Solar X-rays as Signature for New Particles

K. Zioutas

U. of Thessaloniki & CERN

Results and Perspectives in Particle Physics

La Thuile, Aosta Valley,

February 29 - March 6, 2004

References :

K.R. Dienes et al., ***PRD 62 (2000) 105023***
Invisible Axions and Large-radius Compactifications

L. DiLella, A. Pilaftsis, G. Raffelt, K. Z. ***PRD 62 (2000) 12501***
Search for solar Kaluza-Klein axions in theories of low-scale quantum gravity

L. DiLella, K. Z., ***Phys. Lett. B531 (2002) 175 & Astropart. Phys. 19 (2003) 145***
Observational evidence for gravitationally trapped massive axion(-like) particles

K. Z., K. Dennerl, L. DiLella, D.H.H. Hoffmann, J. Jacoby, Th. Papaevangelou,
ApJ. (May 2004) *Quiet Sun X-Rays as Signature for New Particles*

D.H.H. Hoffmann, K. Z., ***(2004)*** in preparation
On the Correlation between Solar X-rays and Magnetic Fields

Solar corona problem

→ *Grotrian 1939*
Naturwissenschaften 27 (1939) 214

The physics of coronal heating remains one of the most fundamental problems in stellar (and solar) astrophysics.

Güdel, Audard , Kashyap, Drake, Guinan *ApJ. 582 (2003) 423*

In spite of … **half a century**, this key (coronal heating) problem in space physics remains ***unresolved***.

Transition region dynamics … *significant developments…*

UK Solar Physics *meeting Dublin from 7–11 April 2003*
Erdélyi, Fletcher, Doyle
http://star.arm.ac.uk/preprints/AAG44313.pdf

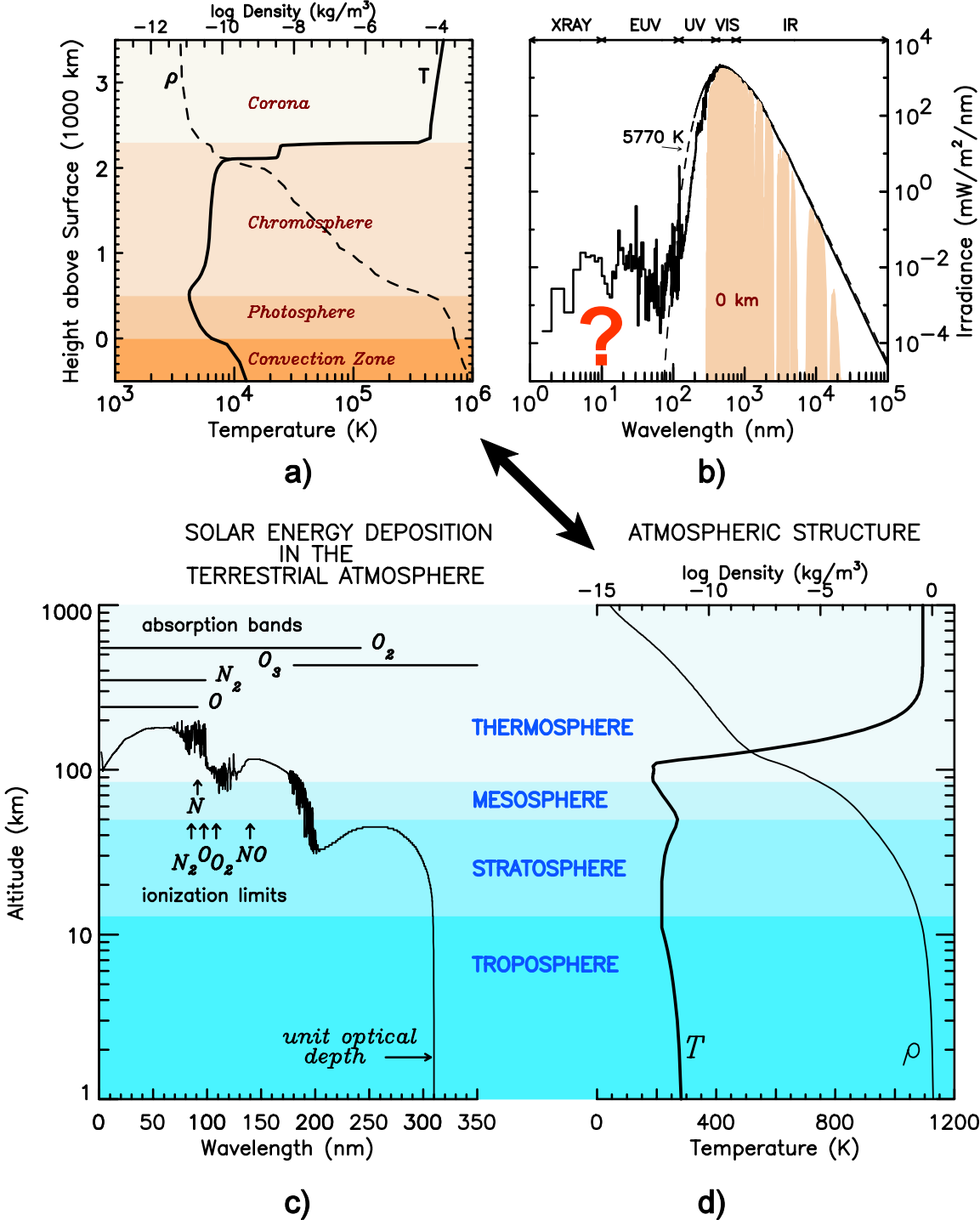
…the coronal plasma is somehow being heated continuously. … our results have made the coronal heating process even more of a mystery.

