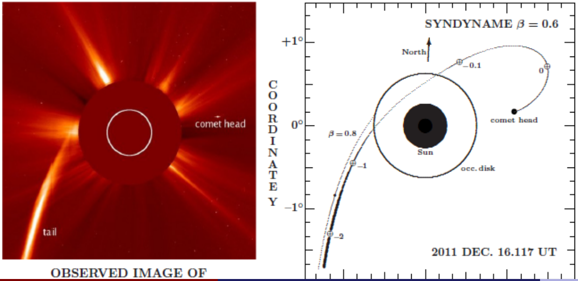
Received 2012 May 12; accepted 2012 July 30; published 2012 September 11

ABSTRACT

We describe the physical and orbital properties of C/2011 W3. After surviving perihelion passage, the comet was observed to undergo major physical changes. The permanent loss of the nuclear condensation and the formation of a narrow spine tail were observed first at Malargue, Argentina, on December 20 and then systematically at Siding Spring, Australia. The process of disintegration culminated with a terminal fragmentation event on December 17.6 UT. The postperihelion dust tail, observed for ~3 months, was the product of activity over <2 days. The

The Astrophysical Journal, 757:127 (33pp), 2012 October 1 Sekanina & Chodas

SOHO C2 IMAGE AND MODEL OF DUST TAIL OF C/2011 W3 ON DEC. 16



OBSERVED IMAGE OF

Spherules

10.1073/pnas.1301760110

Proceedings of National Academy of Sciences (US) PNAS June 4, 2013 vol. 110 no. 23 E2088-E2097

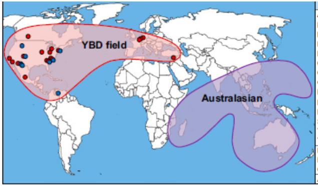
How did an impact distribute these spherules, that is the question here!

Significance

We present detailed geochemical and morphological analyses of nearly 700 spherules from 18 sites in support of a major cosmic impact at the onset of the Younger Dryas episode (12.8 ka). The impact distributed ~10 million tonnes of melted spherules over 50 million square kilometers on four continents. Origins of the spherules by volcanism, anthropogenesis, authigenesis, lightning, and meteoritic ablation are rejected on geochemical and morphological grounds. The spherules closely resemble known impact materials derived from surficial sediments melted at temperatures >2,200 °C. The spherules correlate with abundances of associated melt-glass, nanodiamonds, carbon spherules, aciniform carbon, charcoal, and iridium.

Evidence for deposition of 10 million tonnes of impact spherules across four continents 12,800 y ago

James H. Wittke[a], James C. Weaver[b], Ted E. Bunch[a,1], James P. Kennett[c], Douglas J. Kennett[d], Andrew M. T. Moore[e], Gordon C. Hillman[f], Kenneth B. Tankersley[g], Albert C. Goodyear[h], Christopher R. Moore[i], I. Randolph Daniel, Jr.[j], Jack H. Ray[k], Neal H. Lopinot[k], David Ferraro[l], Isabel Israde-Alcántara[m], James L. Bischoff[n], Paul S. DeCarli[o], Robert E. Hermes[p,2], Johan B. Kloosterman[q,2], Zsolt Revay[r], George A. Howard[s], David R. Kimbel[t], Gunther Kletetschka[u], Ladislav Nabelek[u,v], Carl P. Lipo[w], Sachiko Sakai[w], Allen West[x], and Richard B. Firestone[y]

