A GENTLE INTRODUCTION TO HELIOPHYSICS
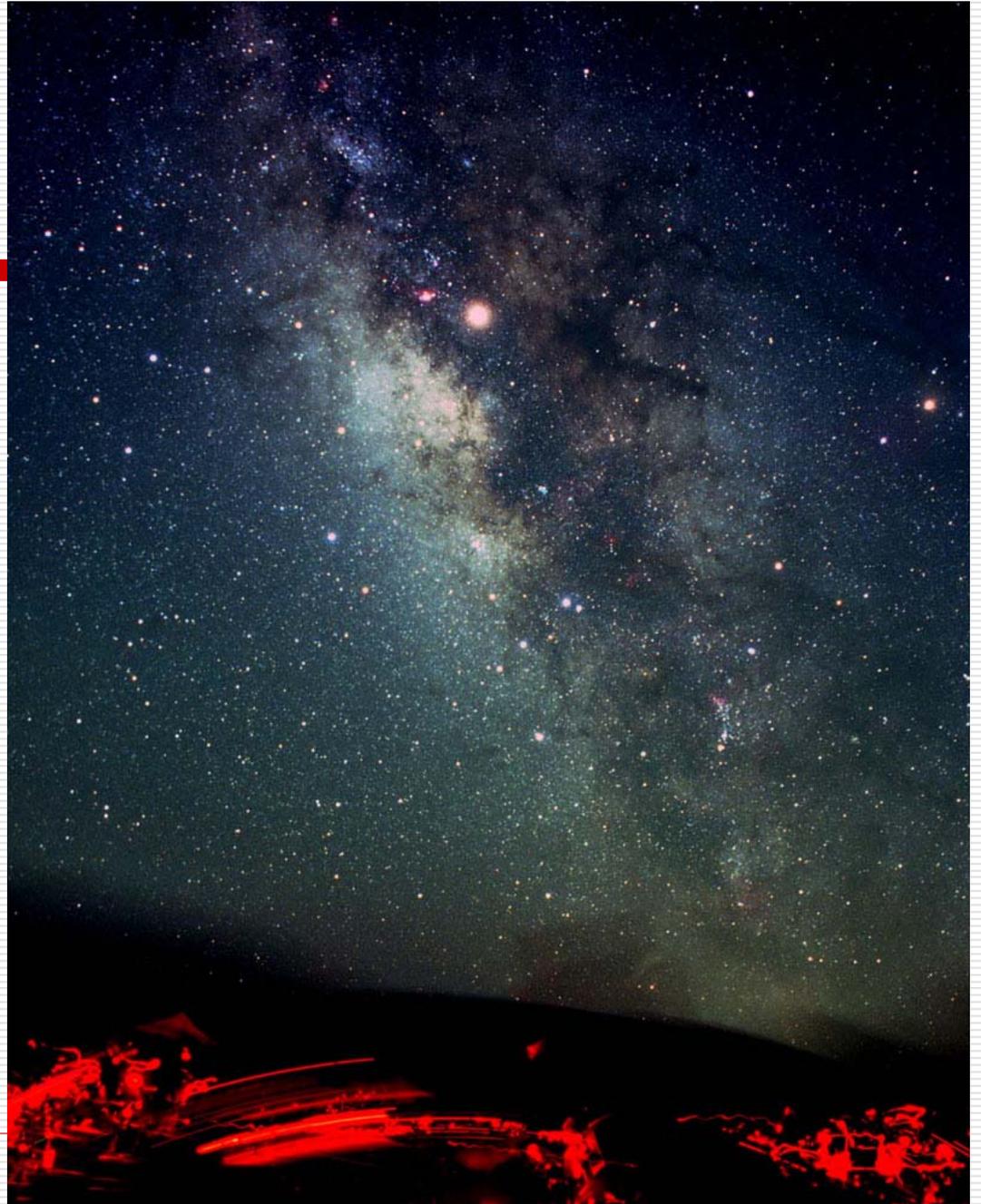
THOMAS J. BOGDAN

NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION/SPACE WEATHER PREDICTION CENTER

