

Instrumentation of Energetic Neutral Atoms for Space Weather Monitoring

Yoshifumi Futaana

X.-D. Wang, S. Barabash, M. Wieser

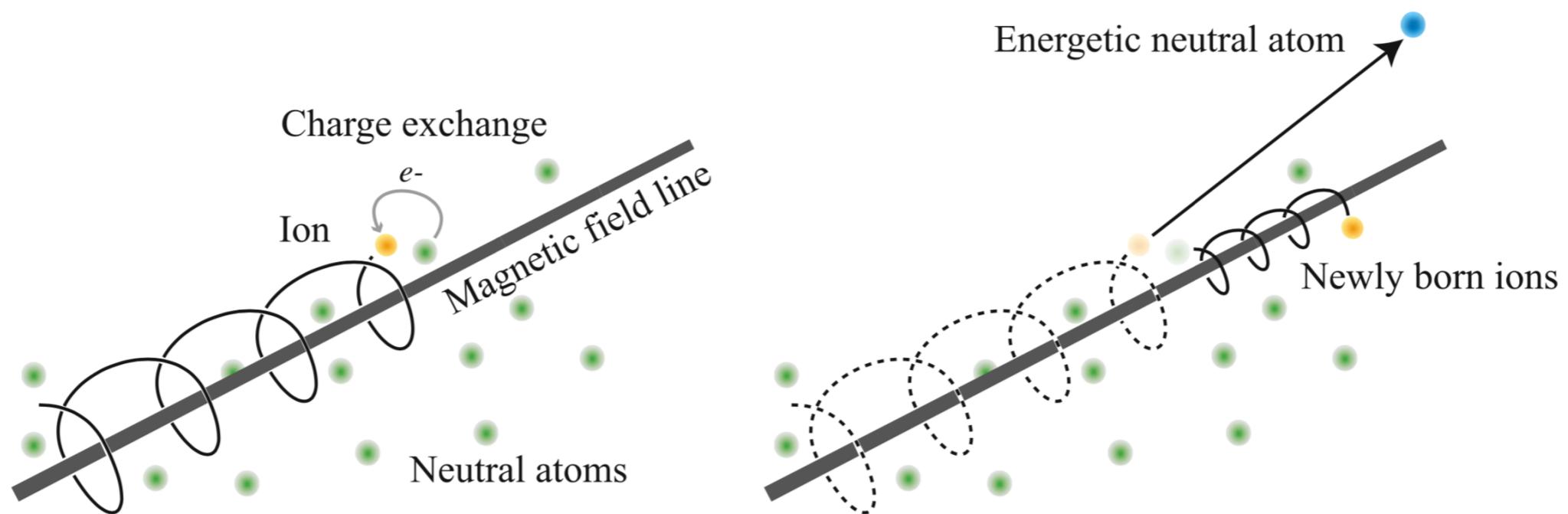
Swedish Institute of Space Physics (IRF), Kiruna, Sweden

P. Wurz (University of Bern, Switzerland)

F. Cipriani (ESTEC, ESA, The Netherlands)

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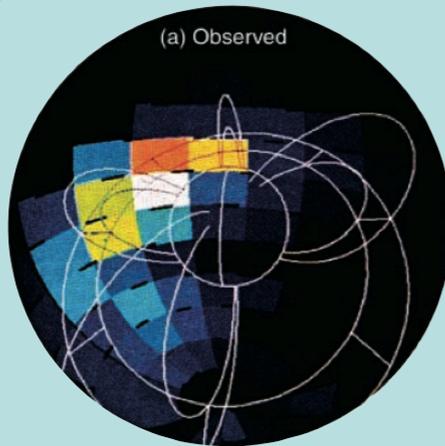
- Energetic Neutral Atoms (ENAs) imaging & spectroscopy for remote sensing of plasma
 - Energetic neutral atoms are produced by interaction of parent plasma and neutral atoms or another plasma population
 - ENAs retain the characteristics of the parent ions
 - ENAs propagate along a ballistic trajectory.