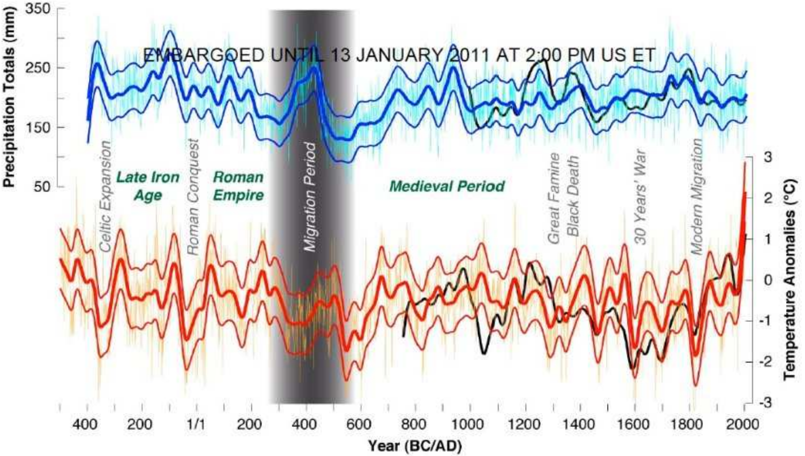


Site/Location	Details	Strat	Env	Setting
Arlington Cyn, CA	B,C,A,M	A	A	Coastal cyn
Barber Crk, NC	A	A,E	A	Relict dune
Big Eddy, MO	A	A	A	Flood-plain
Blackville, SC	--	A,E	I	Carolina bay
Blackwater, NM	B,C,A,M	A,L	A	Streambed
Chobot, ALB	B,C,A,M	A,L	A	Lakeshore
Cuitzeo, MEX	B,C,M	L	A	Lake bed
Gainey, MI	B,C,A,M	A,G	I	End-glacial
Kimbel Bay, NC	--	C,E	A	Carolina bay
Melrose, PA	--	C,G	I	End-glacial
Murray Spgs AZ	B,C,A,M	C,L	A	Streambed
Sheriden Cv, OH	B,C,A,M	C	A	Karst-cave
Talega, CA	B,A	A,C	I	Streambed
Topper, SC	A	A,C	I	River bank
Lingen, GER	B,C	E	A	Paleo-dunes
Lommel, BEL	B,CA	E	A	Paleo-dunes
Ommen, NED	B,C	E	A	Paleo-dunes
Abu Hureyra, SYR	B,C,A	A,E	I	Mound (tell)

Fig. 1. YDB impact field, based on data from 27 locations. In the YDB strewnfield (red), there are 18 YDB sites in this study (red dots; see table on *Right*). Eight independent studies have found spherules and/or scoria-like objects at nine additional sites (blue dots) located in Arizona, Montana, New Mexico, Maryland, South Carolina, Pennsylvania, Mexico, and Venezuela. The largest accepted impact strewnfield, the Australasian (purple), is shown for comparison with each strewnfield covering ~50 million square kilometers or ~10% of the planet. Table shows location of sites and lists site details (A, archeological material; B, black mat; C, charcoal; M, megafaunal remains, present either at the sampling location or in the vicinity). Also given are stratigraphic settings (Strat: A, alluvial; C, colluvial; E, eolian; G, glacial; and L, lacustrine) and relative physical stability of depositional paleoenvironments (Env: A, active, e.g., riverine, lacustrine, or eolian; I, inactive).

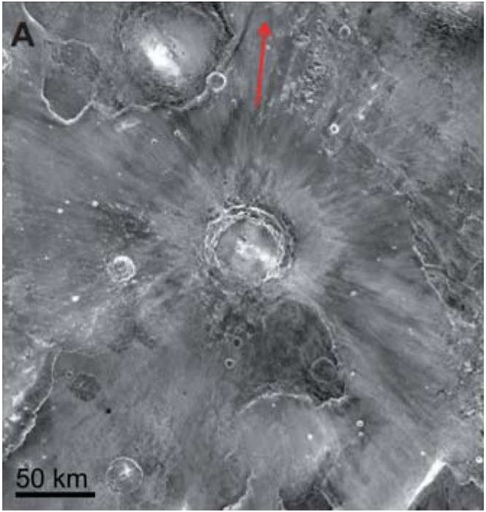
AD 536 Event

...is hotly contested: a comet or a giant volcano eruption (not found). Is it a '6-month coincidence', probability 10^{-3}? Or, a modest size dressed CUDO puncture and associated transport of material into upper atmosphere. Further milder weather fluctuations are also not well understood.



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.

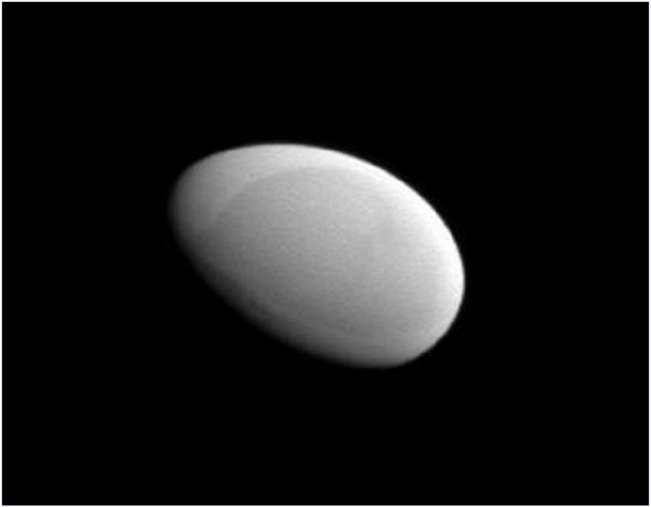


Do you like diamonds?