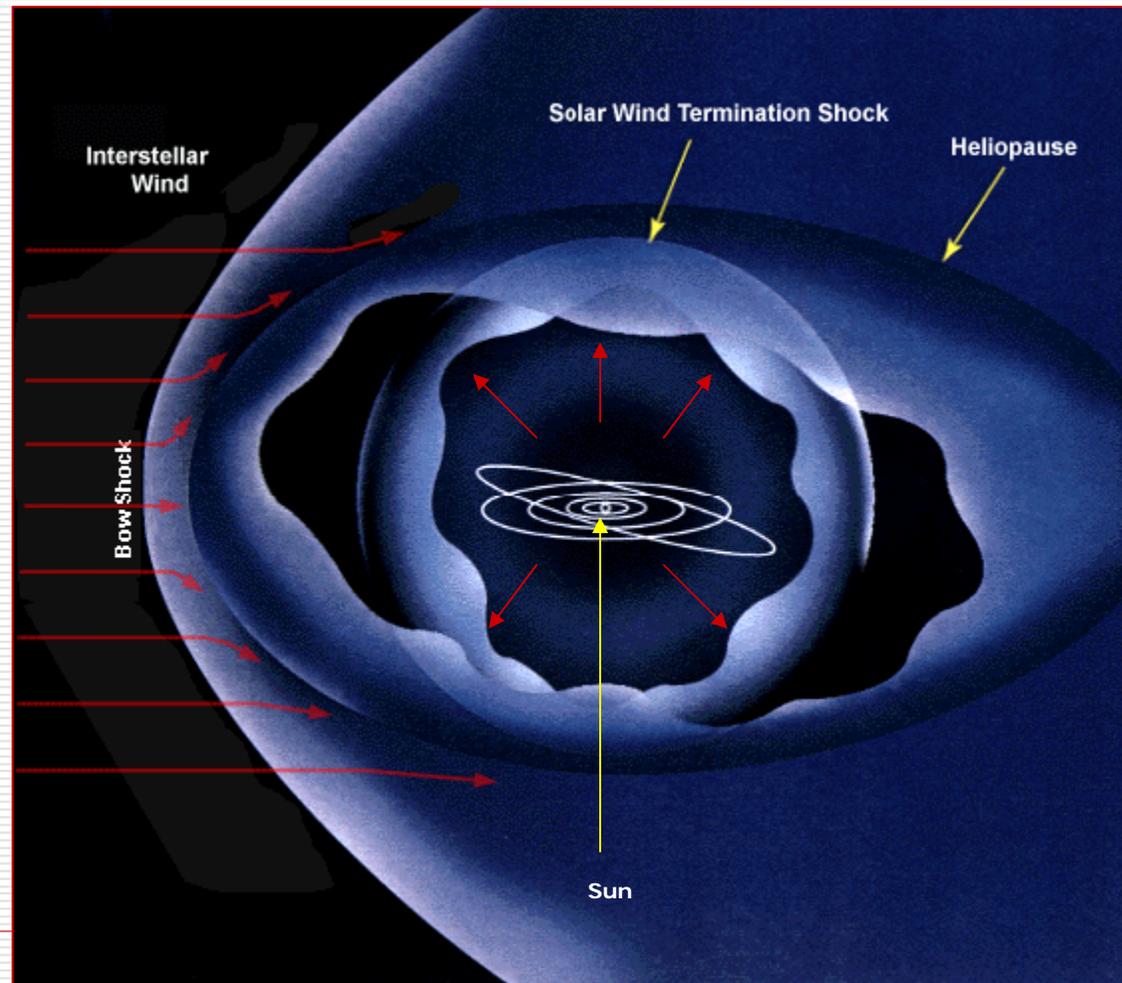LWS/IHY HELIOPHYSICS SUMMER SCHOOL
BOULDER, COLORADO   30 JULY 2007

AN ABUNDANCE OF HELIOSPHERES

ANATOMY OF A
HELIOSPHERE

WHAT IS HELIOPHYSICS?

- A SYSTEMS APPROACH TO SPACE SCIENCE THAT UNITES ALL OF THE LINKED PHENOMENA IN A REGION OF THE COSMOS INFLUENCED BY A STAR LIKE OUR SUN

- A COURSE OF STUDY THAT EMBRACES THE EXPLORATION, DISCOVERY AND UNDERSTANDING OF OUR SPACE ENVIRONMENT

WHAT IS HELIOPHYSICS?

- A DISCIPLINE THAT CONCENTRATES ON THE SUN, ITS VARIABILITY AND ITS EFFECTS ON THE EARTH, THE OTHER PLANETS AND BODIES IN THE SOLAR SYSTEM, AND THE CHANGING CONDITIONS IN SPACE
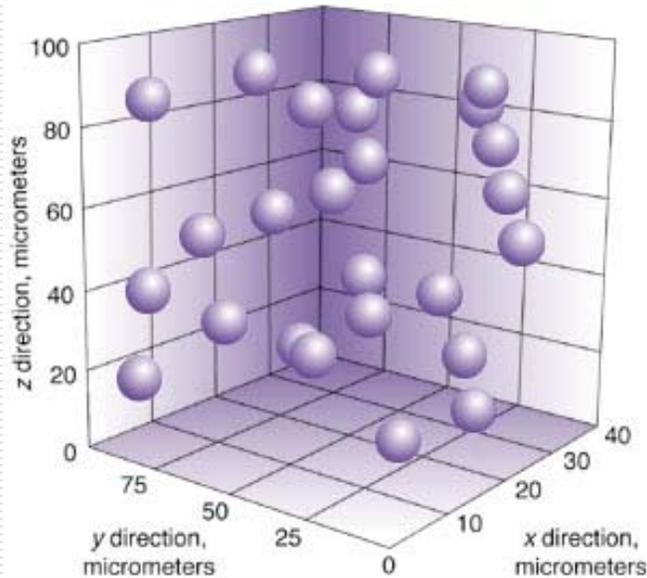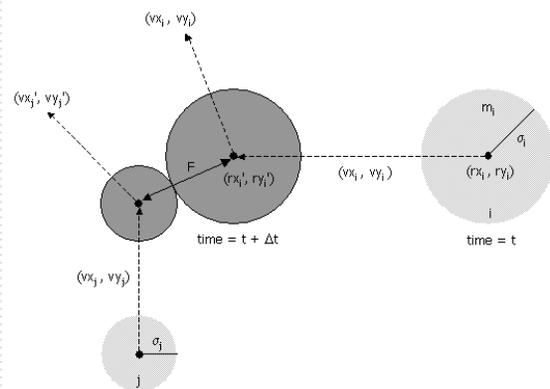
WHAT IS HELIOPHYSICS?

- ☐ A UNIFIED SCIENCE THAT ENCOMPASSES
  - ■ COSMIC RAYS AND PARTICLE ACCELERATION
  - ■ SPACE WEATHER AND PENETRATING RADIATIONS
  - ■ DUST AND MAGNETIC RECONNECTION
  - ■ SOLAR AND STELLAR ACTIVITY CYCLES
  - ■ AERONOMY AND SPACE PLASMAS
  - ■ MAGNETIC FIELDS AND GLOBAL CHANGE
  - ■ INTERACTION OF OUR SOLAR SYSTEM WITH THE INTERSTELLAR MEDIUM
  - ■ COMPARATIVE STUDIES

