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Title: Jupiter's Radiation Belt and Pioneer 10 and 11

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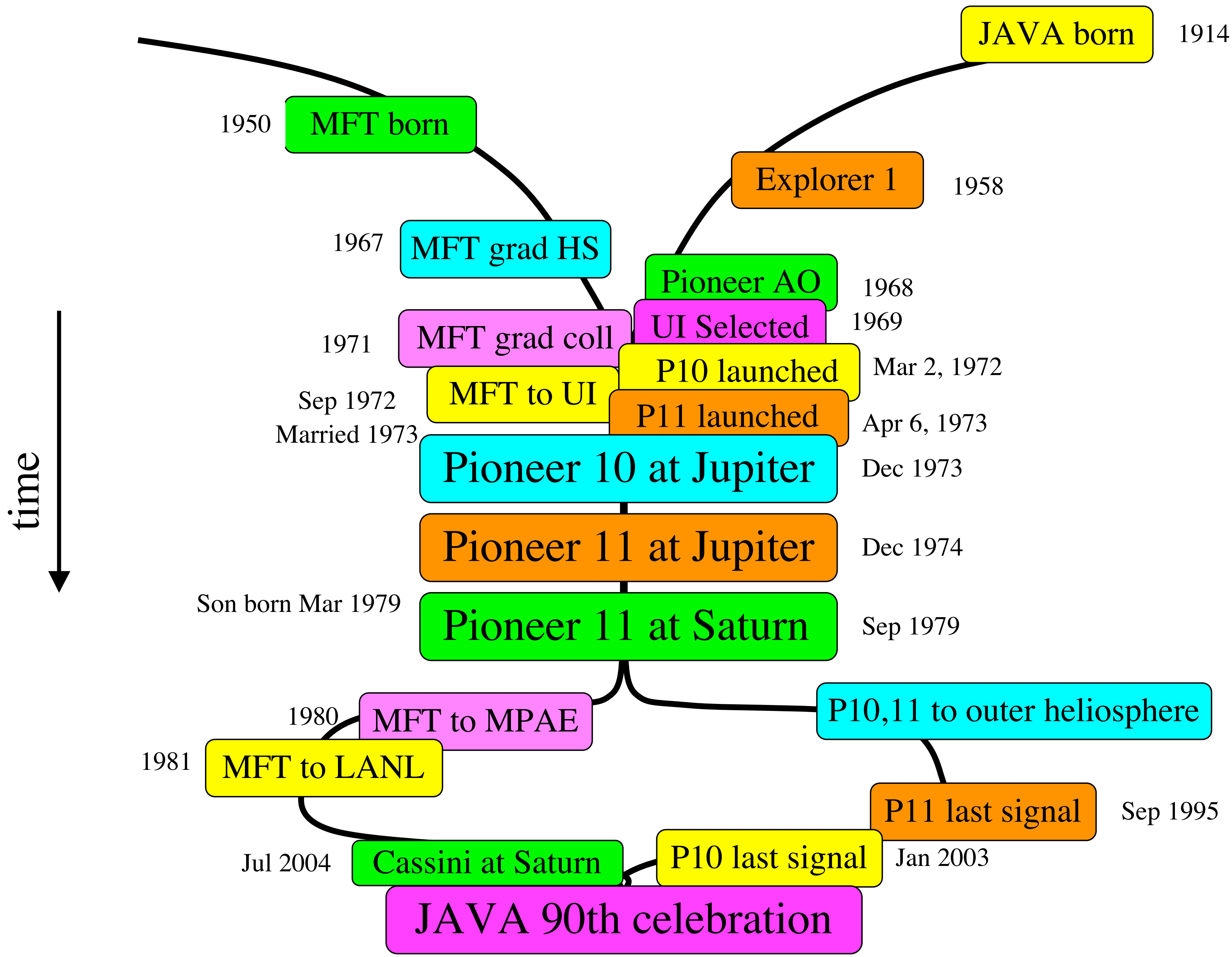
Los Alamos
NATIONAL LABORATORY

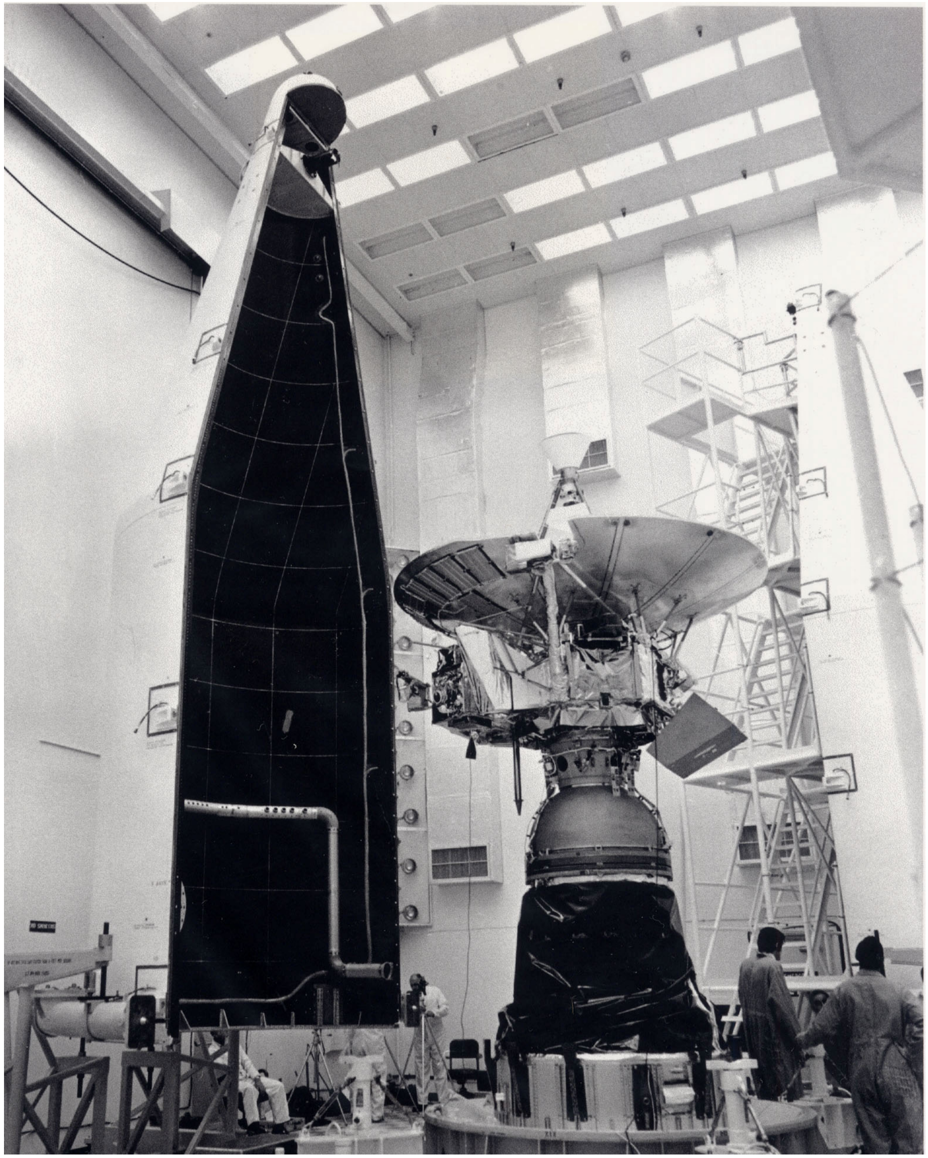
Jupiter's Radiation Belt and Pioneer 10 and 11

Michelle F. Thomsen

Los Alamos National Laboratory

AMNESIACS REMINISCING


JAVA born
1914
1950
MFT born
Explorer 1
1958
1967
MFT grad HS
Pioneer AO
1968
UI Selected
1969
1971
MFT grad coll
P10 launched
Mar 2, 1972
Sep 1972
MFT to UI
P11 launched
Apr 6, 1973
Married 1973
time
Pioneer 10 at Jupiter
Dec 1973
Pioneer 11 at Jupiter
Dec 1974
Son born Mar 1979
Pioneer 11 at Saturn
Sep 1979
1980
MFT to MPAE
P10,11 to outer heliosphere
1981
MFT to LANL
P11 last signal
Sep 1995
Jul 2004
Cassini at Saturn
P10 last signal
Jan 2003
JAVA 90th celebration



