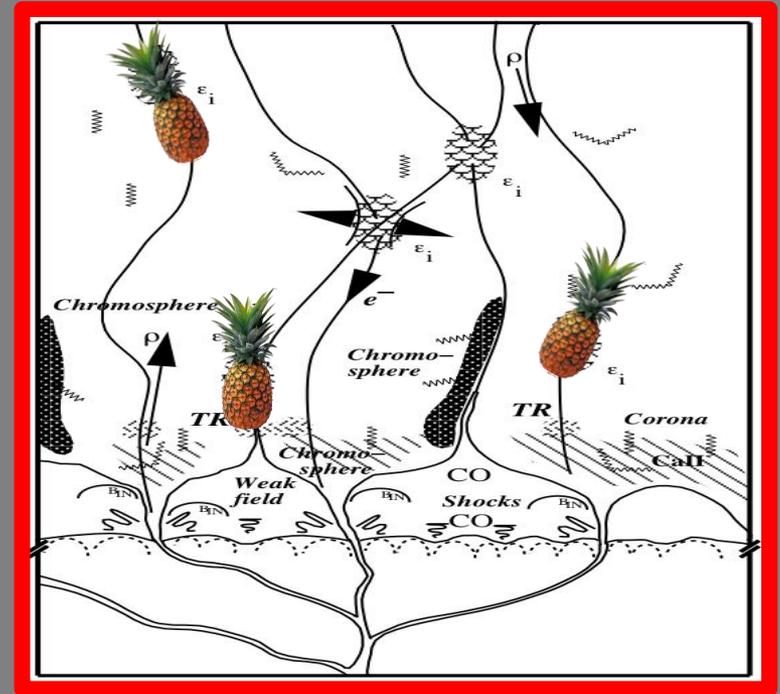


The Ups and Downs of Alpha Centauri & Friends

Tom Ayres (CASA)



Activity Highlights

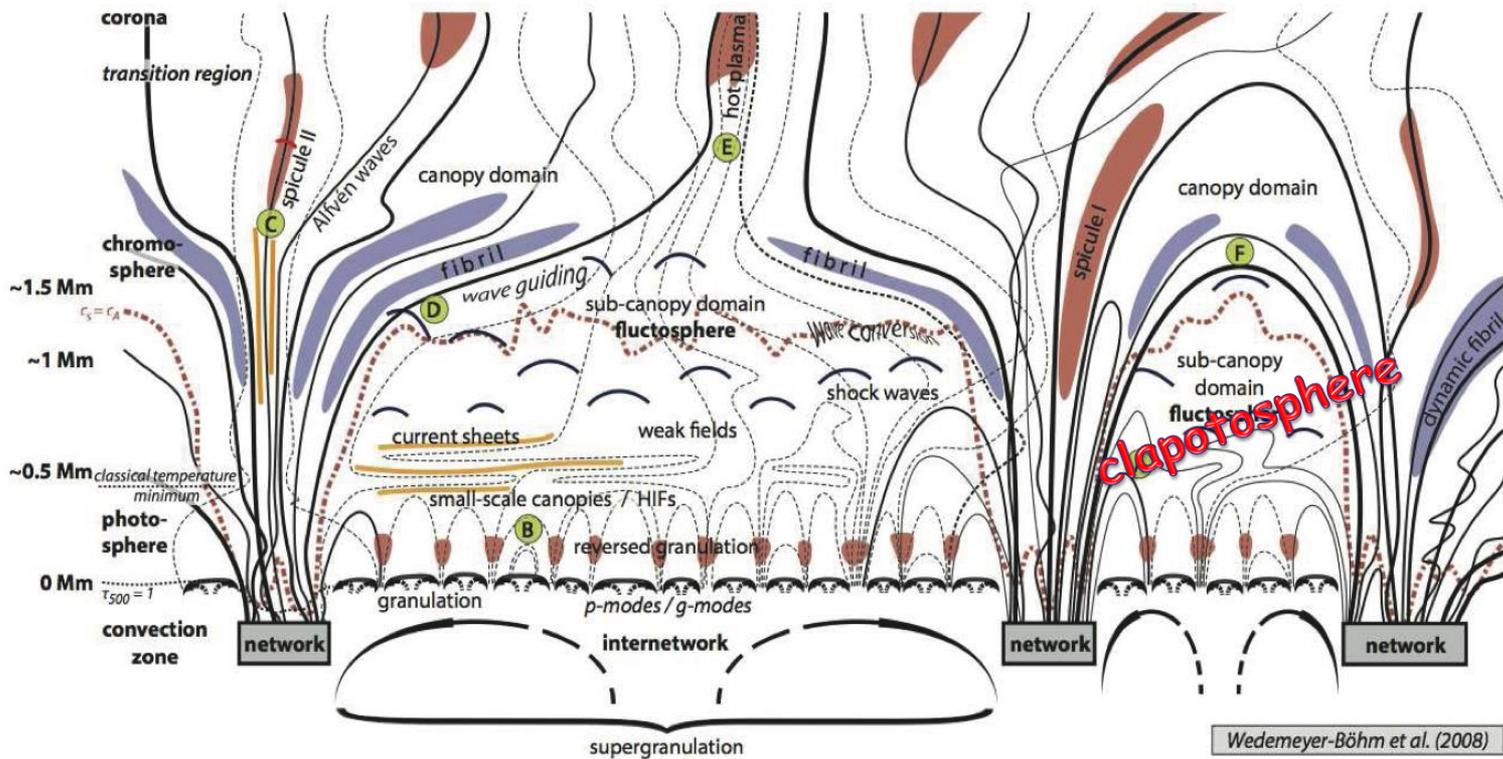
- Signs of stellar *Activity* found most commonly in **cool half of H-R Diagram** [convection is *power source*]
- *Activity* depends on *Stellar Rotation* (catalyst for Dynamo action), and **fades** over time owing to magnetic *wind braking* (stars more active in youth)
- *Chromospheres* ($T \sim 10^4$ K) **most powerful** at all ages, though **Coronae** ($T \sim 10^6 - 10^7$ K) **rival at youngest** ages
- Decadal *Activity Cycles* **common** on sunlike stars; **flat activity** (like Maunder Min) and **double cycles** also seen. Opt photometry: *plage-dominated* vs. *spot-dominated*
- *Spectral signatures*: **X-ray spectra softer** in low-activity sources; FUV 'hot lines' **bimodal** and **redshifted**
- Sun *Typical* for class and age

Phenomenology

- Starspots (“Doppler imaging,” *Kepler*)
- Flares (HXR, white-light “**superflares**”)
- Chromospheric emissions: Ca II, Mg II & H I Ly α (but **not always magnetic**)
- High-energy radiation (FUV, EUV, X-rays): $T \sim 10^5 - 10^7$ K
- Non-thermal radio emissions
- Hot coronal winds (**perhaps also cool winds of Red Giants**)

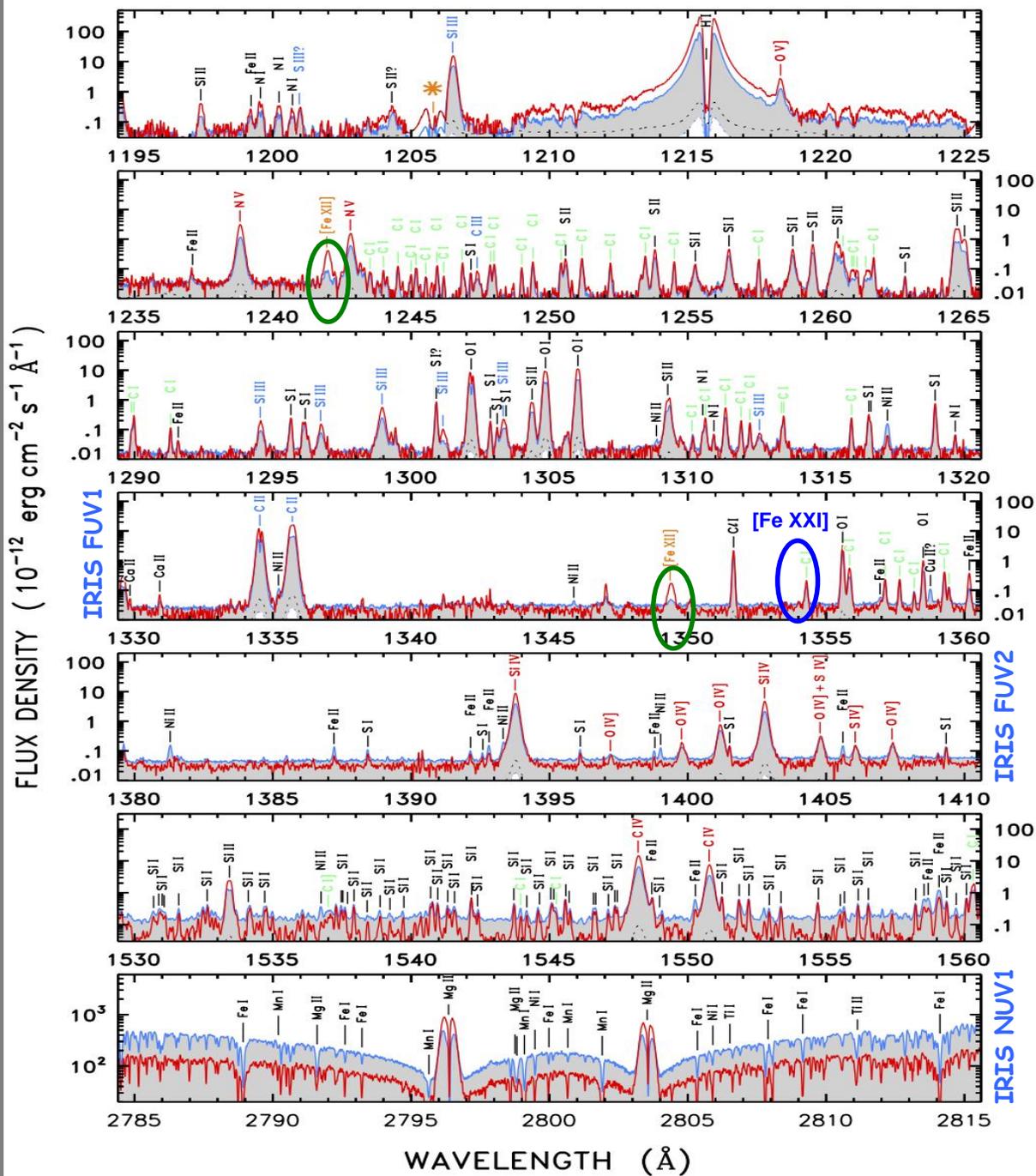
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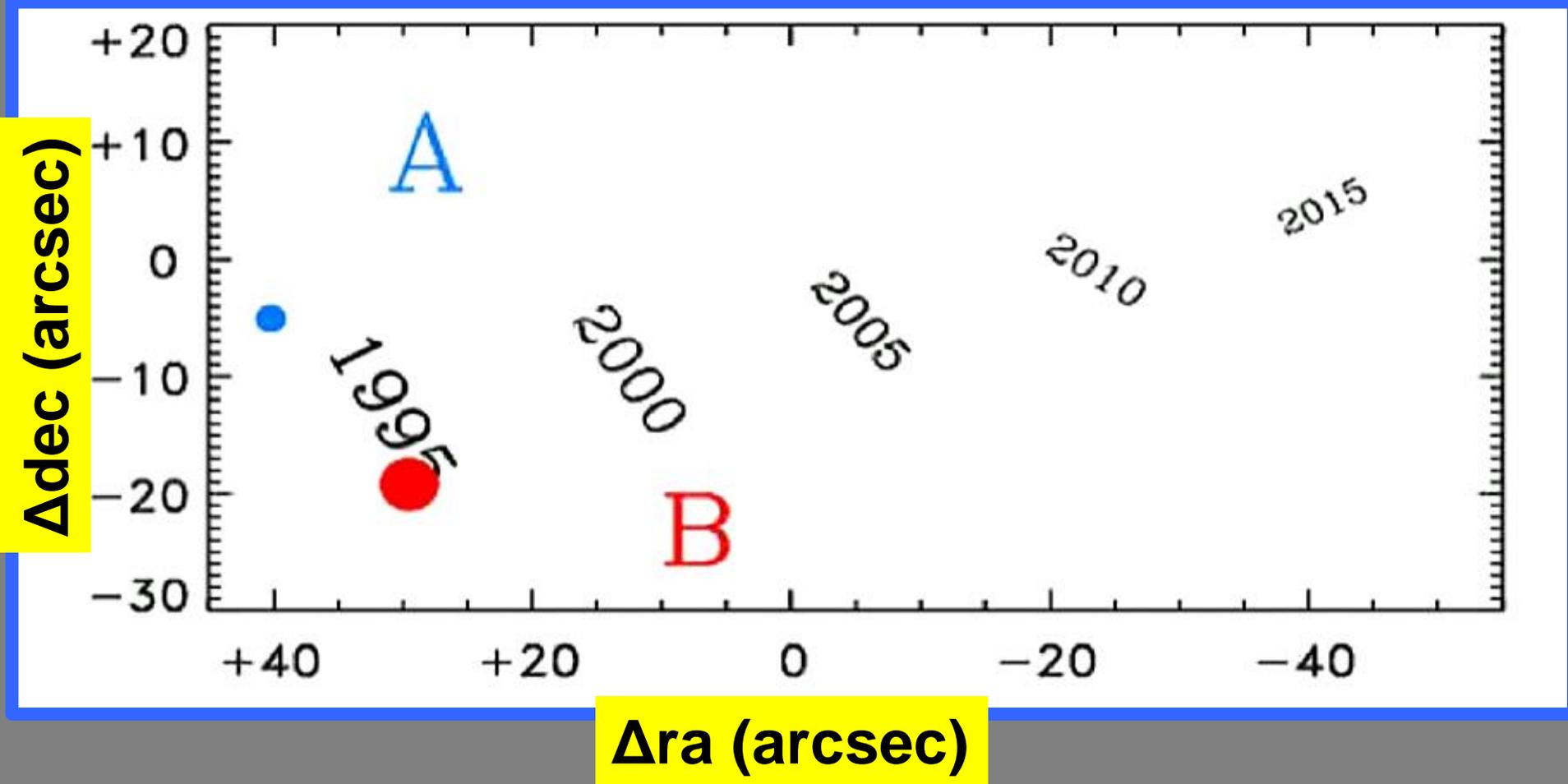
Schematic quiet Sun atmosphere. From *Wedemeyer-Böhm, Lagg, & Nordlund, ISSI*