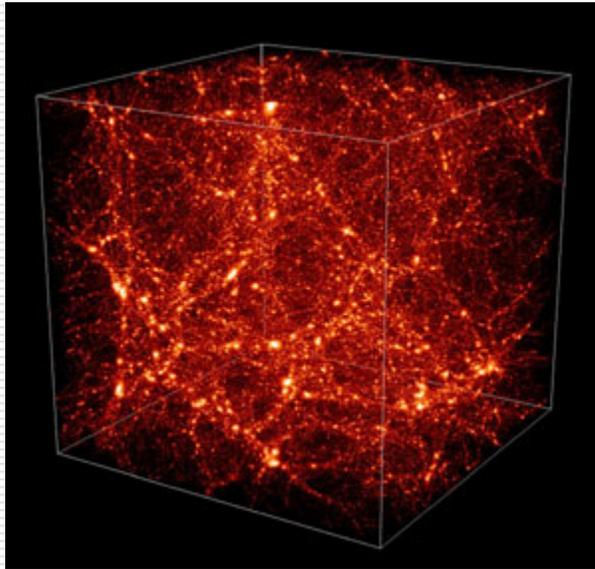# LANGUAGE AND LITERATURE: BOLTZMANN/VLASOV

$$\frac{\partial f_\mu}{\partial t} + \frac{\partial f_\mu}{\partial \mathbf{x}} \cdot \frac{\mathbf{p}}{m_\mu} + \frac{\partial f_\mu}{\partial \mathbf{p}} \cdot \mathbf{F} = \left.\frac{\partial f_\mu}{\partial t}\right|_{\text{coll}}$$
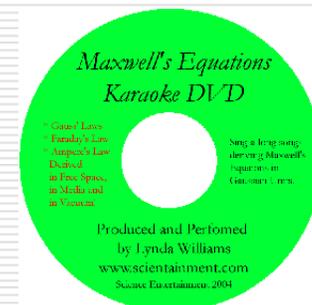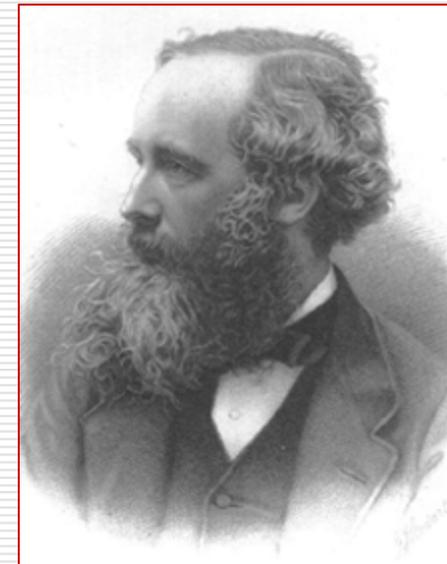
LANGUAGE AND LITERATURE: POISSON/NEWTON

$$\nabla^2 \Phi = -4\pi G \rho$$

LANGUAGE AND LITERATURE: MAXWELL/FARADAY

MKS units	Gaussian units	
$\nabla \cdot \mathbf{D} = \rho$	$\nabla \cdot \mathbf{D} = 4\pi\rho$	
$\nabla \cdot \mathbf{B} = 0$	$\nabla \cdot \mathbf{B} = 0$	
$\nabla \times \mathbf{H} = \mathbf{J} + \frac{\partial \mathbf{D}}{\partial t}$	$\nabla \times \mathbf{H} = \frac{4\pi}{c}\mathbf{J} + \frac{1}{c}\frac{\partial \mathbf{D}}{\partial t}$	
$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$	$\nabla \times \mathbf{E} = -\frac{1}{c}\frac{\partial \mathbf{B}}{\partial t}$	
$\mathbf{F} = q(\mathbf{E} + \mathbf{v} \times \mathbf{B})$	$\mathbf{F} = q\left(\mathbf{E} + \frac{1}{c}\mathbf{v} \times \mathbf{B}\right)$	Lorentz force law
$\mathbf{D} = \epsilon_0 \mathbf{E} + \mathbf{P}$	$\mathbf{D} = \mathbf{E} + 4\pi\mathbf{P}$	(general)
$\mathbf{D} = \epsilon_0 \mathbf{E}$	$\mathbf{D} = \mathbf{E}$	(free space)
$\mathbf{D} = \epsilon \mathbf{E}$	$\mathbf{D} = \varkappa \mathbf{E}$	(isotropic linear dielectric)
$\mathbf{B} = \mu_0(\mathbf{H} + \mathbf{M})$	$\mathbf{B} = \mathbf{H} + 4\pi\mathbf{M}$	(general)
$\mathbf{B} = \mu_0 \mathbf{H}$	$\mathbf{B} = \mathbf{H}$	(free space)
$\mathbf{B} = \mu \mathbf{H}$	$\mathbf{B} = \mu \mathbf{H}$	(isotropic linear magnetic medium)

Maxwell's Equations Karaoke DVD

Produced and Performed by Lynda Williams
www.scientainment.com
Science Entertainment 2004

LANGUAGE AND LITERATURE: IDEAL MAGNETOHYDRODYNAMICS

$$\frac{\partial \rho}{\partial t} + \boldsymbol{\nabla} \cdot (\rho \boldsymbol{u}) = 0 \,,$$

$$\frac{\partial S}{\partial t} + \boldsymbol{u} \cdot \boldsymbol{\nabla} S = 0 \,,$$

$$\frac{\partial \boldsymbol{B}}{\partial t} - \boldsymbol{\nabla} \times (\boldsymbol{u} \times \boldsymbol{B}) = 0 \,,$$

$$\frac{\partial \boldsymbol{u}}{\partial t} + (\boldsymbol{u} \cdot \boldsymbol{\nabla})\boldsymbol{u} + \frac{1}{\rho}\nabla p = \frac{1}{4\pi\rho}(\boldsymbol{\nabla} \times \boldsymbol{B}) \times \boldsymbol{B} - g\hat{\boldsymbol{z}} \,,$$

$$e = \frac{1}{\gamma - 1}\frac{p}{\rho}\,, \quad S = c_v \log\left(p/\rho^{\gamma}\right) \,,$$

