X-rays from stars with planets and their relevance for the ARIEL mission

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and

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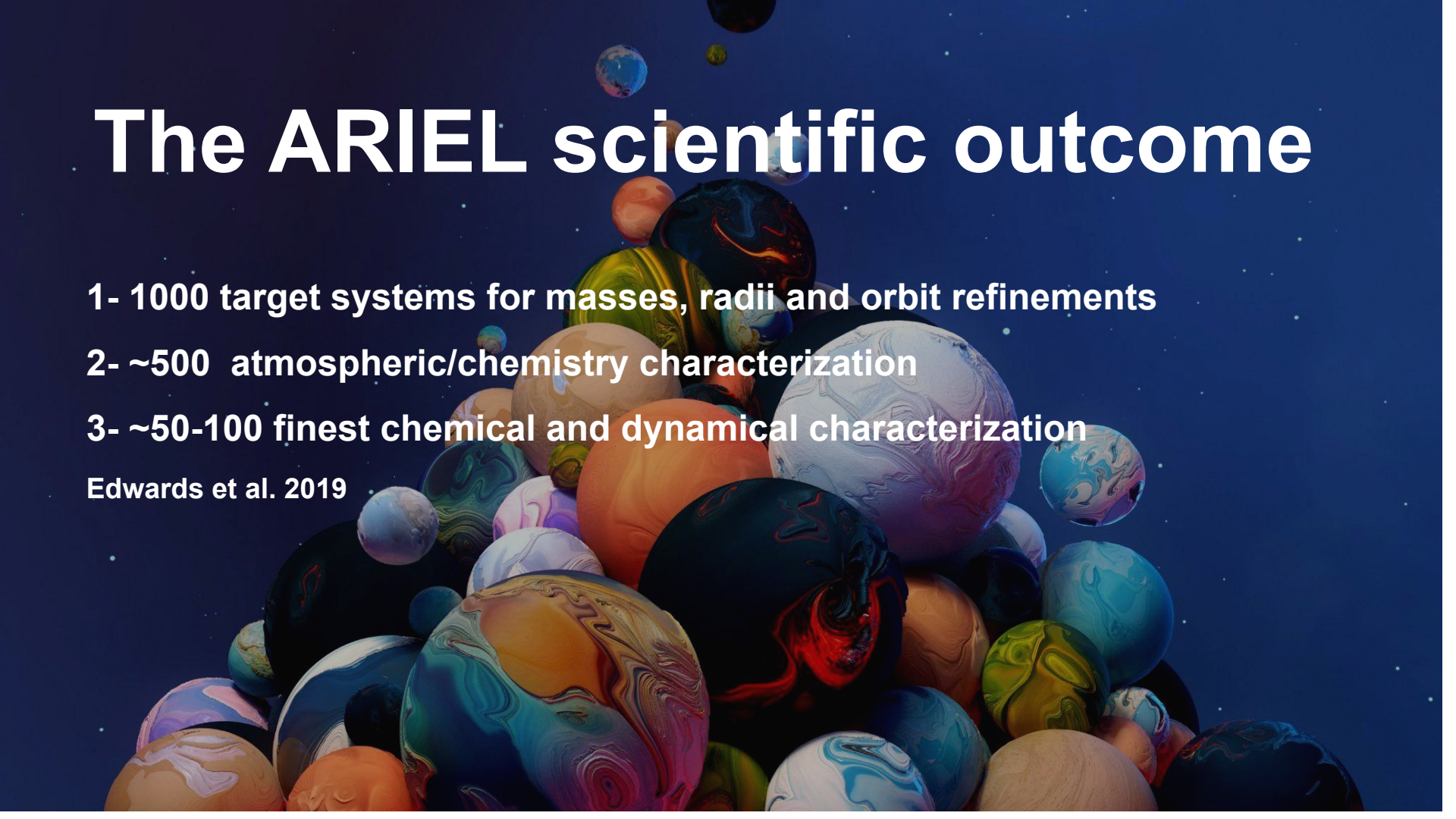
ARIEL-IT Science Meeting, 25-27 May 2022

The ARIEL scientific outcome



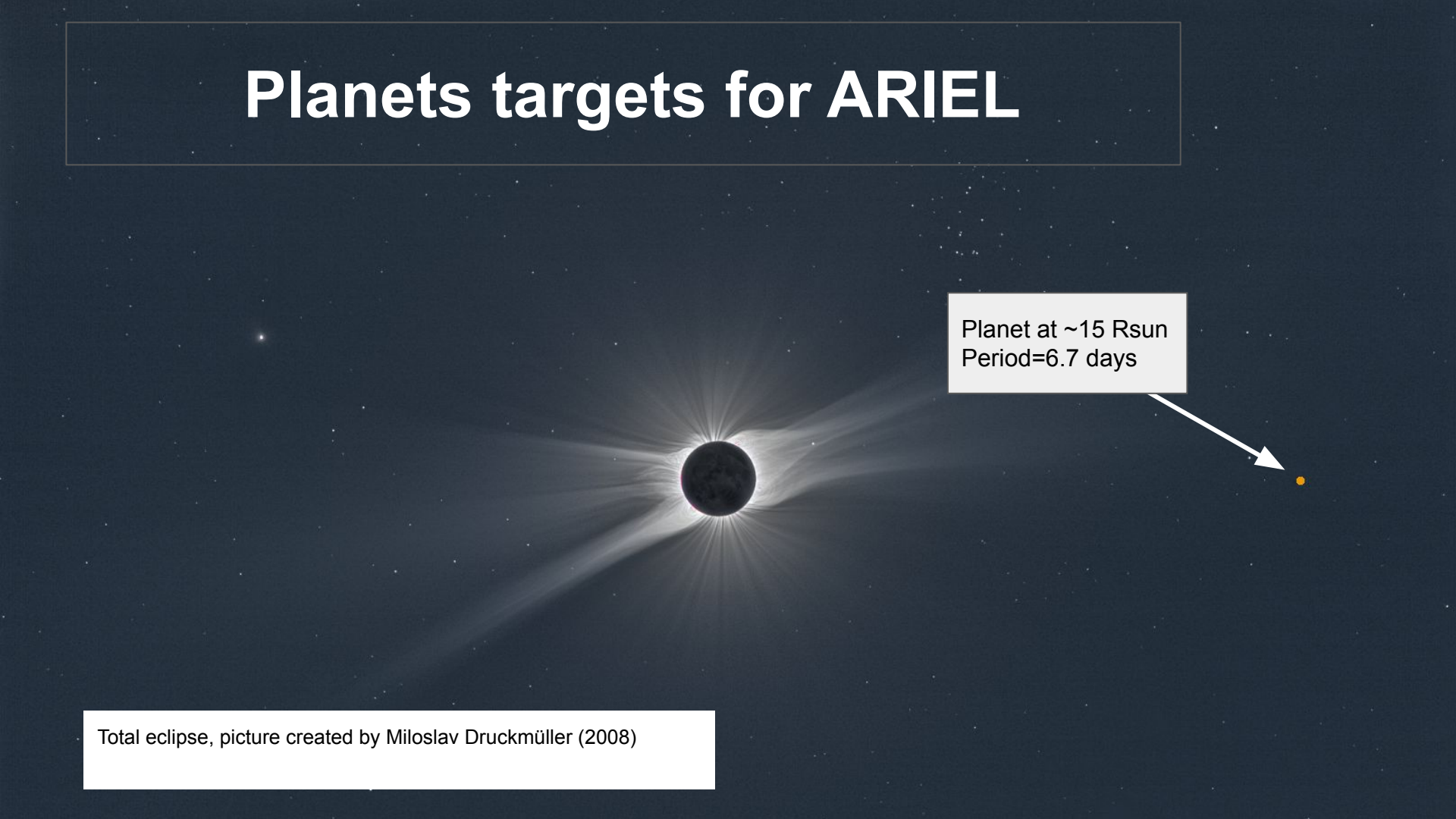
1- 1000 target systems for masses, radii and orbit refinements

2- ~500 atmospheric/chemistry characterization

3- ~50-100 finest chemical and dynamical characterization

Edwards et al. 2019

Planets targets for ARIEL



Total eclipse, picture created by Miloslav Druckmüller (2008)