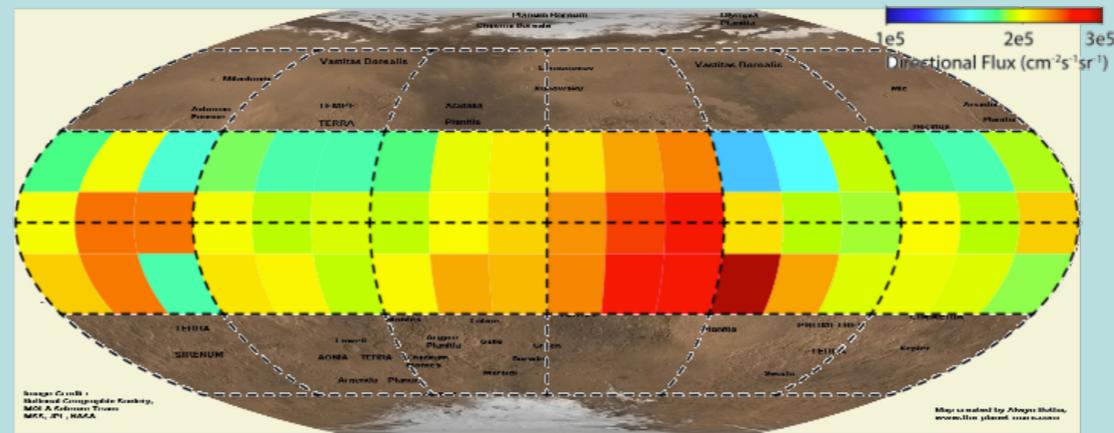
Futaana+2011

Energetic Neutral Atom Imaging

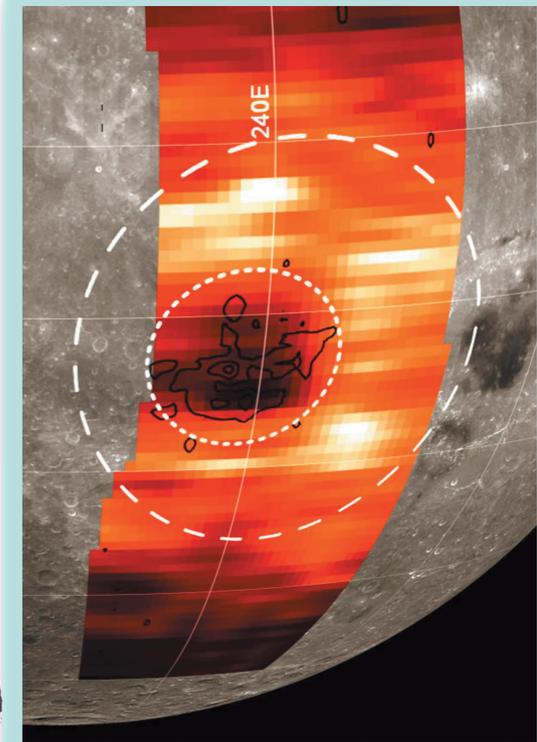
ENA imaging is established technique to investigate space plasma



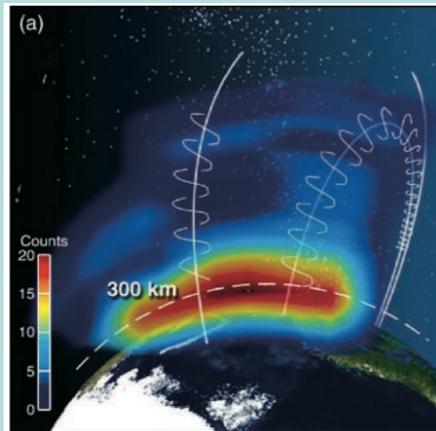
Roelof et al., 1987



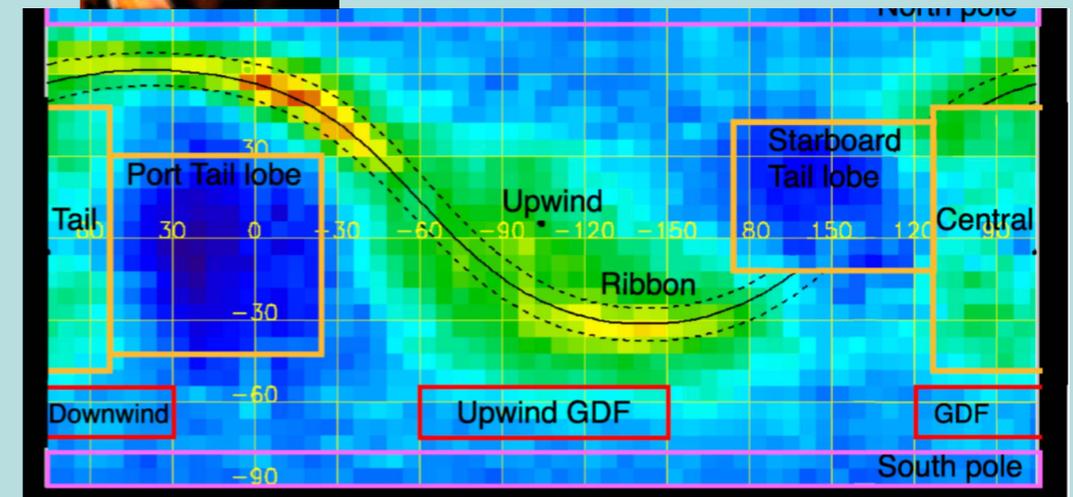
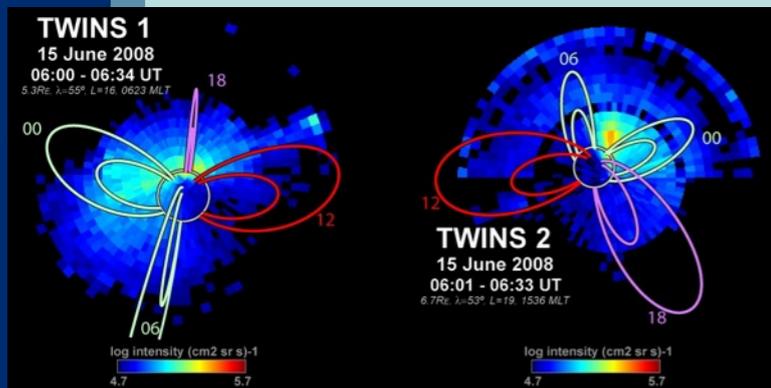
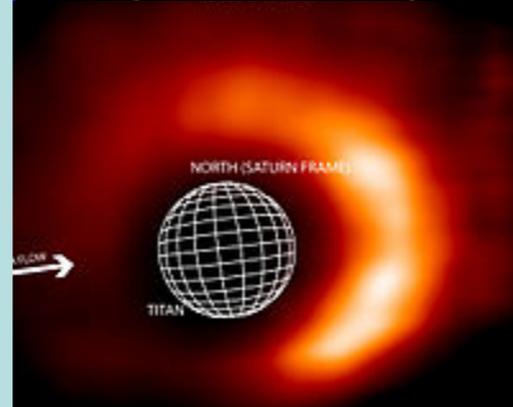
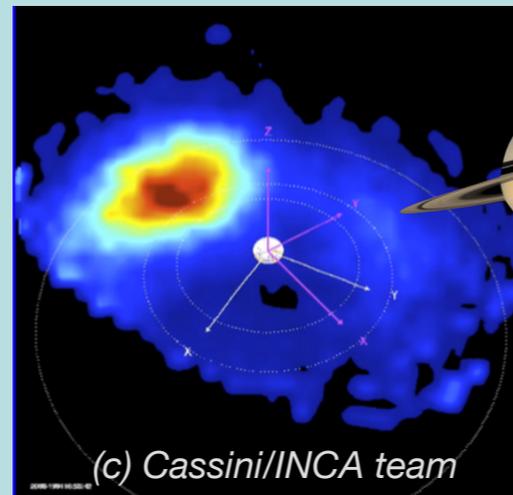
Wang et al., 2014



