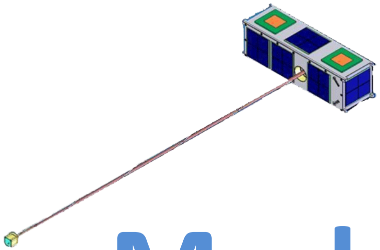

Modeling of Energetic Neutral Atom Emissions for CINEMA/TRIO

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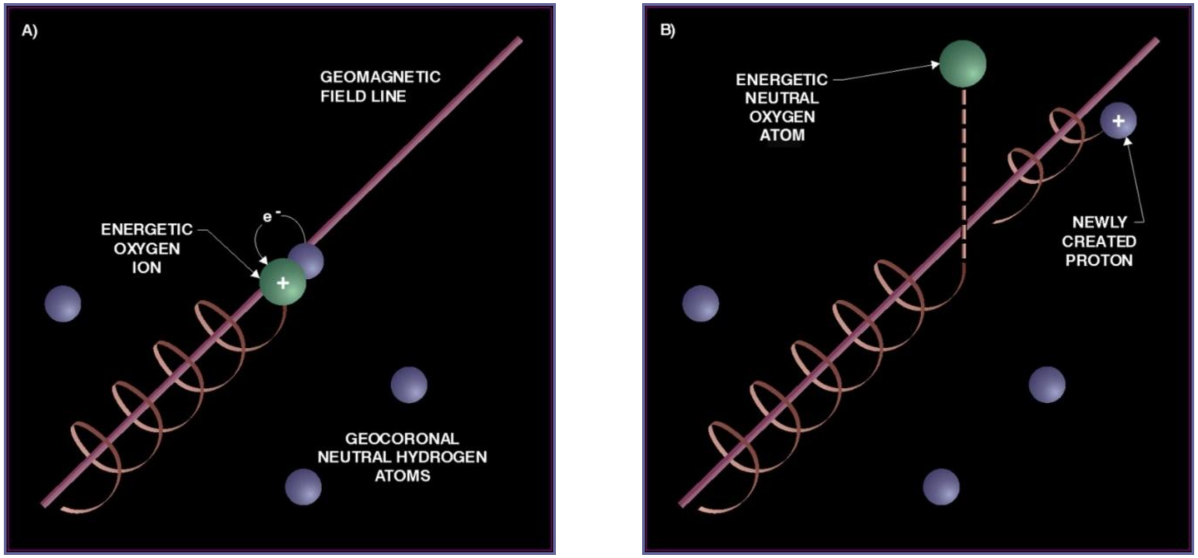
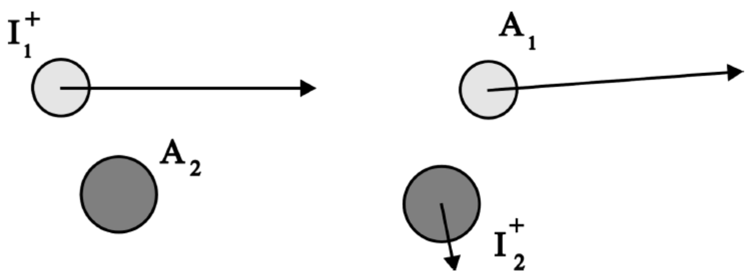
Energetic Neutral Atoms (ENAs) in Space





before collision

I_1^+: energetic ion

A_2: cold neutral atom

→

after collision

A_1: energetic neutral atom (ENA)

I_2^+: cold ion

Energetic Neutral Atoms (ENAs) in Space

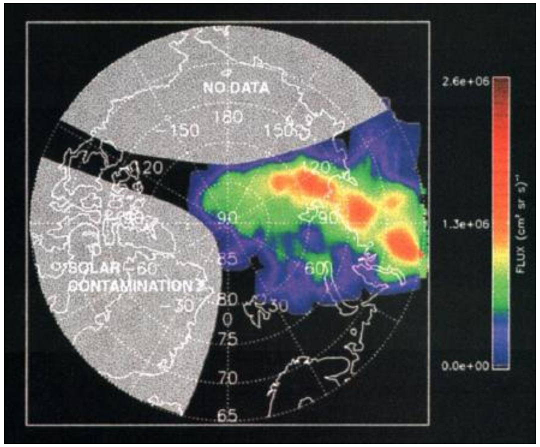
A_1: energetic neutral atom (ENA)