Know the star know the planet

Current solar activity
photos taken from my backyard

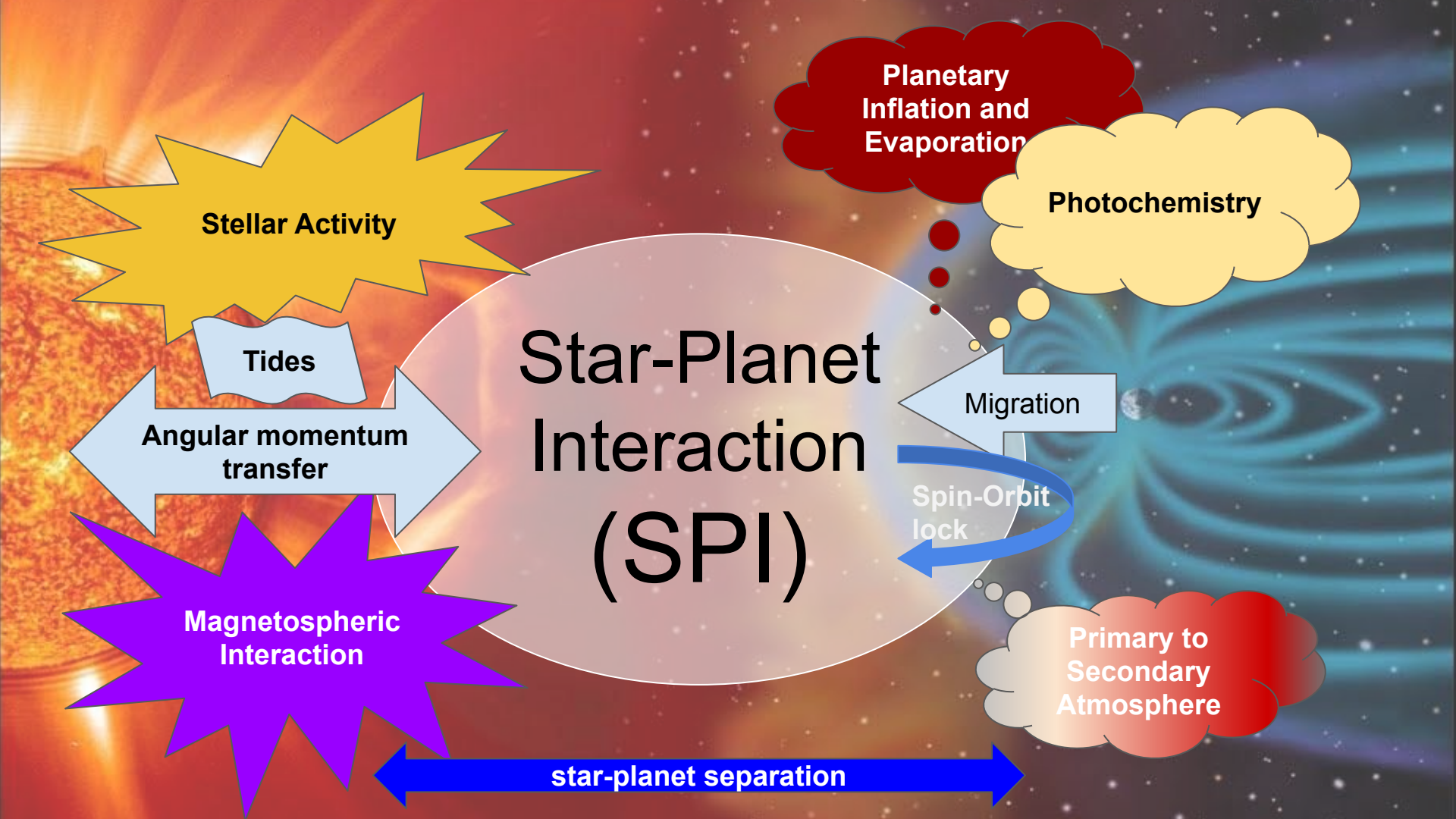
Hot planets and Star-Planet interaction (SPI)

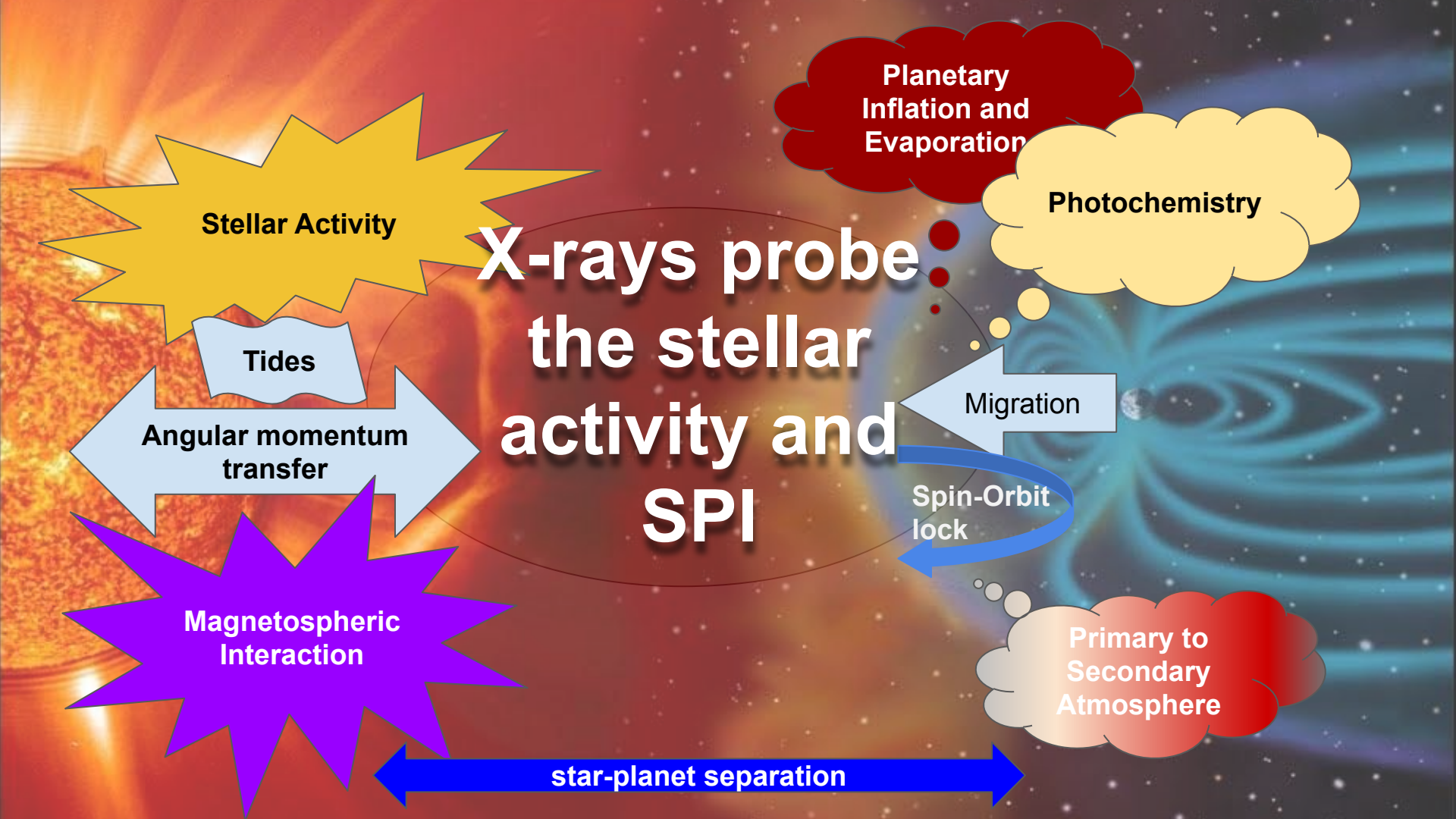
Different phenomena affecting both the **planets** and the **stars**