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

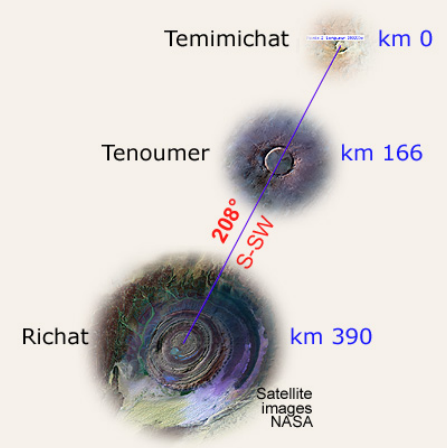


Methone: Smooth Egg Moon of Saturn
Image Credit: Cassini Imaging Team, ISS, JPL, ESA, NASA

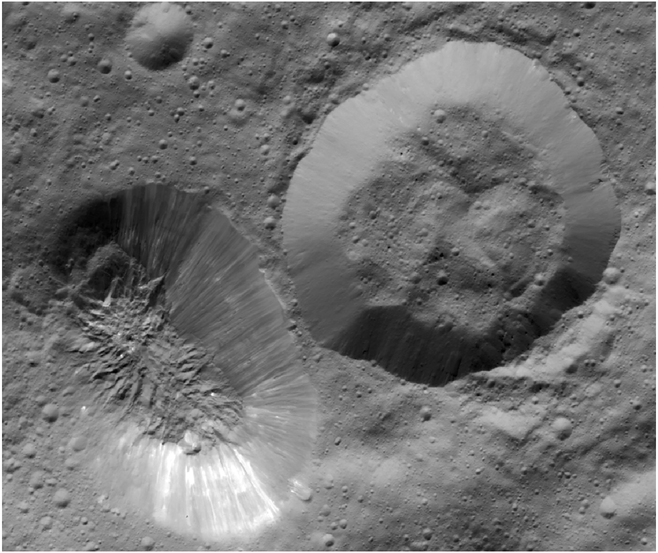
Explanation: Why is this moon shaped like a smooth egg? The robotic Cassini spacecraft completed the first flyby ever of Saturn's small moon Methone in May and discovered that the moon has no obvious craters. Craters, usually caused by impacts, have been seen on every moon, asteroid, and comet nucleus 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

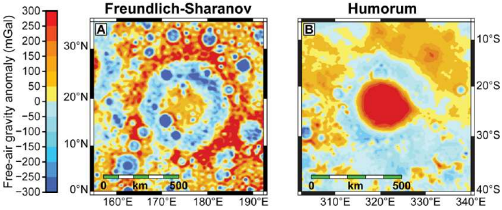


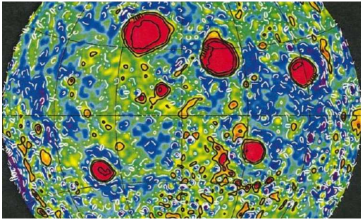
Ahuna Mons anomalie on CERES: Man made mining pit or CUDO uplifted & turned fragment?

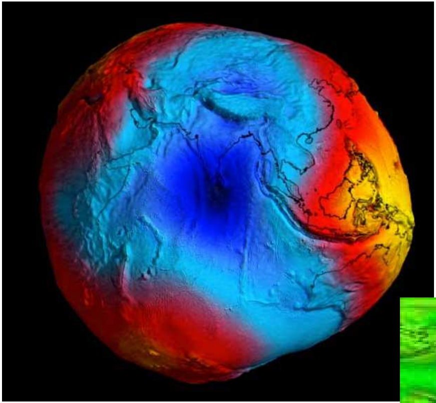


Remote Sensing: MASCONS

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



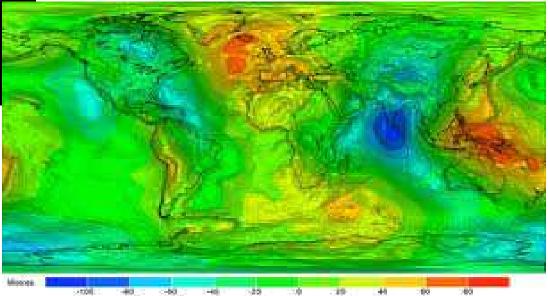




What made this?

