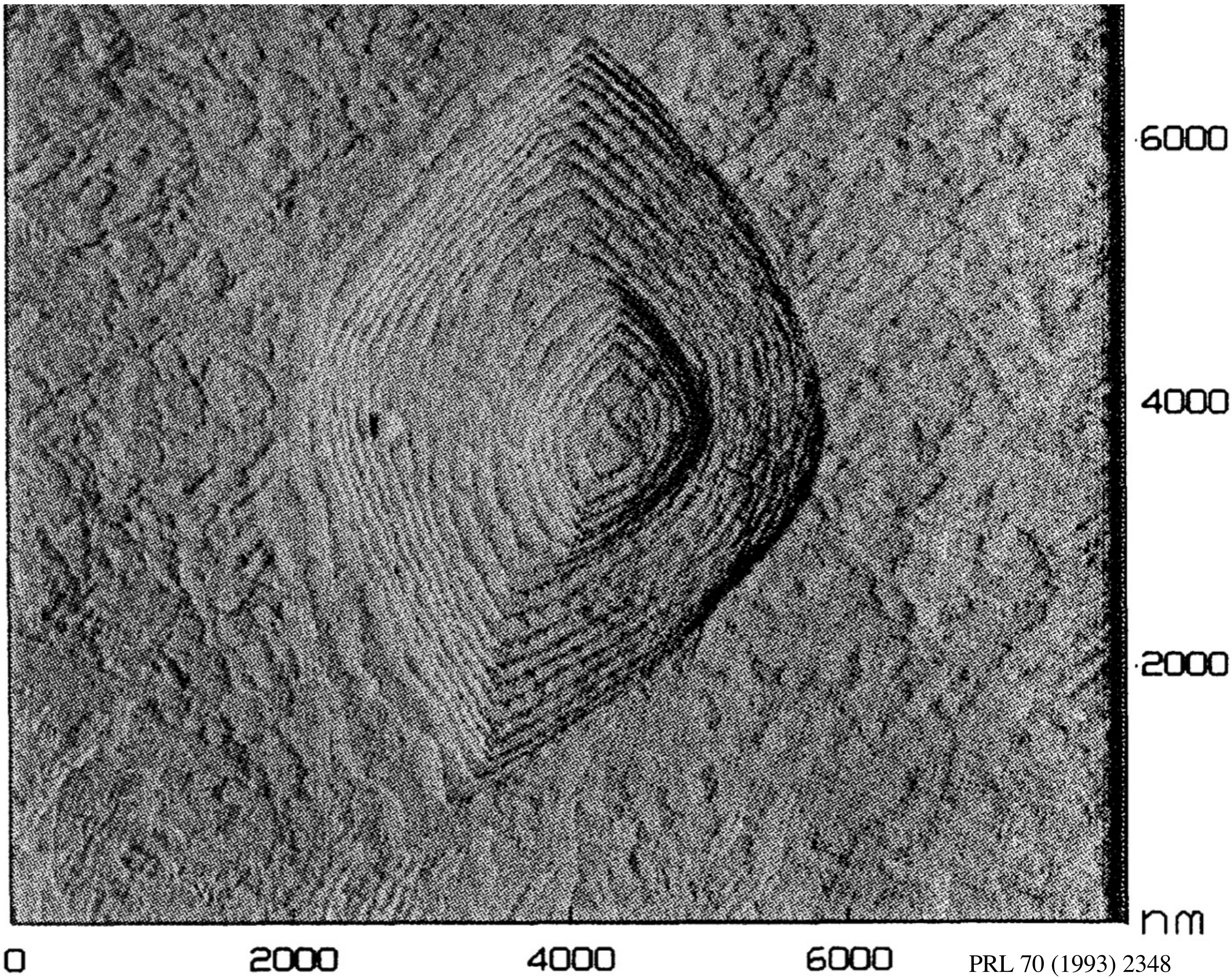
Paleohistory of Paleodetectors



PRL 70 (1993) 2348

First (and thus far only) success of PDs

VOLUME 56, NUMBER 12 PHYSICAL REVIEW LETTERS 24 MARCH 1986

Search for Supermassive Magnetic Monopoles Using Mica Crystals

P. B. Price and M. H. Salamon

Department of Physics, University of California, Berkeley, California 94720

(Received 18 November 1985)

The observed absence of monopole tracks in large, ancient mica crystals enables us to set an upper limit of less than $\sim 10^{-18}$ cm^{-2} sr^{-1} s^{-1} on the flux of supermassive monopoles with $0.0004c < V < 0.0015c$ that are stably attached to nuclei. This limit takes into account the fraction of monopoles not initially bound to protons, the fraction that attach with nuclei on their way to the mica, and the measured storage times for tracks with thermal stability similar to that of monopole tracks.

