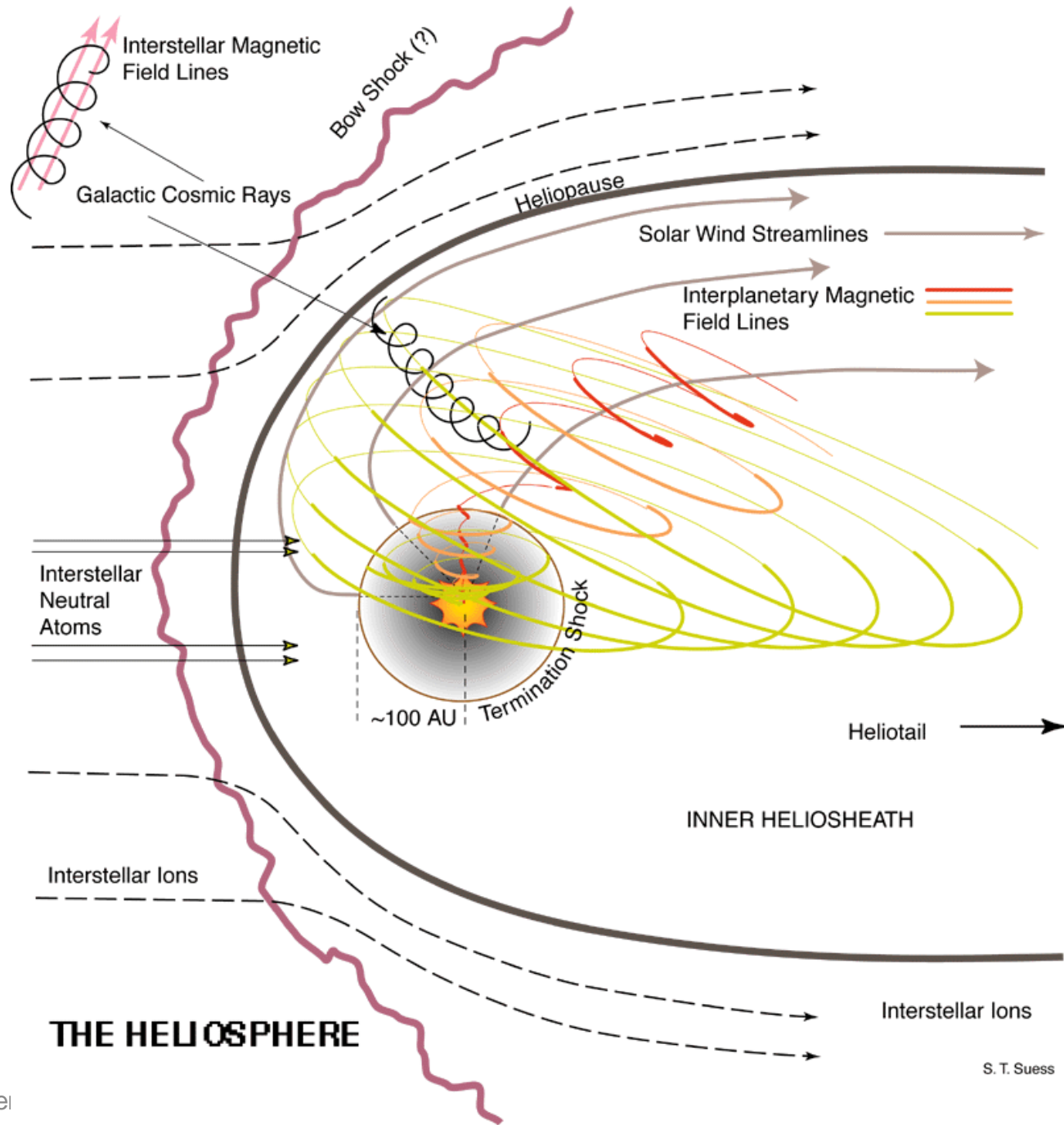# Application of EUV Measurements for the Derivation of Parameters for the Interstellar Gas Flow through the Heliosphere

Peter Bochsler and Eberhard Möbius*)

Space Science Center and Department of Physics

University of New Hampshire

*) also at Space Science and Applications

Los Alamos National Laboratory

THE HELIOSPHERE

Interstellar Magnetic Field Lines

Bow Shock (?)