- originally an energetic ion, which obtained an e- by collision with a cold neutral atom
- maintain the energy and momentum of the original energetic ion
- travel without being affected by magnetic field: **remote sensing**

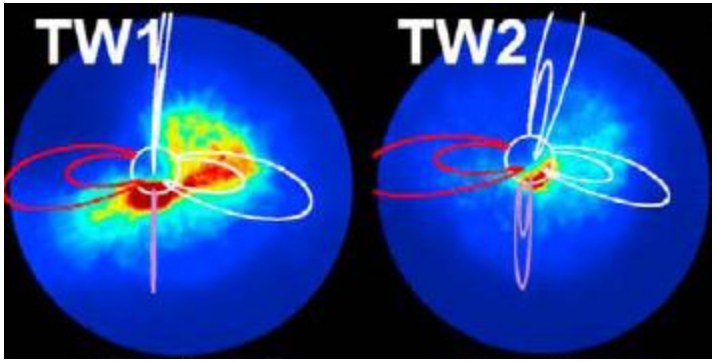
→ ENAs can provide a kind of **imaging of energetic ion distribution**

Previous ENA missions

- Astrid: low-altitude, terrestrial magnetosphere
- IMAGE: terrestrial magnetosphere
- TWINS: terrestrial magnetosphere
- Cassini: Saturn and Jupiter
- Mars Express: Mars
- IBEX: heliosphere

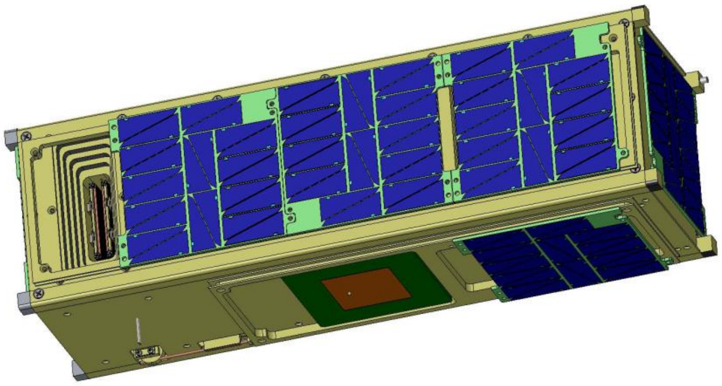


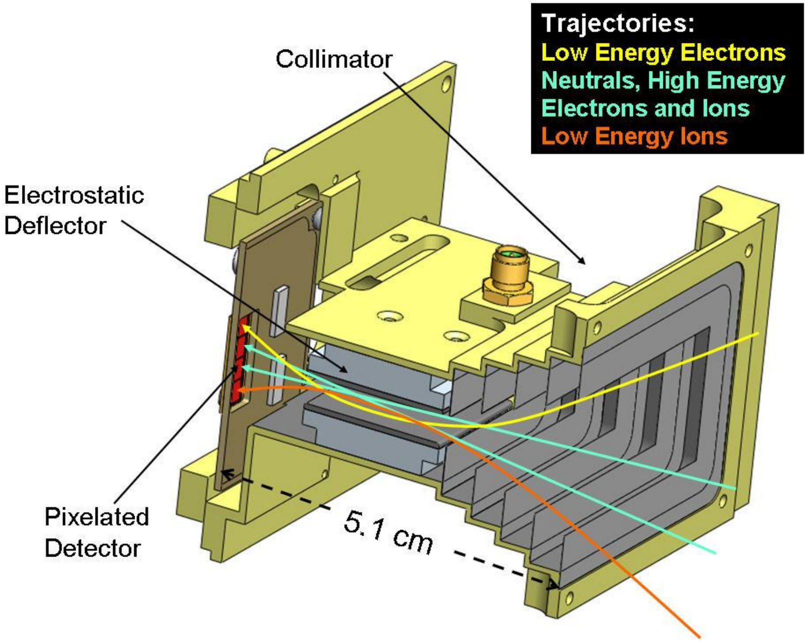
ENAs over polar cap by Astrid
(Brandt et al., 2001)



ENAs by TWINS
(Fok et al., 2010)