Wieser et al., 2010



Brandt et al., 2005



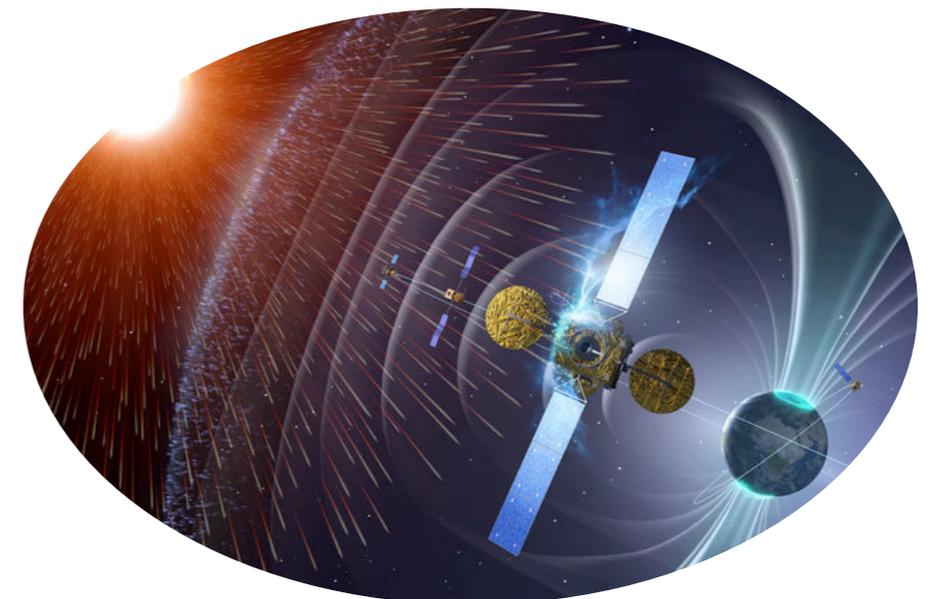
McComas et al., 2017

Why Energetic Neutral Atoms?