Galactic Cosmic Rays

Heliopause

Solar Wind Streamlines

Interplanetary Magnetic Field Lines

Interstellar Neutral Atoms

~100 AU

Termination Shock

Heliotail

INNER HELIOSHEATH

Interstellar Ions

Interstellar Ions

S. T. Suess
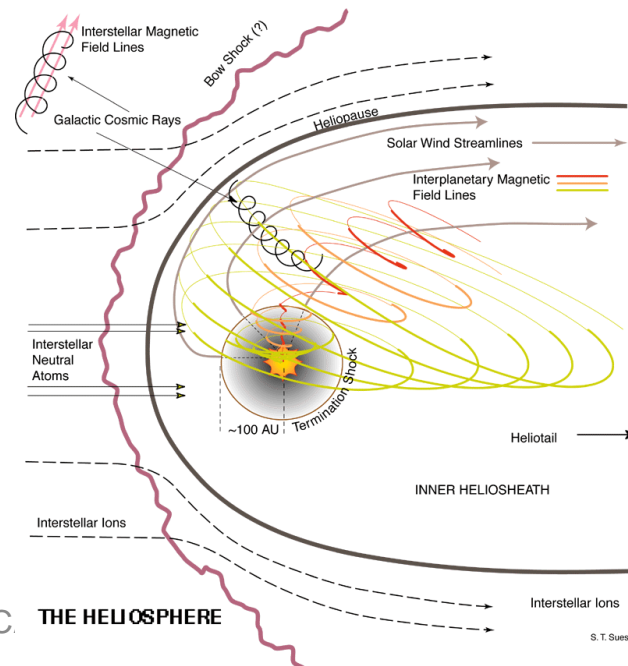
Characteristics of the Interstellar Gas

Speed at infinity: 23.5 + 3.0(-2.0) km/s = 4.95 AU/y

T_{He} = 5000-8200K

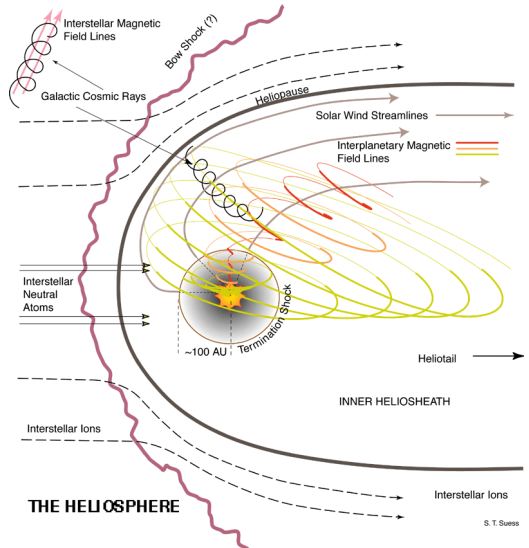Typical speed at 1 AU (due to gravitational acceleration) :
     48 km/s = 10 AU/y

Travel time from termination shock to 1 AU: ~ 20 y.

THE HELIOSPHERE

Interaction of Solar EUV with Interstellar Neutrals

Radiation pressure
(e.g., resonant interaction of H atoms with Lyman-α)
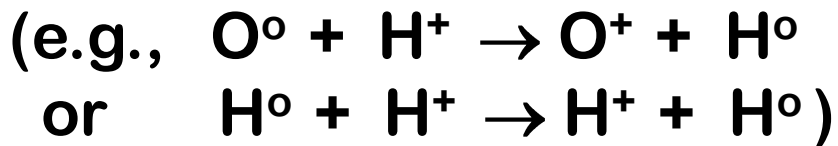
Photoionization

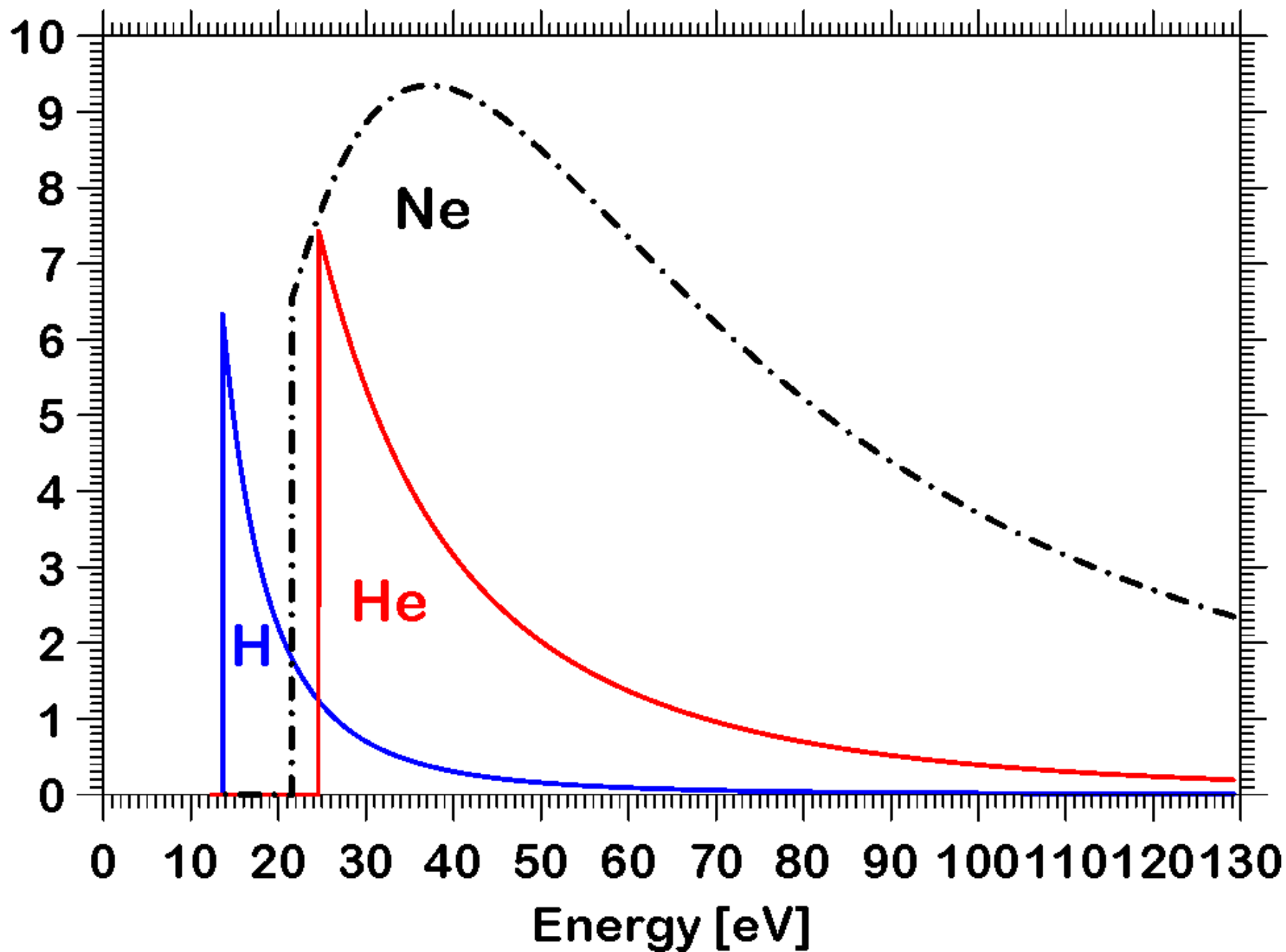# Ionization of Interstellar Neutrals in the Inner Heliosphere

