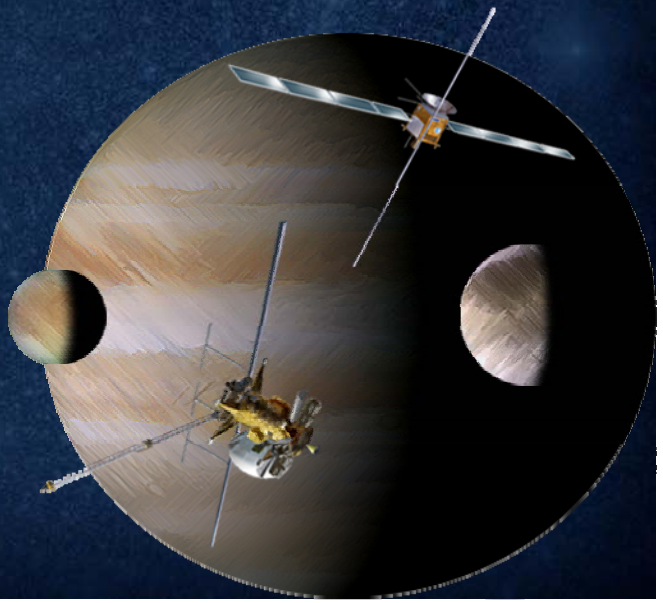
Space Environment Models

Insoo Jun

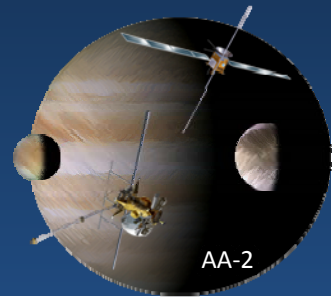
EJSM Instrument Workshop

July 27 – 29, 2010



Models to be Covered

- Magnetic field models
  - VIP4
  - Khurana
- Jovian trapped radiation environment models
  - High energy electrons and protons:
    - Divine
    - GIRE
    - JOREM
  - Low energy (i.e., plasma) electrons and protons:
    - Divine-Garrett
  - Trapped heavy ions: HIC
- Other environment models



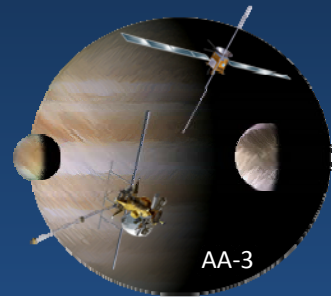
Magnetic Field: VIP4

What is it?

- **V**oyager **I**o **P**ioneer **4**th order spherical harmonic magnetic field model
- Based on Pioneer and Voyager in-situ data plus Earth-based Io flux tube footprint observations
- Fixed to System-III rotational coordinates
  - Dessler, "Physics of the Jovian Magnetosphere", Appendix B (1983)
- Accepted current standard for internal component of Jupiter magnetic field

Where do you find it?

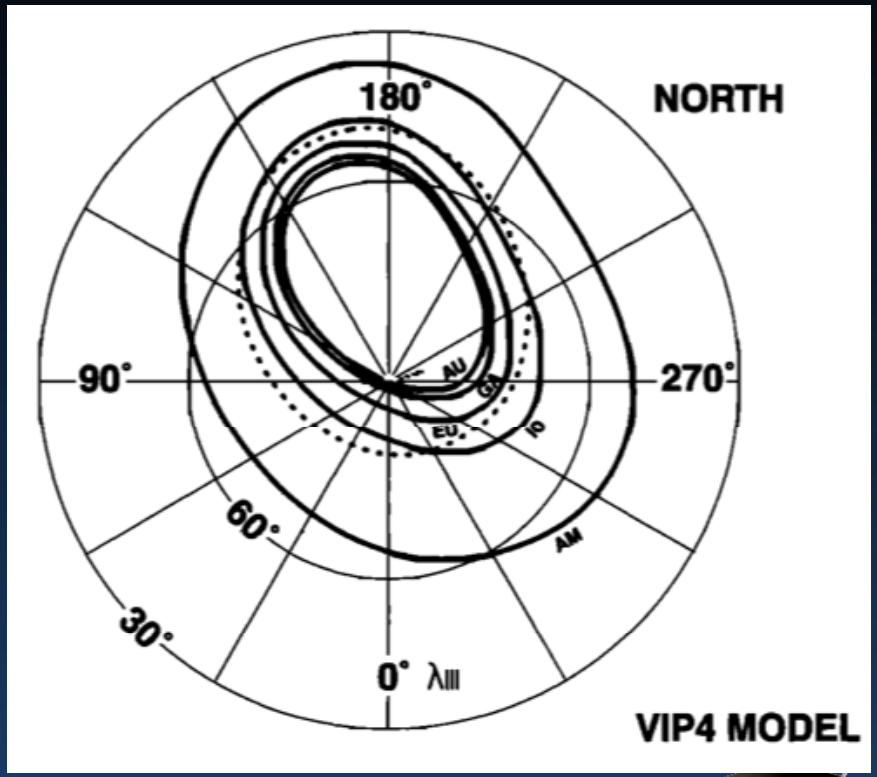
- VIP4 Model: Connerney et al., "New models of Jupiter's magnetic field constrained by the Io flux tube footprint", J. Geophys. Res., 103, 11929-11939, 1998.