Antiochos, Karpen, DeLuca, Golub, Hamilton ApJ. 590 (10.6.2003) 547

L. DiLella, K. Z.,
Astropart. Phys. 19 (2003) 145

➔ **solar X-ray self-irradiation**

? how ?



Possible solution :

*Whole Sun irradiation by the radiative decay/interaction of gravitationally trapped massive **axion-like** particles around the Sun.*

Generic candidates :

Solar KK-axions gravitationally trapped by the Sun

$$I(^{KK} \leq {}^{escape} \approx 600 - 1200 \text{ km/s}) \approx \mathbf{10^{-7}}$$

➔ ***accumulate over cosmic times***

➔ $g^{a\gamma\gamma} = 9.2\times10^{-14}\ \text{GeV}^{-1}$ & $\tau^{KK} \cong 10^{20}$ s

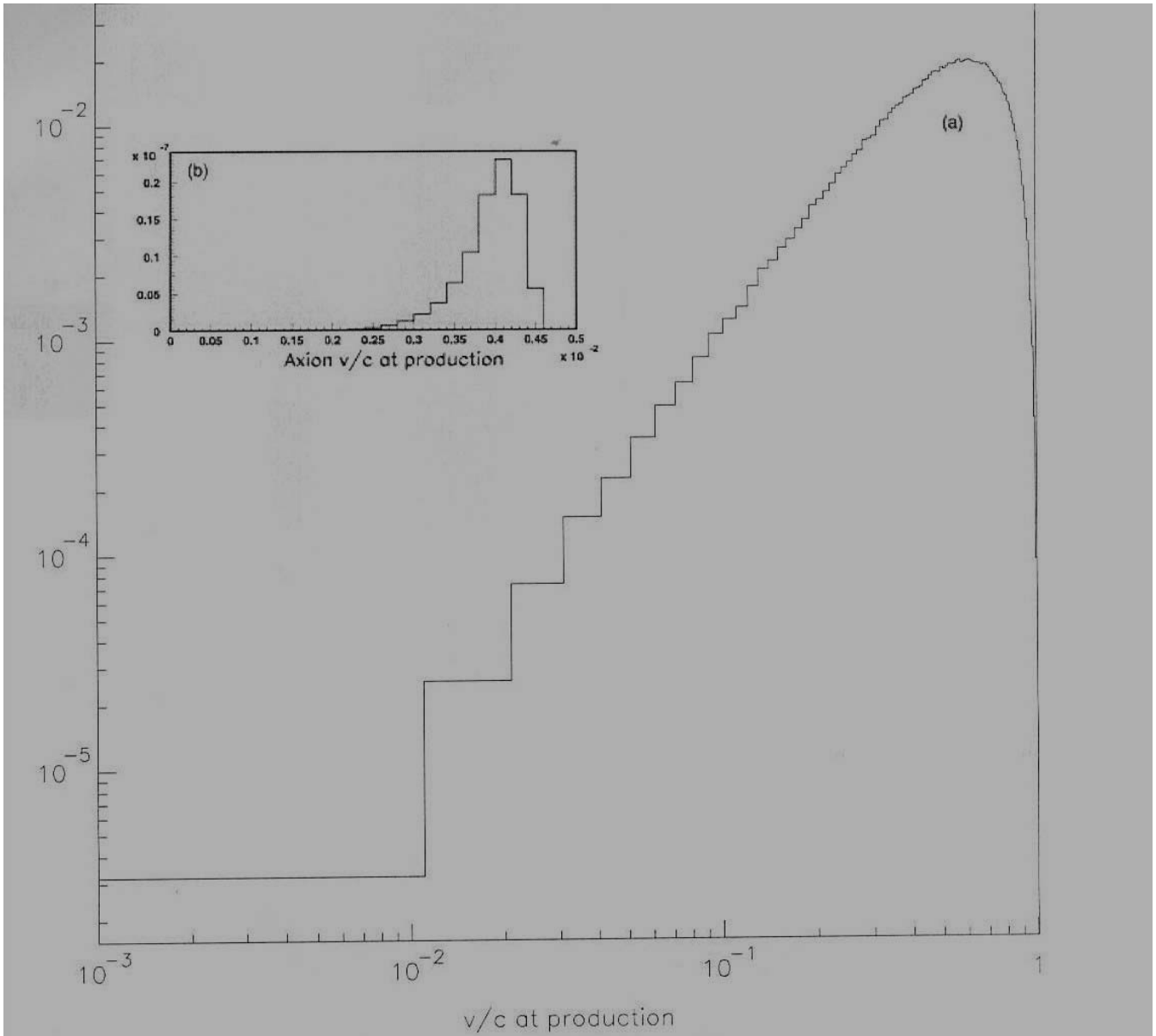
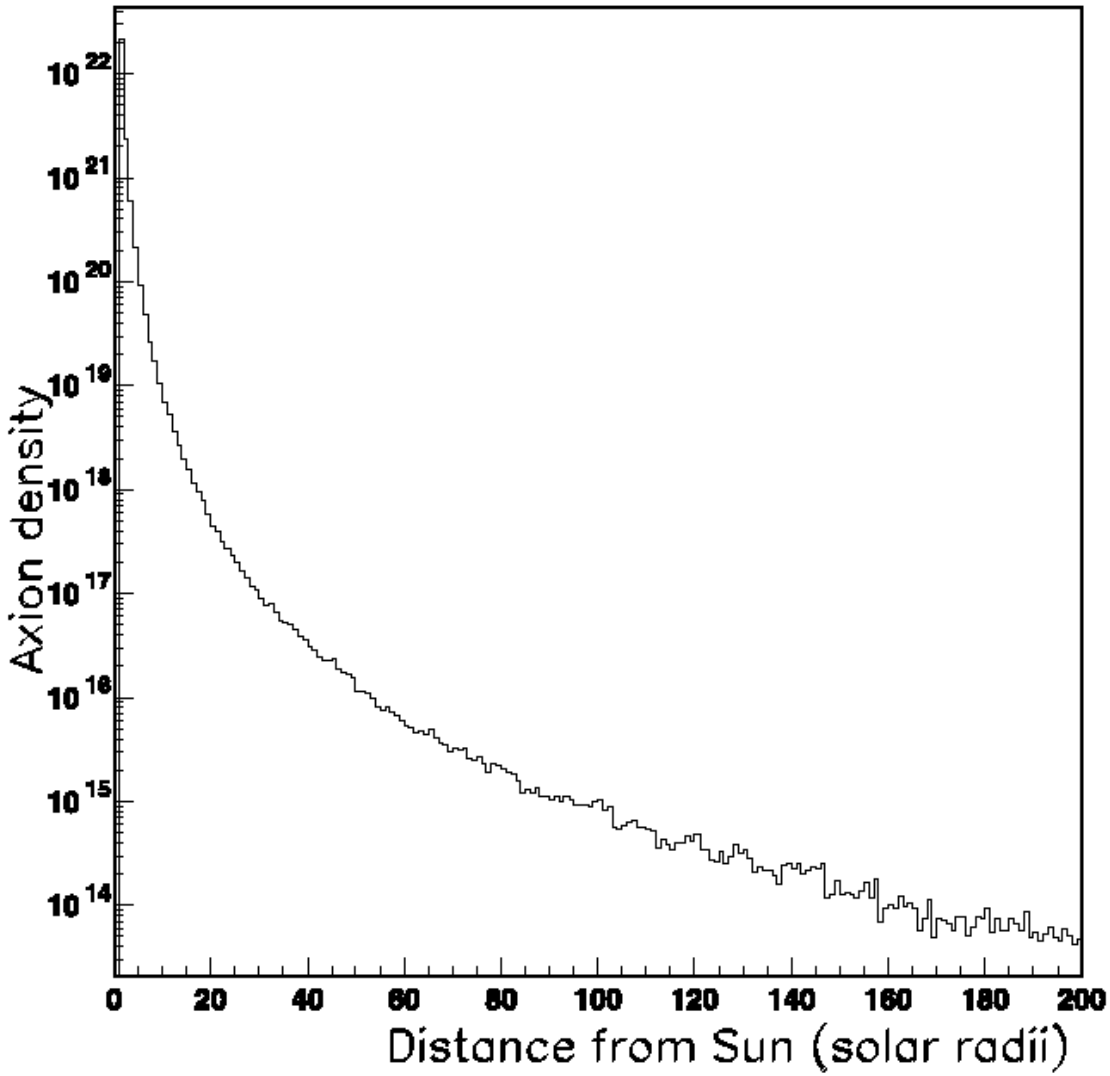
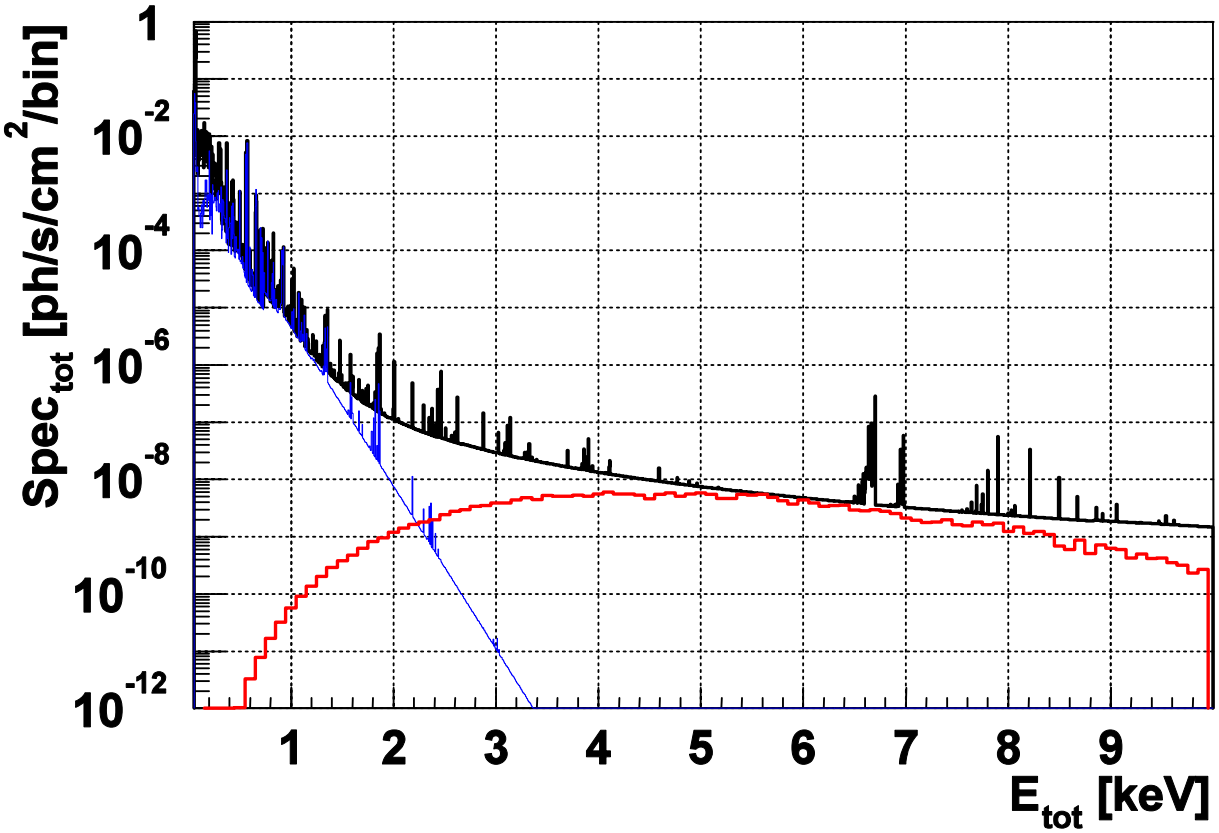


