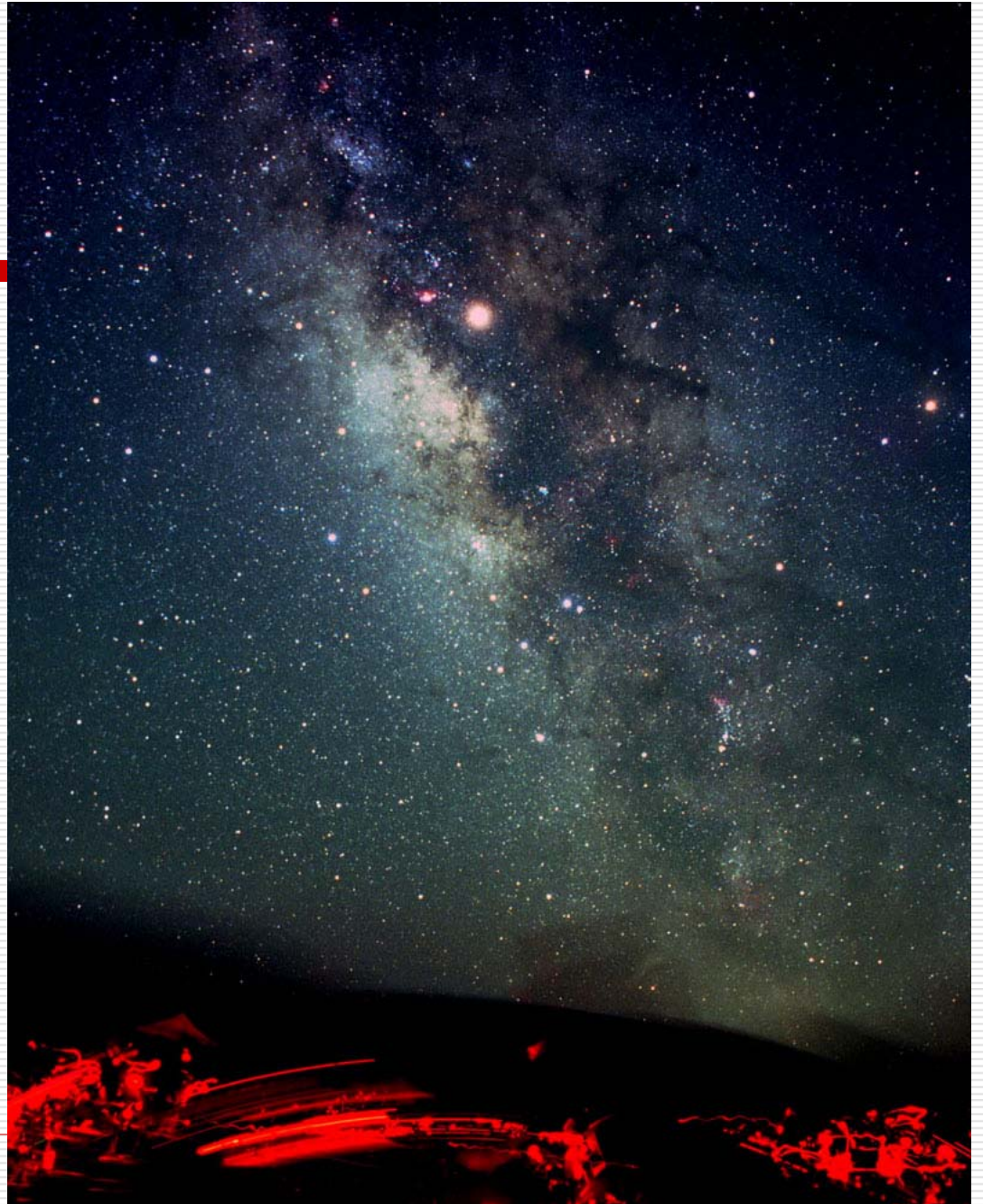


A GENTLE INTRODUCTION TO HELIOPHYSICS

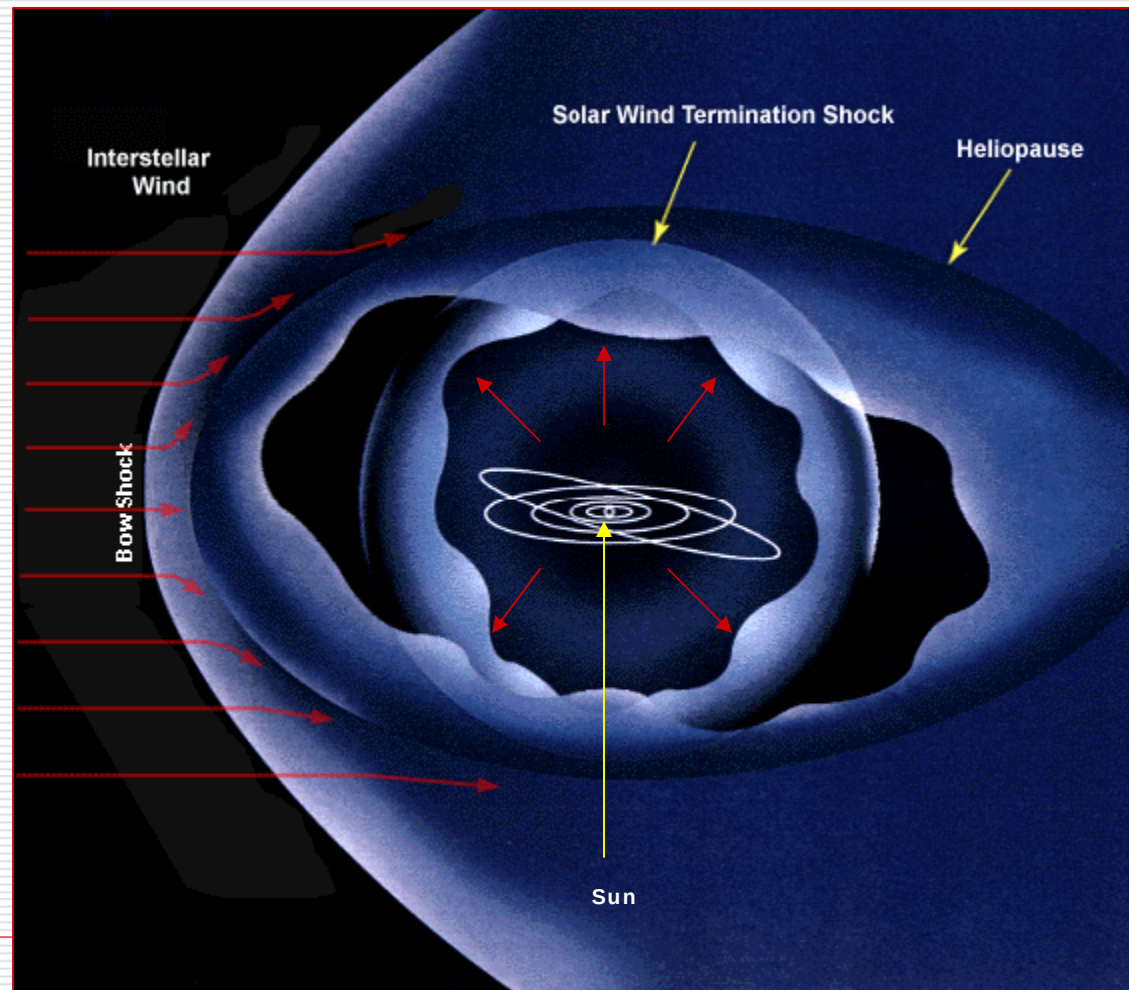
THOMAS J. BOGDAN
NATIONAL OCEANIC & ATMOSPHERIC
ADMINISTRATION/SPACE WEATHER
PREDICTION CENTER