STEIN onboard CINEMA/TRIO





- altitude ~ 650 km

→ lower than Astrid (~1000 km)

- E: a few keV - ~300 keV
- energy resolution: ~1 keV
- FOV: 20° × 70°
- time resolution: ~15 sec - ~1 min

STEIN onboard CINEMA/TRIO

• concerns for ENA observation by STEIN

- very low altitude (~650 km) → within very thick neutral geocorona

- very wide FOV ($20^o \times 70^o$)

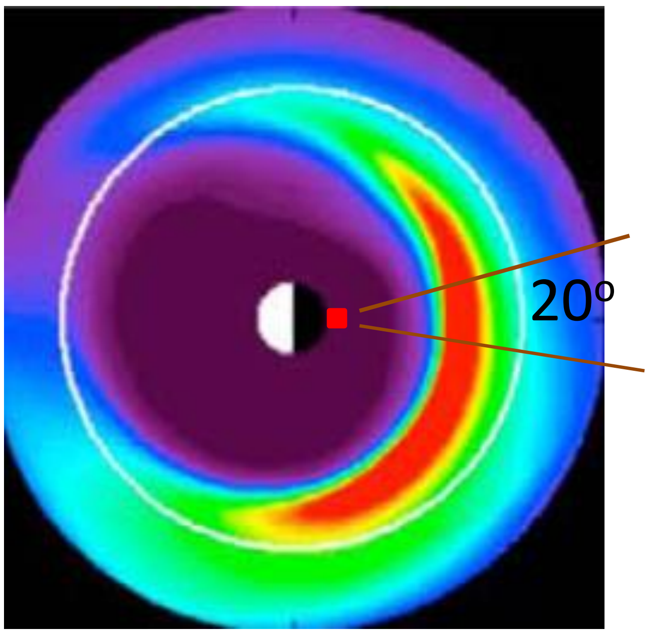
→ What will it see?

• in present study

- describe a tool to model ENA observations using an empirical ring current ion distribution model

