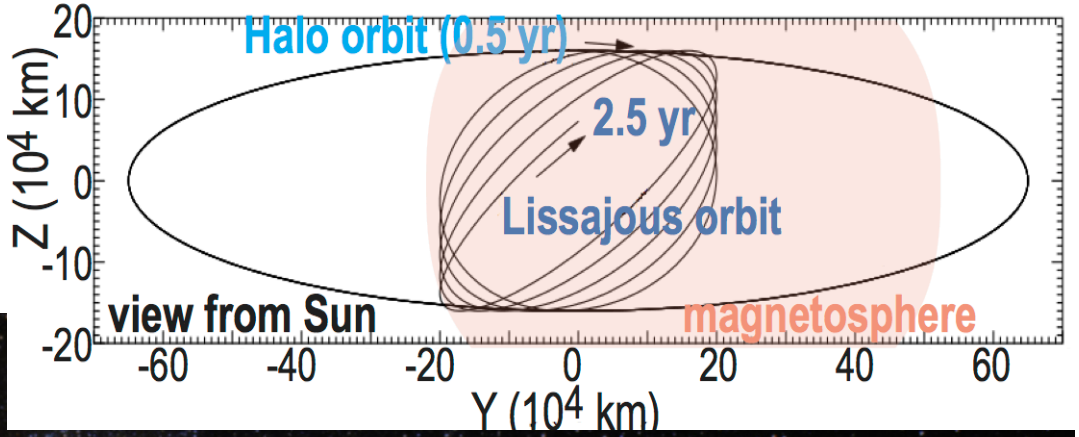
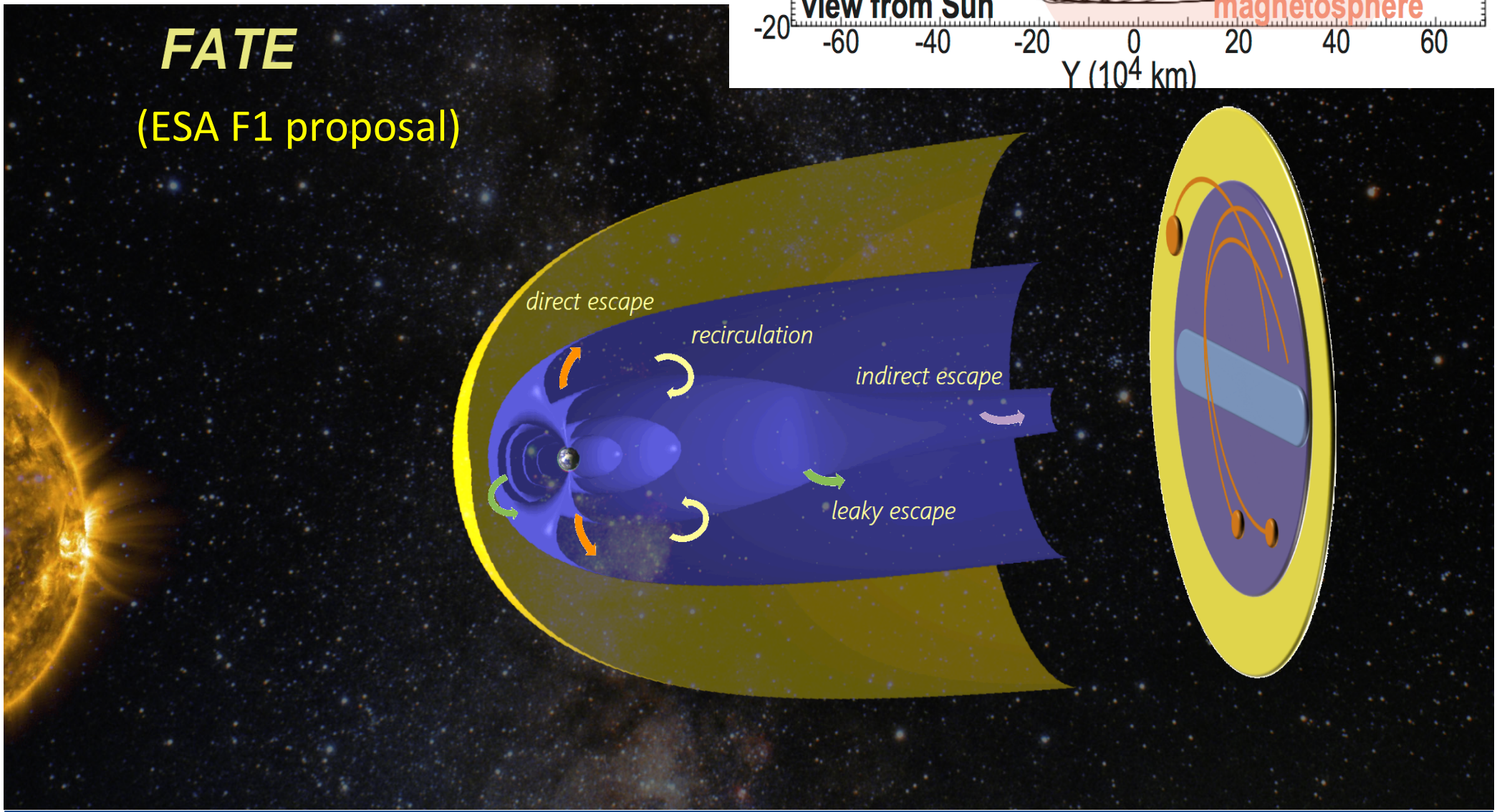
FATE:
Far Tail Explore