Pioneer 10 and 11: Mission to Jupiter and Saturn

P10
Launch: 2 Mar 1972
Jupiter encounter: Dec 1973

P11
Launch: 6 Apr 1973
Jupiter encounter: Dec 1974
Saturn encounter: Sep 1979

Pioneer Instrument Teams

Magnetic Fields Experiment
P.I.: E. J. Smith, JPL
Co-Investigators
P. Dyal, D. S. Colburn, NASA Ames
C. P. Sonnett, U. Ariz.
D. E. Jones, BYU
P. J. Coleman, Jr., UCLA
L. Davis, Jr., Caltech

Cosmic Ray Energy Spectra Experiment
P.I.: F. B. McDonald, GSFC
Co-Investigators
K. G. McKracken, MRL, Aust
W. R. Webber, E. C. Roelof, Univ. NH
B. J. Teegarden,
J. H. Trainor, GSFC

Asteroid-Meteoroid Astronomy Expmt
P.I.: R. K. Soberman, Drexel U.
Co-Investigator
H. A. Zook, NASA JSC

Fluxgate Magnetometer Expmt
P.I.: M. H. Acuña, GSFC
Co-Investigator
N. F. Ness, GSFC

Jovian Charged Particle Expmt (Geiger Tube Telescope)
P.I.: J. A. Van Allen, U. Iowa
Collaborators
C. K. Goertz,
B. A. Randall, R. F. Randall,
D. N Baker, D. D. Sentman,
M. F. Thomsen, M. E. Pesses,
U. Iowa

Jovian Trapped Radiation Expmt
P.I.: R. W. Fillius, UCSD
Co-Investigator
C. E. McIlwain, UCSD

Jovian IR Thermal Structure Expmt
P.I.: Guido Münch, Caltech
Co-Investigators
A. .Ingersoll, G. Neugebauer, Caltech
S. Chase, SBRC
L. Trafton, UT Austin
G. Orton, JPL

Plasma Analyzer Expmt
P.I.: J. H. Wolfe, NASA Ames
Co-Investigators
A. Barnes, J. Mihalov, H. Collard, D. D. McKibbin, NASA Ames
L. A. Frank, U. Iowa
R. Lüst, MPI
D. Intriligator, USC
W. C. Feldman, LASL

Charged Particle Composition Experiment
P.I.: J. A. Simpson, U. Chicago
Co-Investigators
J. J. O'Gallagher, U. Md.
J. Tuzzolino, R. B. McKibben, U. Chicago

Imaging Photopolarimetry Expmt
P.I.: T. Gehrels, U. Ariz.
Co-Investigators
C. Blenman, A. Clements, J. Hameen-Antilla, C. KenKnight, W. Swindell, M. Tomasko, U. Ariz.
D. Coffeen, GISS
R. F. Hummer, SBRC
…

What was known about Jupiter's magnetosphere before Pioneer?

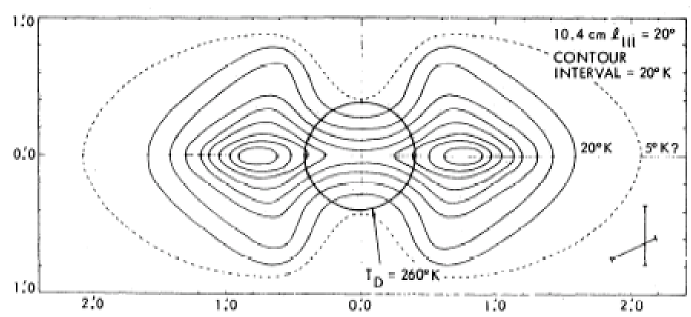
- Discovery of radio emissions at 22.2 Mhz [Burke and Franklin, 1955]
    - Complex structure (time, frequency, polarization)
    - Correlated with central meridian longitude
    - Correlated with longitude of Io

Decametric Radiation

- Nonthermal radiation detected at 20-70 cm [1959, several observers]
    - Linearly polarized approximately parallel to rotational equator, rocking as Jupiter rotates
    - Minima when polarization parallel to planetary equator
    - Emission extended out to 3 R_J

Decimetric Radiation

10.4 cm



[Berge, 1966, copyright by The University of Chicago Press]

Implications

• Jupiter has an intrinsic magnetic field.

• The magnetic axis is tilted by ~9 deg relative to the rotational axis, toward ~200˚ System III longitude.

• The north magnetic pole is in the northern hemisphere (opposite to Earth).

• Jupiter has trapped relativistic electrons, with peak fluxes perpendicular to the magnetic field in the magnetic equator.

• The satellites interact with the magnetosphere.

[*Astrophysical Journal*, *136*, p. 567, 1962]

SYNCHROTRON RADIATION AS THE SOURCE OF JUPITER'S POLARIZED DECIMETER RADIATION*

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AND

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California Institute of Technology

Received April 10, 1962

ABSTRACT

Formulae are given for the synchrotron radiation from a shell of relativistic electrons in a dipole field. The results obtained by evaluating these formulae by digital computer for 13 cases are presented in tables showing the intensity and polarization of the radiation in 10 zones parallel to the dipole axis Fourier transforms of the intensity and polarization for directions parallel and normal to the dipole axis are also tabulated. The partially polarized decimetric radiation observed to come from Jupiter could be obtained from such electron shells, provided that a large number of electrons have relatively flat helices. Magnetic fields of the order of 0 1–1 gauss in the emitting region and about sixty times as much at the poles are required. The electrons must have energies in the 5–75-Mev range and densities of the order of 10^{-3}–10^{-2} cm^{-3}. The problem of obtaining high-energy, flat-helix electrons in the planetary magnetic field is briefly considered.

0.1-1 G

5-75 MeV

What was unknown about Jupiter's magnetosphere before Pioneer?

Everything else!

How big is it?

How does the solar wind interact with it?

Are there trapped radiation belt ions?

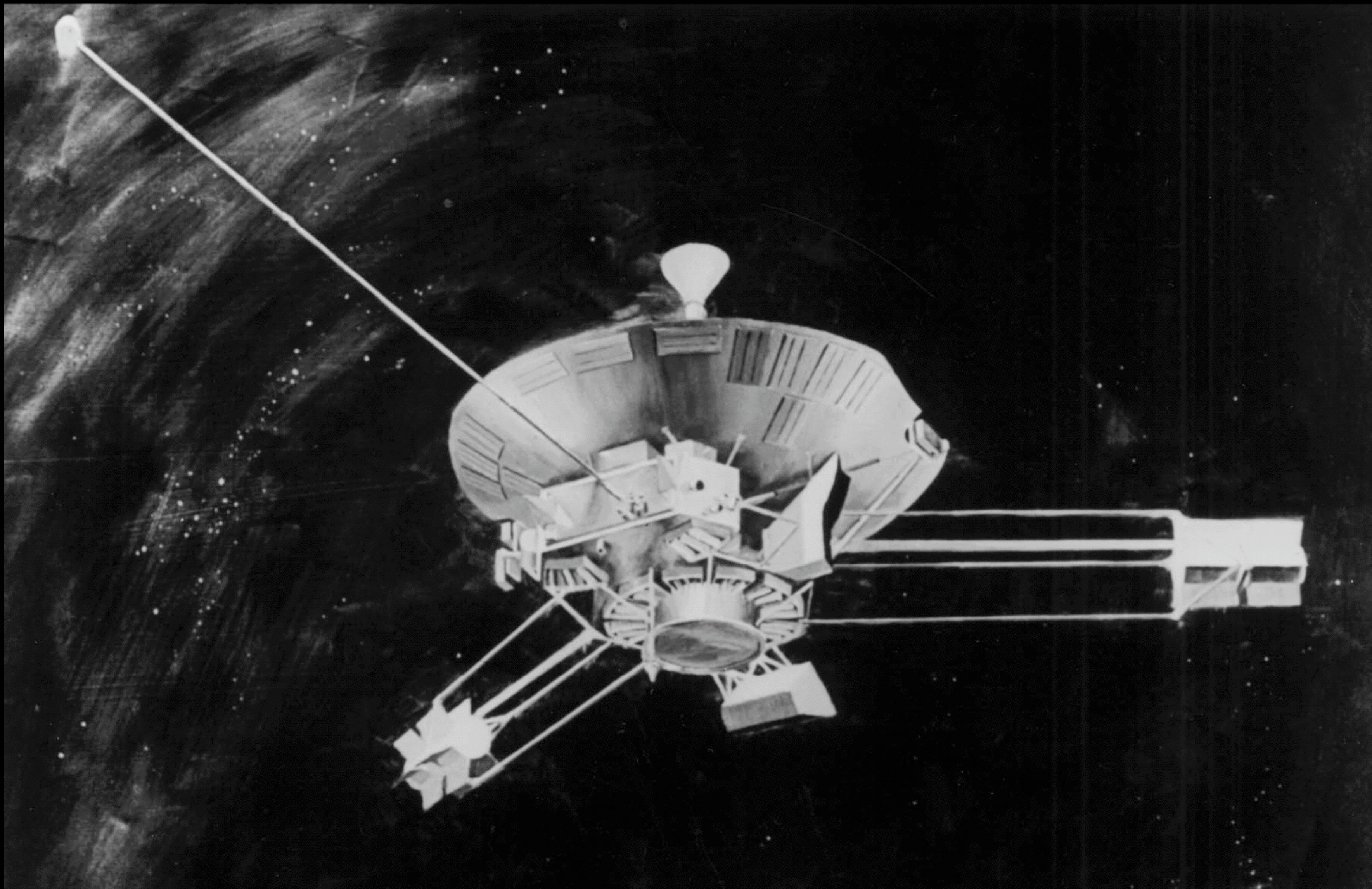
Where do the relativistic electrons come from? How are they transported? How are they energized? How are they lost?