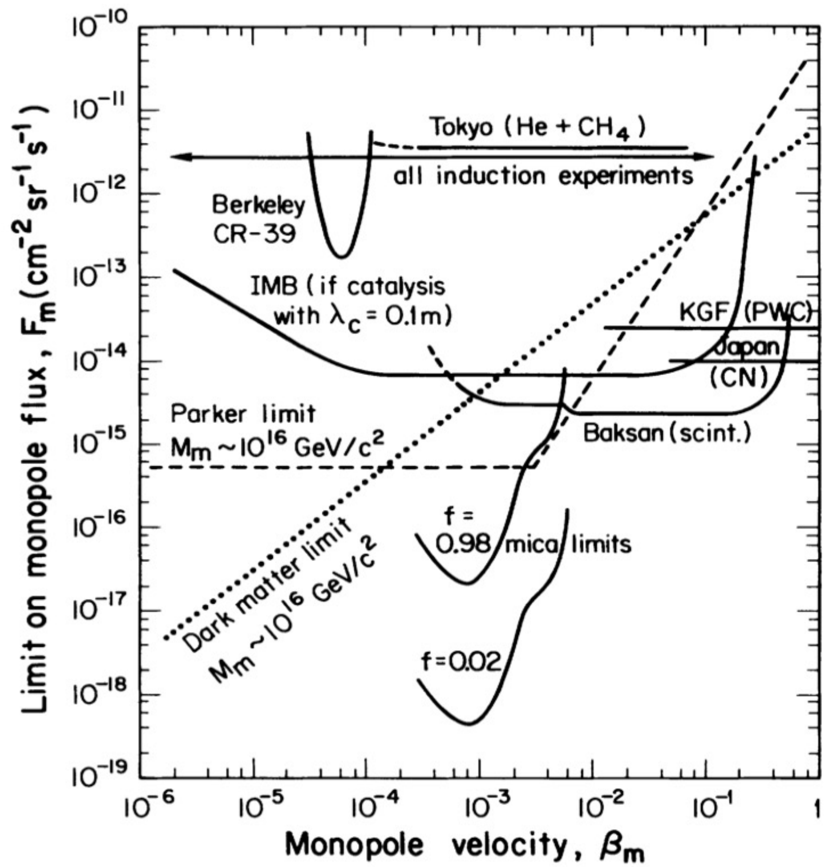


FIG. 3. Monopole flux upper limits (90% C.L.) for several direct searches (solid curves) and indirect astrophysical arguments (dashed curves). Mica limits are calculated for the extreme cases of 2% of monopoles initially bound to protons and for 98% bound to protons.

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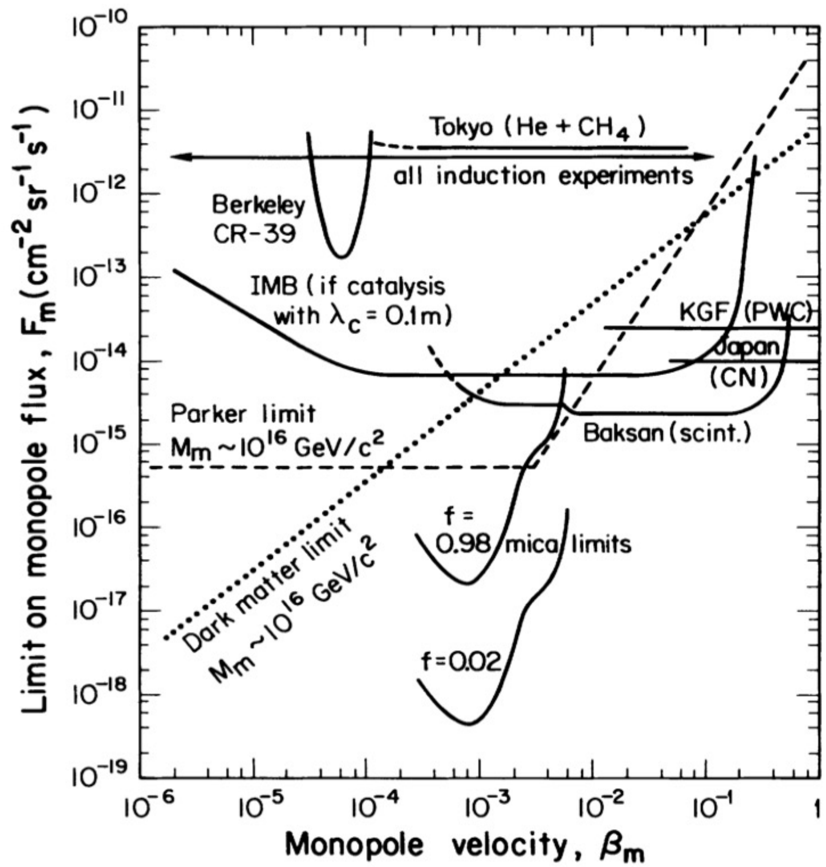