Science 1: Ion escape from the Earth

Ancient solar forcing (young M-stars)

(a) **much higher EUV flux** than present

(b) **faster solar wind** than present

(c) **much faster rotation** than present

⇒ stronger solar dynamo

⇒ **stronger flare / CME / SEP**
(Solar Energetic Particle)

⇒ **Kp=10** or P_{SW}=100 as proxy of the past

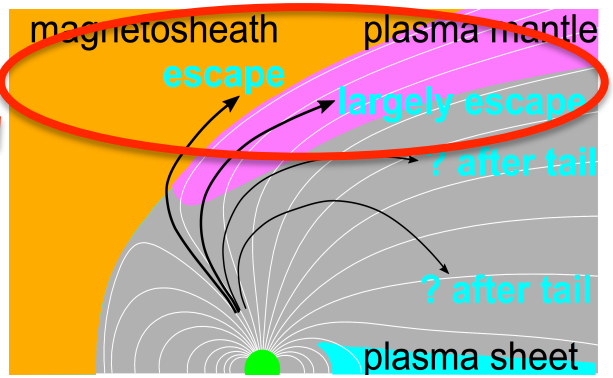
Loss rate : ∝ **exp(0.45*Kp)**
or ∝ $P_{SW}^{2.5}$

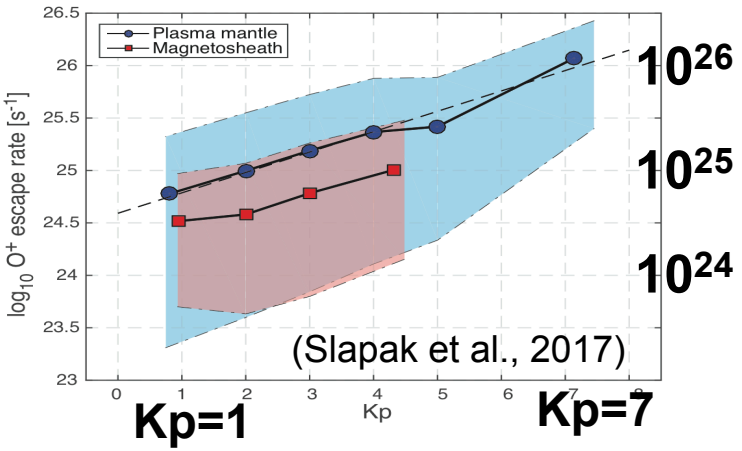
⇒ We expect **10^{27} s^{-1}** for only this route

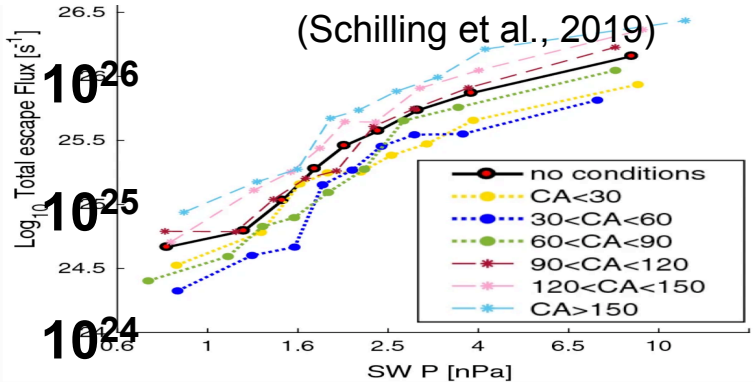
⇒ $3 \cdot 10^{43}$ O^+ over **1 Gyr** ($3 \cdot 10^{16}$ sec)