How stable are the radiation belts?

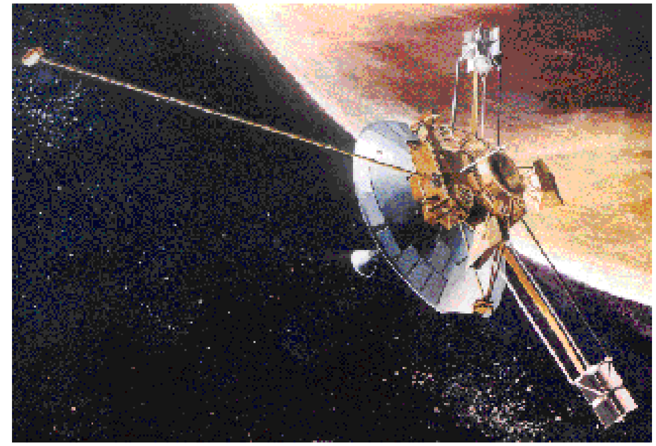
Is there low-energy plasma in the magnetosphere?

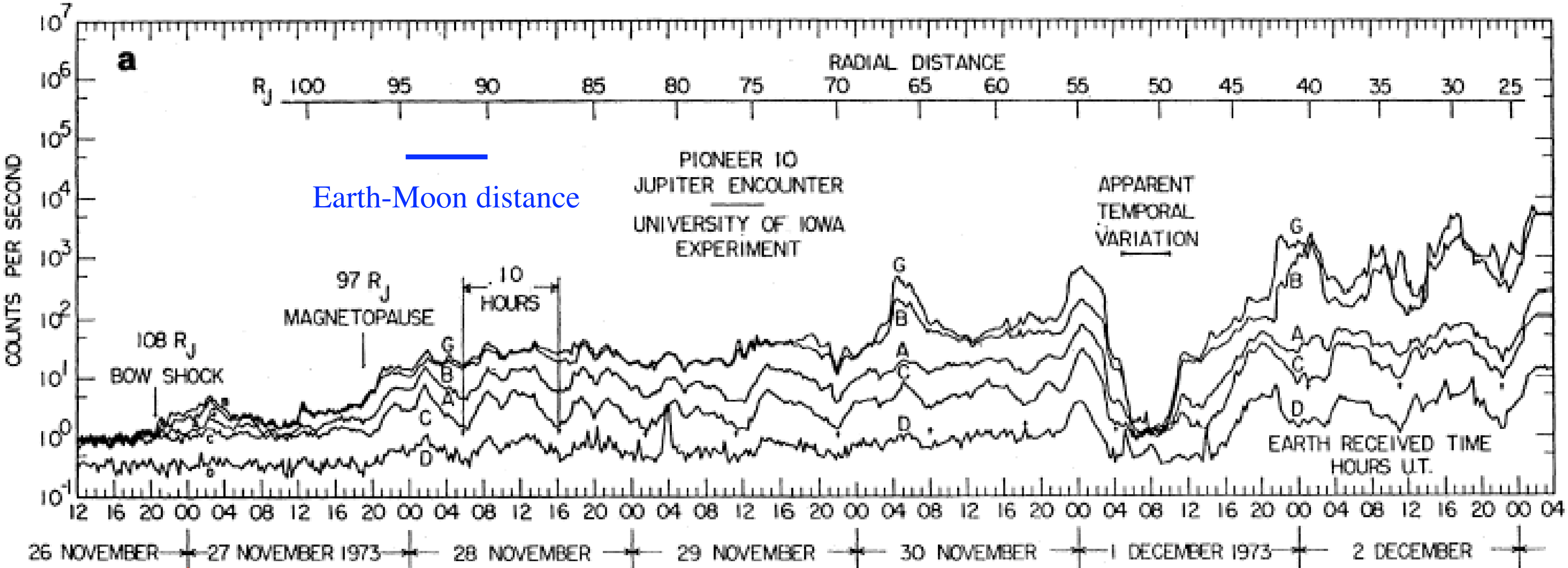
What is the effect of the satellites on the magnetospheric particles? What is the effect of the magnetospheric particles on the satellites? . . .

