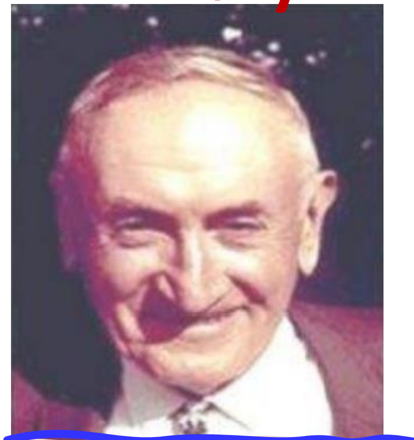
Zwicky



CAST and after-CAST

Konstantin Zioutas

University of Patras / Greece

HEP conference ~**1997**
magnets in the LHC epoch
➔ CAST conception ←

Begining: October 1999
End: 2024

With Frank Avignone, Georg Raffelt + Juan Collar we defended the CAST proposal to CERN. 24 years later **>>** praise CAST **>>> !!!**

Dieter Hoffmann

First **-CHF** ➔ **GSI** / Darmstadt
First **CHF** ➔ **ΓΓΕΤ** / GR

>> **Thanking greek representatives**

Ioannina, 8th April 2023

CAST conception - approval:

Annual Greek HEP conference ~1997:

- LHC large scale magnets!

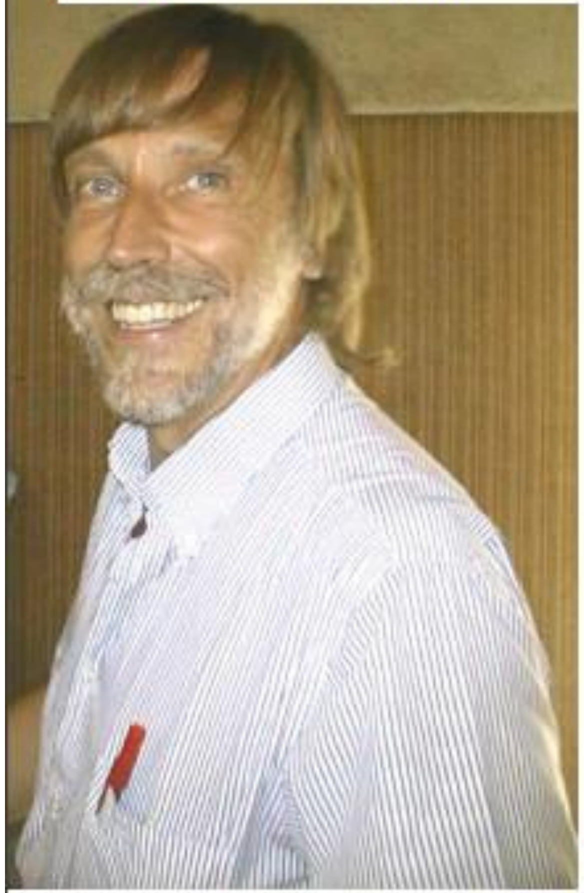
Via Buenos Aires / Argentina SOLAX collaboration meeting

- 1st suggestion to professor Frank AVIGNONE! → YES

then proposal to CERN DG → show 1 MCHF → zero

- 1-2 years later → nomore zero MCHF → approved

Alvaro de Rujula



< 1998

AXION SEARCHES

are

- ◯ MANDATORY
- ◯ FUN, CREATIVE
- ◯ PROCEEDING

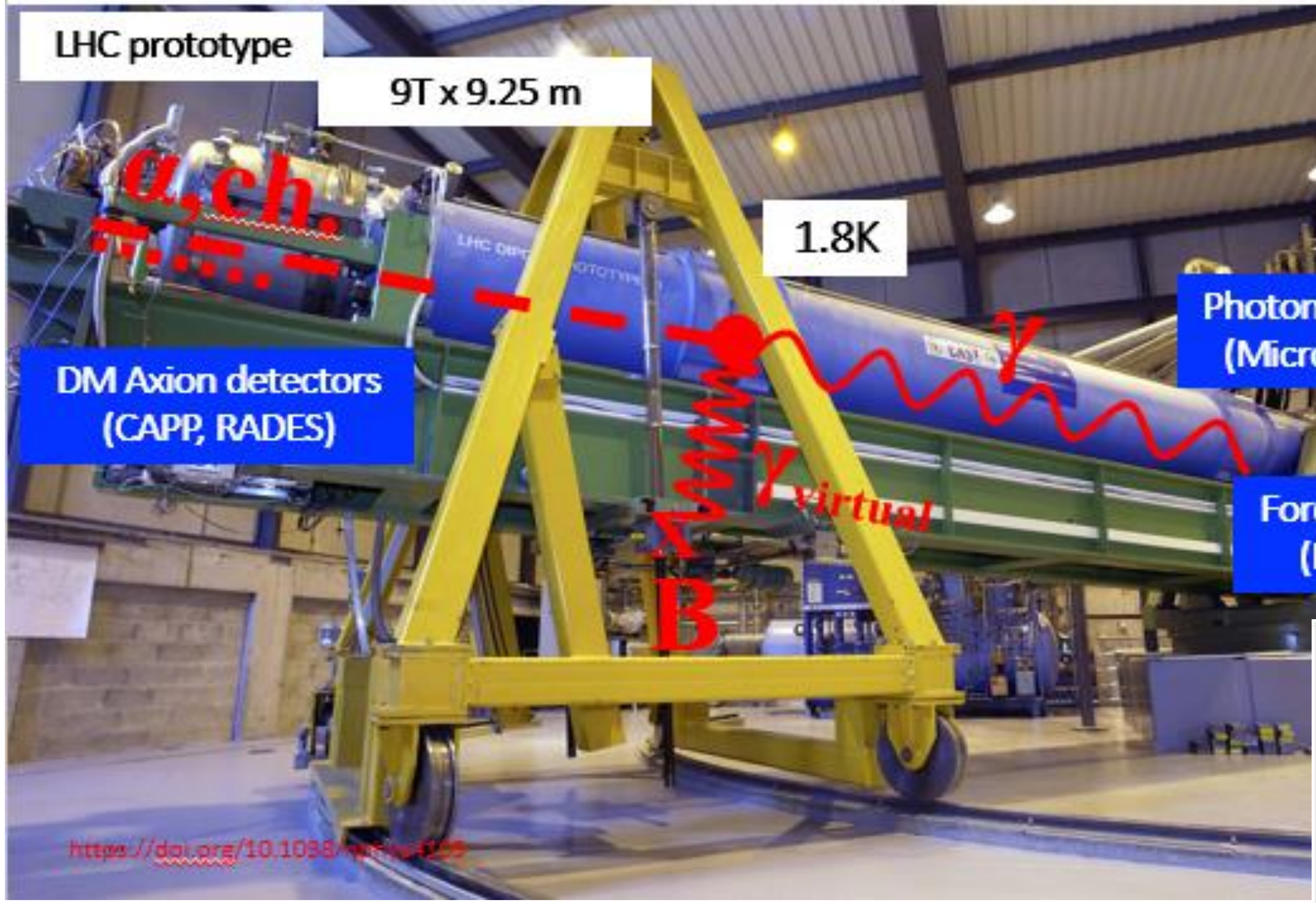
Axion Helioscope

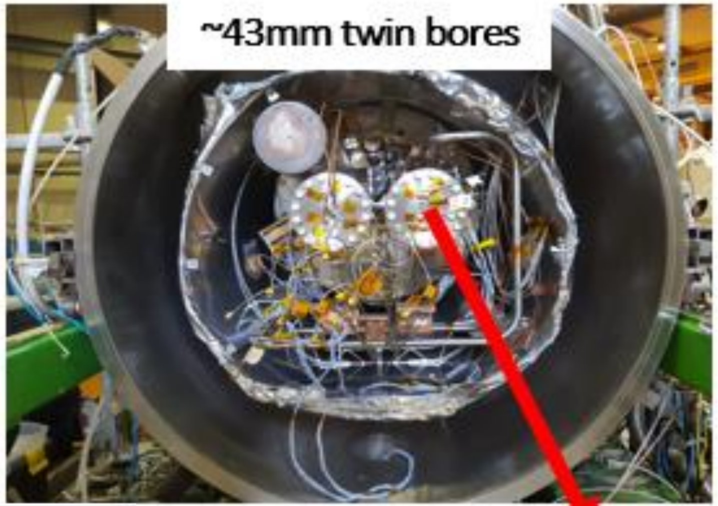
Solar Axions

2019 →

Axion Haloscope

DM Axions





P. Sikivie

CAST-CAPP

← **Our Father**....1983-

πάτερ ημών...

With CAST

From **solar axions**

- **H.E. solar Axions**
- **Solar Chameleons**
- **DM axions**

- **unexpected obs's, e.g. planetary relationships**

SPINOFFs

Beyond initial proposal

Also:

XRTelescope from DE astrophysics ➔ astropart. Phys.

Phase matched 4 cavities ➔ ∞

~fast scanning ~10 MHz / min (single cavity)

CAST: physics achievements

1PRL &
2NATURE papers
…. more?

+

- young people 'start-ups', promotions
- education in astrophysics & cosmology …

ILIAS >> EU network

[March 2023]

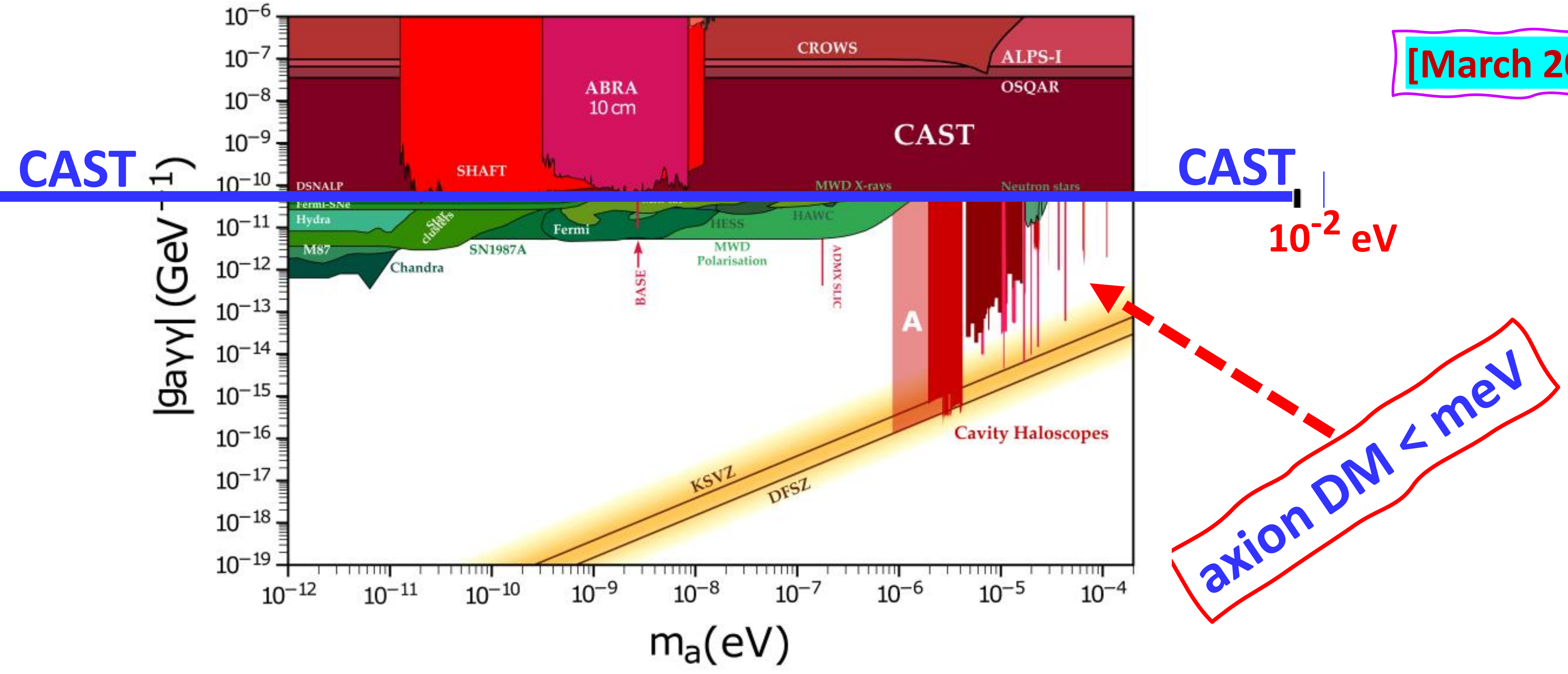


FIG. 1: Limits on the axion electromagnetic coupling $g_{a\gamma\gamma} \equiv g_\gamma \frac{\alpha}{\pi} \frac{1}{f_a}$ as a function of axion mass m_a, obtained by various axion dark matter searches. In addition, the light shaded area labeled A indicates the sensitivity, under assumptions spelled out in Section VI, of a search using a reentrant or dielectrically loaded cavity inserted in the "Extended Frequency Range" (EFR) magnet that ADMX plans to operate at Fermilab. The figure was made by modifying Ciaran O'Hare's code [14] available at https://github.com/cajohare/AxionLimits

https://arxiv.org/abs/2303.07116

PHYSICAL REVIEW LETTERS

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First Results from the CERN Axion Solar Telescope

2005

K. Zioutas *et al.* (CAST Collaboration)
Phys. Rev. Lett. **94**, 121301 – Published 1 April 2005

Article | References | Citing Articles (276) | PDF | HTML | Export Citation

ABSTRACT

Hypothetical axionlike particles with a two-photon interaction would be produced in the sun by the Primakoff process. In a laboratory magnetic field ("axion helioscope"), they would be transformed into x-rays with energies of a few keV. Using a decommissioned Large Hadron Collider test magnet, the CERN Axion Solar Telescope ran for about 6 months during 2003. The first results from the analysis of these data are presented here. No signal above background was observed, implying an upper limit to the axion-photon coupling $g_{a\gamma} < 1.16 \times 10^{-10}\ \mathrm{GeV}^{-1}$ at 95% C.L. for $m_a \lesssim 0.02\ \mathrm{eV}$. This limit, assumption-free, is comparable to the limit from stellar energy-loss arguments and considerably more restrictive than any previous experiment over a broad range of axion masses.

ARTICLES
PUBLISHED ONLINE: 1 MAY 2017 | DOI: 10.1038/NPHYS4109

2017

nature physics

OPEN

New CAST limit on the axion–photon interaction

CAST Collaboration†

V. Anastassopoulos[1], S. Aune[2], K. Barth[3], A. Belov[4], H. Bräuninger[5], G. Cantatore[6], J. M. Carmona[7], J. F. Castel[7], S. A. Cetin[8], F. Christensen[9], J. I. Collar[10], T. Dafni[7], M. Davenport[3], T. A. Decker[11], A. Dermenev[4], K. Desch[12], C. Eleftheriadis[13], G. Fanourakis[14], E. Ferrer-Ribas[2], H. Fischer[15], J. A. García[7†], A. Gardikiotis[1], J. G. Garza[7], E. N. Gazis[16], T. Geralis[14], I. Giomataris[2], S. Gninenko[4], C. J. Hailey[17], M. D. Hasinoff[18], D. H. H. Hoffmann[19], F. J. Iguaz[7], I. G. Irastorza[7]*, A. Jakobsen[9], J. Jacoby[20], K. Jakovčić[21], J. Kaminski[12], M. Karuza[6,22†], N. Kralj[22†], M. Krčmar[21], S. Kostoglou[3], Ch. Krieger[12], B. Lakić[21], J. M. Laurent[3], A. Liolios[13], A. Ljubičić[21], G. Luzón[7], M. Maroudas[1], L. Miceli[23], S. Neff[19], I. Ortega[3,7], T. Papaevangelou[2], K. Paraschou[13], M. J. Pivovaroff[11], G. Raffelt[24], M. Rosu[19†], J. Ruz[11], E. Ruiz Chóliz[7], I. Savvidis[13], S. Schmidt[12], Y. K. Semertzidis[23†], S. K. Solanki[25†], L. Stewart[3], T. Vafeiadis[3], J. K. Vogel[11], S. C. Yildiz[8†], K. Zioutas[1,3]

