MHD Equations

$$\frac{\partial \rho_m}{\partial t} + \nabla \bullet (\mathbf{m}) = 0$$

$$\frac{\partial \mathbf{m}}{\partial t} + \nabla \cdot (\mathbf{m}\frac{\mathbf{m}}{\rho_m}) + \nabla \mathbf{P} = \mathbf{J} \times \mathbf{B} + \rho_m \mathbf{g}(\mathbf{r})$$

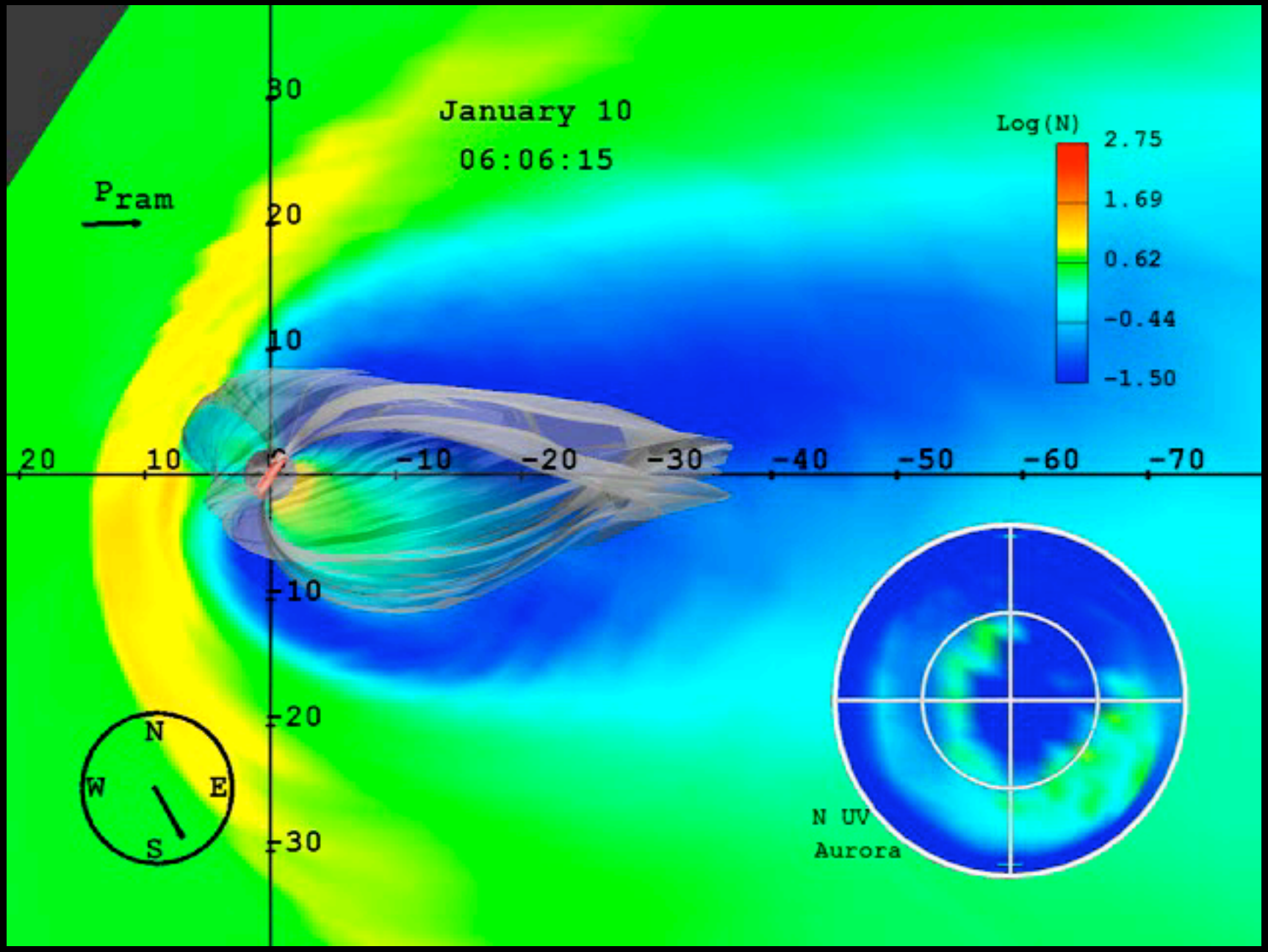
$$\frac{\partial e}{\partial t} + \nabla \cdot (\frac{\mathbf{m}}{\rho_m}(e + P)) = \mathbf{E} \cdot \mathbf{J} + \mathbf{m} \cdot \mathbf{g}(\mathbf{r}) \quad \text{where} \quad e = \frac{1}{2}\frac{\mathbf{m}^2}{\rho_m} + \frac{P}{\gamma - 1}$$

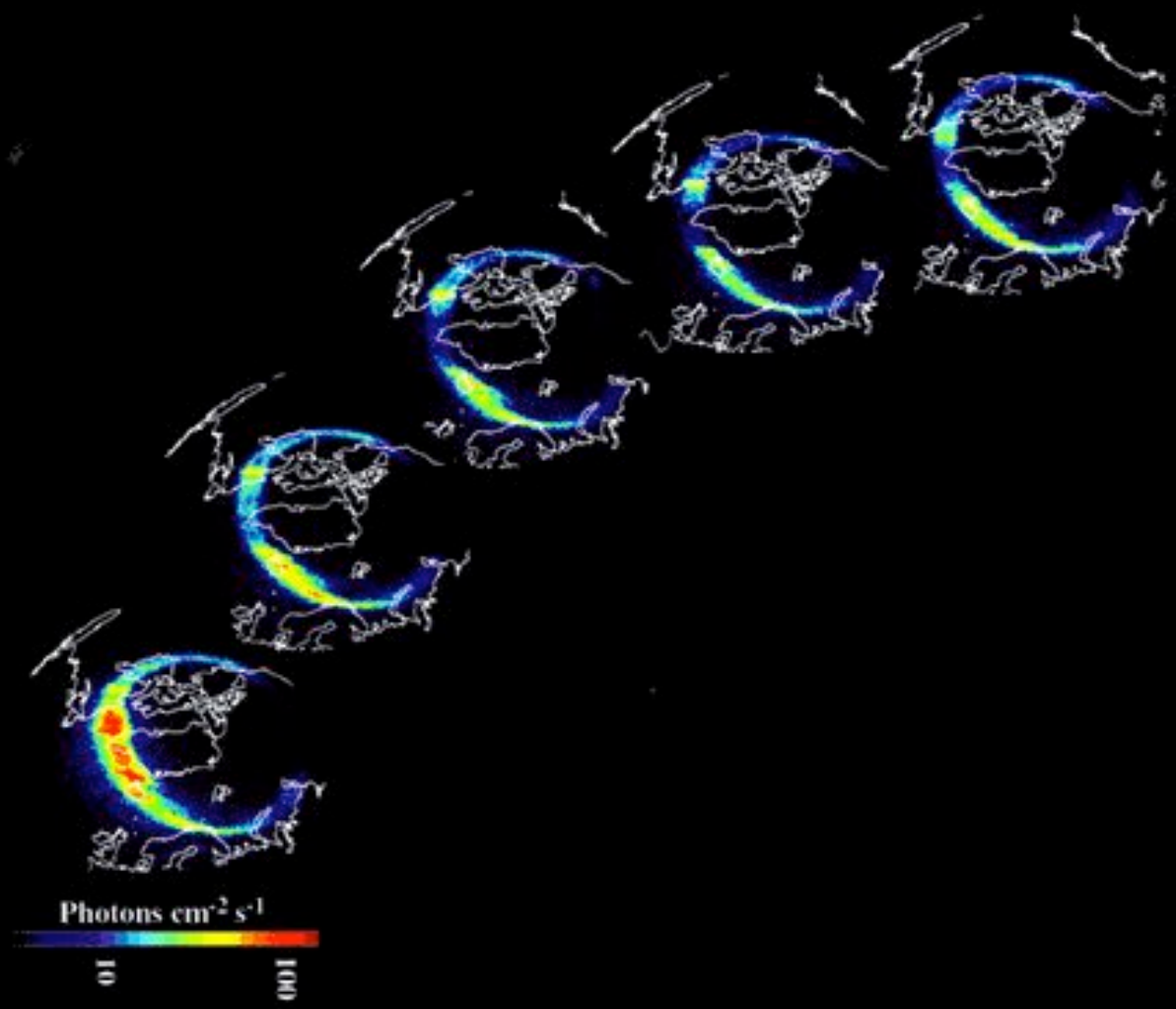
or $$\frac{\partial P}{\partial t} = -\gamma \nabla \cdot (P\mathbf{u}) + (\gamma - 1)\mathbf{u} \cdot \nabla P$$