- present preliminary results of the modeling

ENA modeling



$$J_{\mathrm{ENA}} \sim \int dl\,(n_{\mathrm{H}} \sigma J_{\mathrm{ion}})$$

n_H: density of neutral atoms

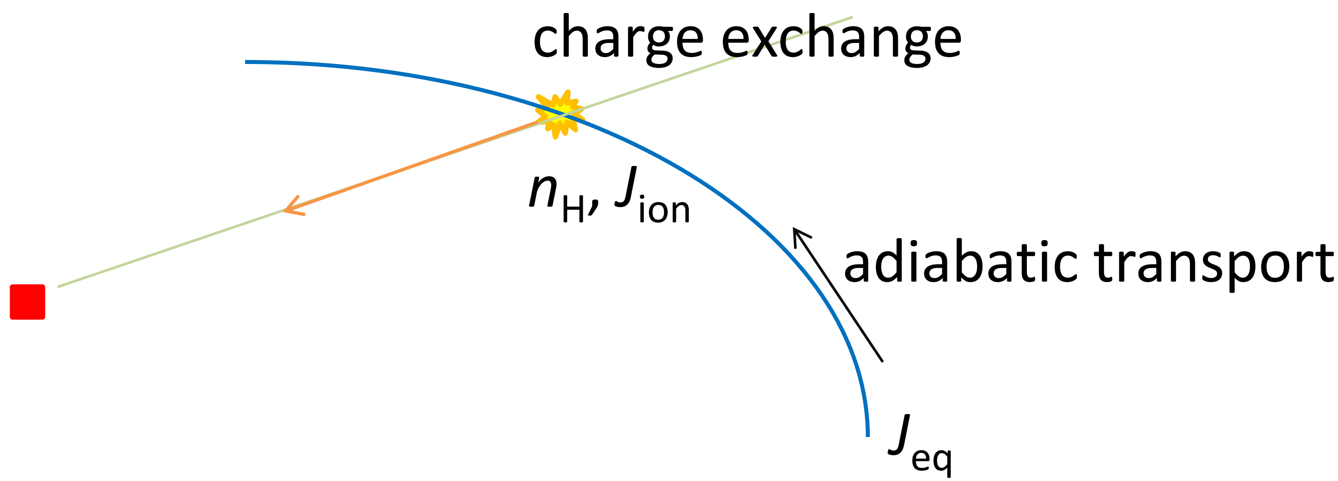
J_{ion}: ion flux

σ: charge exchange cross section

dl: line element along line of sight

J_{ENA} – accumulation of fluxes within the FOV along line of sight

$$J_{\mathrm{ENA}} \sim \int dl\,(n_{\mathrm{H}} \sigma\, J_{\mathrm{ion}})$$



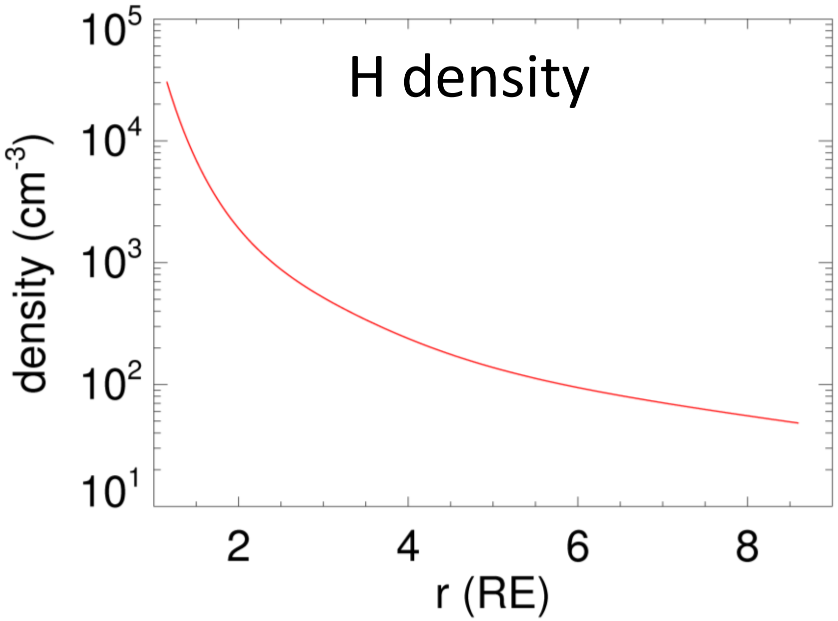
- need to know n_H and J_{ion} where a line of sight crosses a field line
- J_{ion} → estimated from J_{eq} (ion flux in the equatorial plane)
  assuming adiabatic transport of ions along the field line
  Liouville theorem can be used

Magnetic field model

- Tsyganenko model (TS04) with IGRF model

Neutral geocorona model

- Rairden et al. (1986) and østgaard et al. (2003)



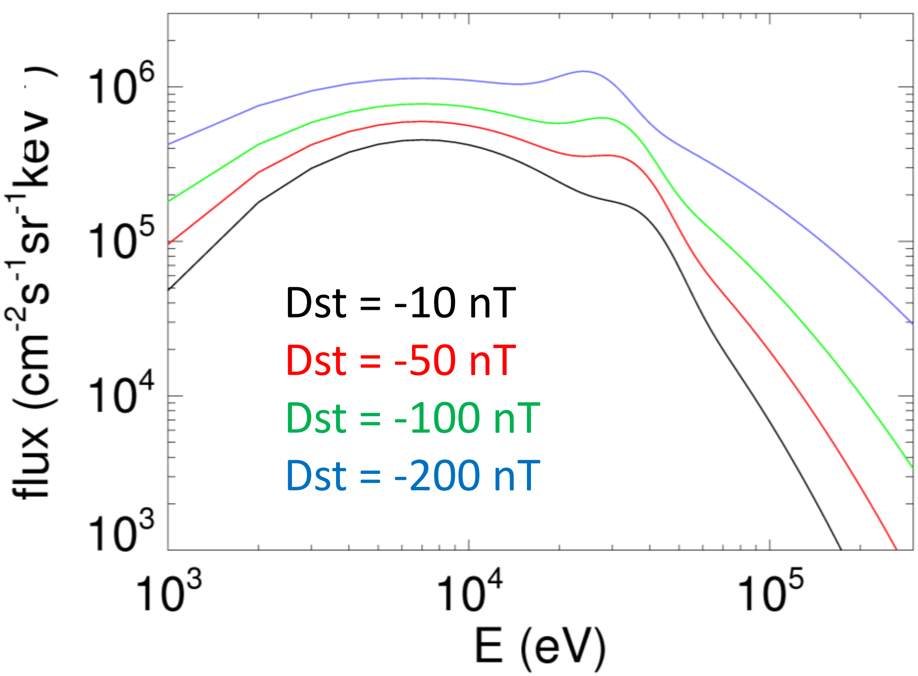
Equatorial ion distribution model

- Milillo et al. (2006)