Activity consequence of chaotic mix of structures, dynamics, and timescales in "Magnetic Complexity Zone"



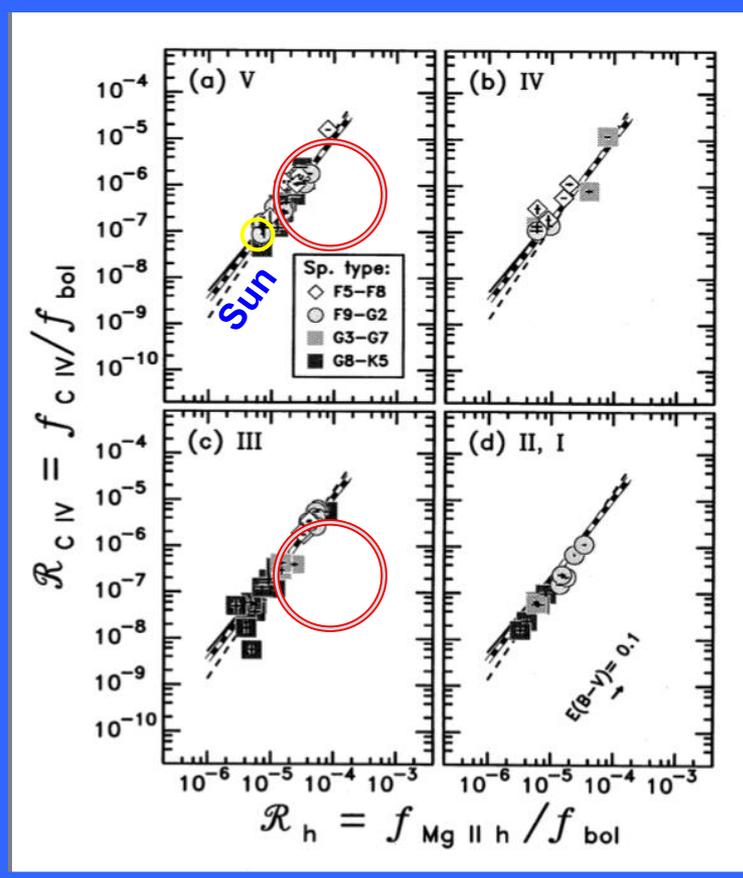
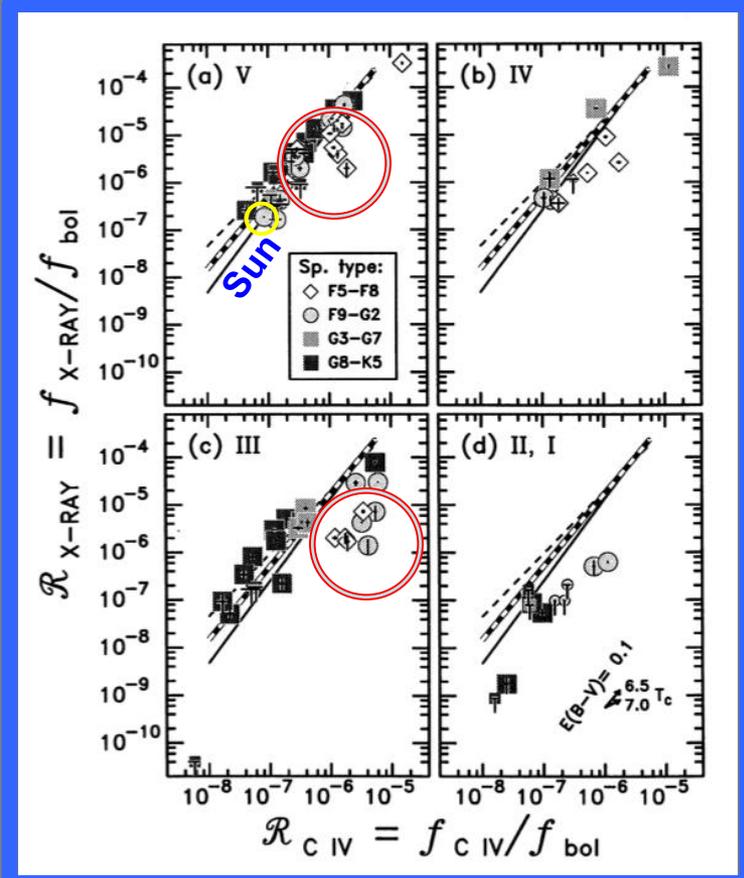
HST/STIS
ultraviolet
spectra of
sunlike
stars
 α Cen A
[G2V] and
B [K1V]

α Centauri A (G2V) and B (K1V) X-rays: The MOVIE



Flux-Flux Correlograms

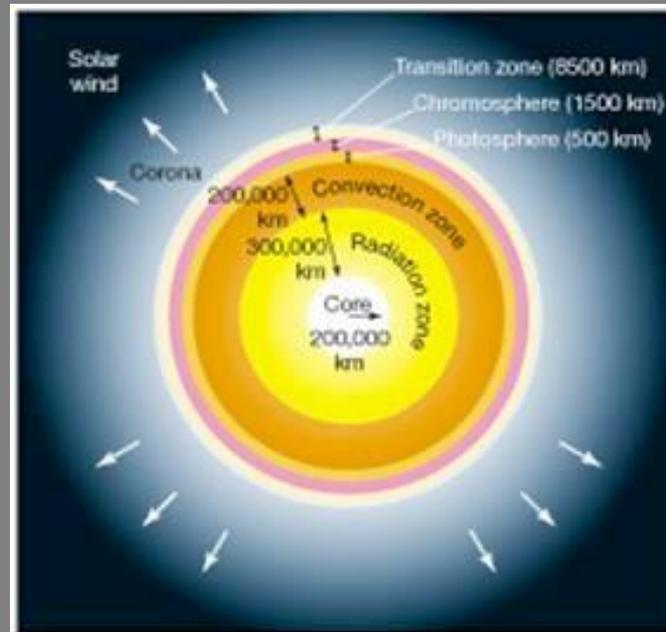
Ayres+1995 "RIASS Coronathon"



Coronal *X-rays* show *good correlation* with *C IV* (except 'X-ray deficient stars'); *power law > 1*
Mg II & *C IV* *well correlated* for all types

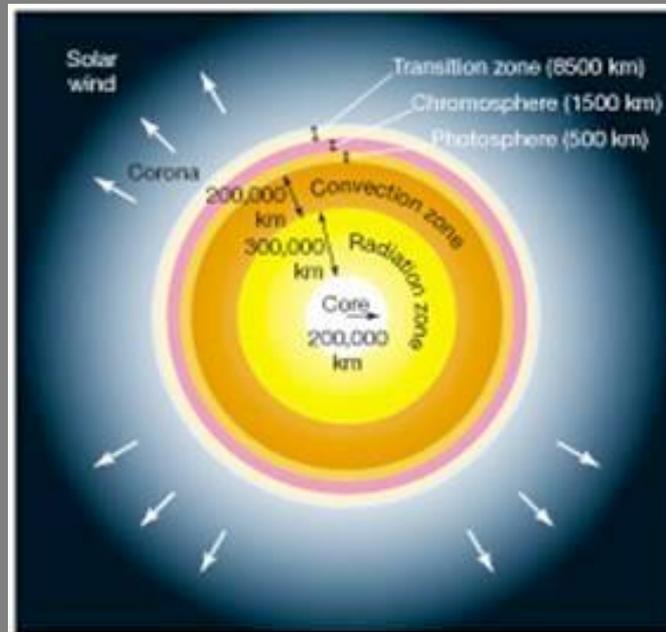
Radiative Losses of Atmosphere: (cooling balances heating)