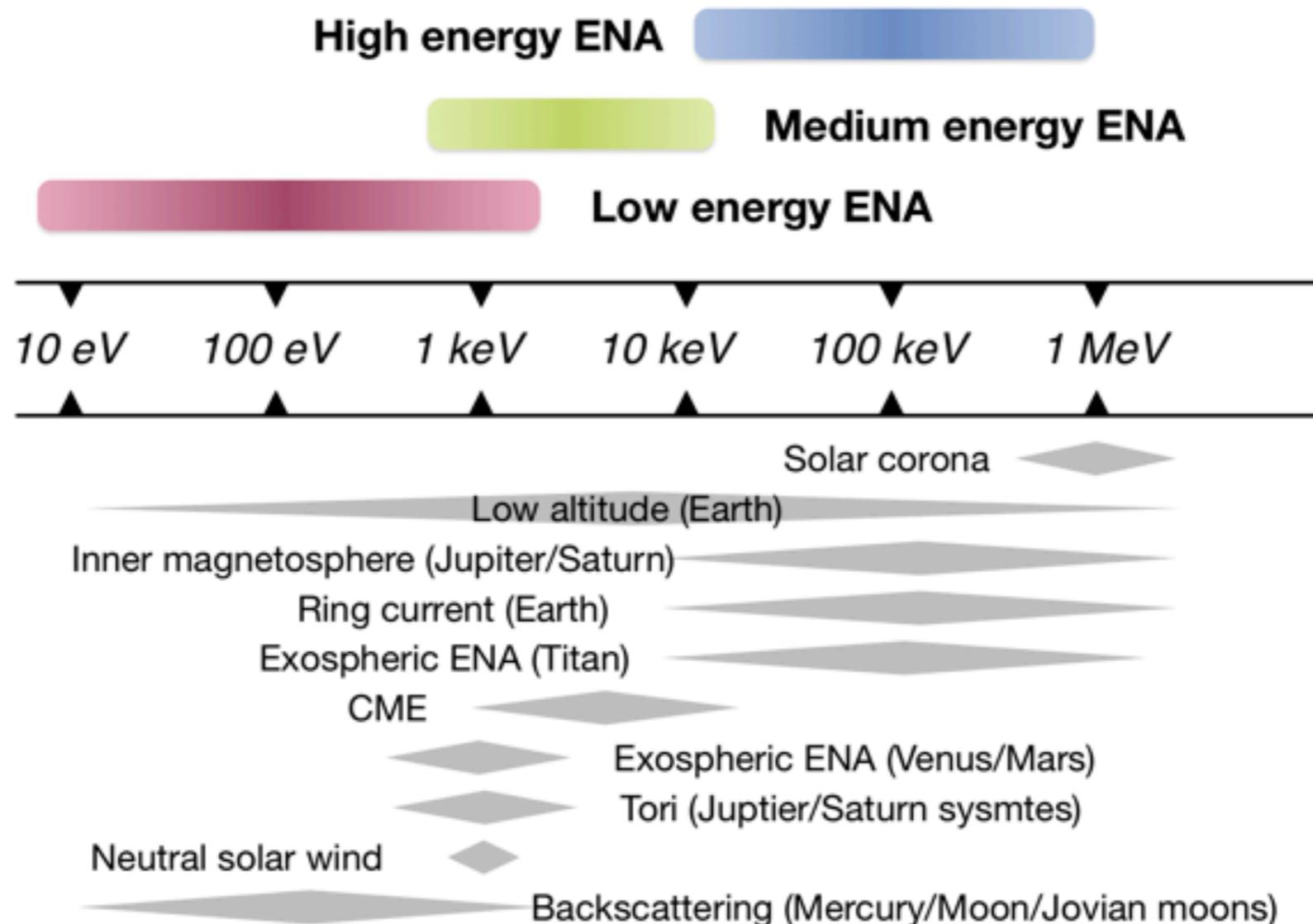
A new channel of space weather monitoring

- Providing complementary data to the conventional instruments
- Unique information to be added
 - From ENA energy spectra, energy spectra of remote plasma (integration from Sun to Earth) can be reconstructed
 - More precise and detailed understanding of the complicated system