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TBD…

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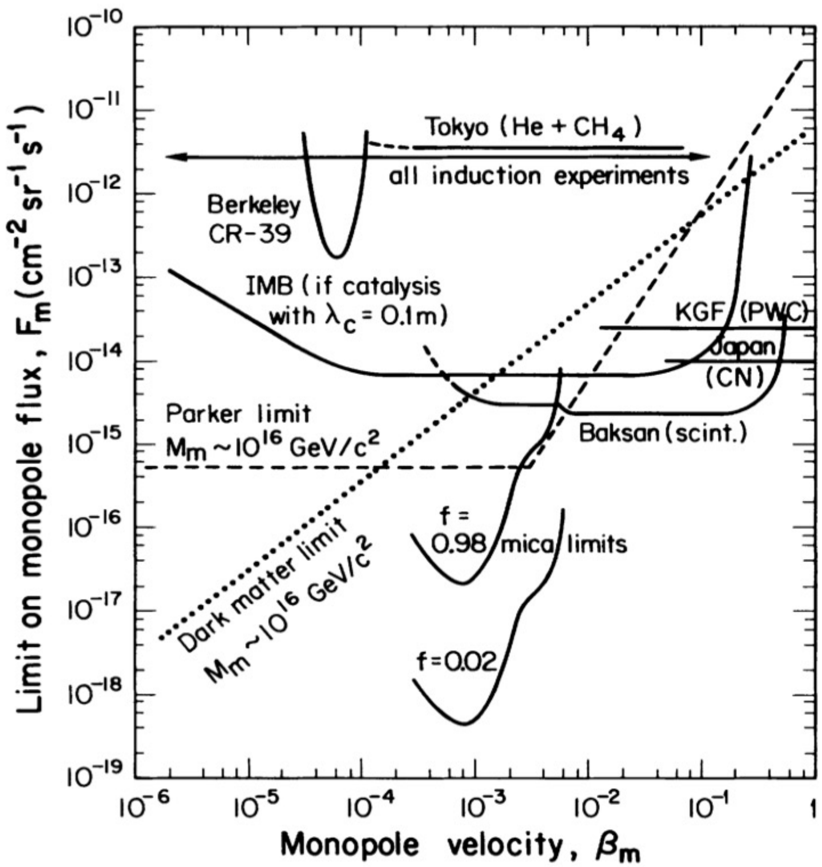

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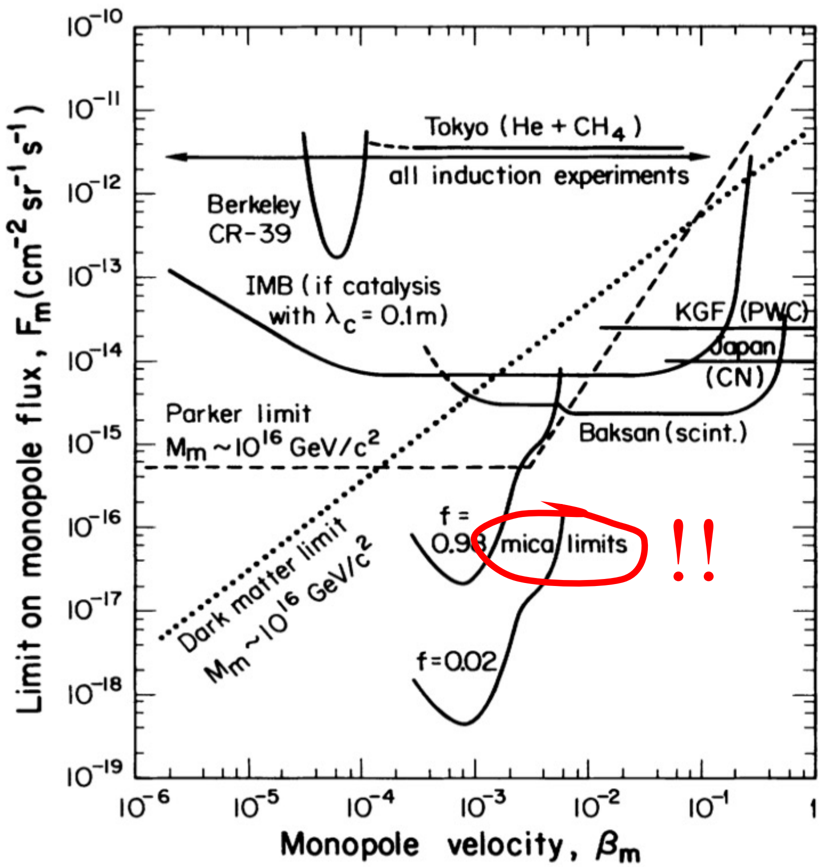

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Dramatic illustration of paleodetectors:
exposure = Mt

A next natural step (WIMP dark matter)

VOLUME 70, NUMBER 15 PHYSICAL REVIEW LETTERS 12 APRIL 1993

Atomic-Force-Microscopic Observations of Dissolution of Mica at Sites Penetrated by keV/nucleon Ions

D. Snowden-Ifft,[1] P. B. Price,[1] L. A. Nagahara,[2] and A. Fujishima[2]

Old school: calibration before limit. Describes DM application.
(flies under our radar, but caught in time)

Nuclear Instruments and Methods in Physics Research B 95 (1995) 349–354

Nuclear tracks from Cold Dark Matter interactions in mineral crystals: a computational study