- ❏ Planetary inflation and evaporation
- ❏ Photochemistry, transition from primary to secondary atmospheres
- ❏ Orbit migration, planetary rotation (possibly affecting the planetary magnetic field)
- ❏ Angular momentum transfer, stellar spin up, consequences for stellar activity
- ❏ Interaction between stellar and planetary magnetospheres

(see Cuntz et al. 2000, Vidotto 2019)

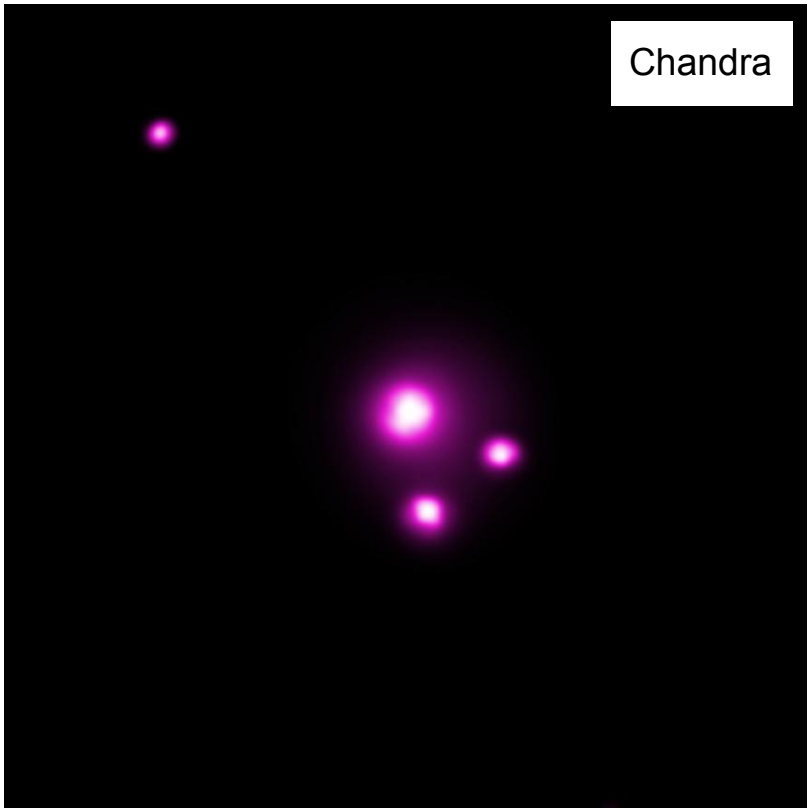
Strong dependence on star-planet separation

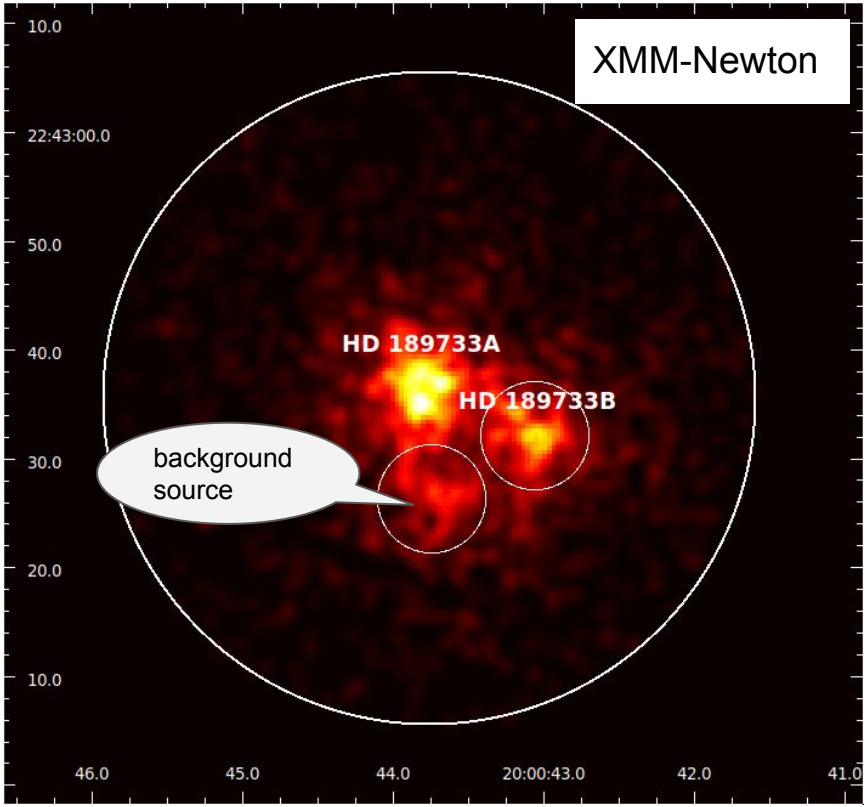

Planetary Inflation and Evaporation
Photochemistry
Stellar Activity
Tides
Angular momentum transfer
Star-Planet Interaction (SPI)
Migration
Spin-Orbit lock
Magnetospheric Interaction
Primary to Secondary Atmosphere
star-planet separation


Planetary Inflation and Evaporation
Photochemistry
Stellar Activity
X-rays probe the stellar activity and SPI
Tides
Angular momentum transfer
Migration
Spin-Orbit lock
Magnetospheric Interaction
Primary to Secondary Atmosphere
star-planet separation

Stars with planets observed in X-rays

X-rays from HD 189733 (Chandra & XMM-Newton)