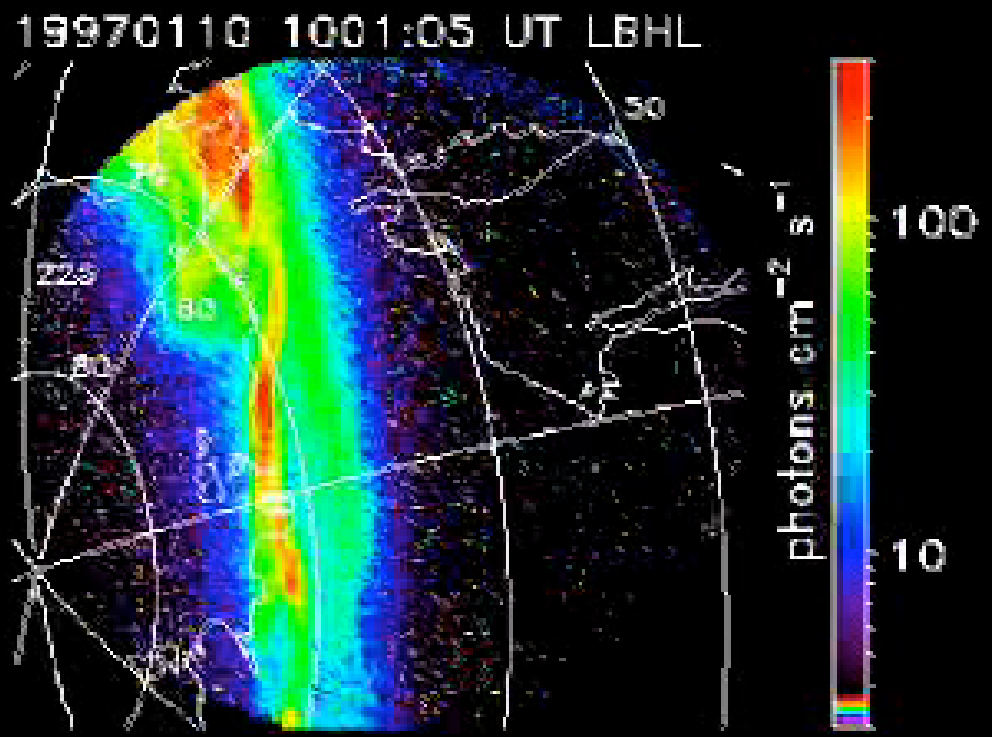
$$\frac{\partial \mathbf{B}}{\partial t} + \nabla \times \mathbf{E} = 0$$

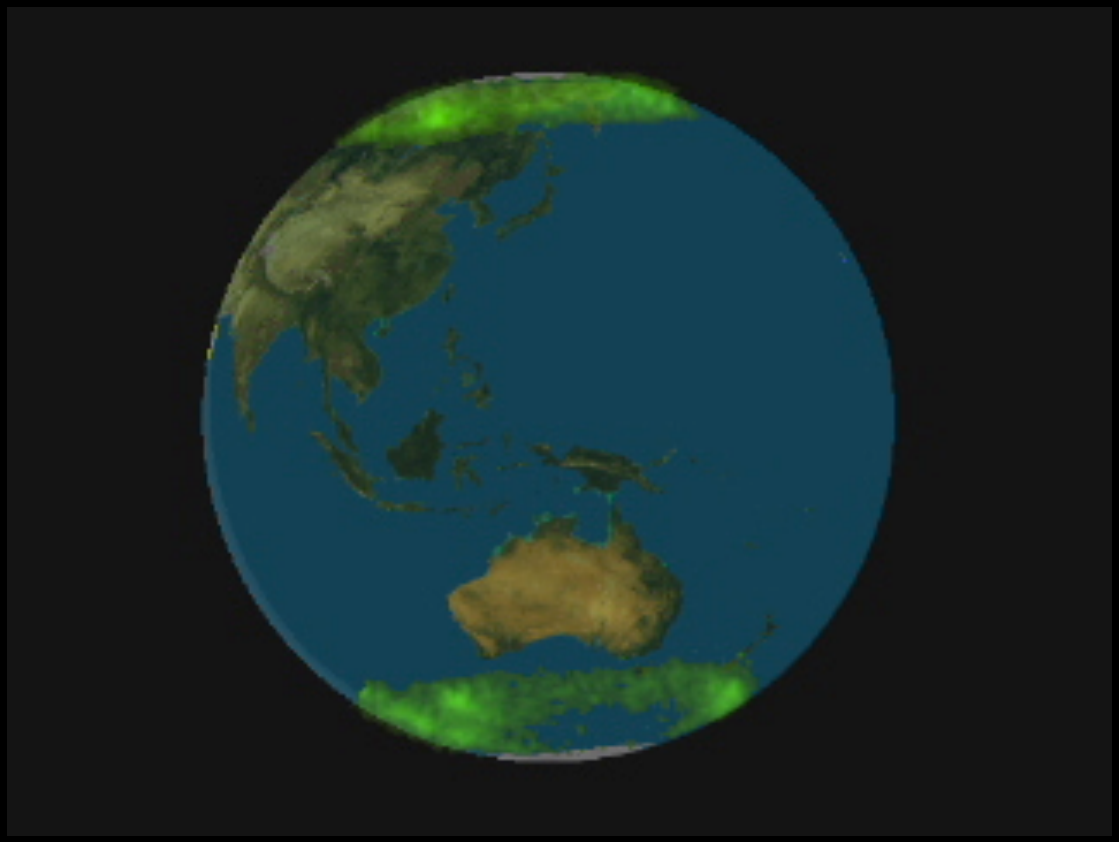
$$\mathbf{J} = \frac{1}{\mu_o} \nabla \times \mathbf{B}$$