THE 5 THINGS YOU MUST KNOW ABOUT HELIOPHYSICAL PLASMAS

- ☐ MAGNETIC FIELDS ARE CONTINUALLY BEING CREATED AND DESTROYED
- ☐ MAGNETIC FIELDS SERVE AS CONDUITS BETWEEN DIFFERENT HELIOPHYSICAL SYSTEMS
- ☐ PREVALENT SPONTANEOUS FORMATION OF DISCTONTINUITIES AND FINE-SCALE STRUCTURE ALMOST EVERYWHERE
- ☐ EXPLOSIVE ENERGY CONVERSION AND RELEASE
- ☐ RAPID AND EFFICIENT ENERGIZATION OF PENETRATING RADIATIONS
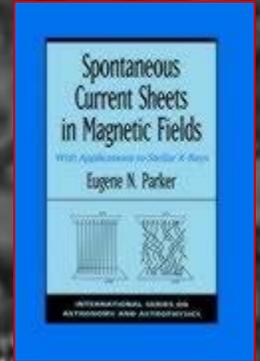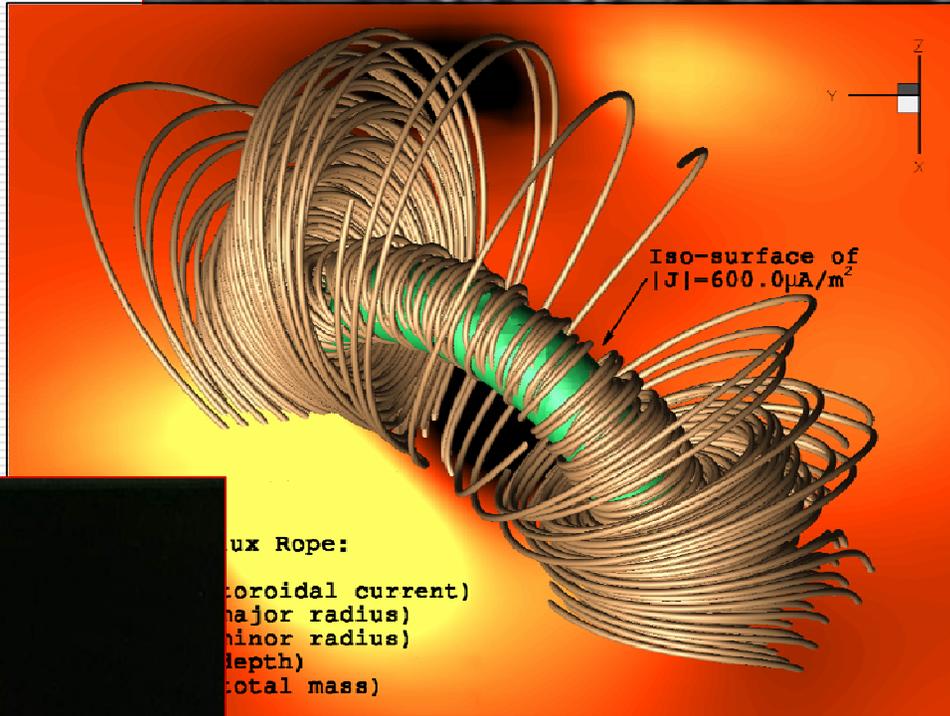
THE CREATION AND DESTRUCTION OF MAGNETIC FIELDS
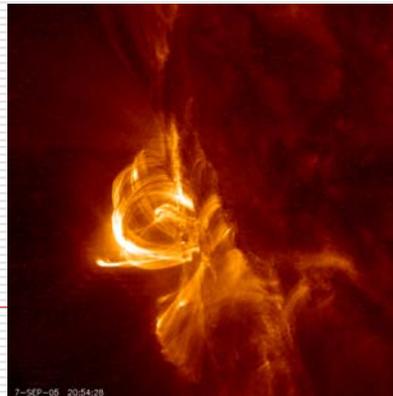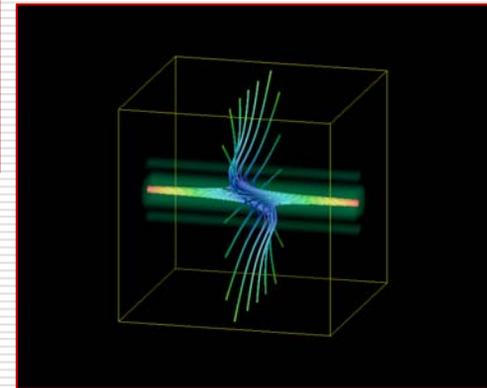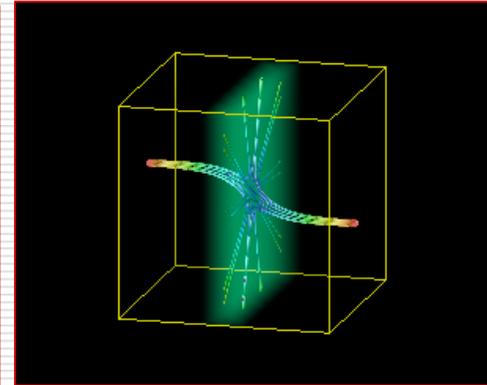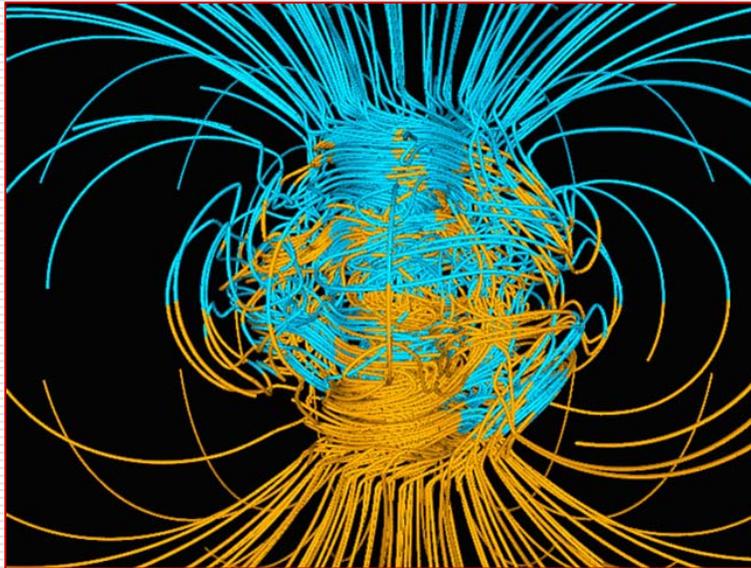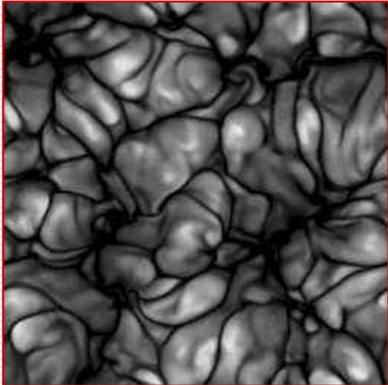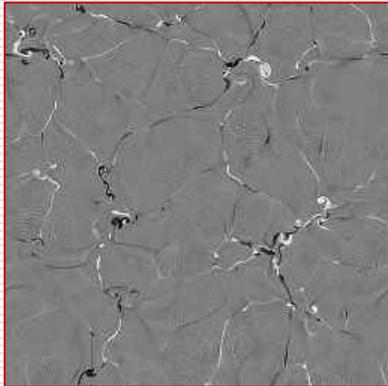
MAGNETIC FIELDS AS PLASMA SUPERHIGHWAY SYSTEMS