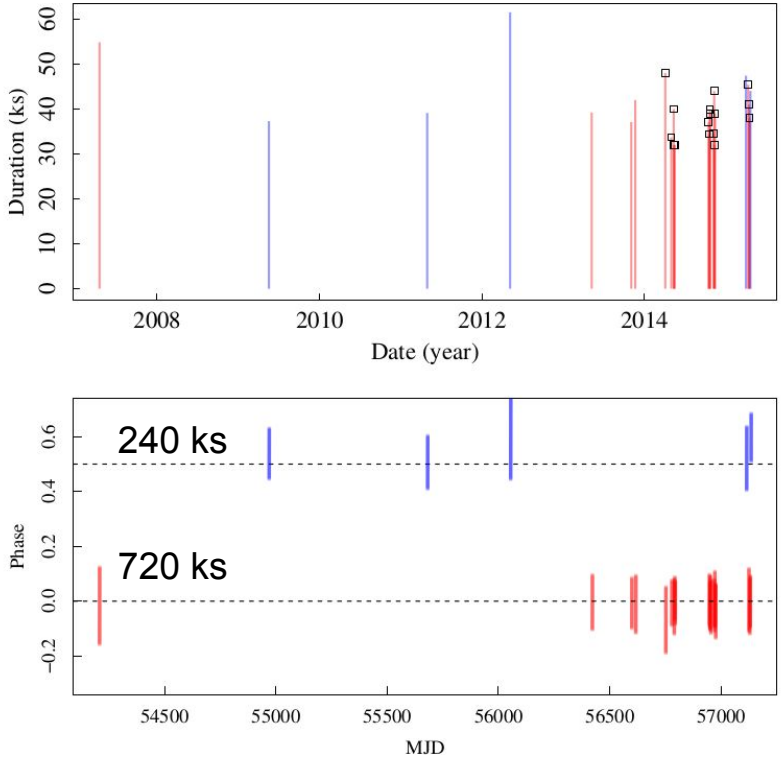




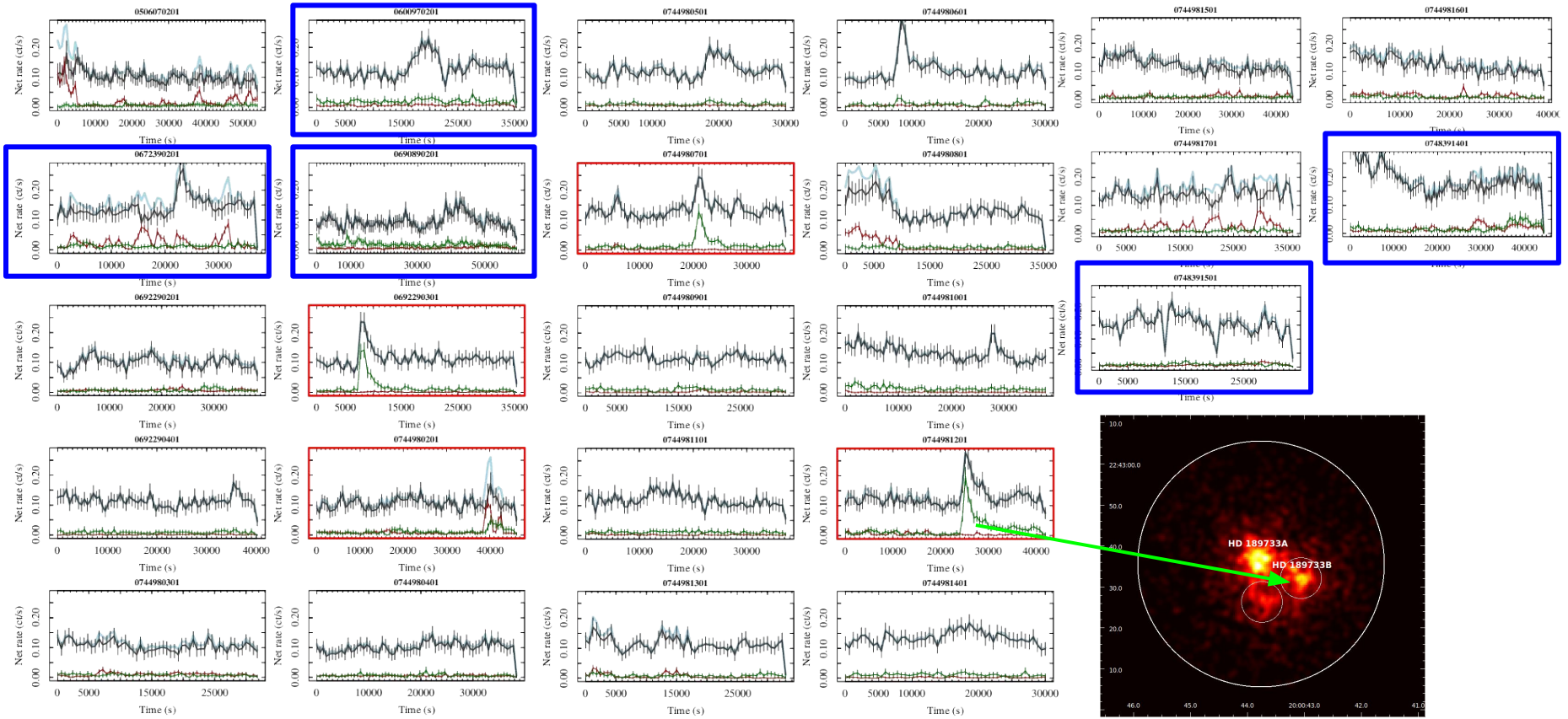
X-rays from HD 189733 (Pillitteri et al. 2022)

	OBSERVATION_ID	RA_NOM	DEC_NOM	START_UTC	DURATION	PI_SURNAME	FILTER
1	506070201	20 00 43.70	+22 42 39.0	2007-04-17 14:06:31.000	54858	Wheatley	Thin1
2	600970201	20 00 43.70	+22 42 39.0	2009-05-18 21:15:54.000	37315	Wolk	Medium
3	672390201	20 00 43.70	+22 42 39.0	2011-04-30 23:14:20.000	39112	Pillitteri	Medium
4	690890201	20 00 43.70	+22 42 39.1	2012-05-07 18:24:32.000	61516	Pillitteri	Medium
5	692290201	20 00 43.70	+22 42 35.8	2013-05-09 20:16:00.000	39218	Wheatley	Thin1
6	692290301	20 00 43.71	+22 42 35.8	2013-11-03 07:54:13.000	37100	Wheatley	Thin1
7	692290401	20 00 43.71	+22 42 35.8	2013-11-21 00:58:40.000	42000	Wheatley	Thin1
8	744980201	20 00 43.71	+22 42 35.3	2014-04-05 05:05:20.000	48000	Wheatley	Thin1
9	744980301	20 00 43.71	+22 42 35.3	2014-05-02 01:22:25.000	33700	Wheatley	Thin1
10	744980401	20 00 43.71	+22 42 35.3	2014-05-13 01:55:22.000	39999	Wheatley	Thin1
11	744980501	20 00 43.71	+22 42 35.3	2014-05-15 09:57:00.000	32000	Wheatley	Thin1
12	744980601	20 00 43.71	+22 42 35.3	2014-05-17 14:21:12.000	32000	Wheatley	Thin1
13	744980801	20 00 43.71	+22 42 35.3	2014-10-17 16:08:26.000	37000	Wheatley	Thin1
14	744980901	20 00 43.71	+22 42 35.3	2014-10-19 20:38:36.000	34400	Wheatley	Thin1
15	744981001	20 00 43.71	+22 42 35.3	2014-10-22 01:39:14.000	39900	Wheatley	Thin1
16	744981101	20 00 43.71	+22 42 35.3	2014-10-24 06:15:47.000	39000	Wheatley	Thin1
17	744981301	20 00 43.71	+22 42 35.3	2014-11-08 20:16:34.000	34600	Wheatley	Thin1
18	744981201	20 00 43.71	+22 42 35.3	2014-11-11 00:37:26.000	44000	Wheatley	Thin1
19	744981401	20 00 43.71	+22 42 35.3	2014-11-13 06:46:05.000	32000	Wheatley	Thin1
20	744980701	20 00 43.71	+22 42 35.3	2014-11-15 09:48:00.000	39000	Wheatley	Thin1
21	744981501	20 00 43.71	+22 42 35.3	2015-04-13 02:37:23.000	45400	Wheatley	Thin1
22	744981601	20 00 43.71	+22 42 35.3	2015-04-17 12:34:55.000	41000	Wheatley	Thin1
23	744981701	20 00 43.71	+22 42 35.3	2015-04-19 19:06:26.000	38000	Wheatley	Thin1
24	748391401	20 00 43.69	+22 42 39.1	2015-04-03 03:30:49.000	47400	SCHARTEL (PS)	Medium
25	748391501	20 00 43.69	+22 42 39.1	2015-04-23 06:17:15.000	44000	SCHARTEL (PS)	Medium