J.I. Collar *, F.T. Avignone III
Department of Physics and Astronomy, University of South Carolina, Columbia, SC 29208, USA

Received 26 July 1994; revised form received 8 November 1994

VOLUME 74, NUMBER 21 PHYSICAL REVIEW LETTERS 22 MAY 1995

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D. P. Snowden-Ifft,* E. S. Freeman, and P. B. Price*
Physics Department, University of California at Berkeley, Berkeley, California 94720

(Received 20 September 1994)

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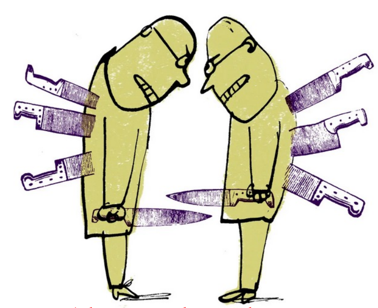
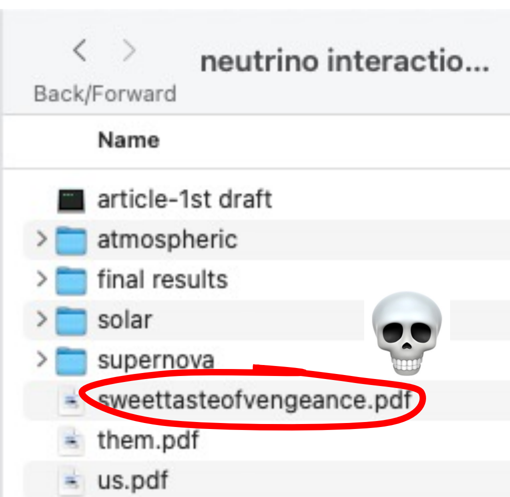


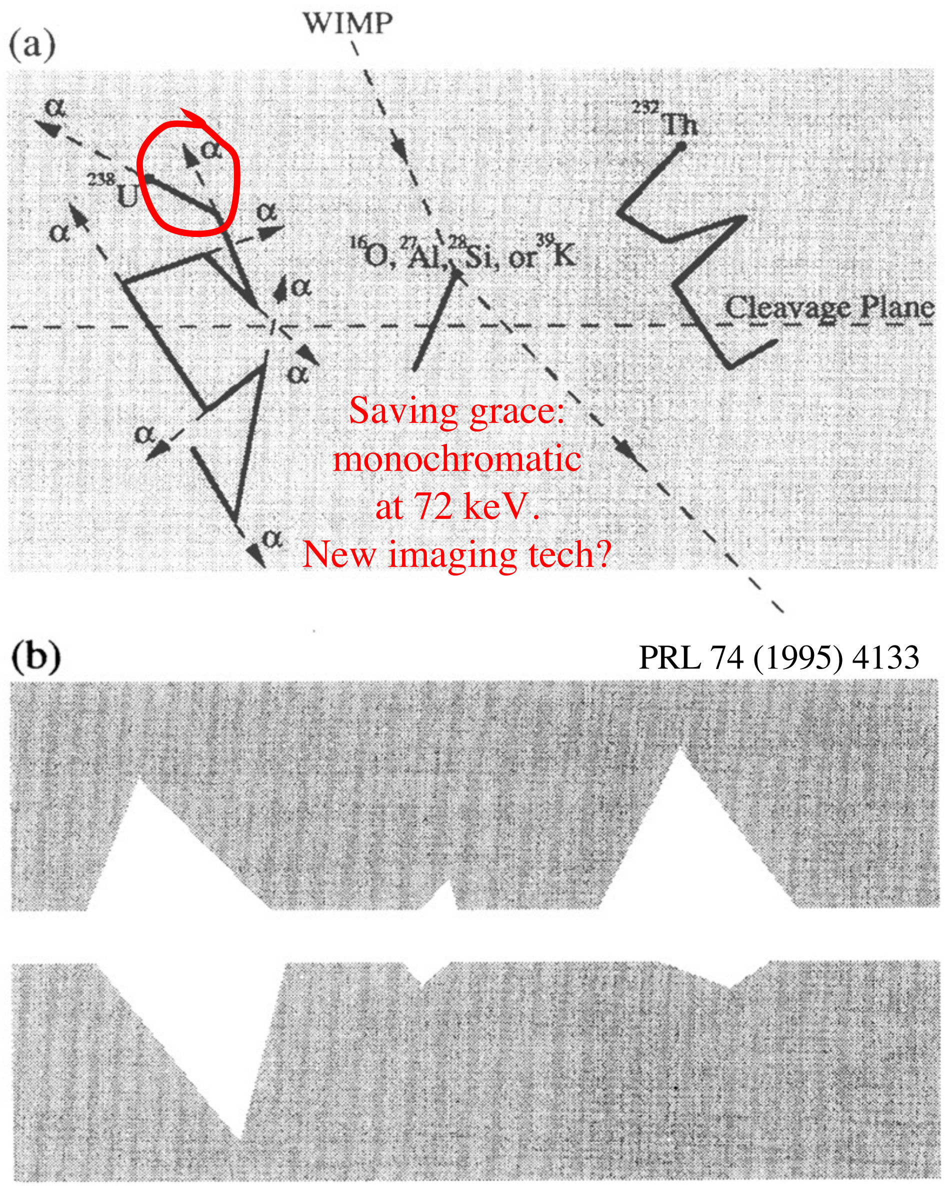
(the grad students have entered the chat)