60 authors **25%** greeks

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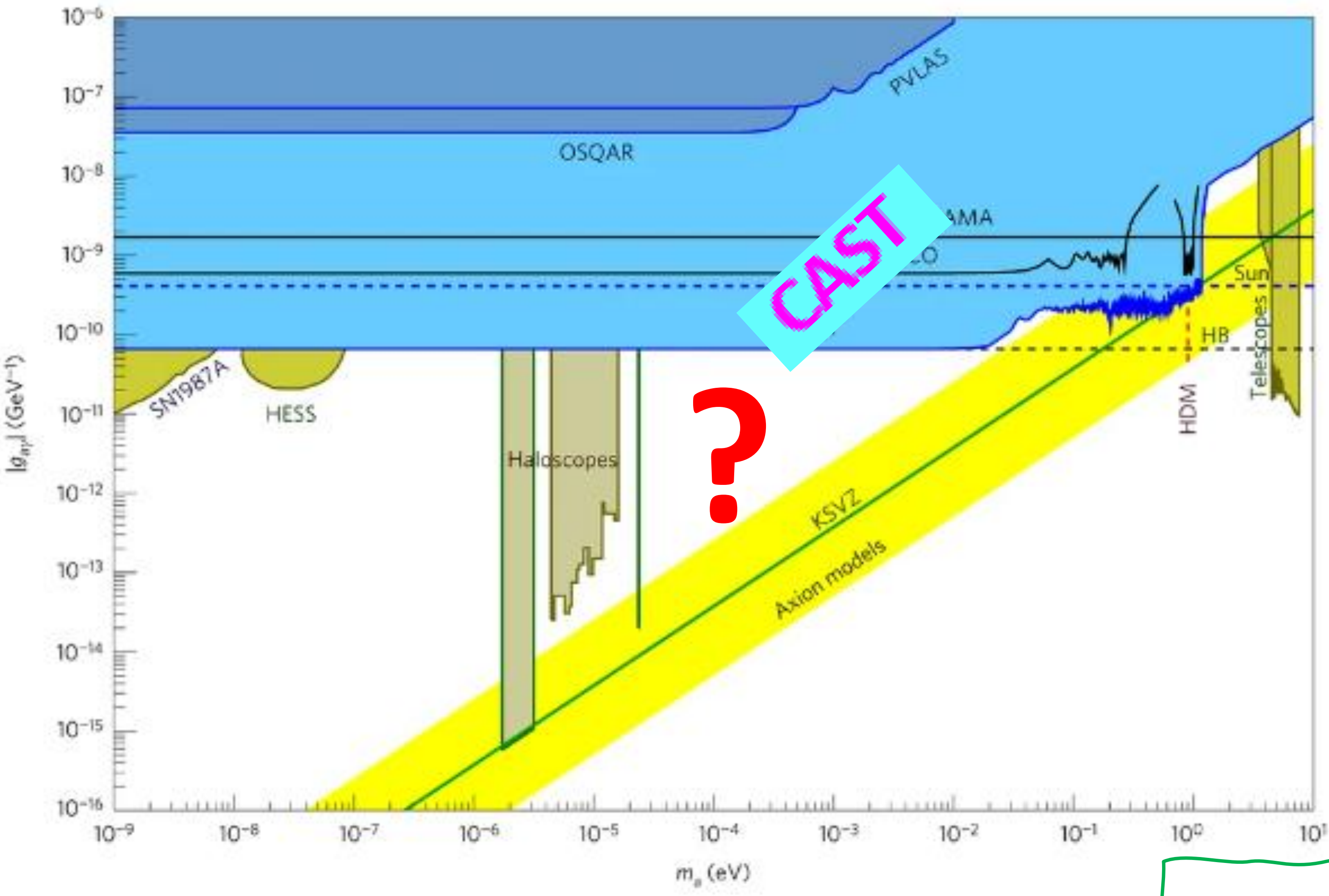
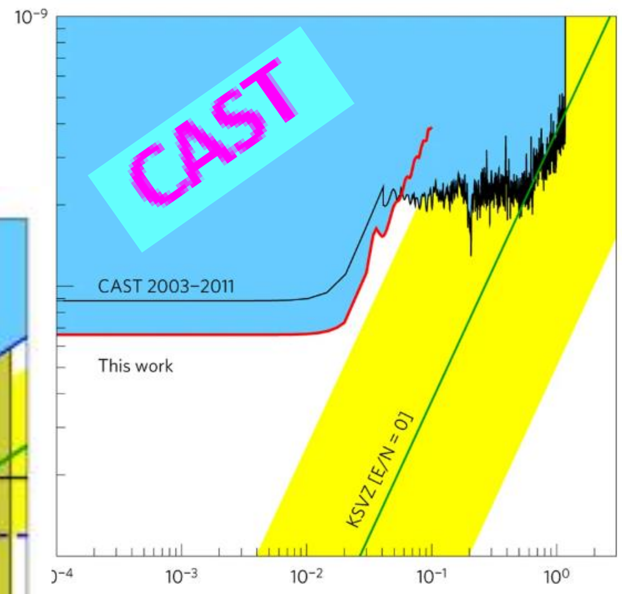
https://www.nature.com/articles/nphys4109

2017

Constraints on the two-photon coupling $g_{a\gamma\gamma}$ of axions and similar particles depending on their mass m_a.

[New CAST limit on the axion–photon interaction]





WHY?

we look(ed) into the Sun?

The arguments:

a priori* ≠ *a posteriori

1999 — Best $g_{a\gamma\gamma}$ - limit

2022 — This talk

https://www.nature.com/articles/nphys4109

PHYSICAL REVIEW D **85**, 035018 (2012) => Exper. Publication => 2022

Prospects for searching axionlike particle dark matter with dipole, toroidal, and wiggler magnets

Oliver K. Baker,[1] Michael Betz,[2] Fritz Caspers,[2] Joerg Jaeckel,[3] Axel Lindner,[4] Andreas Ringwald,[4]
Yannis Semertzidis,[5] Pierre Sikivie,[6] and Konstantin Zioutas[7] 9 Authors / 7 afiliations

[1]*Department of Physics, Yale University, New Haven, Connecticut 06520-8120, United States, USA*
[2]*CERN, CH-1211 Geneva, Switzerland*
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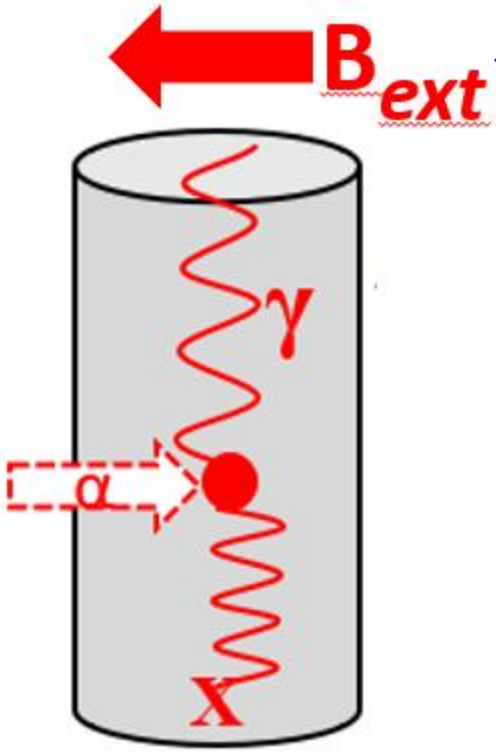
[4]*Deutsches Elektronen Synchrotron DESY, Notkestrasse 85, D-22607 Hamburg, Germany*
[5]*Brookhaven National Laboratory, New York-USA*
[6]*Department of Physics, University of Florida, Gainesville, Florida 32611, USA*
[7]*University of Patras, Patras, Greece*
(Received 10 November 2011; published 17 February 2012)

In this work, we consider searches for dark matter made of axions or axionlike particles using resonant radio frequency cavities inserted into dipole magnets from particle accelerators, wiggler magnets developed for accelerator based advanced light sources, and toroidal magnets similar to those used in particle-physics detectors. We investigate the expected sensitivity of such axionlike-particle dark-matter detectors and discuss the engineering aspects of building and tuning them. Brief mention is also made of even stronger field magnets which are becoming available due to improvements in magnetic technology. It is concluded that new experiments utilizing already-existing magnets could greatly enlarge the mass region in searches for axionlike dark matter particles.

DOI: 10.1103/PhysRevD.85.035018 PACS numbers: 14.80.Va, 95.35.+d

AXION HALOSCOPE *à la Sikivie*



CAST magn. pipes

nature communications

2022

Article

https://doi.org/10.1038/s41467-022-33913-6

Search for Dark Matter Axions with CAST-CAPP

64 authors **17%** greeks

Received: 19 November 2021

Accepted: 7 October 2022

Published online OCTOBER 2022

Check for updates

C. M. Adair[1], K. Altenmüller[2], V. Anastassopoulos[3], S. Arguedas Cuendis[4], J. Baier[5], K. Barth[4], A. Belov[6], D. Bozicevic[7], H. Bräuninger[8], G. Cantatore[9,10], F. Caspers[4,11], J. F. Castel[2], S. A. Çetin[12], W. Chung[13], H. Choi[14], J. Choi[13], T. Dafni[2], M. Davenport[4], A. Dermenev[6], K. Desch[15], B. Döbrich[4], H. Fischer … W. Funk[4], J. Galan[2], A. Gardikiotis[3,16], S. Gninenko[6], J. Golm[4,17], M. D. Hasinoff[1], D. H. H. Hoffmann[18], D. Díez Ibáñez[2], I. G. Irastorza … K. Jakovčić[19], J. Kaminski[15], M. Karuza[9,20,21], C. Krieger[15,26] … B. Lakić[19,31], J. M. Laurent[4], J. Lee[14], S. Lee[13], G. Luzón[2], C. … C. Margalejo[2], M. Maroudas[3] ✉, L. Miceli[13], H. Mira… …s[2], A. Özbey[12,27], K. Özbozduman[12,28] ✉, M. J. Pivo… …Rosu[23], J. Ruz[22], E. Ruiz-Chóliz[24], S. Schmidt[15], M. Schumann[5], … …dis[13,14], S. K. Solanki[25], L. Stewart[4], I. Tsagris[3], T. Vaf… …Vogel[22], M. Vretenar[20,30], S. Youn[13] & K. Zioutas

So far: CAST-CAPP => SHM

NATURE communications Highlight articles

https://www.nature.com/collections/iaiaadijih

4 referees!

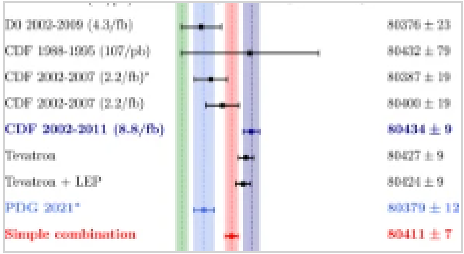
Featured articles

Article
Open Access
7 Feb 2023
Nature Communications

Hadronic uncertainties versus new physics for the *W* boson mass and Muon $g-2$ anomalies

The tension between measured W mass and its Standard Model prediction might arise from uncertainties in the hadronic contribution, and the same is true for the muon g − 2. Here, the authors show that such a common origin for the two anomalies is unlikely, while a model involving leptoquarks might explain them both.

Peter Athron, Andrew Fowlie ... Bin Zhu

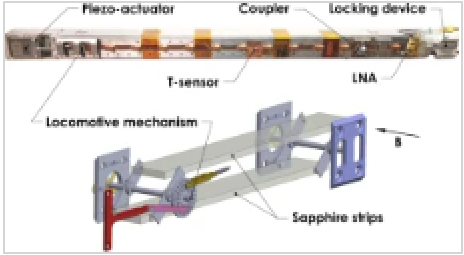


Article
Open Access
19 Oct 2022
Nature Communications

Search for Dark Matter Axions with CAST-CAPP

Haloscopes aim at detecting axions by converting them into photons using high-quality resonant cavities, where the cavity resonance should be tuned with the unknown axion mass. Here, the authors improve exclusion limits using four phase-matched resonant cavities and a fast frequency scanning technique.

C. M. Adair, K. Altenmüller ... K. Zioutas



nature communications => October 2022 => https://rdcu.be/cXQ71

CAST

3.)

$\propto \sqrt{1/\rho_a}$

1.)

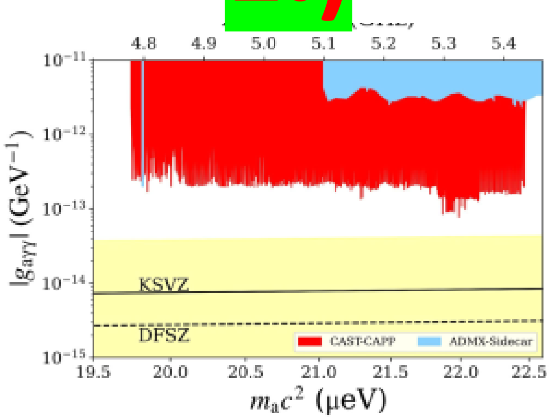


Fig. 5 | CAST-CAPP exclusion limit on the axion-photon coupling as a function of axion mass at 90% confidence level (left), and compared to other axion search results[10,25,30,34–41] within the mass range 1–25 μeV (right). The higher

Nature Communications | _####################_ 6

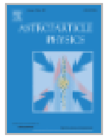
2.)

- ✓ Phase-matching of all four cavities.
- ✓ Fast resonance scanning.
- ✓ Unexplored parameter space.

ρ_0 ➔ DM streams / clusters ➔ improve sensitivity

1^{st} spinoff

Astroparticle Physics
Volume 20, Issue 1, October 2003, Pages 73-78



Gravitational lensing ⇔ c
⇔ 0.001c

Gravitational lensing by the Sun of non-relativistic penetrating particles

← DM

a "first"

D.H.H Hoffmann [a], J Jacoby [b], K Zioutas [a c d]

Show more

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https://doi.org/10.1016/S0927-6505(03)00138-5
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$$\Delta\Phi = \frac{4MG}{bc^2}$$

Abstract

The flux of weakly interacting particles from celestial sources, moving with a velocity $v \approx 0.2c$, can be temporarily amplified at the site of the Earth, due to gravitational lensing effects by the Sun. The effective amplification factor can be as much as $\sim 10^3$ to $\sim 10^4$, for a velocity bin-width of ~0.1%. The theoretically motivated solar Kaluza-Klein axions provide a generic example of particles with a wide velocity spectrum, filling the gap between $v \approx c$ (e.g. neutrinos) and $v \approx 10^{-3}c$ (e.g. dark matter (DM) candidates). If the putative particles come from a direction along the projected path of the Sun in the Sky, within a strip of ~0.1° along the ecliptic, then, time windows of possible enhanced flows can be predicted. This suggestion can be implemented in the (re)-analysis of data from DM-experiments, and, it does not need any major experimental modification. In particular, performing a cross-correlation of data taken over a period more than 1 year, from the same or even also from other experiments, this can result to (un)predictable time windows of interest. Because, if burst-like events re-appear in following years in fixed dates, this will be an unambiguous identification of the cosmic origin of underground events, which were ignored before. Thus, thanks to solar gravitational effects, DM-experiments can be transformed to telescopes of penetrating non-relativistic particles with a field-of-view of ~0.1°, or even more, along the ecliptic.

→ The missing access to DM-data does not allow us to test this technique. We therefore suggest to the astroparticle physics community to release its data. ←

All you need is ..

STREAMS

Moon → Earth **focusing:** ≤400 km/s

amplification ≈10^4×

Earth intrinsic self-focusing: max @ 17 km/s (10^9×)

[Sofue] **2020** https://arxiv.org/abs/2005.08252

[A. Kryemadhi, M. Maroudas, A. Mastronikolis, K. Z. (**2023**) https://arxiv.org/abs/2210.07367 PRD

Overlooked in DM research

Prezeau

! **Also: planetary grav. self-focusing: Streams → "hairs"** !

Flux enhancements : ~10^8×

Modern Physics Letters A
Vol. 29, No. 37 (2014) 1440008 (7 pages)

DOI: 10.1142/S0217732314400082

2014 → https://arxiv.org/abs/1309.4021

arXives

The 11 years solar cycle as the manifestation of the dark Universe

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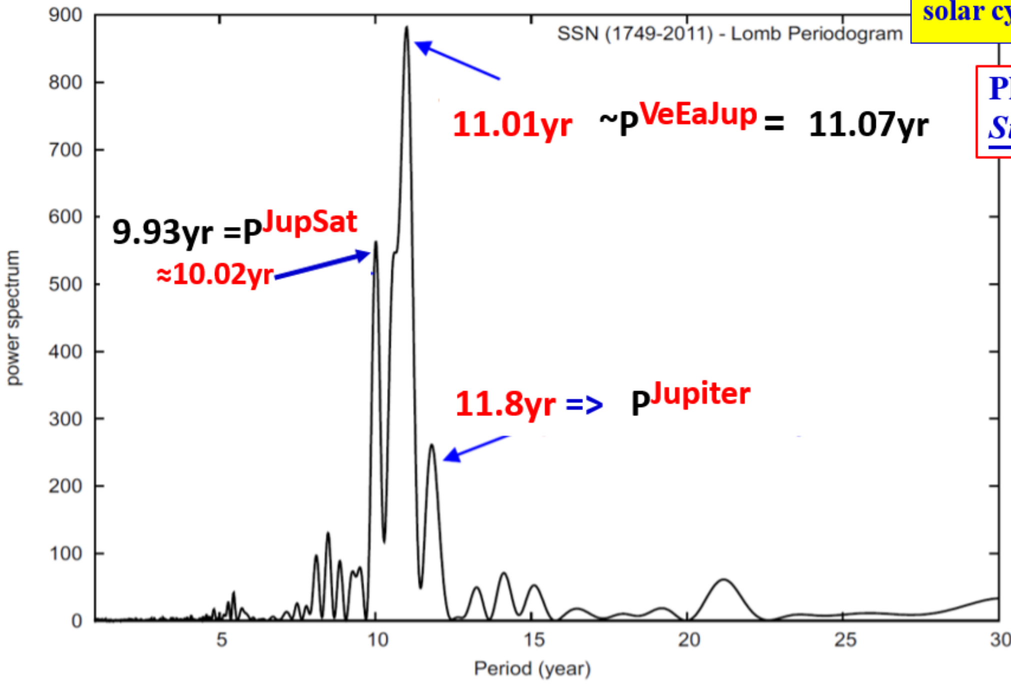
Received 29 January 2014
Accepted 18 September 2014
Published 26 November 2014

Sun's luminosity in the visible changes at the 10^{-3} level, following the 11 years period. This variation increases with energy, and in X-rays, which should not even be there, the amplitude varies up to $\sim 10^5$ times stronger, making their mysterious origin since the discovery in 1938 even more puzzling, and inspiring. We suggest that the multi-faceted mysterious solar cycle is due to some kind of dark matter streams hitting the Sun. Planetary gravitational lensing enhances (occasionally) slow moving flows of dark constituents toward the Sun, giving rise to the periodic behavior. Jupiter provides the driving oscillatory force, though its 11.8 years orbital period appears slightly decreased, just as 11 years, if the lensing impact of other planets is included. Then, the 11 years solar clock may help to decipher (overlooked) signatures from the dark sector in laboratory experiments or observations in space.