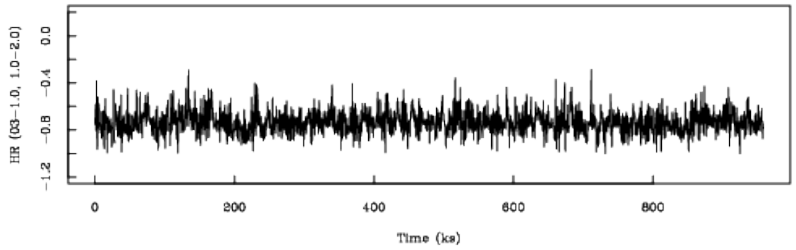
Total: 960 ks ~ 11.2 days

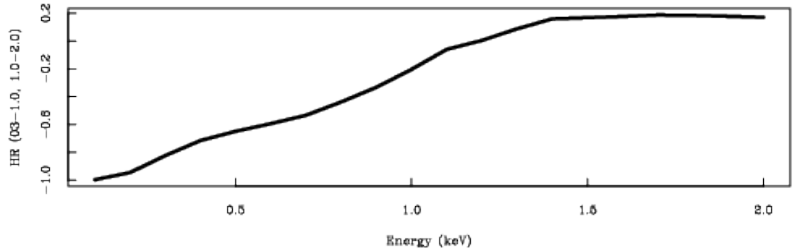


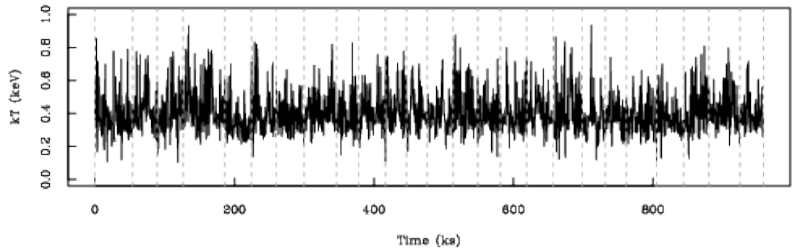
Variability in X-rays of HD 189733

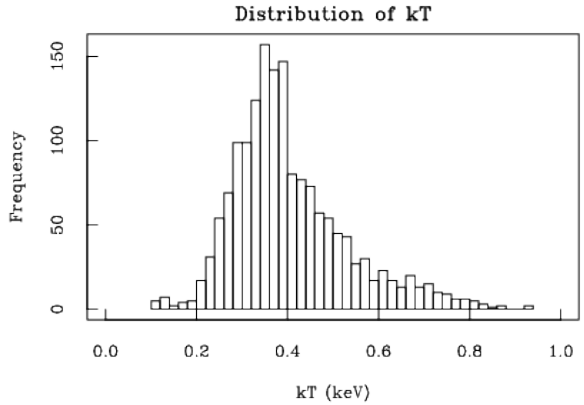


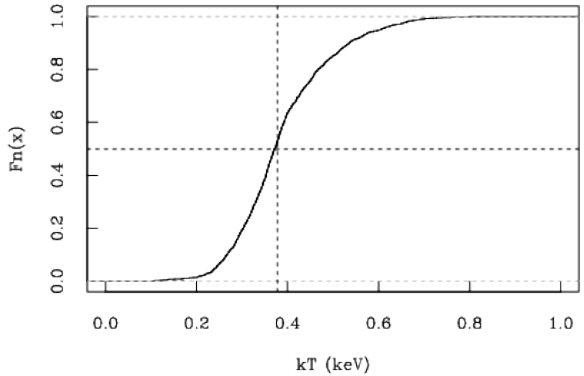
Hardness ratio / Coronal Temperature of HD 189733



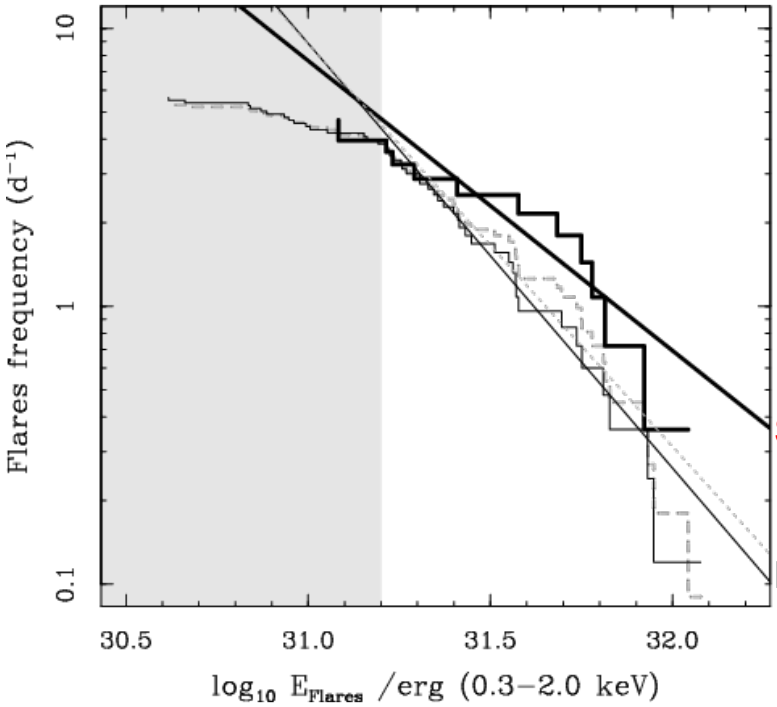








Flare energies distribution: primary vs secondary transits

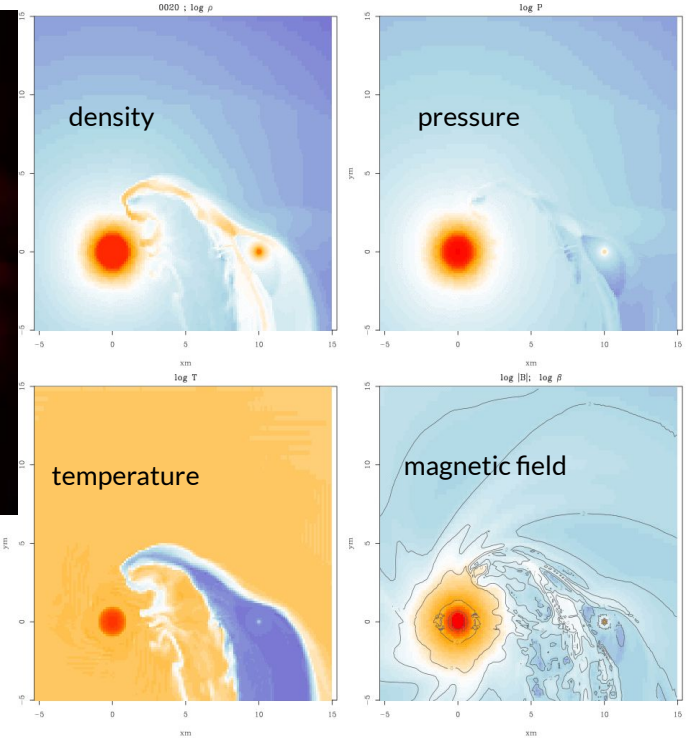


Secondary transits phases

Primary transits

Pillitteri et al. 2022

MHD modeling of Star Planet Interaction



- Dynamics of the plasma star-planet region (Cohen et al. 2011, Matsakos et al. 2015)
- Cometary tails, bow shocks (Llama&Shkolnik 2016)
- magnetic field shielding
- magnetic reconnection and enhanced flare activity (Lanza 2009).
- Search for observables in XUV, radio (and possibly IR) bands

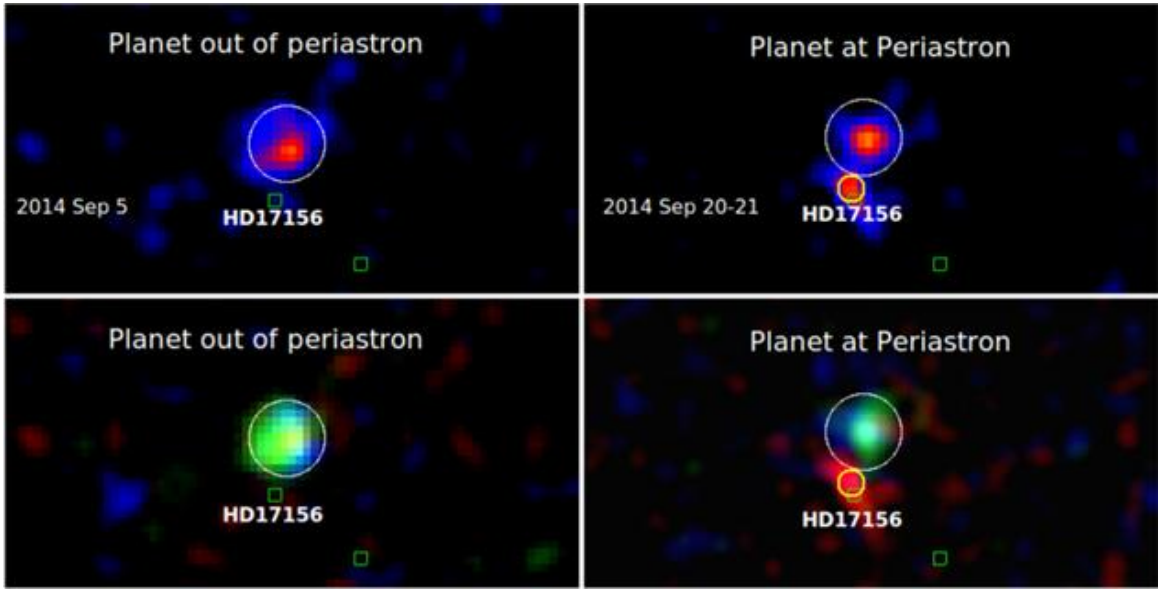
MHD modeling of star+planet at INAF-OAPA, S. Colombo 2022 in prep.

SPI and eccentric orbits: HD 17156

HD 17156: hot Jupiter in an eccentric orbit.