= **70% of present atmospheric O_2** (15% of N_2)

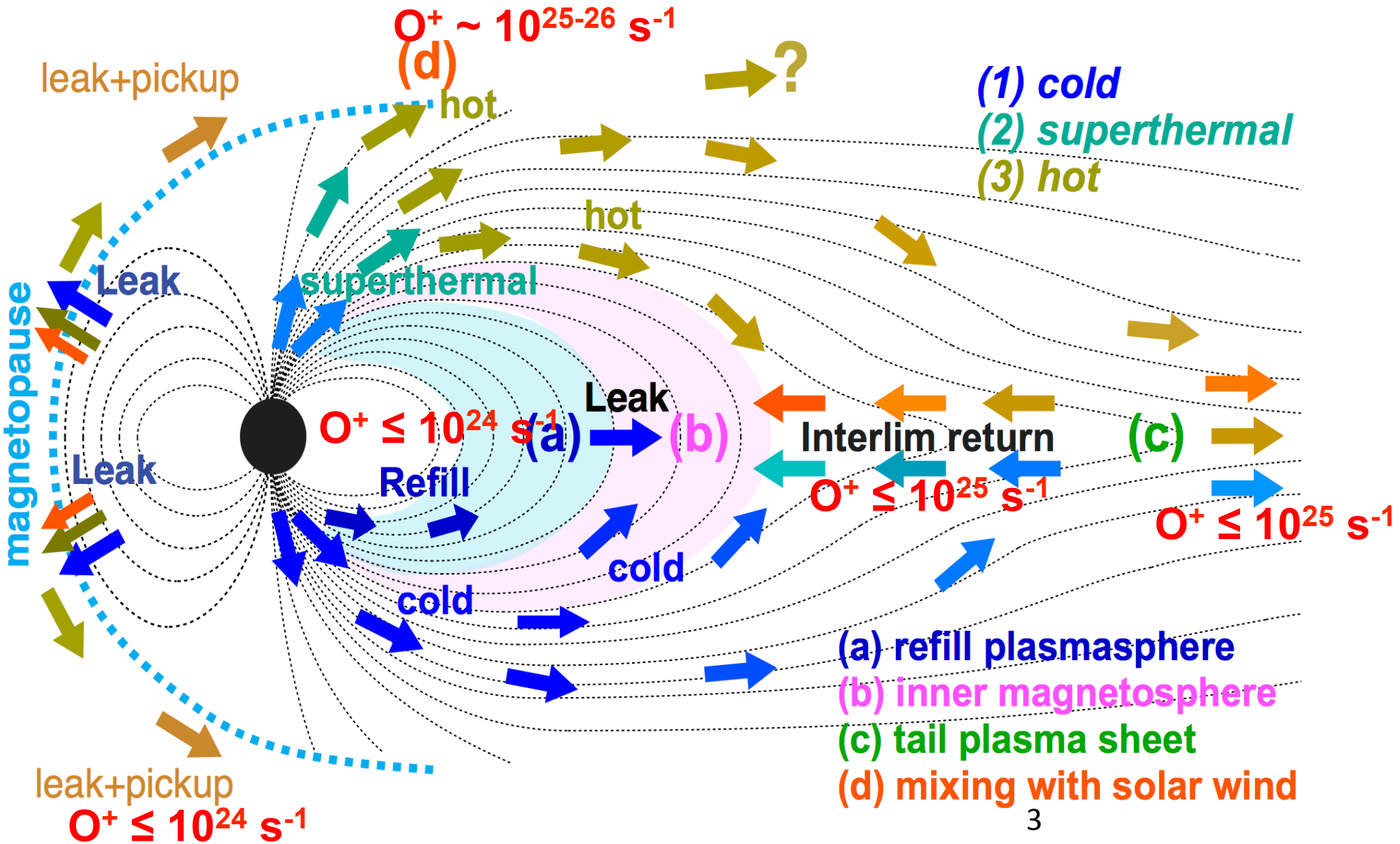
cf. Observed O/N ratio fluctuate in 0.1 byr : **not easy to explain by bioactivity**