Photosphere (6000 K)	60 MW / m ²	1.000000
Chromosphere (10,000 K)	3 kW / m ²	0.000050
TZ (100,000 K)	30 W / m²	0.000001
Corona (1 MK)	40 W / m²	0.000001



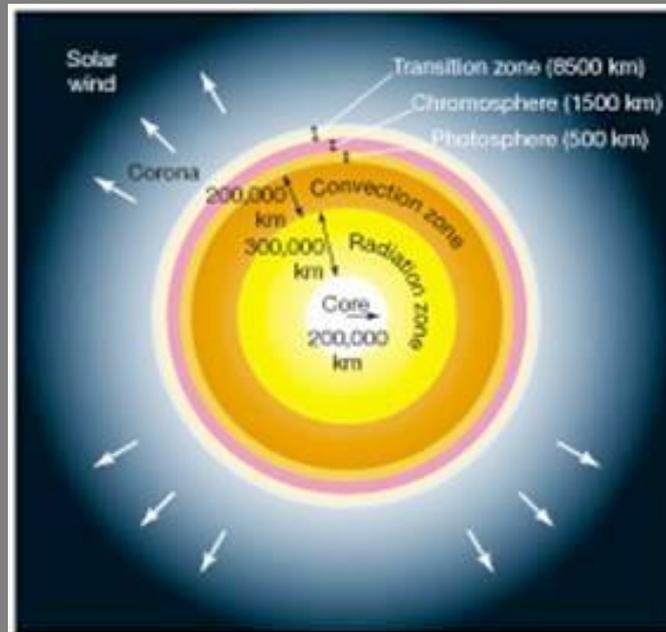
Masses of Atmospheric Layers:

Photosphere	4×10^{17} tonnes	1.000000 ($2 \times 10^{-10} M_{\odot}$)
Chromosphere	2×10^{15}	0.005000
Corona	6×10^{12}	0.000015
CME	2×10^9	<i>really small</i>



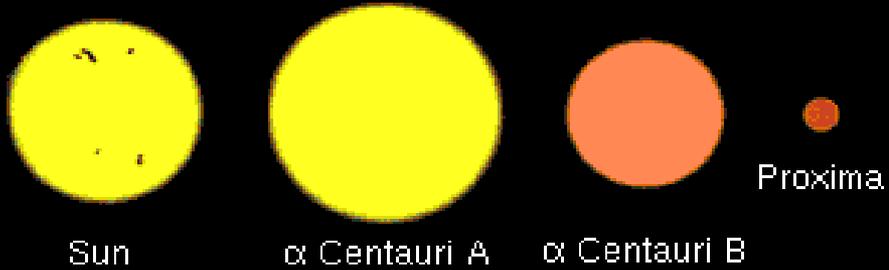
Radiative Losses of *Hyper-Active* Stars

Photosphere	60 MW / m ²	1.000 (1.00x☉)
Chromosphere	Max: 50 kW / m ²	0.0010 (15x☉)
TZ	Max: 3 kW / m ²	0.0001 (100x☉)
Corona	Max: 30 kW / m ²	0.0005 (500x☉)



Case Study: Cycles of Alpha Cen

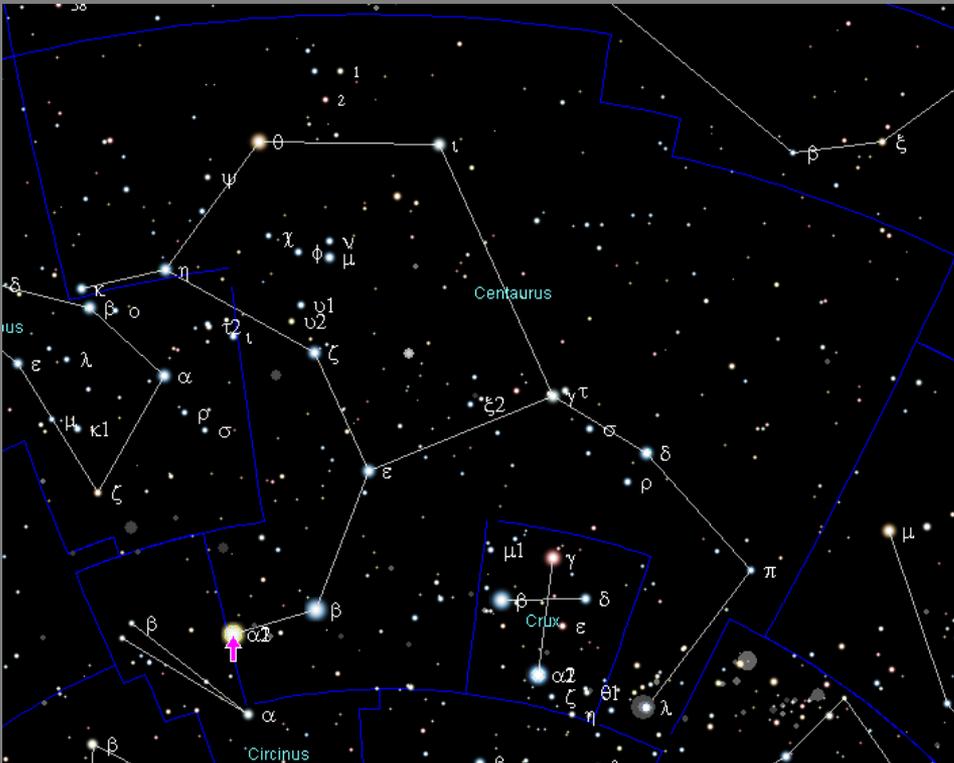
In true relative scale

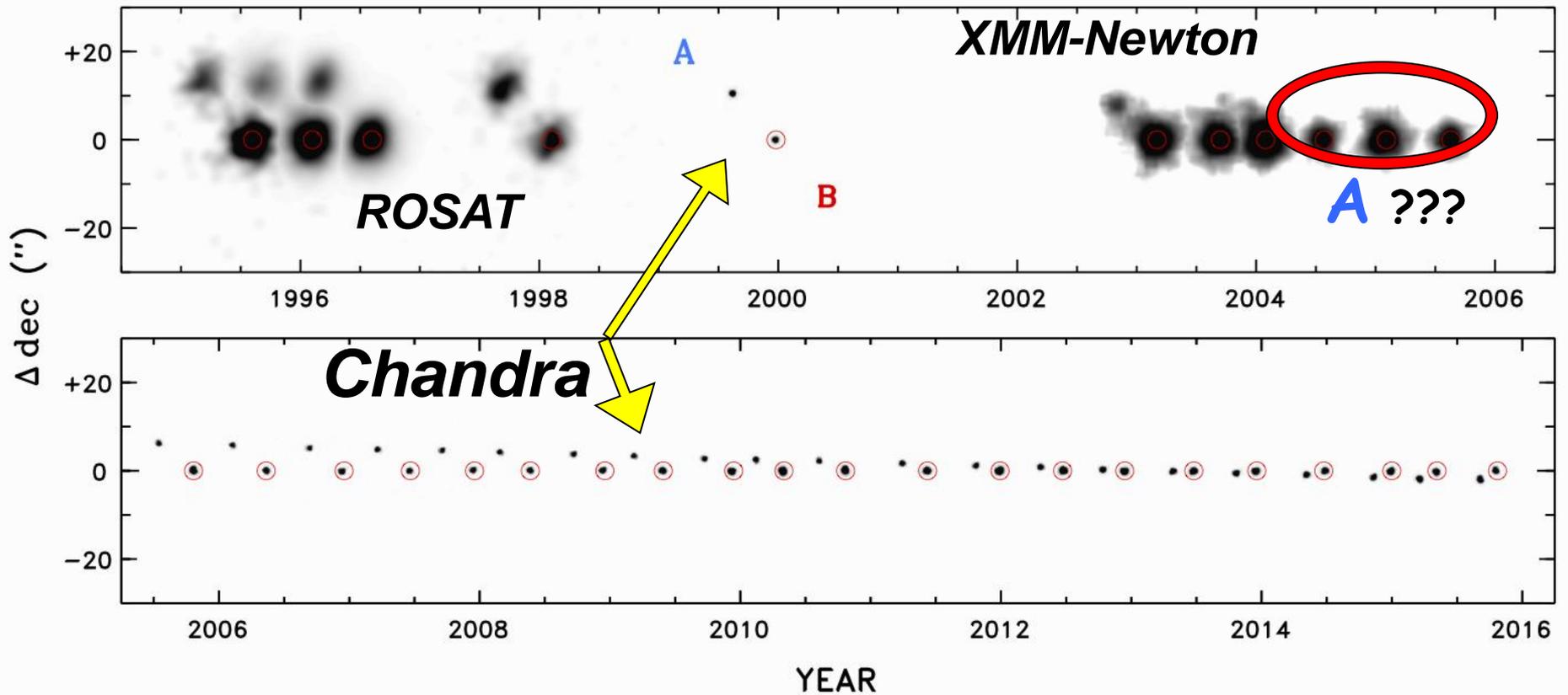


Alpha Centauri triple system. Two solar-like stars about 20 au apart (Sun-Uranus); dim red dwarf 10,000 au away



Slightly metal rich compared with Sun, older by ~1 Gyr.
G2V primary (“A”) near twin of our Sun