Fig. 5. Velocity distribution at production for solar axions from photon coalescence: (a) all axions (distribution normalized to unity); (b) gravitationally trapped axions (distribution normalized to f_{trap}).



Present density (axions per m^3) of gravitationally trapped axions in the region around the Sun, as a function of the distance from the Sun centre.

L. DiLella, K. Z., ***Astropart. Phys. 19 (2003) 145***

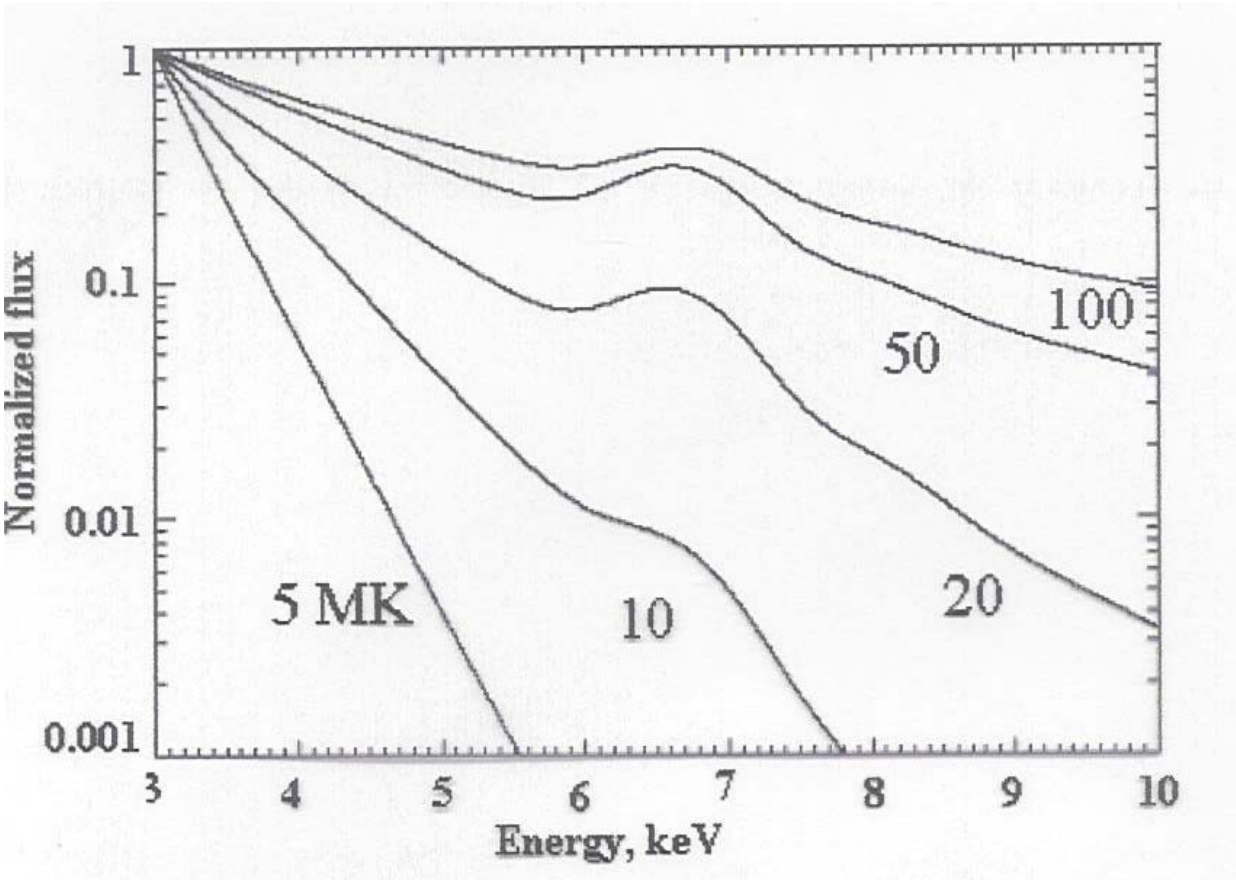


The solar X-ray spectrum reconstructed from the emission measure distribution (EM(T)) for the **non-flaring Sun at the solar minimum** **[16]**. A thermal component of ~1.8 MK is also shown (thin line in **blue**). Bin size =6.1 eV. (EM(T) is approximately the product of the square of the electron density with the emitting volume V(T) as a function of temperature).