Period ~ 21 days

X-ray flare (and chromospheric activity) just after the periastron (Maggio et al. 2015)

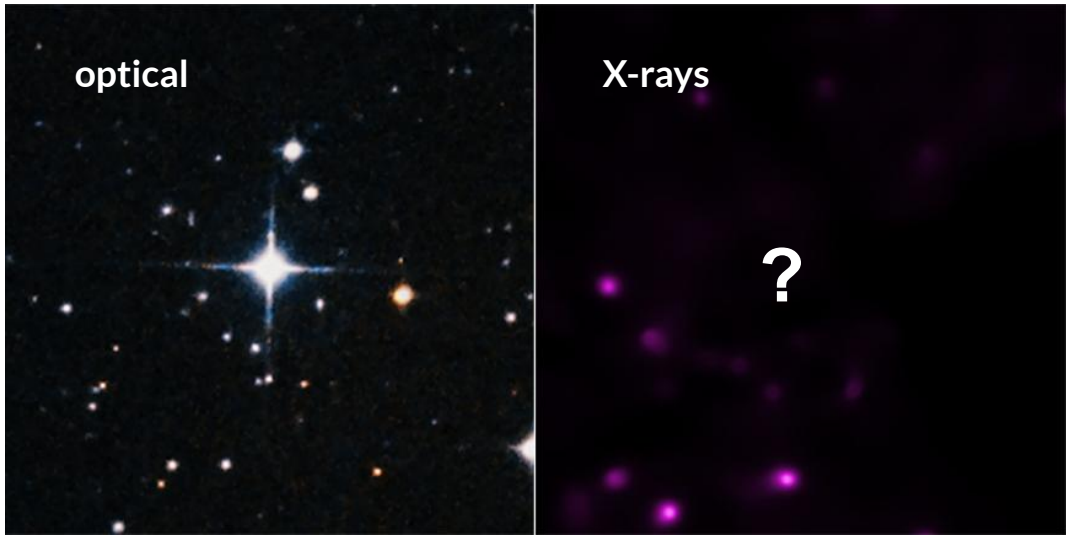


WASP-18 and F stars with hot Jupiters

WASP-18: No X-rays and other variability.
Hot Jupiter of 10 Mj, <1 day orbital period.

Disruption of coronal structure or magnetic dynamo due to tidal interaction?

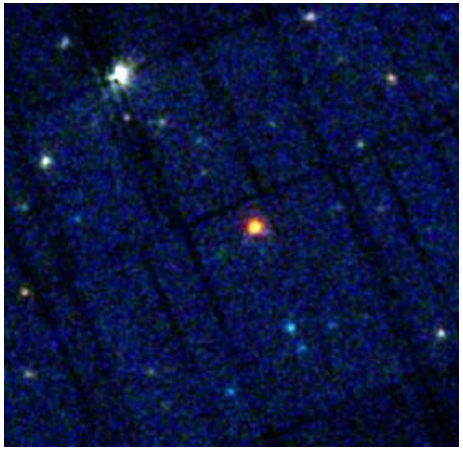
(Pillitteri et al. 2014)



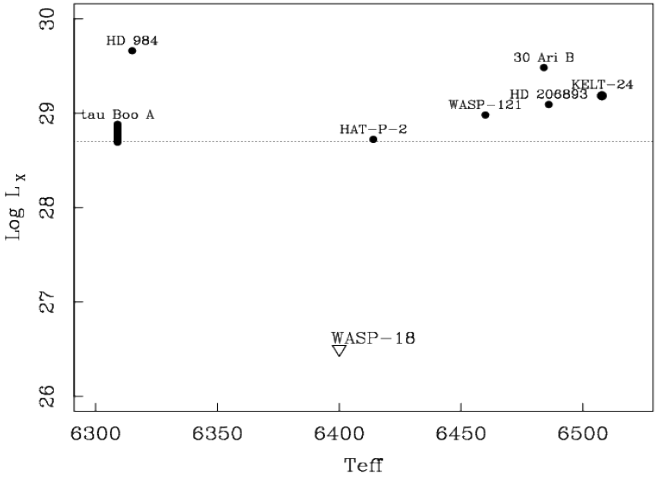
WASP-18 and F stars with hot Jupiters

Kelt-24: F star, 700 Myr, 5 Mj planet in 5.6 days orbit (Pillitteri et al. 2022 in prep.)

XMM image

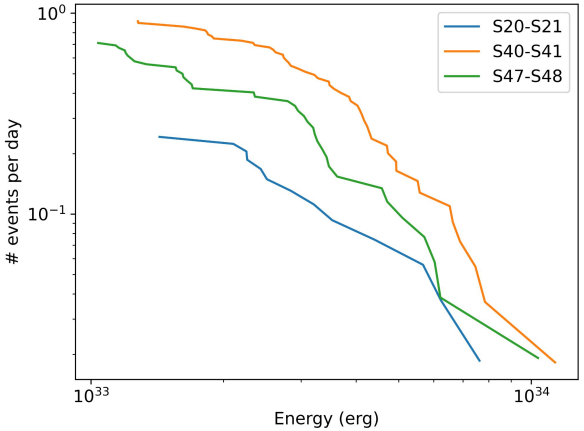


X-ray luminosity of F stars with hot Jupiters



TESS optical flares of KELT-24

(see also Colombo et al. 2022)



Young Planets

Star activity is at its maximum during the first phases of planetary formation and evolution

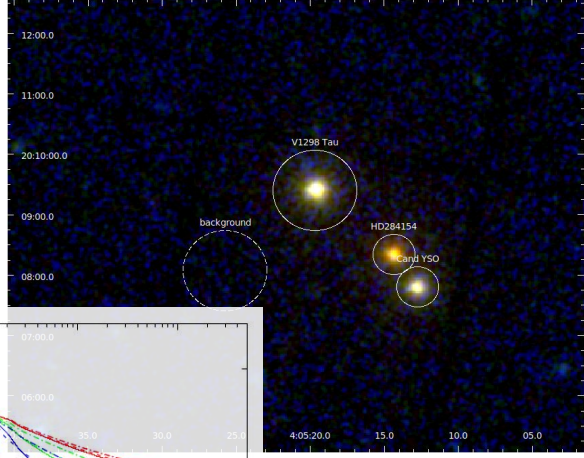
A few very young planets discovered so far: V1298 Tau b,c,d,e; DS Tuc Ab

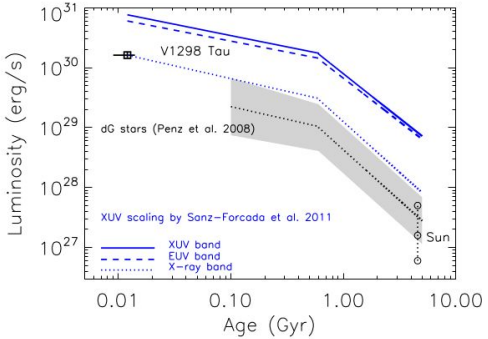
X-rays are a crucial ingredient for the chemical and dynamical transformation of primary atmospheres

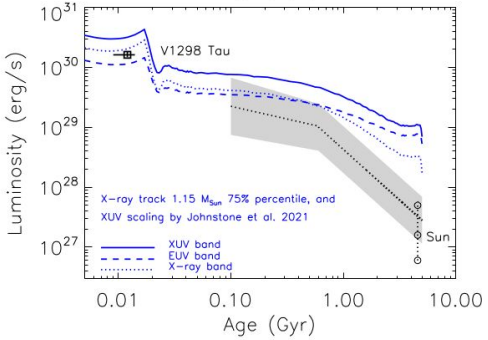
Flares/CMEs effects on young planets.