All ions should go to L2



Escapes mechanisms

mechanism	explanation	Where?
Jeans escape	Thermal tail exceeds the escape velocity	exobase (M, ancient E?)
Hydrodynamic blow off (neutrals)	Massive escape when thermal energy exceeds escape energy	near exobase (ancient)
Momentum exchange (neutrals)	Light neutrals collide with heavy molecules	above exobase (M, ancient E/V?)
Photochemical energization (mixed)	Recombination *etc.* supply the escape energy	exosphere (M, ancient)
Charge-exchange (mixed)	Trapped ion with escape velocity strives an electron from neutral	above mirror altitude (E)
Atmospheric sputtering (both)	Precipitating heavy ions (pickup or trapped ones) impact the atmosphere	around and above exobase (M, V>E)
Ion pickup	Cold ions that are newly exposed to solar wind are removed by the solar wind ExB	outer exosphere (M>V, ancient E?)
Ions accelerated by field reach SW	$E_{//}$ acceleration (DC field) and wave-particle interactions (AC field).	ionosphere & magnetosphere (E>M>V?)
Large-scale momentum transfer & instabilities (ions)	Solar wind $P_{Dynamic}$ and EM forces push the planetary plasma anti-sunward.	magnetospheric boundary and tail (E>M, V)
Magnetopause shadowing (ions)	The drifting ions overshoot the magnetospheric boundary.	inner magnetosphere (E)
Plasmaspheric wind and plumes	Detachment or expansion of cold plasma by instability or pressure	plasmasphere (E)

4

Main escape mechanism for the Earth

mechanism	present Earth	ancient Earth?
Jeans escape	-	yes? (need to understand present exosphere)
Hydrodynamic blow off	-	yes? (need to understand present exosphere)
Momentum exchange	-	yes? (need to understand present exosphere)
Photochemical energization	-	yes
Charge-exchange	yes	? (need to understand ring current)
Atmospheric sputtering	-	yes? (need to understand past cusp)
Ion pickup	-	yes
Ions accelerated by field reach SW	YES !	yes
Large-scale momentum transfer & instabilities	yes	yes? (need to understand past magnetosphere)
Magnetopause shadowing (ions)	yes	yes? (need to understand past ring current)
Plasmaspheric wind and plumes	yes	yes? (need to understand past plasmasphere)