Red line : solar KK-axion model →

L. DiLella, K. Z., ***Astropart. Phys. 19 (2003) 145***

[16] G.Peres, S.Orlando, F.Reale, R.Rosner,H.Hudson ***ApJ. 528 (2000) 537***


Normalized flux
1
0.1
0.01
0.001
3
4
5
6
7
8
9
10
Energy, keV
5 MK
10
20
50
100

Quiet Sun X-rays as Signature for New Particles

K.Z., K.Dennerl, L. DiLella, D.H.H. Hoffmann,J.Jacoby, Th.Papaevangelou

ApJ. (May 2004)

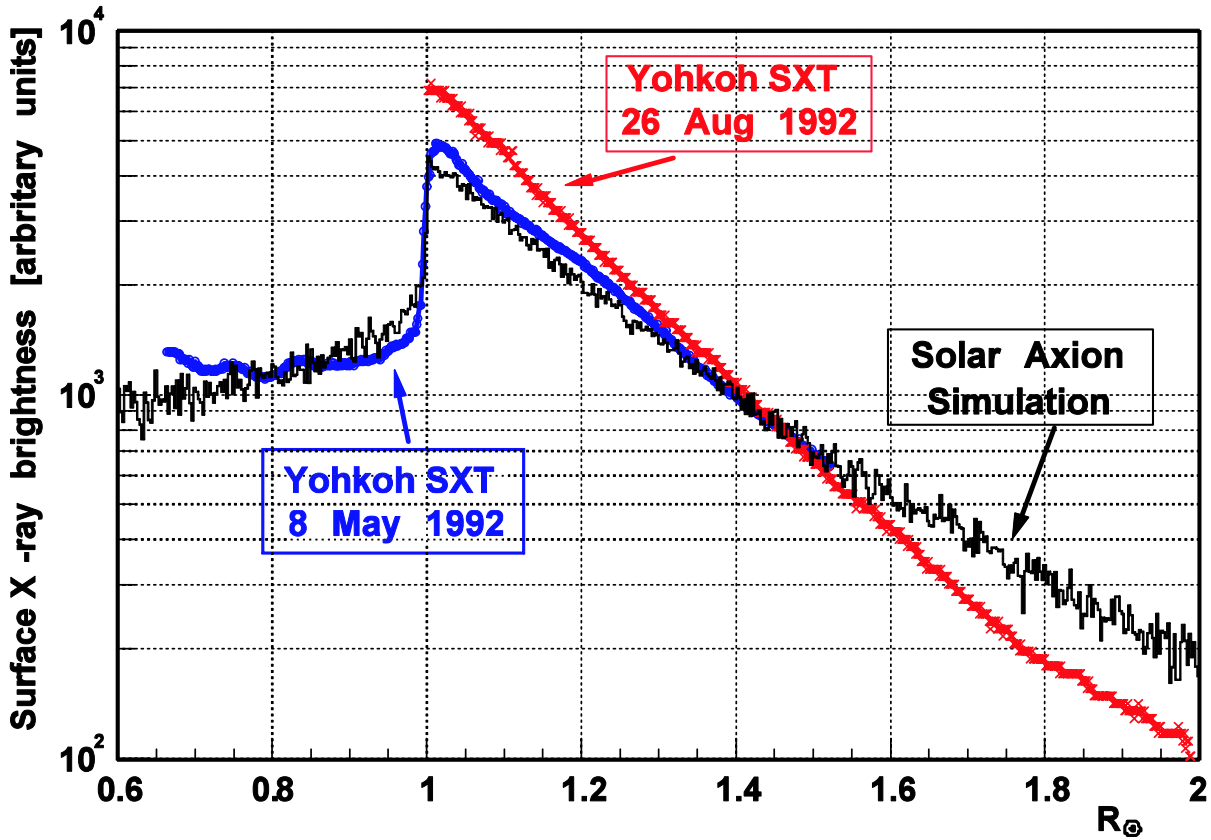


Fig. 1.— Theoretical (DZ03) and experimental (Sturrock et al. 1996; Wheatland et al. 1997) soft X–ray surface flux distributions from the quiet Sun. The simulated curve has been shifted relative to the experimental points of both observations, which implies $g_{a\gamma\gamma} \leq 40 \cdot 10^{-14}$ GeV^{-1}. The effective exposure time was 136.5 s and 121.3 s for the May and August observation, respectively.