Photoionization

(Resonant) Charge Exchange with Solar Wind Ions
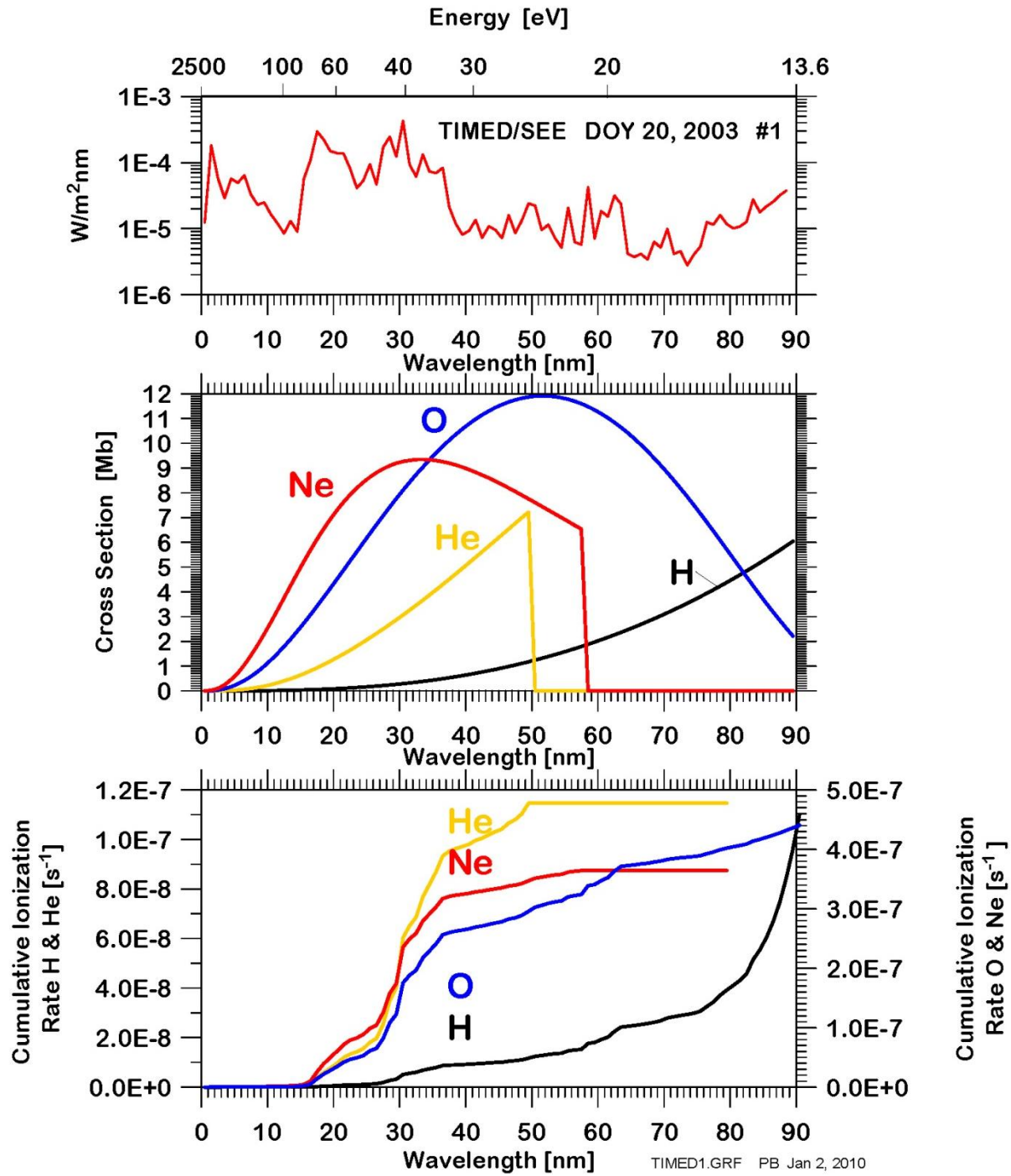
(e.g., $O^o + H^+ \rightarrow O^+ + H^o$
or $H^o + H^+ \rightarrow H^+ + H^o$)

Collisional Ionization by Solar Wind Electrons

(recombination is very slow because of low densities!)