This is why we cannot have nice things

(origin of the 30-year halt in PDs)

Comment on "Limits on Dark Matter Using Ancient Mica" PRL 76 (1996) 331





PRL 74 (1995) 4133

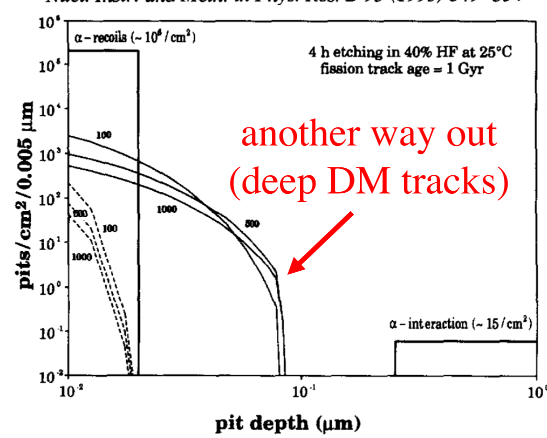
with PDs, you have to embrace the backgrounds:

soning. The ^{238}U chain proceeds as $^{238}\mathrm{U} \xrightarrow{\alpha} {}^{234}\mathrm{Th} \xrightarrow{\beta^-} {}^{234}\mathrm{Pa} \xrightarrow{\beta^-} {}^{234}\mathrm{U} \xrightarrow{\alpha} {}^{230}\mathrm{Th} \ldots$ with α-emission half-lives $T_{1/2}^{238} = 4.4 \times 10^9$ yr, $T_{1/2}^{234} = 2.4 \times 10^5$ yr (the very fast β^- decays produce no observable recoil tracks). The long $T_{1/2}^{234}$ results in some ^{234}Th recoils not being accompanied by a second one, thereby mimicking a WIMP recoil. These

$a < 10^{-10}$ atom fraction, 10^{-11} in the purest mica. This is $N > 10^{-11} \times 9 \times 10^{22}$ ^{238}U atoms/cm^3, or a lower limit of $n > 5.4 \times 10^{-5} N = 4.9 \times 10^7$ ^{234}U atoms/cm^3, n also being the density of latent "fake" WIMP tracks. The

In view of this, the AFM mica search (having covered 1/1240 cm^2) might soon run into this competitive background, not to be taken for a WIMP signal. If this is so,

Nucl. Instr. and Meth. in Phys. Res. B 95 (1995) 349–354



This is why we cannot have nice things

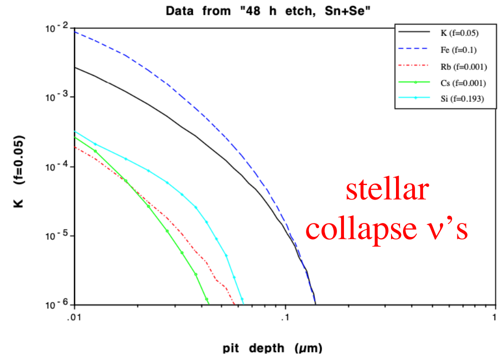
(origin of the 30-year halt in PDs)