Yohkoh-SXT 1992 observations :

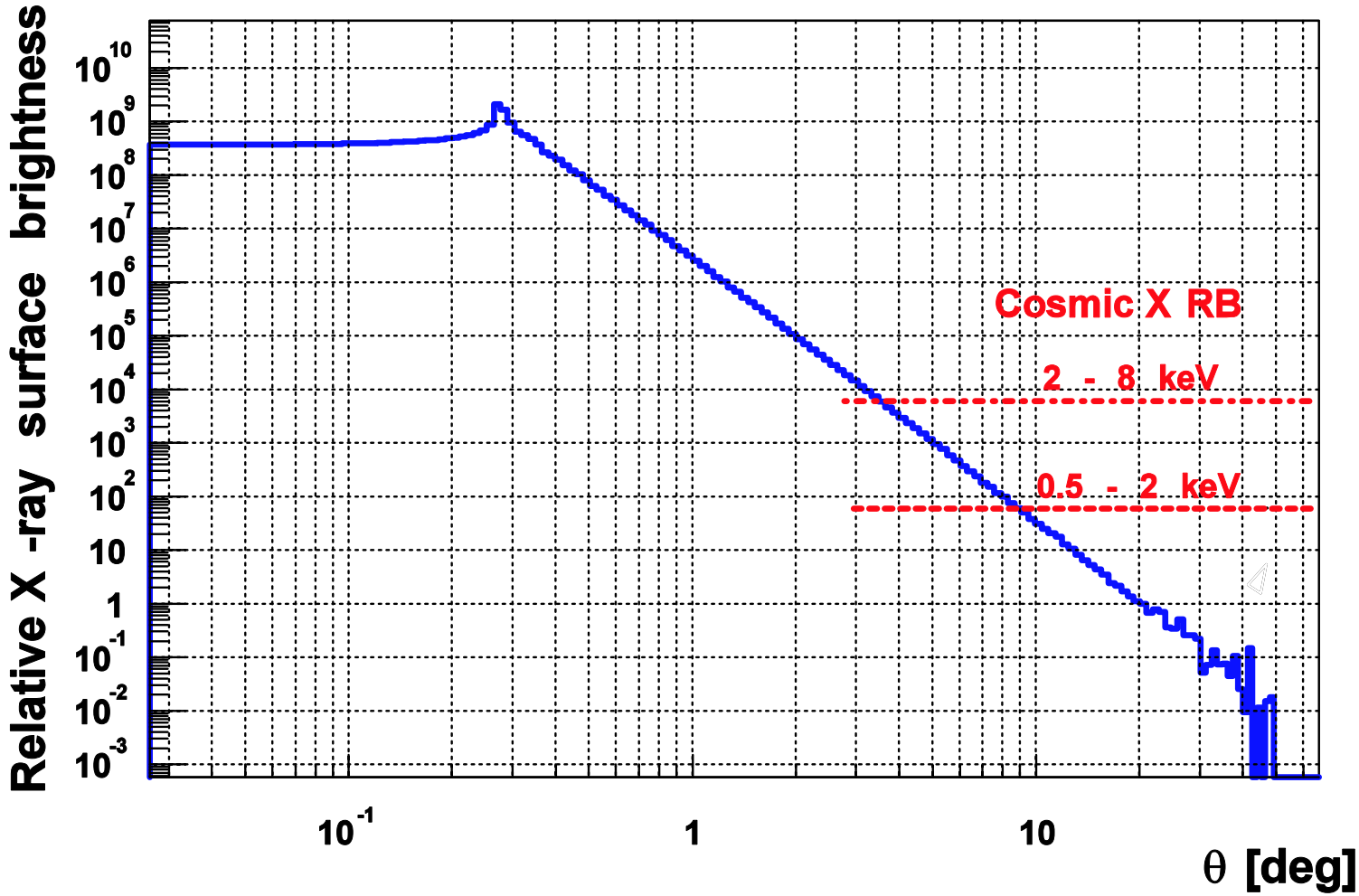
The standard view : the deposition of nonthermal energy occurs low in the "inner corona," and that this region in turn supplies heat to the upper corona and to the "solar wind," a term used to represent the continuous expansion of the corona into interplanetary space.

The standard view may need revision … *the solar wind may supply heat to the inner corona rather than the other way around.*

…. There is no evidence of nonthermal heating in either the observed regions or in the inner corona.