- empirical model using AMPTE/CCE and LANL satellites

$$f(L) = \left[\mathrm{AG2} \cdot \exp\left(-\frac{(P_D \cdot L - \mathrm{PG2})^2}{2 \cdot \mathrm{WG2}^2}\right) + \mathrm{CO}\right] \cdot \exp\left(-\frac{\mathrm{IS}^2}{(P_D \cdot L - \mathrm{PS})^2}\right) + \mathrm{AG3} \cdot \exp\left(-\frac{(P_D \cdot L - \mathrm{PG3})^2}{2 \cdot \mathrm{WG3}^2}\right)$$

proton flux vs. E at L = 6.6

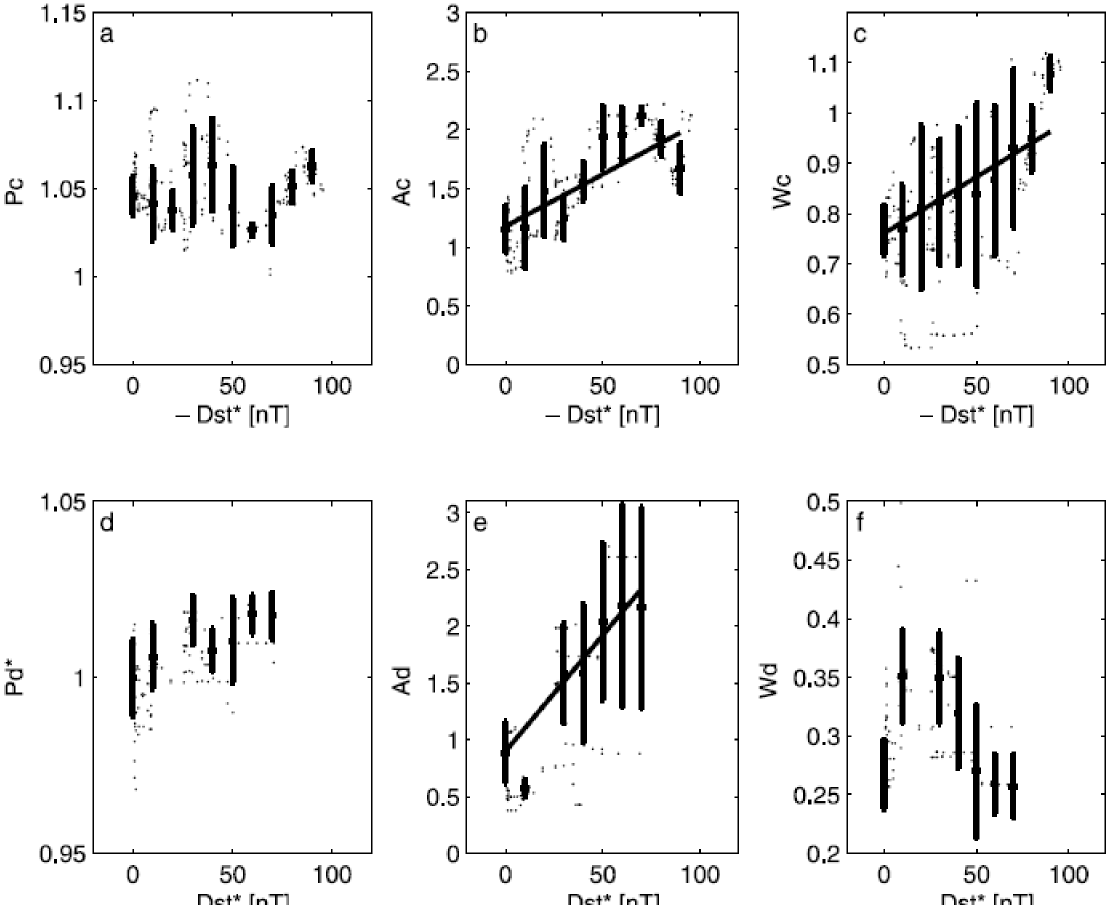


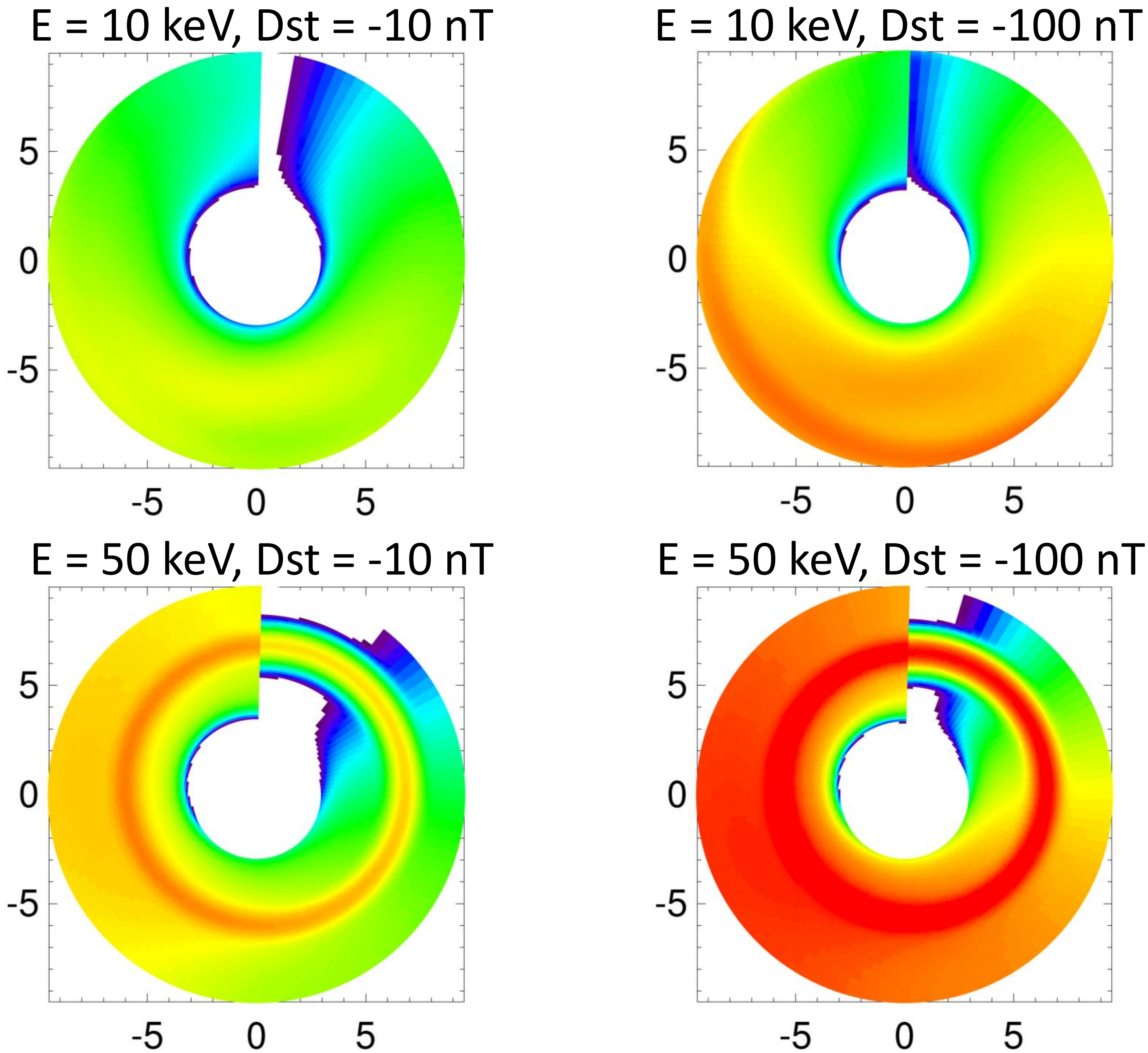
• Milillo et al. (2006)