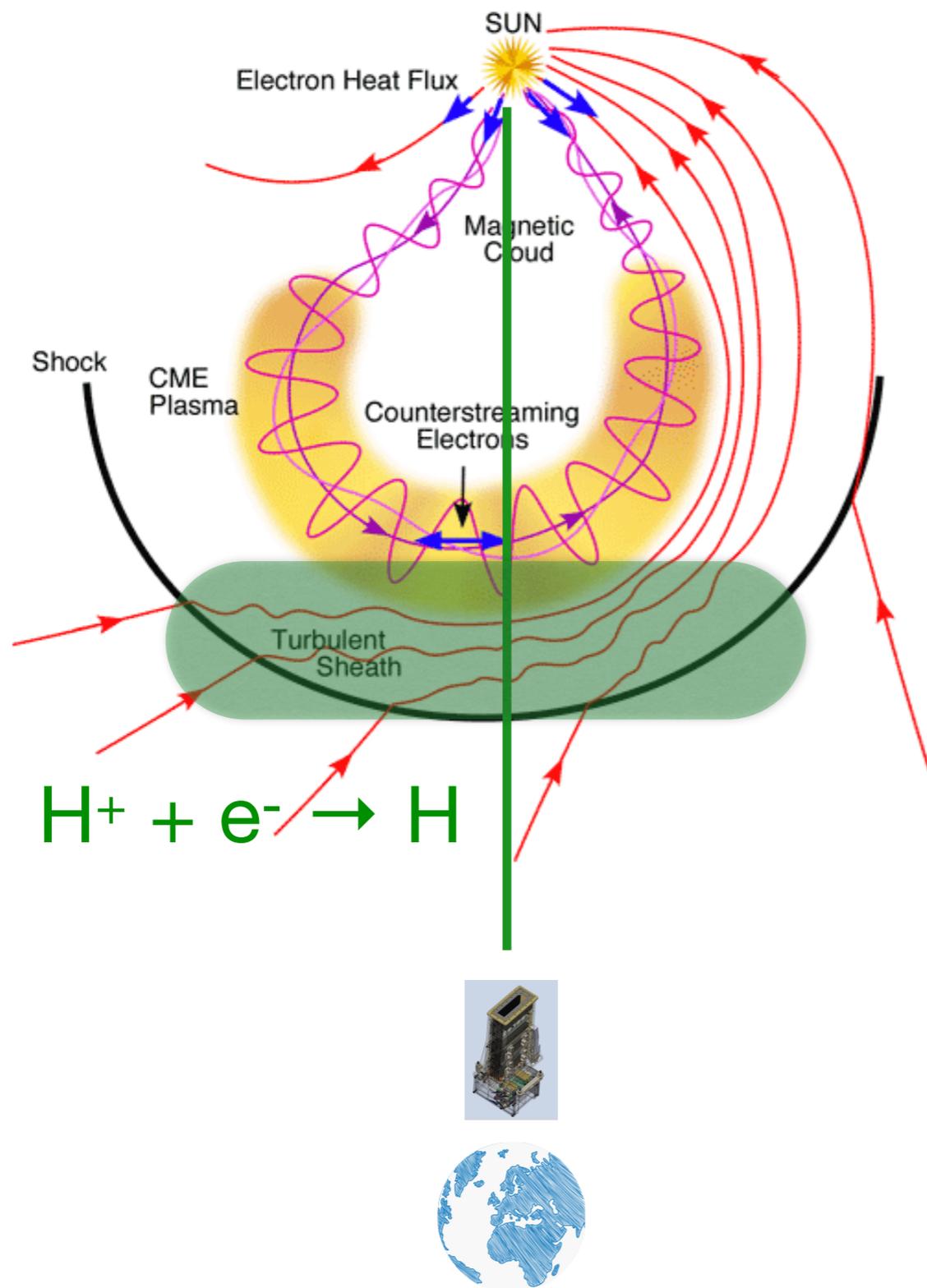


ENA instrumentation: A challenge

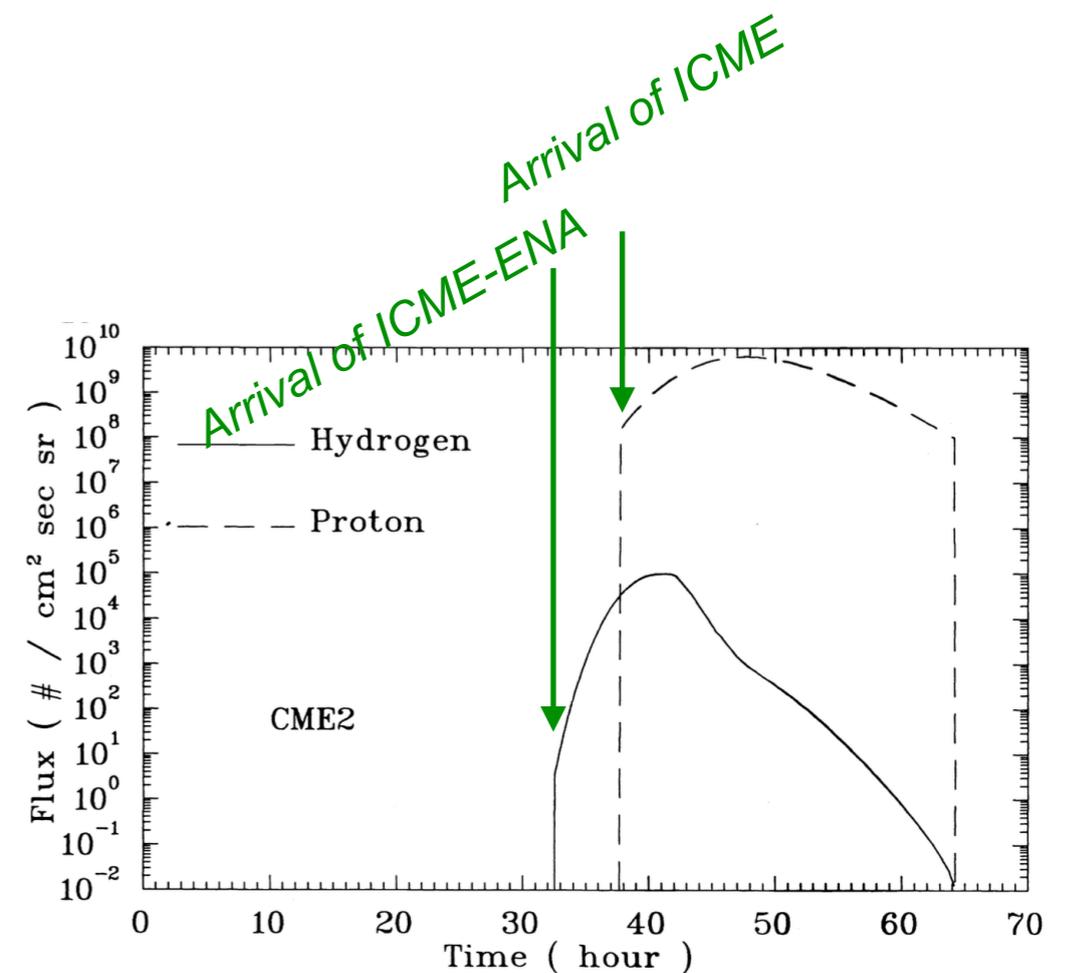
- ENAs fly straight. No deflection. No mirror. Ionization needed. Efficiency of ENA instrument becomes so low
- No technology available for high energy plasma in Europe
- Low energy ENA focused