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?

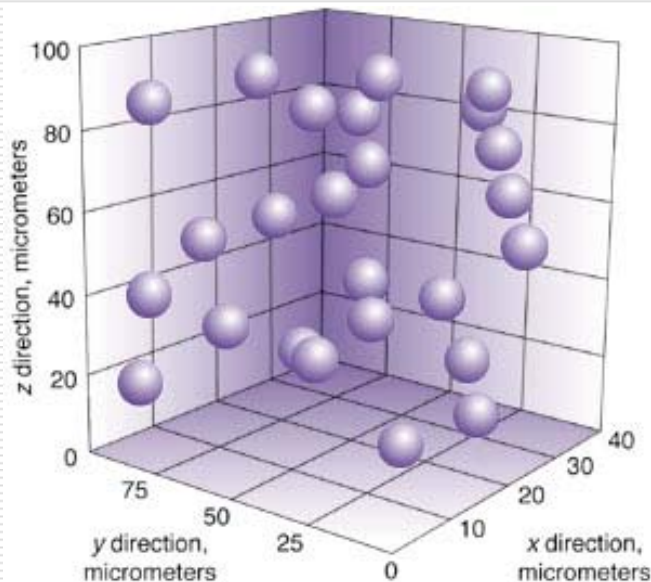
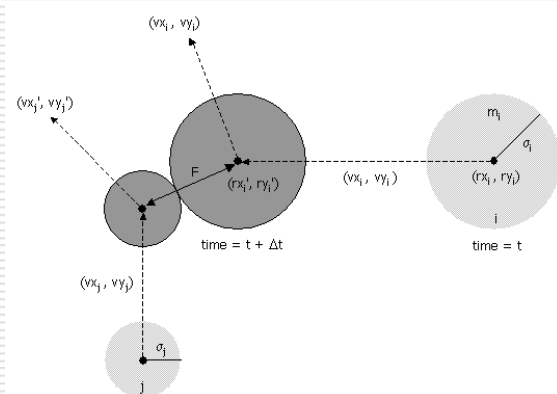
- ❑ A DISCIPLINE THAT CONCENTRATES ON THE SUN, ITS VARIABILITY AND ITS EFFECTS ON THE EARTH, THE OTHER PLANETS AND BODIES IN THE SOLAR SYSTEM, AND THE CHANGING CONDITIONS IN SPACE
-

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
-

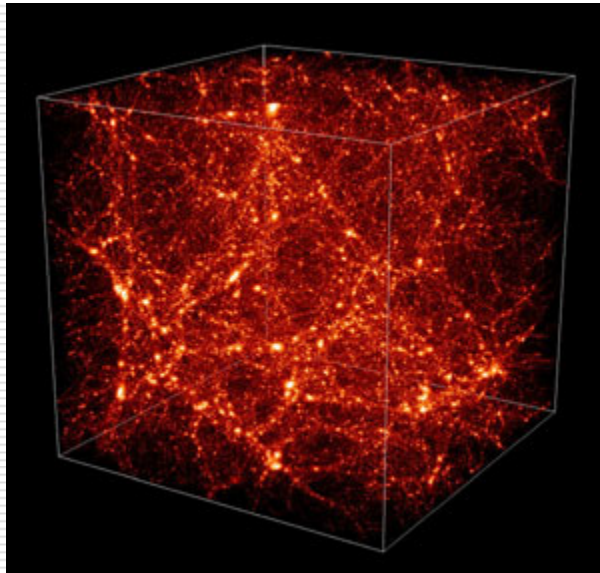
LANGUAGE AND LITERATURE: BOLTZMANN/VLASOV

$$\left. \frac{\partial f_\mu}{\partial t} + \frac{\partial f_\mu}{\partial \mathbf{x}} \cdot \frac{\mathbf{p}}{m_\mu} + \frac{\partial f_\mu}{\partial \mathbf{p}} \cdot \mathbf{F} \right|_{\text{coll}} = 0$$