Keywords: 11 years solar cycle; dark matter; gravitational lensing.

The ~ubiquitous 11-year solar cycle



11yrs ≈ 11.86 yrs
solar cycle ≈ $P^{JUPITER}$

Planetary dependence
***Suspected* since 1859**

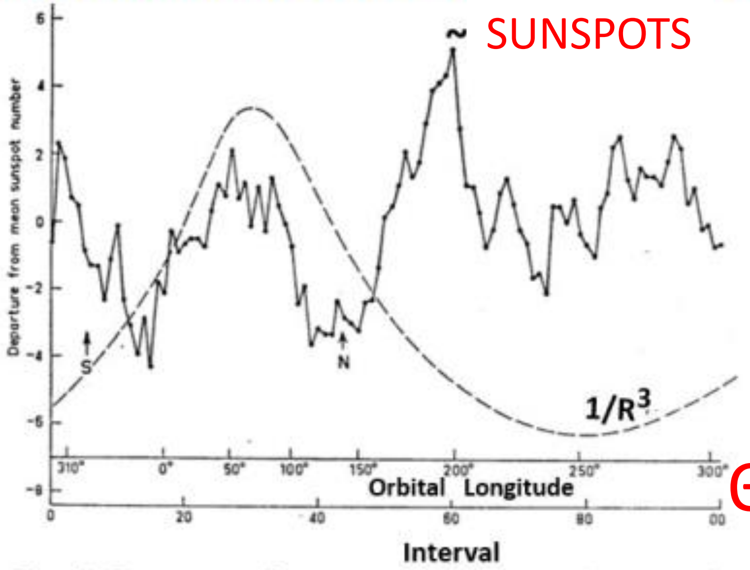
Remote Force?

The Q ever since!

Discarded... 1967 ⟷ MERCURY ⟷ 2017 Planetary dependence

because inconsistent w' $1/R^3$ tidal force

http://adsabs.harvard.edu/abs/1967AJ.....72..463B AJ (1967)



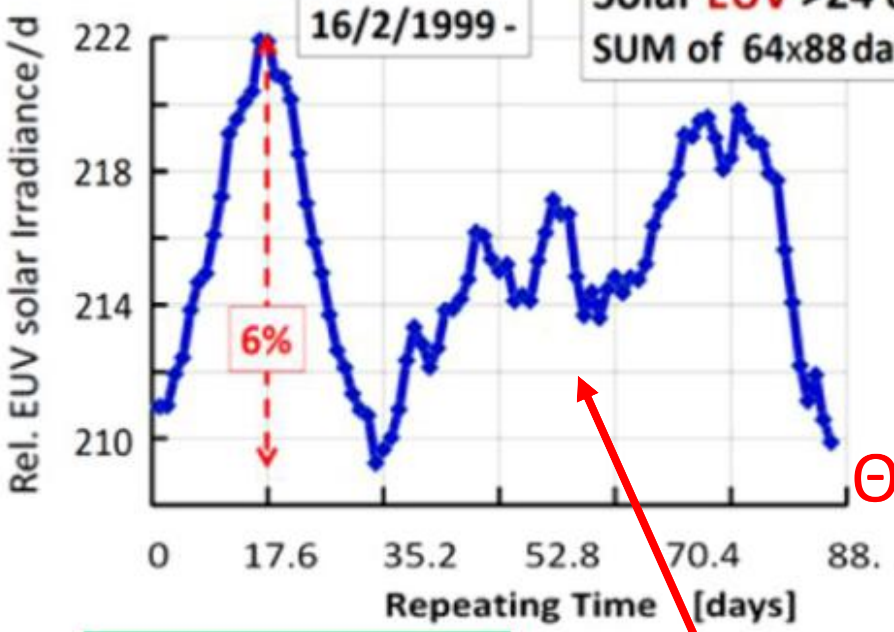
$\Theta_{MERCURY}$

FIG. 4. Departures from mean sunspot numbers as a function of Mercury's position. Equivalent to the mean waveform of the detected signal.

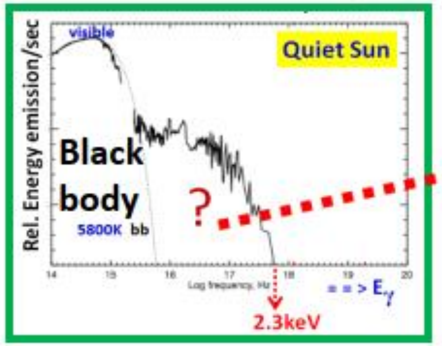
"It is immediately obvious that <u>no simple theory will entirely account for this complex pattern</u>, but one of the maxima occurs near Mercury's closest approach to the sun and the two conspicuous minima occur quite close to the planet's greatest departures from the plane of the earth's orbit (N and S in Fig.)."

http://dx.doi.org/10.1016/j.dark.2017.06.001

Phys.Dark Univ. (2017)



$\Theta_{MERCURY}$



The manifestation of the hot corona

Sunspot Nr / EUV ➔ solar activity proxy

WHY solar axions?

- Axion theory
- Sun *a permanent big bang~16MK*
- From the Sun *~grav. focusing*

➔ exo-solar origin ⟵

Best SPINOFF

DM: .001c ➔ Grav. Focusing within solar system => STREAMS D. Hoffmann, J. Jacoby, K.Z, Astroparti. Phys. 20 (2003) 73; https://www.sciencedirect.com/science/article/pii/S0927650503001385

Sun's dynamical behaviour

=> **a multiple mystery:** e.g. corona heating & its T – inversion 1939 – , 11 years cycle, sunspots, flares, EUV, solar radius variation, … F10.7 radio line (=**solar proxy**)

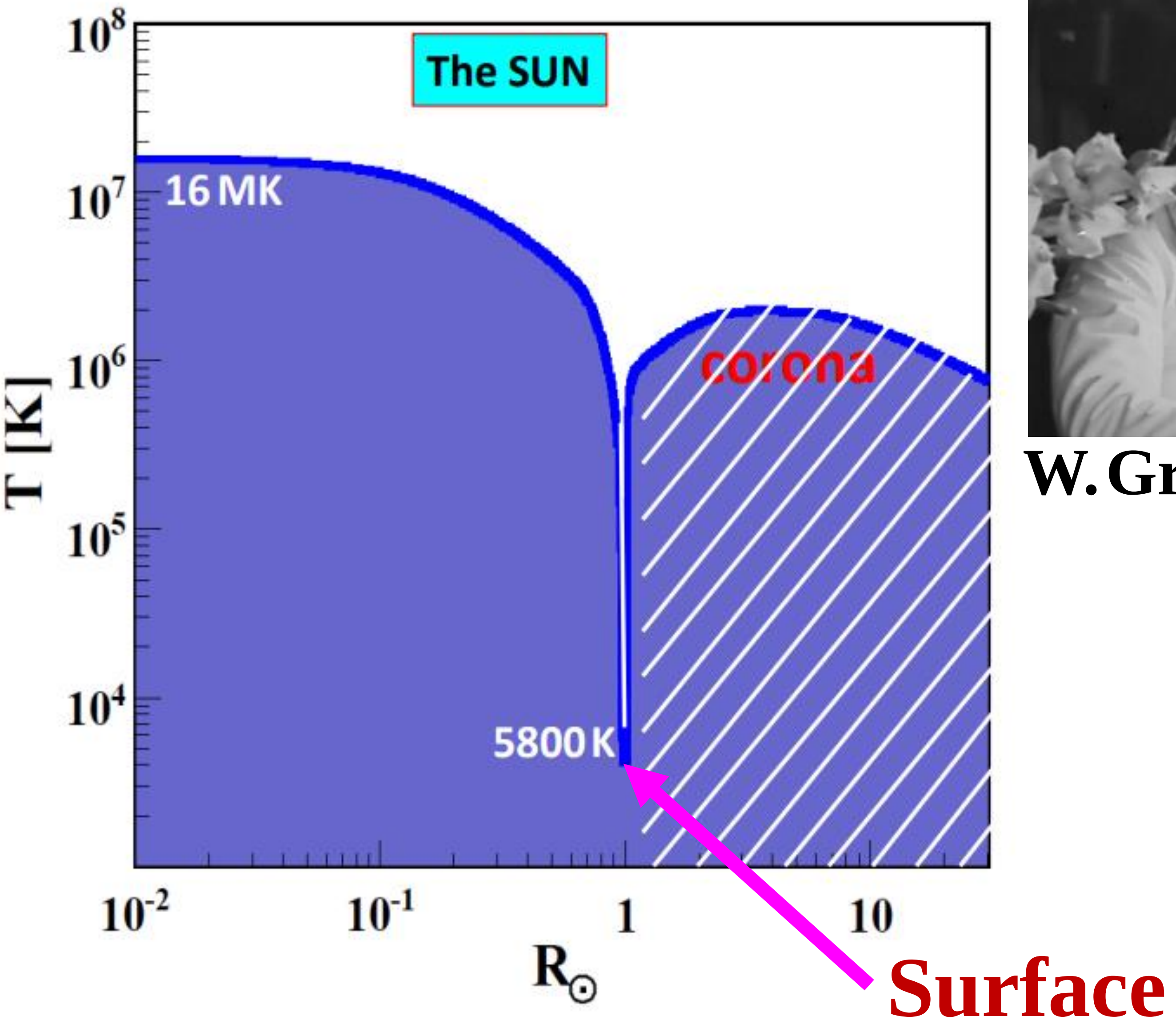
➔ every solar observable

?*Best choice*?

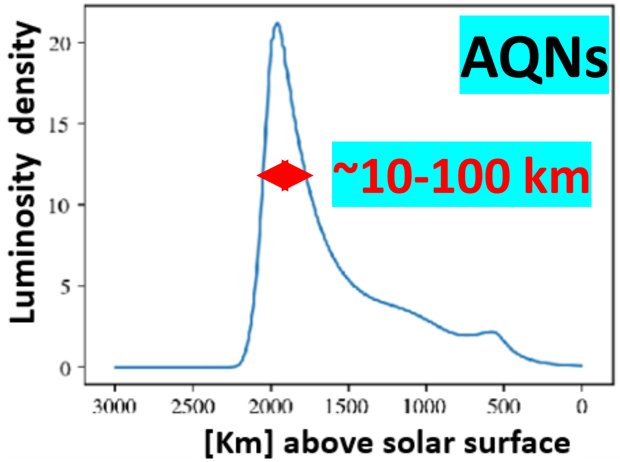
Frank Wilczek (CENR seminar):

"~focus on anomalies / mysteries"

A mysterious solar observation: $T_{SUN} = f(R)$



W. Grotrian 1939



N. Raza, L. van Waerbeke, **A. Zhitnitsky**, *Solar Corona Heating by the AQN DM*, arXiv:1805.01897 (**2018**)

The AQN model is being tested by CAST

“Spacecraft Makes **Progress** on Solar Heating Mystery”

October 2022 • ***Physics* 15, 157** Parker Solar Probe confi

a long-suspected heat source for the Sun’s … Experts are not sure why the solar and the solar wind are hundreds of times hotter than the surface of the Sun, but **they have several theories**. **Researchers have now confirmed one suspected source of heating.**

***surprisingly hot corona*, *but there may be others*.**

https://physics.aps.org/articles/v15/157

See also https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.129.165101?utm_source=email&utm_medium=email&utm_ca alert

A long lasting mystery

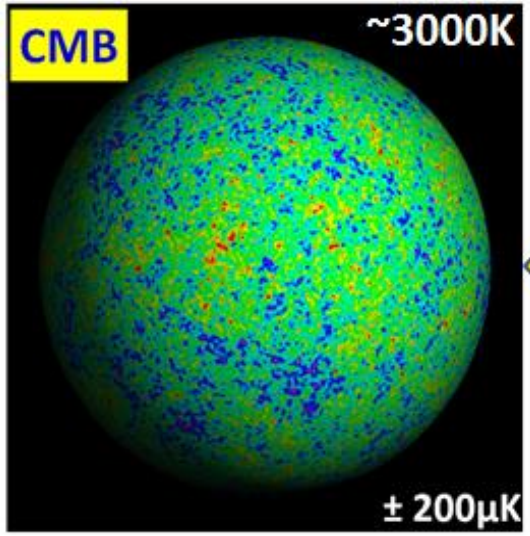
It is extremely difficult to simulate the details of coronal heating …Thus

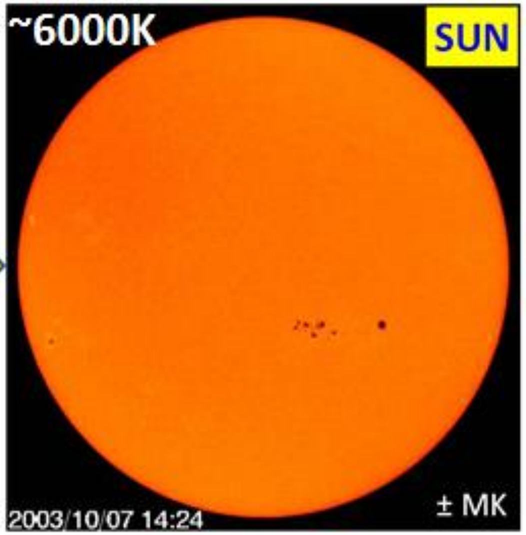
testing realistic models with observations is a major challenge.

JA. **Klimchuk** et al., ApJ (**2022**) accepted 2nd **Nov. 2022**

UNIVERSE **SUN**

~10^5 years ~10^9 years





$\Delta T/T \sim 10^{-5}$ $\Delta T/T \sim 10^{+3}$

SUN:
not thermalized after 4.5 Gyrs
=> **WHY NOT?**

look at!

Observation & cosmology ➔
invisible streams @ solar system

p.t.o.

The dynamical **solar behaviour** remains a **mystery!** + **inspiring**

11 years cycle, Corona anomaly, sunspots, flares, EUV, solar radius variation … F10.7 radio line (=**solar proxy**) ➔

All show planetary dependencies! HOW?

a posteriori

CONCLUSION:

The Sun is a set of anomalies / mysteries

⇒ **Look at** e.g.: w. an **XRT**
or, w. **DM equipment!**

Unexpected……potential discovery!

!Surprise!?

Fine-Grained Streams from Cosmological Simulations

The cold nature of dark matter yields particles with nearly zero dispersions (**~10^{-10} c** for WIMPs and **10^{-17} c** for Axions) at the last scattering

Mark Vogelsberger and Simon D. M. White used N-body equations of motion:

The DM distribution at a typical point in the halo is described as a superposition of many ***fine-grained streams*** with discrete velocity distributions, each of which has a very small velocity dispersion.

Mark Vogelsberger and Simon D. M. White,
Mon. Not. R. Astron. Soc. 413 (**2011**) 1419

arXiv:2108.11647 [pdf]

The Dark Universe is not invisible

K. Zioutas, V. Anastassopoulos, A. Argiriou, G. Cantatore, S.A. Cetin, A. Gardikiotis, D.H.H. Hoffmann, S. Hofmann, M. Karuza, A. Kryemadhi, M. Maroudas; E.L. Matteson, K. Ozbozduman,;T. Papaevangelou, M. Perryman, Y.K. Semertzidis, I. Tsagris, M. Tsagri, G. Tsiledakis, D. Utz, E.L. Valachovic **Phys. Sci. Forum 2021, 2(1), 10**

Febr. **2021**

Trillions of DM particles may lurk in Earth's crust

https://doi-org.ezproxy.cern.ch/10.1016/S0262-4079(22)01808-5

Oct. **2022**

Dunkle Materie weniger dunkel?

Translated: **Is DM less dark?**

https://www.scinexx.de/news/kosmos/dunkle-materie-wer-enigdunkel/ Febr. **2023**

Seminar at CERN 28/3/2023, M. Hostert. **Semi-Visible Dark Photons**

https://arxiv.org/abs/2302.05410 Febr. **2023**

The Dark World is not dark!