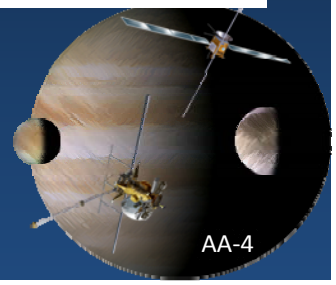


Magnetic Field: VIP4

What is its typical use?

- Vector magnetic field
- Valid in the inner and middle magnetosphere within 30Rj
- Field line mapping from Galilean satellites to Jupiter





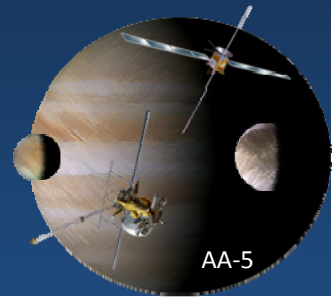
Magnetic Field: Khurana

What is it?

- Global Jupiter magnetic field model.
- Includes VIP4-derived internal component and multiple external components including dipole tilt, ring current, magnetopause current and tail current.
- Internal component fixed to System-III rotational coordinates and external components in JSO Jupiter-Sun fixed coordinates.

Where do you find it?

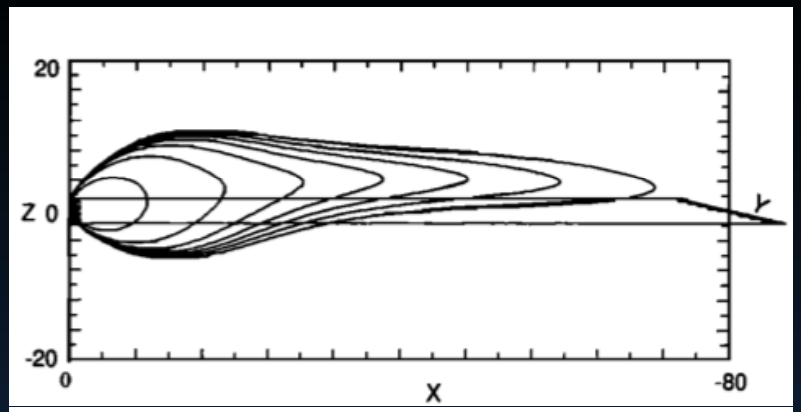
- Khurana K.K. and N. A. Tsyganenko, Towards a global magnetic field model of Jupiter's magnetosphere derived from observations of Galileo and previous missions, talk presented at the spring AGU meeting, 17-21 May 2004, Montreal, Canada, 2004.
- Current version available from author.

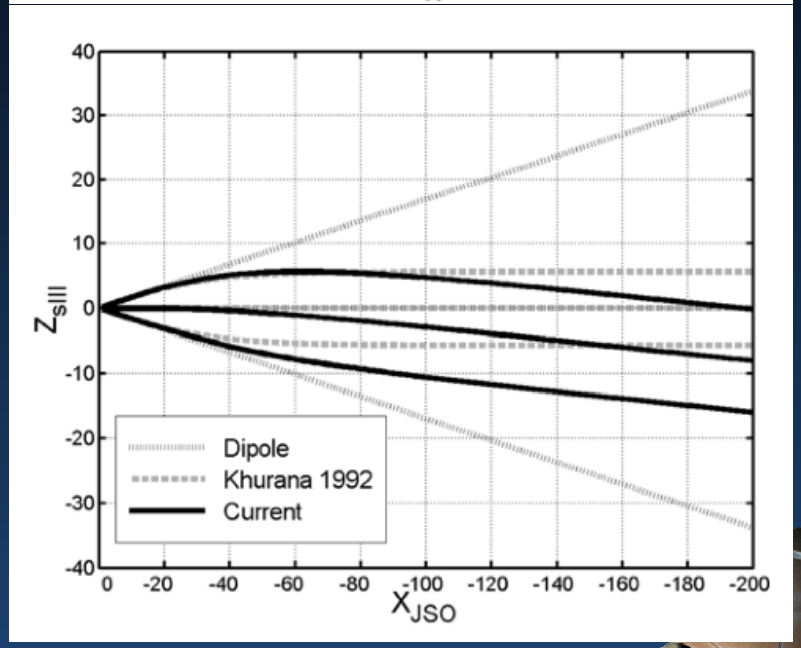


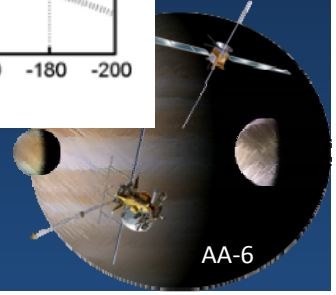
Magnetic Field: Khurana

What is its typical use?