The Encounter Experience



Arrival at Jupiter

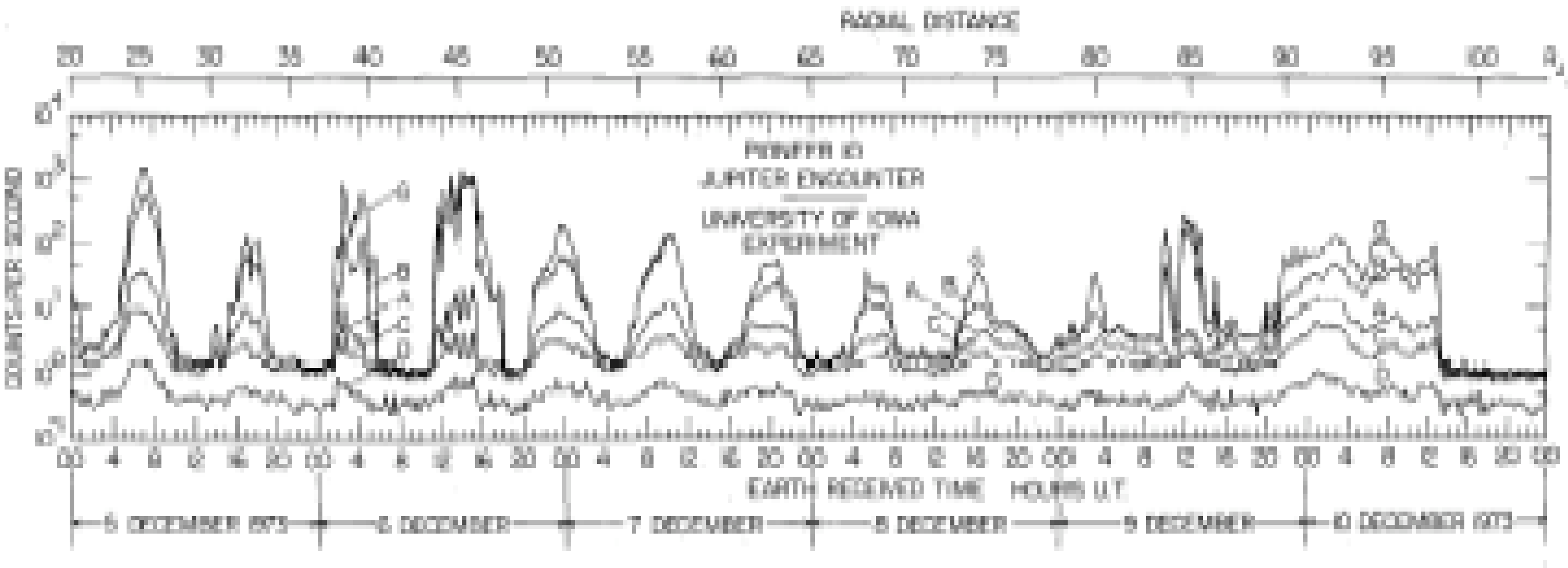




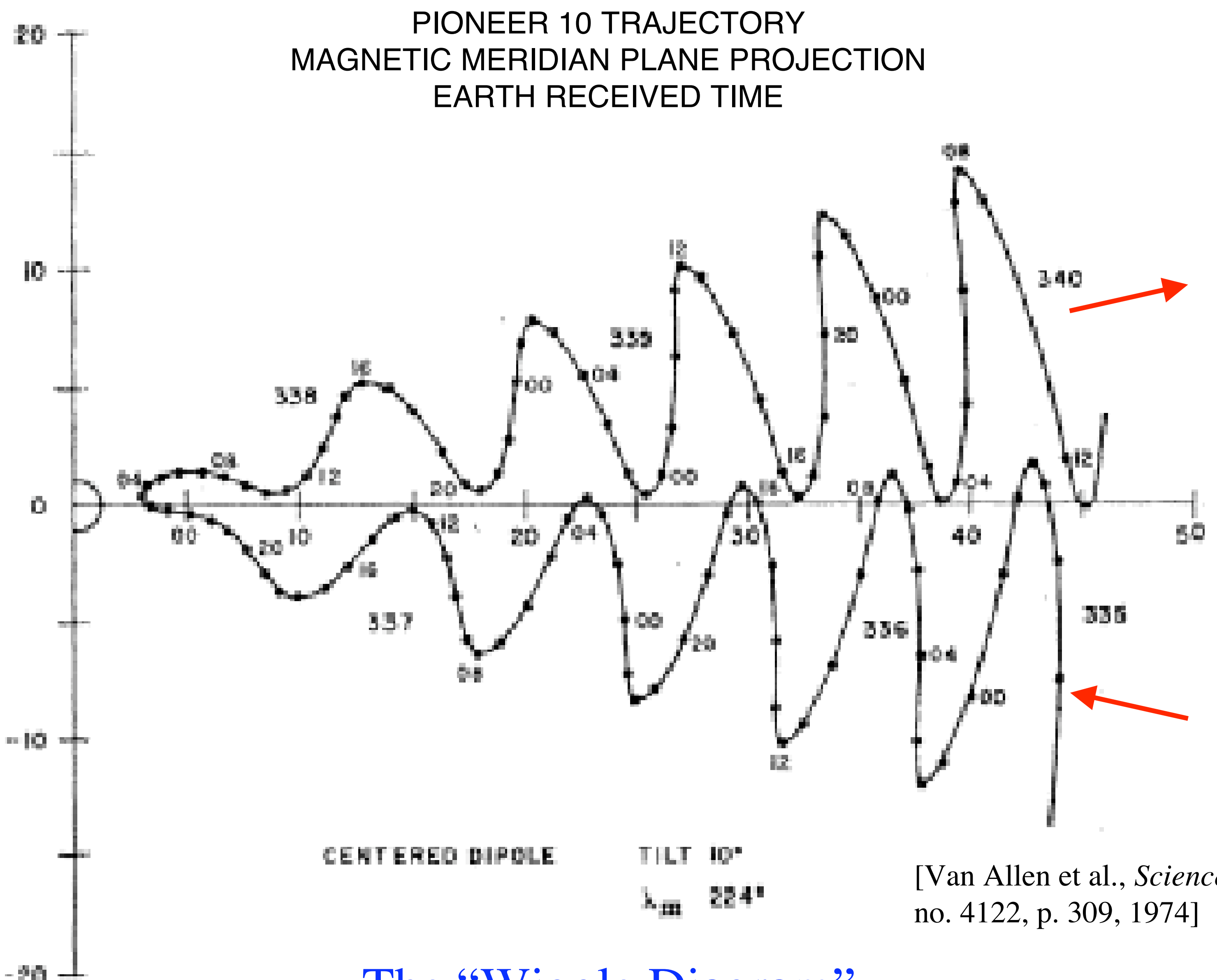
T_p-7 days
7 million km from Jupiter

[Van Allen et al., *Science, 183,* no. 4122, p. 309, 1974]

Pioneer 10 outbound: Strong 10-hr periodicity



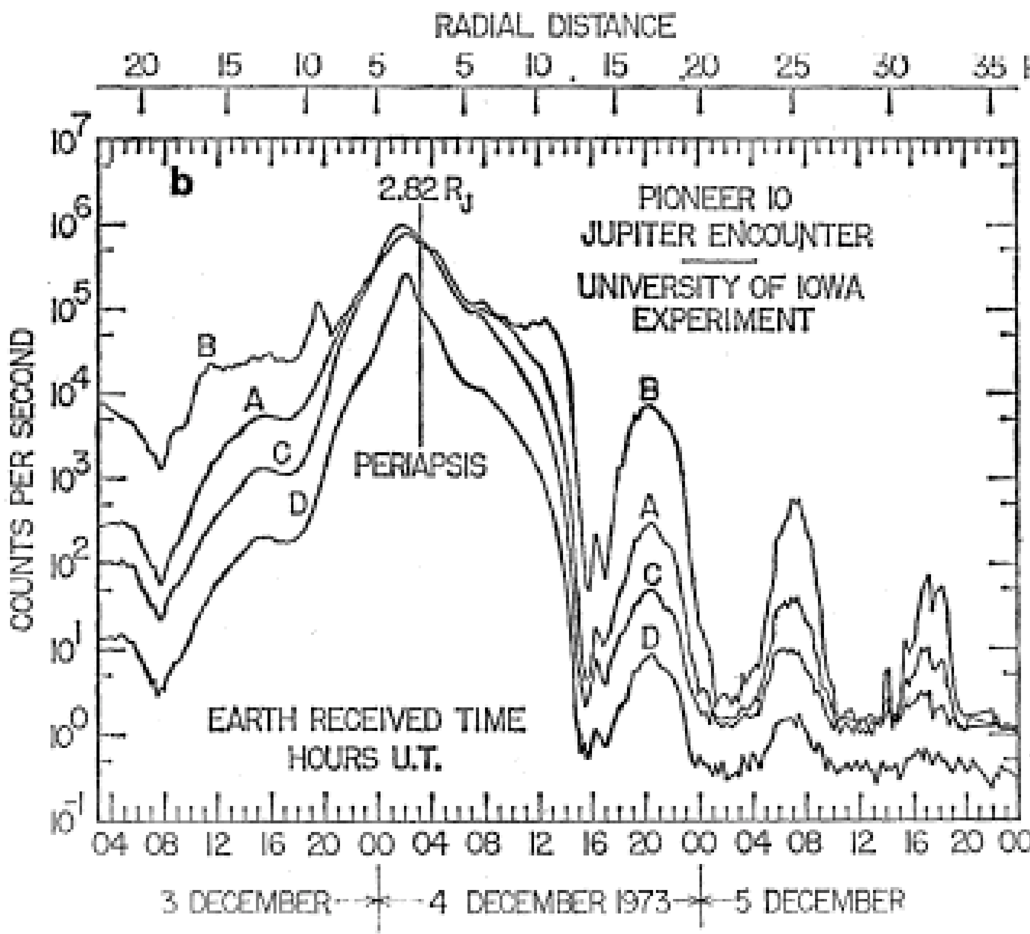
[Van Allen et al., *J. Geophys*. *Res*., *79,* 3559, 1974]



[Van Allen et al., *Science, 183,* no. 4122, p. 309, 1974]

The “Wiggle Diagram”