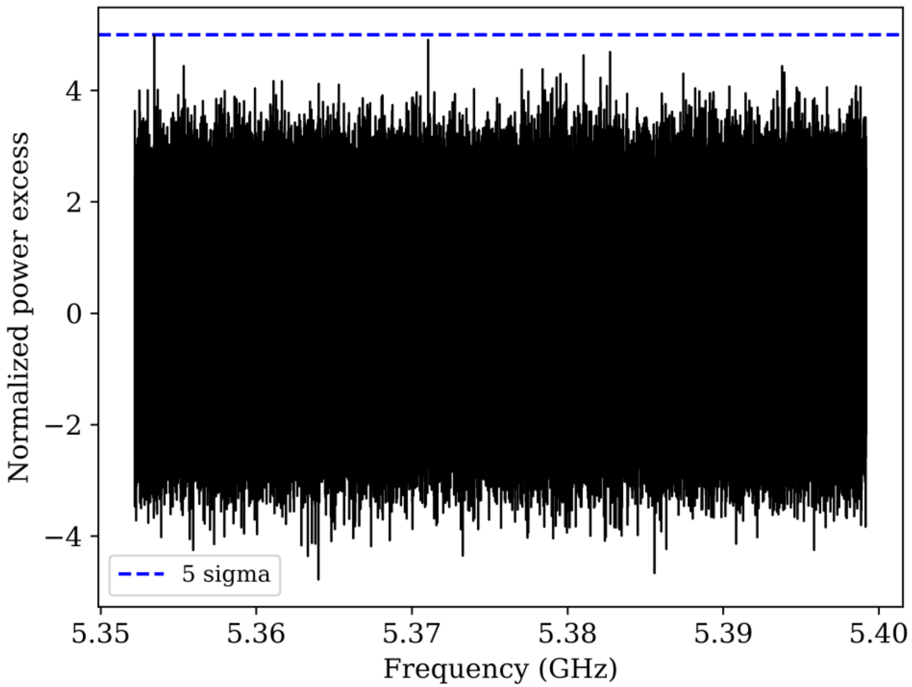

PHASE 2
CAST
AxionSearch
THANK YOU + CASTers

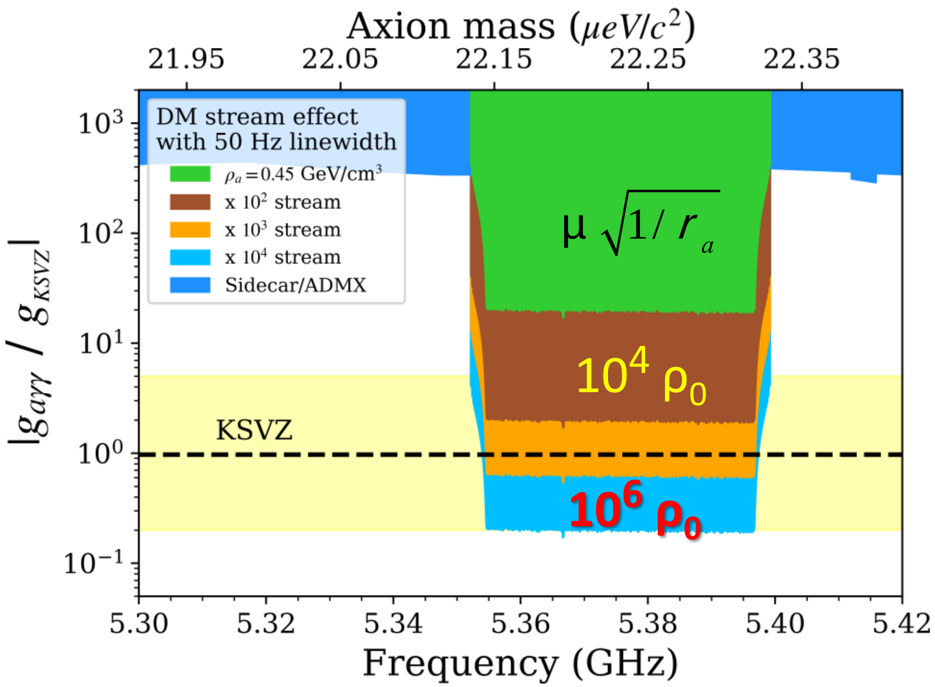
Additional slides

STREAMING DARK MATTER

- **New procedure** for transient events such as axion streams or axion-mini clusters.
- Second measurement channel is decisive for such searches.

- Example measurement for 4.5h on 24/11/2020 (19:19 – 23:53 local time).
- Fast scanning method over 42 MHz (5.3547 GHz – 5.3967 GHz).
- Combined spectrum (RBW = 50Hz) shows no lines above 5σ threshold.
- *"Local"* exclusion plot assuming axion streams with modest flux enhancement $10^2 – 10^4$.
- Future tests with even smaller RBW including also raw IQ data in time-domain.





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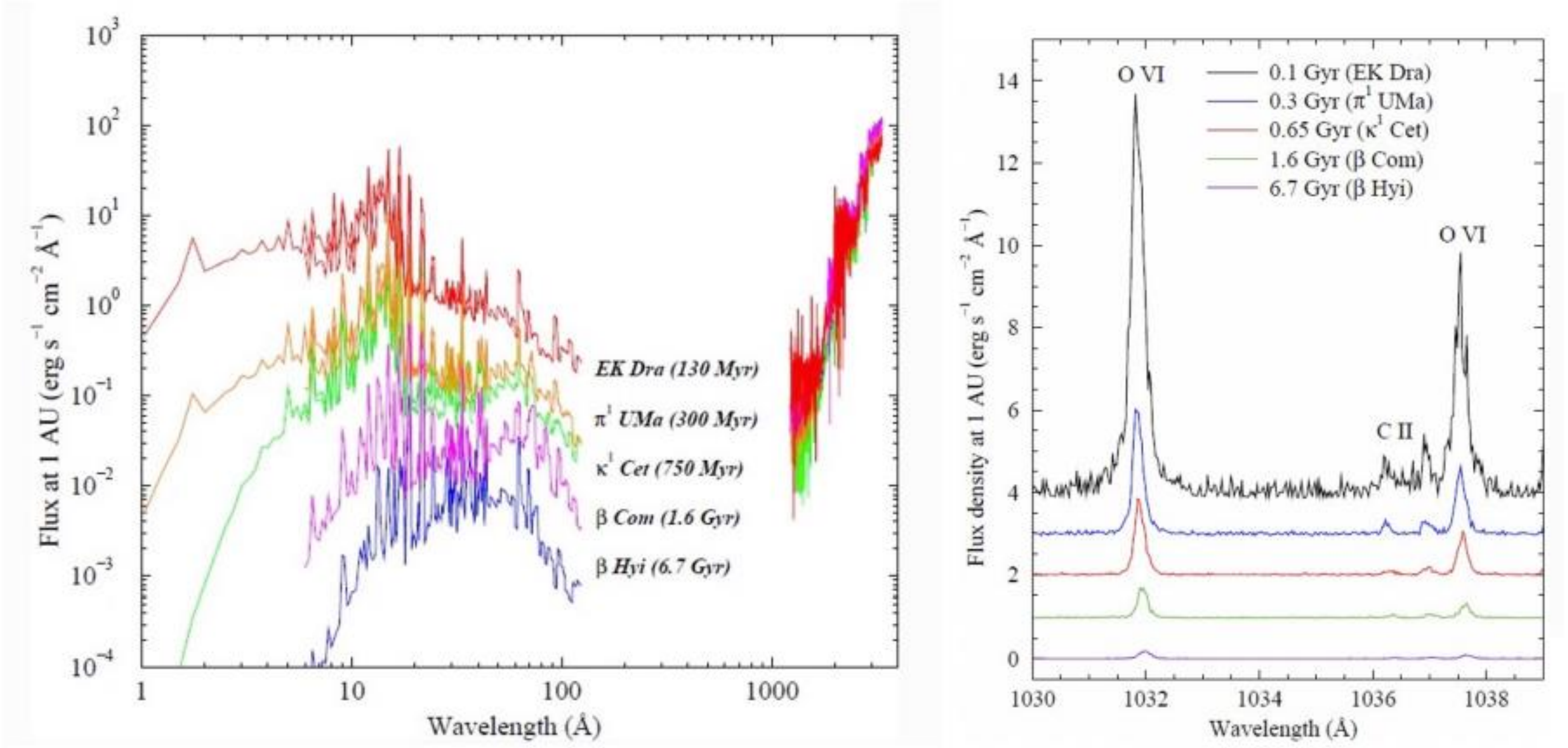
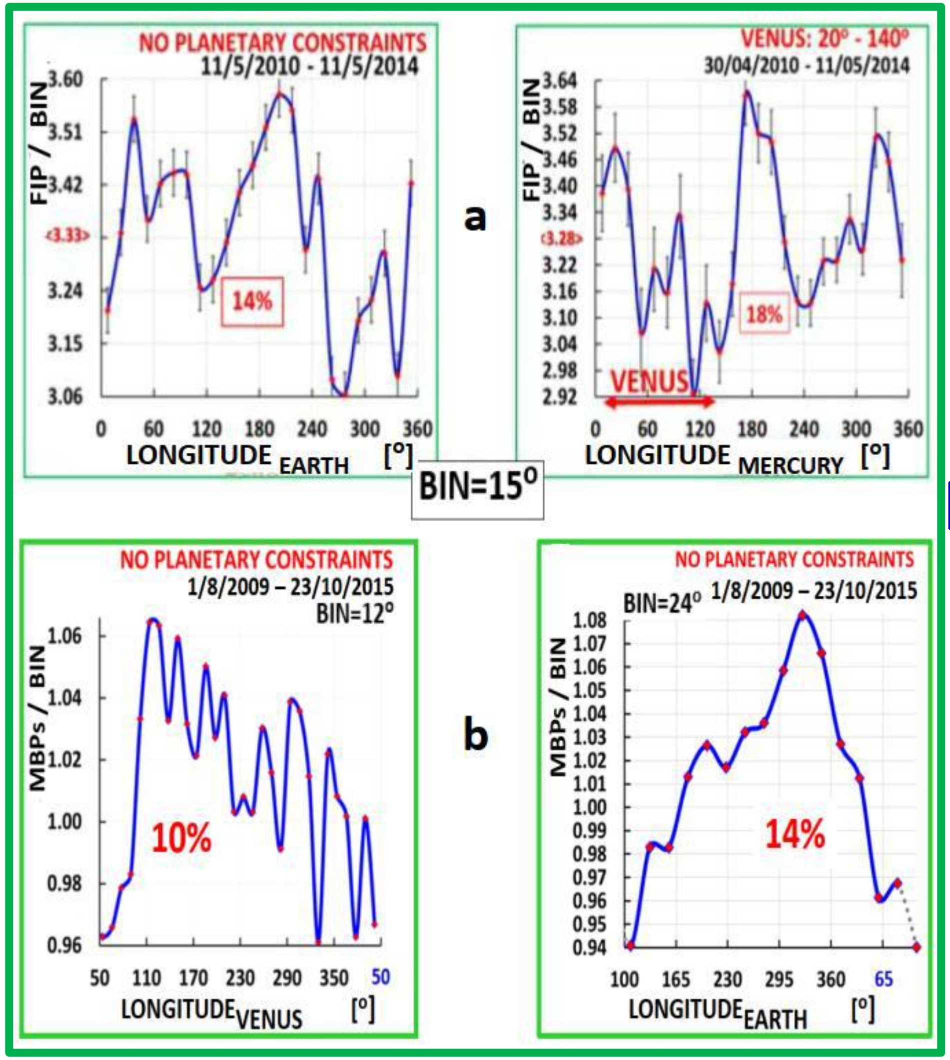


Fig. 9. Levels of emission from Sun-like stars are shown as a function of age on the main sequence. Flux densities at the stellar surface can be derived by multiplying by $(1\mathrm{AU}/R_\odot = 215)^2 = 4.6 \cdot 10^4$. Note the logarithmic and linear scales plotted, and the gap between 120 and 1000 Å caused by interstellar absorption. Figures from [22].

Elemental Composition ▯

Magnetic Bright points ▯



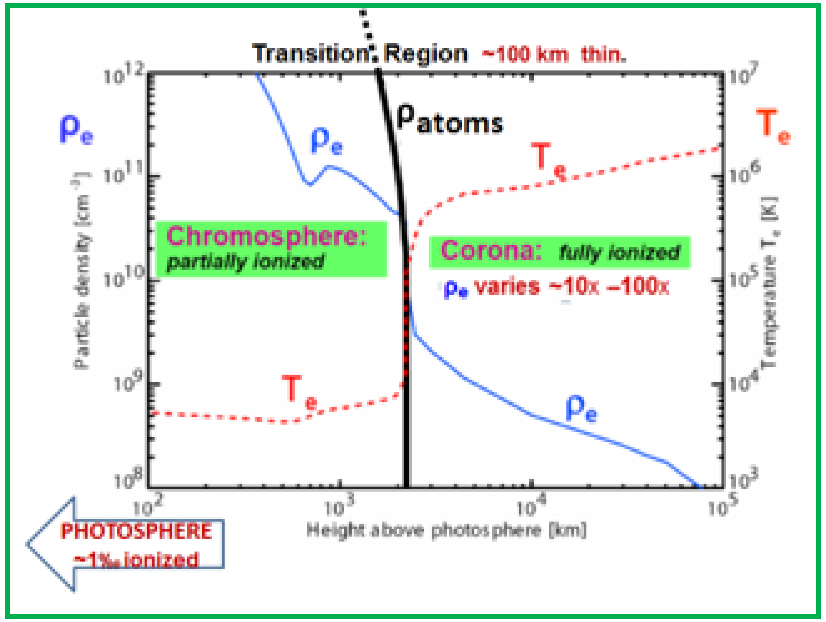
Planetary relations:
how to reconcile w. conventional picture?

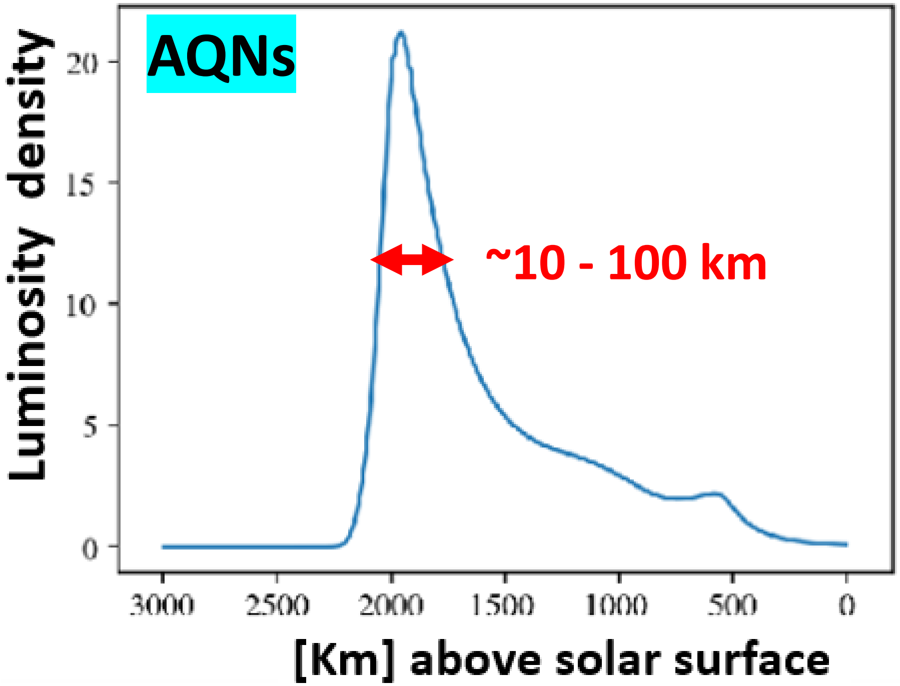
(a) https://www.nature.com/articles/s41467-017-00328-7 NATURE Comm. 2017

(b) https://arxiv.org/abs/1710.01678 PASJ 2017

M. Maroudas and D. Utz, work in preparation 2021

Chromosphere ⇔ Corona





AQNs: *the only solar atmospheric model reproducing the ~100 km thin Transition Region*

planetary dependence of the flaring Sun

more? >>> *unexplained obs'* ?!

34A

N. Raza, L. van Waerbeke, **A. Zhitnitsky**, *Solar Corona Heating by the AQN DM*, arXiv:1805.01897 (**2018**)

The theory of a planetary modulation of solar activity → Overlooked!