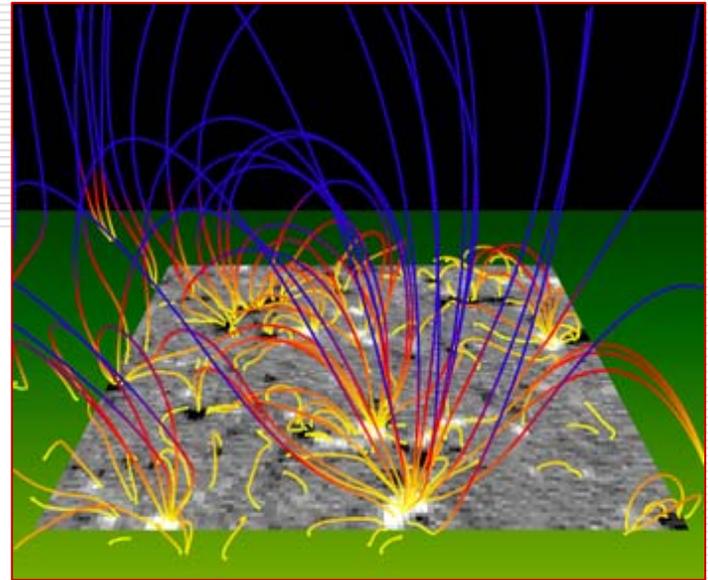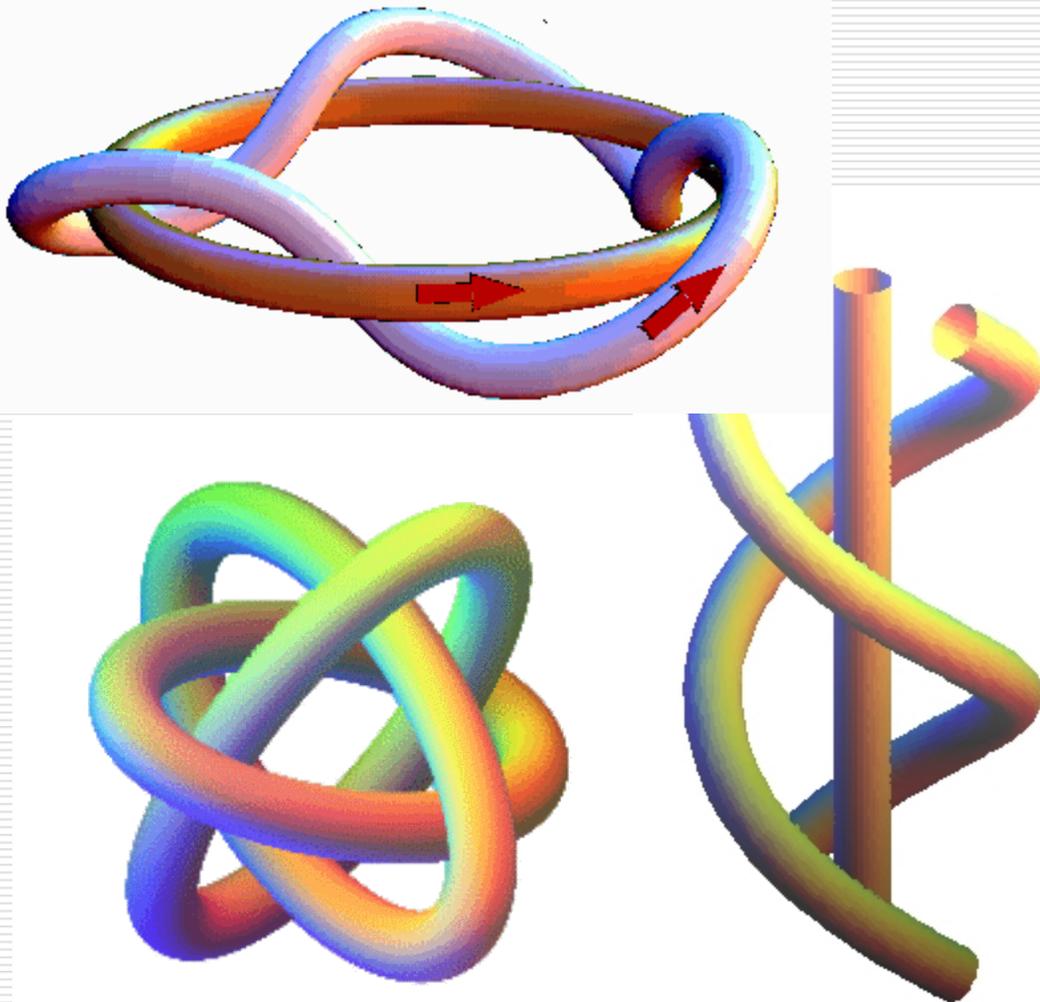
SPONTANEOUS FORMATION OF FINE-SCALE STRUCTURE
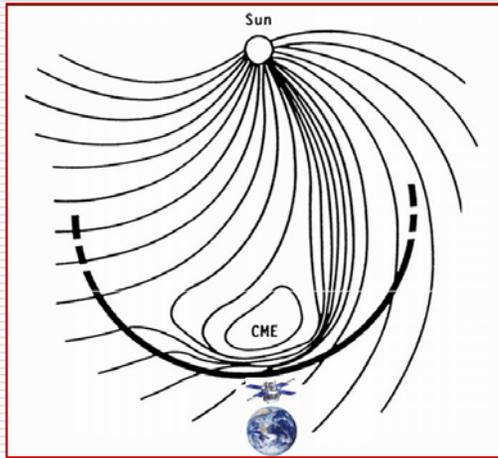
EXPLOSIVE ENERGY CONVERSION AND RELEASE
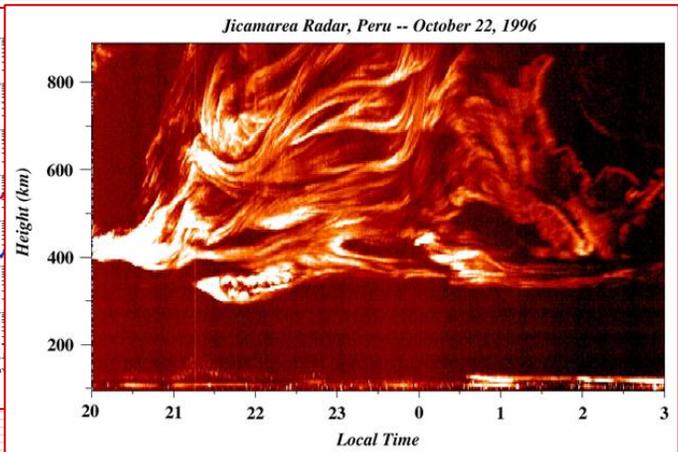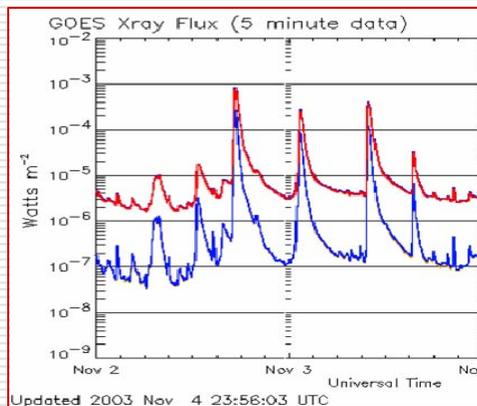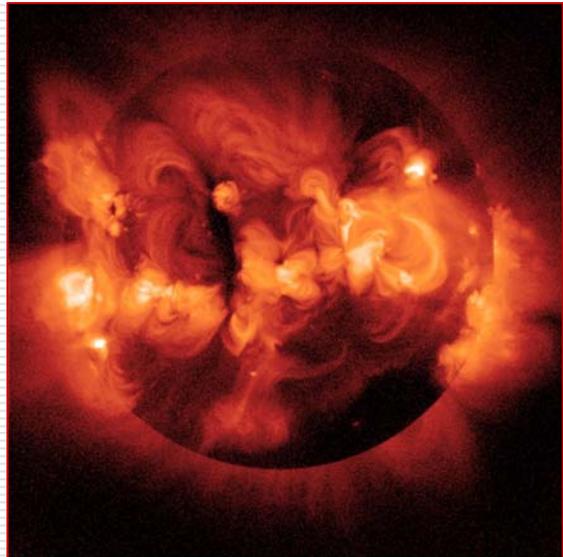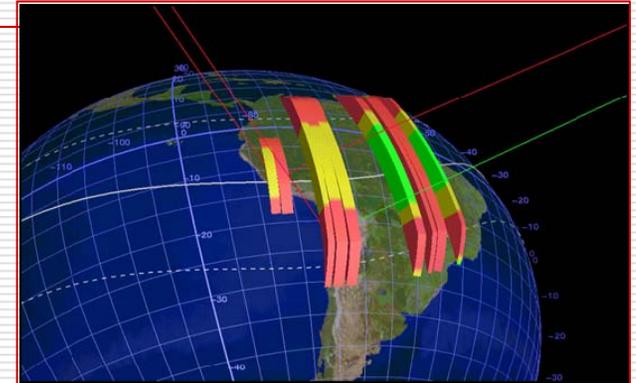