Monitoring ICME produced ENA

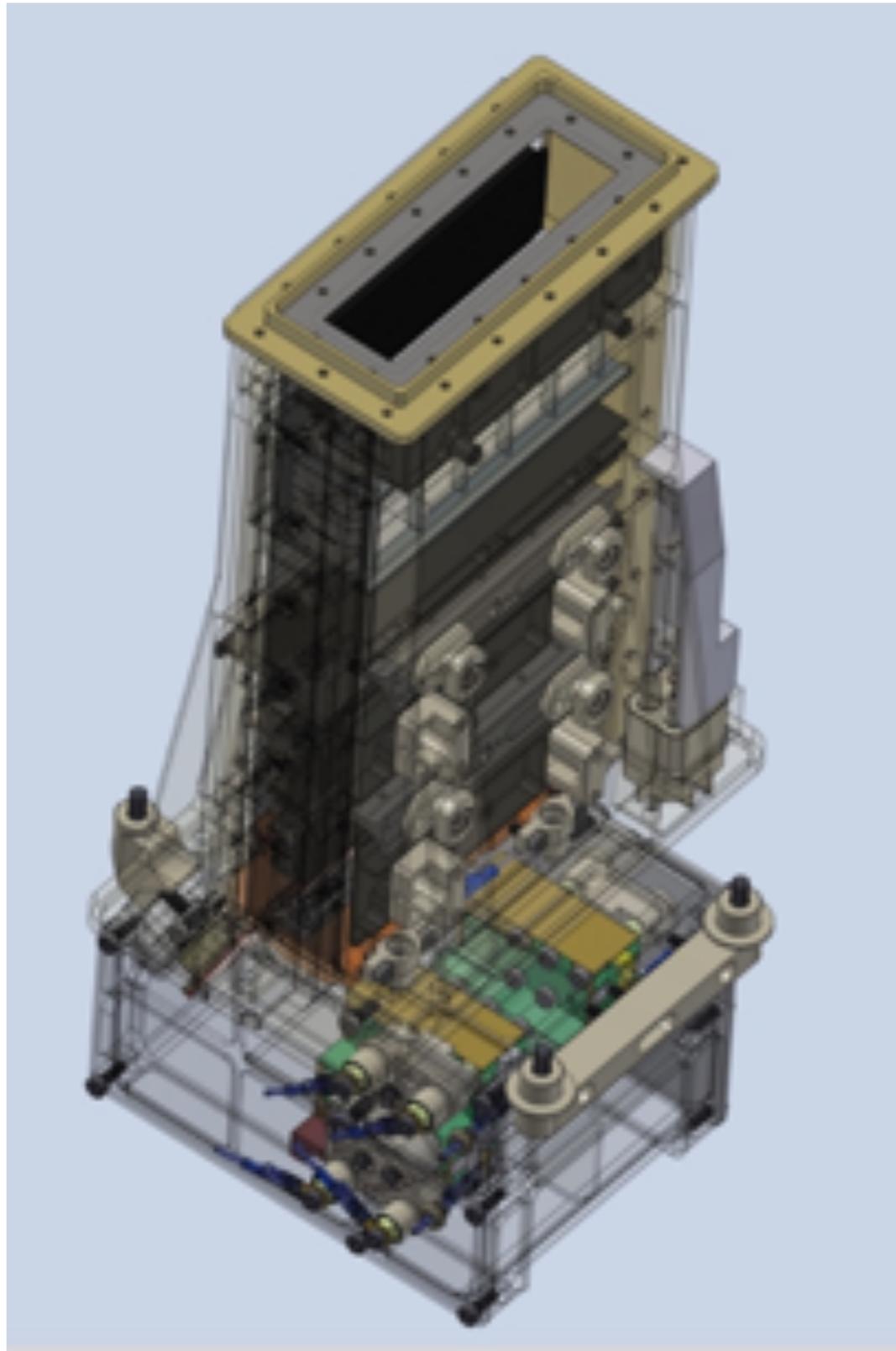


- Objectives: Unique dataset
 - ICME arrival (several hours before)
 - ICME/IPS proton characteristics (energy)



