Lagrange L2 Mission:
for magnetospheric and planetary evolution studies

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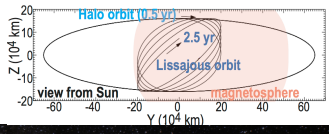
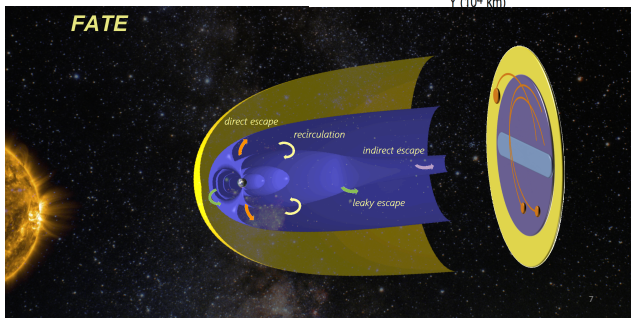
Escapes mechanisms

	mechanism	explanation	Where?
neutrals	Jeans escape	Thermal tail exceeds the escape velocity	exobase (M, ancient E?)
	Hydrodynamic blow off	Massive escape when thermal energy exceeds escape energy	near exobase (ancient)
	Momentum exchange	Light neutrals collide with heavy molecules	above exobase (M, ancient E/V?)
	Photochemical energization	Recombination *etc.* supply the escape energy	exosphere (M, ancient)
both mixed	Charge-exchange	Trapped ion with escape velocity strives an electron from neutral	above mirror altitude (E)
	Atmospheric sputtering	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?)
ions	Large-scale momentum transfer & instabilities	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)

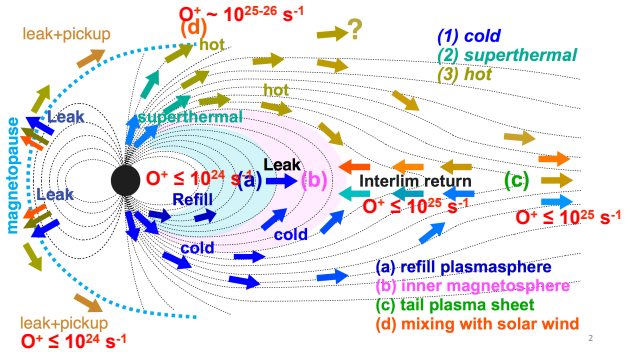
All ions should go to L2 + satellite can stay L2

(along Semi-stable Lissajous orbit)
+ many space telescopes are expected
⇒ **Why not L2 piggy-back mission**





Atmospheric escape is large enough to affect the **Evolution of the Life** in geological scale

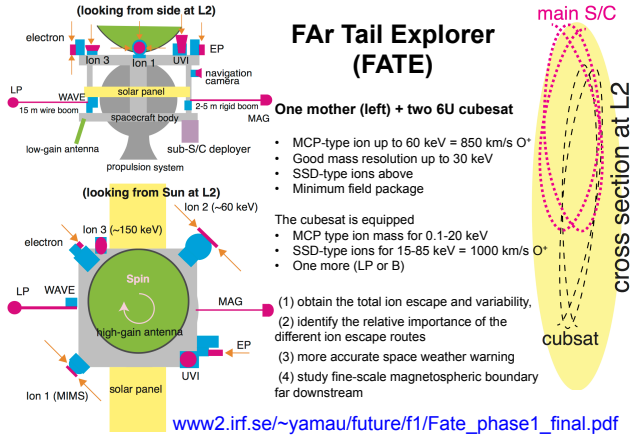


Main escape mechanism for the Earth

	mechanism	present Earth	ancient Earth?
neutrals	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
both mixed	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
ions	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)

Ion mission is fine
⇒ ***can be downstream***

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



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

www2.irf.se/~yamau/future/f1/Fate_phase1_final.pdf

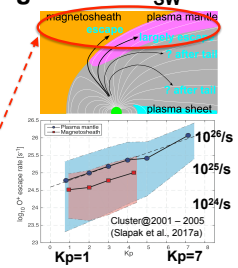
Scaling to the past : high EUV + P_{SW}

Ancient solar forcing (young M-stars)
(e.g., Wood, 2006)

(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)

⇒ We scale **Kp=10** or use **extreme events** as proxy of the past

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



Loss rate : ∝ exp(0.45*Kp)

⇒ $3 \cdot 10^{43}$ O^+ over **1 Gyr** ($3 \cdot 10^{16}$ sec)
= **70% of present atmospheric O_2** (15% of N_2) ⇒ **ion escape cannot be ignored**

cf. Observed O/N ratio fluctuate in 0.1 byr :
not easy to explain by bioactivity ⇒ **ion escape might be important**

cube-FATE

One 6U-12U cubesat
- MCP (Micro-channel plate) type ion mass for 0.1-20 keV
- SSD (Solid state detector) type ions for 15-85 keV (cover up to 1000 km/s O^+
- One more (SEP monitor or LP or B)

It is possible to accommodate electric propulsion in 6U cube and send to L2!

Cost ~ order of 10 Meur