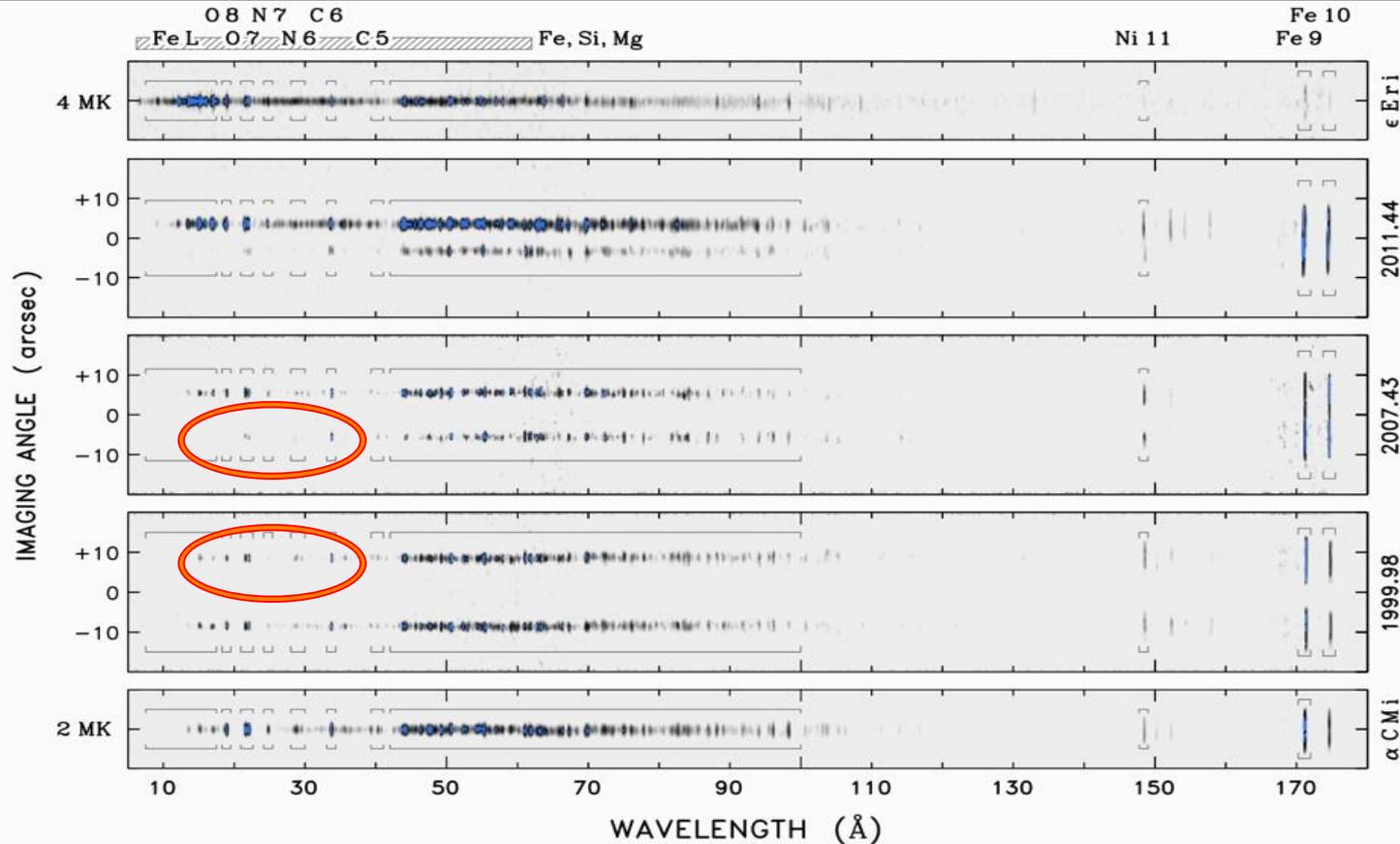
Imaging of α Cen AB in X-rays
 (0.2-2 keV) 1995-2015:
 Note `fainting' of A in 2005

The 'Fainting' of Alpha Cen A



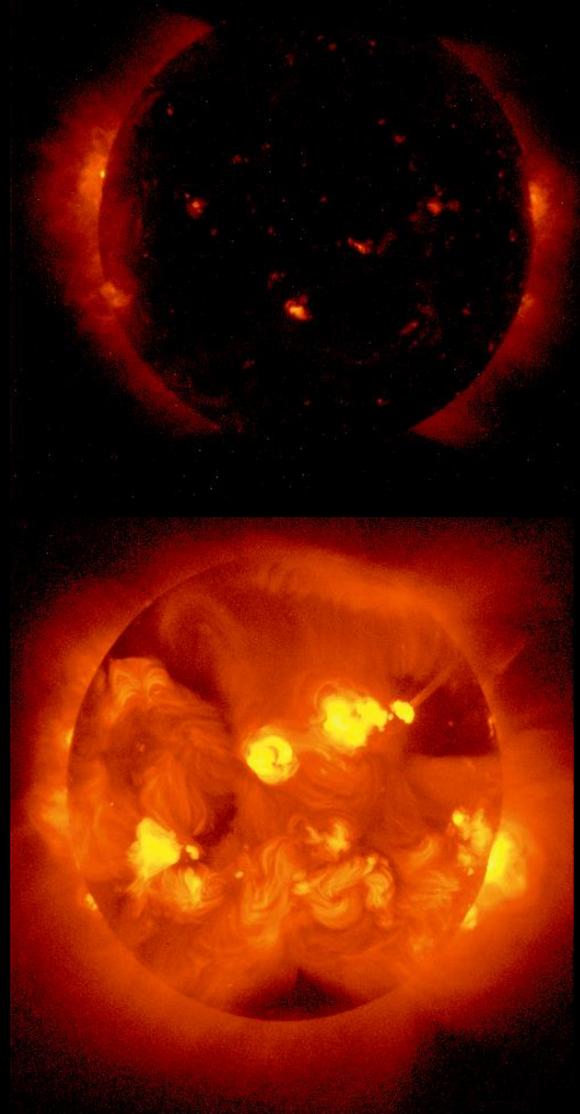
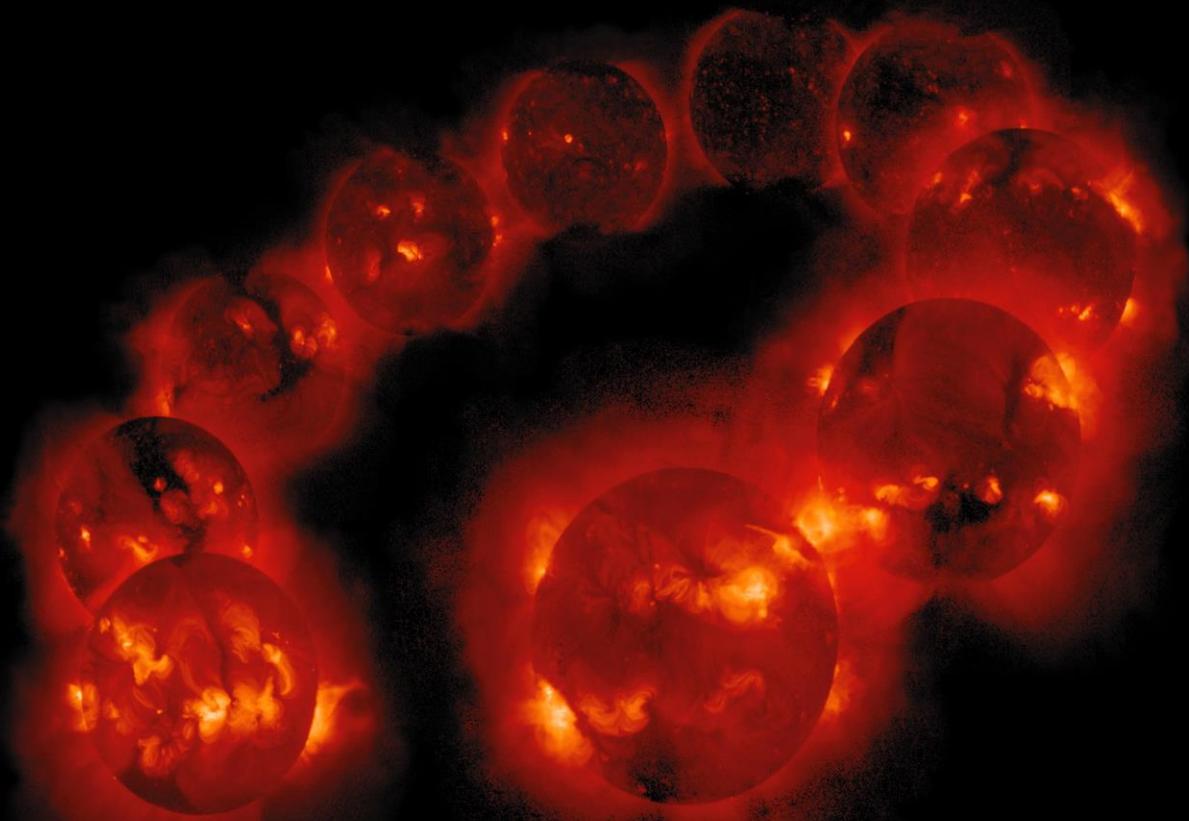
Solar physicist frets over stunning $50x$ drop of Sun's twin in XMM count rates: Sun's soft X-ray cycle depth is only $\sim 5x$; is a Cen behavior what it's like in Maunder Min?