⇩

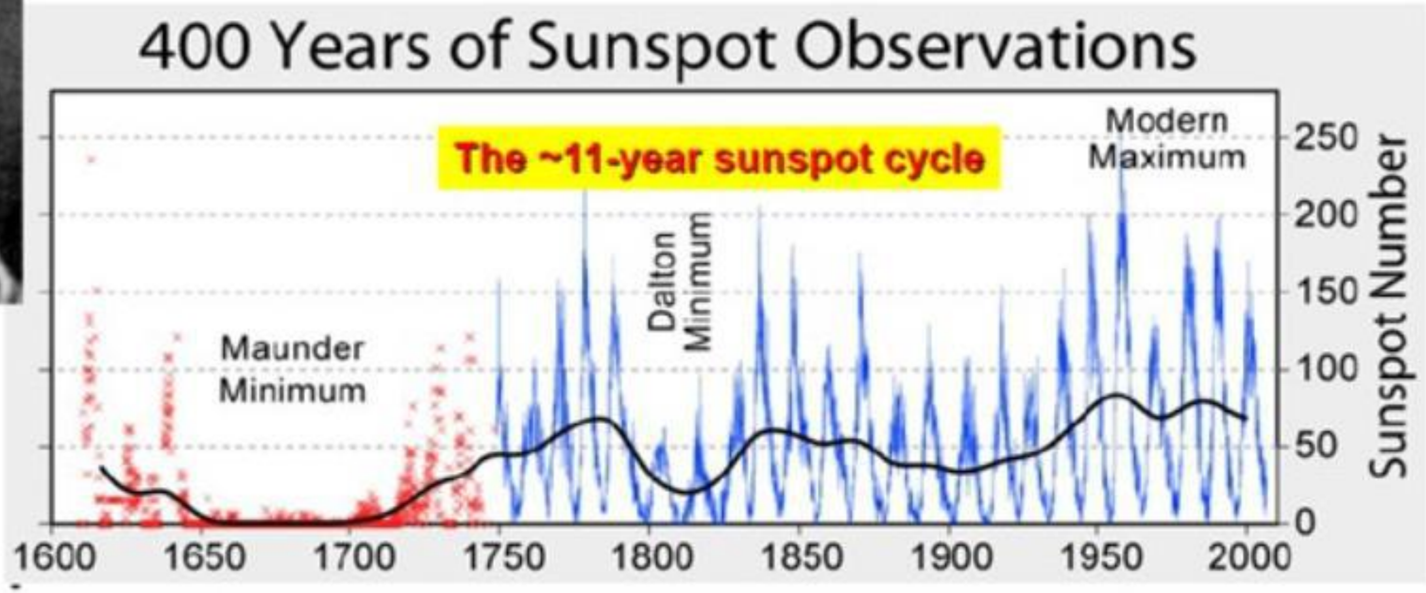
Too weak within known physics

⇩

therefore abandoned!

Extract of a Letter from Prof. R. Wolf, of Zurich, to Mr. Carrington, dated Jan. 12, 1859.

(Translation.)



the same planets, the conclusion seems to be inevitable, that my conjecture that the variations of spot-frequency depend on the influences of *Venus, Earth, Jupiter, and Saturn*, will not prove to be wholly unfounded. The preponderating planet

The variations of sunspot
Periodicity depend oninfluences
Of Venus, Earth, Jupiter & Saturn

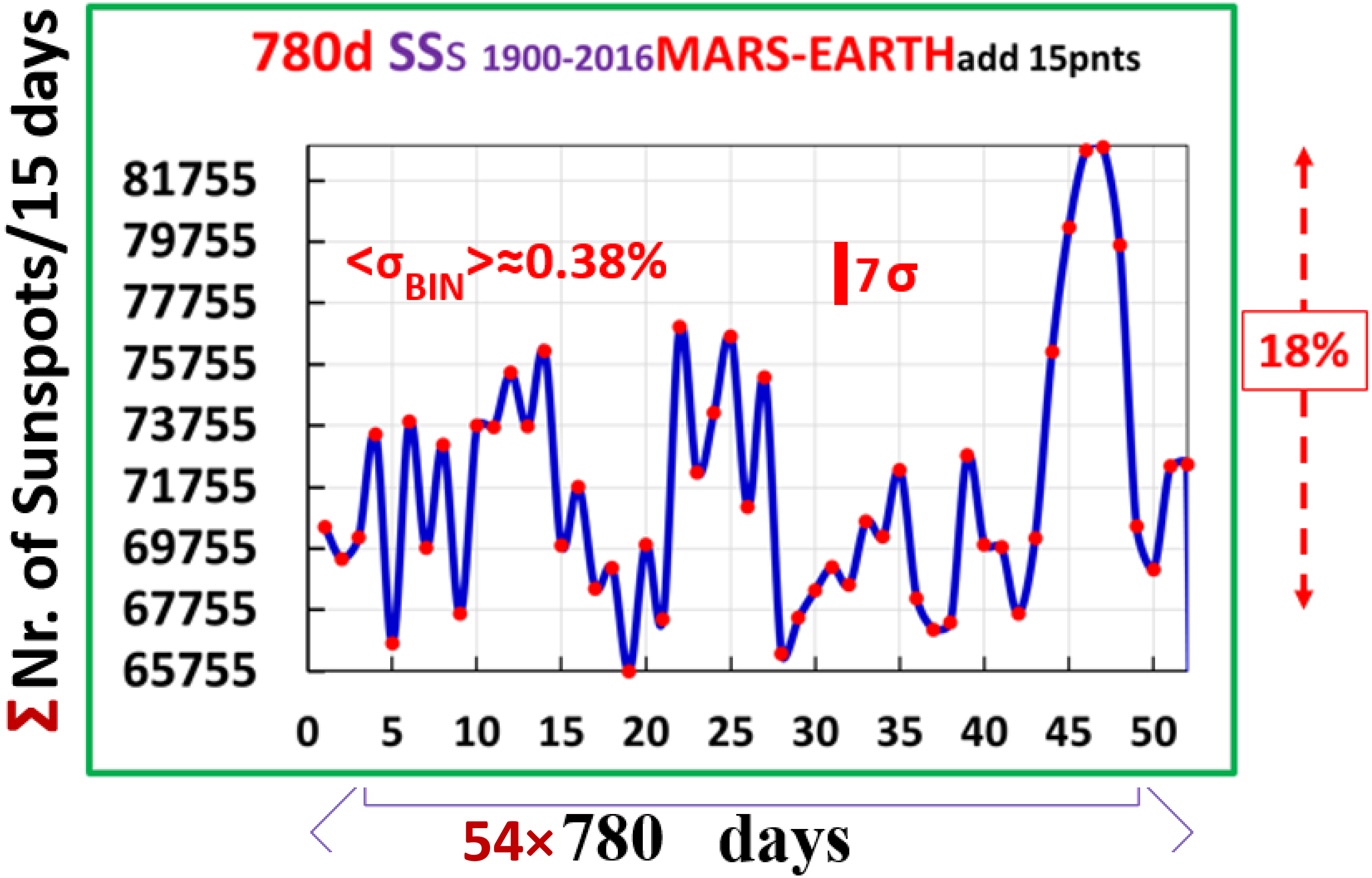
http://people.duke.edu/~ns2002/pdf/Scafetta_AGU-2012.pdf

Scafetta, N.: 2012a, J. Atm. Sol. Terr. Phys., 80, 296

44

https://slideplayer.gr/slide/7988163/

Sunspots 1900-2016>>MARS-EARTH synod = 54×780 days => substructure!

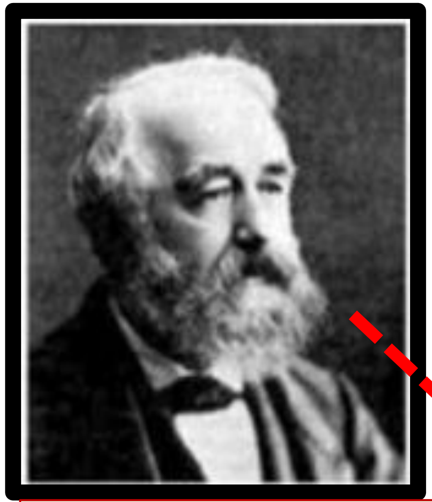


Combined planetary relationship

Synod

Simplest FOURIER analysis with more information.

R. WOLF



The variations of sunspots depend on Venus, Earth, Jupiter & Saturn

The 11-year solar cycle

$P_{JUPITER}$ = 11.86 years ≈ 11 years

1859- Suspected planetary dependence

The **only** remote tidal planetary force => too weak!

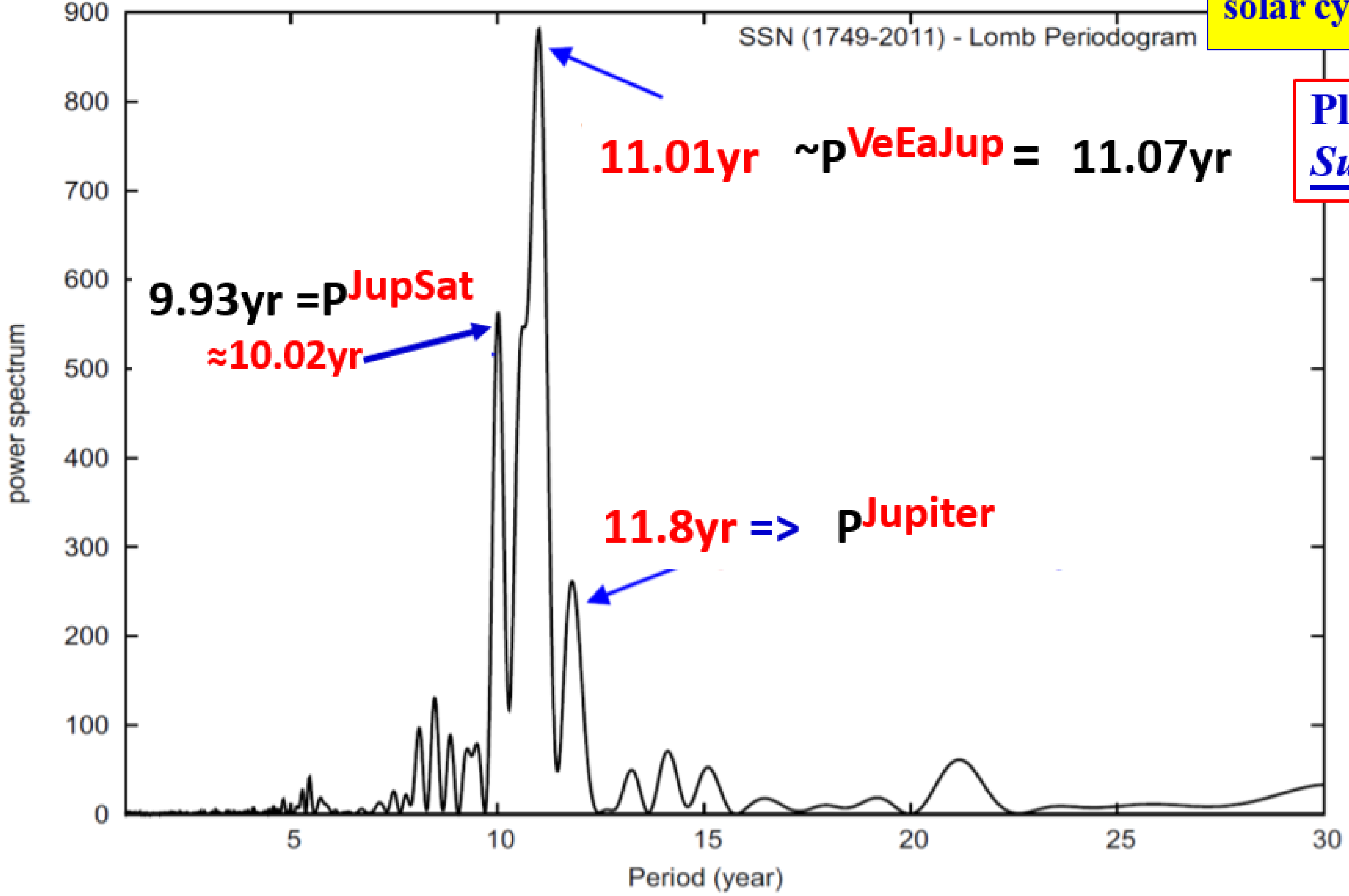
Following known physics

missing factor ~10^{11}

follow-up! …. more quantitatively ➔

The ~ubiquitous 11-year solar cycle

11yrs ≈ 11.86 yrs
solar cycle ≈ $P^{JUPITER}$



Planetary dependence
Suspected since 1859

Remote Force?

The Q ever since!

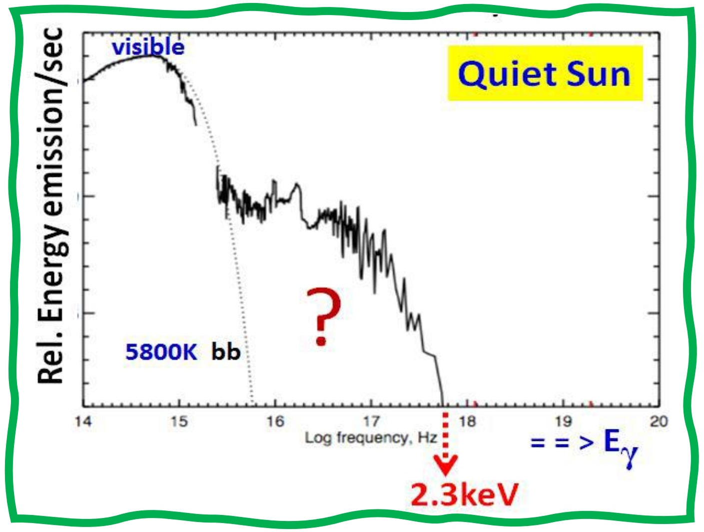
https://arxiv.org/abs/1309.4021

Solar Corona 1939- >>> observational mystery.

Sun's upper atmosphere much hotter than its surface => why?

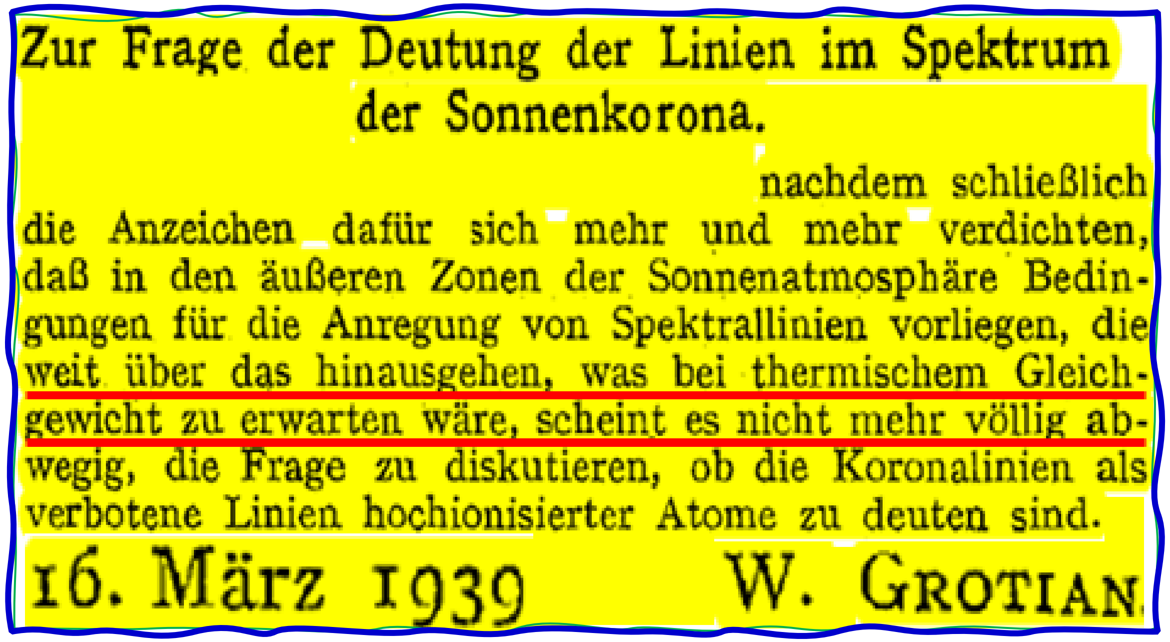
- *" a major open issue in astrophysics"* **2015**
- *"one of the fundamental outstanding problems in solar physics"* **2015**
- *"for **84** years…one of the outstanding unsolved problems in astrophysics"* **2015**

[http://arxiv.org/abs/1502.07401 ; http://arxiv.org/abs/1508.05354; DOI: 10.1098/rsta.2014.0269]



*The striking **EUV excess** of the quiet Sun is the manifestation of the **solar corona problem**.*

H.S. Hudson



Zur Frage der Deutung der Linien im Spektrum der Sonnenkorona.

… nachdem schließlich die Anzeichen dafür sich mehr und mehr verdichten, daß in den äußeren Zonen der Sonnenatmosphäre Bedingungen für die Anregung von Spektrallinien vorliegen, die weit über das hinausgehen, was bei thermischem Gleichgewicht zu erwarten wäre, scheint es nicht mehr völlig abwegig, die Frage zu diskutieren, ob die Koronalinien als verbotene Linien hochionisierter Atome zu deuten sind.

16. März 1939 W. GROTIAN

http://dx.doi.org/doi:10.1007/BF01488890

NEWSCIENTIST https://doi.org/10.1016/S0262-4079(22)01808-5
Volume 256, Issue 3407 8 October 2022, Page 17

DARK matter can be trapped inside massive objects, and much of it may be closer to the surface of stars and planets than we realised. **On Earth, there may be more than 10 trillion dark matter particles in each cubic centimetre of the planet's crust.**

Physics

Trillions of dark matter particles may lurk in Earth's crust

DARK matter can be trapped inside massive objects, and much of it may be closer to the surface of stars and planets than we realised. On Earth, there may be more than 10 trillion dark matter particles in each cubic centimetre of the planet's crust.

Dark matter is a hypothetical form of matter that isn't visible because it doesn't seem to interact with light. However, it does interact with regular, or baryonic, matter via gravity, and particles of dark matter may occasionally smash into particles of baryonic matter.

Rebecca Leane at Stanford University in California and Juri Smirnov at the University of Liverpool in the UK calculated how these collisions would affect the distribution of dark matter inside celestial bodies. Our galaxy and most others are in huge clouds of dark matter, so a constant stream of these particles is probably entering every planet and star in the galaxy.