TIMED1.GRF   PB Jan 2, 2010

Spatial and temporal variability of ionization rates at 1 AU

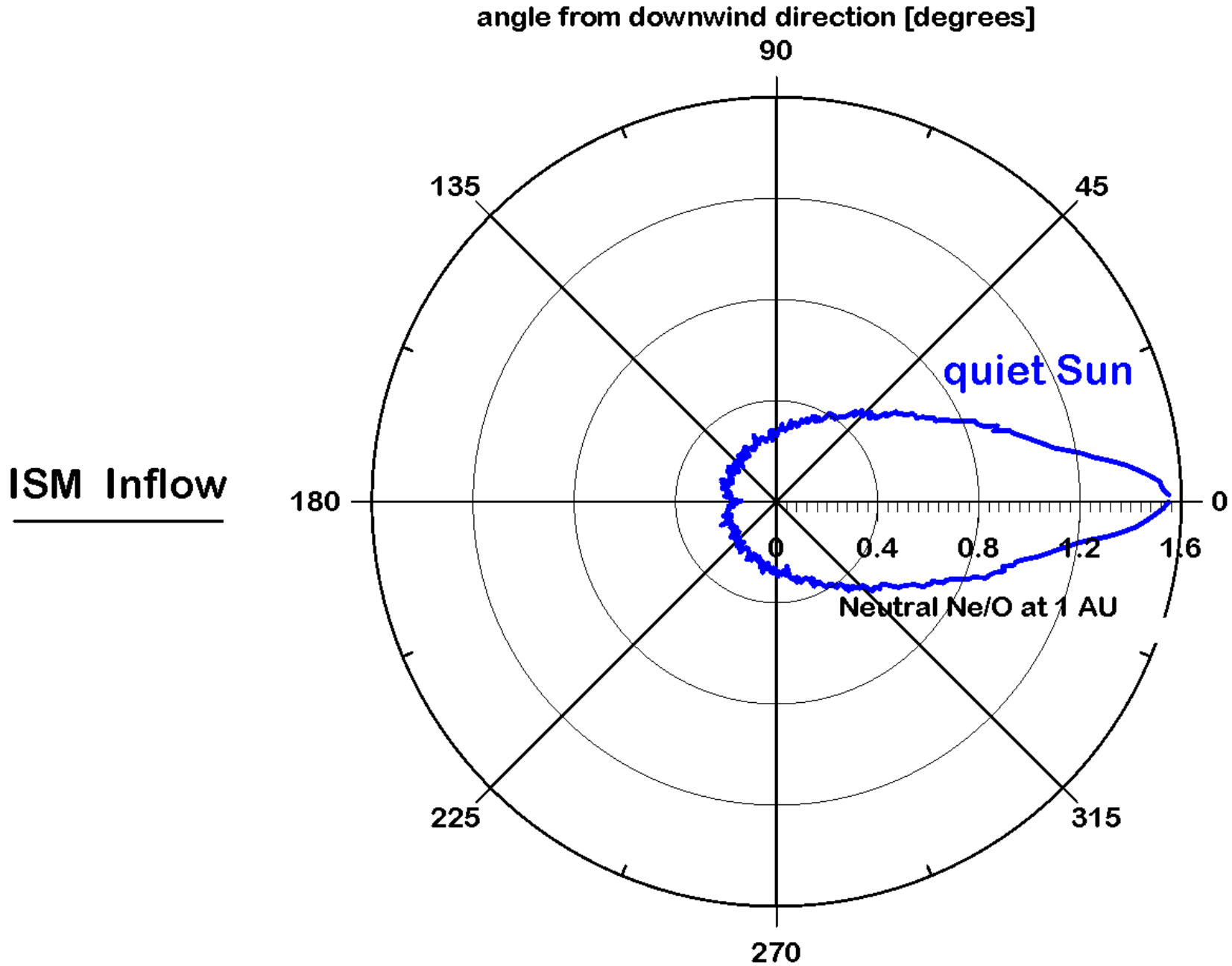Required time resolution determined by travel times of neutrals: ~ 1 AU/month

Short time flares only of importance if they contribute significant fraction to total EUV fluence

Latitudinal dependence of solar EUV is required

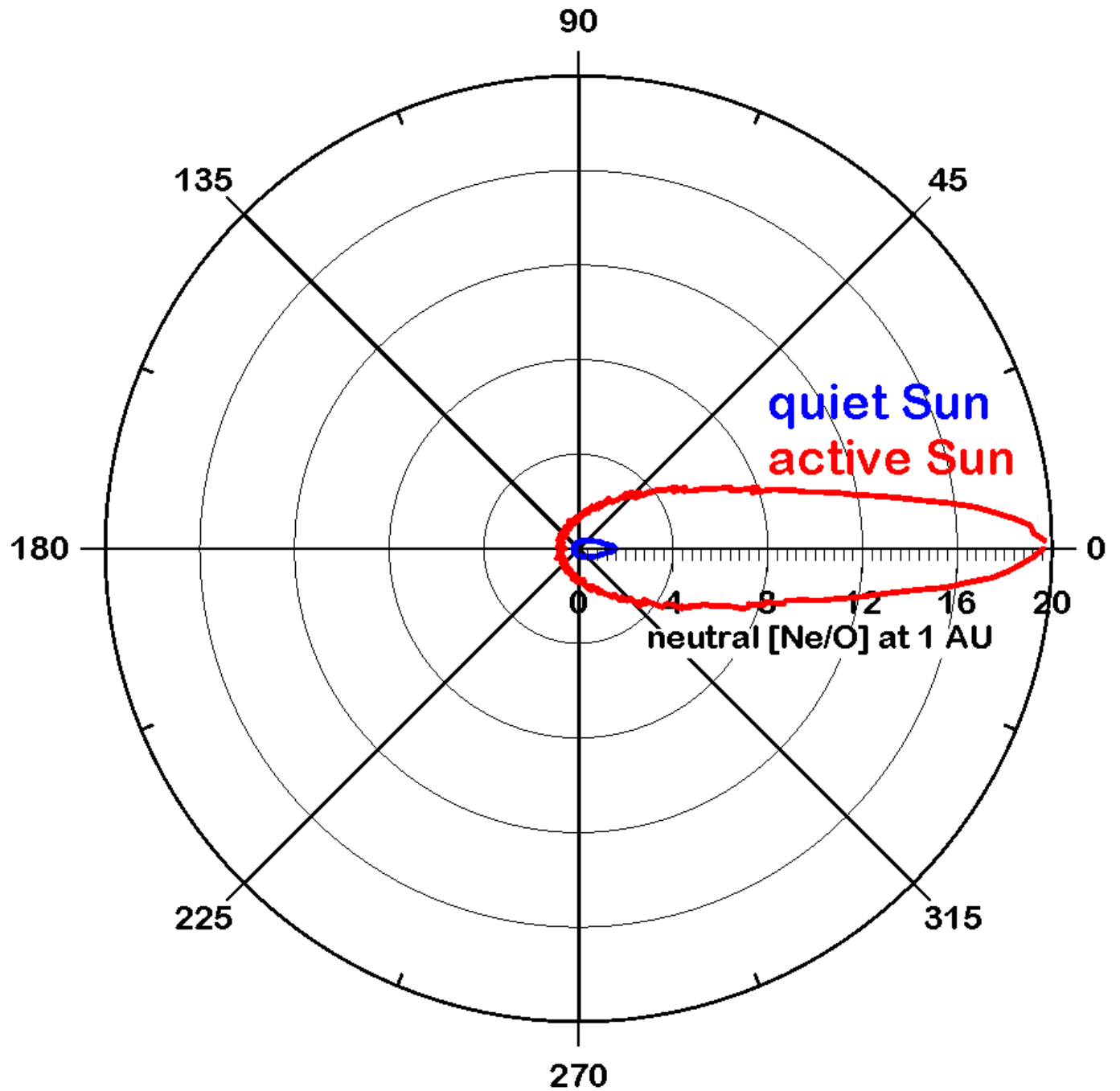**Spatial and temporal variability of ionization rates at 1 AU**