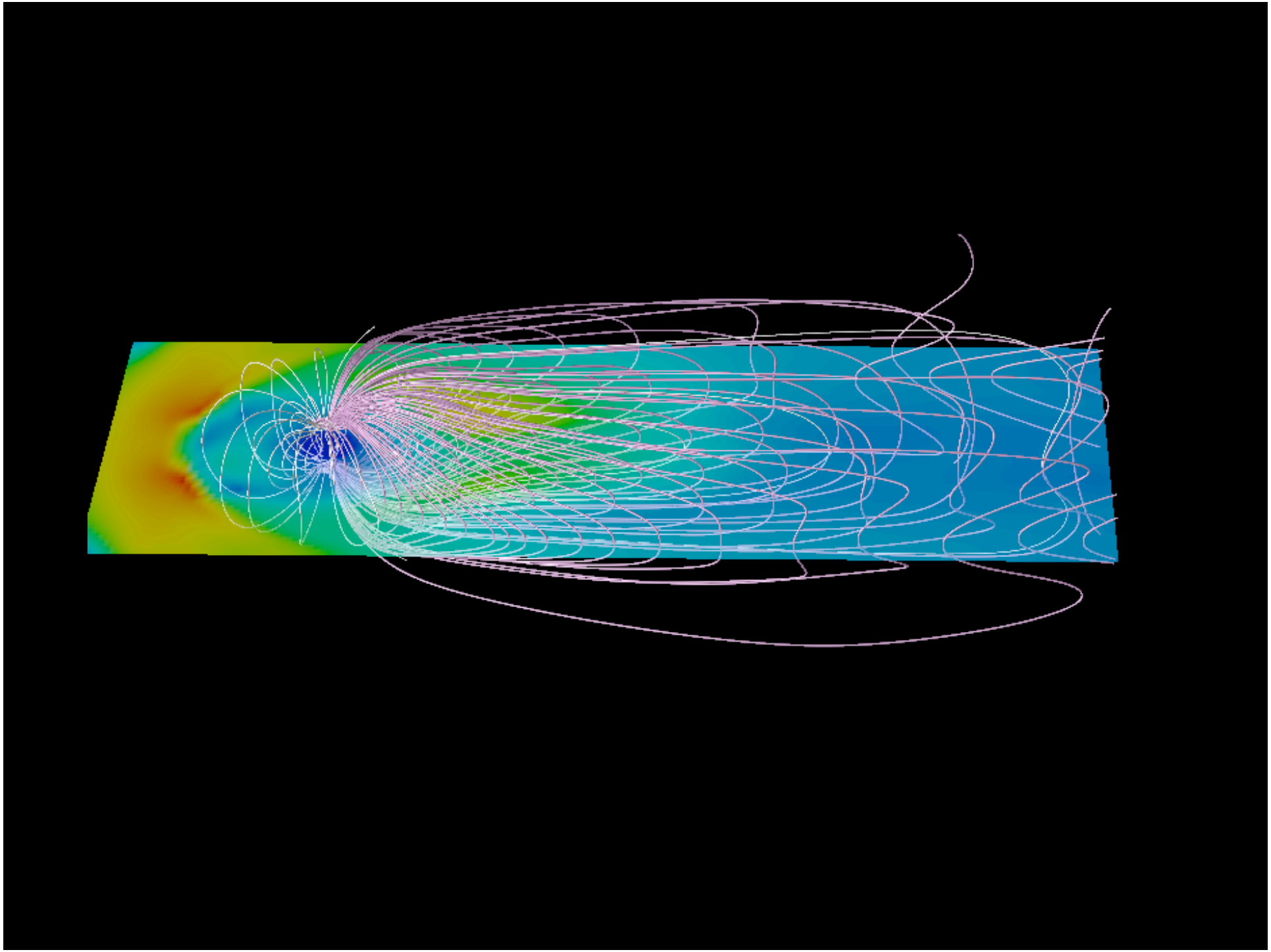
$$\mathbf{E} = -\mathbf{u} \times \mathbf{B} + \eta \mathbf{J}$$

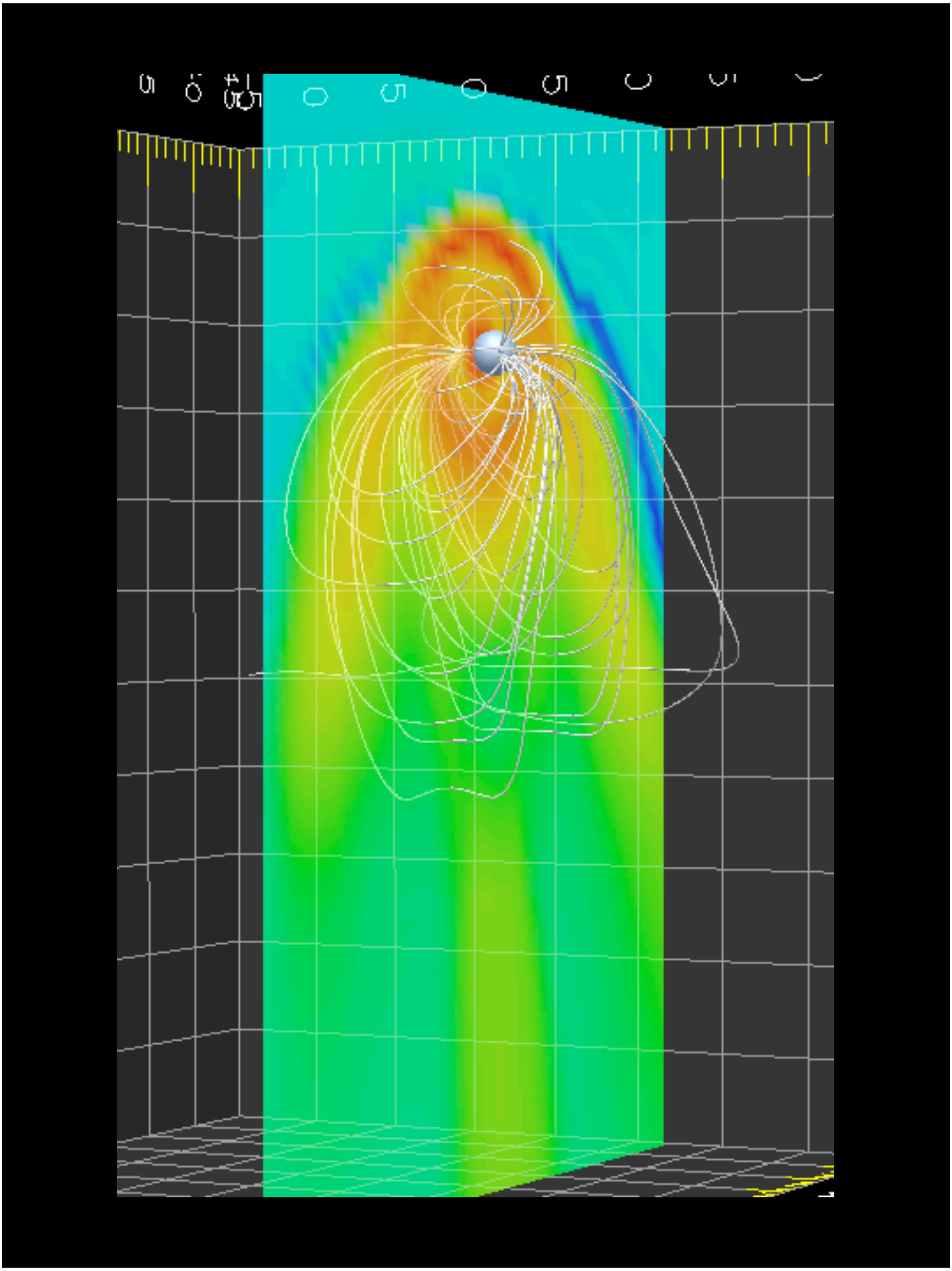

January 10
06:06:15
Pram
Log(N)
2.75
1.69
0.62
-0.44
-1.50
30
20
10
-10
-20
-30
20
10
0
-10
-20
-30
-40
-50
-60
-70
N
W
E
S
N UV
Aurora