neutrals

both mixed

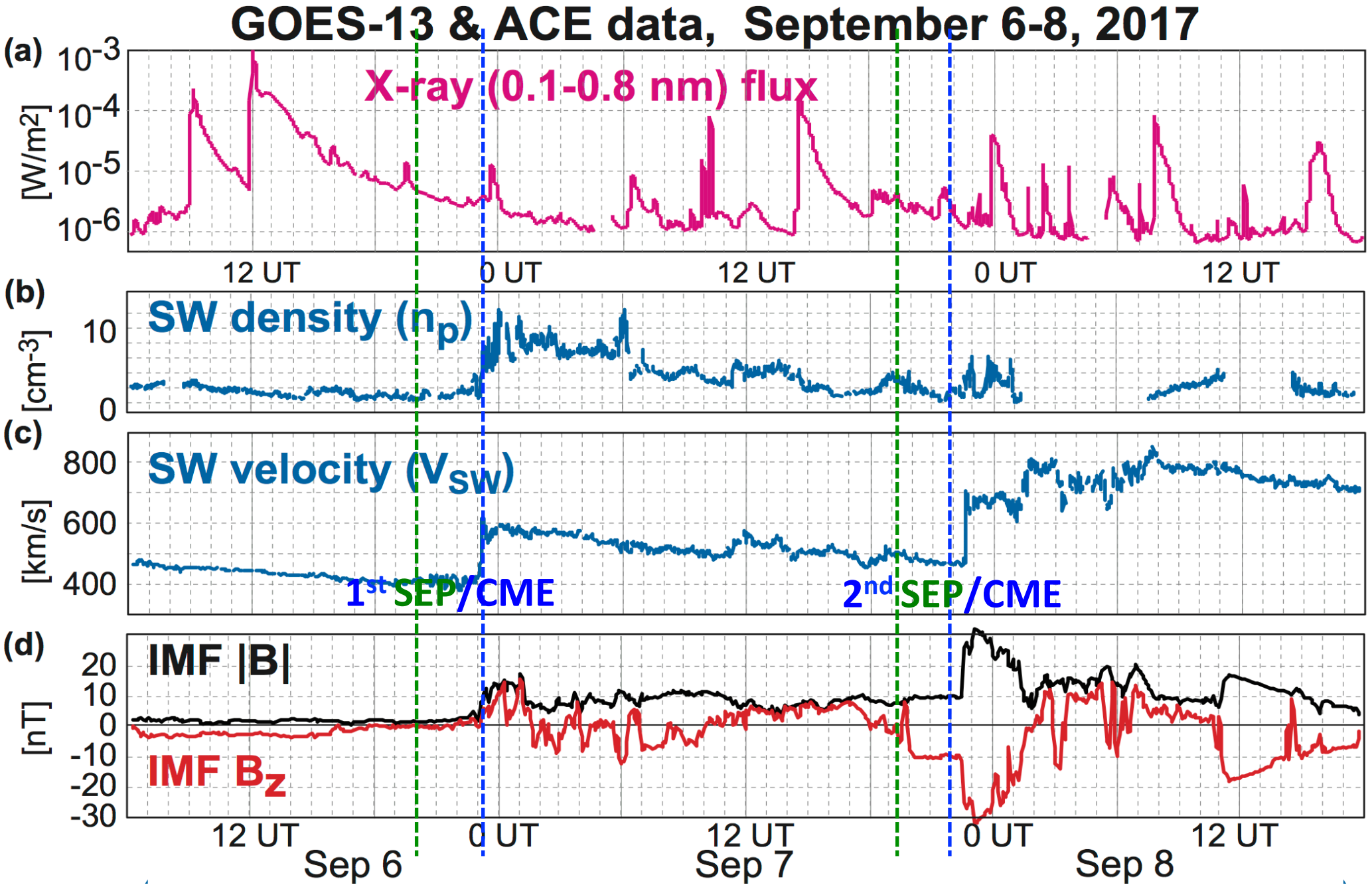
ions

Mission for only ion
⇒ ***can be downstream***