- Vector magnetic field
- Applicable to inner, middle and outer (magnetopause and tail) magnetic field
- Current sheet and magnetic equator position estimates for middle and outer magnetosphere



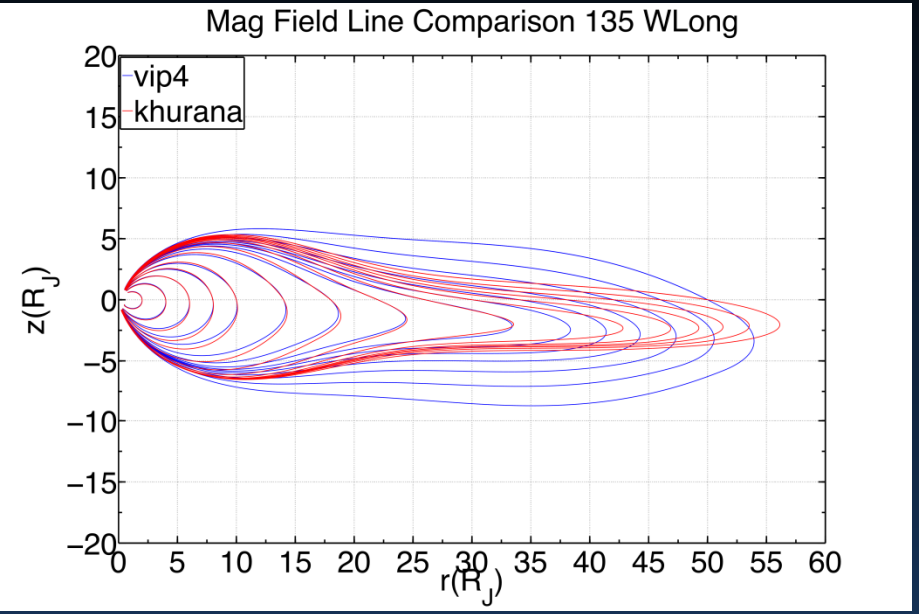


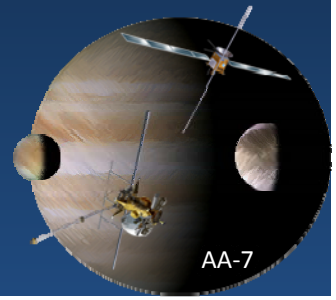


Magnetic Field: VIP4 or Khurana?

Which model should I use?

- Depends on what information you need.
- Both models have the same internal field component.
- Nearly the same vector magnetic field estimates in SIII equator inside for 15 RJ (within 5% total field strength).
- VIP4 is simpler.
- Khurana is more complex, yet includes additional external components.

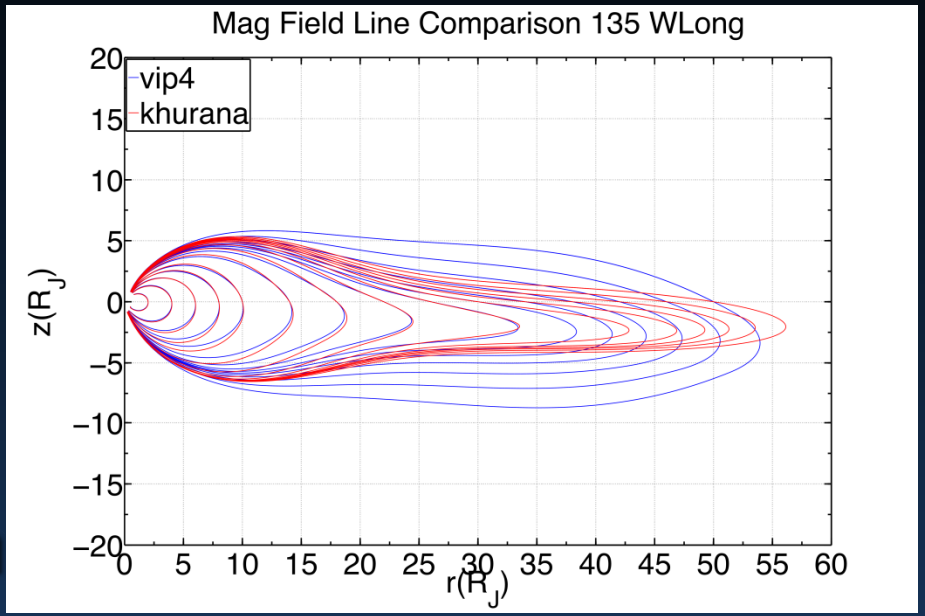


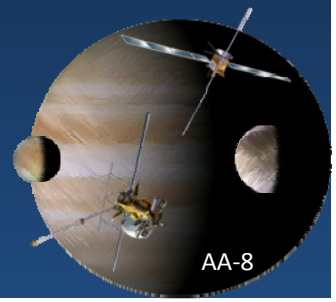


Magnetic Field: VIP4 or Khurana?

Which model should I use?

- Inside 15 RJ (on the SIII equator) both models have nearly identical vector magnetic field (within 5% total field strength). Use either model.
- Outside 30 RJ, VIP4 is not applicable. Use Khurana.
- Between 15 and 30 RJ, magnetic field estimates from both models are often similar, but not always. Use best judgment.





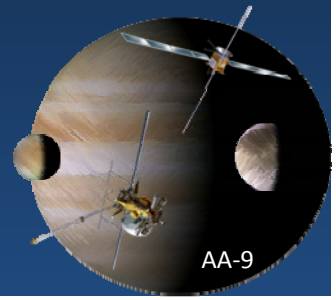
Trapped Particles: Divine-Garrett

What is it?