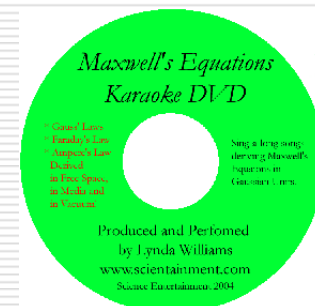
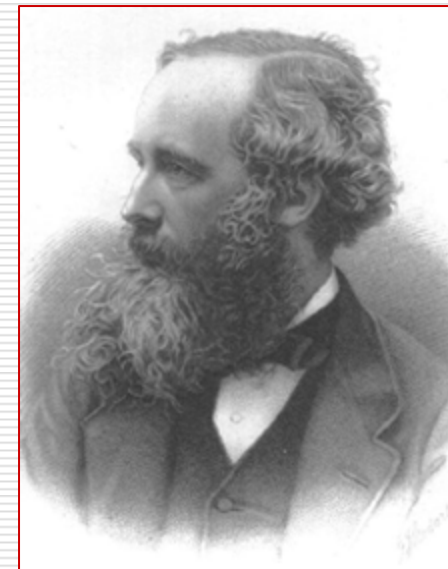
LANGUAGE AND LITERATURE: POISSON/NEWTON

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



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)
$\mathbf{D} = \epsilon \mathbf{E}$	$\mathbf{D} = \chi \mathbf{E}$	(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)



LANGUAGE AND LITERATURE: IDEAL MAGNETOHYDRODYNAMICS

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

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

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

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

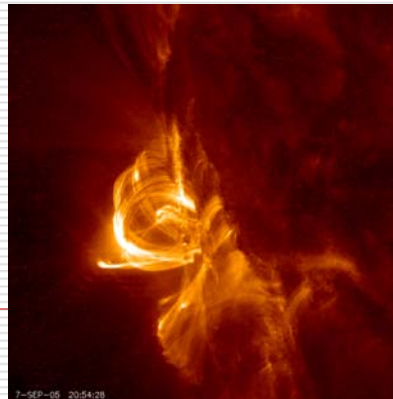
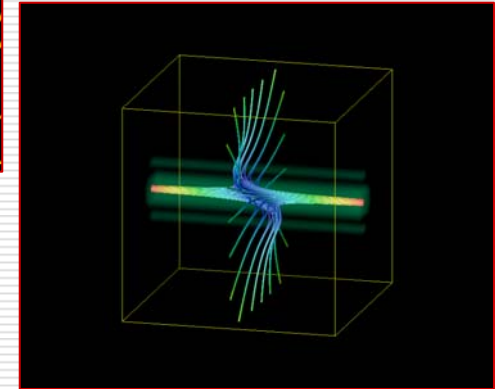
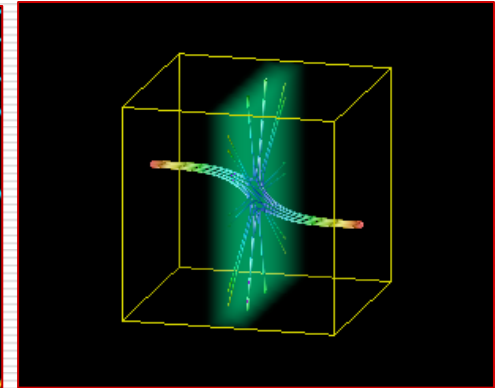
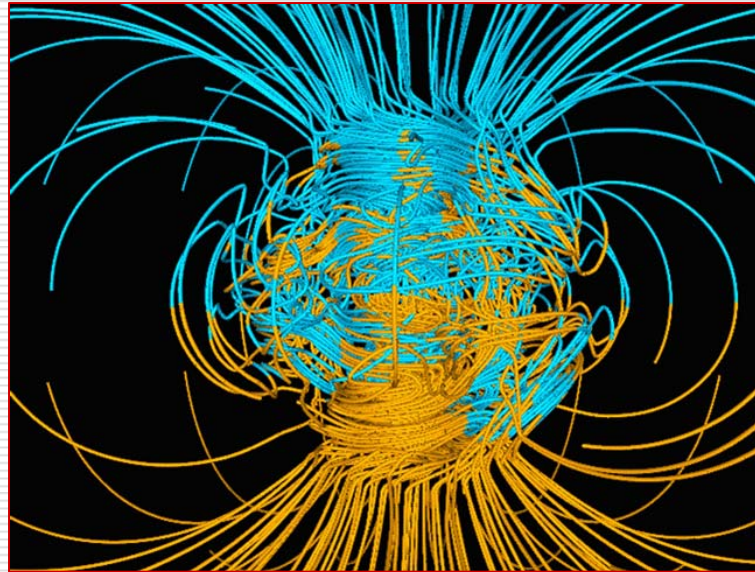
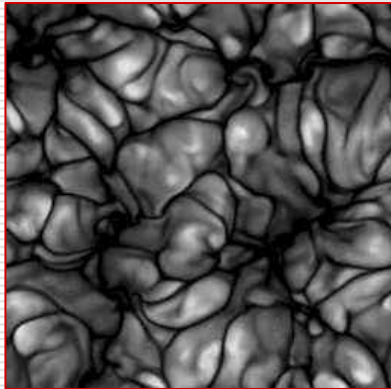
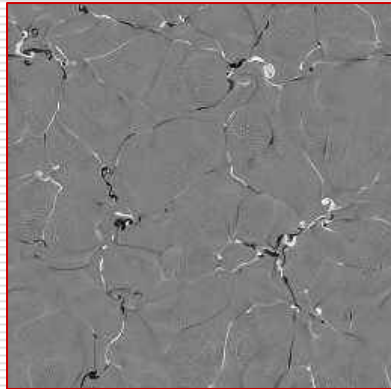
$$e = \frac{1}{\gamma - 1} \frac{p}{\rho} , \quad S = c_v \log (p / \rho^\gamma) ,$$