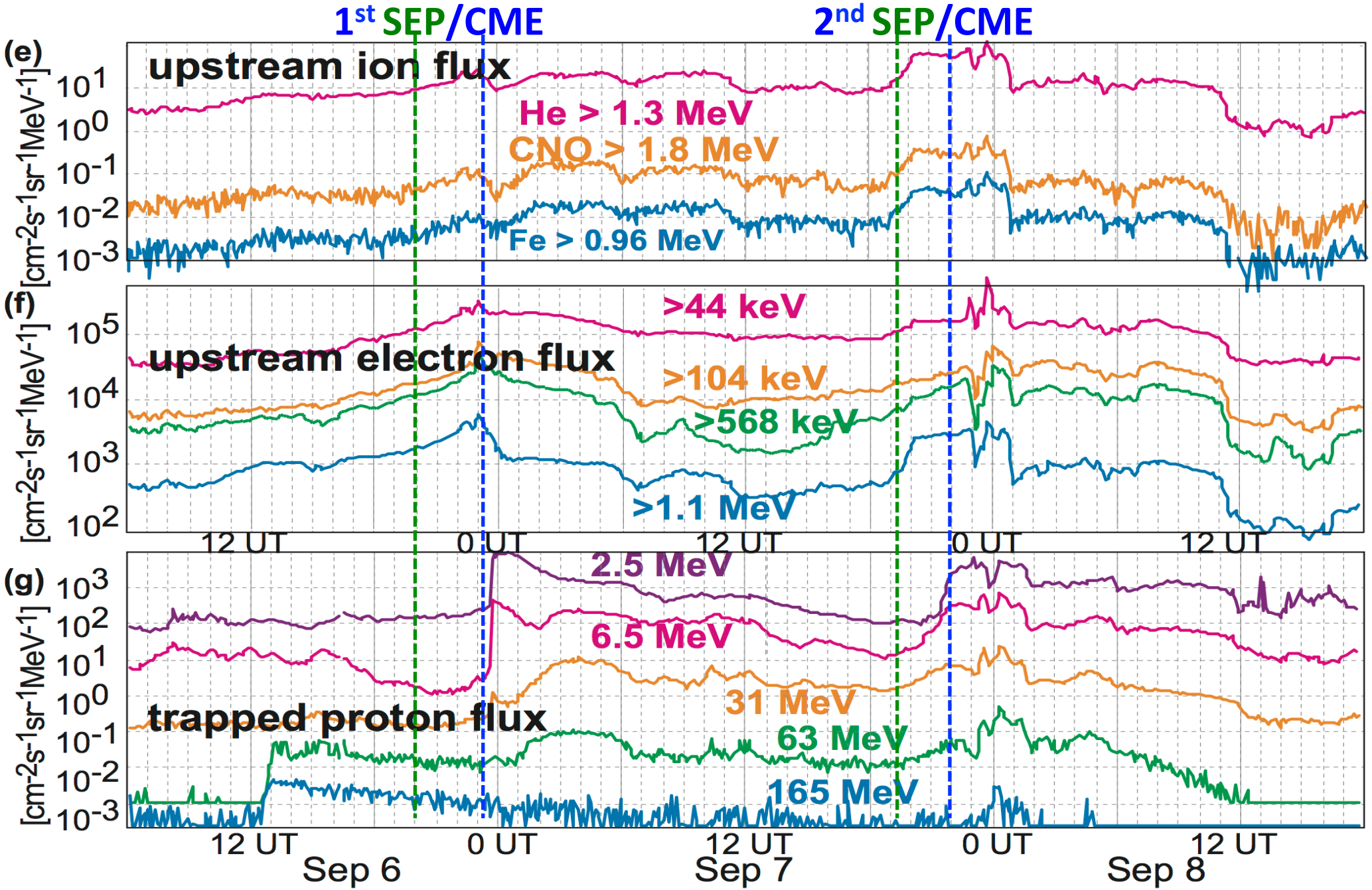
To understand both ion and neutral, low perigee elliptic orbit is needed
⇒ ***ESCAPE***