Examples of neon and oxygen

ISM Inflow

angle from downwind direction [degrees]

quiet Sun

Neutral Ne/O at 1 AU

ISM Inflow

quiet Sun
active Sun

neutral [Ne/O] at 1 AU

90
135
45
180
0
0 4 8 12 16 20
225
315
270

ISM_COMBINE.GRF   PB   April 4, 2011

IBEX-Lo

IBEX-Hi
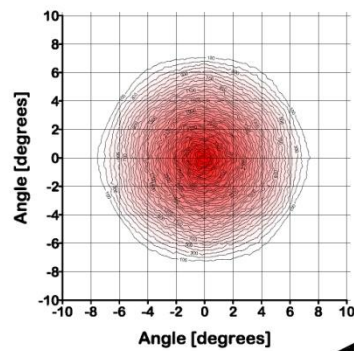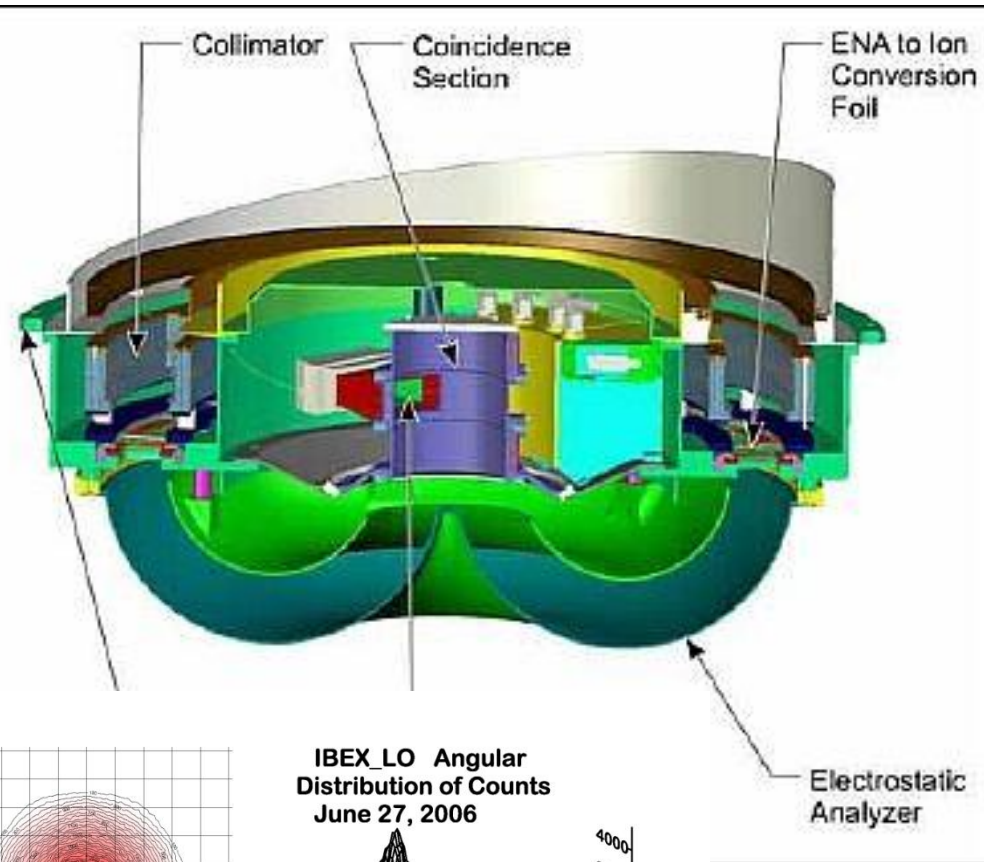
IBEX_LO Angular
Distribution of Counts
June 27, 2006

Launch Vehicle
Launch to 200 km circular injection orbit

Pegasus Avionics Ring

Pegasus XL Launch Vehicle
No modifications to standard XL.

Solid Rocket Motor
Boost to 37 R_E apogee transfer orbit

Motorized Lightband separation systems

Adapter Cone

STAR 27 SRM

STAR 27 Solid Rocket Motor
Simple spinning upper stage. Provides delta-V to raise apogee to 37 R_E.

Spacecraft
Boost perigee to 7000 km
Perform science mission
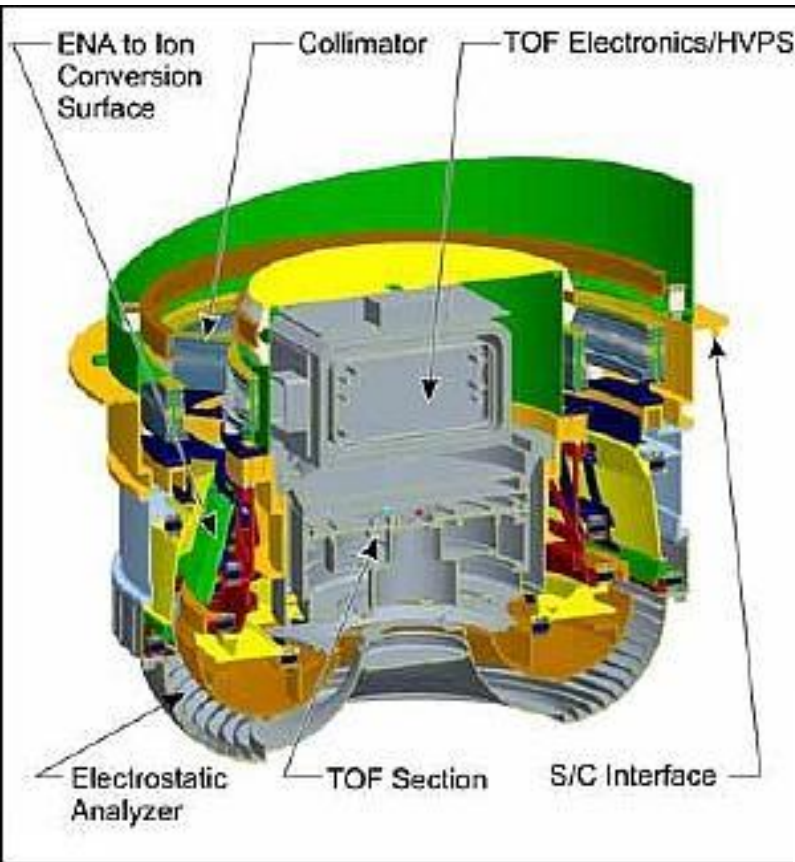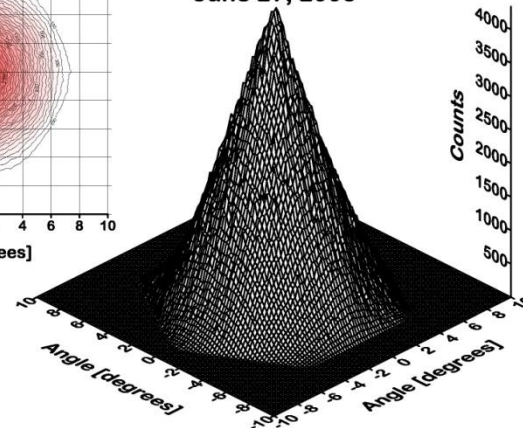
IBEX-Lo