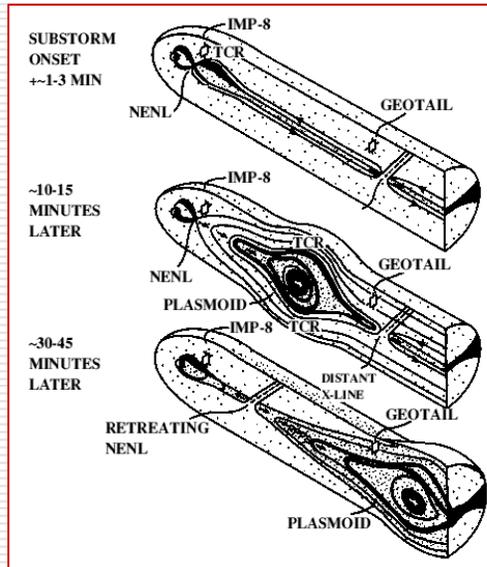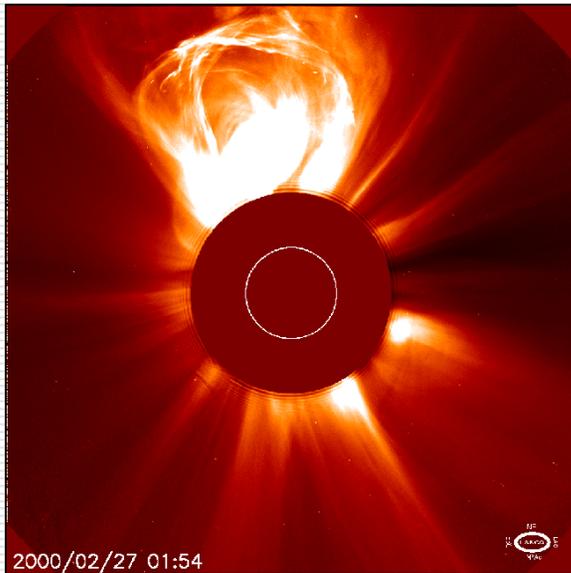
RAPID AND EFFICIENT ENERGIZATION OF PARTICLES
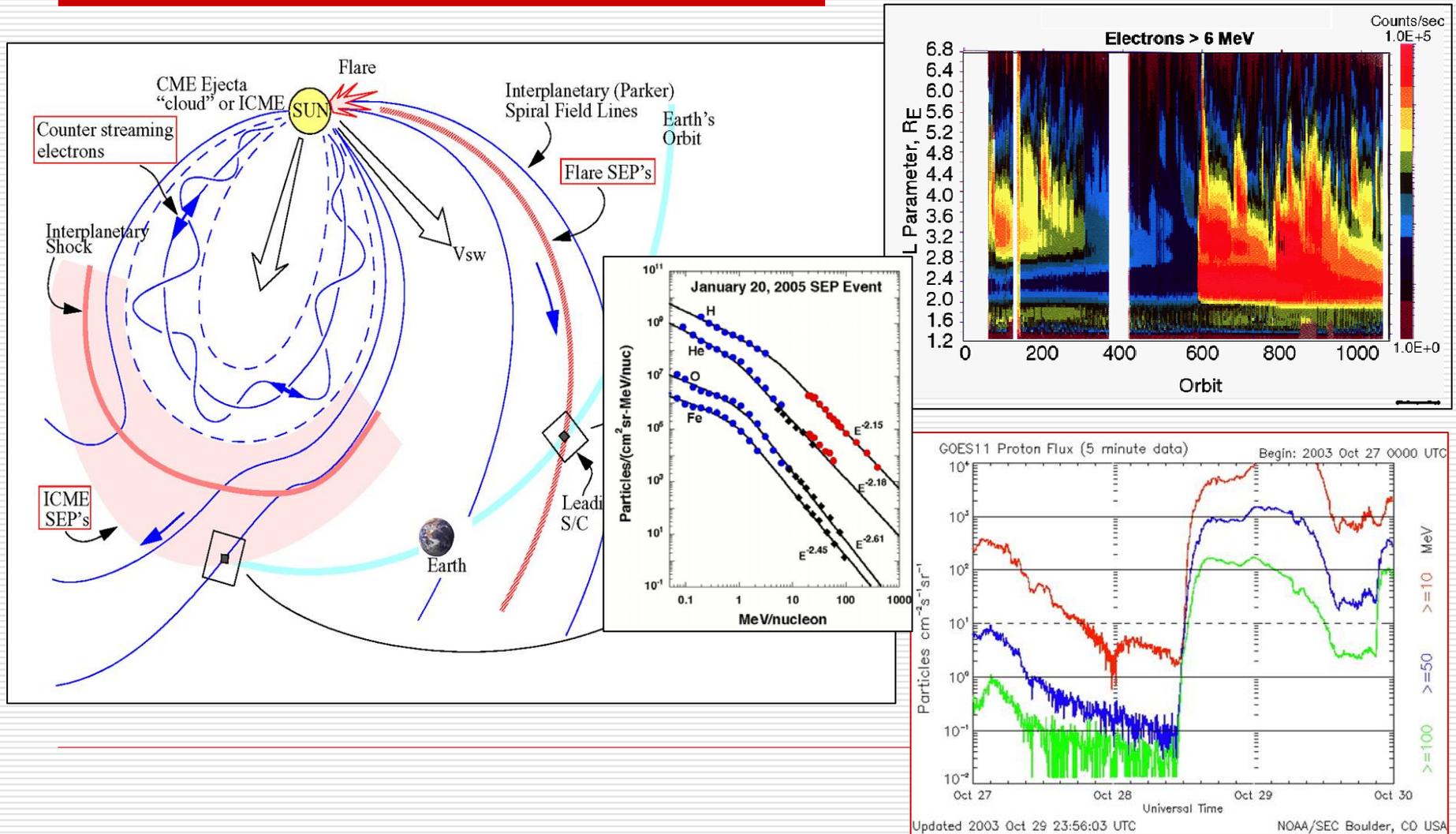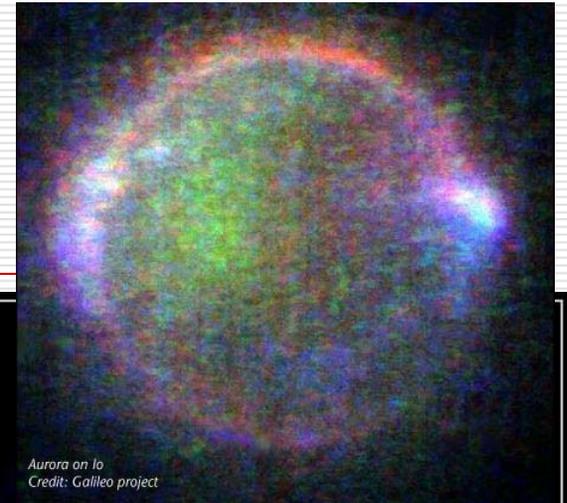
COMPARATIVE STUDIES: BOW SHOCKS AND MAGNETOSPHERES
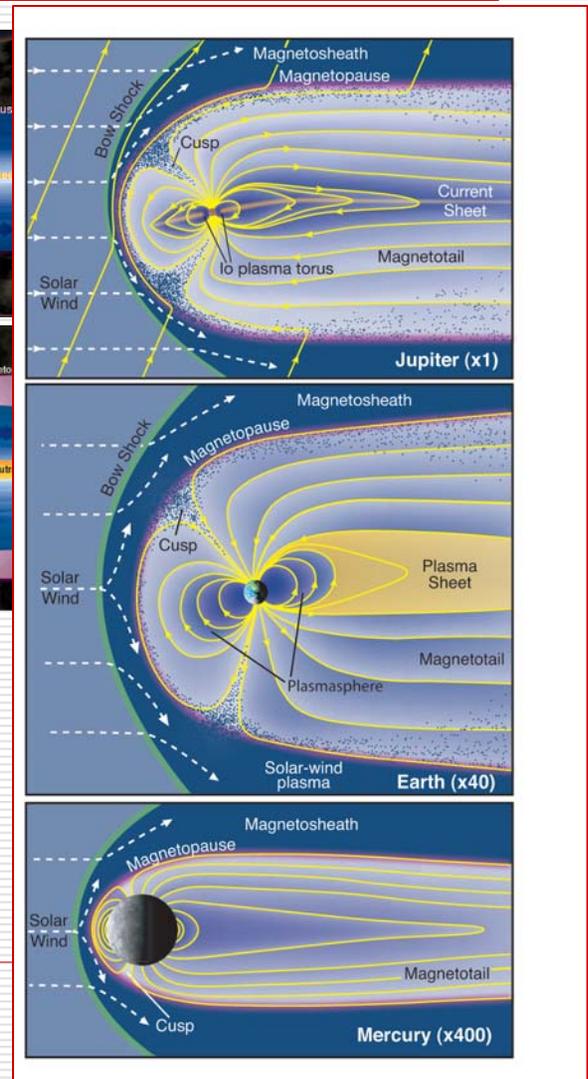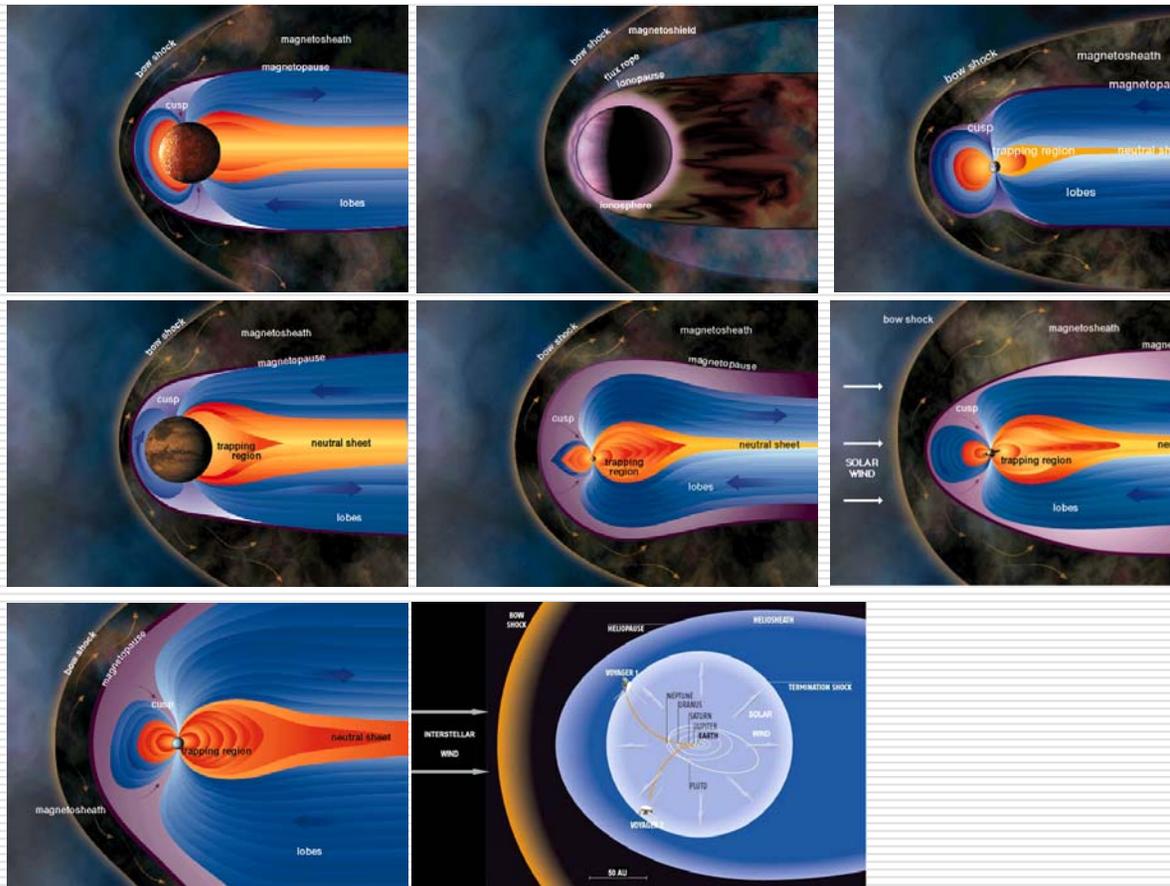
COMPARATIVE STUDIES: PLANETARY AURORAE
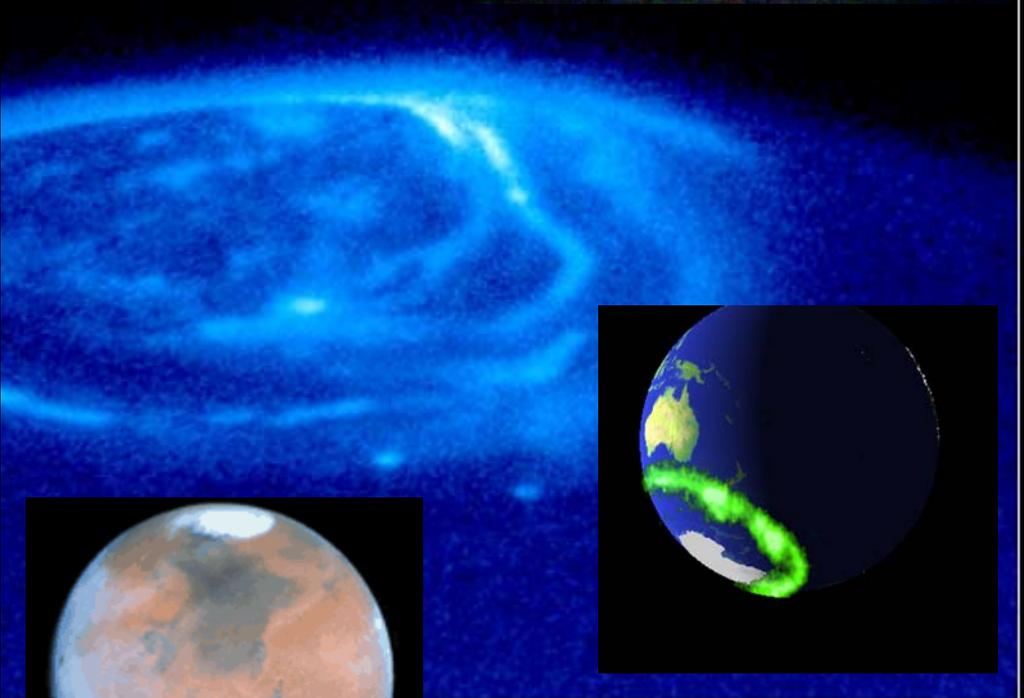