Science 2: Space Weather

CME is along the solar wind, but not Solar Energetic Particles (SEP)



CME is along the solar wind, but not SEP



CME is along the solar wind, but not SEP

L1 obs ≠ Geosynchronous

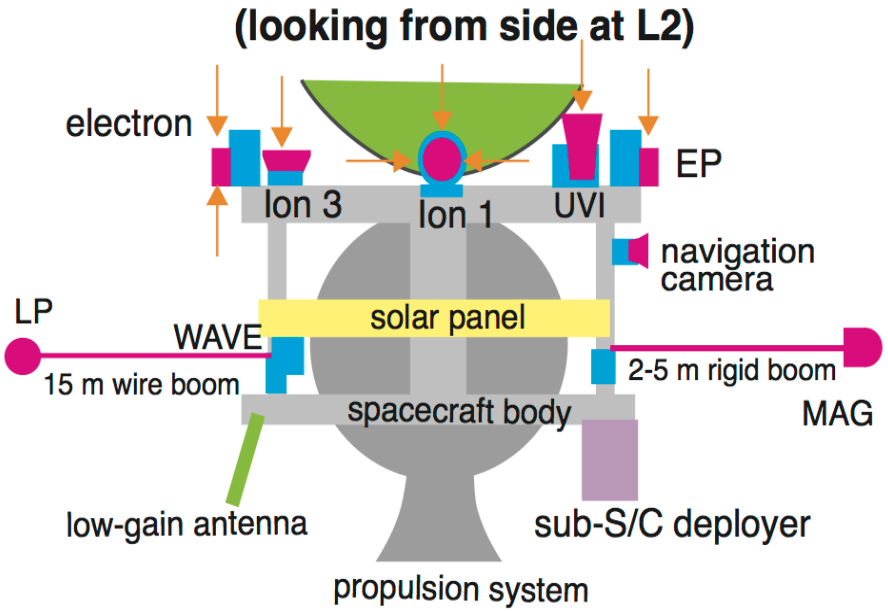
SEP flow along B rather than along SW

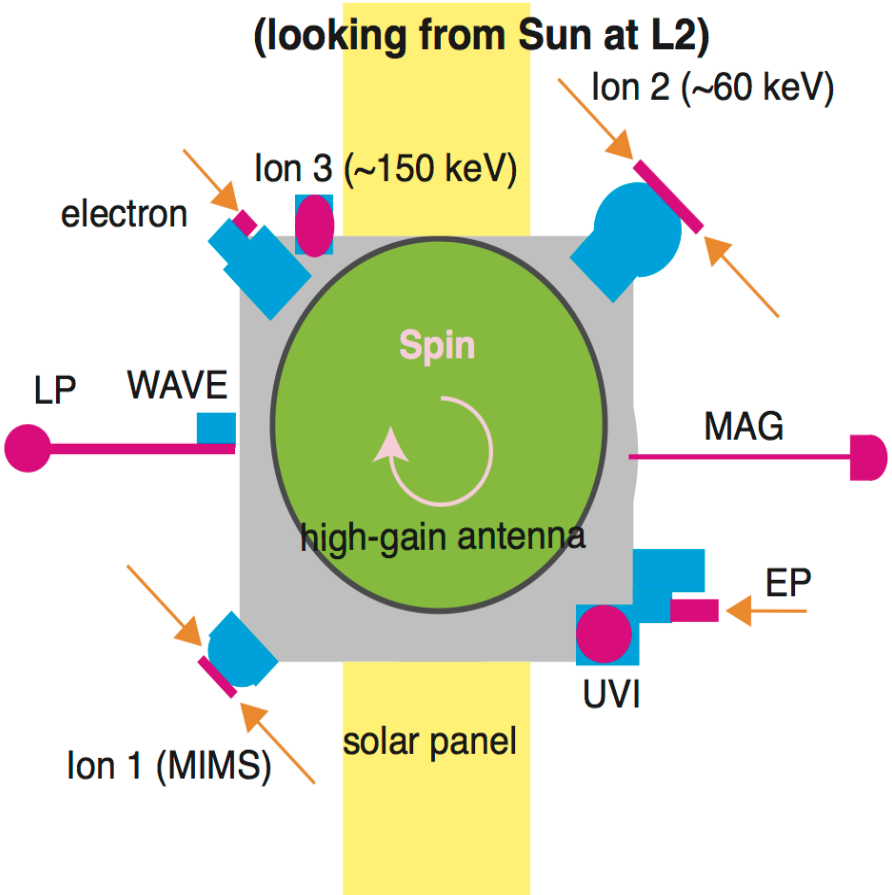
⇒ Space Weather does not protect space telescope at L2

& L1 + L2 combined data must be compared to GOES data

⇒ **Solar wind + SEP monitor at L2**

FAr Tail Explorer (FATE)





One mother (left) + two 6U cubesat

- MCP-type ion up to 60 keV = 850 km/s O^+
- Good mass resolution up to 30 keV
- SSD-type ions above
- Minimum field package

The cubesat is equipped

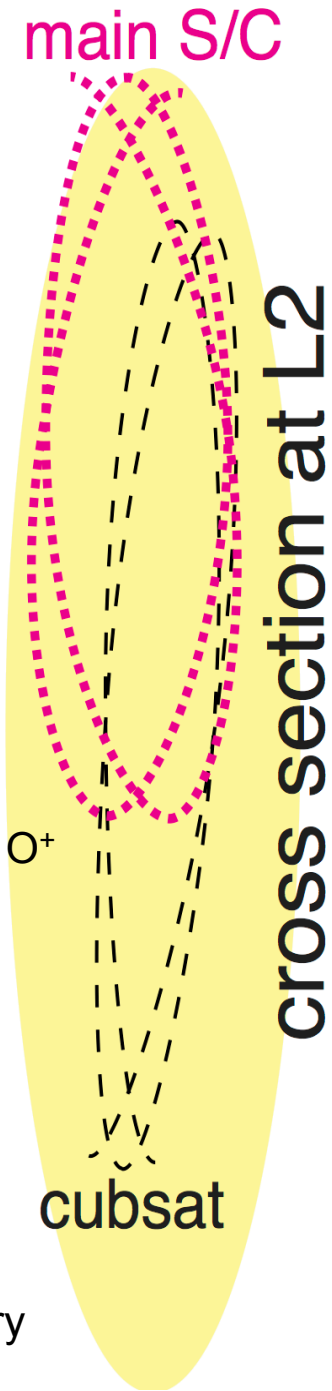
- MCP type ion mass for 0.1-20 keV
- SSD-type ions for 15-85 keV = 1000 km/s O^+
- One more (LP or B)

(1) obtain the total ion escape and variability,

(2) identify the relative importance of the different ion escape routes

(3) more accurate space weather warning

(4) study fine-scale magnetospheric boundary far downstream



M. Yamauchi
Kiruna, Sweden