- A comprehensive Jupiter radiation model - reference Jupiter radiation environment model since 1983.
- Pioneer and Voyager in-situ data plus Earth-based Synchrotron observations
- Limited in temporal and spatial coverage

Where do you find it?

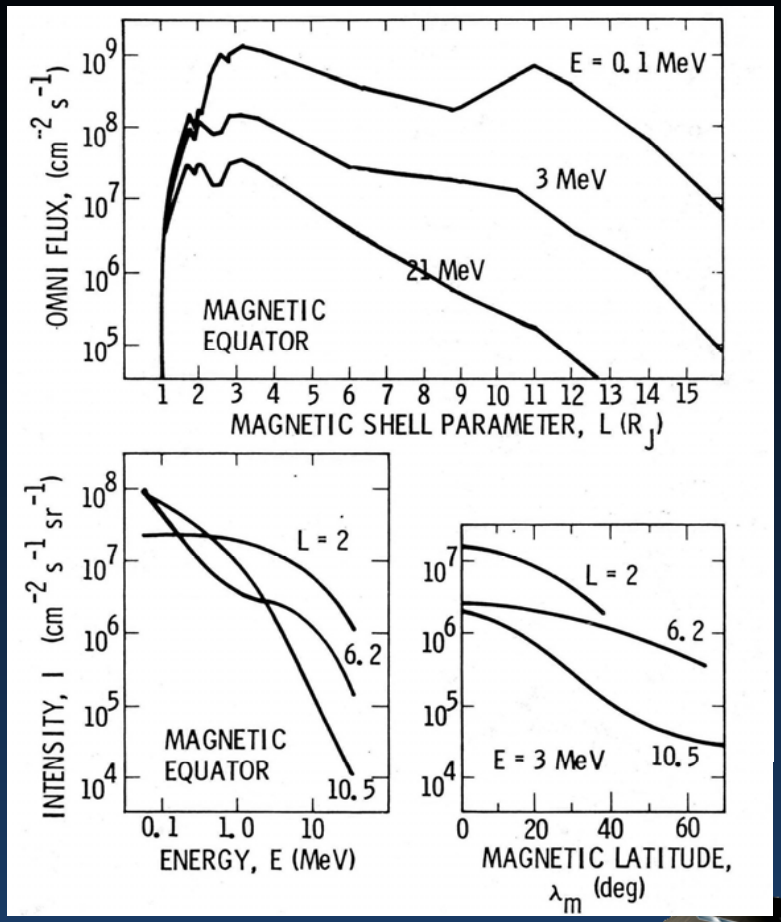
- Divine Electron and Proton Models: Divine, N. T., Garrett, H. B., "Charged Particle Distributions in Jupiter's Magnetosphere", J. Geophys. Res., 88, 6889-6903, 1983



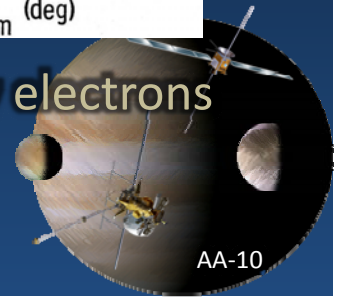
Trapped Particles: Divine-Garrett

What is its typical use?

- Is a reference standard
- Covers radial distance out to 50 Rj.
- Used a simpler tilted offset dipole model
- Also provides estimates of the ion, electron, and proton plasma environment



Example: DG high energy electrons



Trapped Particles: GIRE

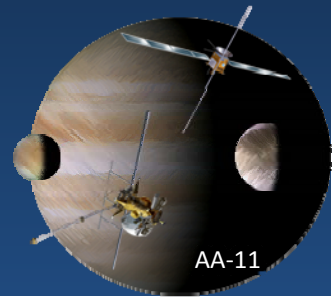
What is it?

- **G**alileo **I**nterim **R**adiation **E**lectron Model
- Update to Divine-Garrett radiation model using Galileo EPD electron data and VIP4 B-field model

Where do you find it?

- Garrett, H. B., I. Jun, J. M. Ratliff, R. W. Evans, G. A. Clough, and R.W. McEntire, "Galileo Interim Radiation Electron Model", JPL Publication 03-006, 72 pages, The Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, 2003.
- Complete description and program listings at:

  http://www.openchannelfoundation.org/projects/GIRE/



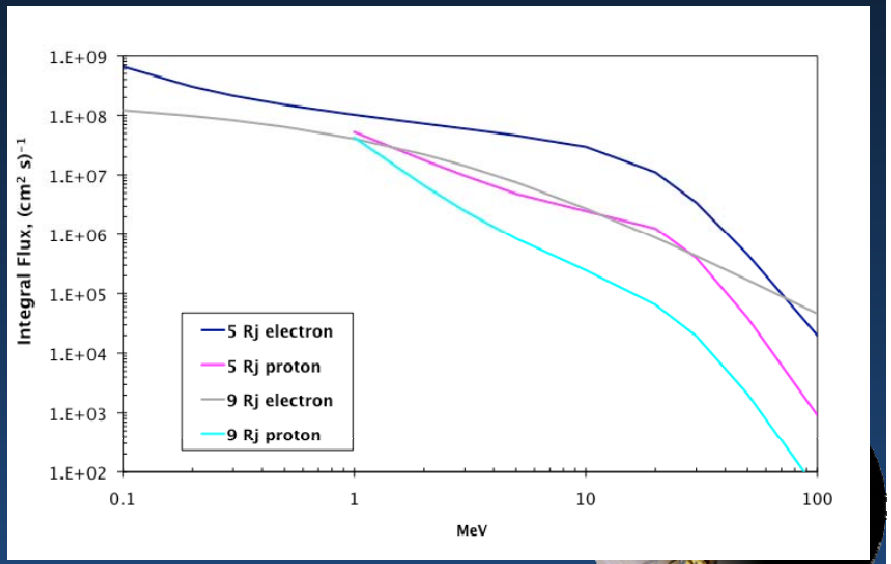
Trapped Particles: GIRE

What is its typical use?

- Primarily intended to cover radial distance 1-16 Rj for electrons
- Electrons estimated by Divine model for Rj>16
- Uses Divine pitch angle distributions and proton model
- Covers energy range 0.1 MeV to ~30 MeV.

Example:

- Mission fluence energy spectra
- Fluxes at 6Rj, 9Rj, 15Rj, etc.



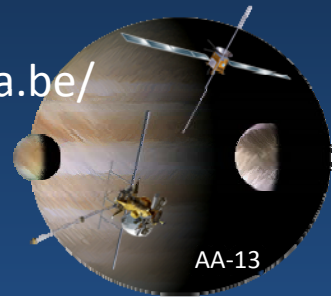
Trapped Particles: JOREM

What is it?

- **JO**vian **R**adiation **E**nvironment and **M**odel
- Analysis of in situ data from flyby and orbit mission: Pioneer 10/11, Voyager 1/2, Ulysses, Galileo
- Improving of discontinuities at ~Ganymede distance
- Output includes confidence level

Where do you find it?

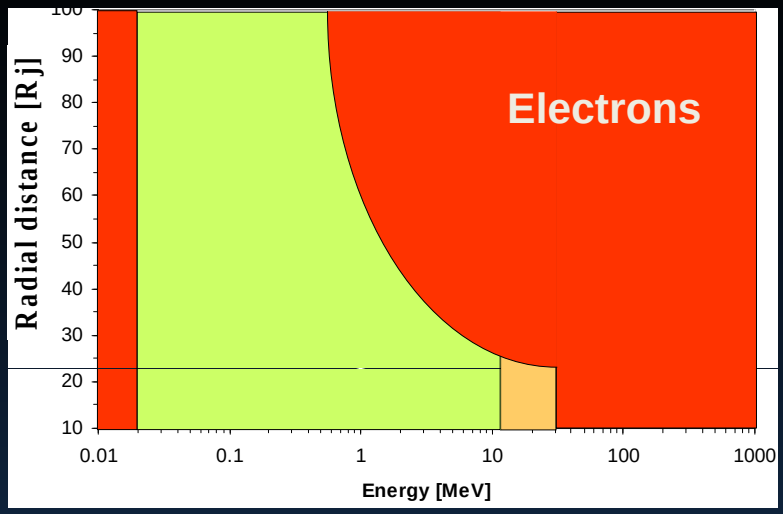
- JOREM model will be presented at RADECS and EPSC (20 – 24 September 2010)
- Will be made available through SPENVIS http://www.spenvis.oma.be/

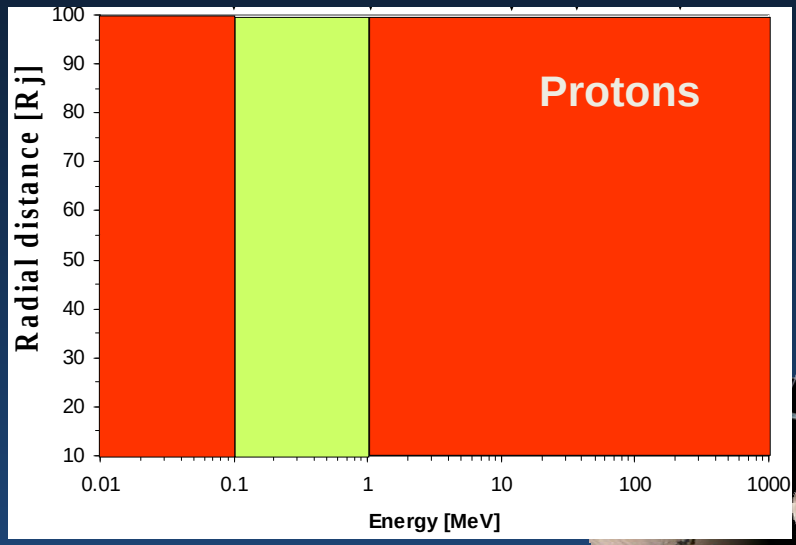


Trapped Particles: JOREM

What is its typical use?

