PUIs ENAs and ACRs

a trio of acronyms

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What do they stand for?

- **PUIs (Pick-Up Ions)**
  Non thermal ions in environments like the solar wind formed by the pick-up process $\sim 10$ keV

- **ACRs (Anomalous Cosmic Rays)**
  High energy ions that contend with "real" cosmic rays in energy $\sim 1-100$ MeV

- **ENAs (Energetic Neutral Atoms)**
  Neutral atoms originating from high energy ions from $\sim 10$ eV to $\sim 1$ MeV

Allow us to "see" invisible signatures of these ions from quite a long way away.
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Picture of pick-up process

400 km/s

25 km/s
Picture of pick-up process

- 30 km/s
- 400 km/s
Picture of pick-up process

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PUIs, ENAs, and ACRs
How are they ionized?

**Charge Exchange**
An ion interacts with the neutral atom stealing an electron

**Photo-Ionization**
UV Radiation interacts with the outermost electron ionizing the neutral atom

- Photo-Ionization dominates close to the sun
- Past a couple AU, Charge Exchange dominates
A ring shaped phase space distribution caused by pick-up process.

- Magnetic field is out of the plane.
- There is no preferential gyrophase for the neutrals to be picked up.
Heliosphere description

Heliosphere
The contents of the Heliopause

Heliosheath
The region between the Termination Shock and the Heliopause
- PU1s get dragged to the heliosheath by the solar wind.
- Particles get accelerated here and escape back towards the center of the heliosphere.
How are they accelerated?

- Fermi acceleration along shocks (Pesses et al. 1981)
  Particles bounce between the fast upstream inflow and the slower downstream outflow gaining energy each bounce

- Stochastic acceleration (Fisk and Gloekler 2006)
  Random fluctuations of the electric and magnetic fields interact with particles such that they gain energy

- Acceleration within magnetic islands (Oka 2010, Drake et al. 2010)
  Particles interact with reconnection electric fields present near islands, and can be Fermi accelerated in closing islands
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A particular power law distribution is predominantly found (Fisk and Gloekler 2006)

- velocity distribution that goes off like $v^{-5}$
- this is equivalent to an kinetic energy distribution that goes off like $E^{-2}$ (Differential number density)
- which is equivalent to an kinetic energy distribution that goes off like $E^{-1.5}$ (Differential intensity)

(Fisk and Gloekler 2006)
What are ENAs?

- Opposite of PUIs
- Energetic ions that gain an electron and become neutral
- Allows us to see from remote locations where the neutralization takes place

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Satellites Measuring ENA’s

- **Cassini (INCA) (1997-present)**
  Looks at the magnetosphere of Saturn

- **IMAGE (2000-2005)**
  Looks at the Earth’s magnetosphere

- **TWINS (2008-present)**
  Looks at the Earth’s magnetosphere

- **IBEX (2008-present)**
  Looks at an all sky view of the Heliosheath
A ribbon shaped signature of ENAs found around the nose of the heliosphere

There is still no consensus on the source of this ribbon

(McComas et al. 2009)
PUIs (Pick-Up Ions)
a core set of high energy ions that can be accelerated to become ACRs

ACRs (Anomalous Cosmic Rays)
high energy particles $\sim$ 1-100 MeV that were accelerated by at least one of the contending acceleration mechanisms

ENAs (Energetic Neutral Atoms)
let us see things like the ribbon or a global picture of the Earth’s magnetosphere