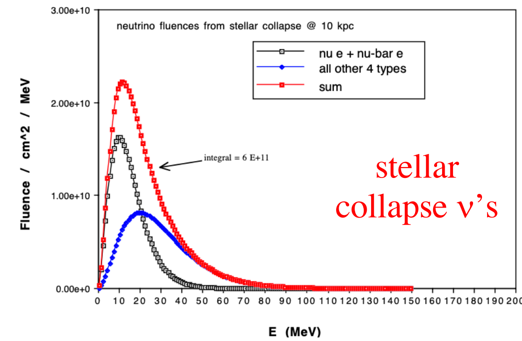
mel·an·chol·y

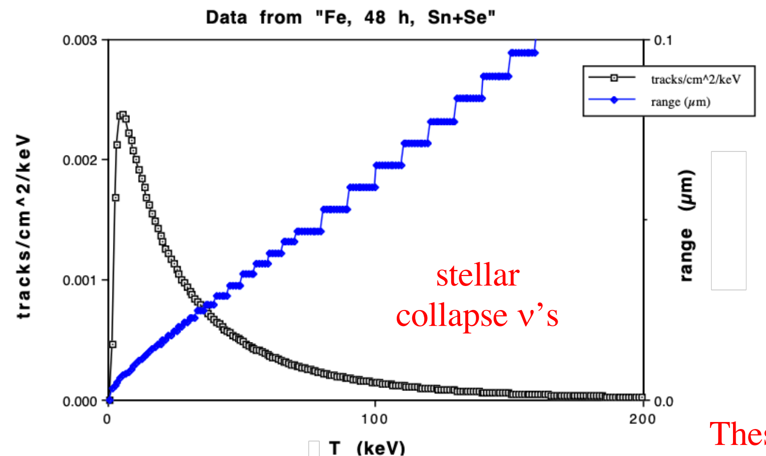
/ˈmel(ə)nˌkälē/

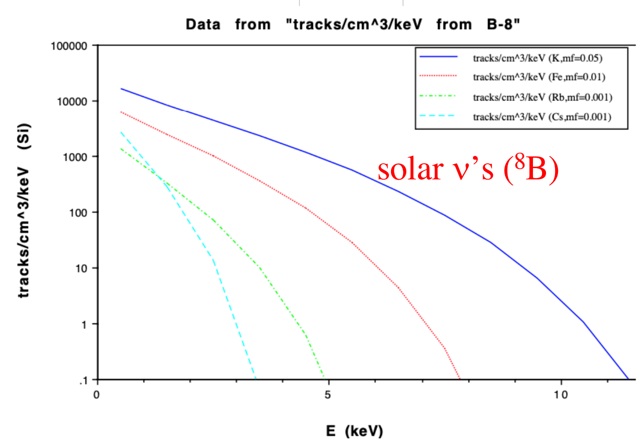
This caveat is unfortunate, since the AFM mica technique could have been exploited for more than WIMP searches. Calculations similar to those in [4] show that recoils from stellar collapse neutrinos and ^{8}B solar neutrinos induce etchable tracks with $\rho \gtrsim 0.03/\mathrm{cm}^2$ in the $\lesssim$100 Å depth region, at fluxes predicted by standard models of the galaxy and Sun. Competitive experimental limits on the stellar collapse rate in our Galaxy could have been obtained with $O(1)$ cm^2 areas. Similarly, the large historical variations in the temperature of the solar core and hence in the ^{8}B neutrino flux that some solar models predict could have been ruled out.

(if you ask nicely, PRL will publish a lament)









These plots from 1994…

Hidden treasures of NIM-B

(and obvious knee-jerk reaction)

Nuclear Instruments and Methods in Physics Research B 117 (1996) 134–139

GeV latent ion tracks in sugar; fullerenes and other radiochemical products

D. Fink [a,*], H.J. Möckel [a], H. Melzer [a], R. Klett [a], F. Hosoi [b], H. Omichi [b],
L.T. Chadderton [c], L. Wang [d]

OTHER MYTHICAL BEASTS: Monopoles, Nuclearites, Q-balls, Dyons...
(all HEAVILY ionizing)

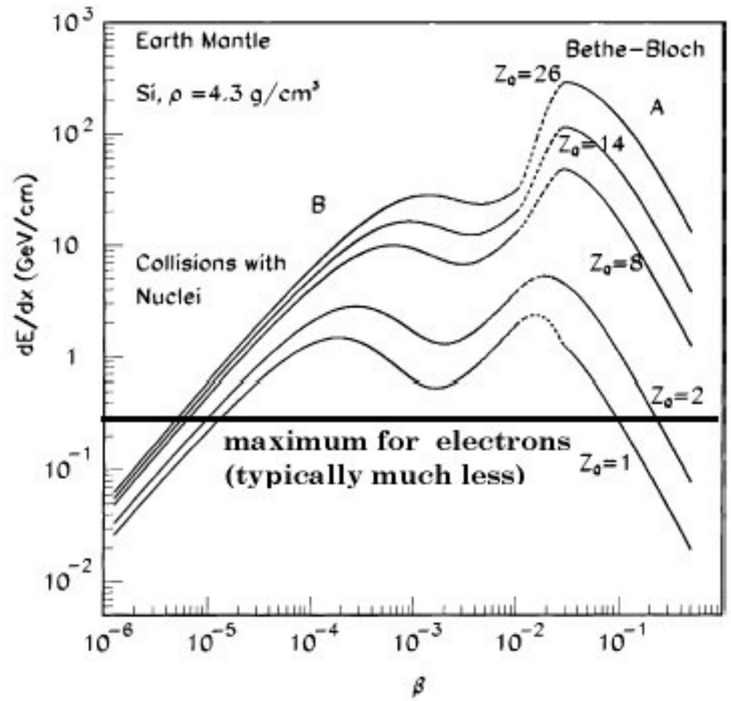
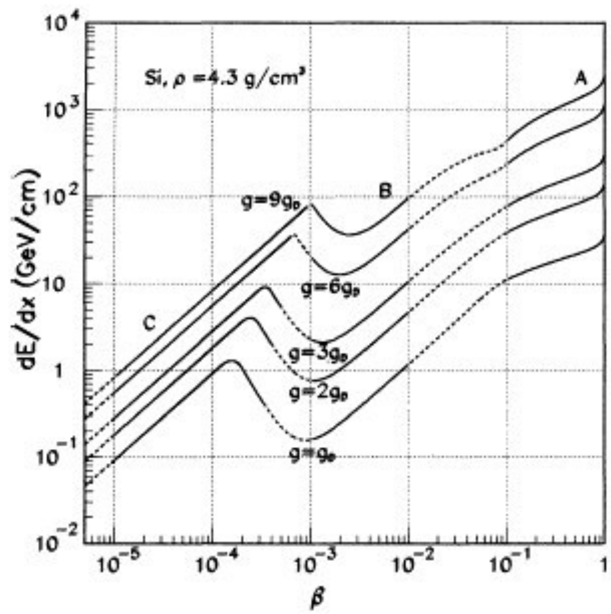