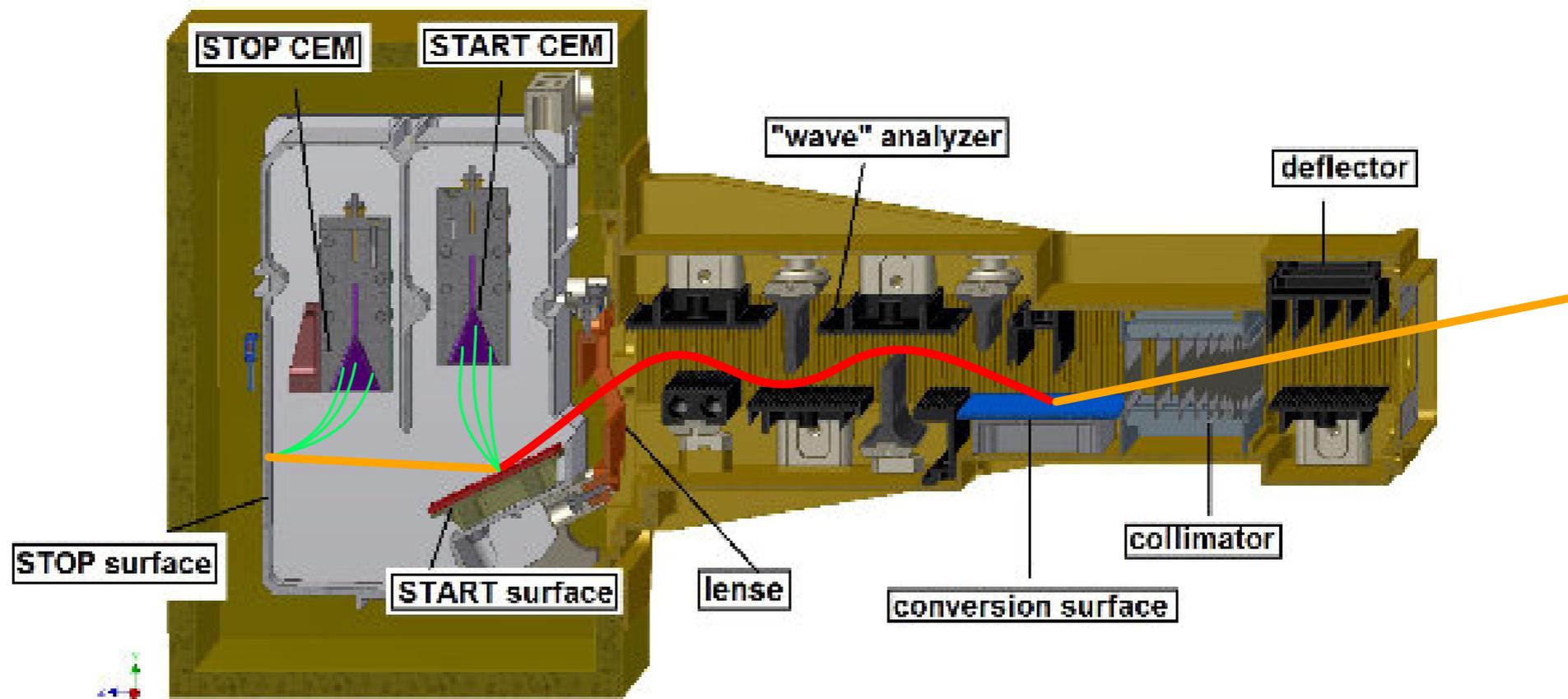
Hsieh, 1992

The NANT instrument



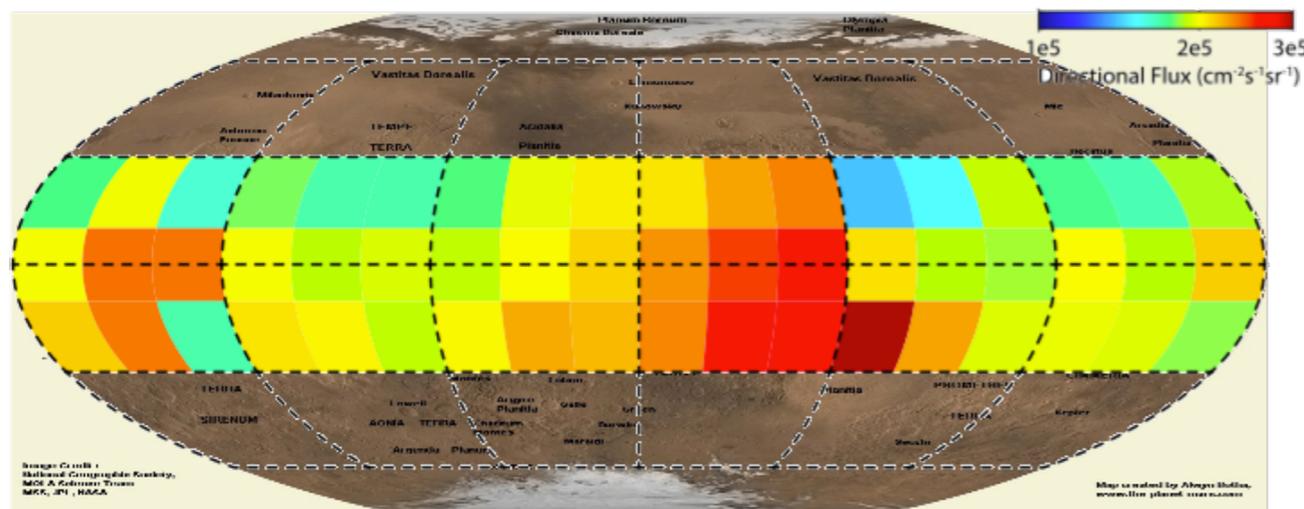
- NANT (Narrow Angle Neutral Telescope) instrument
- Matured technology
 - Replica of the Lunar Neutral Telescope (LNT) developed for Lunar Resource Orbiter (Roscosmos)
- LNT STM, EM delivered. FM 50% manufactured

