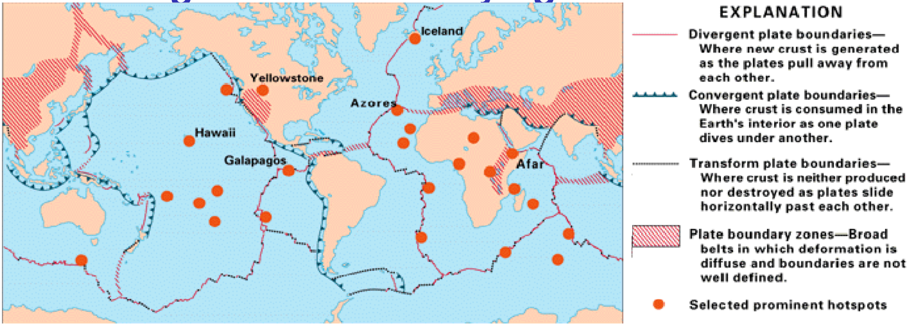
Something STRANGE is Flying Around



Where is the meteorite? Just maybe it went into the Earth: we consider compact ultra-dense objects (CUDO) meteors made predominantly of ultra dense matter such as STRANGElet = fragments of neutron stars filled with strange quarks, Dark Matter bound objects, MICRO BLACK HOLES. For such exotic impactors each planet or moon is a macroscopic detector accumulating CUDO impact signature over geological time scale. Only a fraction of the CUDO kinetic energy is damaging the entry/exit surface regions since CUDOs high density of gravitating matter assures surface-penetrating puncture – shot into, and even through, a moon or the planet. CUDOs could be the origin of hot-spots (random location shield volcanoes that are fed from depth of Earth across solid crust). Recent (geologically) CUDOs maybe recognized by impact (exit) features such as the cave in Pavonis Mons on Mars, and on Earth by coincident impactor with climatic excursions created by high atmosphere "volcanic" eruption (happening usually without a known volcano!). Rocky objects in solar system accumulate impact scars for billions of years. Asteroid belt could harbor captured CUDOS with 31 Polyhymnia a high density (75g/cc!) candidate and the "egg in space" offering another suspect case. Last not least, the Earth energy balance could depend on captured CUDOs.

*Invite your undergrad students: Lecture to be entertaining and (mostly) non-technical, equations inadvertently appearing on slides will be (mostly) skipped***.**

Reading document: http://www.physics.arizona.edu/ rafelski/PS/1801CUDOatAZ.pdf

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

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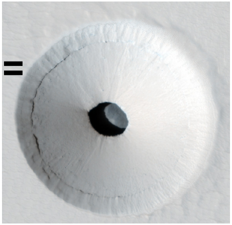


Mars-hole Hirise#2560

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) = mirac

cudo (colloq. Polish) =

of surprising and exceptional character (gender related)

Questions, questions:

1. Are there (self-interacting) 'dark matter' meteor and asteroid-like bodies in the Universe? Maybe – will describe fascinating possibilities.
2. Could CUDOs have collided with solar system bodies and the Earth? Yes. All (rocky) objects in the solar system are 'detectors' for CUDO impacts
3. What is CUDOs' distinct observable? The surface-penetrating puncture and sometimes shot through. On rocky planets impact signatures are long-lived.
4. How is the 'target' damaged? Only a fraction of the kinetic energy damaging the solid surface on both entry/exit (partial stopping).
5. How can we distinguish CUDO from normal geological activity? Impactors without impact material; high atmospheric 'eruptions' for shot across the body with rain down of material.

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: $p = uud, n = ddu, \Lambda = uds$

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

Proposed 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 → 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. Strangeness in depth of compact stars

(30y track of work [Glendenning, Alcock, Alford, 1986-present])
Neutron star mergers or collisions eject fragments

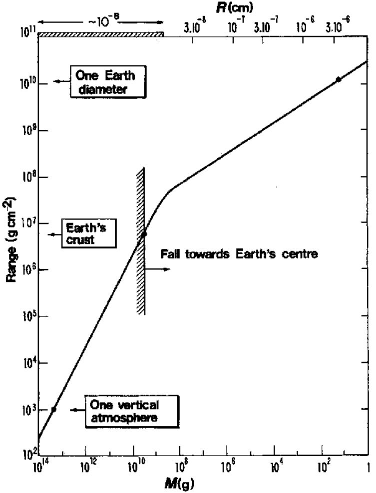
[Madsen,JPG,28(2002) & Bauswein,PRL,103(2009)]

Strangelet meteorites='Nuclearites' considered for 30+ years:

micro-micro-CUDO impacts on Earth: 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: small strangelets unstable, large CUDO's rare.**

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 Non-Baryonic and Baryonic 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,

The Astrophysical Journal, 648:L109–L113, 2006 September 10

A DIRECT EMPIRICAL PROOF OF THE EXISTENCE OF DARK MATTER[1]

Douglas Clowe,[2] Maruša Bradač,[3] Anthony H. Gonzalez,[4] Maxim Markevitch,[5,6]
Scott W. Randall,[5] Christine Jones,[5] and Dennis Zaritsky[2]
Received 2006 June 6; accepted 2006 August 3; published 2006 August 30

We present new weak-lensing observations of 1E 0657−558 (z = 0.296), a unique cluster merger, that enable a direct detection of dark matter, independent of assumptions regarding the nature of the gravitational force law. Due to the collision of two clusters, the dissipationless stellar component and the fluid-like X-ray–emitting plasma are spatially

Dark Matter is (weakly) 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:

- **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**
- **CUDO comprises** $10^{11} - 10^{19}$ **fewer particles** $\Rightarrow$ **requires smaller correlation volume contributing**
- **Dark particle-particle gravitational interaction** $10^{6} - 10^{10}$ **times larger maybe capable to 'kick out' visible matter to bind .**
- **High surface acceleration CUDOs stable against gravitational disruption (especially in collisions with normal matter objects)**
  $\Rightarrow$ **persist into present era at rest in CBM frame of reference**

Stellar DM Meteor formation Possible? – Qualitative Consideration

- **Dark matter accretion to stellar objects have been studied, concentration in stellar object cores**
- **Formation of gravitationally bound dark matter CUDOs unavoidable**
- **Stellar SN explosions practically always asymmetric, stellar core CUDO left behind**

Compact stars as dark matter probes

Citing Articles (70)

PHYSICAL REVIEW D

Gianfranco Bertone and Malcolm Fairbairn

Phys. Rev. D **77**, 043515 – Published 15 February 2008

We discuss the consequences of the accretion of dark matter (DM) particles on compact stars such as white dwarfs and neutron stars. We show that in large regions of the DM parameter space, these objects

Difference to primordial dark CUDOs which at rest in CBM frame:
Stellar catalysis CUDOs follow galactic dynamics, have strangelet-like velocity distribution

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

Moving fast across the following physics pages, those interested please consult these references:

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

Properties of Gravitationally Bound Dark Compact Ultra Dense Objects
C. Dietl, L. Labun and JR, Phys. Lett. B 709, 123 (2012)
http://www.sciencedirect.com/science/article/pii/S0370269312001463

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

We considered two types of DM CUDOs

Analogous to compact objects composed of SM matter:

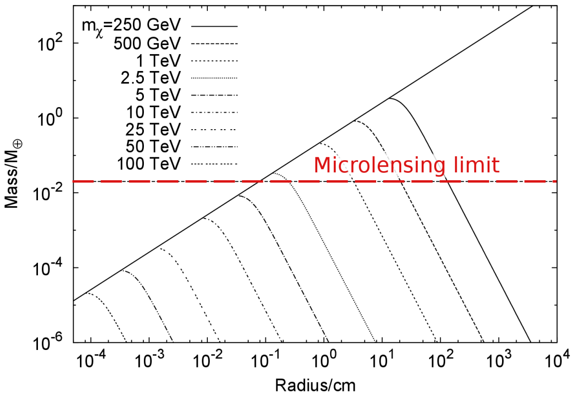
Fundamental fermion	Composite
mass $m_\chi \gtrsim 1\,\mathrm{TeV}$	Bag model vacuum pressure $B \gtrsim (1\,\mathrm{TeV})^4$
supported by pressure of degenerate fermi gas	self-bound by interactions
analogy to white dwarf, neutron star	analogy to quark-star, strangelet

Solve for equilibrium configuration in Oppenheimer-Volkoff equations C. Dietl, L. Labun and J. Rafelski, *Properties of Gravitationally Bound Dark Compact Ultra Dense Objects,* Phys. Lett. B 709, 123 (2012) [arXiv:1110.0551]

TeV-scale Fundamental Fermi particle

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

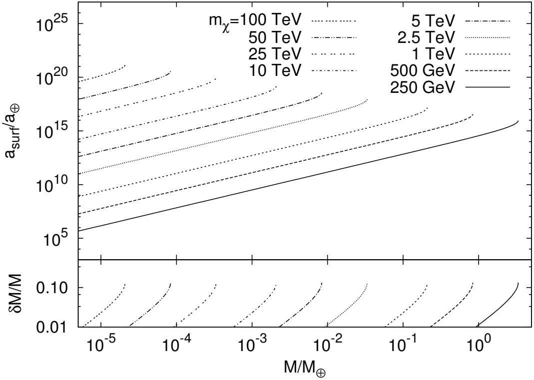
$M_{\max} \propto m_\chi^{-2}$



★ **upper end (near 'diagonal' of curve are objects stable and robust in collisions**

Gravitational Stability and Tidal Force

Compact: Size of object comparable to gradient of gravitational field ⇒ Tidal force important $a_{\rm tidal} = \frac{2GM}{r^2}\frac{L}{r} = a_{\rm surf}\frac{R^2_{\rm surf}}{r^2}\frac{2L}{r}$



$a_\oplus = 9.8\mathrm{m/s}^2$
$=$ **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 visible matter

Summary: Fundamental Fermi and Composite/Bag

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

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

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

$\Rightarrow$ **Highly compact and not too heavy**

Summary: Mass and Size Limit Examples

Fermion mass	$M_{\max}(M_\odot)$	$R_{\min}$	comment
100 GeV	10^{-4}	1 m	neutralino star (cold dark matter)
1 GeV	1	10 km	neutron star
1 GeV/0.5 MeV	1	10^3 km	white dwarf
10 keV	10^{10}	10^{11} km	sterile neutrino star
1 keV	10^{12}	10^{13} km	axino star (warm dark matter)
1 eV	10^{18}	10^{19} km	neutrino star
10^{-2} eV	10^{22}	10^{23} km	gravitino star

Maximum M_{max} and R_{min} for various cold compact stars made of a free Fermi gas

$$M_{max} = 0.627\ M_\odot \cdot \left(\frac{1\ \mathrm{GeV}}{m_f}\right)^2 \qquad R_{min} = 8.115\ \mathrm{km} \cdot \left(\frac{1\ \mathrm{GeV}}{m_f}\right)^2$$