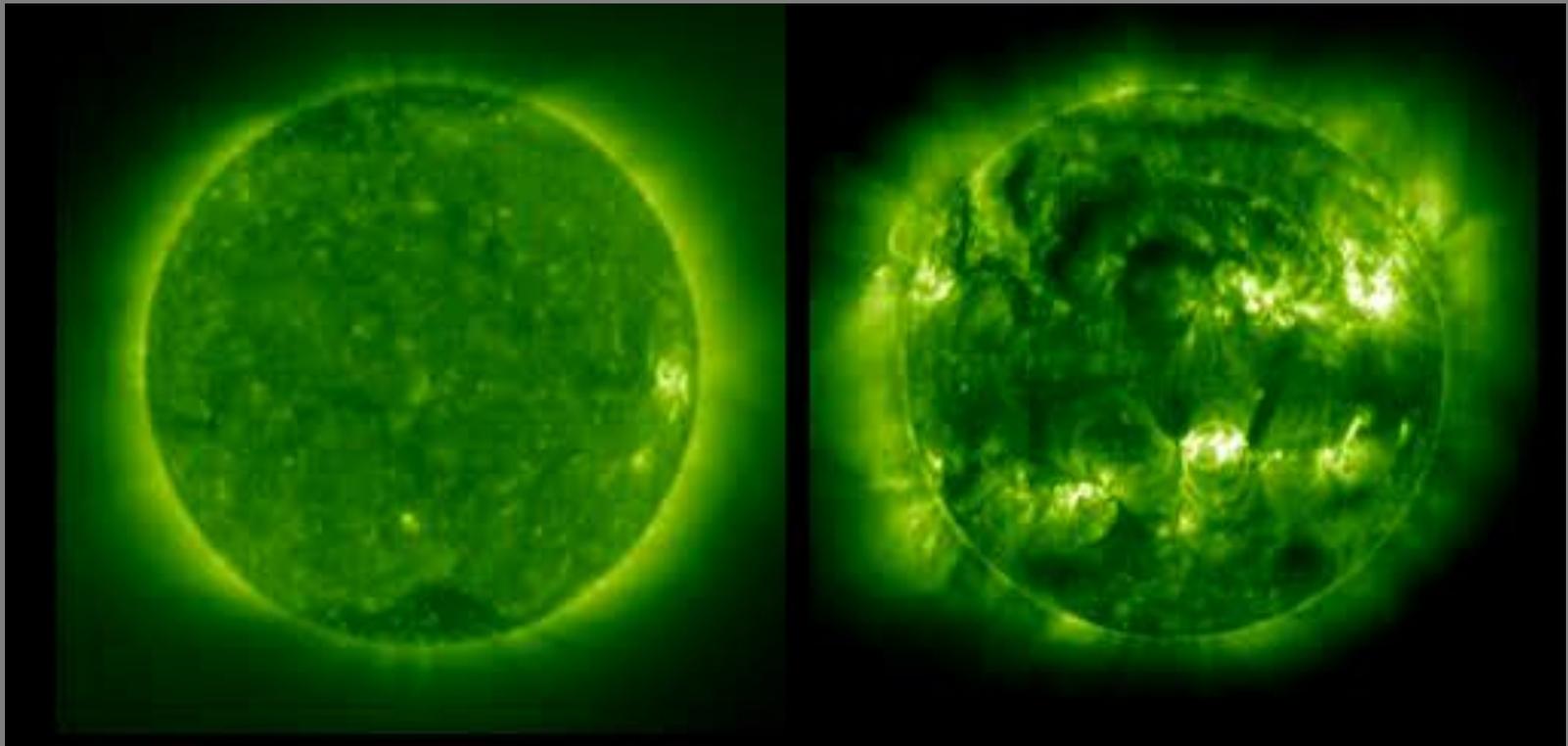
X-ray spectra resolve the dilemma



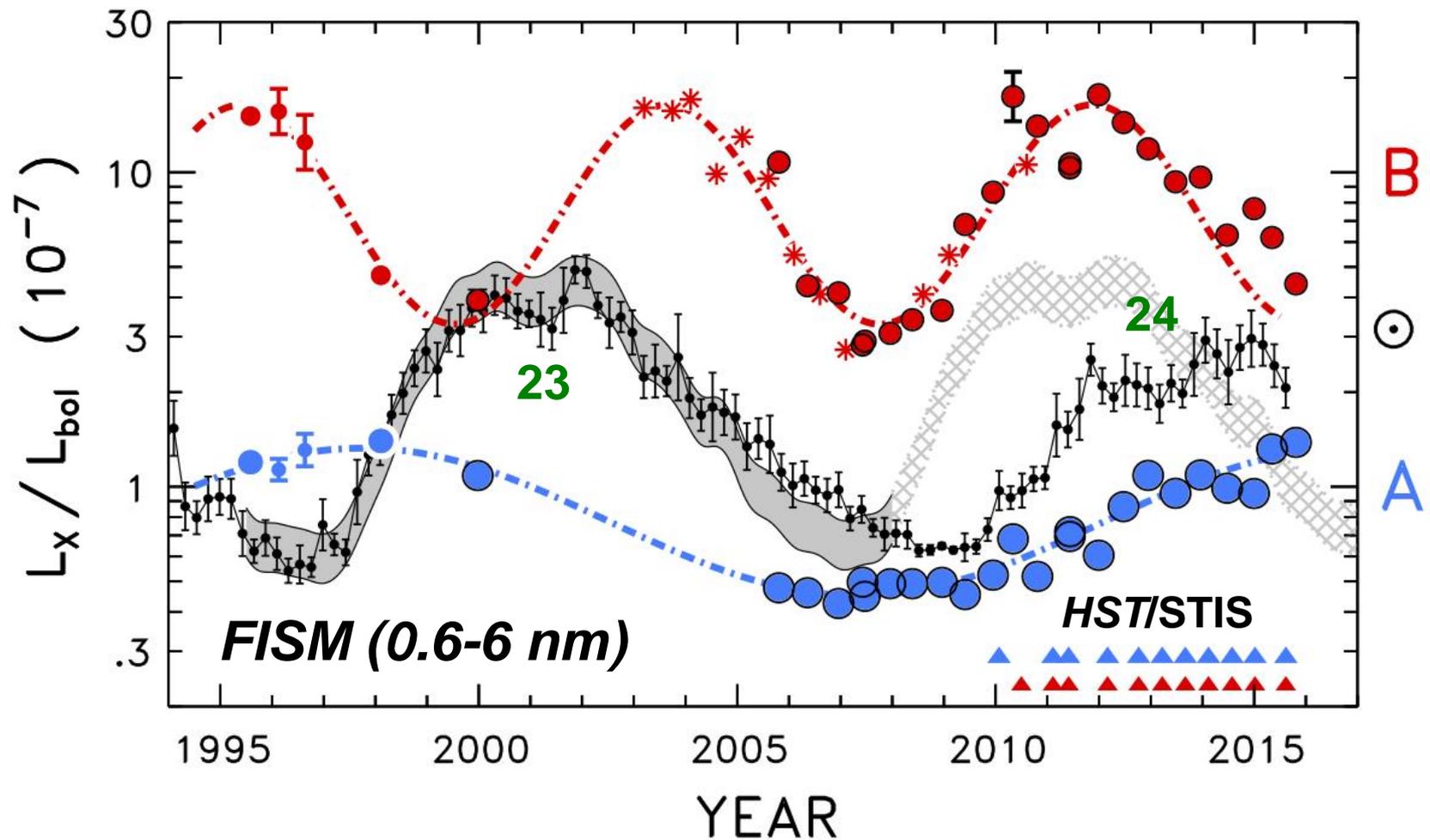
Chandra **L**ow-**E**T Transmission **G**rating **S**pectrometer
 α Cen AB in three epochs, + two comparison stars
 (ε Eri: **K2V** [moderate-activity]; α CMi: **F5IV** [low])

High-energy Yohkoh X-ray imaging, '96-'06:
2-3 MK, almost *exclusively* from active regions

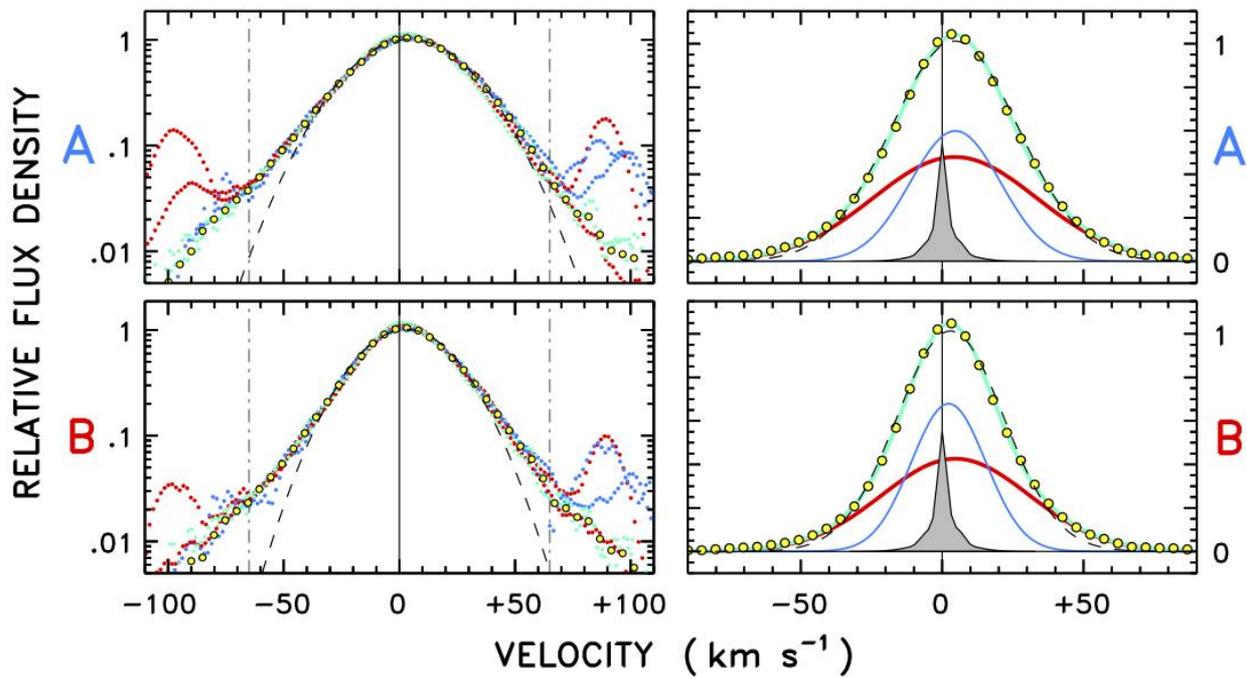




SoHO EIT Fe XII $\lambda 195$ (1 MK) coronal emission persists at spot minimum (*left ; max at right*).
'Fuzzy ball' devolves from magnetic carpet: small clumps of flux built by *local dynamo*, independently of deep seated *el jefe* Dynamo responsible for sunspots and decadal cycling