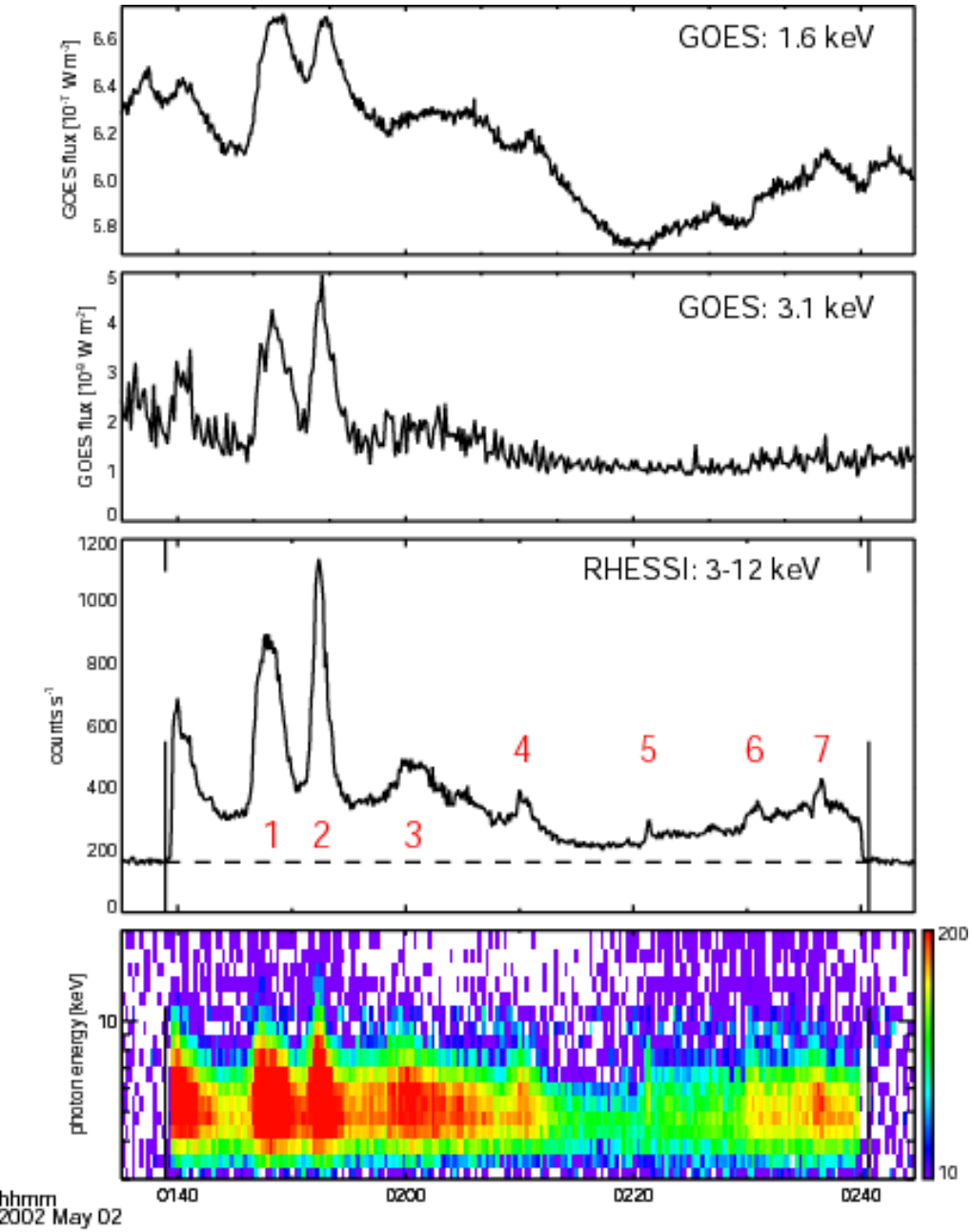
➔ …re-think the standard picture of the corona-solar-wind system

http://www.stanford.edu/dept/physics/newsletter/96/corona.html



The predicted solar X-ray brightness from the Sun direction. The level of the cosmic X-ray background radiation in the soft and hard energy band is also shown defining the size of the observable X-ray halo due to decaying solar axions.

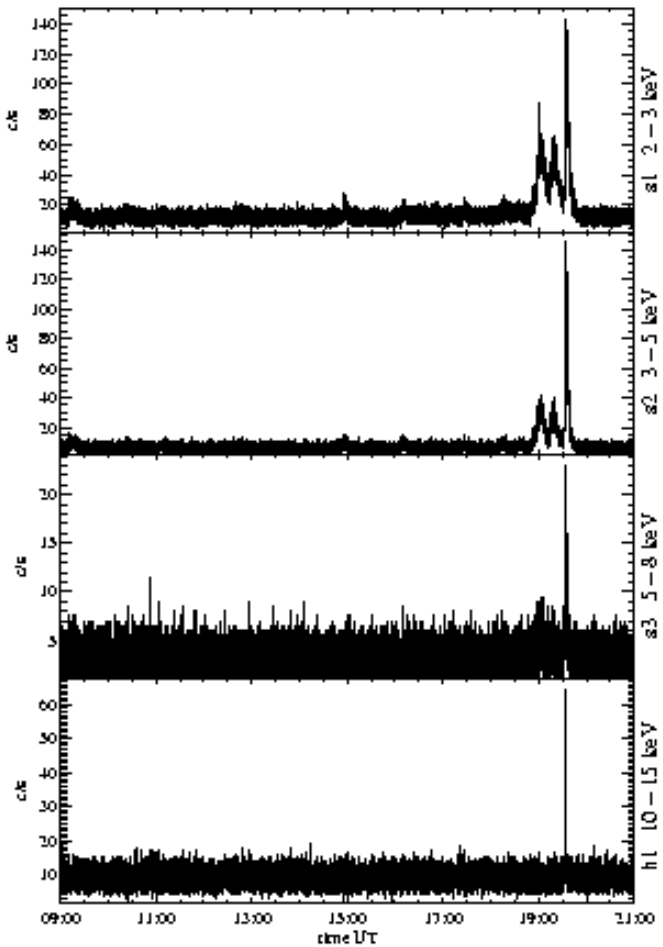
K.Z., K. Dennerl, L. DiLella, D.H.H. Hoffmann, J. Jacoby, Th. Papaevangelou,
ApJ. (May 2004)



The GOES and RHESSI (from top to bottom) X-ray observations during 1h of low solar activity. The vertical lines define the spacecraft day. The RHESSI detector background level is measured before and after the daylight part of the orbit (dashed line). The RHESSI count spectrogram plot (bottom) is background subtracted.