Collisions: a) Tidal Forces

in PRL

Consider CUDO passing through normal density matter: capture for distance R_c when energy gain of attached matter is greater than the kinetic energy this material must acquire $R_c := \frac{2GM}{v^2}$

$$\frac{R_c}{R_\oplus} = \frac{M_{\rm CUDO}}{M_\oplus} \left(\frac{v_\oplus}{v}\right)^2$$

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,

gravitational pressure $>$ compressional strength

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

$\Rightarrow$ **Material fails somewhere within Fracture length**

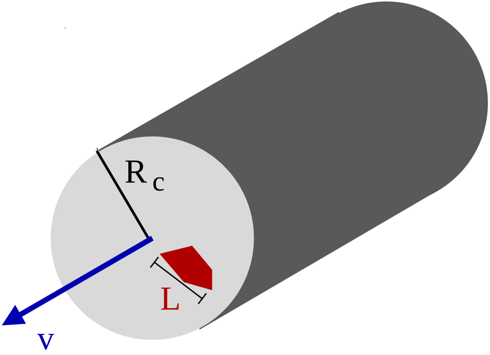
$$\frac{L}{R_c} = \sqrt{2}\frac{c_s}{v}\left(\frac{r}{R_c}\right)^{3/2}$$

$c_s =$ **Bulk sound speed**

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

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

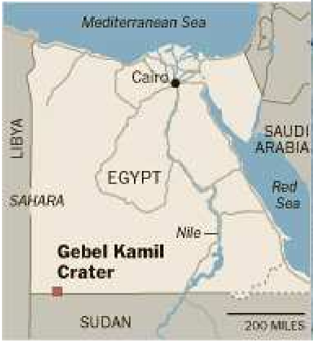
sound speed c_s **representing bulk modulus (strength) of medium**

Impactors: usual and not so usual:

The entertaining CUDO story

- **Impacts on Earth**
- **Impact Winter**
- **Raining of matter (spherules)**
- **Hot Spots**
- **CUDOs in solar system**
- **Diverse pictures**

There can be: a visible impactor



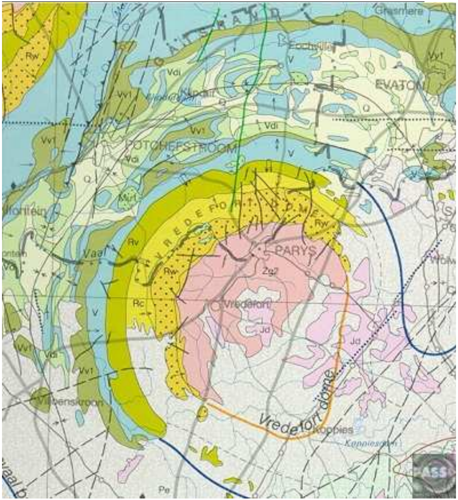
Iron-nickel (20%) Gebel-Kamil: 22^{0}01’06"N, 26^{0}05’16"E East Uweinat Desert, Egypt: 44.8m in diameter, 15.8m deep meteorite crater: 1600 kg of iron meteorite shrapnel, 3400 kg >10 g pieces remained today. Upon hypervelocity impact, the 1.3 meters wide 5 to 10 tons meteorite was disrupted into thousands 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

Missing meteorite case is not singular

John W. MORGAN et. al. ^{190}Pt-^{186}Os and ^{187}Re-^{187}Os systematics of the Sudbury Igneous Complex, Ontario; Geochim. et Cosmochim. Acta 66,(2),273-290 (2002)



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).

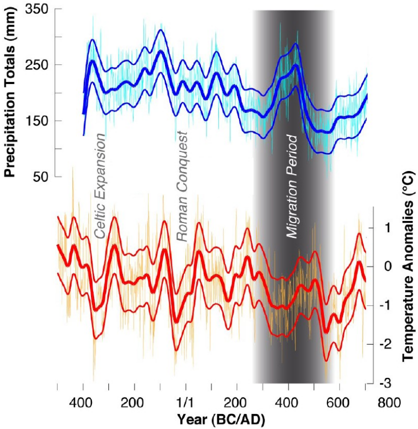
Sudbury, Canada: (and Vredefort, South Africa;) major mining districts of the world, where “something” called an impact seems to have pulled from the depth the Earth siderophile metals.

CLIMATE excursions: AD 536 Event

E. Rigby, M. Symonds, D. Ward-Thompson, *A comet impact in AD 536?* **Astron. Geophys. 45, 1.23-1.26 (2004).**

L.B. Larsen, et al. *New ice core evidence for a volcanic cause of the A.D. 536 dust veil* **Geophys. Res. Lett. 35, L04708 (2008).**

...cause is contested: a comet or a giant volcano(not found) eruption. The 6-month (time measurement resolution) dual event coincidence has probability 10^{-3}. Can be more naturally explained by a dressed CUDO puncture and associated transport of material into upper atmosphere. Other recent climate fluctuations are also not well understood, e.g. year 1465 *BBC: It was 10 October 1465 -the day of the wedding of King Alfonso II of Naples ... middle of the day, the Sun had turned a deep azure, plunging the city into eerie darkness ... Four years later, Europe was hit by a mini ice age... It was the biggest eruption for 700 years but scientists still can't find the volcano*



U. Büntgen, et al *2500 Years of European Climate Variability and Human Susceptibility* Science 331 (6017) pp. 578-582 (2011)

BBC: 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.