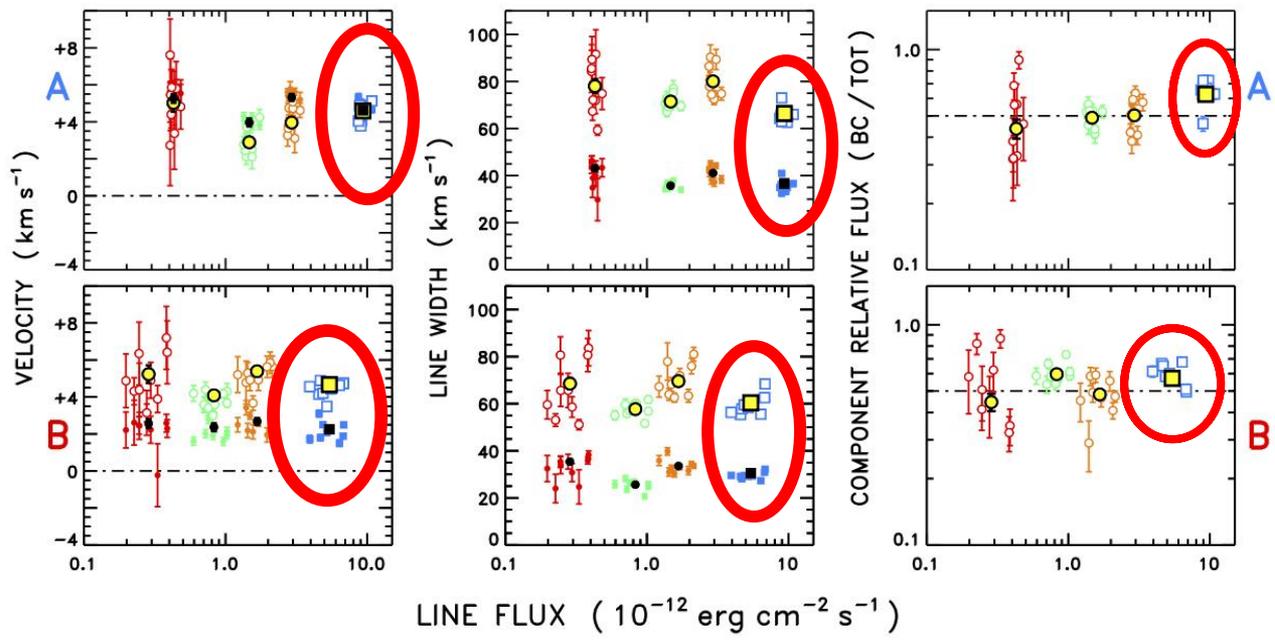


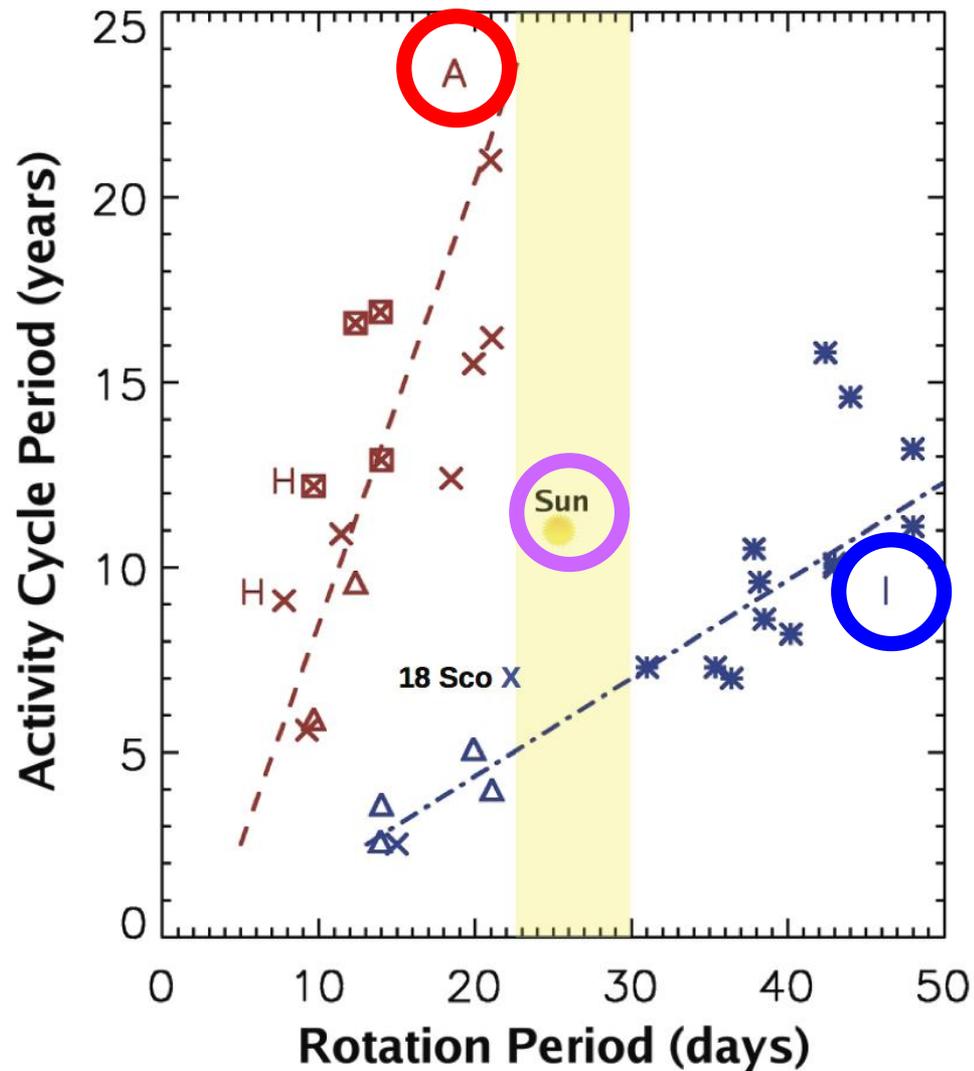
Coronal histories: *Sun* = black error bars (gray shaded: Cyc 21-23 average); a *Cen Chandra/ROSAT* (dots: **A=blue B=red**) & *XMM* (asterisks: scaled) **B** ~8 yr cycle, now falling to min; **A** ~19 yr (?) rising to max; modest cycle depth (flat activity star?)



a Cen **A** & **B**
 NV+SiIV+CIIV
 average
 bimodal,
redshifted
 (top left)

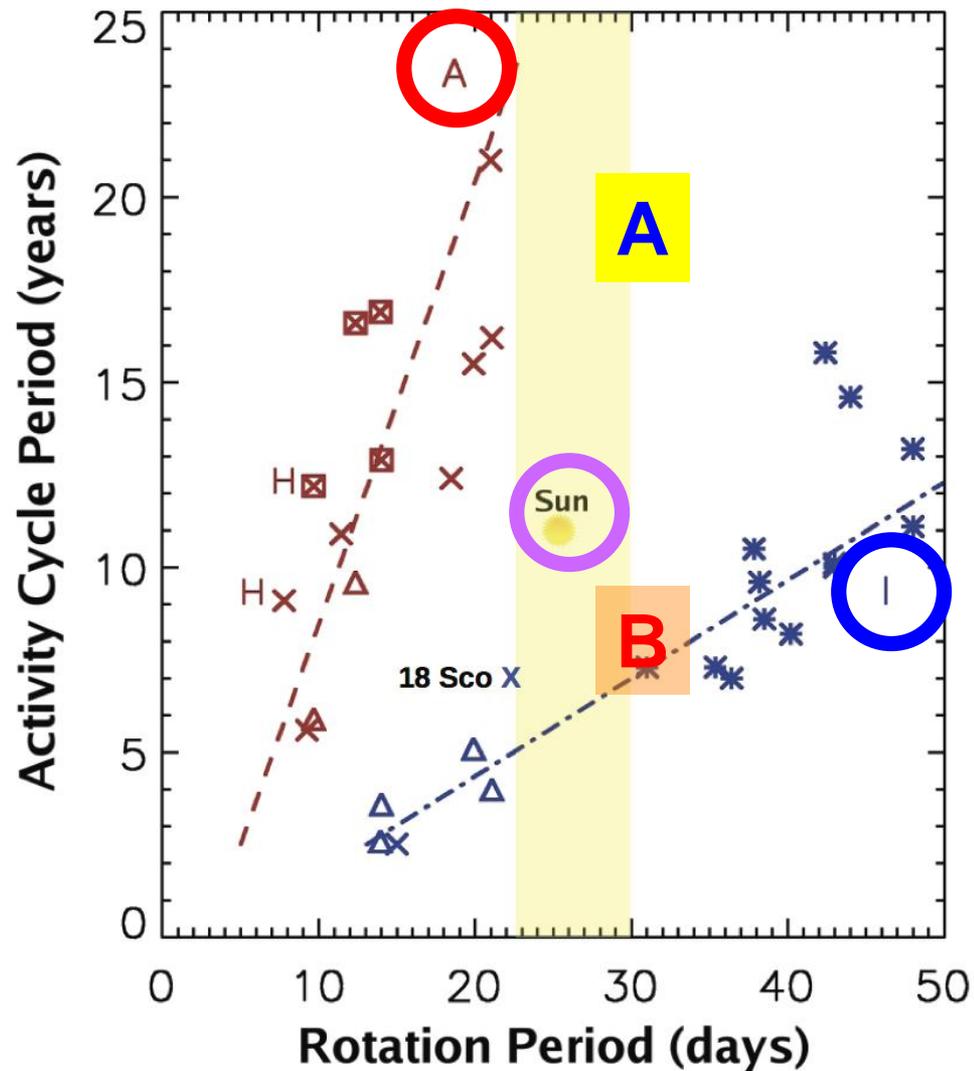
Not much
 change over
 B's cycle
 (bottom):
network BPs
 at Min;
plage BPs at
 Max?





Böhm-Vitense (2007)

Suggestion of two branches of cycles: “**A**ctive” (short rotation periods) and “**I**nactive” (long P_{ROT}): **Sun** in middle— **transitional state** or **data selection biases**??



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Suggestion of two branches of cycles: “**A**ctive” (short rotation periods) and “**I**nactive” (long P_{ROT}): **S**un in middle— **t**ransitional state or **d**ata selection biases??

Lessons Learned

- For *plage-dominated* stars like Sun, changes at FUV/XUV wavelengths are in response to **increases in the plage area** over the cycle, contrasted to **background emission** from the plage-like bright points of the **supergranulation** network as well as the **shock-heated** transient acoustic **BPs**. Both provide a **floor** below which the integrated emission of the star is unlikely to fall, even in a Maunder Minimum, since the **SG BPs** likely derive from a **near-surface dynamo**, and the **acoustic BPs** probably **don't care about the surface fields**. This is reflected in the *success of few-component models* of the total solar irradiance.
- *Be careful* of drawing inferences **about the Sun** from incompletely observed **stellar counterparts**: stars often are recorded with quite different techniques, sometimes with **hidden biases**. *Be wary* of claims that the **Sun is** somehow **unusual**, *but also acknowledge* that because of its advanced age and low activity level, the **Sun might be in a somewhat unstable transition** between cycling and non-cycling states (M-Min).

Take-away Thought

- *What's the best way to measure the solar cycle, with regard to comparisons with other stars, and to model solar irradiances??* Sunspot numbers bottom out at zero, when activity still is present; also, no equivalent for stars. Ca II HK flux is low-contrast diagnostic; OK for stars, but sketchy for irradiance modeling. Hard X-rays only come from flares; tough to record in stars. EUV closely tracks cycle, but challenging to measure in stars. This leaves soft X-rays: strong cycle response and easily captured in stars. Therefore, important to continue (and improve) solar SXR monitoring.

