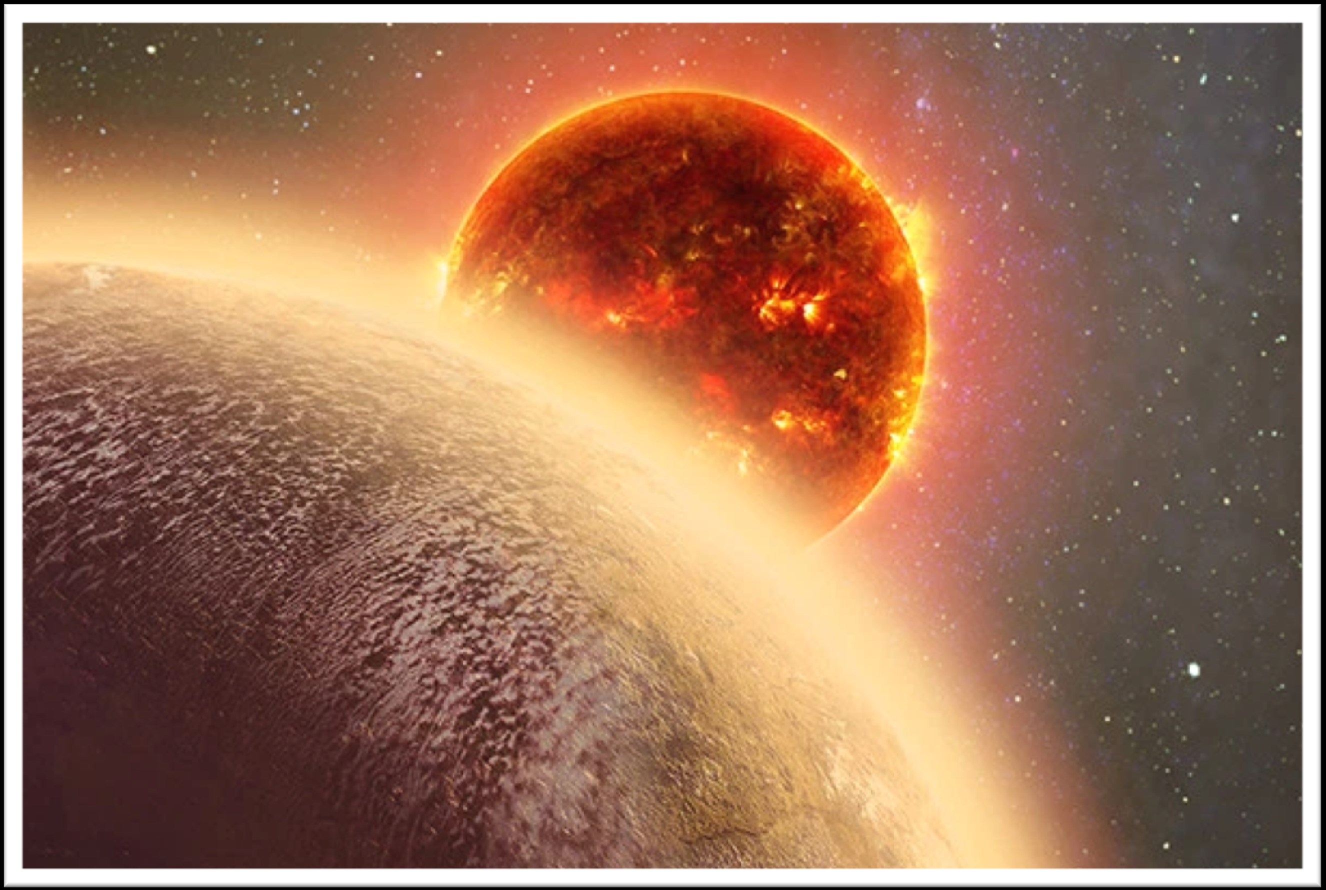
SOLAR Focus Meeting

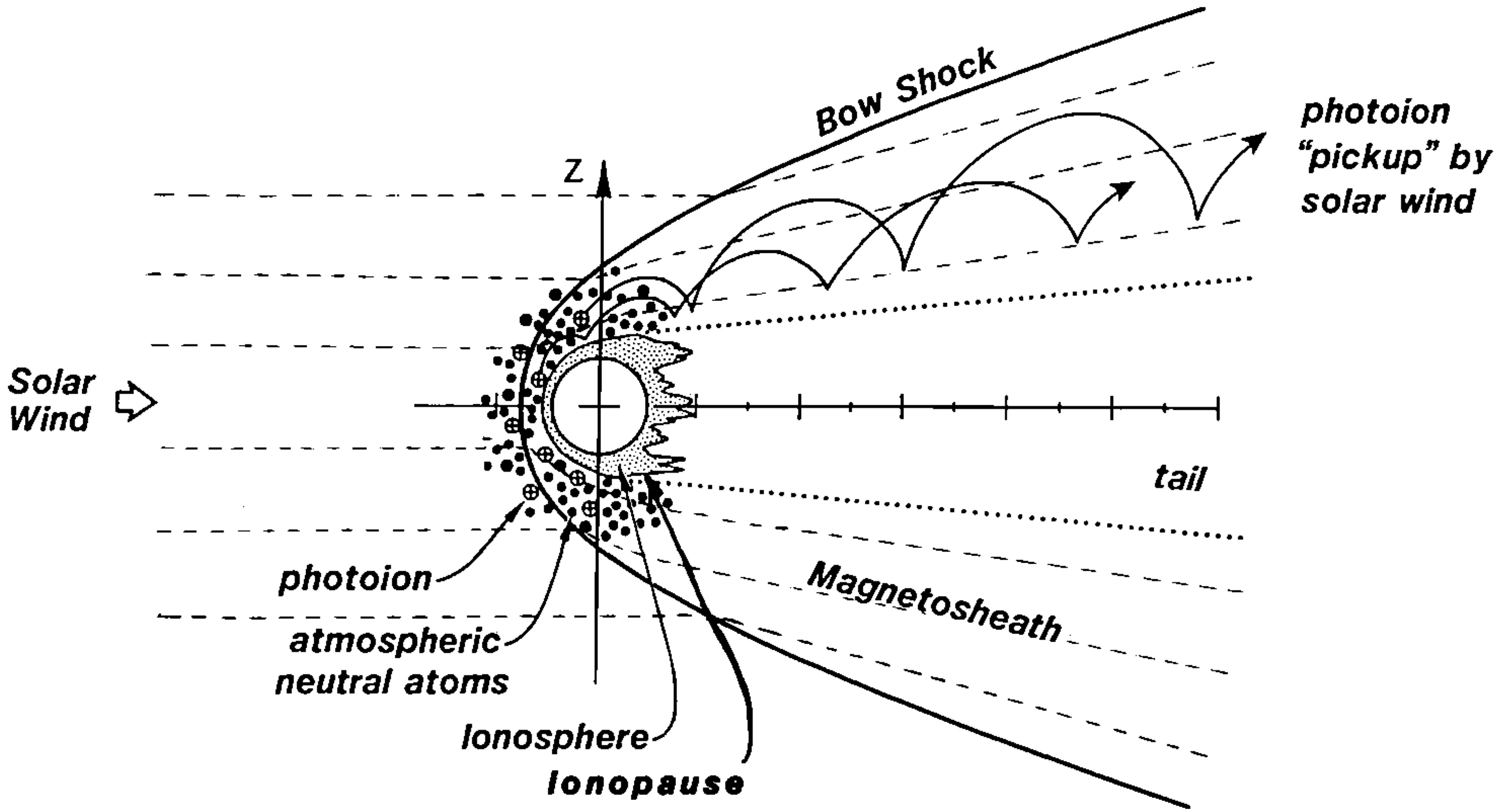
Radiative & Other Influences of Host Stars on their Exoplanets