IBEX-Hi

Spacecraft
Orbital's MicroStar S/C bus. Separates from SRM after SRM burn completed. Hydrazine system used to boost perigee to > 7000km.

Payload
Dual 7° x 7° ENA cameras

IBEX-Lo
0.01-2 keV in 8 energy bands

IBEX-Hi
0.3 - 6 keV in 6 energy bands

Combined Electronics Unit (CEU)

APPLICATIONS FOR ISM

A Simple Set-up:

Models describing the motion of neutral interstellar gas atoms through the inner heliosphere are particularly simple (e.g., much simpler than solar wind models)

The IBEX experiments have simple, well-behaved properties

A Simple <u>Set-Up</u>:

Models describing the motion of neutral interstellar gas atoms through the inner heliosphere are particularly simple (e.g., much simpler than solar wind models)

The IBEX-Lo experiment has simple, well-behaved properties

➤ **Potential for very precise determination of flow parameters**

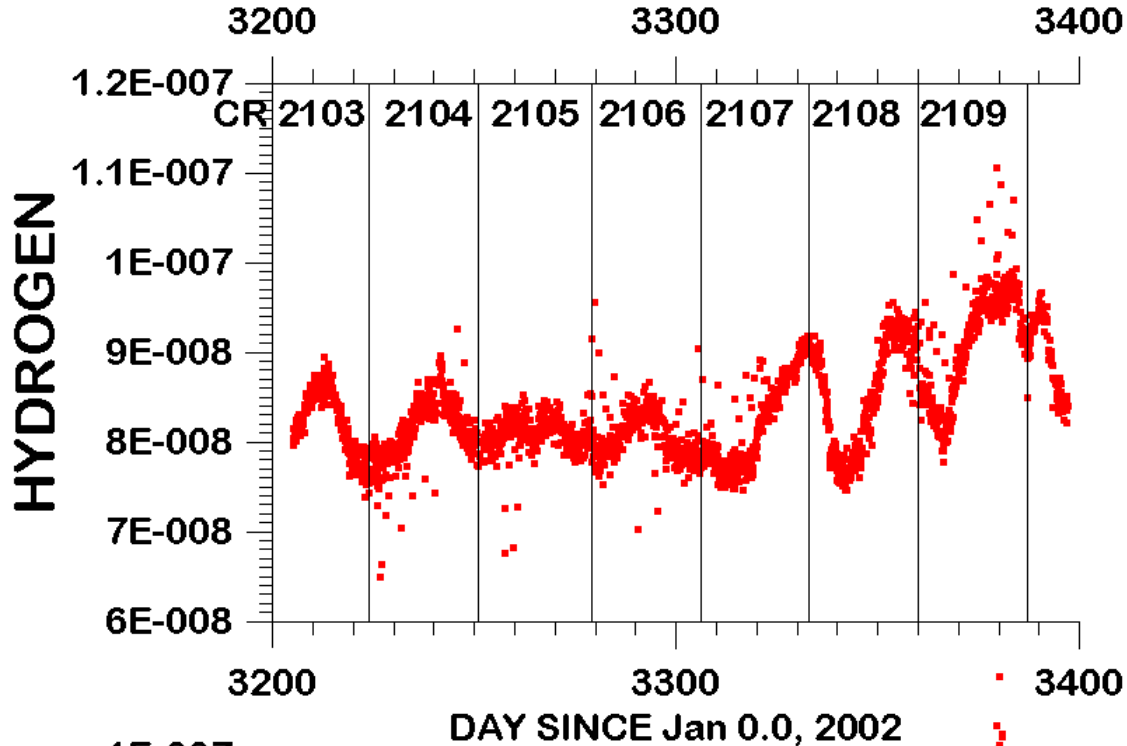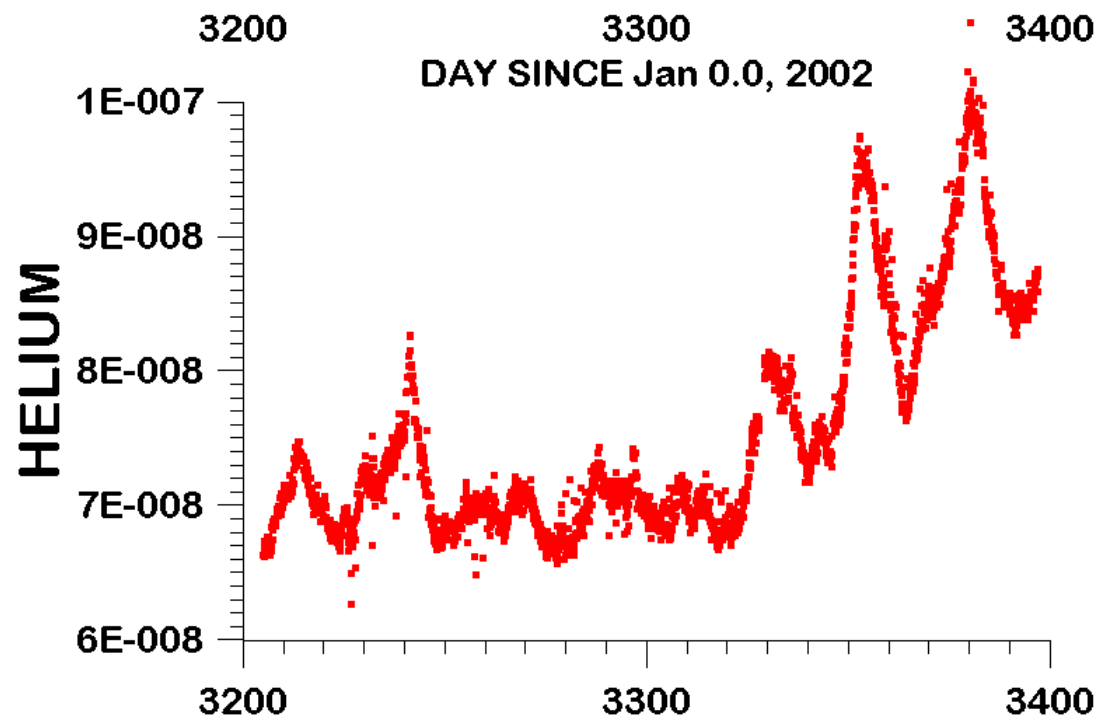➤ **Crucial ingredient: Photoionization rates with <10% uncertainties**