Glass rain from the sky: Spherules

www.pnas.org/cgi/doi/10.1073/pnas.1301760110
This article contains supporting information online at www.pnas.org/lookup/suppl/doi:10.1073/pnas.1301760110/-/DCSupplemental.
(received for review January 28, 2013)
PNAS Early Edition | 1 of 10

PNAS PLUS

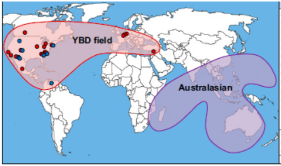
Evidence for deposition of 10 million tonnes of impact spherules across four continents 12,800 y ago

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]

Airbursts/impacts by a fragmented comet or asteroid have been proposed at the Younger Dryas onset (12.80 ± 0.15 ka) based on identification of an assemblage of impact-related proxies, including microspherules, nanodiamonds, and iridium. Distributed across four continents at the Younger Dryas boundary (YDB), spherule peaks have been independently confirmed in eight studies, but unconfirmed in two others, resulting in continued dispute about their occurrence, distribution, and origin. To further address this dispute and better identify YDB spherules, we present results from one of the largest spherule investigations ever undertaken regarding spherule geochemistry, morphologies, origins, and processes of formation. We investigated 18 sites across North America, Europe, and the Middle East, performing nearly 700 analyses on spherules using energy dispersive X-ray spectroscopy for geochemical analyses and scanning electron microscopy for surface

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.

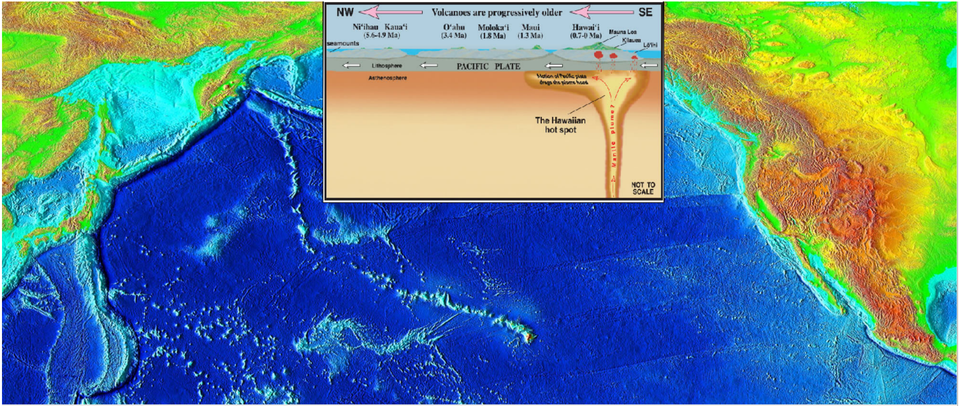


Site/Location	Details	Strat	Env	Setting
Arlington Cyn, CA	B,C,A,M	A	A	Coastal cyn
Barber Crk, NC	A	A,E	A	Relict dune
Big Eddy, MO	A	A	A	Flood-plain
Blackville, SC	--	A,E	I	Carolina bay
Blackwater, NM	B,C,A,M	A,L	A	Streambed
Chobot, ALB	B,C,A,M	A,L	A	Lakeshore
Cuitzeo, MEX	B,C,M	L	A	Lake bed
Gainey, MI	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).

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 a dozen islands (edge: next slide)



Plume may by (nearly) stable

The edge in island ridge explained to be dominated by plume dynamics implies plume stable over 50 million years. WHY?

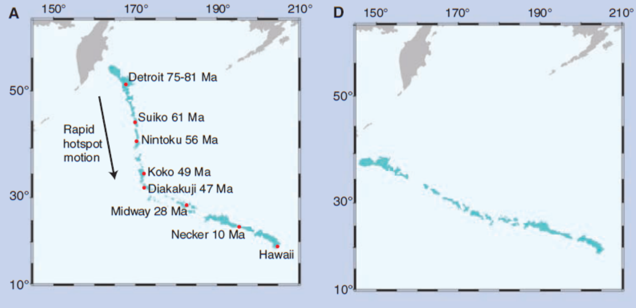
The Bent Hawaiian-Emperor Hotspot Track: Inheriting the Mantle Wind

SCIENCE

John Tarduno, Hans-Peter Bunge, Norm Sleep, Ulrich Hansen

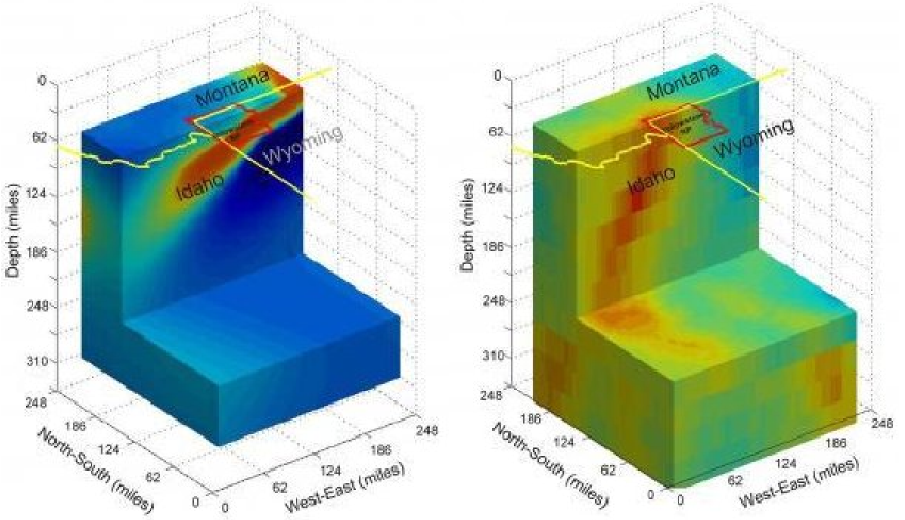
3 APRIL 2009 VOL 324 50

Bends in volcanic hotspot lineaments, best represented by the large elbow in the Hawaiian-Emperor chain, were thought to directly record changes in plate motion. Several lines of geophysical inquiry now suggest that a change in the locus of upwelling in the mantle induced by