Aurora on Io
Credit: Galileo project
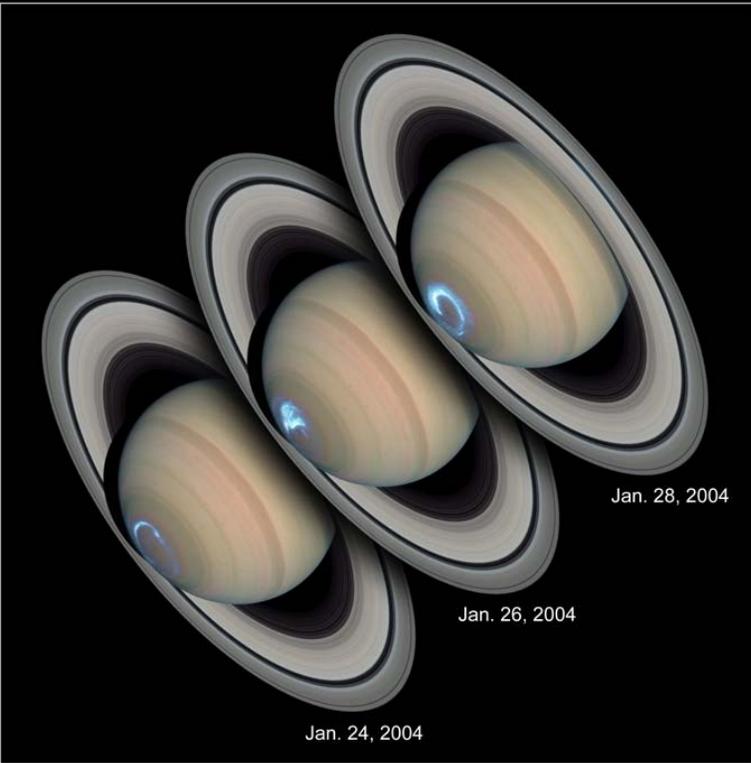
Jan. 28, 2004

Jan. 26, 2004

Jan. 24, 2004

Saturn Aurora
Hubble Space Telescope · ACS · STIS

NASA, ESA and J. Clarke (Boston University)   STScI-PRC05-06a

HST · STIS

NO MATTER WHERE YOU GO, THERE HELIOPHYSICS IS