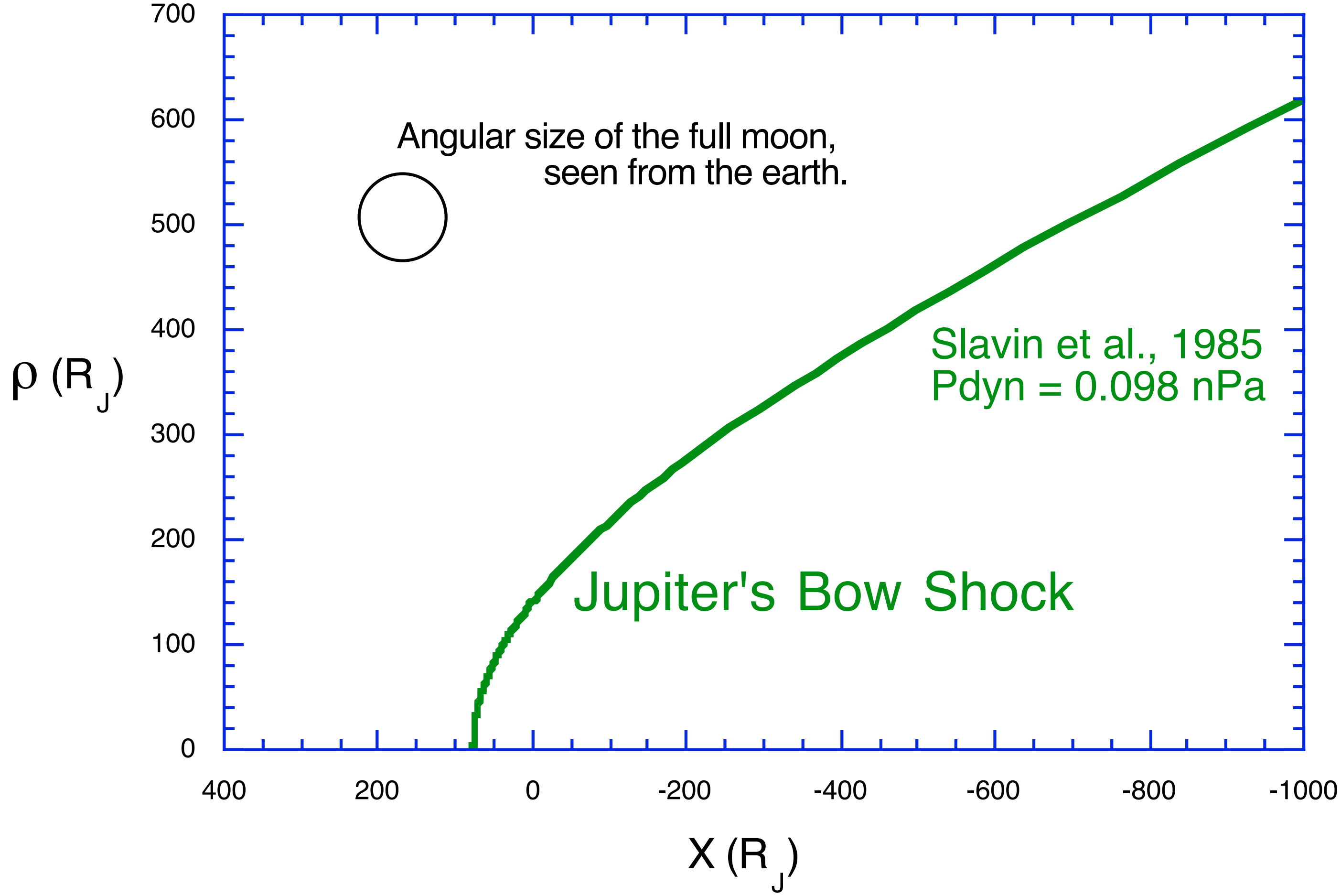
Closest approach: It's hot in there!



[Van Allen et al., *Science, 183,* no. 4122, p. 309, 1974]

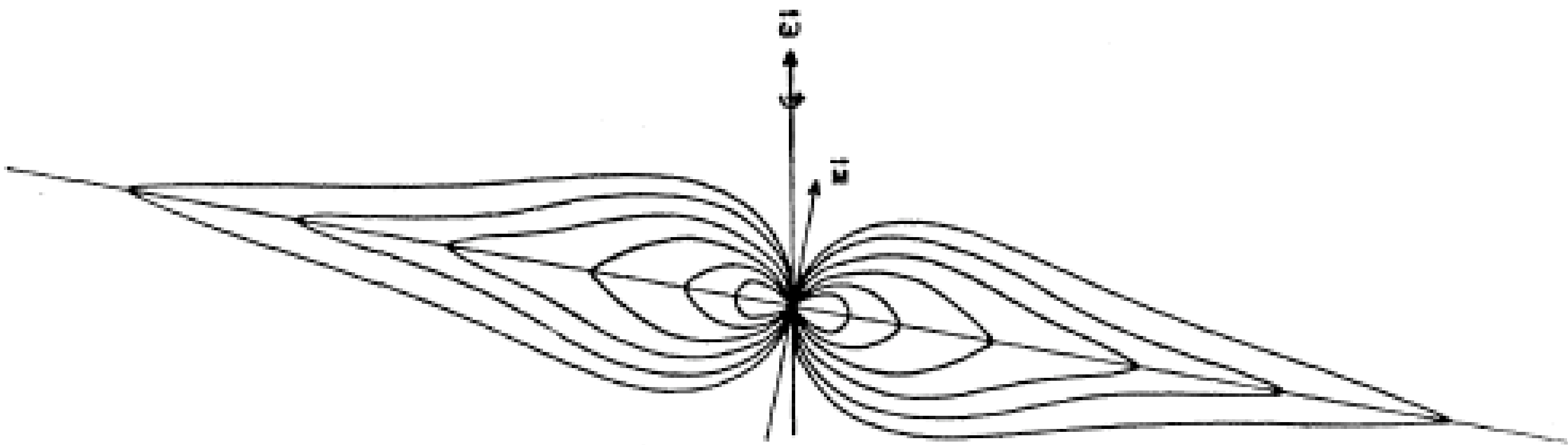
The Press Conference: Instant Science!

What space science learned from Pioneer



Jupiter's magnetosphere is enormous
and highly compressible.

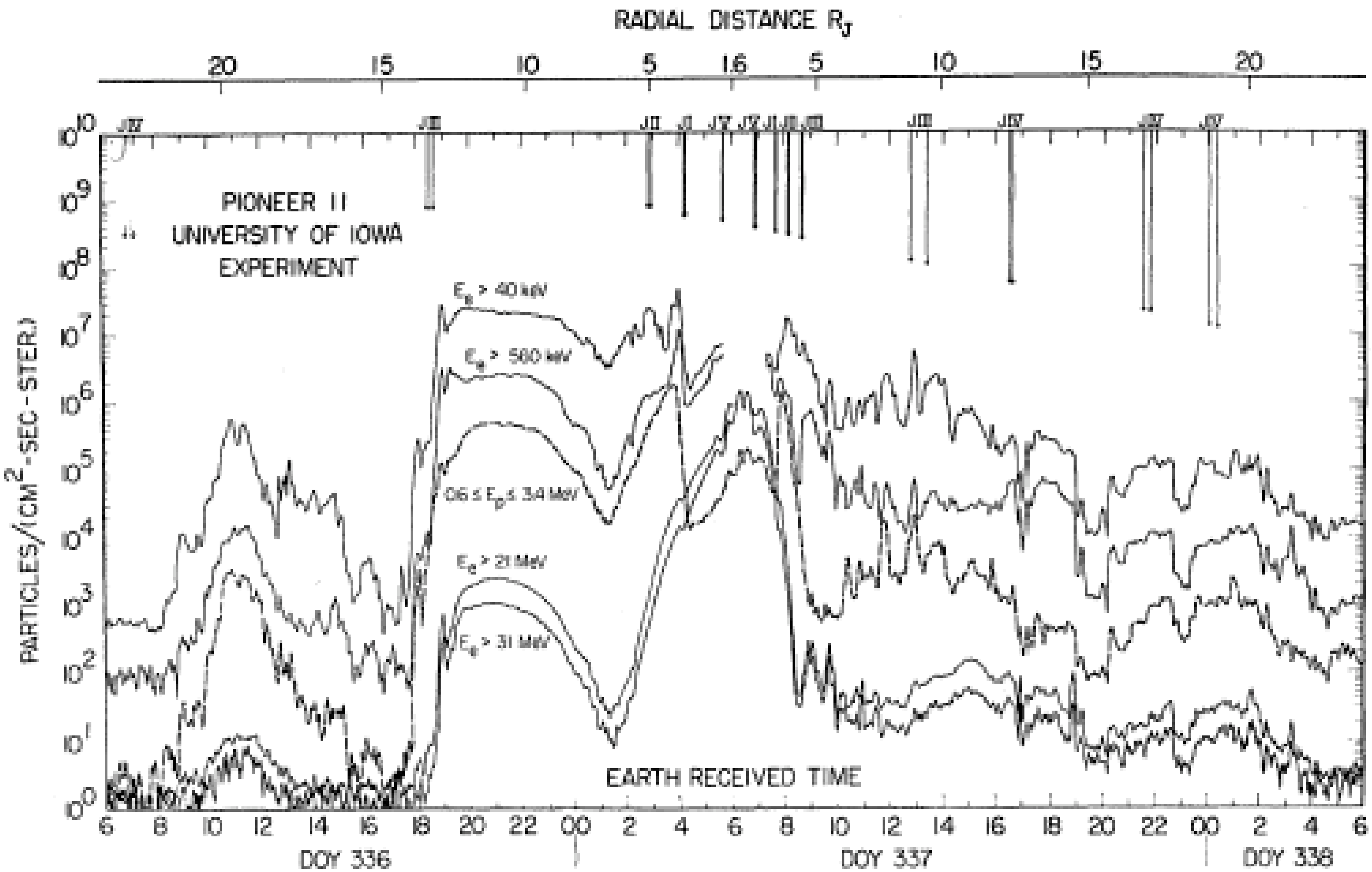
It is greatly distorted by the rapid rotation and strong currents flowing near the magnetic equator.