HYDROGEN

CR 2103 | 2104 | 2105 | 2106 | 2107 | 2108 | 2109

DAY SINCE Jan 0.0, 2002

HELIUM

Table 1. Typical ionization rates of neutral species at 1 AU (in units of 10^{-7}s^{-1})

El.	photoionization		elec.	charge	total	total
	quiet	active	collis.	exch.	quiet	active
	Sun	Sun	ioniz.	protons	Sun	Sun
H	0.62	2.47	0.65	2.07	3.34	5.19
He	0.48	1.90	0.11	0.00	0.59	2.01
B	43.0	23.0	3.04	-	≥8.80	≥26.1
C	5.00	20.0	12.00	0.04	7.05	22.1
N	2.21	8.84	1.04	0.31	3.57	10.2
O	2.20	8.80	0.89	1.00	4.09	10.7
F	1.91	7.64	2.18	-	≥4.09	≥9.82
Ne	1.57	6.28	0.18	0.00	1.75	6.46

TIMESERHHE.GRF PB April 29, 2011

OXYGEN

CR 2103 2104 2105 2106 2107 2108 2109

DAY SINCE Jan 0.0, 2005

NEON

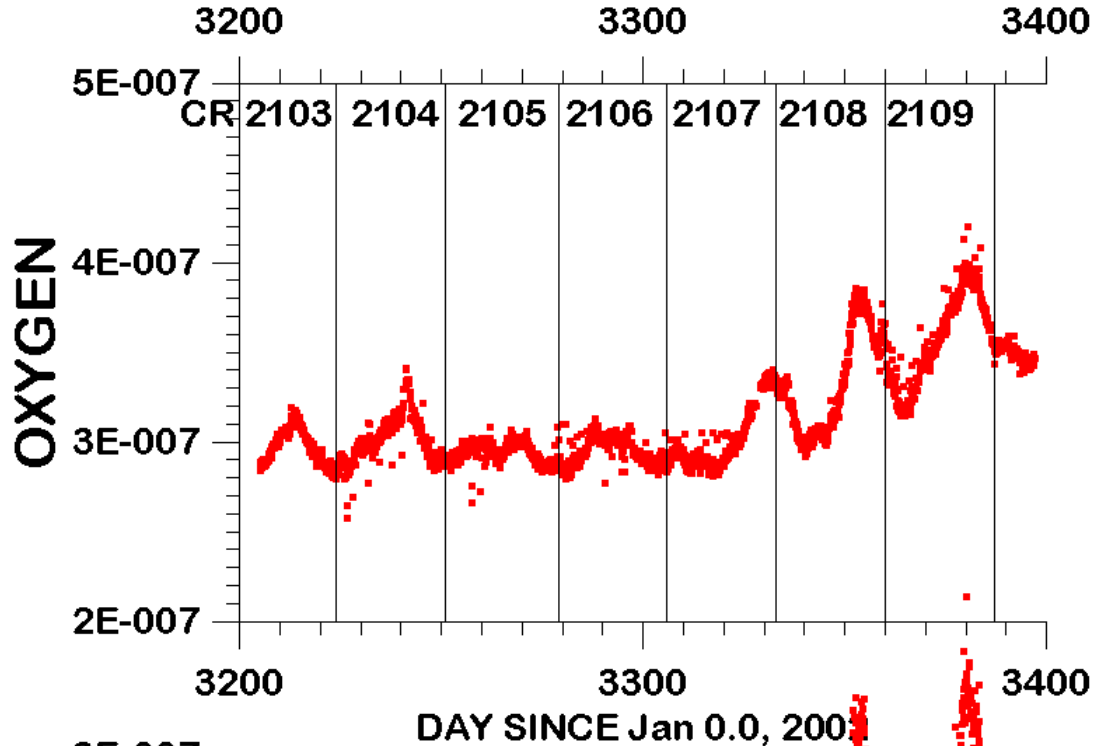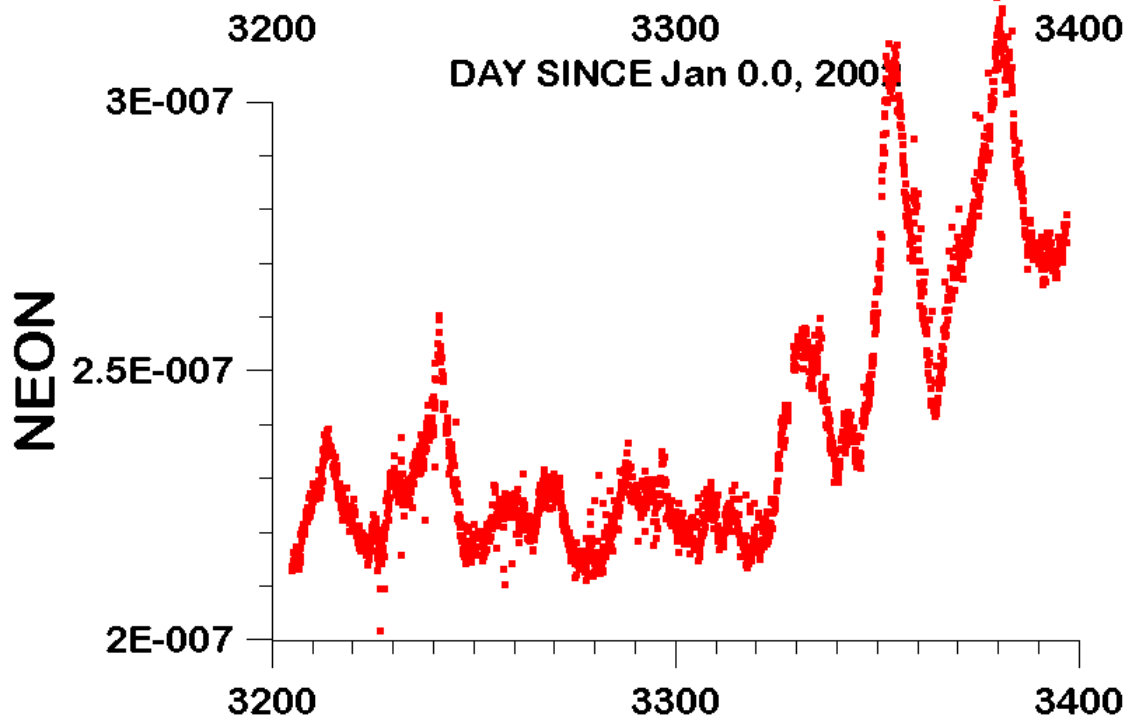*Table 1. Typical ionization rates of neutral species at 1 AU (in units of $10^{-7}s^{-1}$)*