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.



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?**

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

Example: 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} $e\cdot$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} $e\cdot$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)

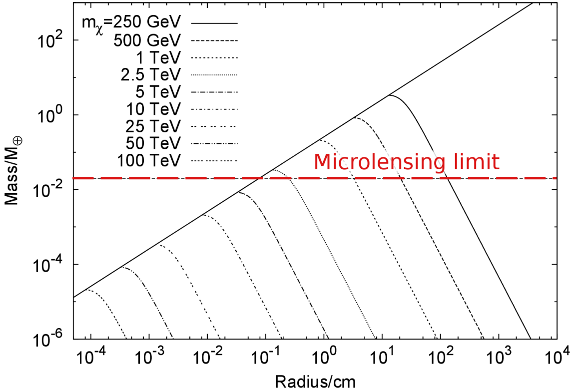
Fundamental fermion	Composite
mass $m_\chi \gtrsim 1\,\mathrm{TeV}$	**B**ag model vacuum pressure $B \gtrsim (1\,\mathrm{TeV})^4$
supported by pressure of degenerate fermi gas	self-bound by interactions
analogy to white dwarf, neutron star	analogy to quark-star, strangelet

Solve for equilibrium configuration in Oppenheimer-Volkoff equations

TeV-scale Fundamental Fermi particle

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

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



★ 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 $m, M_{\rm Pl}$ and need only 1 equation of state $p(\rho)$

Dimensionless...

1) pressure, density

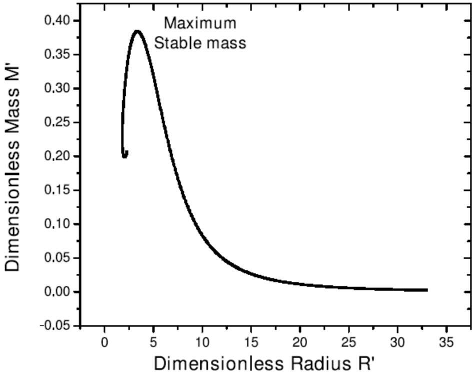
$$\widetilde{p}(\widetilde{\rho}) = m^{-4}\, p(\rho m^{-4})$$

2) total mass of solution

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

3) surface radius of solution

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



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

TOV equations now dimensionless – Solve once!

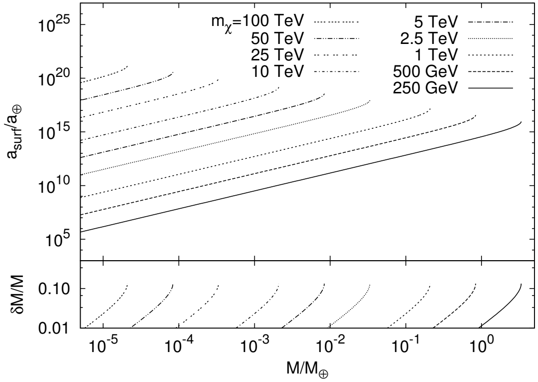
NOT the whole story: check stability against perturbation

Oppenheimer/Serber 1936

Gravitational Stability and Tidal Force

Compact: Size of object comparable to gradient of gravitational field

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



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

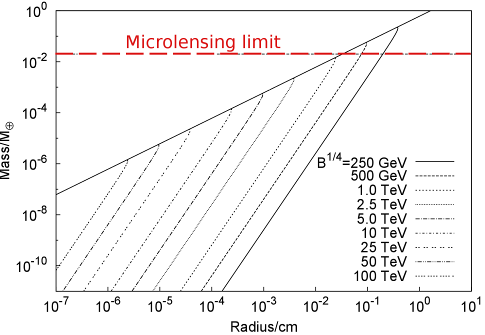
- Tidal acceleration pulls apart atoms in solids: $a_{\rm surf} > 3.5\ 10^{15} a_\oplus$

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

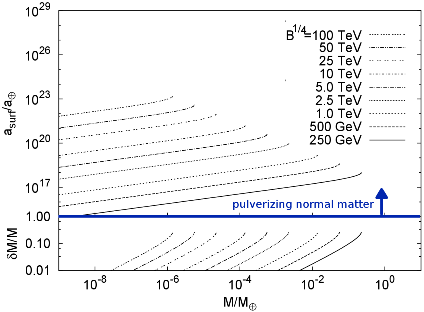
CUDOs not stopped by impact with normal density (visible) matter

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)



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

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