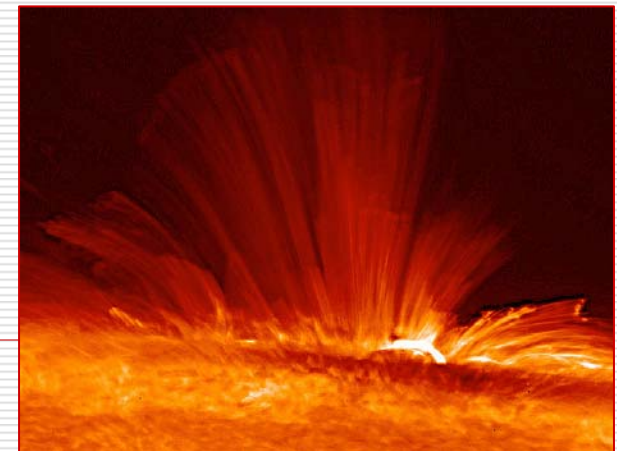
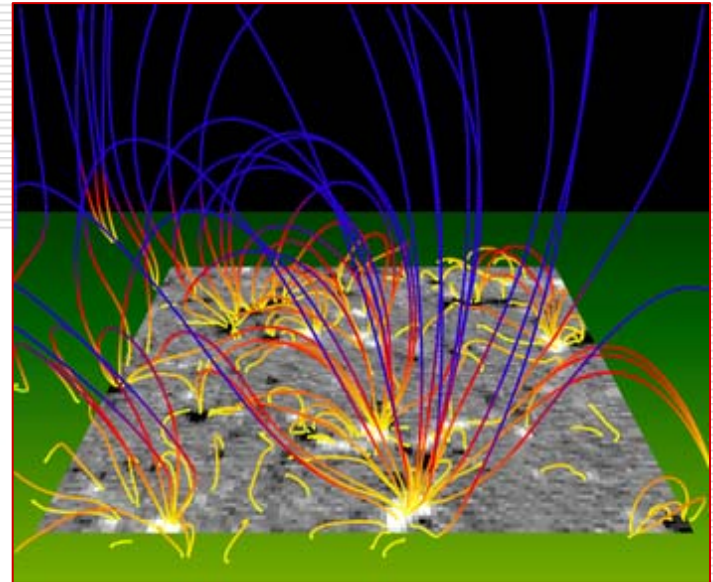
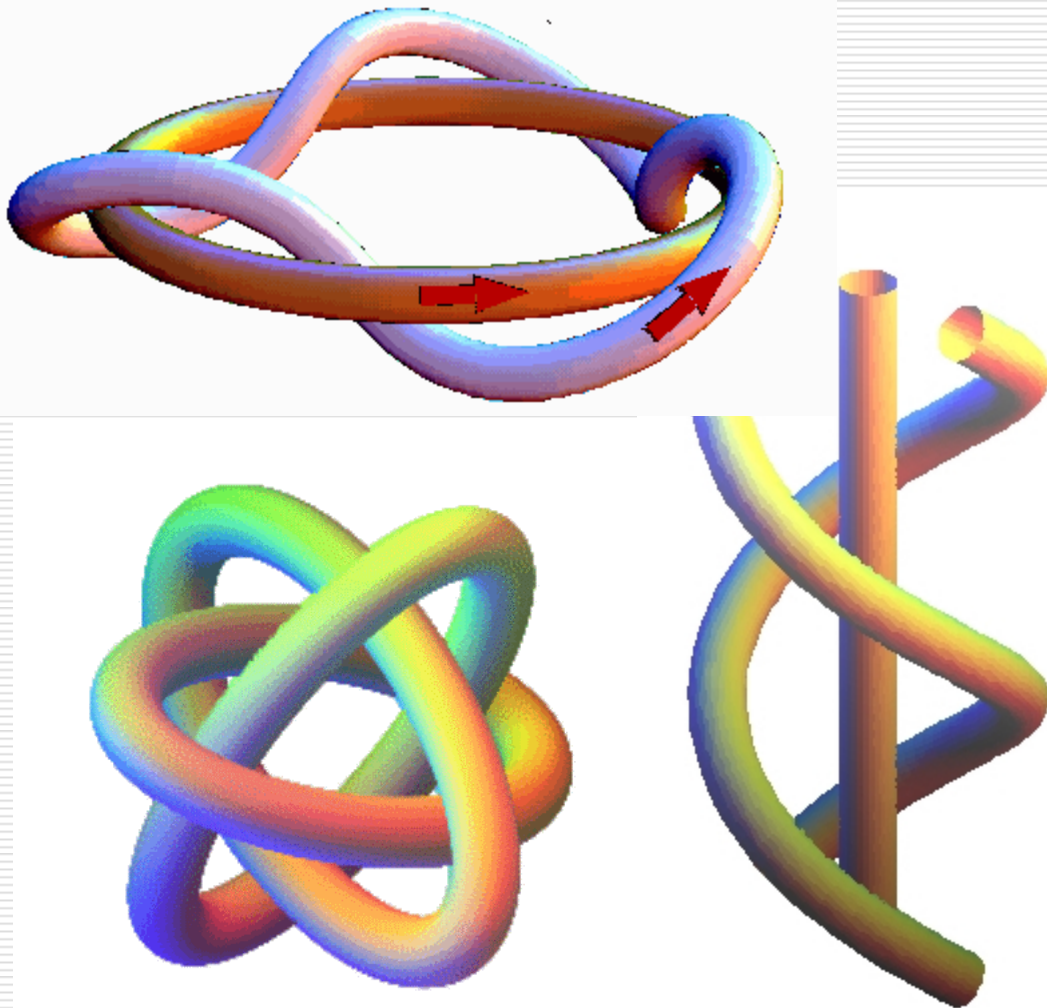
THE 5 THINGS YOU MUST KNOW ABOUT HELIOPHYSICAL PLASMAS