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TIMESERONE.GRF PB April 29, 2011

18

Importance of Ionization for Pickup Ions

•Pickup Ions are an important secondary product of neutral gas populations in the solar wind
Generated by Ionization

•Pickup Ion Velocity Distribution reflects
Neutral Gas Distribution from the Sun to the Observer

•Ionization Rate is of Dual Importance
- Determines radial neutral gas gradient close to the Sun
→ Shape of the Pickup Ion Distribution
-Determines absolute Pickup Ion Flux

•Shape of the Pickup Ion Distribution is a window on Transport processes
→ Ionization Rate must be known

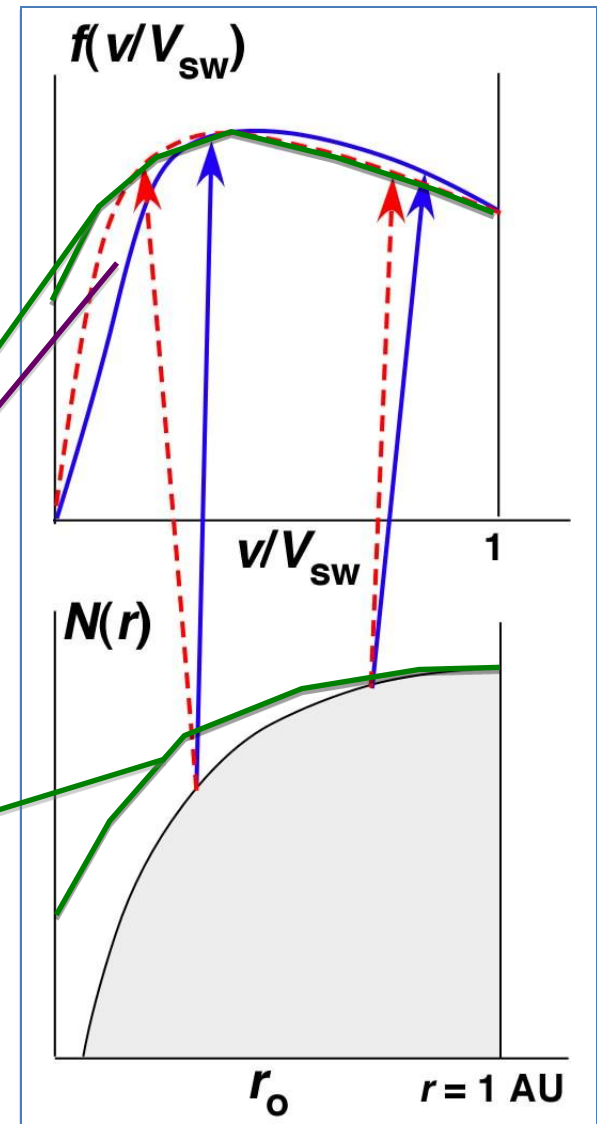# Combination of Ionization & Cooling in Pickup Ion Distribution

•**PUI Distribution Determined by Ionization & Cooling:**

$$f(v/V_{sw}) = \frac{3}{8\rho} \frac{n_{ion\,E}\,r_E}{V_{sw}^{4}} N(r(v/V_{sw})) \cdot \left(\frac{v}{V_{sw}}\right)^{-a}$$

$$N(r) = N_o\, e^{-\Lambda\beta(\sqrt{1+2/\beta r}-1)}$$

Along Inflow Axis
•**Varying α changes the shape**
•**Varying Ionization, i.e. Λ changes the shape**
•**→ Ionization Rate needed to evaluate Cooling**

Conclusions

- Ionization rates are crucial ingredient to the determination of flow parameters of interstellar neutrals

- Neutrals carry information about the local environment of the heliosphere, which can be collected by remote sensing at 1 AU near Earth

- Gathering this information with high accuracy and high reliability provides a baseline for numerous different fields in heliospheric physics