- geomagnetic activity: Dst dependence

$$A_{CApr01} = -(1 \pm 0.6) \cdot 10^{-2} Dst^* + (1.2 \pm 0.4) \qquad r^2 = 0.80$$

$$W_{CApr01} = -(2.1 \pm 0.5) \cdot 10^{-3} Dst^* + (0.76 \pm 0.03) \qquad r^2 = 0.96$$




E = 10 keV, Dst = -10 nT
E = 10 keV, Dst = -100 nT
E = 50 keV, Dst = -10 nT
E = 50 keV, Dst = -100 nT
5
0
-5
-5
0
5

Pitch angle distribution

- simple $\sin^2(\alpha)$ dependence

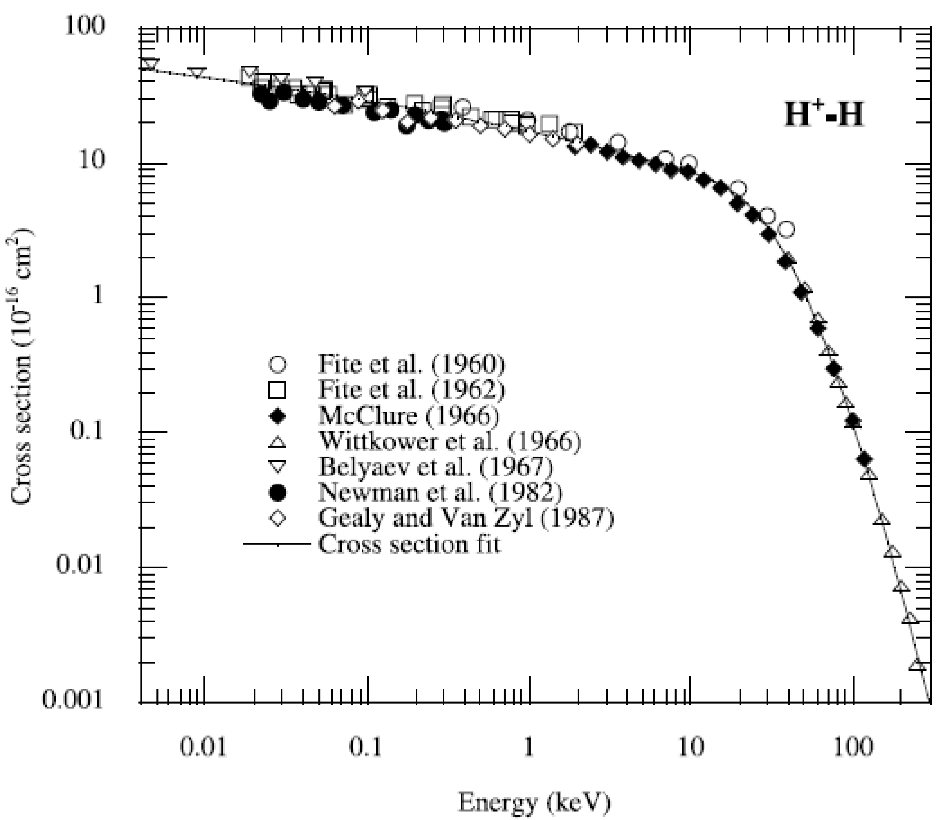
$f(\alpha)=(1+k \sin^2(\alpha))/(1+k)$

Charge exchange cross section

- Lindsay and Stebbings (2005)