INTRODUCTION: Tom Ayres, University of Colorado

Main influence: *Atmospheric Escape*

(Luhmann & Bauer 1992; for unmagnetized Venus & Mars)



Influences of Host Stars on their Exoplanets

Main influence: ***Atmospheric Escape***

(Luhmann & Bauer 1992: Venus & Mars)

Hydrodynamic blowoff (early accretion; overheating close to star [*not relevant to Habitable Zone*])

Thermal Jeans (superthermal neutrals in tail of M-B;
5 km/s escape speed for Mars; 10 km/s for Venus/Earth)

Non-thermal photo-chem (dissoc recomb ion'd molecules)

Direct Scavenging by solar wind (pick*ed*-up ions)

Sputtering (collisions between solar wind particles and atmospheric neutrals; or pickup ions and neutrals)

Note: ***ionization*** by **UV**, wind e^-, or charge-exchange

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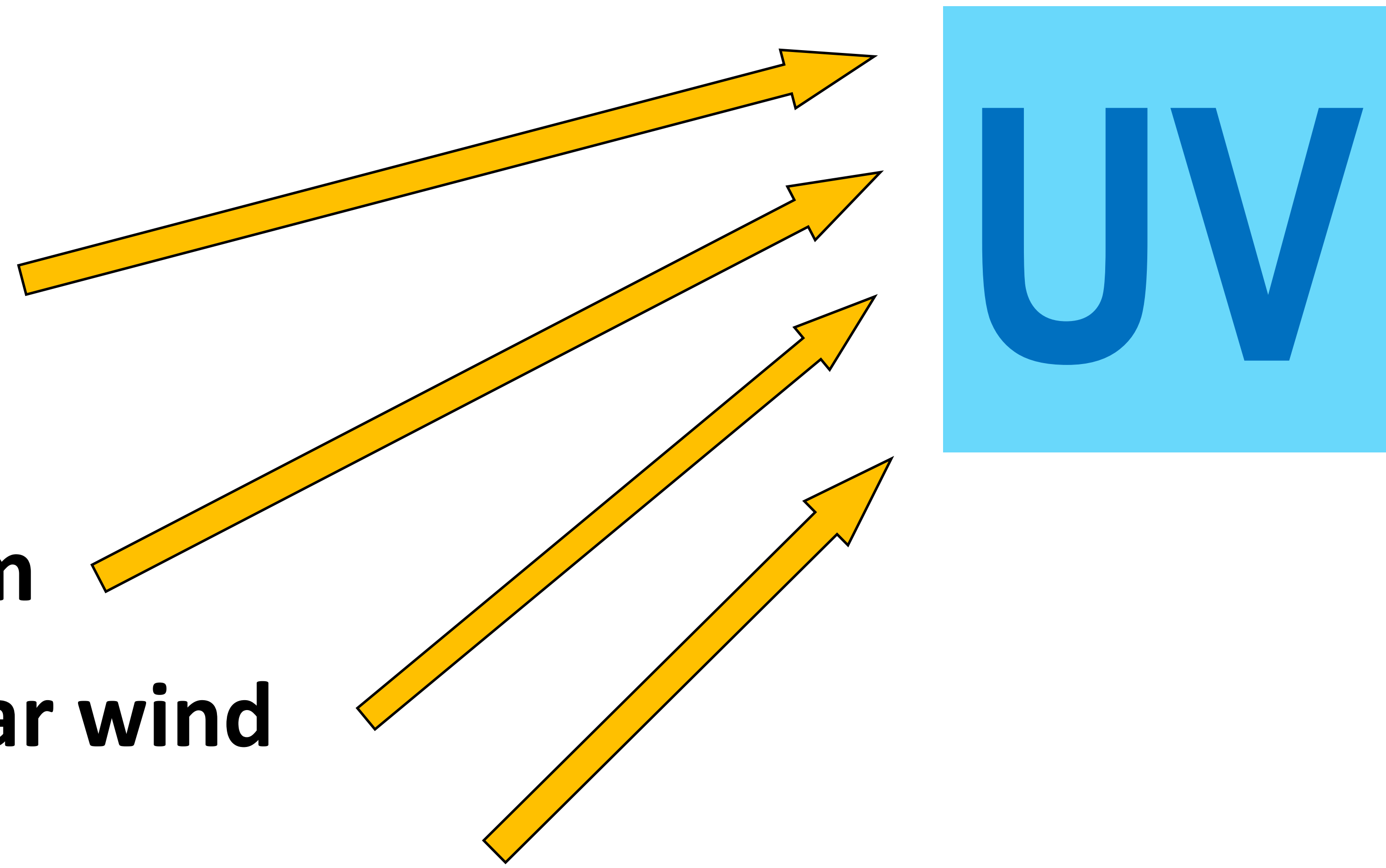