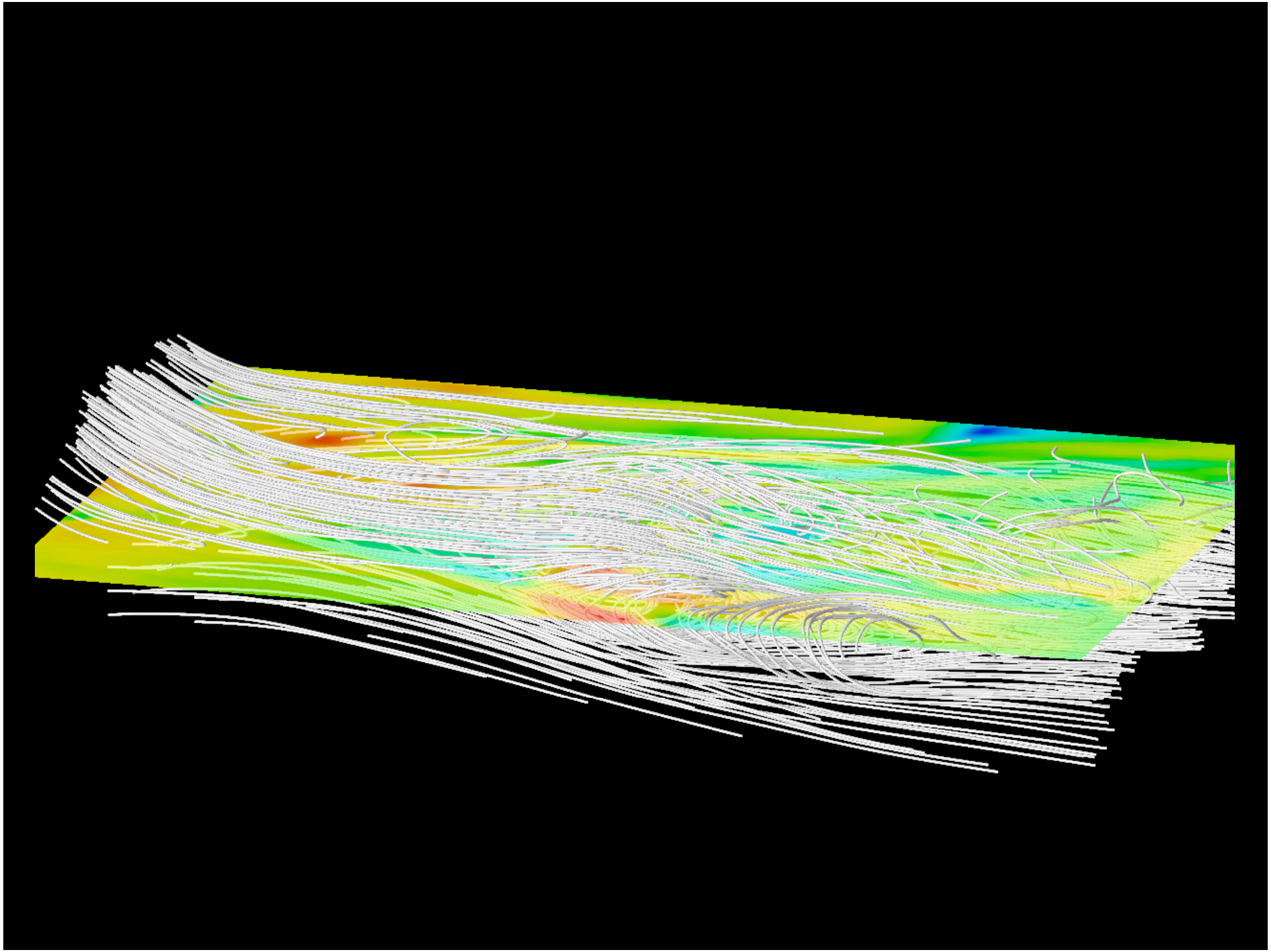

Photons cm-2 s-1
10
100

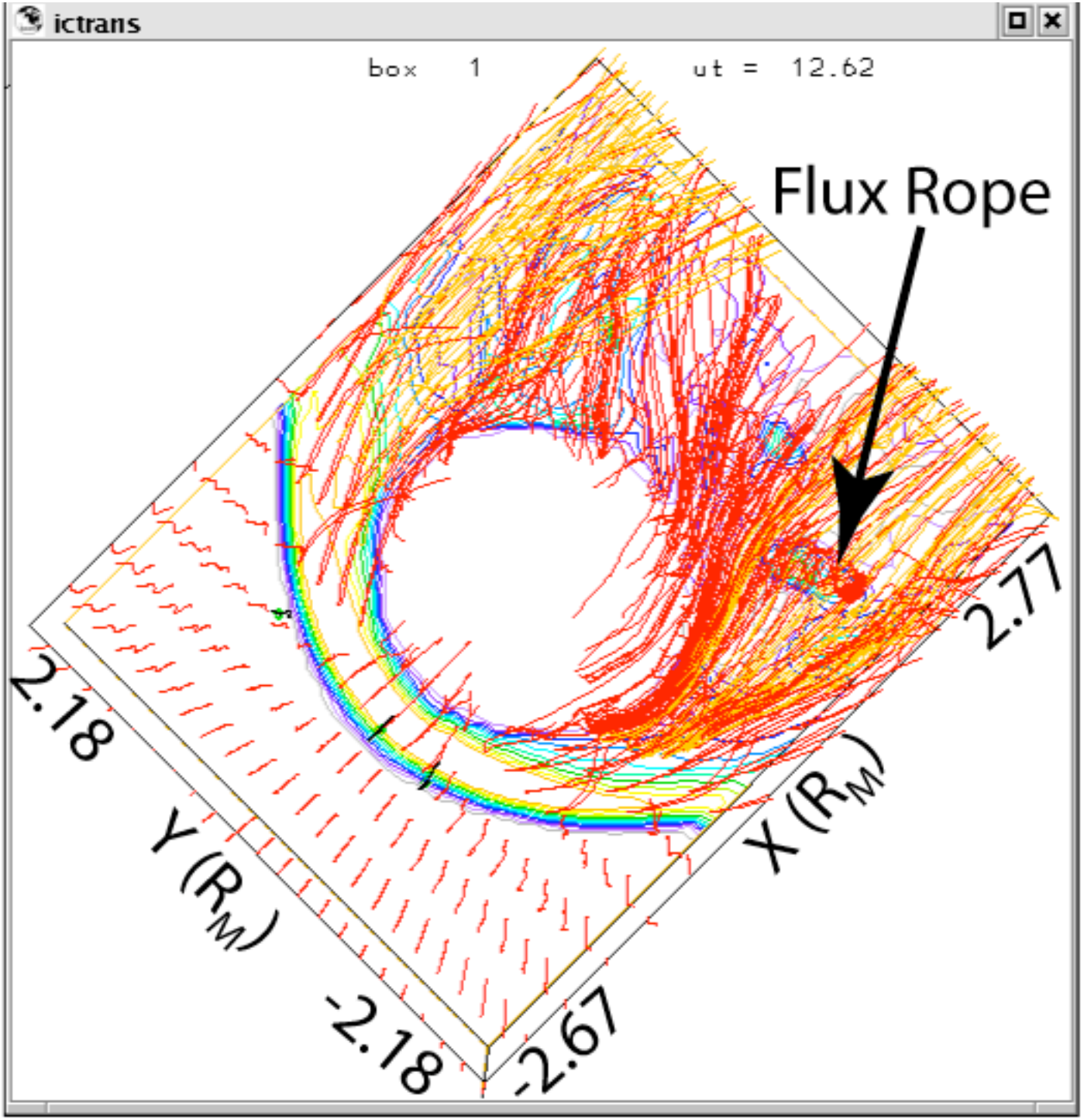

19970110 1001:05 UT LBHL
30
225
80
80
photons cm^{-2} s^{-1}
100
10