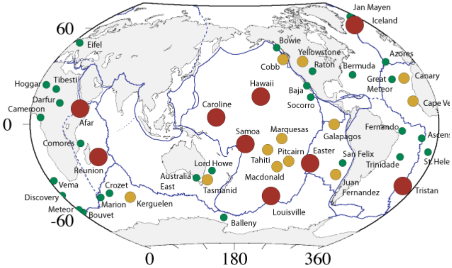


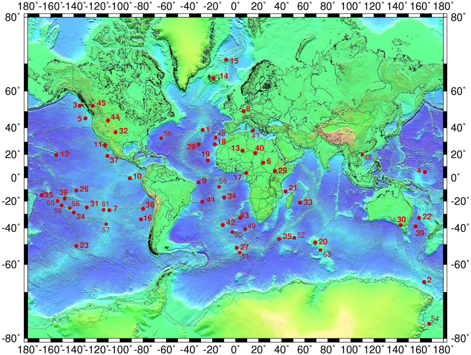
Alternative Hawaiian-Emperor traces. (**A**) Present-day track with ages and episode of rapid hotspot motion highlighted. (**D**) Trace that would have been produced had the Hawaiian hotspot been fixed in the deep mantle

Hot-spot plume may be not vertical
Example: Yellowstone plume



Hotspot=Mantleplume? =Shot-In or Out?





Global distribution of the 61 hot-spots 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 (50mY) reference frame

The Geological Society of America
Special Paper 430 2007

Plate velocities in the hotspot reference frame

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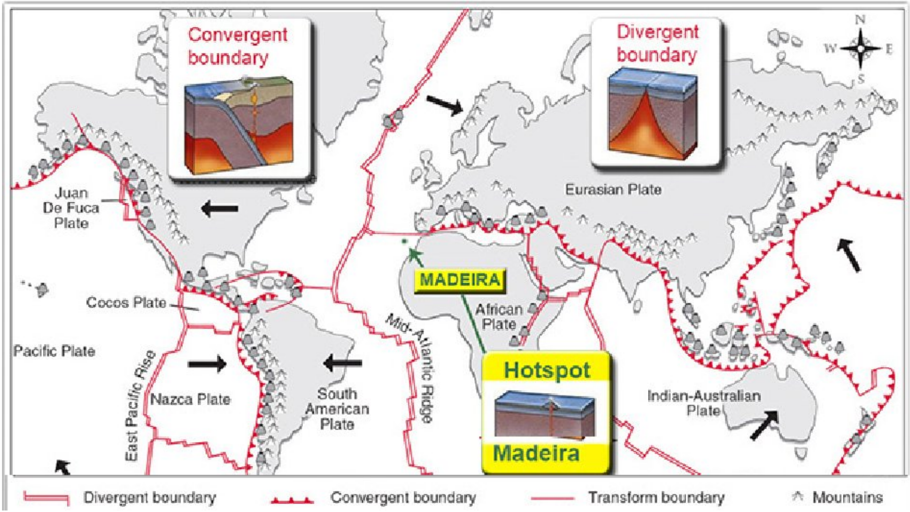
Department of Earth and Planetary Sciences, 20 Oxford Street, Harvard University, Cambridge, Massachusetts 02138, USA
Jason Phipps Morgan
Department of Earth and Atmospheric Sciences, Snee Hall, Cornell University, Ithaca, New York 14853-1504, USA

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.

Field trip: this is worth a CUDO trip

Islands formed ONLY 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.



Beyond Earth: Mars Pavonis Mons hole: CUDO exit?

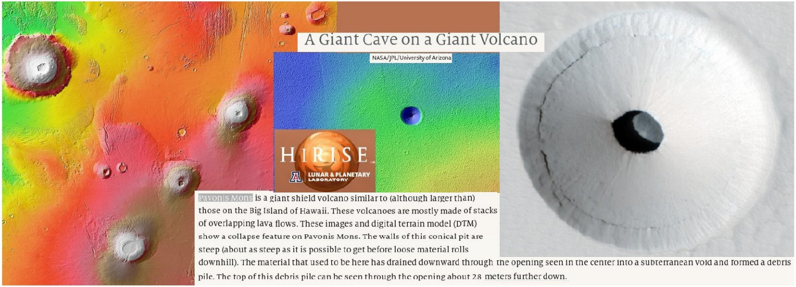
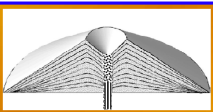
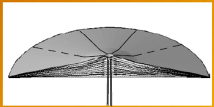


Fig. 9. The largest and aligned shield volcanoes in the Mars Tharsis Montes region are Ascraeus Mons, **Pavonis Mons**, Arsia Mons (on diagonal line), and Olympus Mons (off in NW corner). Arsia Mons has the largest caldera on Mars, having a diameter of 120 km. The main difference between the volcanoes on Mars and Earth is their size; volcanoes in the Tharsis region are up to 100 times larger than those anywhere on Earth. Detailed photography by University of Arizona LPL HiRISE of Pavonis Mons reveals a giant central conical and unexplained cave, see text for more detail. *Photo: Sources NASA, University of Arizona/LPL, Arizona State University*