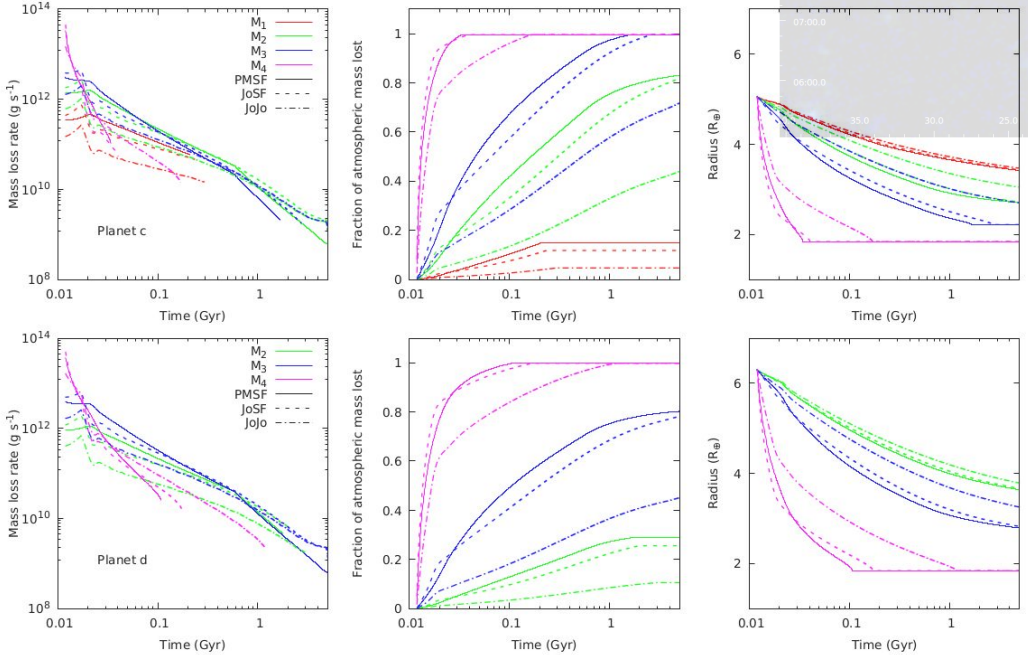
V1298 Tau

~20 Myr, 4 young planets, XUV flux to infer the rate of evaporation









Maggio et al. 2022

V1298 Tau II

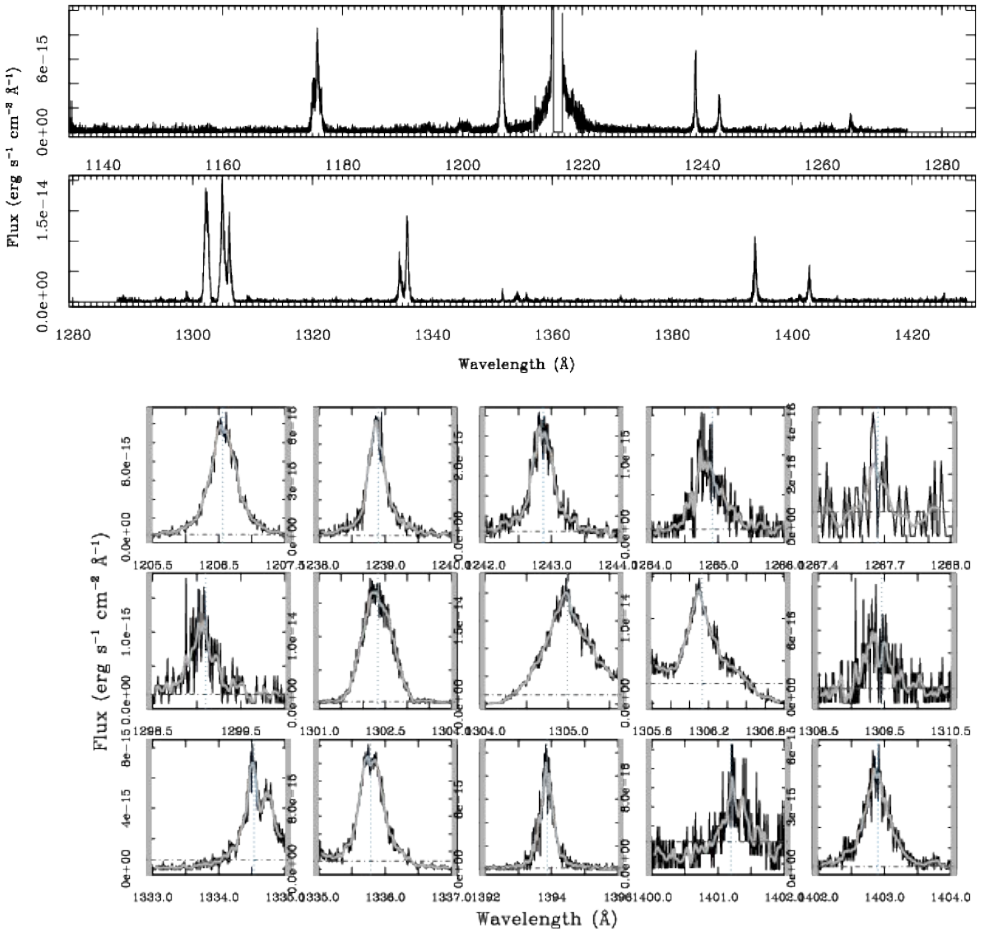
XMM + HST/COS simultaneous observation

Reconstruction of the E.M. over 10^4-10^7 K

X+UV spectrum (bracketing the heavily absorbed

EUV portion: ~100-912 Ang.)

Maggio et al. 2022 in preparation



Same strategy for **HIP 67522**

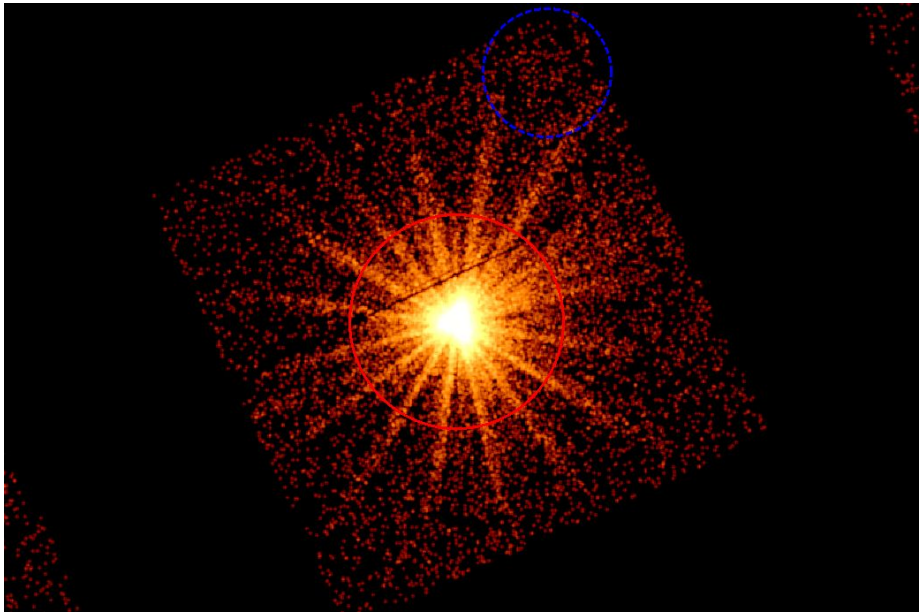
(P.I. Maggio, observation planned for July 2022)