- ❑ MAGNETIC FIELDS ARE CONTINUALLY BEING CREATED AND DESTROYED
 - ❑ MAGNETIC FIELDS SERVE AS CONDUITS BETWEEN DIFFERENT HELIOPHYSICAL SYSTEMS
 - ❑ PREVALENT SPONTANEOUS FORMATION OF DISCONTINUITIES AND FINE-SCALE STRUCTURE ALMOST EVERYWHERE
 - ❑ EXPLOSIVE ENERGY CONVERSION AND RELEASE
 - ❑ RAPID AND EFFICIENT ENERGIZATION OF PENETRATING RADIATIONS
-

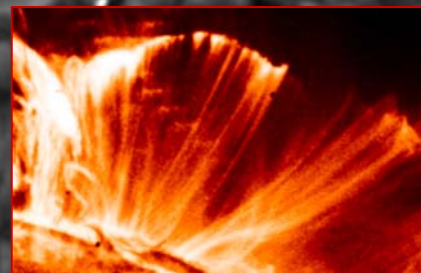
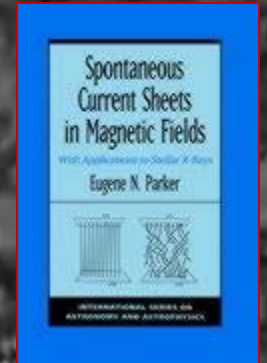
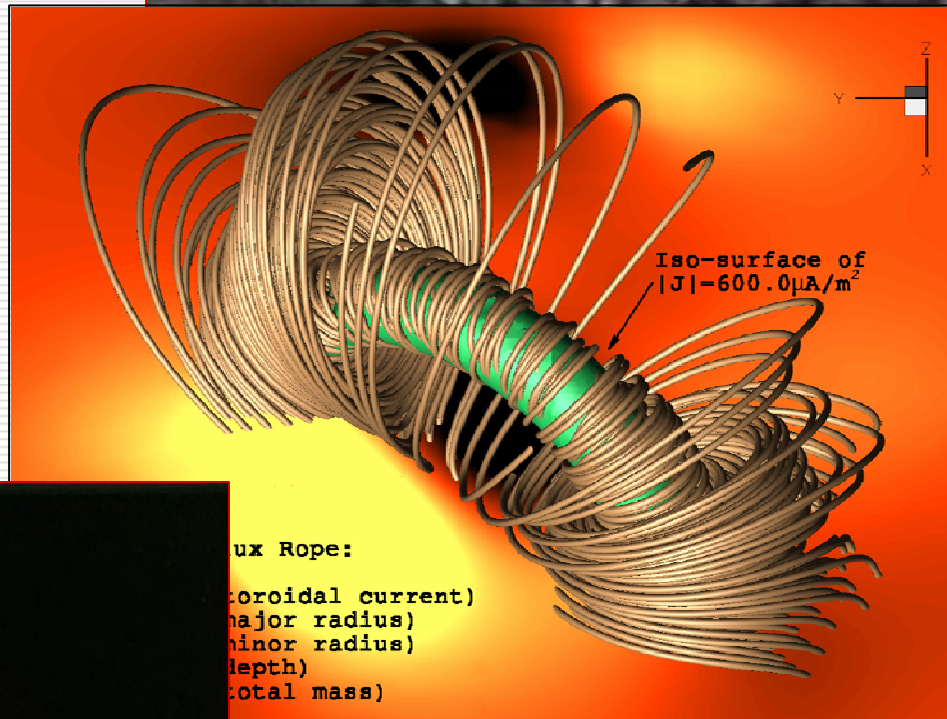
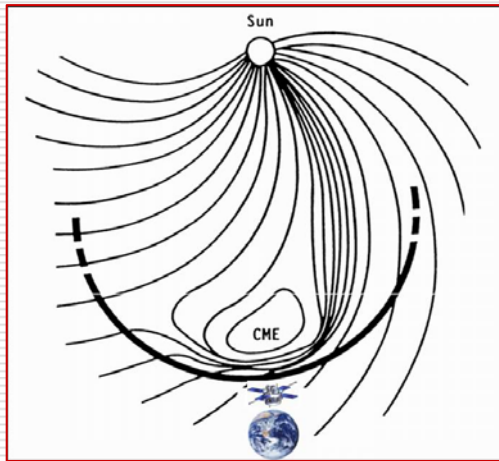
THE CREATION AND DESTRUCTION OF MAGNETIC FIELDS