The rotation extends all the way to the magnetopause.

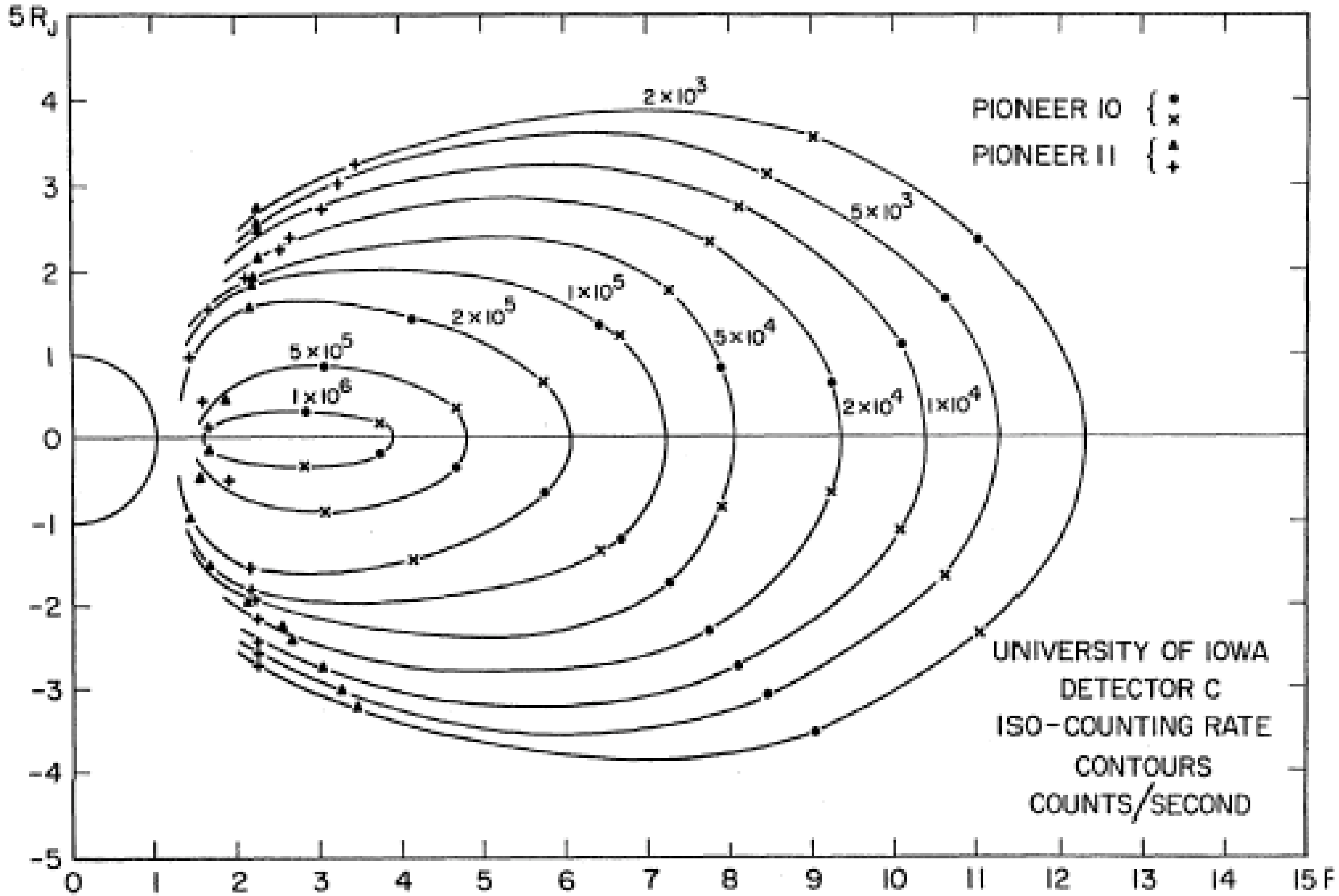
[Van Allen et al., *Science, 183,* no. 4122, p. 309, 1974]

The presence of very high-energy particles in the outer magnetosphere, as well as their angular distributions, imply complex nonadiabatic processes.



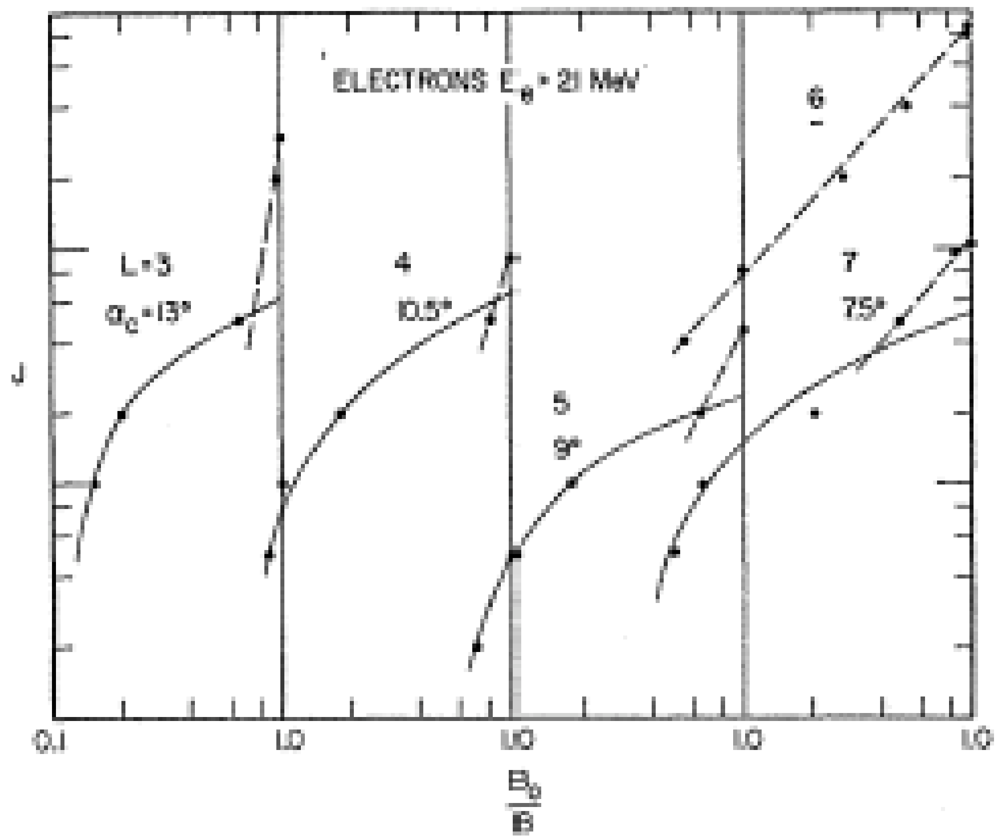
[Van Allen et al., *Science, 188,* no. 4187, p. 459, 1975]

Close to the planet, the radiation belts are intense, well ordered by the magnetic field, and largely confined to the magnetic equator.