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Influences of Host Stars on their Exoplanets

Key atmospheric constituents – **H**, **O** (from CO_2 or H_2O), $\mathbf{O_2}$, and $\mathbf{N_2}$ – all have their photoionization thresholds below Lyα; ***XUV (20–100 nm)*** is most important ionizing radiation. However, pretty much unobservable even in nearest stars owing to LyC absorption. Nevertheless, the crucial species are known from observations of Sun, and proxies can be accessed in **soft X-ray band** (0.1 – 10 keV; 1 – 10 MK ***coronal*** radiation) and **FUV** (100 – 300 nm; 20,000-200,000 K ***chromospheric*** and ***transition-zone*** species, plus *coronal forbidden lines* Fe XII 124 nm [2 MK] and Fe XXI 135 nm [10 MK]).

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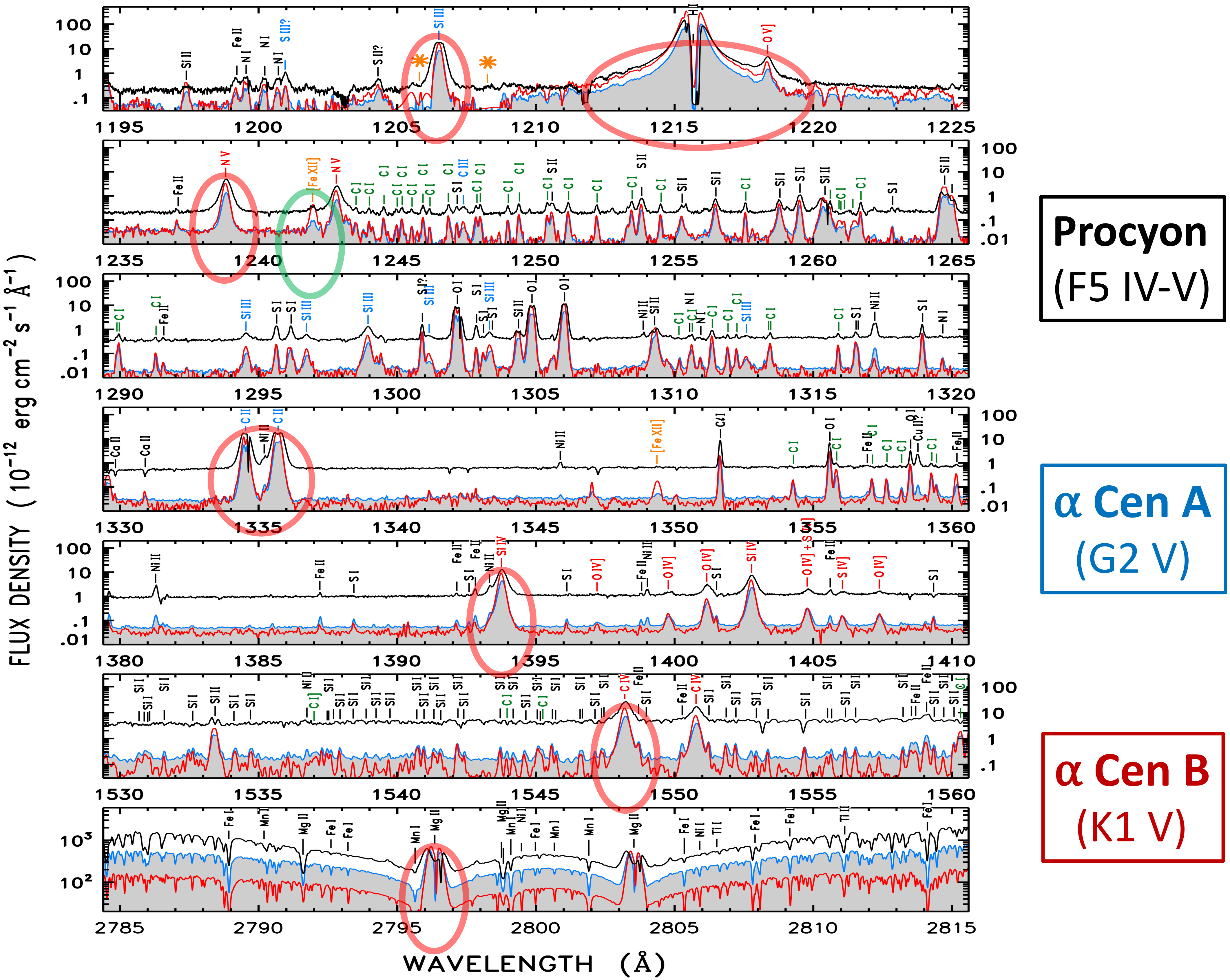