- Electrons and protons >10 R_J
- Electrons 20 keV – 1 & 20 MeV, Protons 100 keV – 1 MeV
- Use for radiation environment with JGO trajectory

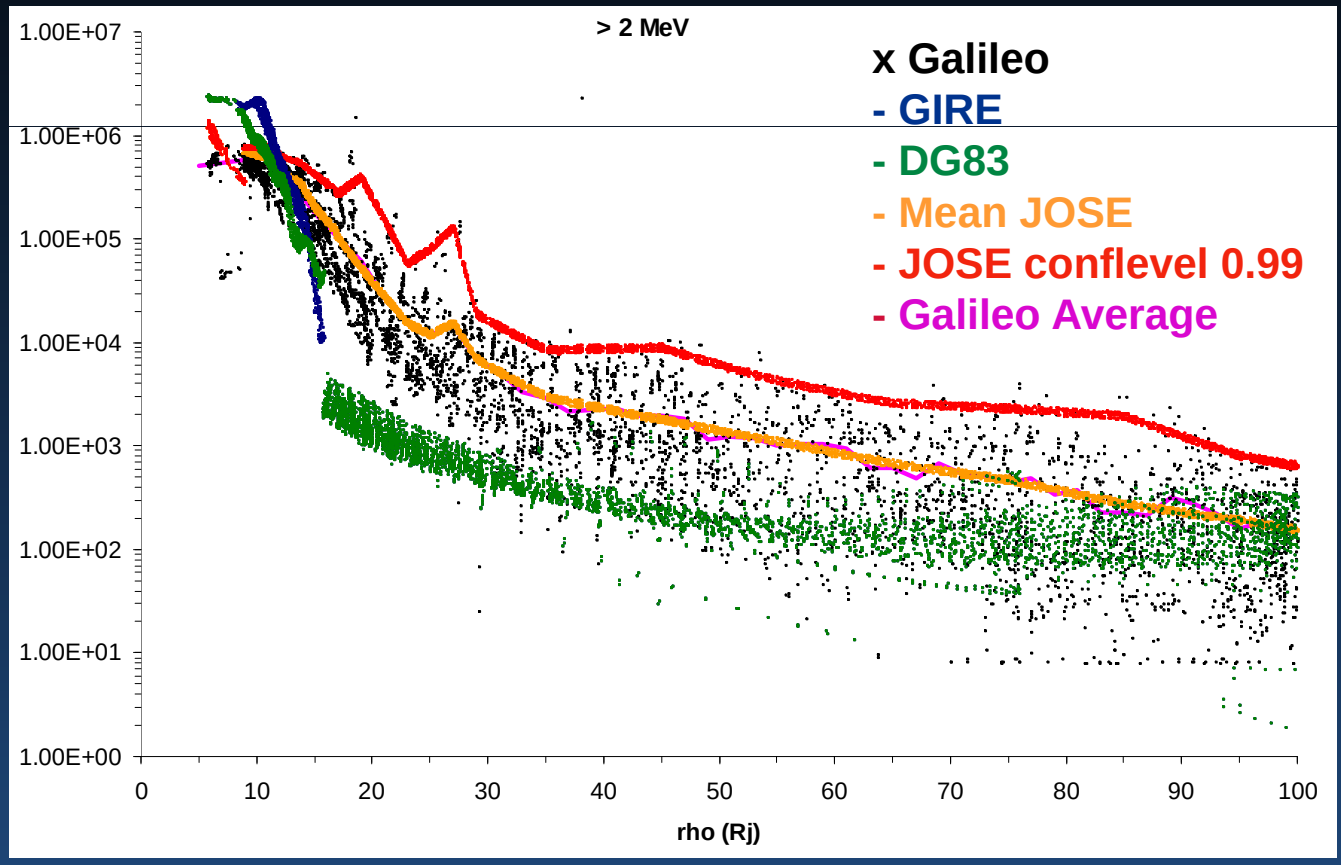


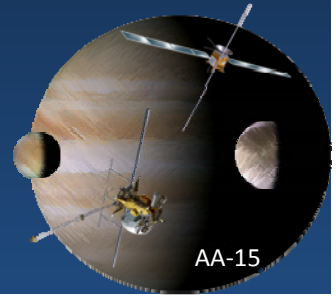


Trapped Particles: JOREM

Example

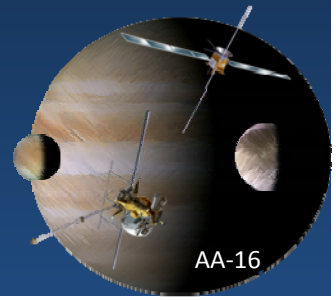
– Flux of >2 MeV electrons at jovigraphic equator





Model Use

- Instruments proposed to the JEO mission shall use the trapped particle environment specifications derived from GIRE
- Instruments proposed to the JGO mission shall use the trapped particle environment specifications defined by ESA



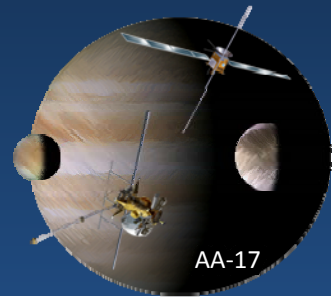
Jovian Plasma Environments: Divine-Garrett

What is it?

- A comprehensive model of the ~1 eV<E<100 KeV electron, proton, and ion plasma.
- Pioneer and Voyager in-situ data
- 1-170 Rj

Where do you find it?