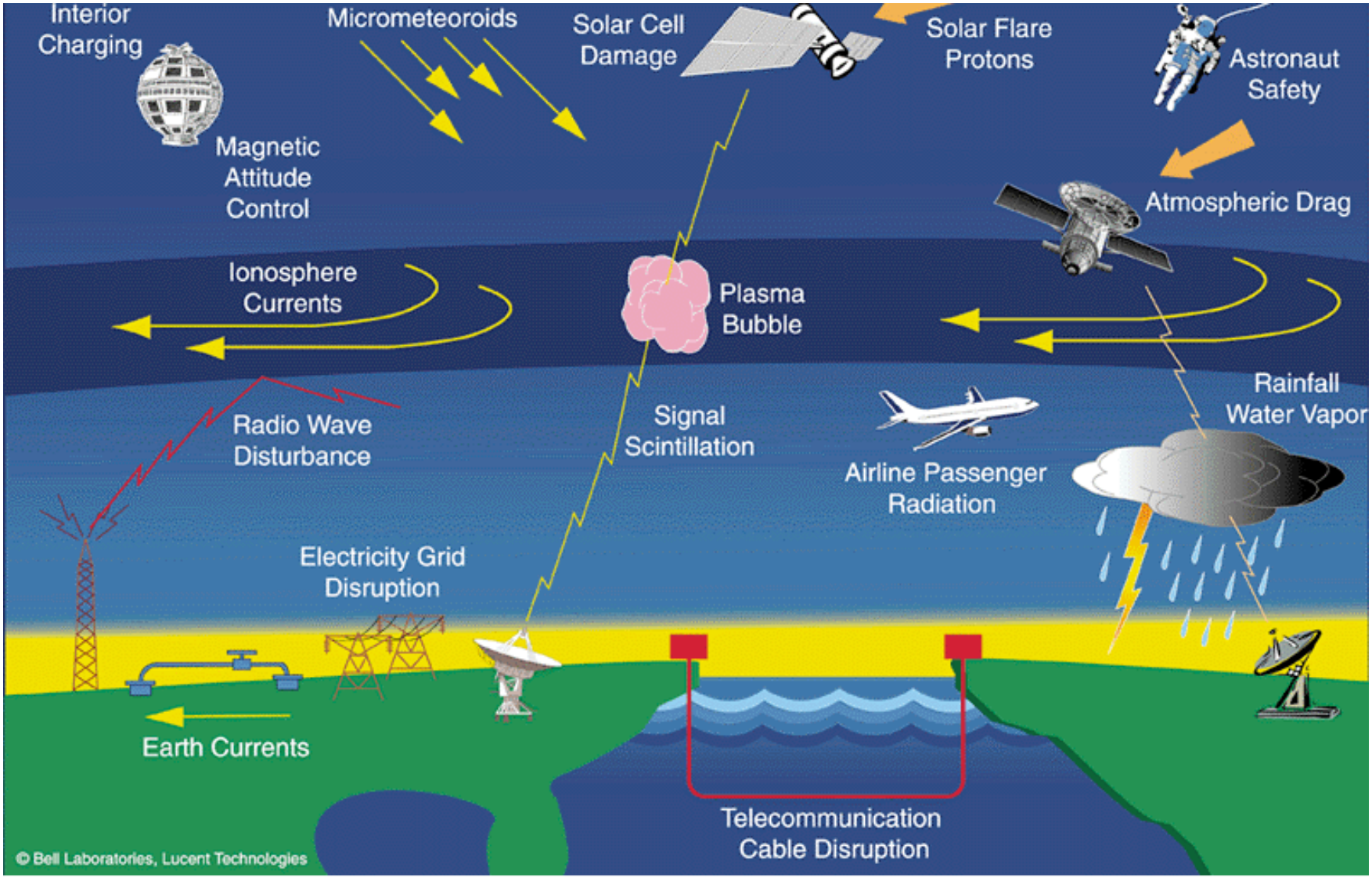








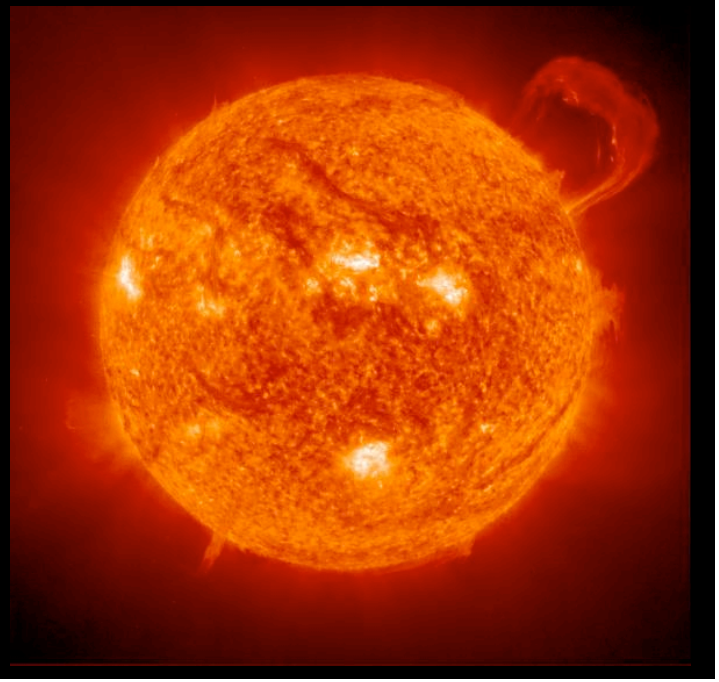

ictrans
box 1
ut = 12.62
Flux Rope
2.18
Y (R_M)
-2.18
-2.67
X (R_M)
2.77

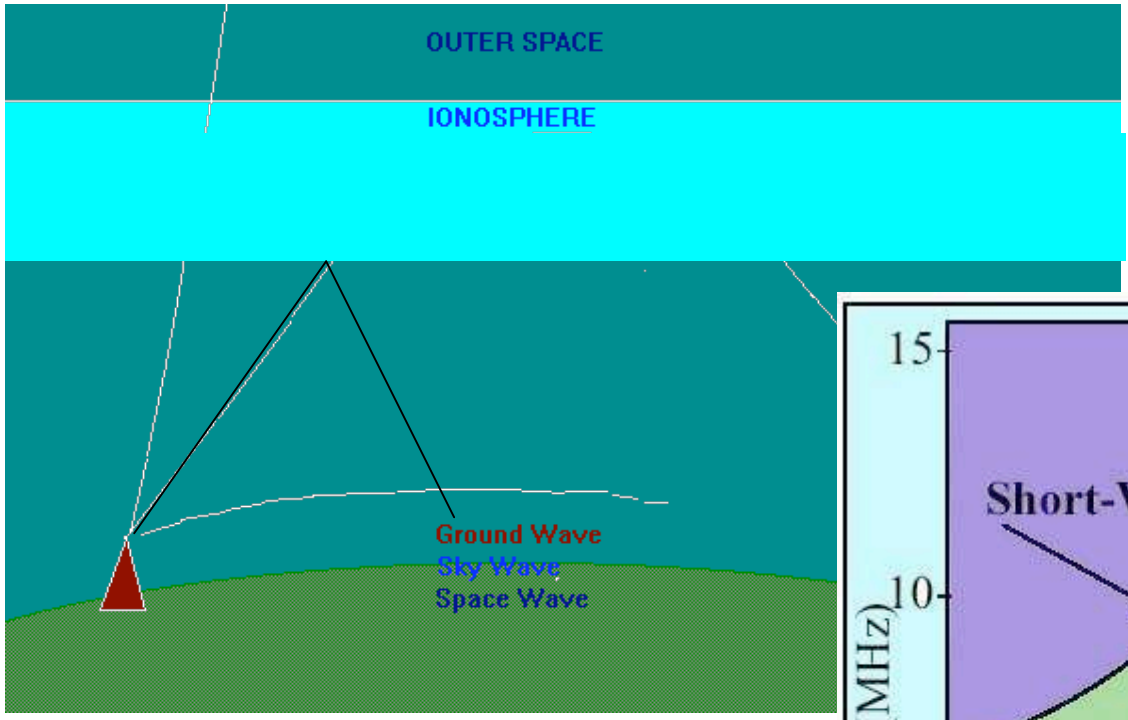