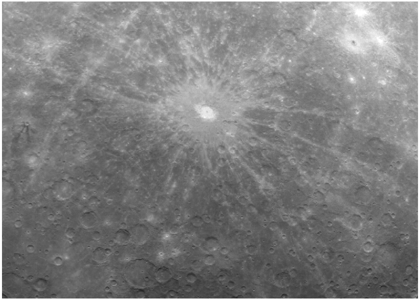
cinder (scoria) cone		• single to multiple eruptions that extend over years to decades • moderately explosive eruptions of mafic (basaltic) composition, including lava flows, due to moderate gas content and low silica magma • builds a small volcano of ash, cinder, and scoria (fragmented magma) that is commonly 0.6 to 1.2 miles (1-2 km) in diameter
shield		• multiple eruptions of long lava flows from a central conduit over a moderately long time period • mostly non-explosive and fluid eruptions, due to low silica and low gas content magma • forms a low, broad volcano with some ash and cinder at the summit

Beyond Earth: Mars, Mercury rayed craters?

Mars:

A dramatic Mars impact crater created between July 2010 and May 2012 photographed by HiRISE camera on board NASA's Mars Reconnaissance Orbiter on Nov. 19, 2013. The 30 meters in diameter crater is surrounded by a 15km large, rayed blast zone.

Mercury:



Mojave Crater on Mars: Source of 80% Mars impactors on Earth

55km large recent crater unexpected: Is this CUDO exit?

By 2ndary impact density 55-kilometer-wide Mojave crater on Mars formed 3-5 million years ago. Based on their cosmic ray exposure, the shergottites from Mars must have broken off between 1 and 5 million years ago. Prior confusion on dating due to melting; this supports CUDO hypothesis.

The Source Crater of Martian Shergottite Meteorites

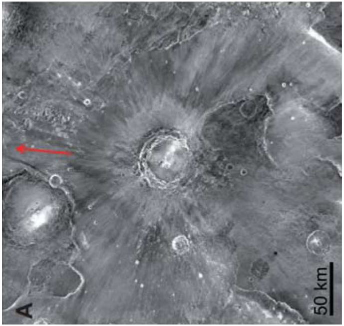
Science 21 Mar 2014:
Vol. 343, Issue 6177, pp. 1343-1346
DOI: 10.1126/science.1247282

Stephanie C. Werner[1,*], Anouck Ody[2], François Poulet[3]

Sourcing Martian Meteorites

There are nearly 150 recognized martian meteorites, but where exactly they came from on Mars is not known. **Werner *et al.*** (p. 1343, published online 6 March) present evidence that the <5 million-year-old Mojave impact crater on Mars is the single ejection site of one type of martian meteorites: the shergottites. The Mojave crater formed on an ancient terrain on Mars, and so the shergottites represent old martian crustal material.

Note rayed structure.



Are CUDOs Flying in the Solar system?

On asteroids of high density

Contents lists available at SciVerse ScienceDirect

Planetary and Space Science

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

Density of asteroids

Planetary and Space Science 73 (2012) 98–118

B. Carry *

European Space Astronomy Centre, ESA, P.O. Box 78, 28691 Villanueva de la Cañada, Madrid, Spain

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

B. Carry / Planetary and Space Science 73 (2012) 98–118

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.

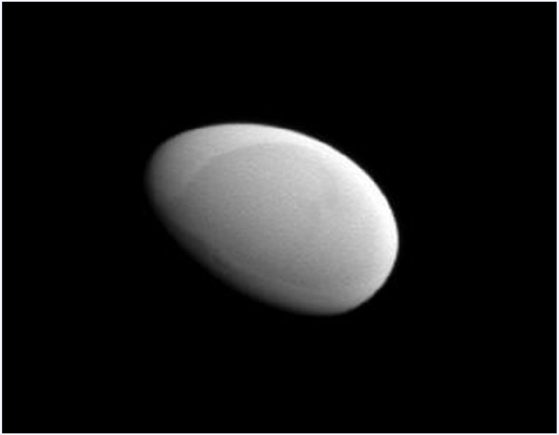
Designation		Classification			Masses (kg)			Diameter (km)			Density		Porosity		Rank
#	Name	Dyn.	Tax.	Met.	M	δM	Fig.	ϕ	$\delta\phi$	Fig.	ρ	$\delta\rho$	$\mathcal{P}$	$\delta\mathcal{P}$	
1	Ceres	MBA	C	CM	9.44	$\pm 0.06 \times 10^{20}$	A.1	944.79	±22.99	B.1	2.13	±0.15	4	±1	A
2	Pallas	MBA	B	CK[1]	2.04	$\pm 0.04 \times 10^{20}$	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

Egg moon of Saturn: Methone

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.

Low 'density' and yet surface reforms and object not blown into pieces

Comet Lovejoy survives encounter with Sun

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

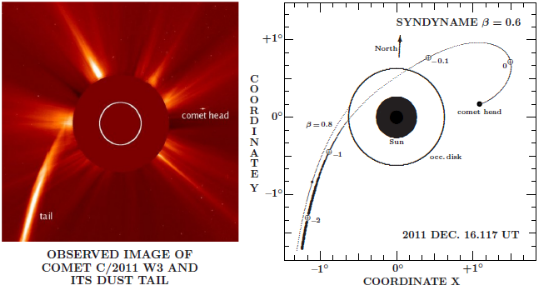


Figure 8. Appearance of comet C/2011 W3 and its dust tail in an image taken with the C2 coronagraph on board the *SOHO* spacecraft on December 16.117 UT, or 0.105 days after perihelion. The tail, to the south-southeast of the Sun, is seen to be completely disconnected from the comet's head, to the west of the Sun.