MAGNETIC FIELDS AS PLASMA SUPERHIGHWAY SYSTEMS

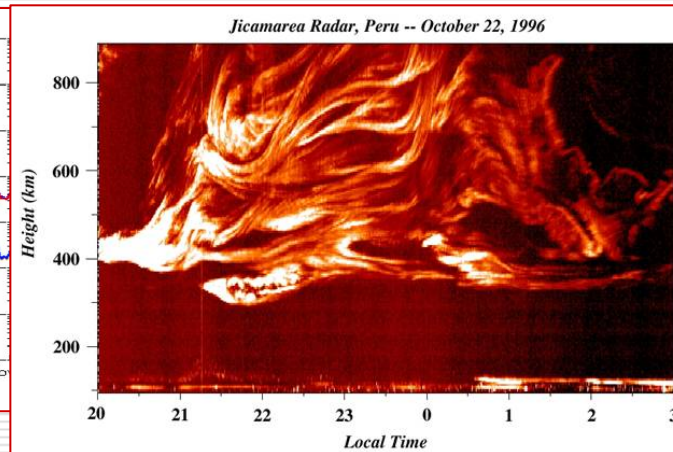
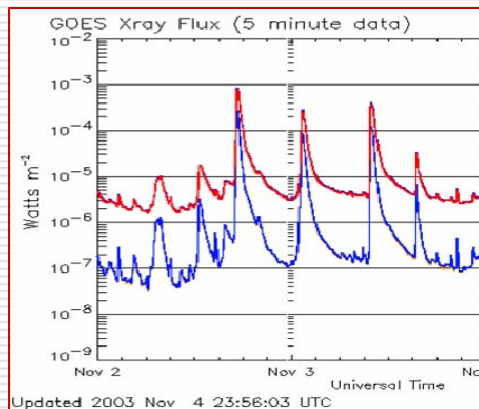
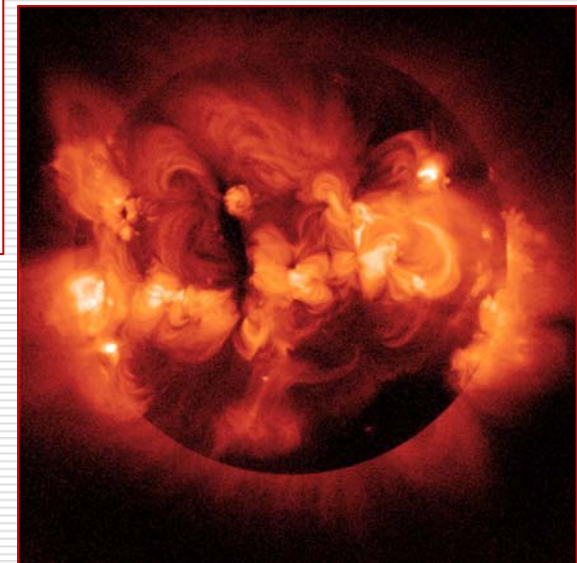
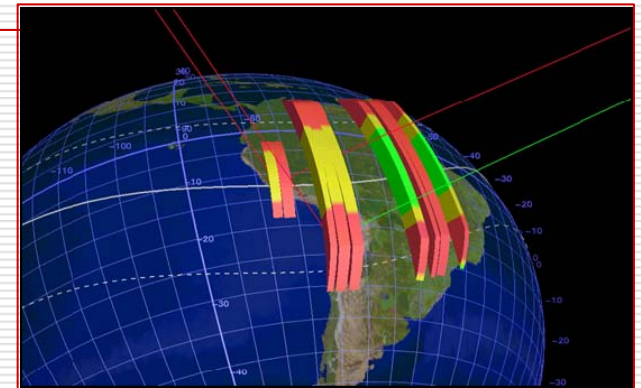
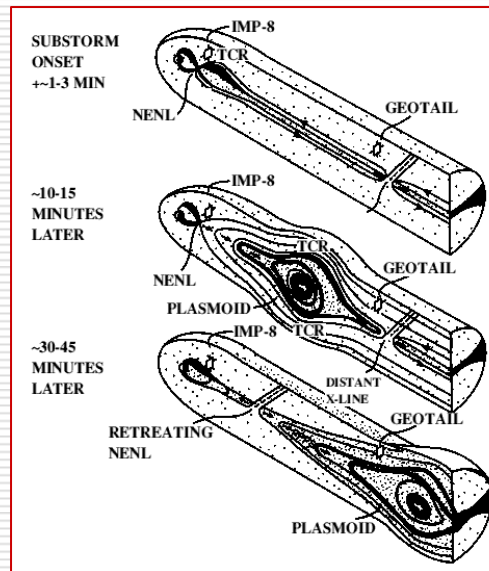
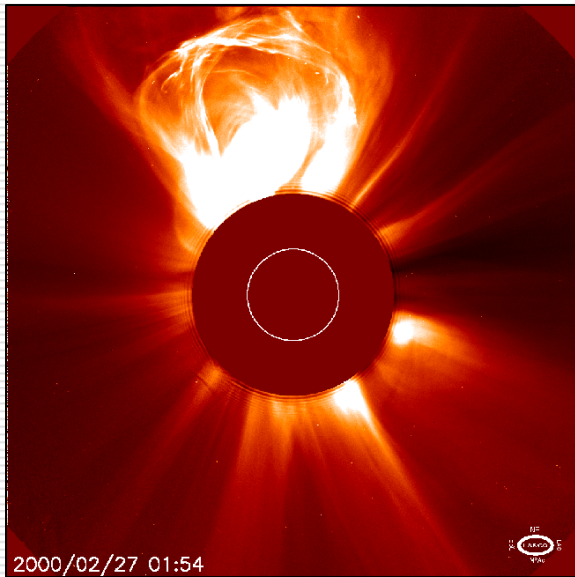