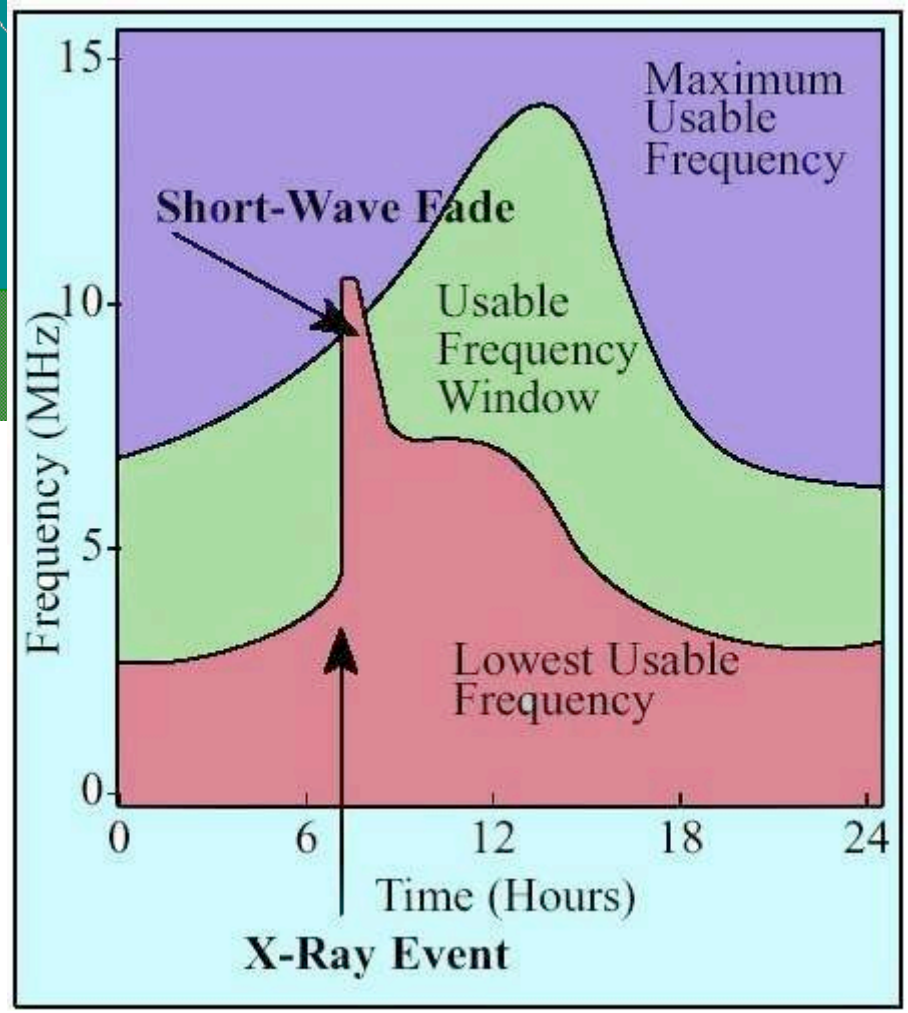
The effects of magnetic storms - what scientists call space weather - extend from the ground to geostationary orbit and beyond.