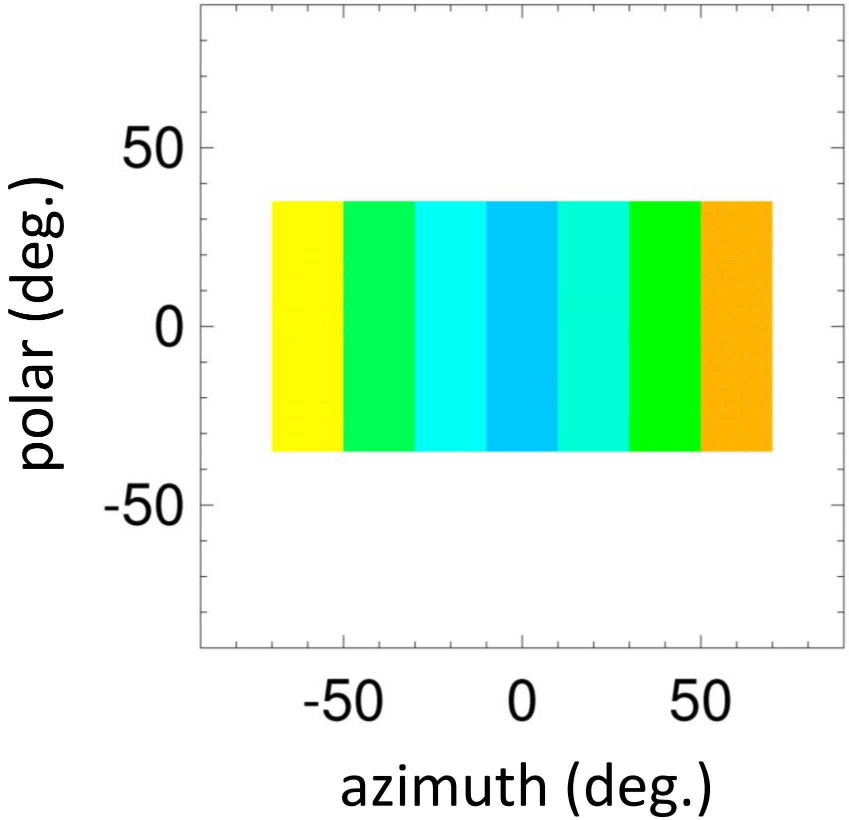
ex.) $H + H^+$: $\sigma(E) = (a1 - a2 \ln E)^2 (1 - \exp(-a3/E))^{4.5}$

$(a1 = 4.15,\ a2 = 0.531,\ a3 = 67.3)$



Simulation Results - Preliminary

- ENA imaging of nightside ring current



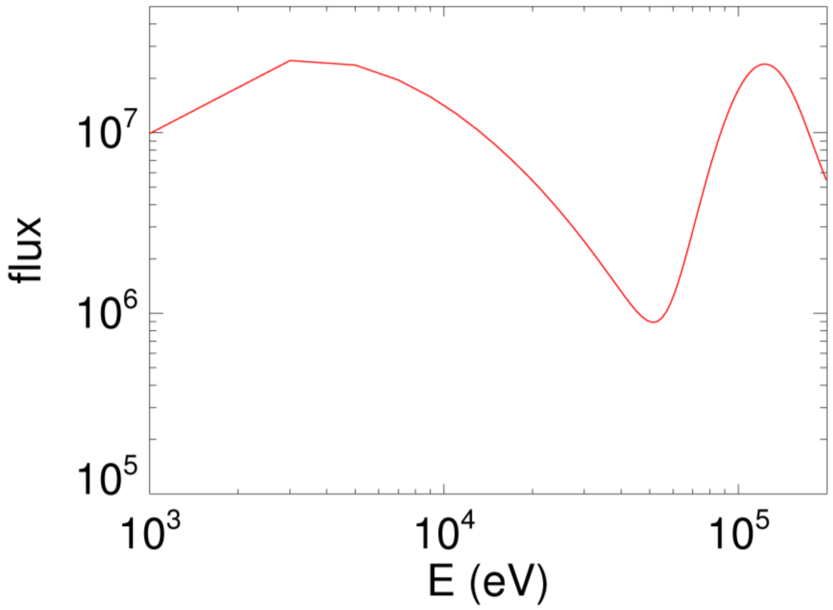
only can get coarse image

- integrated over wide ranges

- cannot specify source locations with only one measurements

→ need elaboration using three point observations

• Energy spectrum



can get good energy spectrum

- we're expecting fine structures in the observed spectrum

Future work

- Empirical models need to be elaborated – including geomagnetic activities: need to incorporate Tsyganenko model and ion flux model with respect to the geomagnetic activities or solar wind conditions.
- Simulation model, e.g., CRCM, will also be used – currently a student is working on using CRCM.
- Temporal variation will be considered using multi-point observations.

Summary

• Modeling of ENA emissions for CINEMA/TRIO is in progress to prepare data analysis.

• A modeling tool has been developed and being tested.

• Preliminary results show that it may be difficult to specify source locations of ENAs due to large FOV.

• Relatively good energy spectrum could be obtained, especially in high energies.