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But, ***how do we scale today's solar fluxes with Age?***
Or, ***stellar FUV fluxes to XUV?***

Zahnle & Walker (1982)

UV/X-ray emissions depend on ***stellar rotation*** (dynamo activity) with power-law behavior that steepens with formation temperature. Stellar ***rotation***, in turn, depends on ***age*** through wind-induced spindown, at least for >200 Myr. At early times, spin sensitive to *initial formation conditions*.

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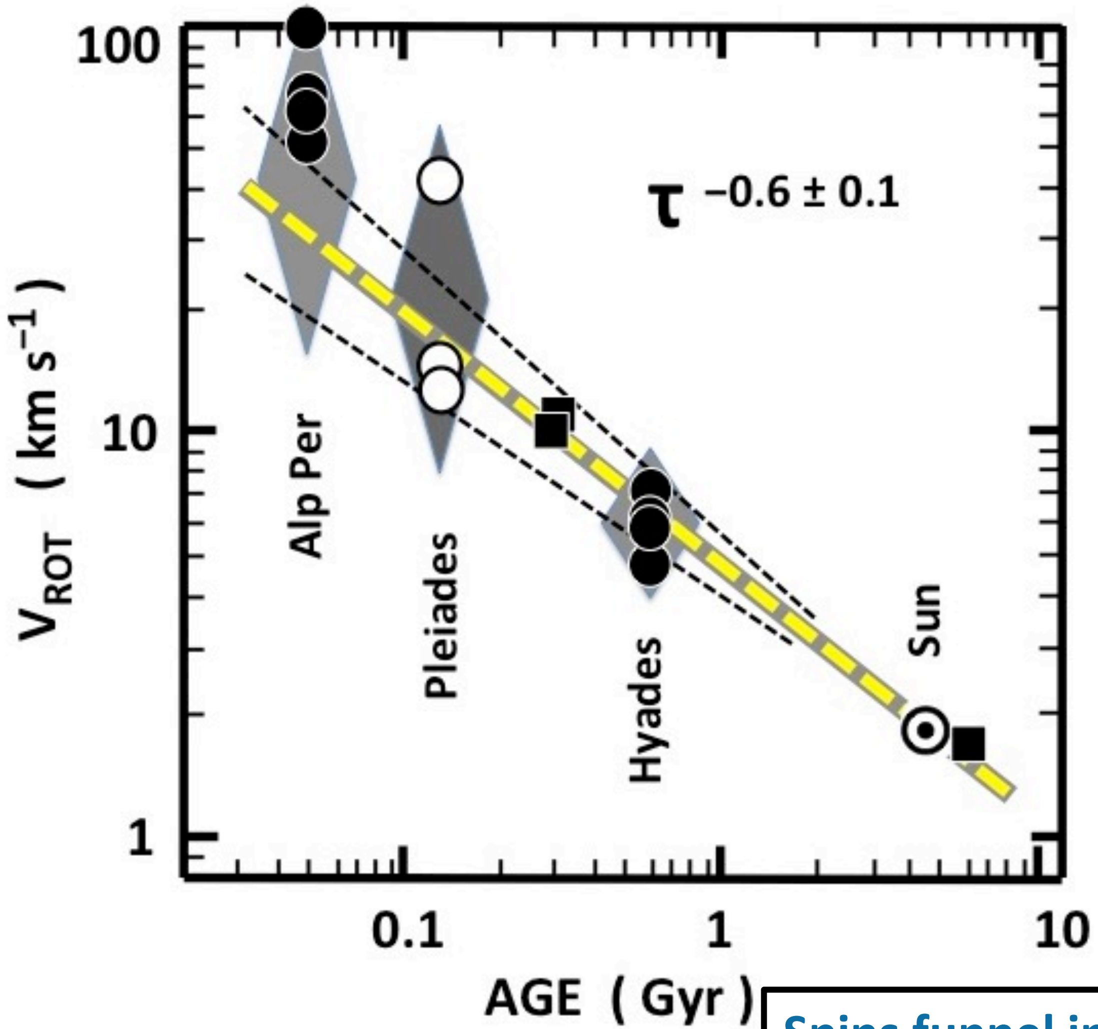
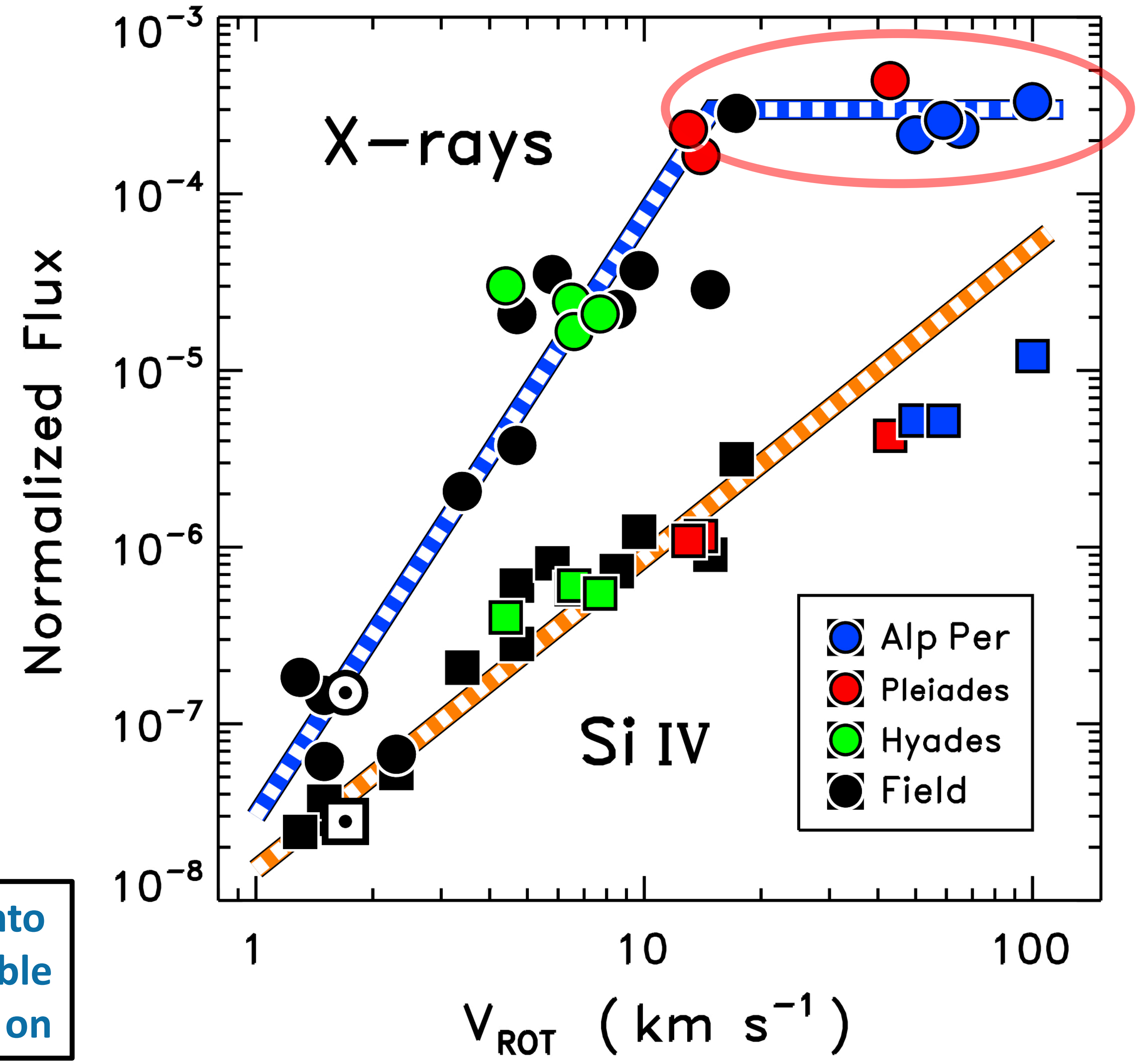
Chaotic early