- Functionality
 - Single pixel ENA instrument
 - Ionization by surface interaction
 - Wave analyzer for energy analysis (sweeping by time)
 - TOF system for mass derivation

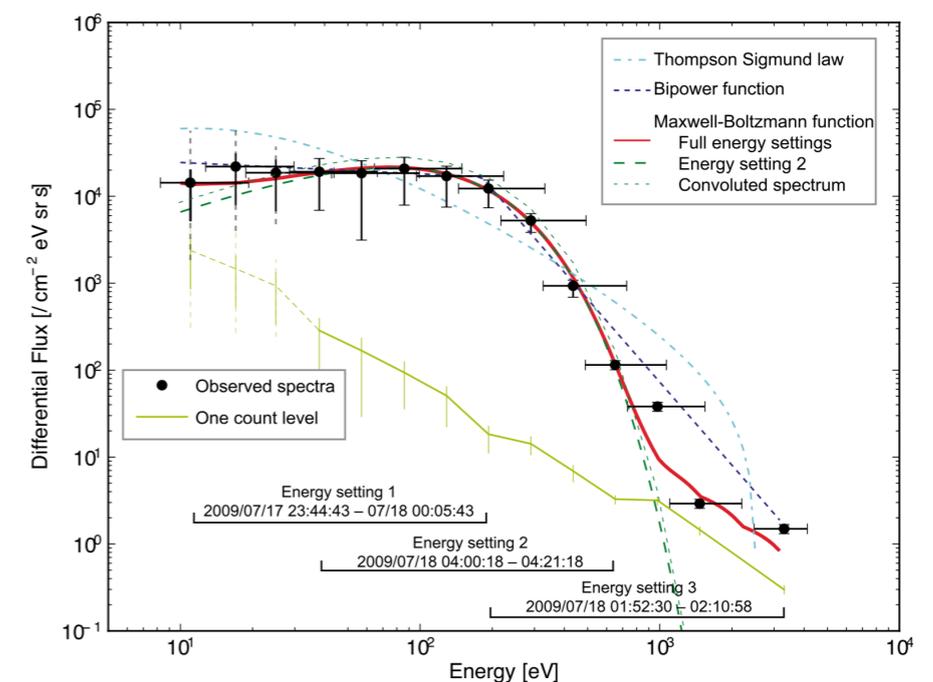


- Heritage of ENA sensors at IRF
 - PIPPI / Astrid-1 (1995)
 - Mars Express / NPI, NPD (2003)
 - Venus Express / NPI, NPD (2006)
 - Chandrayaan-1/CENA (2009)
 - Chang'E-4/ASAN (2018)
 - BepiColombo/ENA (launch in 2018)
 - JUICE/JNA (EM delivered. FM under production)
 - Luna 26 / LNT (EM delivered. FM under production)

Statistical ENA map from Mars
[Wang et al., 2014]



Observed ENA spectra from lunar surface
[Futaana et al., 2012]



- Mechanical design / Electronics design matured
 - Energy range can be extended (by voltage setting optimisation)
 - Mass can be reduced (by mechanical design optimization)
 - Geometric factor can be increased (with development processes)

Energy range	10 eV – 3.3 keV
Energy resolution	50 %
Mass resolution	H, O, Na/Mg-group, K/Ca-group, Fe
Field of view	15x15°
Angular resolution	6x6° FWHM, 1 pixel
Geometric factor	10 ⁻² cm ² sr eV/eV per pixel. Efficiency 1–5%
Mass	3.8 kg (including contingencies and 20% margin)
Power	12 W (max), 10 W (nominal)
Volume	225 x 154 x 247 mm ³
Electric Interface	Bus voltage 3.3V (flexible)
Data interface	Serial link for data transfer. 100 kbps (TBD)

- ENA monitoring adds independent information about space weather in the inner solar system
 - Integration of plasma characteristics from the Sun to the Earth
 - Orbit flexible (from LEO to L1/L5)
 - Pointing: Sun-pointing
- ICME ENAs and SW ENAs
 - ICME arrival with VDF information
 - SW parameter from low orbits
- The NANT design is ready, STM/EM manufactured, and FM under production
- Development to achieve higher performance with fewer resources can be possible
- More information: futaana@irf.se