SPONTANEOUS FORMATION OF FINE-SCALE STRUCTURE

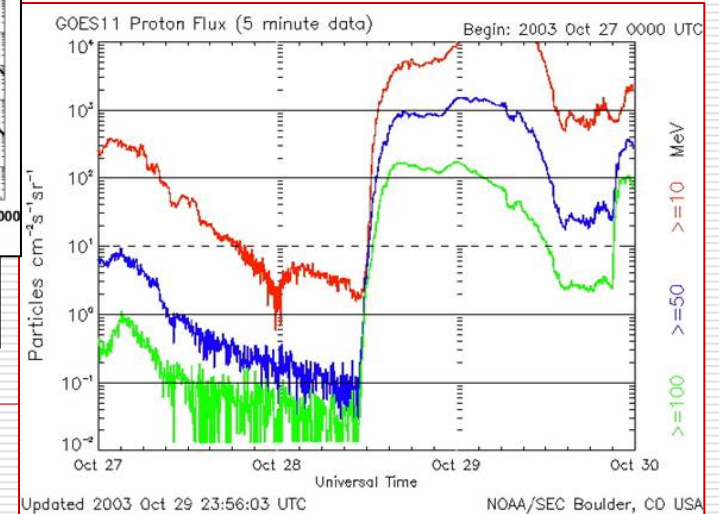
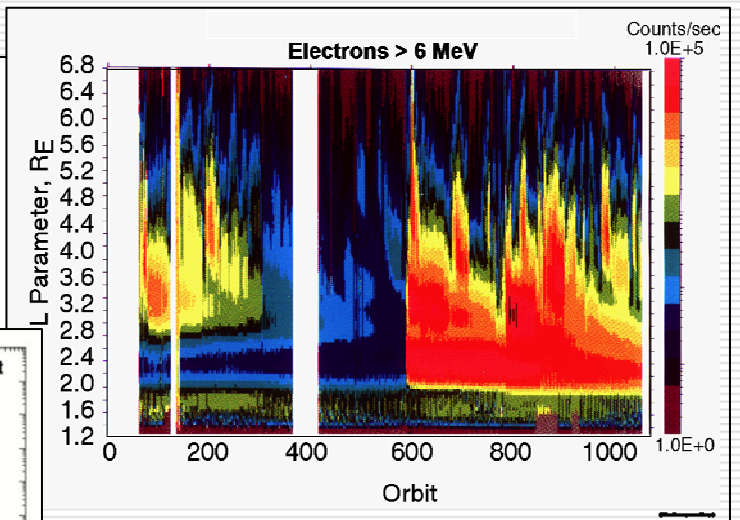
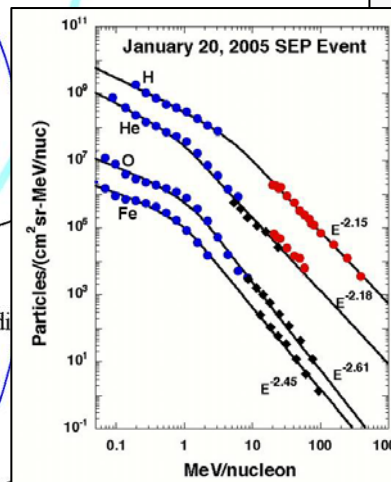
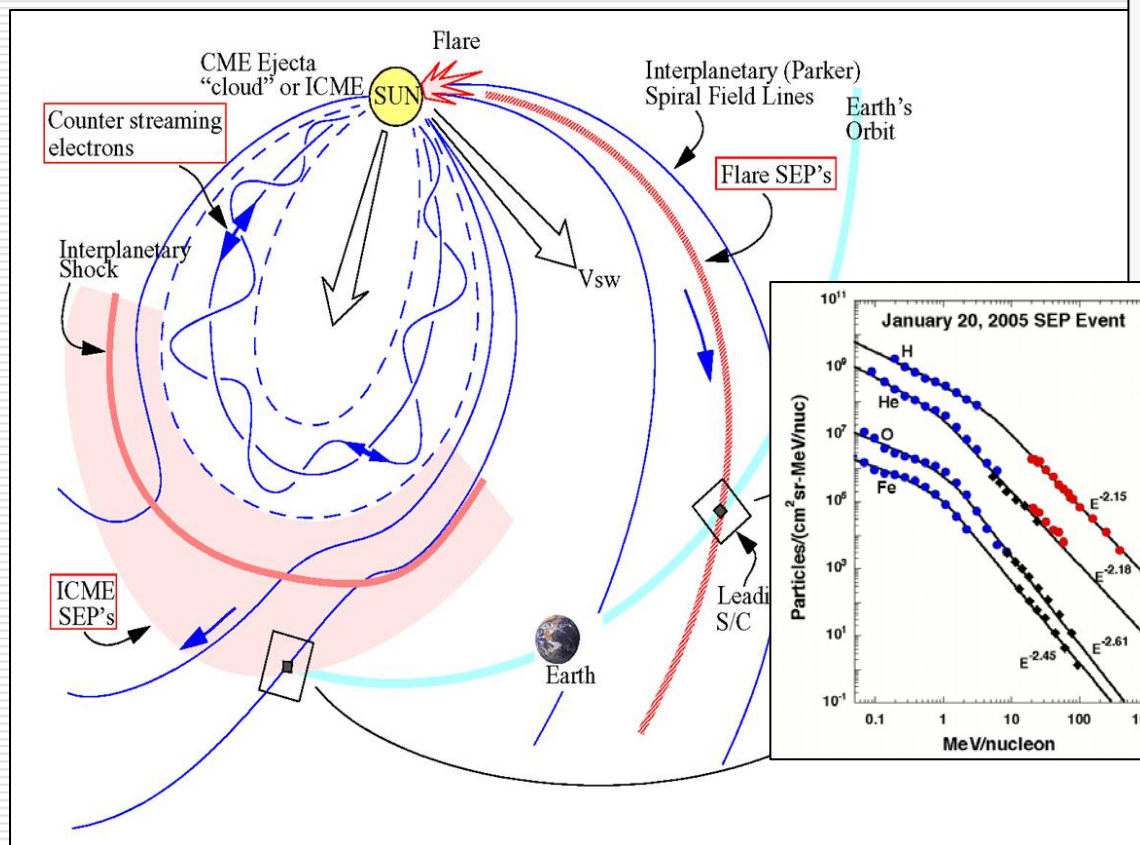


Flux Rope:
(toroidal current)
(major radius)
(minor radius)
(length)
(total mass)