Leane and Smirnov found that this dark matter doesn't simply sink to the centres of planets and stars as some past research has assumed. "If you're a dark matter particle, you have gravity pulling you towards the centre of the star or the planet, but as you head down you're bouncing off of all the matter on the way to the core," says Leane. "It turns out that even if you give the dark matter as much time as it likes, some of it still ends up near the surface because of all this bouncing."

They calculated that, in the sun, this would result in 100 trillion particles of dark matter or more in each cubic centimetre of the surface.

> "If there's a bunch of dark matter at the surface of the Earth, that could make it easier to detect"

While current detectors aren't built to search for this trapped dark matter – it is expected to move slower than dark matter hurtling in from space, so it would carry less energy and be harder to detect – a high concentration near the surface could help future experiments.

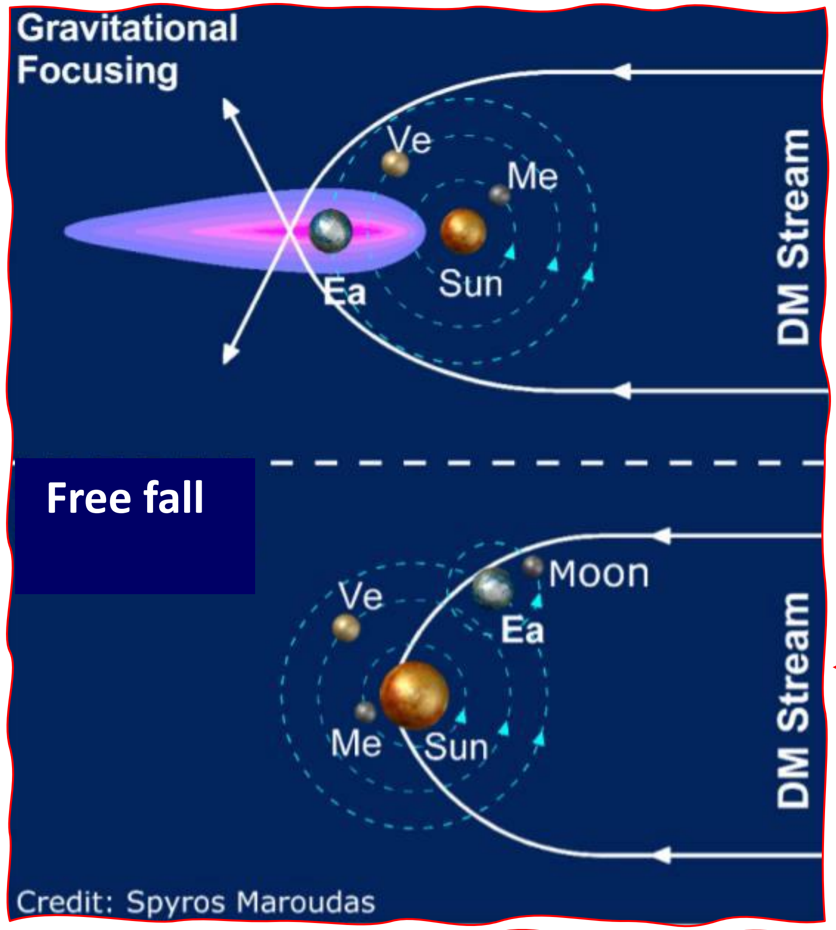
"If there's a bunch of dark matter just sitting at the surface of the Earth, that could make it easier to detect," says Leane. ■

Leah Crane

Gravitational focusing by the solar system!

$$\Delta\Phi = \frac{4MG}{bc^2}$$

❶ ❷



Cartoon illustration of gravitational focusing of low speed streams.

[10,19]

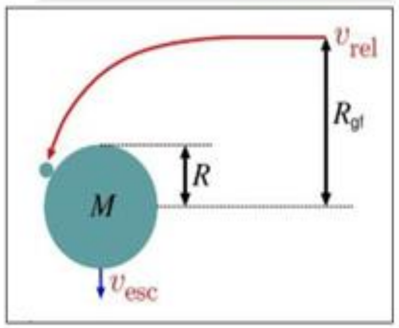
Gal.center

~18[th] December

Coincides with **ionospheric anomaly**

+

planetary dependence ✓



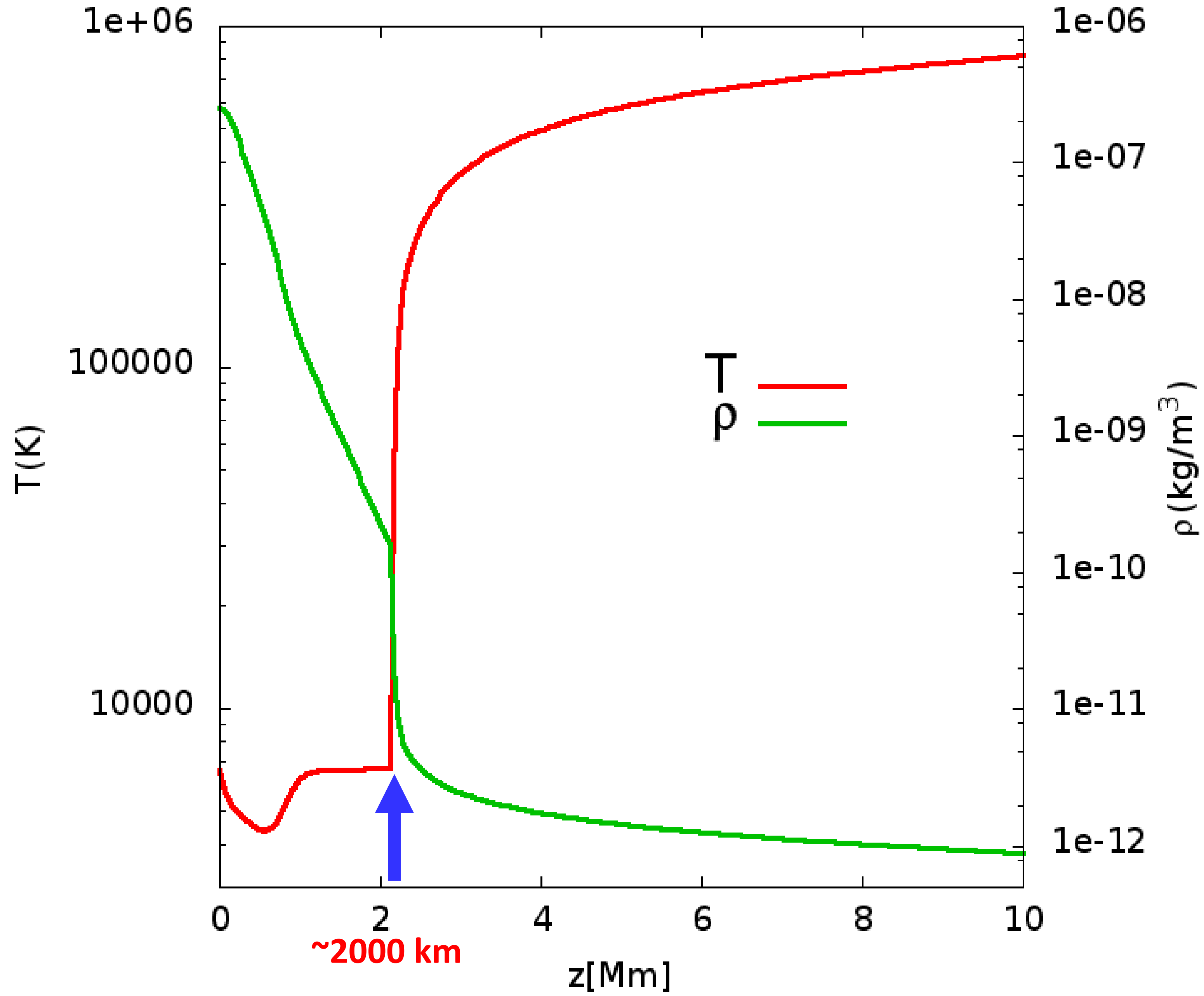
$\sigma_{trap} = \pi R^2 \left(1 + \frac{v_{esc}^2}{v_{rel}^2}\right)$

SUN: v_{esc}=612 km/s

➔ **exo-solar** ✓

2 peaks 180º apart

[Adrien Leleu]



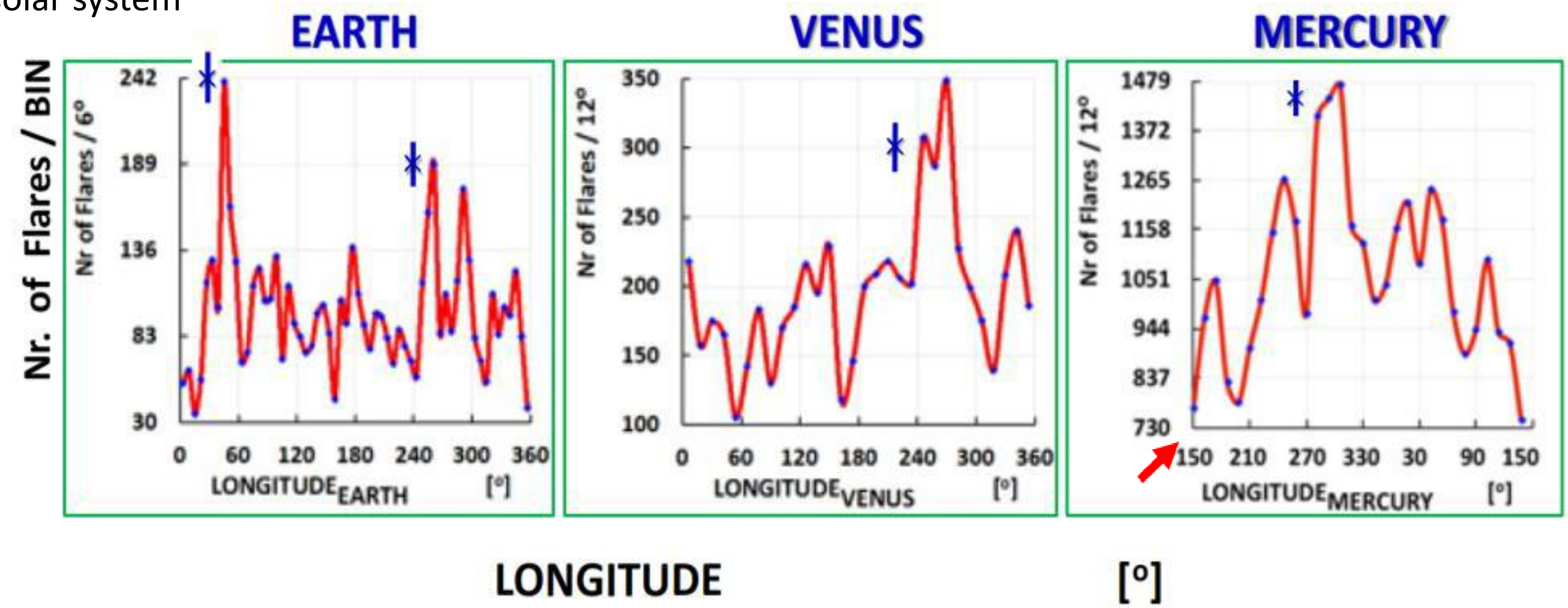
https://www.researchgate.net/profile/Jose-Gonzalez-83/publication/319875817/figure/fig1/AS:539783216590848@1505705755837/Temperature-and-mass-density-as-a-function-of-height-for-the-C7-equilibrium-solar.png

Solar Flares

Biggest and unpredictable "***explosions***" @ solar system

Peaking planetary relationship,

excludes remote planetary interaction, e.g., tidal forces



Repeat search of ?? during peaks!

Data from M.J. Aschwanden

DATA TAKING RESULTS

RESULTS:

- Data-taking time: 4124 h (172 d)
- Frequency range: 660.15 MHz
- Axion Masses: 4.77 - 5.43 GHz
- Data size: ~ 650 TB !!

+

✓ Phase-matching of all four cavities.
✓ Fast resonance scanning.
✓ Unexplored parameter space.

QUALITY CHECKS:

Nr.	Parameters	Criteria
1	Frequency stability	$\Delta\nu_0 < 100\,\text{kHz}$
2	Amplitude variation	$\Delta A_0 < 3\,\text{dB}$
3	Quality factor	$10^3 < Q_L < 4 \times 10^4$
4	Quality factor shift	$\Delta Q_L < 7 \times 10^3$
5	Temperature variation	$\Delta T_{\text{cav}} < 3\,\text{K}$
6	Temperature	$1\,\text{K} < T_{\text{cav}} < 273\,\text{K}$
7	Magnetic field variation	$\Delta\vec{B} < 0.1\,\text{T}$
8	Frequency mismatch	$< 20\,\text{kHz}$ (before) & $< 80\,\text{kHz}$ (after)
9	Amplitude mismatch	$< 1\,\text{dB}$
10	Temperature mismatch	$< 3\,\text{K}$

Total discarded Files: (~4.4%)

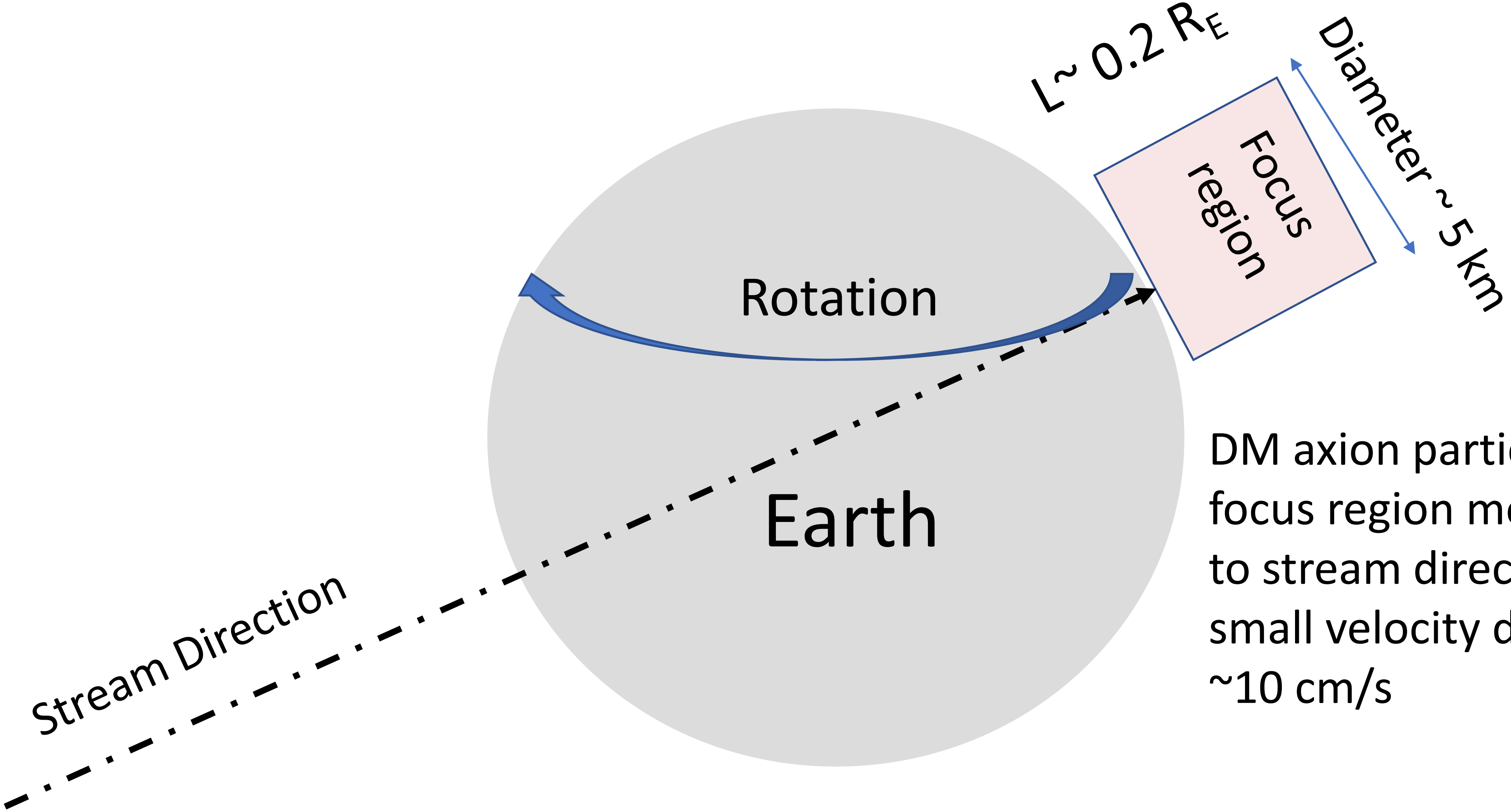
SUN:

Plenty of mysteries and anomalies

e.g. corona heating & its temperature inversion

1939 - present

Fine grained streams, gravitationally produced high density regions with focus on the surface of the Earth



DM axion particles in the focus region mostly parallel to stream direction with a small velocity dispersion of ~10 cm/s

$$t_{enc} \sim \frac{5\ km}{0.45 \frac{km}{s} * \cos(\varphi)}$$

Transient time per day
φ is the latitude of the experiment

Most promising cases

Density over nominal of the focus region produced by gravity on a stream	Number of these density regions on the entire surface of the Earth	Probability per day that an experiment would encounter this density region	
10	20	6e-3	2.2 / yr
100	1.6	5e-4	0.2 / yr
1000	8.0e-02	2.4e-5	0.01 / yr
10^4	2.0e-03	6e-7	
10^5	4.0e-05	1.2e-8	
10^6	8.0e-07	2.4e-10	

Less than 1 numbers here mean that probabilistically the higher density regions are very unlikely

Dear Professor,

Chinese Journal of Mechanical Engineering (CJME) was launched in 1988. It is a peer-reviewed journal under the govern of **China Association for Science and Technology (CAST)** and sponsored by Chinese Mechanical Engineering Society (CMES). CJME is indexed and abstracted by SCIE, EI, SCOPUS, DOAJ, etc. As the only official journal of CMES, CJME has been one of the top journals in Mechanical Engineering in China, aiming to become a world-class one. CJME welcomes original research articles, reviews, letters, research highlights, and editorials.