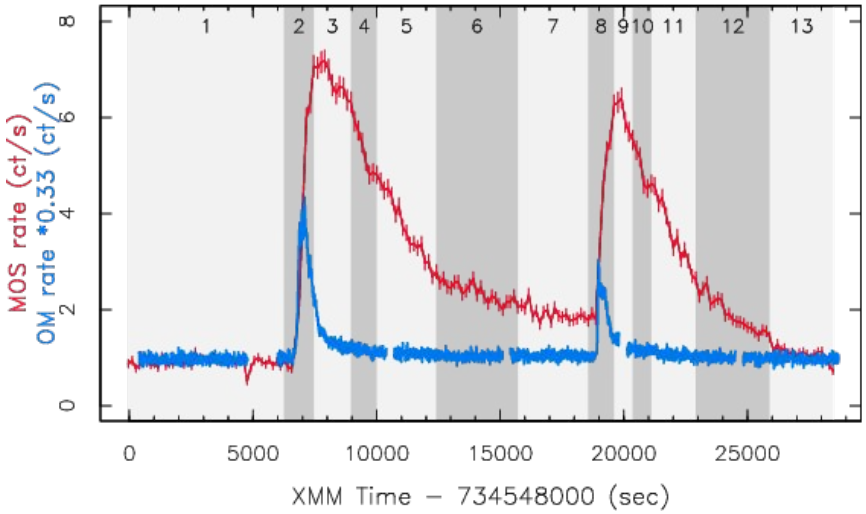
DS Tuc A

40 Myr young star

Mp <14.4 M_{Earth}

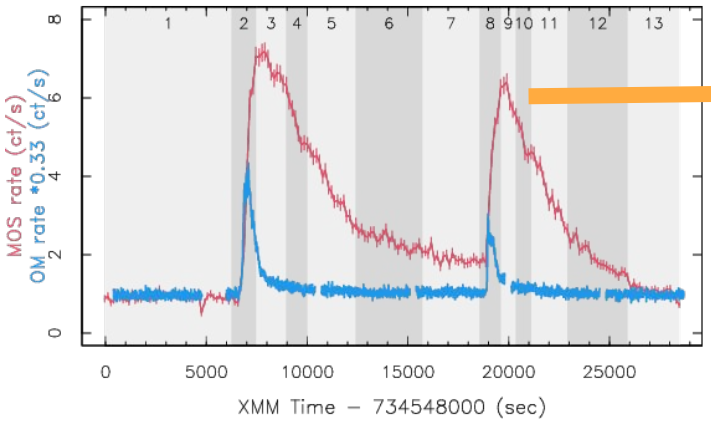
Estimate of evaporation rate due to XUV in Benatti et al. 2021

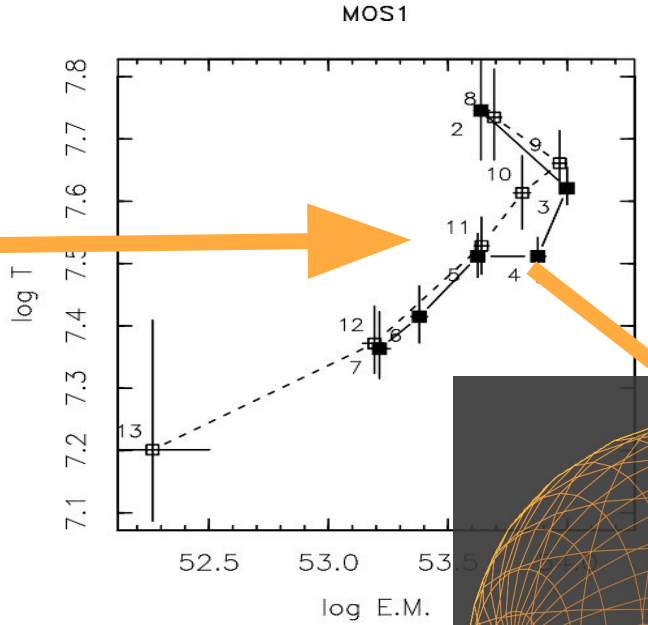


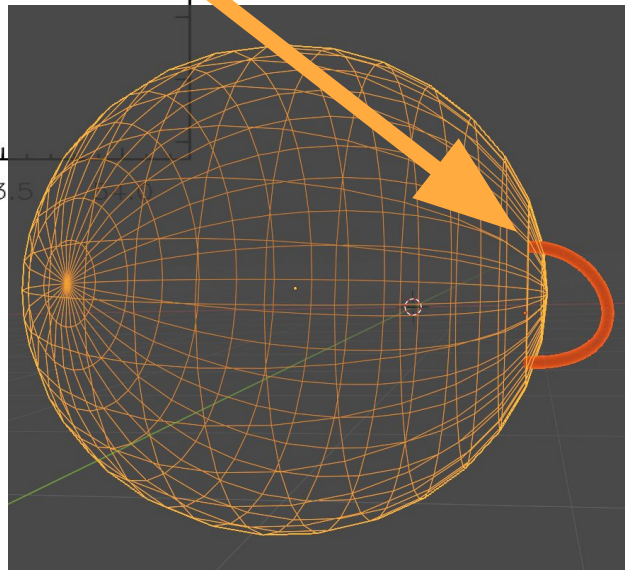


Light curve: Two bright flares
Red: MOS2 (0.3-10 keV)
Blue: OM (200-300 nm)
Pillitteri et al. 2022 (in prep.)

DS Tuc A



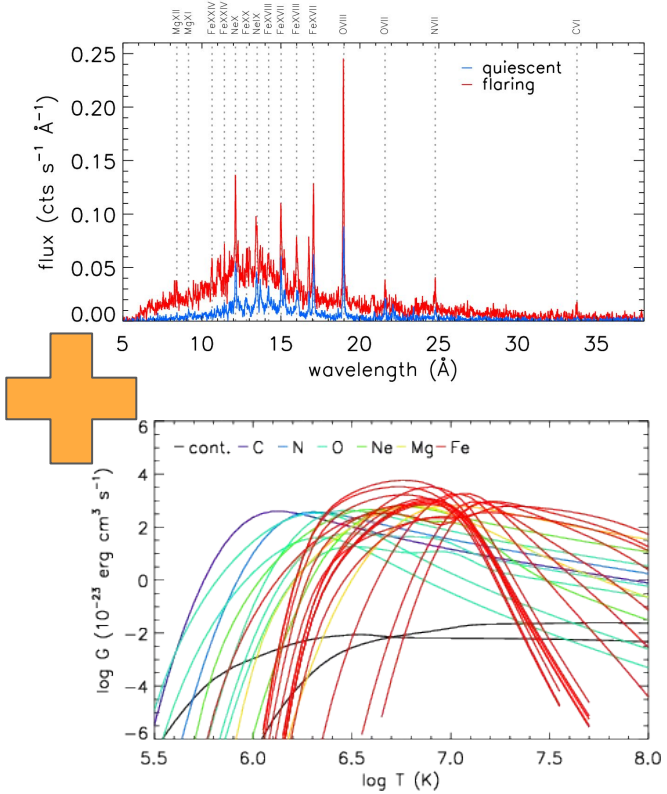


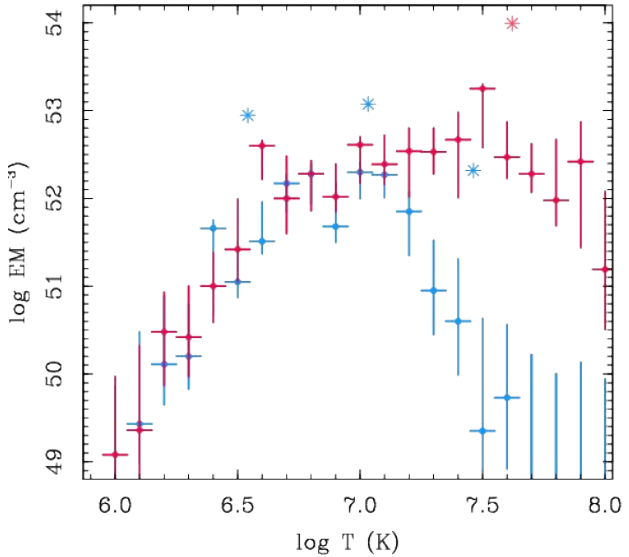


Light curve: Two bright flares in XUV
Red: MOS2 (0.3-10 keV)
Blue: OM (200-300 nm)
Time resolved spectroscopy -> T, EM ->
Loop length, B_{min}, n_{el} (cf. Reale 2007)

DS Tuc A

RGS spectra





Future X-ray missions

Athena: large collecting area, high res non dispersive spectroscopy (XIFU).

- ❏ extend and measure the fluxes and luminosities in a larger number of systems
- ❏ detailed study of coronal lines, abundances and (any) motions due to CMEs
- ❏ inputs for the characterization of planetary atmospheres and SPI

SEEJ: a NASA Small Sat proposal for observing stellar coronae in soft X-rays (P.I. S. Wolk)

- ❏ transits of planets in X-rays (gas scale height and opacity profile)
- ❏ time variability of coronae for inferring their structure
- ❏ any SPI related effect (e.g., variability at some orbital phases)