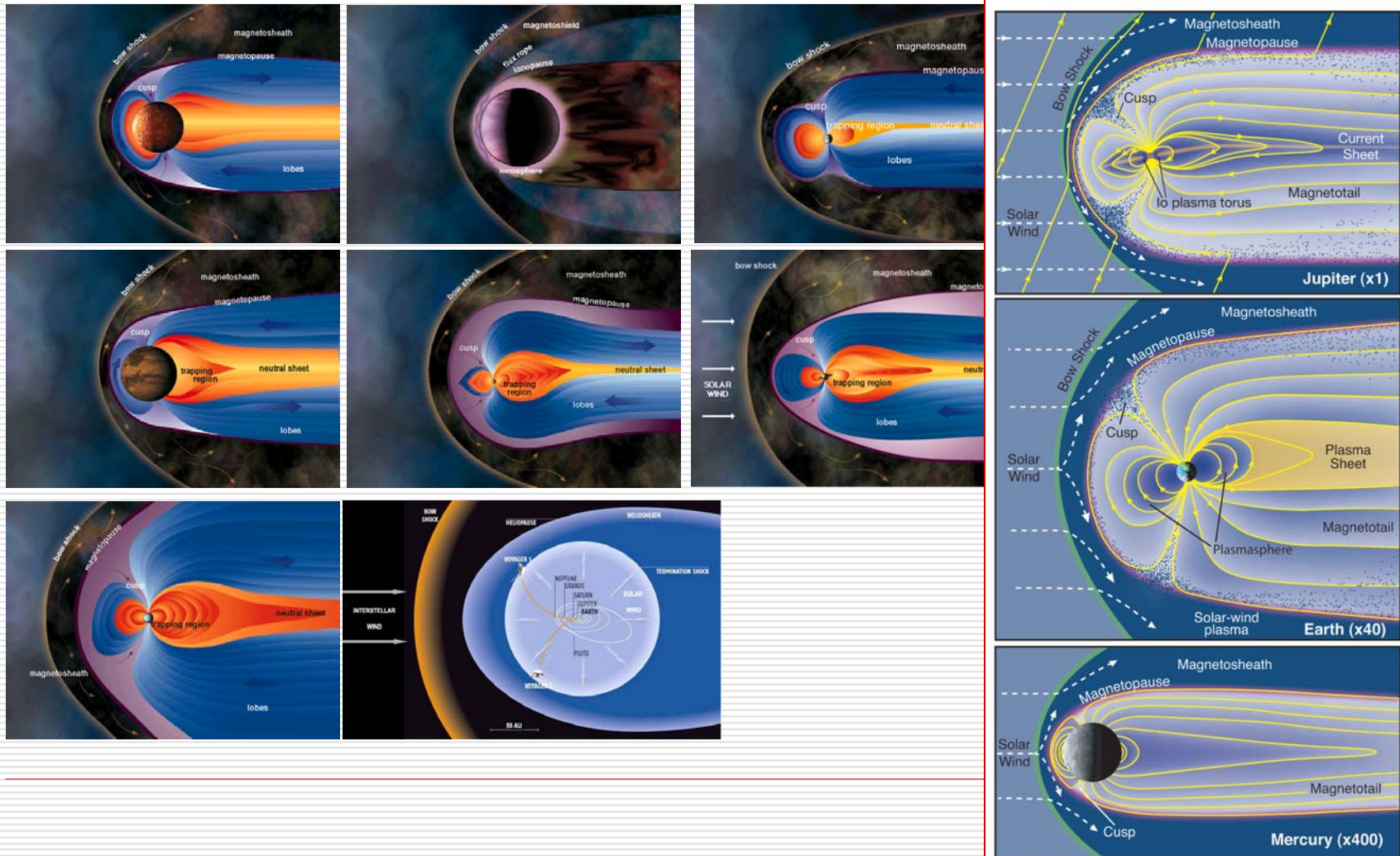
EXPLOSIVE ENERGY CONVERSION AND RELEASE



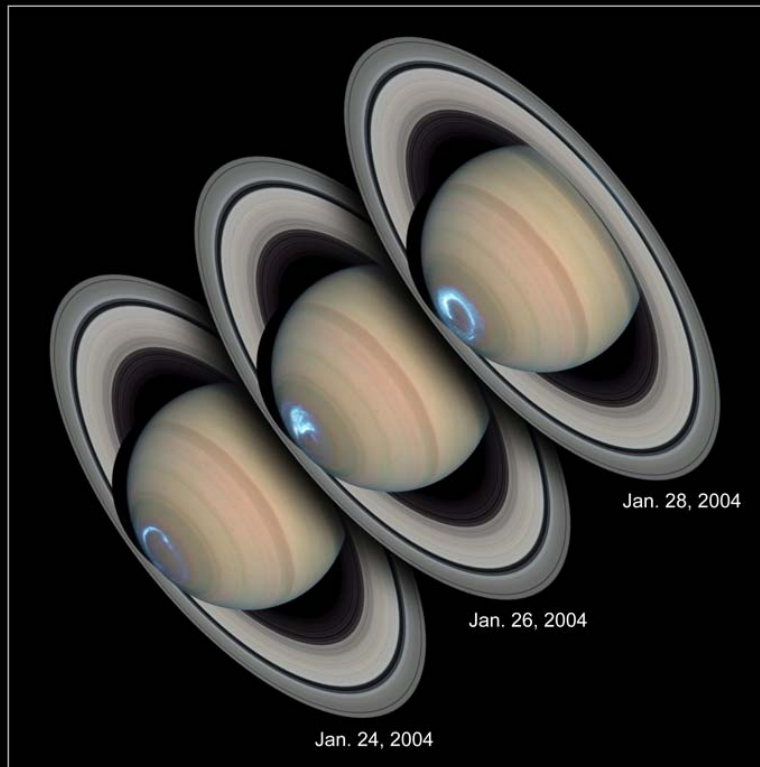
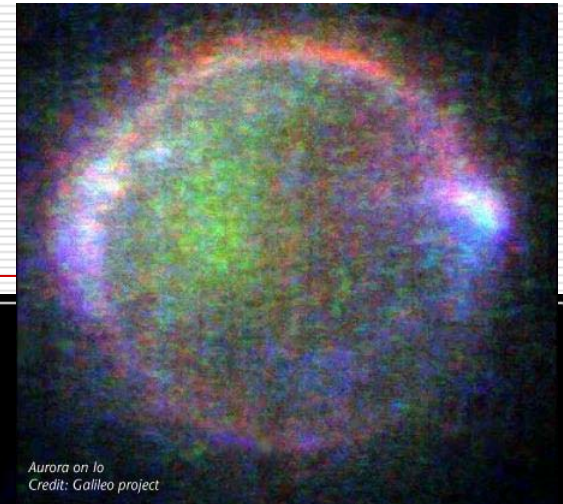
RAPID AND EFFICIENT ENERGIZATION OF PARTICLES



COMPARATIVE STUDIES: BOW SHOCKS AND MAGNETOSPHERES



COMPARATIVE STUDIES: PLANETARY AURORAE



Saturn Aurora
Hubble Space Telescope • ACS • STIS

NASA, ESA and J. Clarke (Boston University)

STScI-PRC05-06a