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

ZDENEK SEKANINA AND PAUL W. CHODAS
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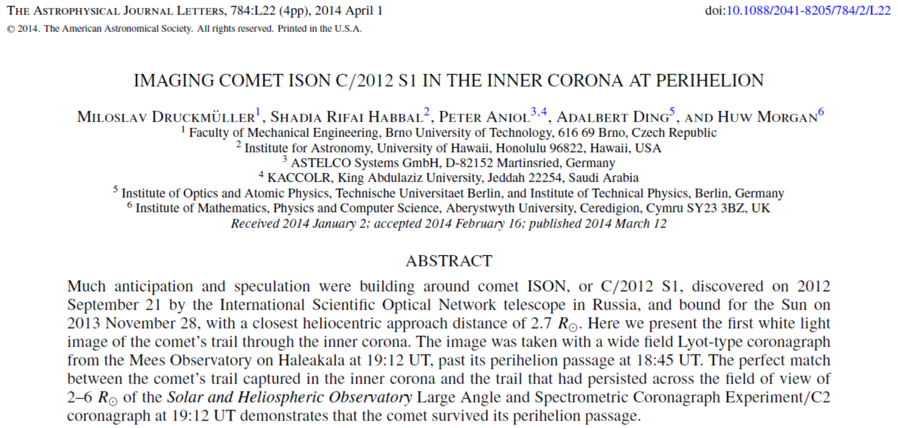
Received 2012 May 12; accepted 2012 July 30; published 2012 September 11

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

Comet Ison survives encounter with Sun


THE ASTROPHYSICAL JOURNAL LETTERS, 784:L22 (4pp), 2014 April 1
doi:10.1088/2041-8205/784/2/L22

IMAGING COMET ISON C/2012 S1 IN THE INNER CORONA AT PERIHELION

MILOSLAV DRUCKMÜLLER[1], SHADIA RIFAI HABBAL[2], PETER ANIOL[3,4], ADALBERT DING[5], AND HUW MORGAN[6]
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[3] ASTELCO Systems GmbH, D-82152 Martinsried, Germany
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Received 2014 January 2; accepted 2014 February 16; published 2014 March 12

ABSTRACT

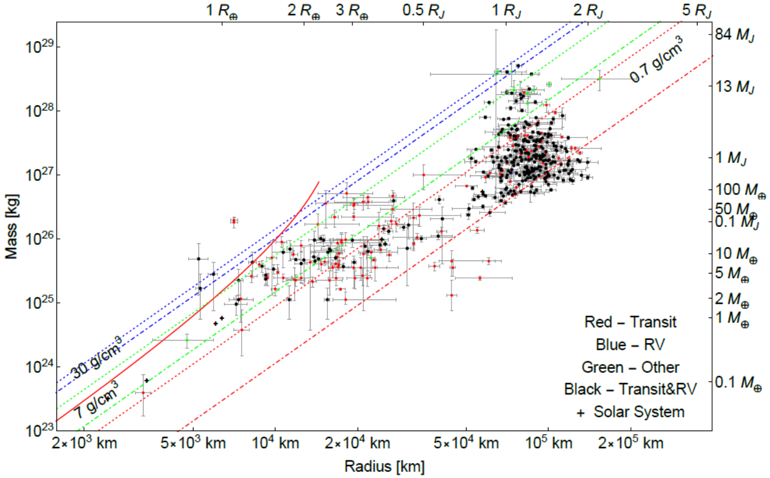
Much anticipation and speculation were building around comet ISON, or C/2012 S1, discovered on 2012 September 21 by the International Scientific Optical Network telescope in Russia, and bound for the Sun on 2013 November 28, with a closest heliocentric approach distance of 2.7 $R_\odot$. Here we present the first white light image of the comet's trail through the inner corona. The image was taken with a wide field Lyot-type coronagraph from the Mees Observatory on Haleakala at 19:12 UT, past its perihelion passage at 18:45 UT. The perfect match between the comet's trail captured in the inner corona and the trail that had persisted across the field of view of 2–6 $R_\odot$ of the *Solar and Heliospheric Observatory* Large Angle and Spectrometric Coronagraph Experiment/C2 coronagraph at 19:12 UT demonstrates that the comet survived its perihelion passage.

CUDOs beyond the Solar system?