Hazards from CMEs

- Radio black-outs

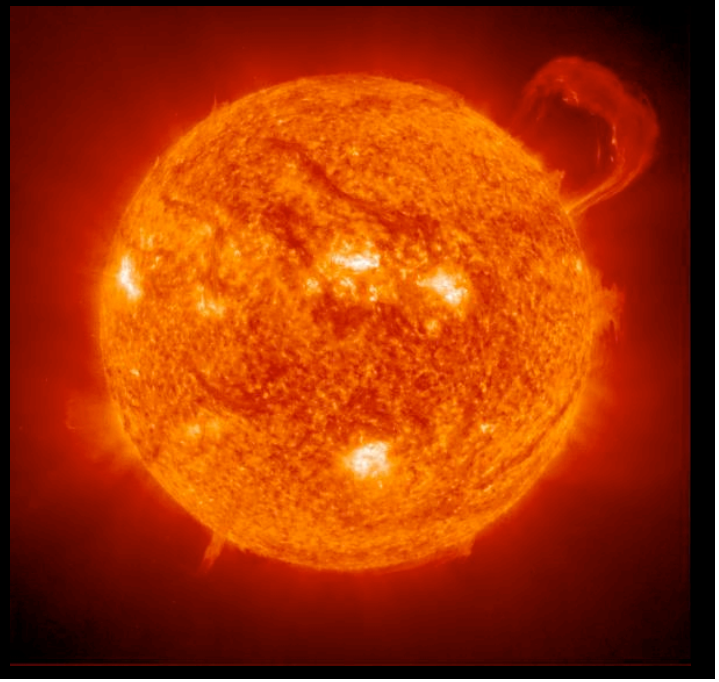


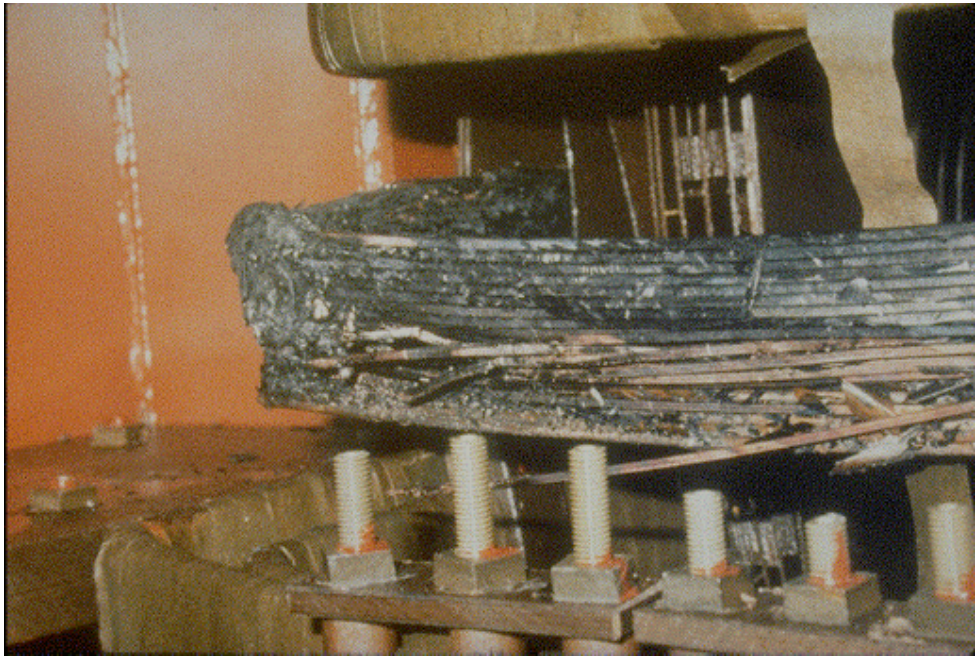

OUTER SPACE
IONOSPHERE
Ground Wave
Sky Wave
Space Wave


15
10
5
0
Frequency (MHz)
Maximum
Usable
Frequency
Short-Wave Fade
Usable
Frequency
Window
Lowest Usable
Frequency
0
6
12
18
24
Time (Hours)
X-Ray Event

Hazards from CMEs

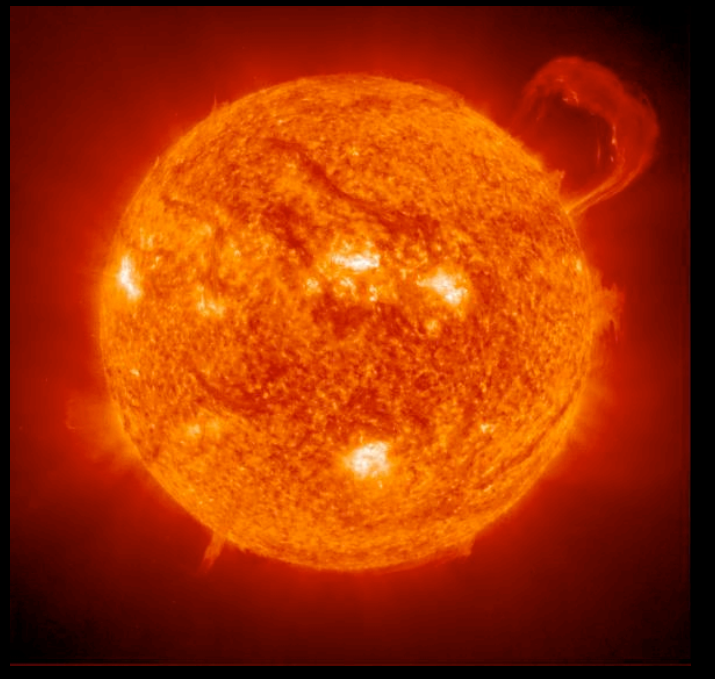
- Radio black-outs
- Power plant failures