Activity

Stellar Coronae in Astrophysical Context:

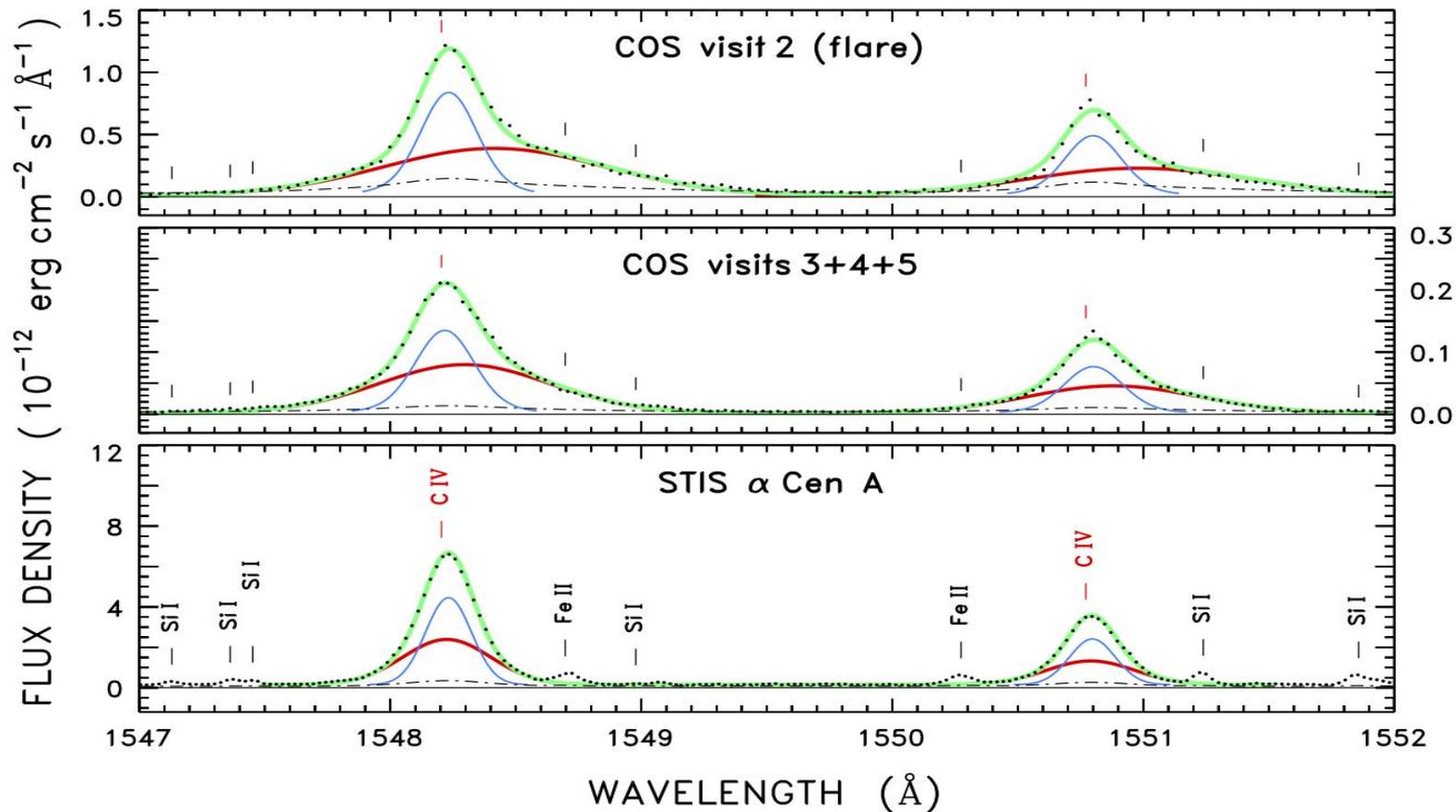
The Cosmic Sexiness Ladder



J.J. Drake

"If the Sun did not have a magnetic field, it *would* be as uninteresting as most astronomers believe it to be."

attrib. to R. Leighton



Giant FUV flare on young solar analog EK Draconis:
X25,000 on GOES scale;

*Bimodal broad component even more strongly
 redshifted than in 'quiescent' profile:*

coronal rain? Failed CME?

Activity

Stellar Coronae in Astrophysical Context:

The Cosmic Sexiness Ladder



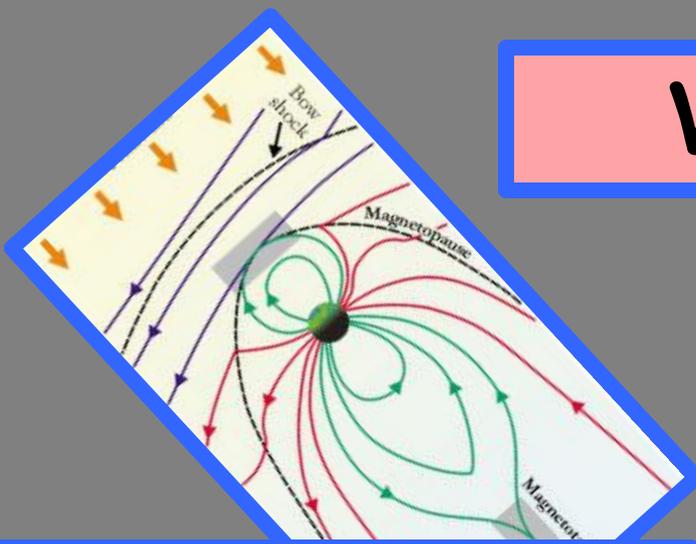
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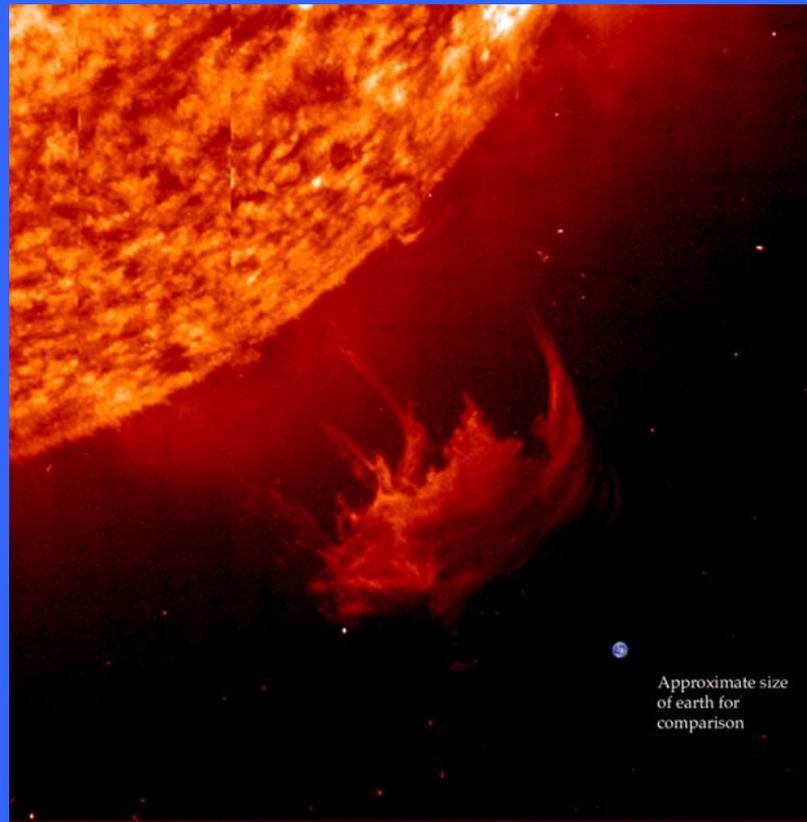
attrib. to R. Leighton

In reality, the Sun is the one astrophysical object that profoundly affects Earth and humankind. Further, the physical processes that are played out on the solar surface, and observable in great detail, also are crucial in many other cosmic environments.

Why do we care ??



Activity strongly influences the heliosphere & Earth, more so in the past when the Sun was more active: atmospheric erosion by EUV ionization and coronal wind stripping is thought to have played role in drying out Mars; similar implications for exoplanets, especially close-in "roasters."



Outline

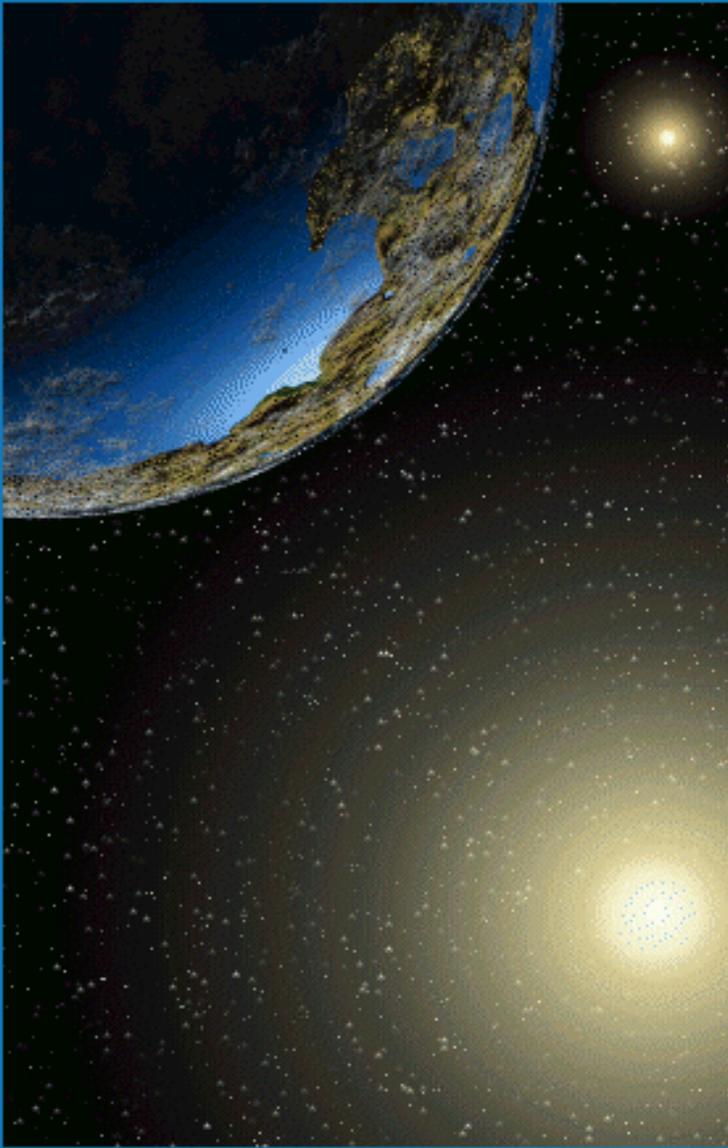
- Activity **OBSERVABLES**
- How do stellar **WINDS** fit in ?
- Stellar **CYCLES**

Guiding questions:

What can *unresolved stellar activity* tell us about the *solar counterpart*, especially the past & future ?