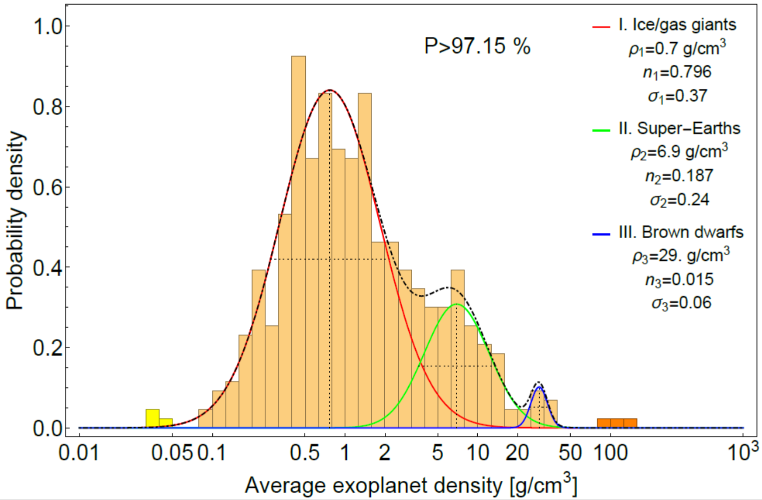
On exoplanets of high density

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

Classification of exoplanets according to density

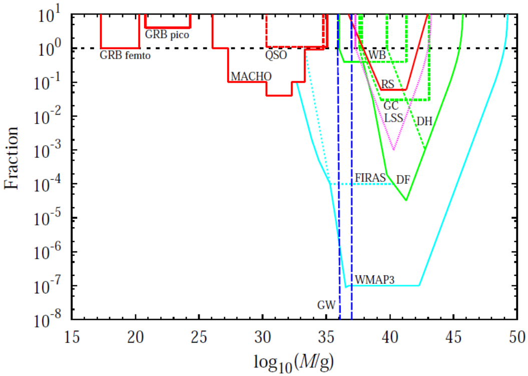


On exoplanets of high density



Microlensing constraints on clumps of matter

MACHOs = Massive Compact Halo Objects
sought by gravitational microlensing surveys (MACHO, EROS, OGLE)



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,**

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.

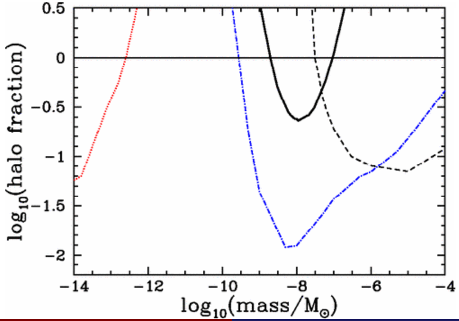


Figure 2

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

Instead of conclusions - a few riddles

What is the matter with Earth heat?

We begin to recognize that Earth heat radiance estimated at 44.2 TW is out of balance: we radiate about 2-3 times the amount produced radiogenically.

Physics of the Earth and Planetary Interiors 269 (2017) 165–171

Physics of the Earth and Planetary Interiors

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

Heat flow evolution of the Earth from paleomantle temperatures: Evidence for increasing heat loss since ~2.5 Ga

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A R T I C L E I N F O

Article history:
Received 29 April 2016
Received in revised form 2 June 2017
Accepted 5 June 2017

A B S T R A C T

Earth currently loses two to five times as much heat through its surface as it is internally produced by radioactivity. This proportion cannot be extrapolated into the past, because it would imply high interior temperatures and catastrophic melting of the planet in ancient times. The heat loss evolution of the Earth cannot therefore be described by a constant heat flow decreasing. This is consistent with previous work

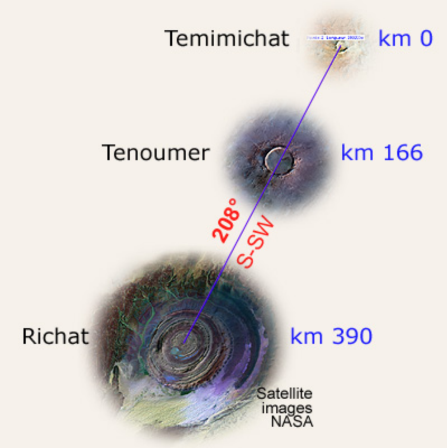
Extreme condition measurement of iron heat conductivity: Earth should have cooled in one billion years (lots of discussion about that in recent years). Only way to reconcile these two observations is that Earth has a 20+ TW internal power generator.

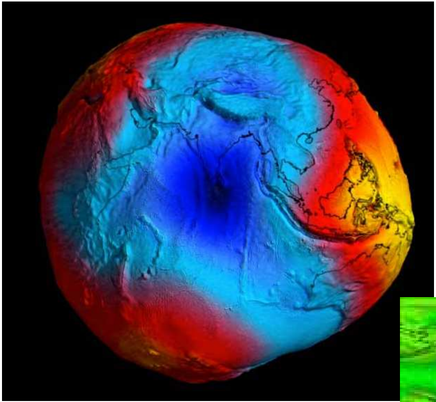
Do you like diamonds?

Kimberley Open pit mine - made by a ‘supersonic gas ejection’

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

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

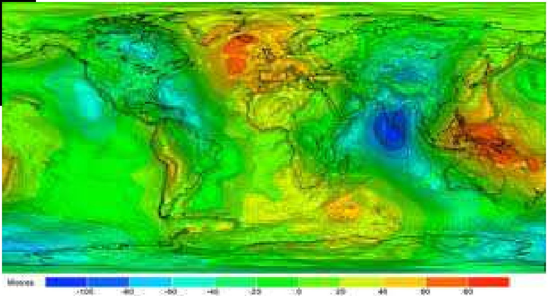




What made this?

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.



To conclude: one new idea: CUDOs allows to explain

- **"Disappearing" giant iron-nickel meteorites**
- **Volcanic hot-spots in middle of thick continental crust**
- **Mantle plumes: deep origin of magma and long-term stability, (some not vertical!)**
- **Dual impact/volcanic activity 'nuclear winter" climate events**
- **Young (post-cooling) volcanic activity on Moon, Mars** *(not described in detail today)*
- **Holes on Mars**
- **Recent large crater on Mars, transfer of material to Earth**
- **Comets fly through Sun**
- **Superdense extraterrestrial bodies**

Earth (all rocky bodies) seem to be punctured many times but: (crust puncture not possible with normal matter impactor [Ivanov, Geology, 31 (2004)])