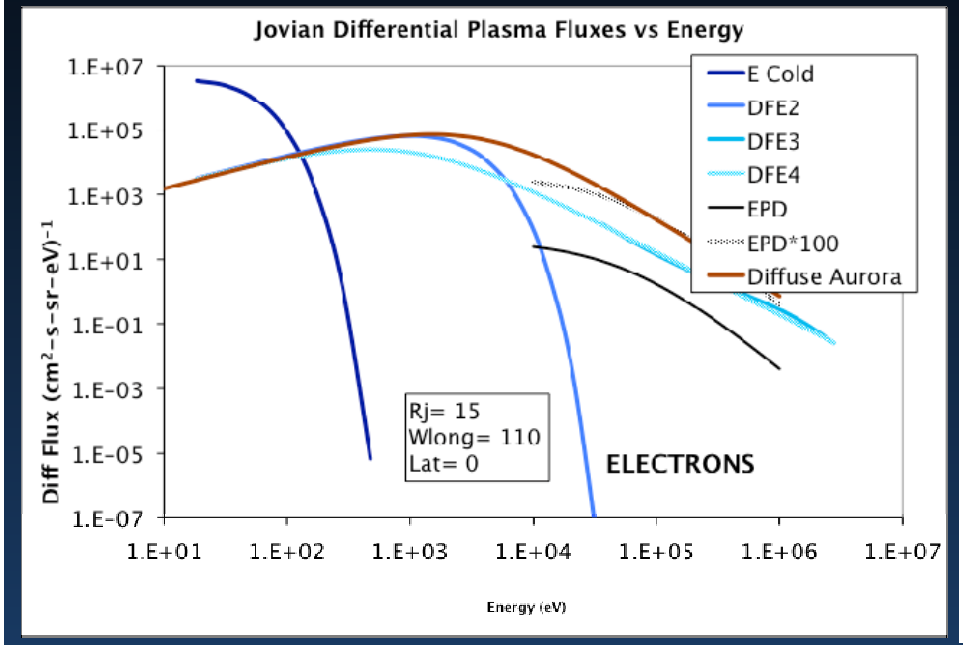
- Divine Electron and Proton Models: Divine, N. T., Garrett, H. B., "Charged Particle Distributions in Jupiter's Magnetosphere", J. Geophys. Res., 88, 6889-6903, 1983

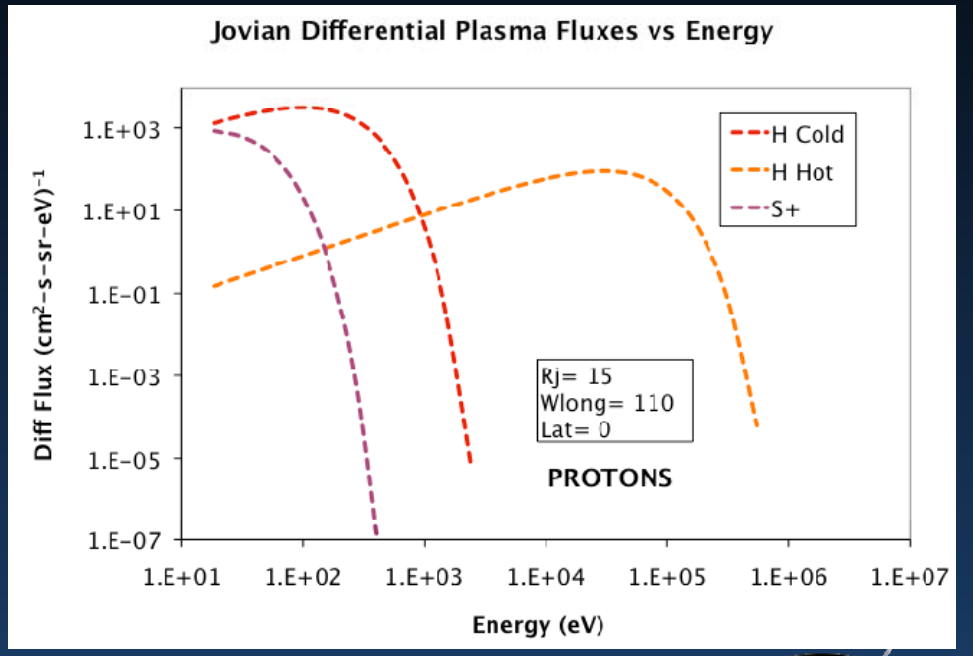


Jovian Plasma Environments: Divine-Garrett

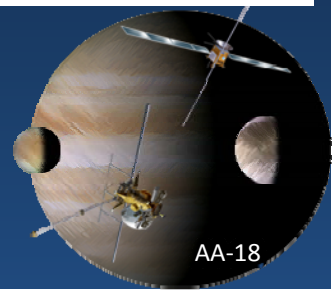
What is its typical use?

- Design standard for plasma environment
- Primarily used for spacecraft charging studies





Example: DG plasma at 15 Rj



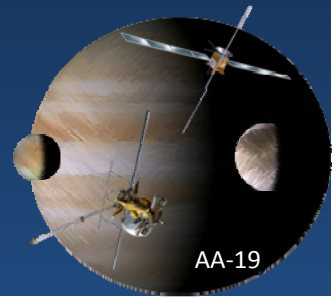
Trapped Particles: HIC

What is it?