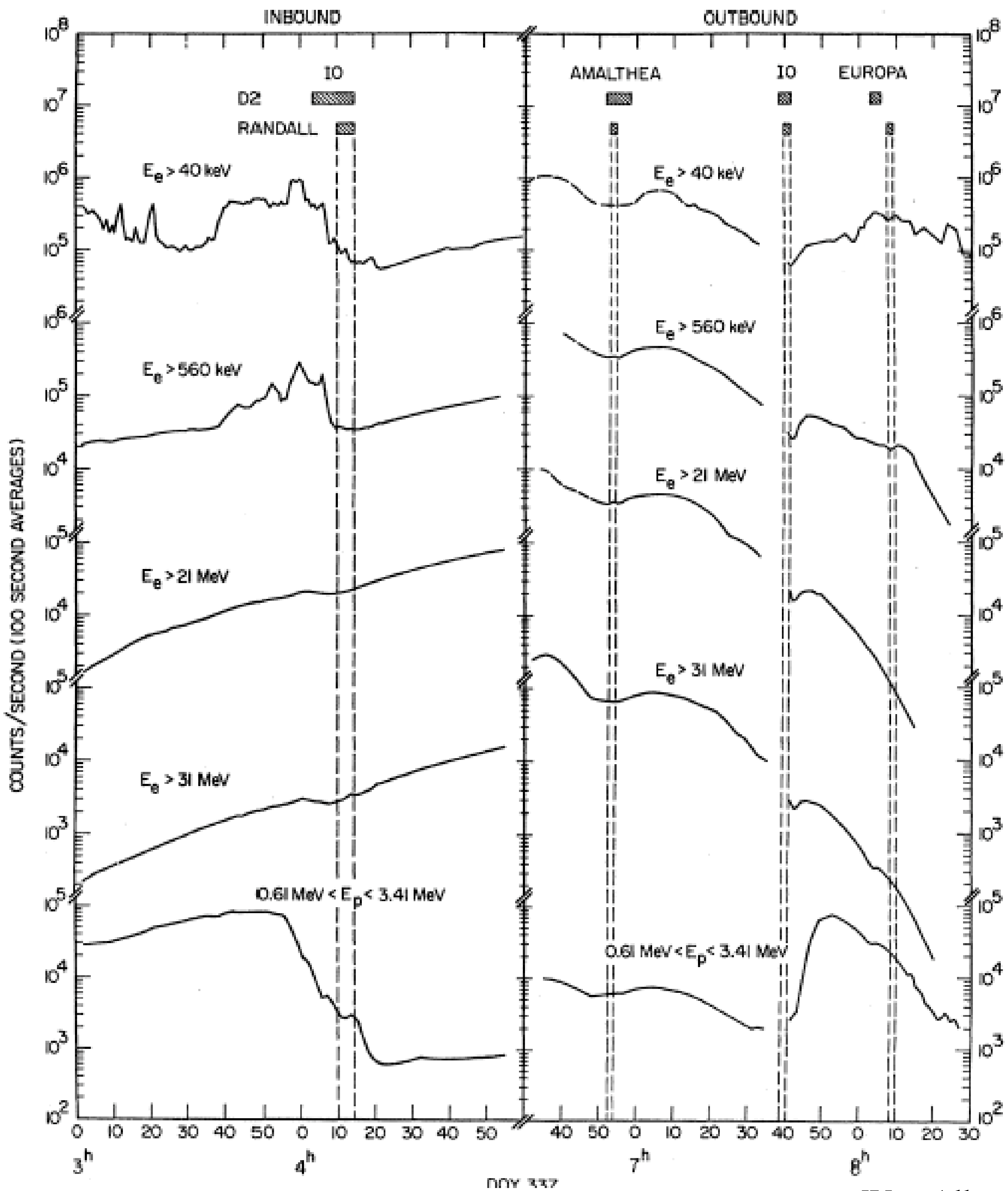
[Van Allen et al., *Science*, *188*, no. 4187, p. 459, 1975]

Radiation belt particles are subject to losses due to wave-particle interactions, causing scattering into the loss cone.



[Van Allen et al., *Science*, *188*, no. 4187, p. 459, 1975]

Because of these losses, the radiation belts must be replenished.



Trapped radiation is also lost to satellite absorption.

⇩

Strength of radial transport

⇩

How the belts are replenished

[Van Allen et al., *Science, 188,* no. 4187, p. 459, 1975]

What the space program learned from Pioneer

The asteroid belt can be safely traversed.

Jupiter's radiation environment is exceedingly hostile, but spacecraft can survive a passage.

Spacecraft can last a lot longer and produce a lot more science than their "nominal" mission.

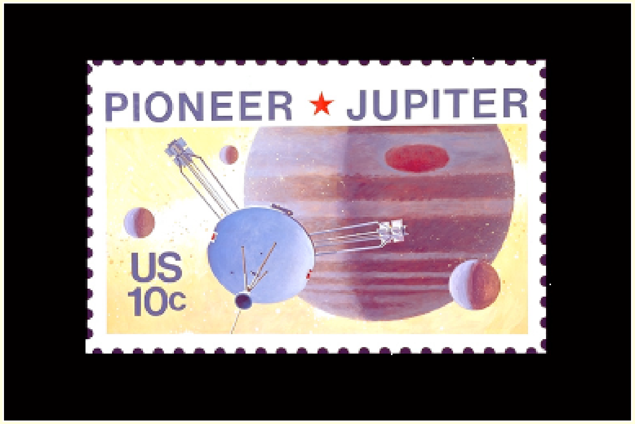
What I learned from Pioneer

Space physics is exciting!

Nature is truly amazing. And sometimes it even makes sense.

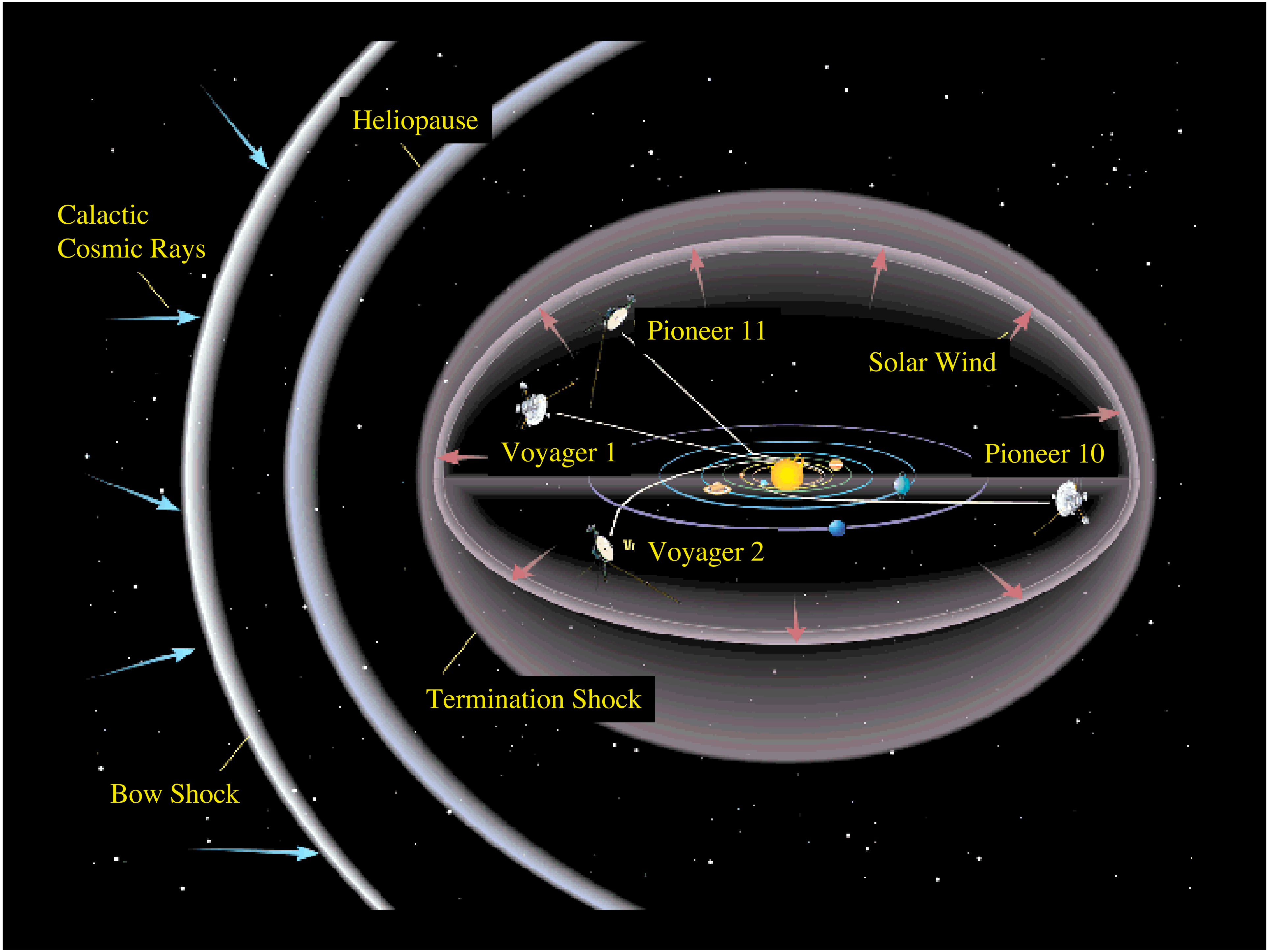
Discovery is a great privilege, made possible by the foresight, creativity, and hard work of many others.