STREAMING DARK MATTER

Cosmological fine grained streams:

M. Vogelsberger and SDM White, Streams + caustics: the fine-grained structure of ΛCDM haloes, MNRAS 413 (**2011**) 1419.

- **DM could be a superposition of many fine-grained streams.**
- Consequence from the collisionless character and the coldness of CDM.
- Each such stream has a **very small velocity dispersion**.

➢ **~10^{14} streams in the solar neighborhood.**

➢ Half of the local DM density is comprised of the 10^6 most massive streams.

➢ The most massive individual stream contributing a 1‰ to the local DM density.

Therefore:

➔ Look **@ (towards)** the Sun!

Steven Weinberg's four tips for aspiring scientists

1. **You don't have to know everything**
2. **Aim for rough water**
3. **Forgive yourself for wasting time**
4. **History of science** ➔ as it will your work seem more worthwhile to you. Because, a work in science may not yield immediate results, but to realize that it would be a part of history is a wonderful feeling. ➔ **CAST!?**

Searching for neutrinos from solar flares … with Super-Kamiokande

No significant solar-flare ν signal

above background rate was observed.

https://arxiv.org/abs/2210.12948 2022

Search for Solar Flare Neutrinos with KamLAND.

found no statistical excess of

ν's and established upper limits

https://iopscience.iop.org/article/10.3847/1538-4357/ac35d1 2022

Evidence for a New Component of HE Solar γ-Ray Production

Fermi-LAT
2008-2017

The observed multi-GeV γ-ray emission from the solar disk—sourced by hadronic cosmic rays interacting with gas and affected by complex magnetic fields—is **not understood** ... **Most strikingly**, although six γ rays above 100 GeV were observed during the 1.4 yr of solar minimum, none were observed during the next 7.8 yr. These features, along with a 30–50 GeV dip … were **not anticipated by theory**.

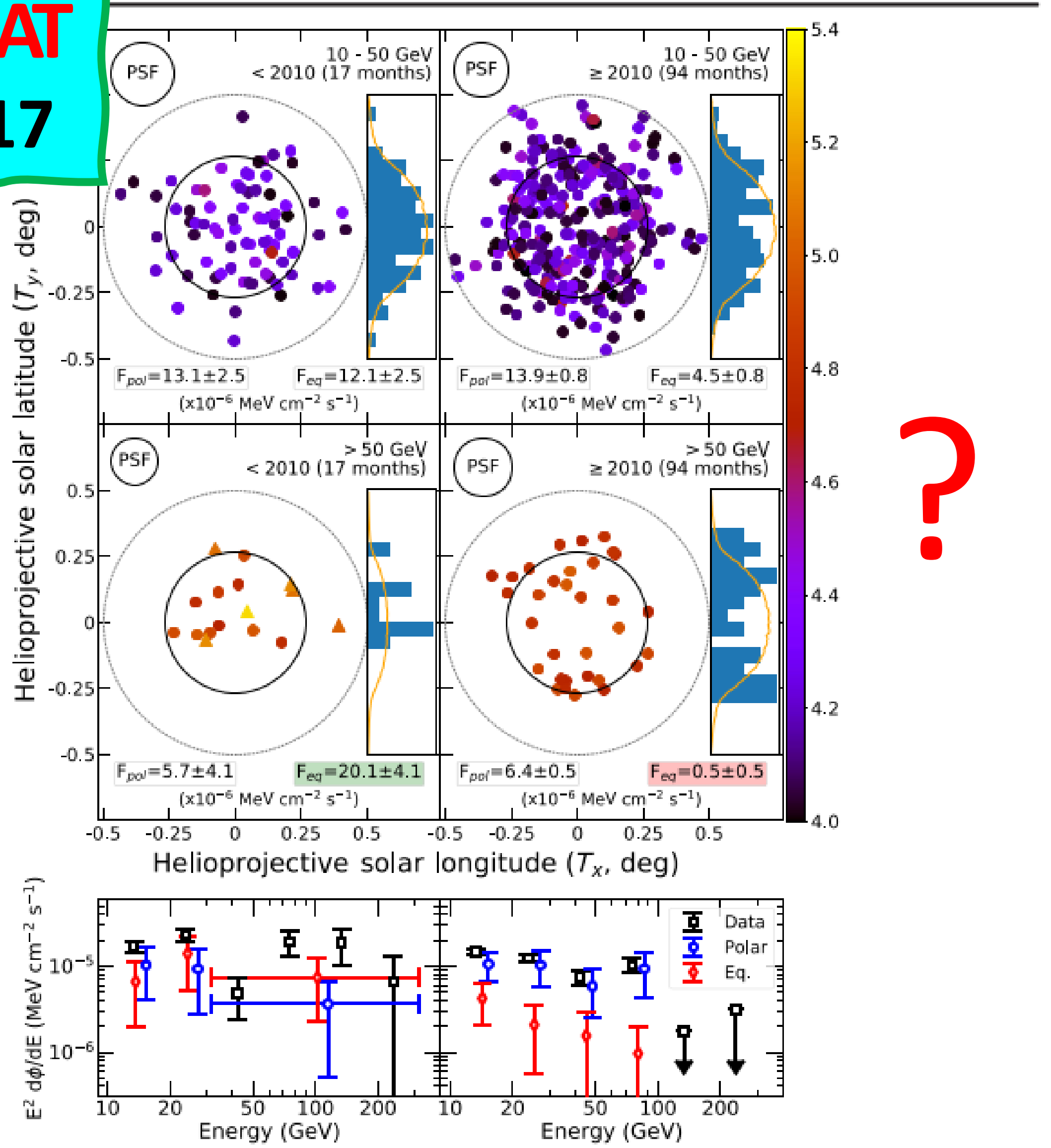
To understand the underlying physics, Fermi-LAT +HAWC obs's of the imminent … solar Minimum are crucial .

?

Our work:

>search for planetary dependence!

PHYSICAL REVIEW LETTERS 121, 131103 (2018)

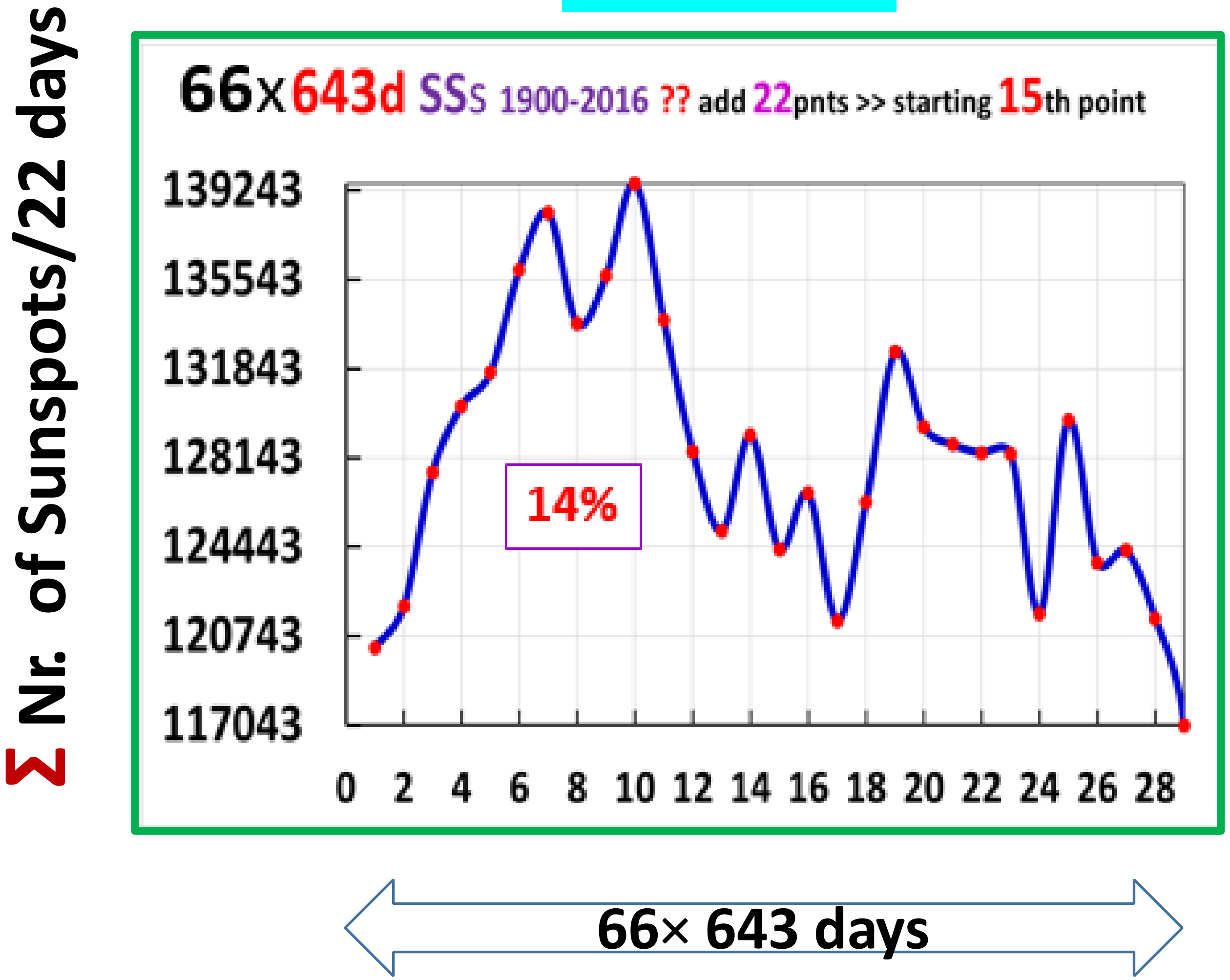


?

FIG. 2. (Top panel) The location and energy of solar γ rays in helioprojective coordinates. Data are cut into two temporal and two energy bins. The solid disk indicates the solar circle, and the dashed circle indicates the 0.5° ROI. The average 68% containment region of γ rays in each bin is depicted at the top left. The histogram depicts the T_y positions of photons compared to the expectation from isotropic solar emission smeared by the PSF (orange line). Events > 100 GeV are marked with triangles rather than circles. We stress that the exposure after solar minimum significantly exceeds the exposure during solar minimum. Thus, the observed number of counts does not indicate the relative flux. In each bin, we report the flux from the modeled polar and equatorial components, as described in the text. (Bottom panel) The energy spectrum of polar and equatorial emission, divided into regions during (left) and after (right) solar minimum. The polar emission is approximately constant, while the equatorial emission decreases drastically after solar minim…

T. Linden, B Zhou, JF Beacom, AHG Peter, KCY Ng, Q-W Tang, Phys. Rev. Lett. 121 (**25th Sept** **2018**) 131103
https://doi.org/10.1103/PhysRevLett.121.131103

NO synod



Σ Nr. of Sunspots/22 days
66x643d SSs 1900-2016 ?? add 22pnts >> starting 15th point
139243
135543
131843
128143
124443
120743
117043
14%
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28
66× 643 days

$$\Delta\Phi = \frac{4MG}{bc^2}$$

b =impact factor

c = velocity …. **NOT from mc^2** ← [6,7]

Gravitational deflection $\Delta\Phi \propto 1/v^2$

- **Deflection (v~1‰ c) → 10^{-6}× Deflection (v=c)**
- **planetary lensing within inner solar system** ✓

+ **Moon => Earth!**

[6,7,10]

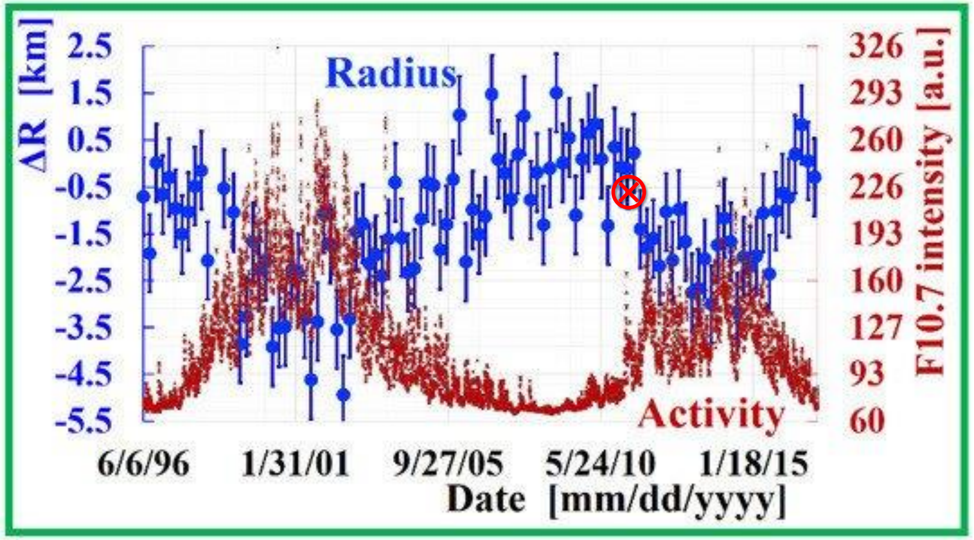
← **2003**

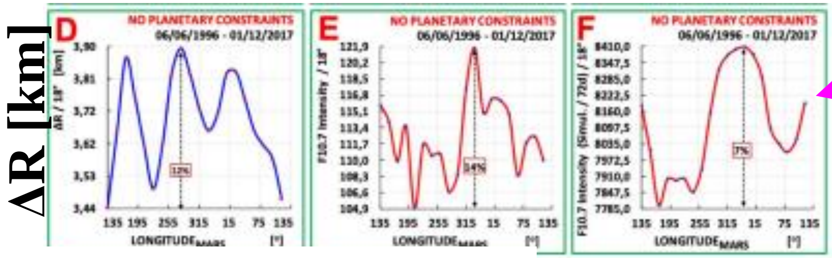
2014

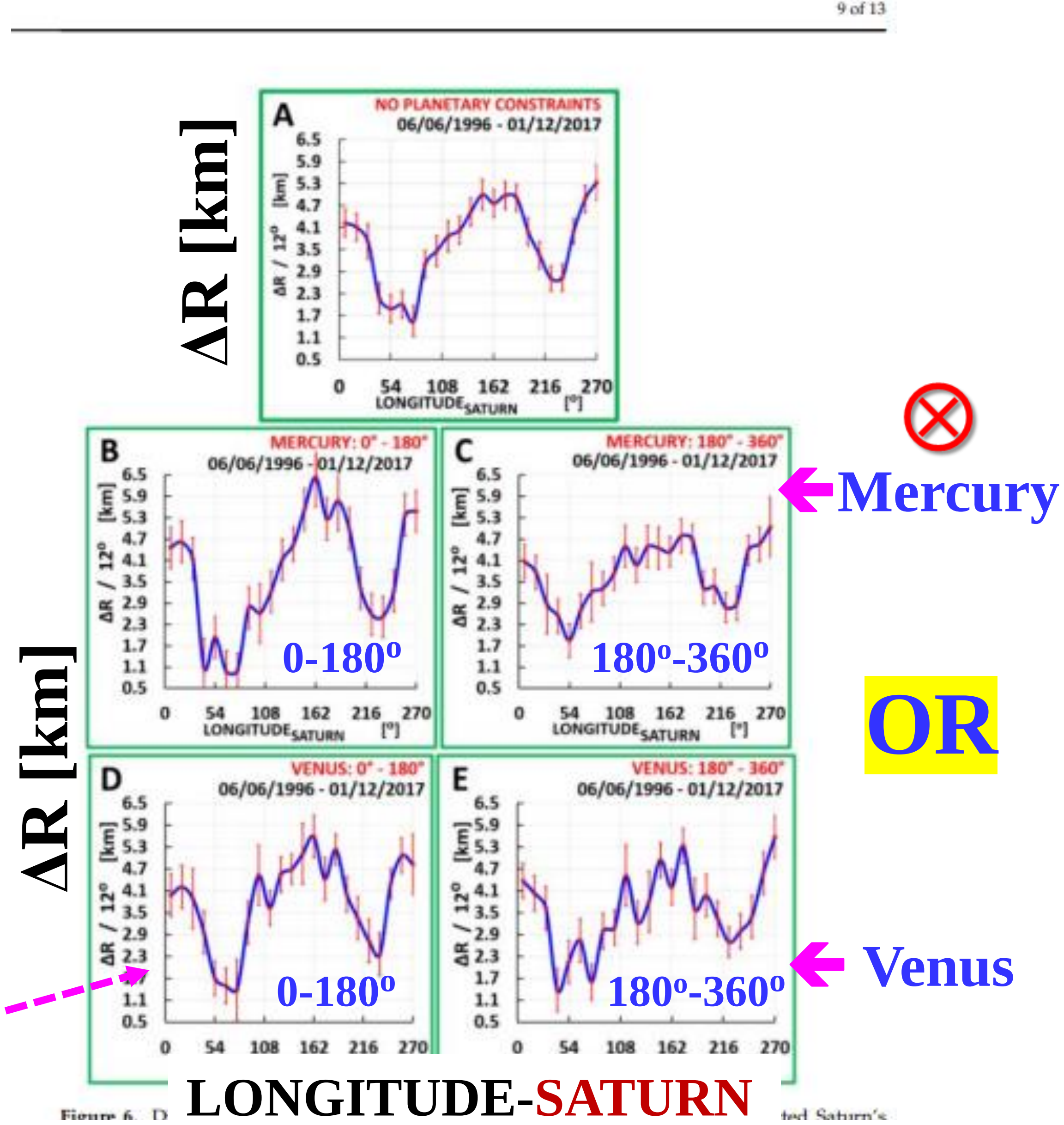
← **2017**

Solar radius variation:

- from helioseismology
  - minimum BIN=72 days
- **Planetary relationship** ✓







Lift 1km photosphere by 1km: required ~ 10^{30} erg.