- Caltech Galileo **H**eavy **I**on **C**ounter (HIC) Radiation Model
- Used data from 31 of the 35 Galileo orbits
- Models three ions: Oxygen, Carbon, and Sulfur.
- Useful for SEE evaluations and radiation effects on surface materials such as sputtering.

Where do you find it?

- Garrett, H.B., Evans, R., Kokorowski, M., and Cohen, C.M.S., "Modeling the Jovian Heavy Ion Radiation Equatorial Environment", IOM 5130-09-014, 7 Dec 2009, The Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA.
- ITAR controlled:
  - Available upon request for US persons.
  - Will release the model through a peer reviewed paper

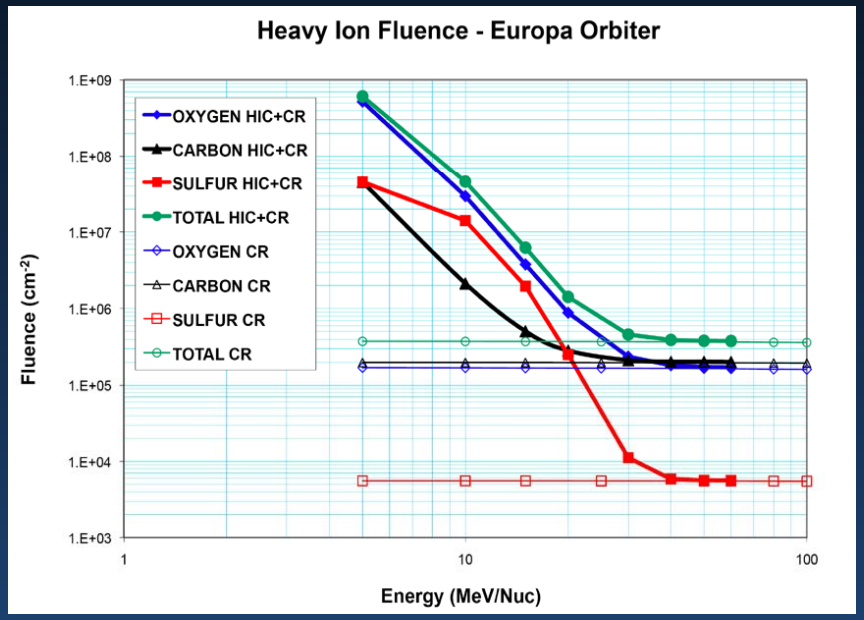


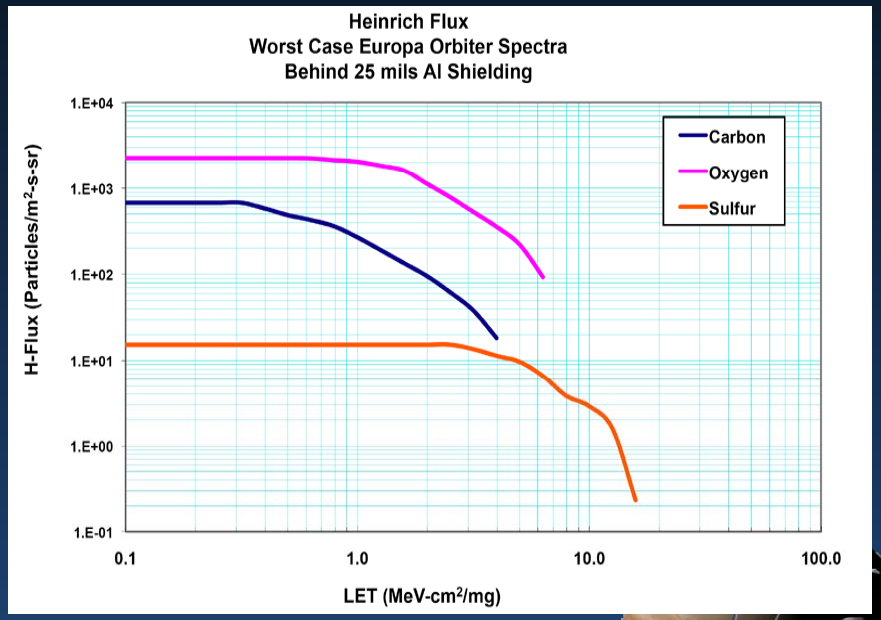
Trapped Particles: HIC

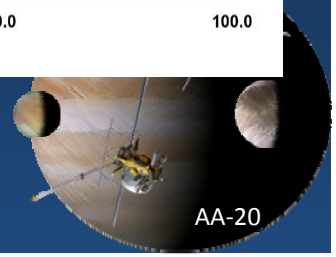
What is its typical use?

- Covers 2.5 Rj to 30Rj and energy range ~6-200 MeV/nucleon
- Model is useful for defining heavy ion flux and fluence spectra for dose and SEE evaluations.
- Readily converted to LET spectra

Examples:







Other Environments

- Various models are available for the following environmental considerations, but not covered here:
  - Solar energetic particles
  - Galactic cosmic rays
  - Solar electromagnetic spectrum
  - Micrometeoroids
  - Jovian ring particles
- The Project ERD will include the requirement specifications for all these environments.