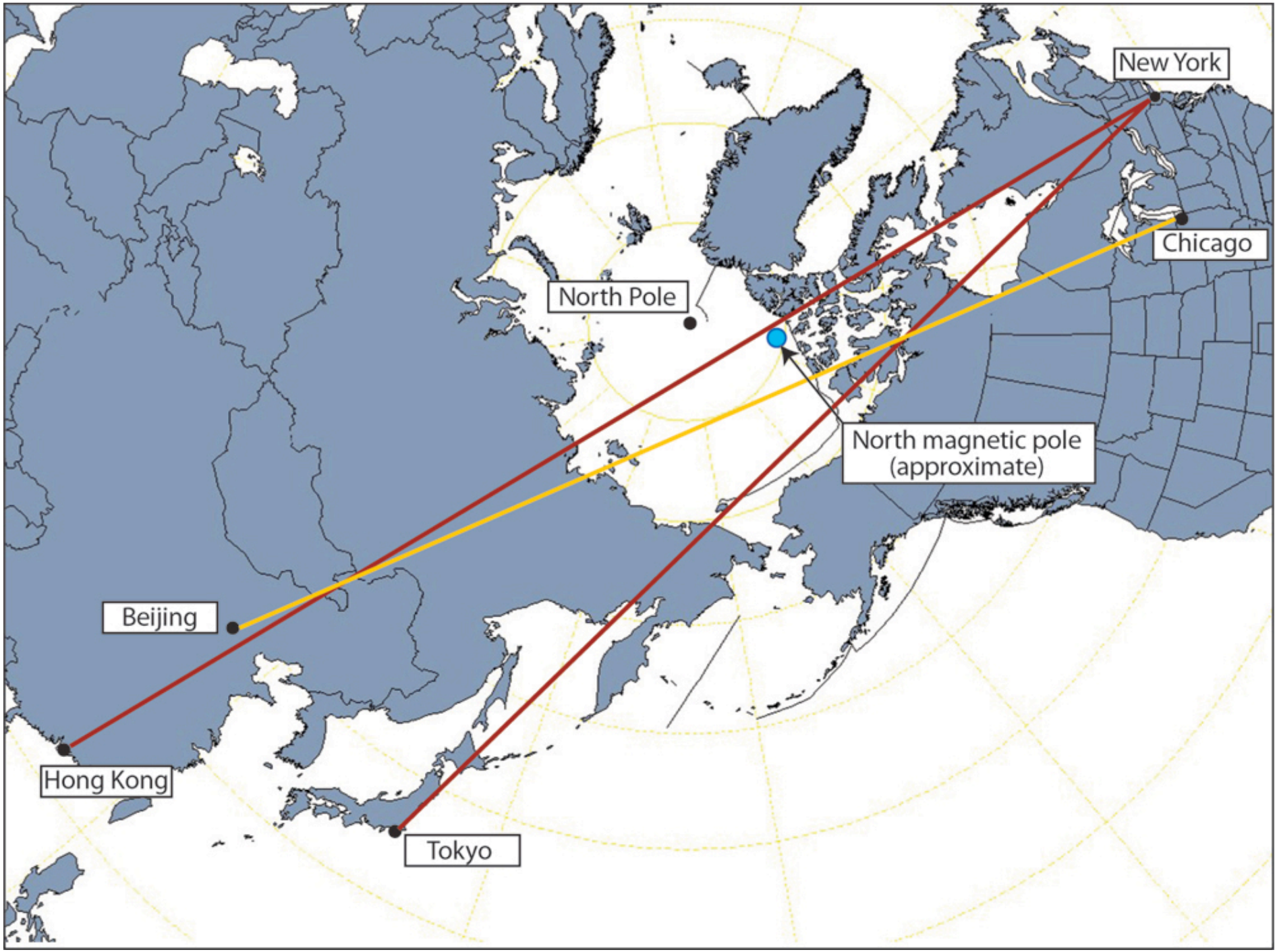




Hazards from CMEs

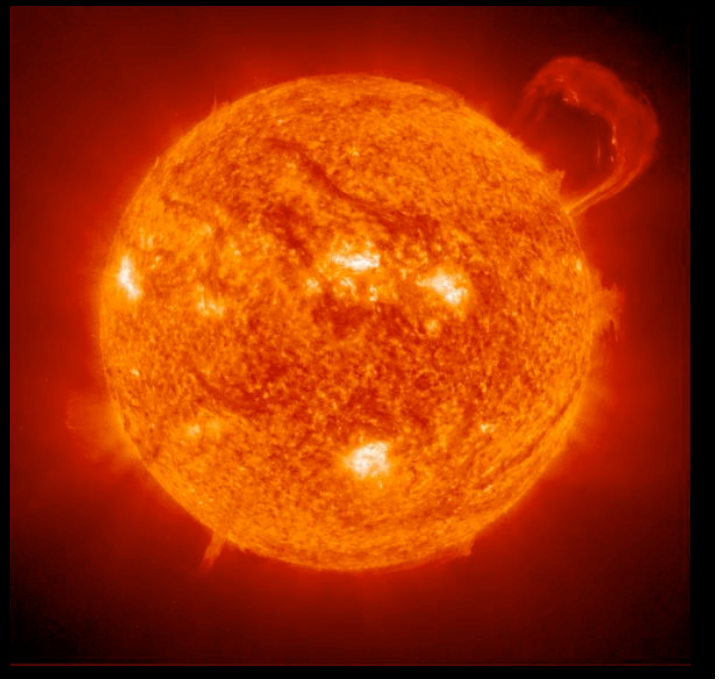
- Radio black-outs
- Power plant failures
- Increased exposure for transcontinental flights



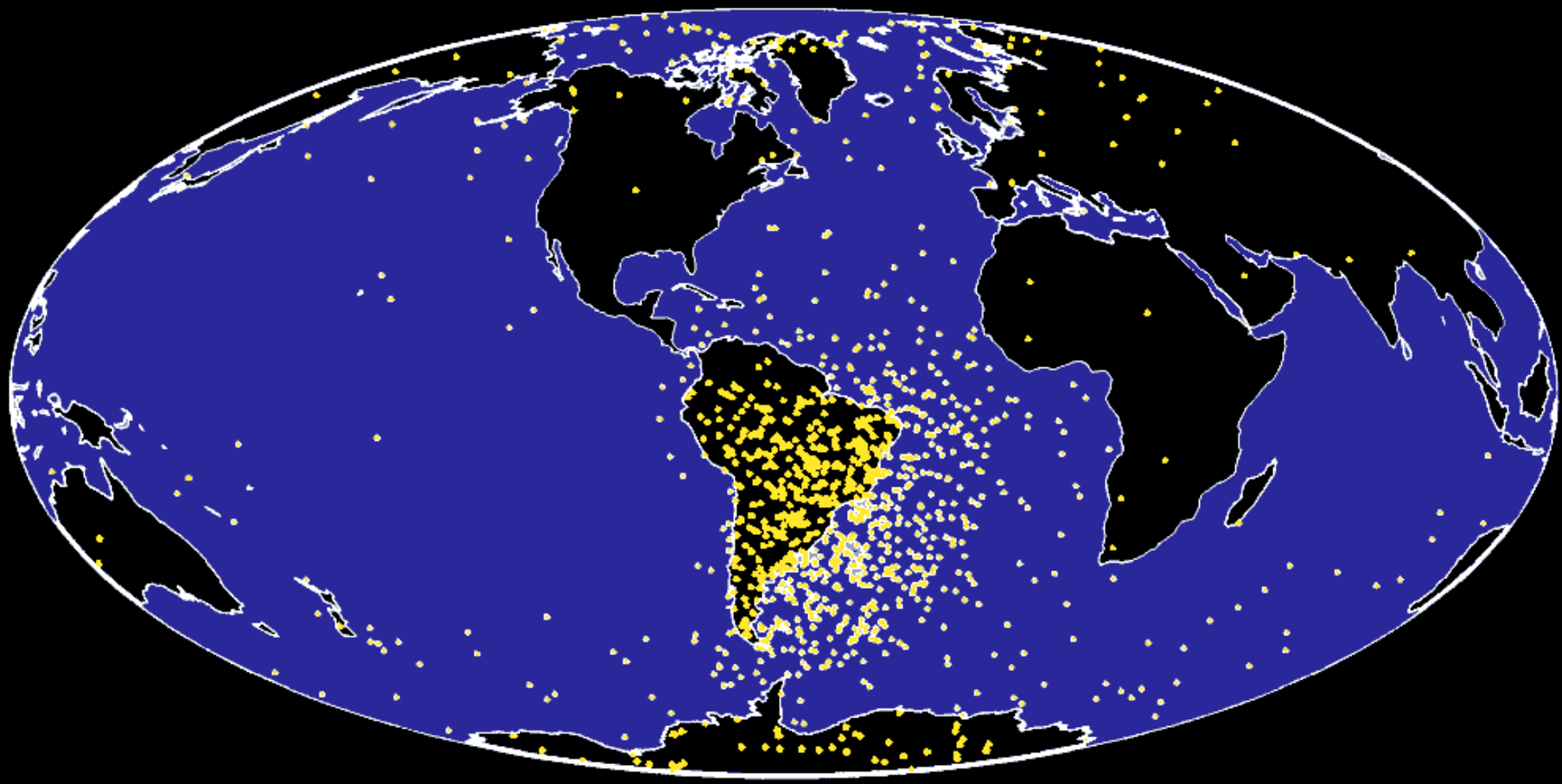

New York
Chicago
North Pole
North magnetic pole
(approximate)
Beijing
Hong Kong
Tokyo

Hazards from CMEs

- Radio black-outs
- Power plant failures
- Increased exposure for transcontinental flights
- Satellite failures



UOSAT-2 Memory Upsets



ESA/ESTEC The Netherlands

NOAA/NGDC Boulder