AntiQuark Nuggets (AQNs):

dark matter + missing antimatter + (much) more?

https://indico.desy.de/indico/event/20012/session/19/contribution/54/material/slides/0.pdf

N. Raza, L. van Waerbeke, **A. Zhitnitsky**, *Solar Corona Heating by the AQN Dark Matter*, arXiv:1805.01897 (**2018**), Phys. Rev. D 98 (**2018**)103527

Pearls

>> **see Holger Nielsen' talk, this workshop**

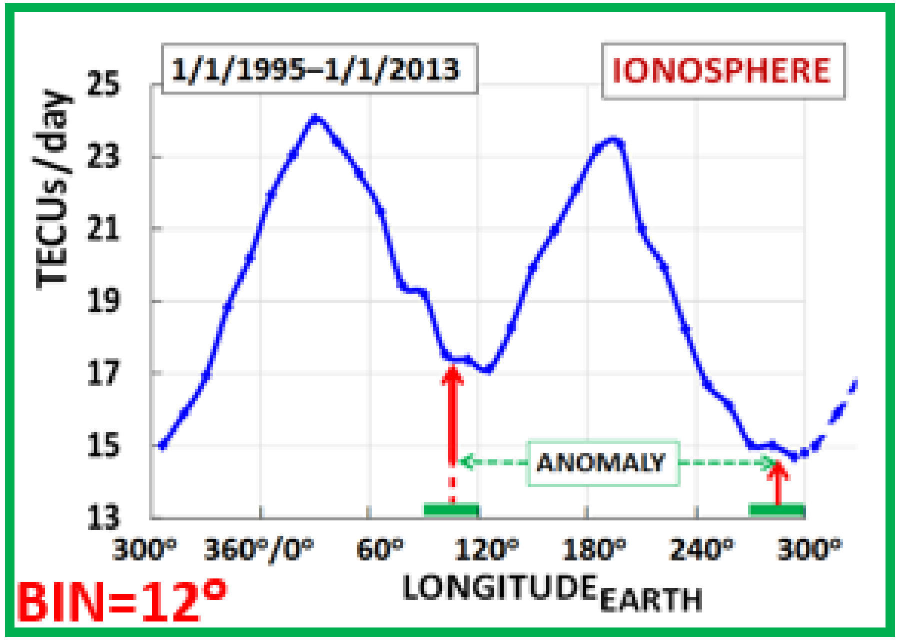
Candidates:

1. - AQNs
   - Pearls
2. Magnetic monopoles
3. Dark photons

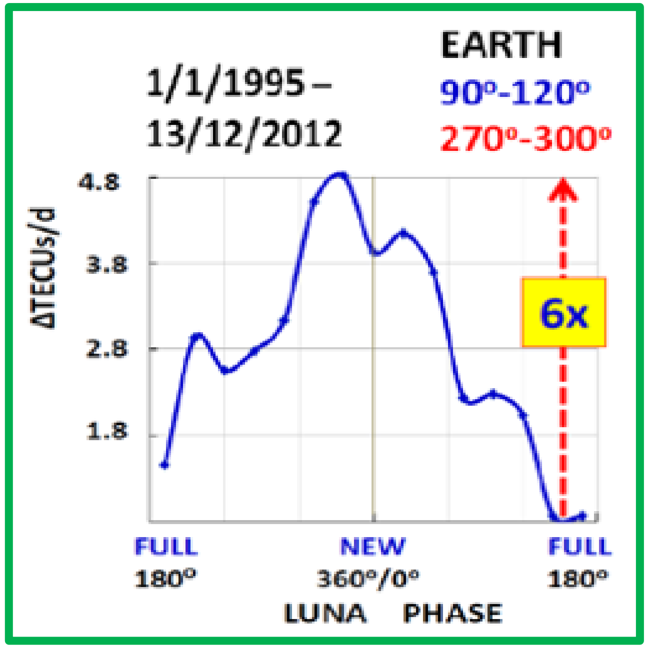
Or, a combination from + more?

https://inspirehep.net/record/1235677/plots

EARTH



EARTH ⍰ MOON PHASE



Stream(s) from G.C. mega-Black Hole?

Longitude ≈ **266°** **+** TOF (Earth **=>** Sun)

❾ **18th December**

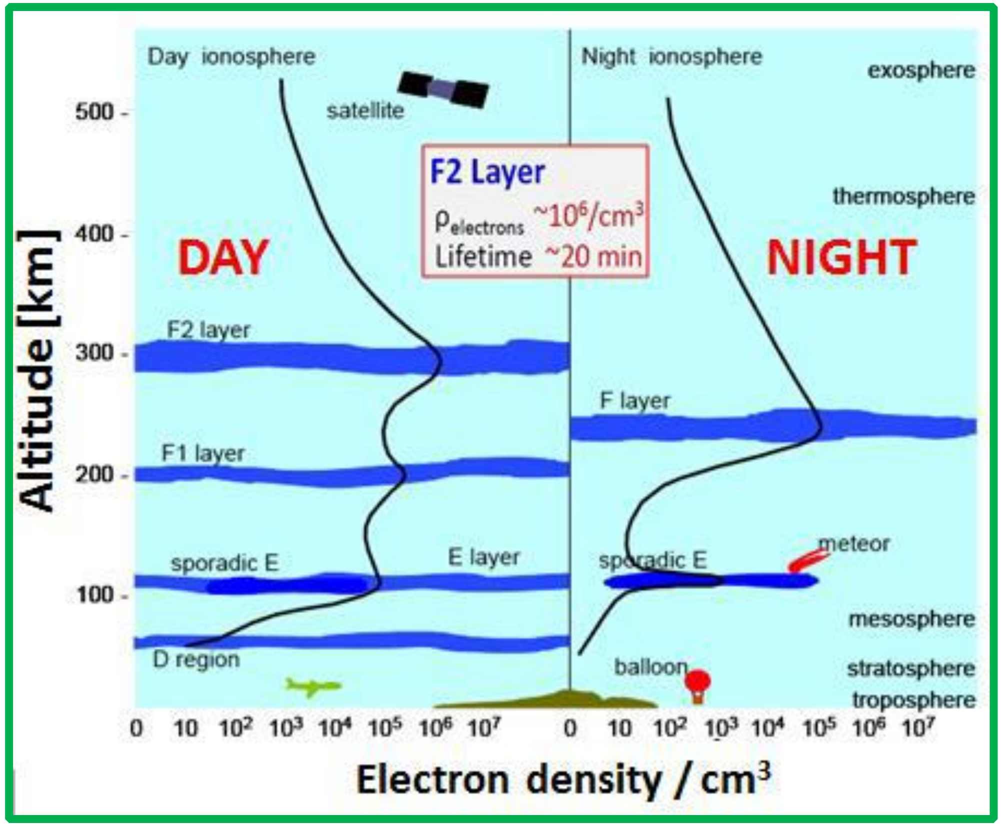
Longitude ≈ **85°** **+** TOF (Moon **=>** Earth)

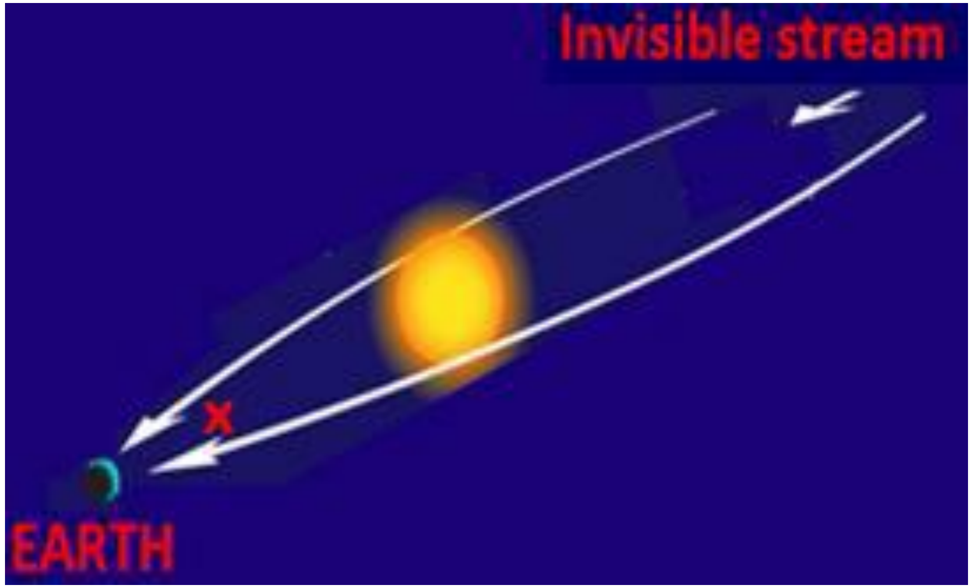
❾ **17th June, ..?..**

EARTH's IONOSPHERE

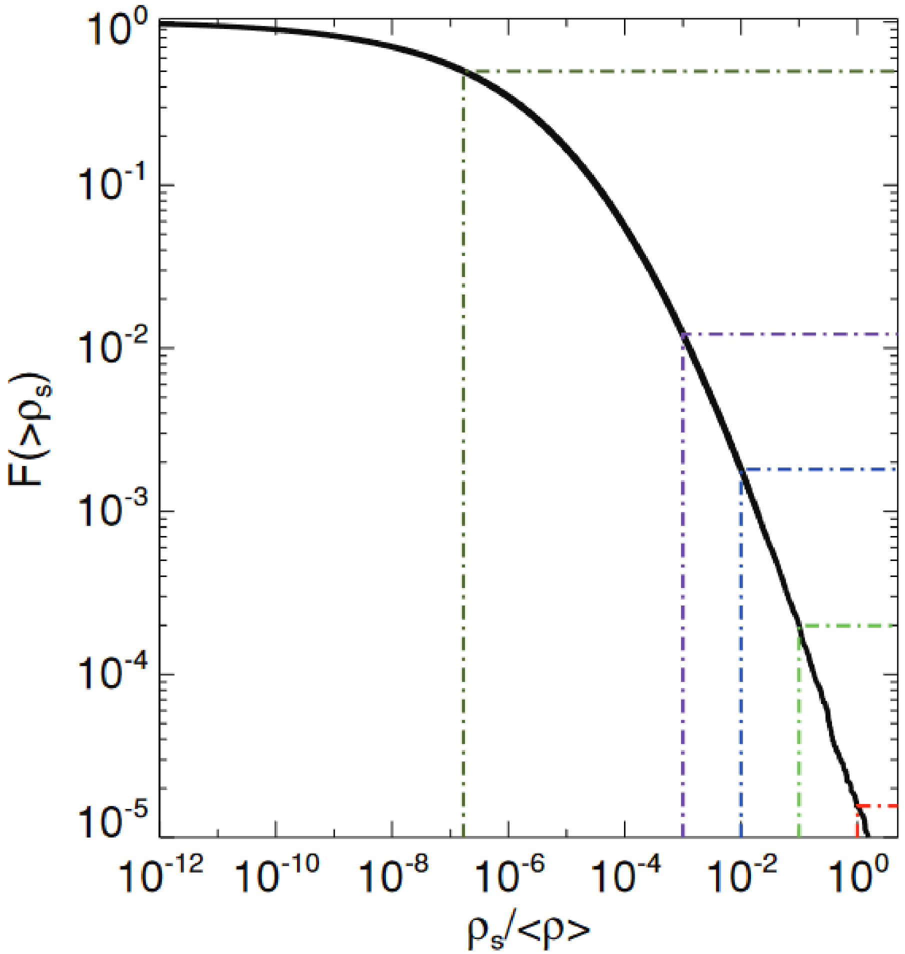
Anomalies lasting for some decades

>>> First obs' 1937/1938





Fine-Grained Stream Abundance



Streams with different densities and their probability in solar neighbourhood.

Density (ρ_s/ρ_0)	Number of streams	Probability (%)
1	1	0.002
0.1	1	0.2
0.01	1	20
10^{-3}	10	100
10^{-4}	500	100
10^{-5}	$2 \cdot 10^4$	100
10^{-6}	$4 \cdot 10^5$	100
10^{-7}	$2 \cdot 10^6$	100

Mark Vogelsberger and Simon D. M. White, Mon. Not. R. Astron. Soc. 413 (**2011**) 1419

2 million streams with density 10^{-7} ρ_0

STREAMING DARK MATTER

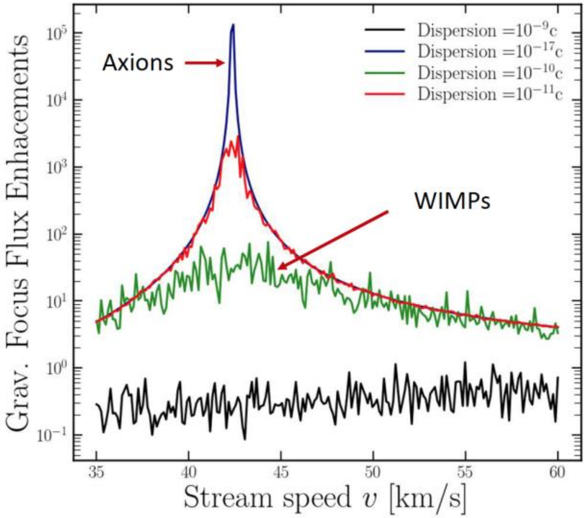
- Conventional halo DM: $u \sim 240$ km/s
  $r \sim 0.45$ GeV/cm^3

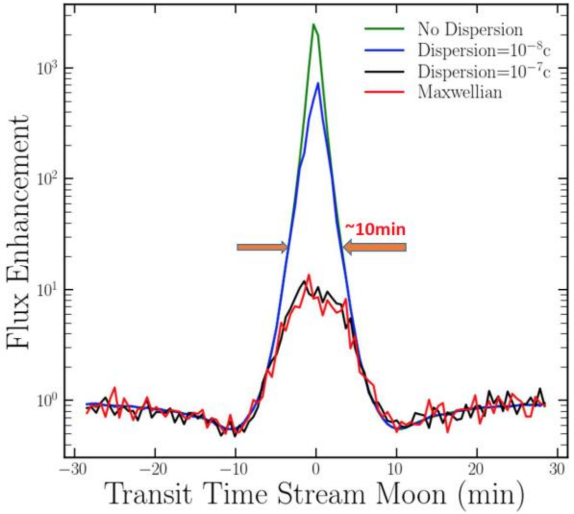
NO direct detection so far..

- Streaming DM: For low-speed ($u \sim 0.01c$ - $0.2c$) streams aligned with **SUN → EARTH:** $A \sim 10^{8\pm3}$
- Streaming DM: Earth's self-focusing effects due to intrinsic mass: $A \pounds 10^9$
- Streaming DM: Other solar system bodies e.g. the Moon: $A_{axions} \sim 10^5$

NEW APPROACH:

- Wide frequency range.
- Short scanning time per frequency.
- Maximum duty cycle.





Wolf, 1859: *solar dynamics is partially driven by* ***planetary tides****.*

a plausible physical mechanism has not been discovered yet…

the planetary tidal forces are too small to modulate solar activity..

although more complex mechanisms can not be excluded.

N. Scafetta, J. Atm. & Sol.-Terr. Phys. 81–82(**2012**)27

SUMMARY & NOVELTIES

A previously unexplored parameter space has been scanned to extend axion search towards larger rest mass values (19.74 - 22.47 μeV).

- Use of a **dipole magnet** as a DM axion haloscope.
- **No mode crossings** over the entire tuning range for the mode of interest.
- Four identical cavities coherently combined through **phase-matching** to increase SNR for the first time in DM axion search.
- State-of-the art tuning mechanism gives a **wide mass range** (~ 660 MHz) → up to 1 GHz.
- Novel **fast-scanning** technique to investigate transient events and exclude outliers faster.
- Introduction of a second simultaneous recording channel for **EMI/EMC** parasites.
- New approach and analysis for **transient events** and search for signal modulations >>> **TBDone**