Fig. 5. Energy losses of SECS versus β in the earth mantle; Z_Q is the electric charge of the Q-ball. The dashed parts of the lines indicate interpolations.

Bakari et al, Astropart. Phys. 15, 137 (2001)



idem for monopoles

Can be enormous for Nuclearites:
dE/dx~(1E-8)x(A^(2/3))... A up to 1E56 !!!

"ASTROBLEMS" (de Rujula & Glashow)
"LINEAR EARTHQUAKES"...

David vs. Goliath

( + ) >> 

VOLUME 83, NUMBER 15 PHYSICAL REVIEW LETTERS 11 OCTOBER 1999

Exotic Heavily Ionizing Particles can be Constrained by the Geological Abundance of Fullerenes

J.I. Collar[1,2,*] and K. Zioutas[3]
[1]*Groupe de Physique des Solides (UMR CNRS 75-88), Université Paris 7, 2 Pl. Jussieu, Paris 75251, France*
[2]*EP Division, CERN, CH-1211 Geneve 23, Switzerland*
[3]*Physics Department, University of Thessaloniki, GR-54006 Thessaloniki, Greece*
(Received 15 March 1999)

The C_{60} molecule exhibits a remarkable stability that leads to its survival in ancient carbonaceous rocks initially subjected to the elevated temperature requisite for its formation. Elementary particles having a large electronic stopping power can similarly form C_{60} and higher fullerenes in their wake. Combined, these two features point at the possibility of using the C_{60} presence in selected bulk geological samples as a new type of nuclear track detector, with applications in astroparticle physics.

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We are indebted to P.B. Price for a critical reading of the manuscript.

A new geochemical PD:

look for tell-tale concentration of fullerenes in ancient C-rich rocks

- True **threshold detector**: natural radioactivity cannot produce enough (if any) fullerenes due to short tracks and feeble dE/dx. Tabula rasa for highly-ionizing exotica.

- C-60 takes a beating and keeps on ticking: it does survive over geological ages once formed (in rocks known to have undergone episodes of intense heating). Extremely stable.

- Fullerenes absent from "middle of the road" carbonaceous rocks (good sensitivity is immediately possible).

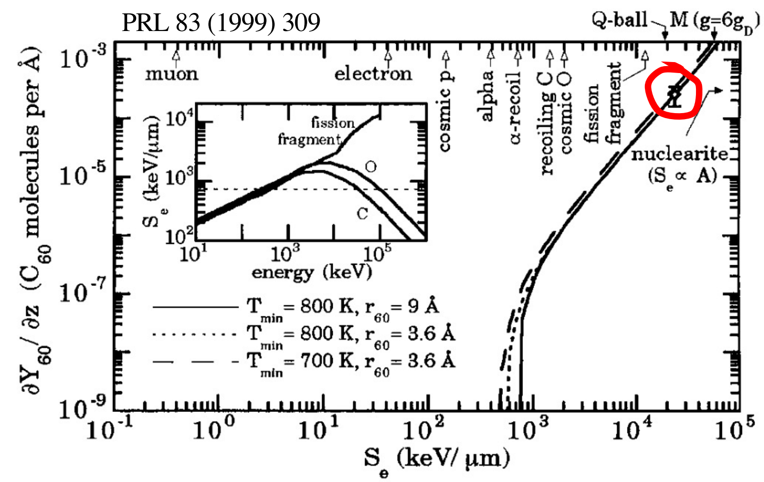


FIG. 1. Estimated C_{60} yield per unit path length vs particle electronic stopping power, in coal-like rocks. The single point corresponds to the overall normalization based on [11]. The dependence on $T_{\min}$ and r_{60} is shown; similar variations of r_0 and $T_{\max}$ have a comparatively negligible effect. The slope at high S_e is in good agreement with [13]. The *maximum* S_e for common natural sources of radiation is indicated (white arrows) and illustrated in the inset for those above the fullerene production threshold $S_e \sim 750$ keV/μm.

Advantages:

1) Bulk chemical processing of rock, no etching of surfaces involved as in SSNTDs.