K.Z., K. Dennerl, L. DiLella, D.H.H. Hoffmann, J. Jacoby, Th. Papaevangelou,

ApJ. (May 2004)



RHESSI 11th Febr. 2004,

http://www.spectrumastro.com/SAI_PressReleases/PR_details.cfm?PRID=147

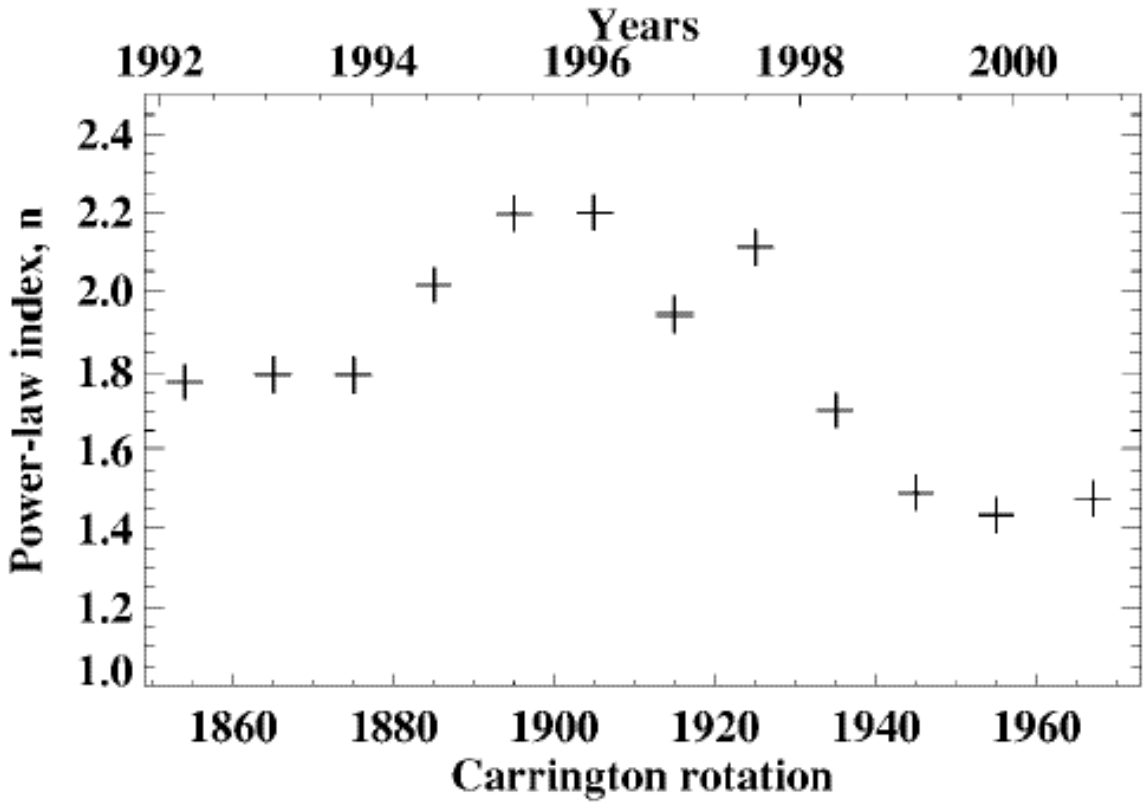
...the first detection of continuous glow from the sun at 3-15 keV

INTERBALL: "We have found it *very unexpected* that there is present quiet-Sun emission in the 10-15 keV band in the period of the lowest solar activity (1995)"

ESA SP-448 (1999) p.176, ed. A. Wilson

M.Siarkowski, J.Sylwester, S.Gburek, Z.Kordylewski

(s. also J. Sywester et al., ***Solar Phys. 197 (2000) 337, Fig.3***)



Power-law index, *n*, of the $I_{AlMg} \sim B^n$ dependence as a function of Carrington rotation number and time.

The relation between the soft X-ray flux …and … the magnetic flux can be approximated by a power law with an averaged index close to 2.

E.E. Benevolenskaya, A.G. Kosovichev, J.R. Lemen, P.H. Scherrer, G.L. Slater,
ApJ. 571 (2002) L181

Conclusion

Observations

a) the shape of T and ρ_e at the thin **TR** (solar chromosphere / corona),

b) the reconstrtucted solar spectrum of the quiet Sun up to **~10 keV,**

c) the **radial distributions** of the two Yohkoh X-ray observations of the quiet Sun,

d) the derived **inward heat flux** in the quiet solar atmosphere of ***some*** nonthermal energy deposition beyond ~ 1 R_{SUN} from the Sun surface,

e) the observed continuous emission of X-rays from the non-flaring Sun (also during solar cycle minimum) in the 3 to ~15 keV range, *i.e.*, a **~ 50-100 MK** component in the solar corona,

f) the solar $L_X \sim B^{1.8\pm0.4}$ dependence

since ~60 years missing conventional explanation ➔

Suggestion

- ***they can be reconciled with a halo of gravitationally bound massive solar axions of the KK-type*** *(generic example)* → ***whole Sun X-ray self-irradiation***

  1) ***radiative decay*** → *constant term*

  2) ***interaction*** with $\mathbf{B_{SOLAR}}$ → *also local effects*

  → ***? 11-years solar cycle ?***

- ***in favour of present / future solar axion searches***

  ← ***the motivation behind these investigations***