Spins funnel into more predictable behavior later on

“Saturation”



Activity power laws

Adapted from Ayres (1997) follow-on to ZW82, and more recent X-ray/FUV observations

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With **rotation-activity, age-rotation, and flux-flux** (e.g., C III 97 nm vs. C III 117nm), one can scale proxy FUV fluxes to XUV (***exoplanets***), and contemporary solar UV irradiances back in time (***Mars, Venus***).

Alternative to empirical scalings involves **numerical models of stellar outer atmospheres** to predict unseen spectrum (*hear about today*)

Also, these scalings, or models, are **only as good as UV observations** upon which they are based, so continuing to acquire new, statistically robust samples is imperative (*hear about today*). Also, Villanova **"Sun in Time," "Living with a Red Dwarf"** and Ayres+ **"Sleuthing the Dynamo"**

However, 300 kg gorilla in the room is stellar ***Coronal Wind***. Very difficult to measure empirically, and equally challenging for *ab initio* theory. ***New observational strategies needed!***

Influences of Host Stars on their Exoplanets

SHINE meeting, 5 – 9 August 2019, Boulder

11. Long-Term Solar/Stellar Variability: Closing the Rift Between Models and Observations

Organizers: Lisa Upton, Andres Munjoz-Jaramillo, Irina Kitiashvilli, Travis Metcalfe

Session Description

Understanding dynamics of solar and stellar interiors. Long-term cyclic behavior continues to challenge solar and stellar astronomy. Stars offer broader perspective; multi-spectral, short- and long-term measurements of Sun provide vast amounts of data; yet still are daunting challenges to develop reliable physics-based models than can reproduce observations.

Key Questions:

1) What can variety in solar/stellar variability tell us about the dynamo?
2) Are cycle variations and MMs dynamo *shifts* or natural randomness?
3) What future data for significant advances in long-term solar variability?
4) Challenges of physics-based models to understand, forecast activity?