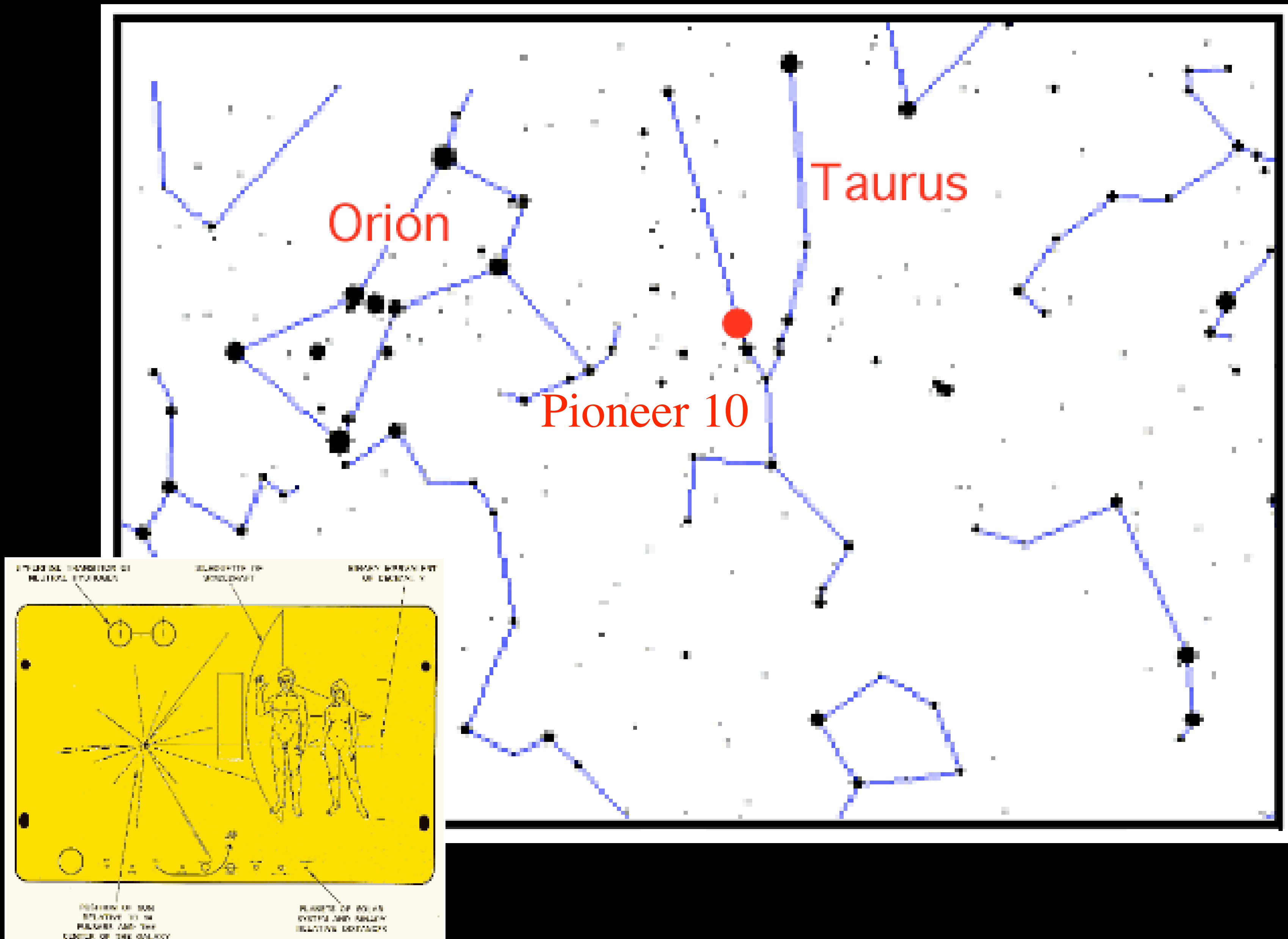
The camaraderie of a shared adventure can be treasured for a lifetime.

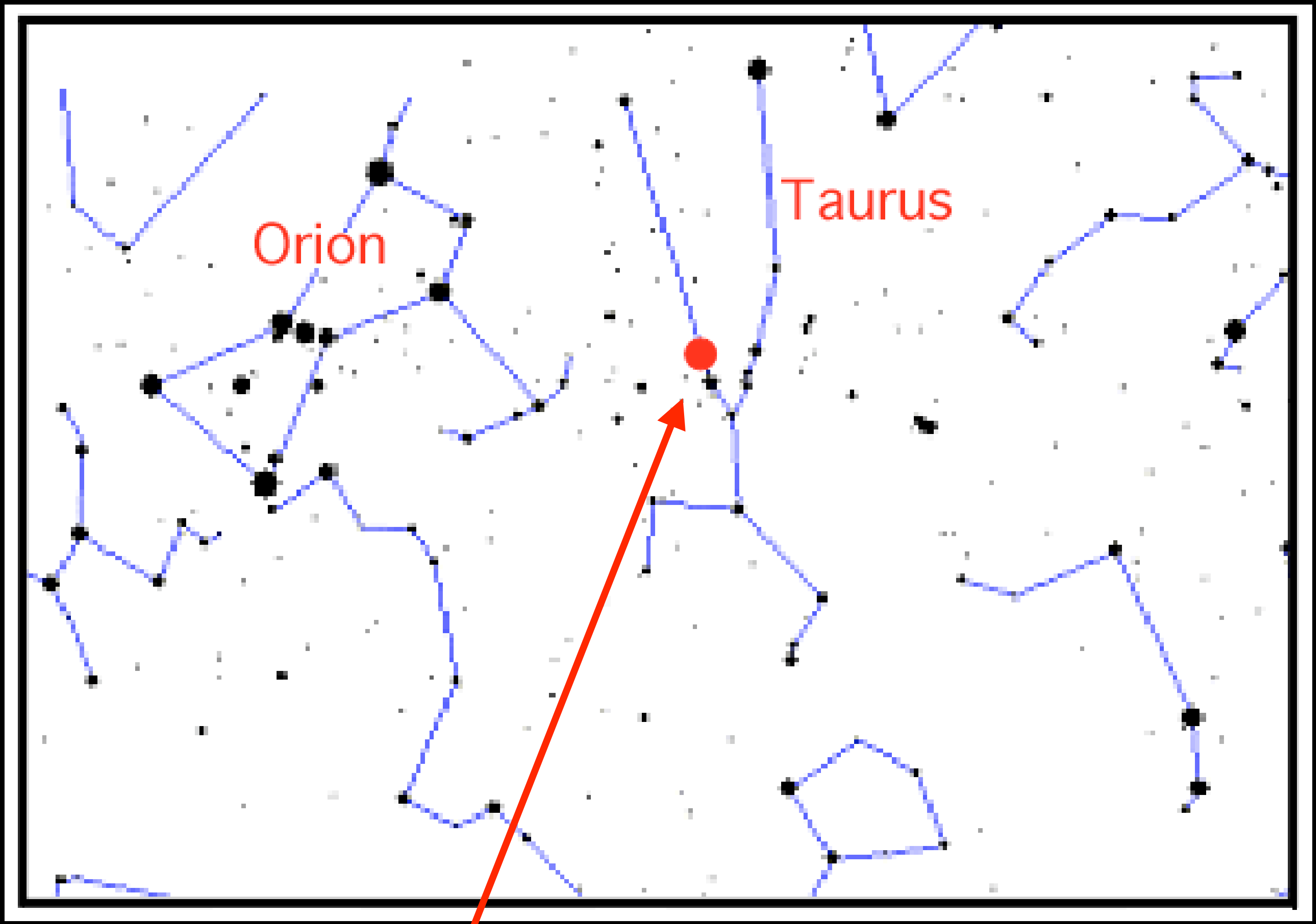


Epilogue

Pioneer 10's last signal was received on 23 January 2003
Current distance from Sun : 86.34 AU
Speed relative to the Sun: 12.18 km/sec
Distance from Earth: 12.91 billion kilometers
Round-trip Light Time = 23 hours 55 minutes


Heliopause
Calactic
Cosmic Rays
Pioneer 11
Solar Wind
Voyager 1
Pioneer 10
Voyager 2
Termination Shock
Bow Shock


Orion
Taurus
Pioneer 10



James Van Allen, your thumb-print is here…

Thanks for the ride!