2) The sensitivity of the technique will grow as chromatographic methods develop (or until we run into a "suspicious" wide-spread and roughly constant fullerene concentration…)

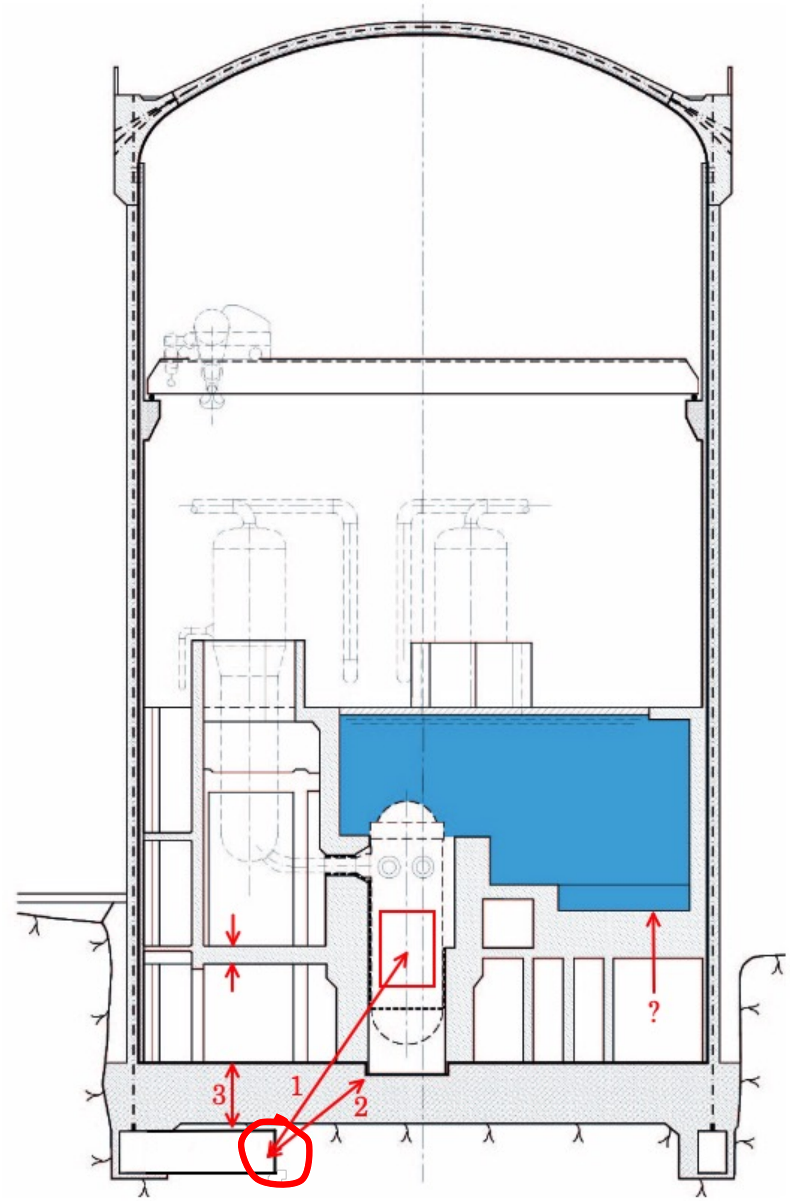
3) Estimates in this paper are conservative (sticky C-H collisions in $C_{12}H_{22}O_{11}$) and possibly outdated (new tech?).

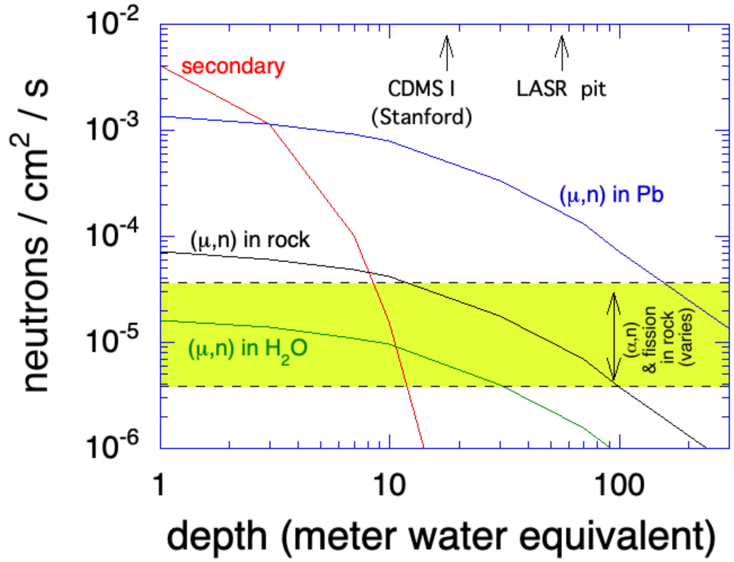
Challenge:

Eminently x-disciplinary effort (geology, chromatography, ion-beam calibrations)

Epilogue

Ringhals RX: ideal location for the hardest trick in this carnival





Based on measurements and discussions summer 2023:

- < 15 m to core.
- > 5.5 m concrete to core. (better than Russian RXs)
- > 30 m.w.e. (prob. ~50 m.w.e.)
- Roomy enough to contemplate PD fabrication mini-laboratory.
- Friendly RX operator (Vattenfall)