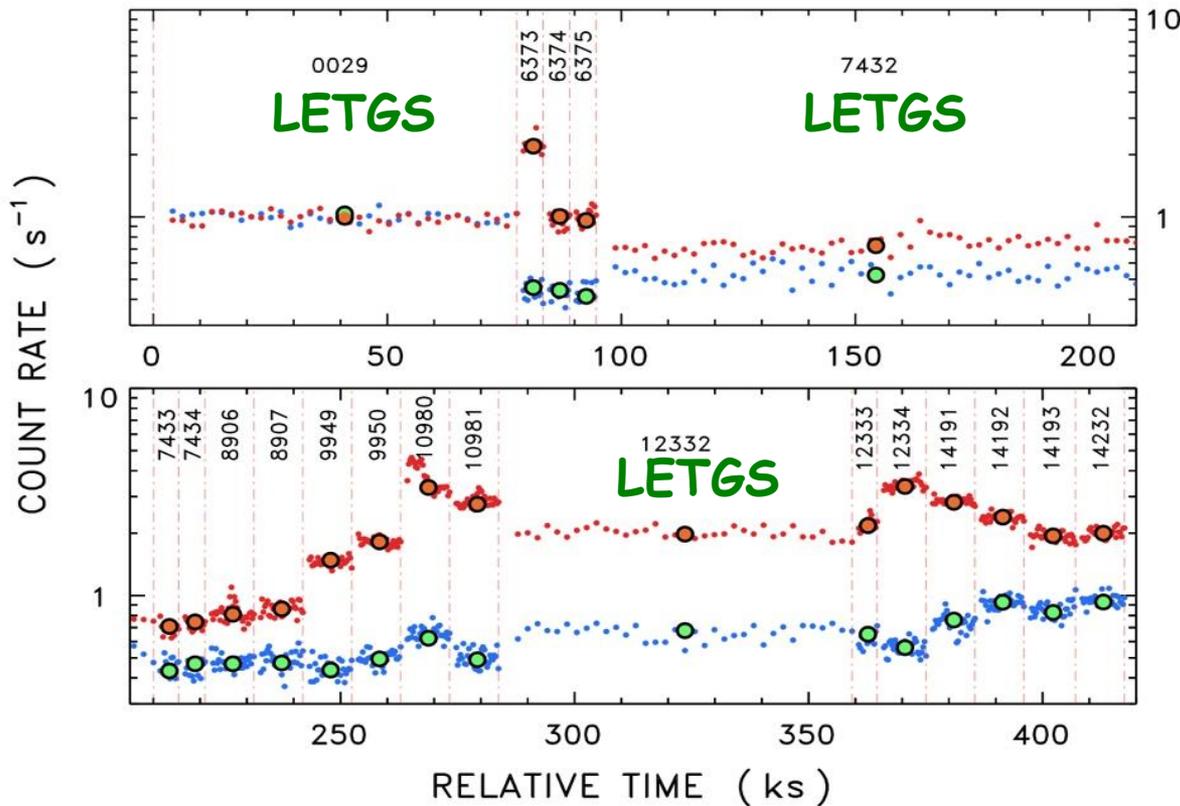
Is *Sun* '*normal*' in cosmic scheme of things ?

Summary

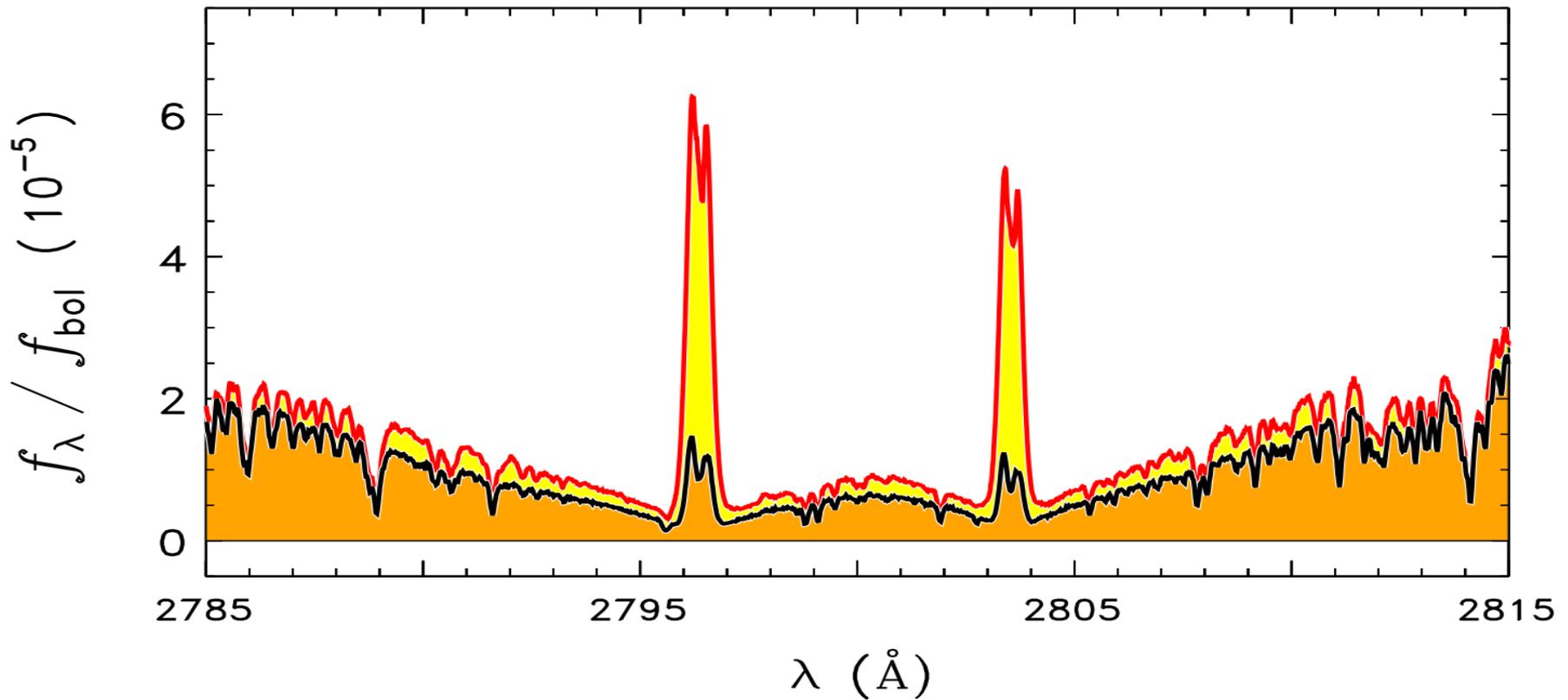


Stellar HK activity cycles solar-like in amplitude & duration; flat activity stars common; long term cycles at low activity give way to stochastic behavior at high, dominated by rotational modulations. At low end, long term photometric changes positively correlated w/ Ca II; opposite true at high activity

Lesson of a Cen A: X-ray cycles very dependent on energy bands & instrumental responses, especially for soft sources like Sun where bulk of coronal emission is $>50 \text{ \AA}$



Light curves for individual pointings
 (small dots: 300s binning for HRC-I; 2100s
 for LETGS), and flare-filtered averages
 (larger symbols); blue=A, red=B

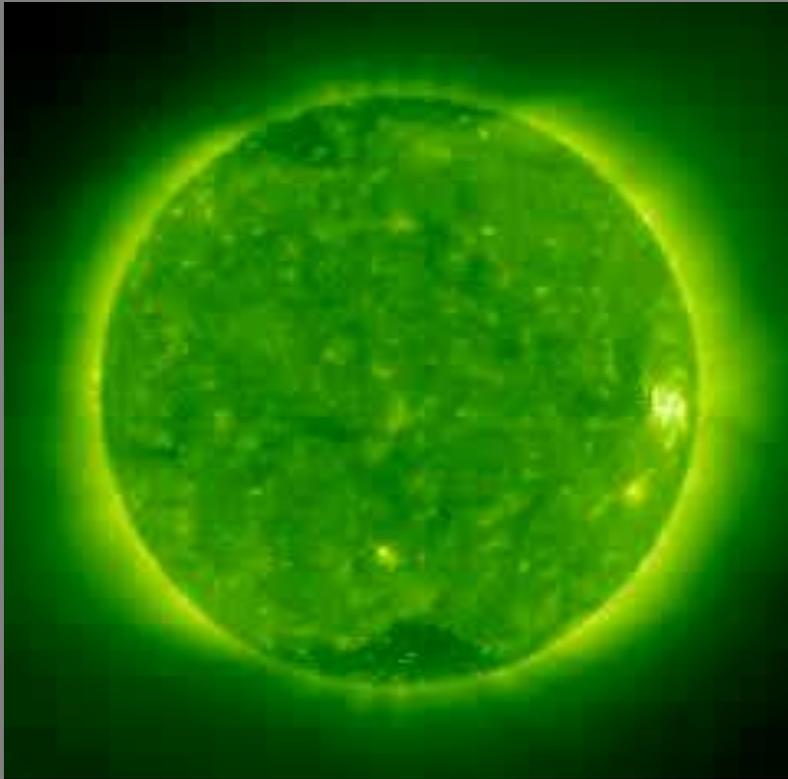


Mg II h & k line wings and cores higher in active dwarfs. Similar behavior seen in Ca II H & K of plage vs. quiet-Sun;

Mg II emissions ~3x brighter than Ca II.

Why study the stars, when the Sun is so close?

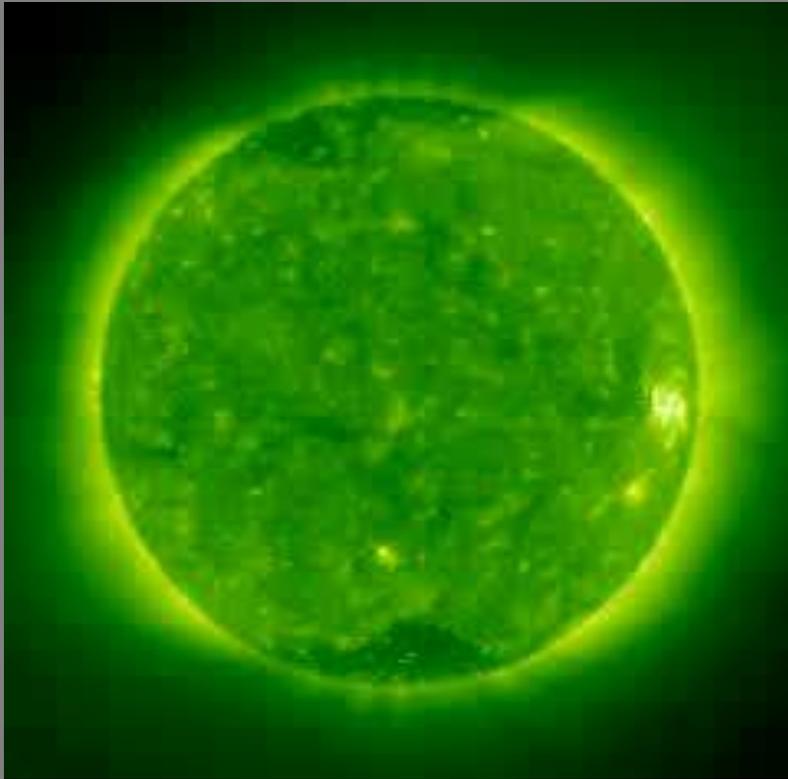
Sun



Star



one Sun



many Stars

