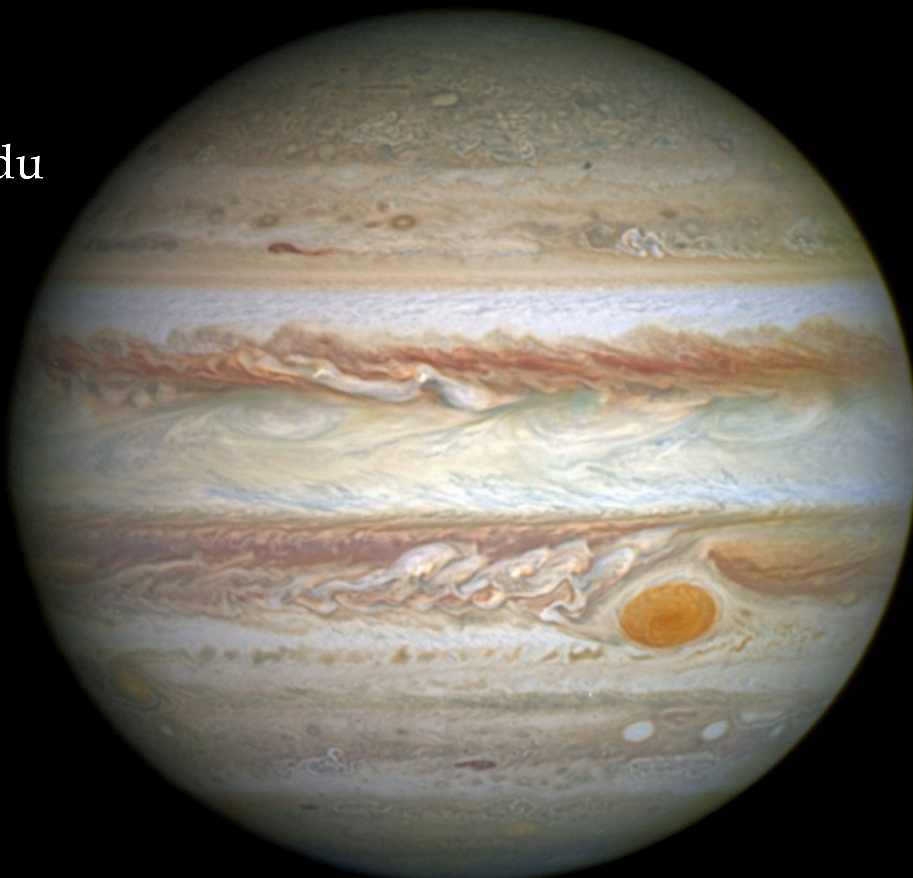
SOLAR WIND PROPAGATION TO JUPITER

mswim.engin.umich.edu



K.C. Hansen

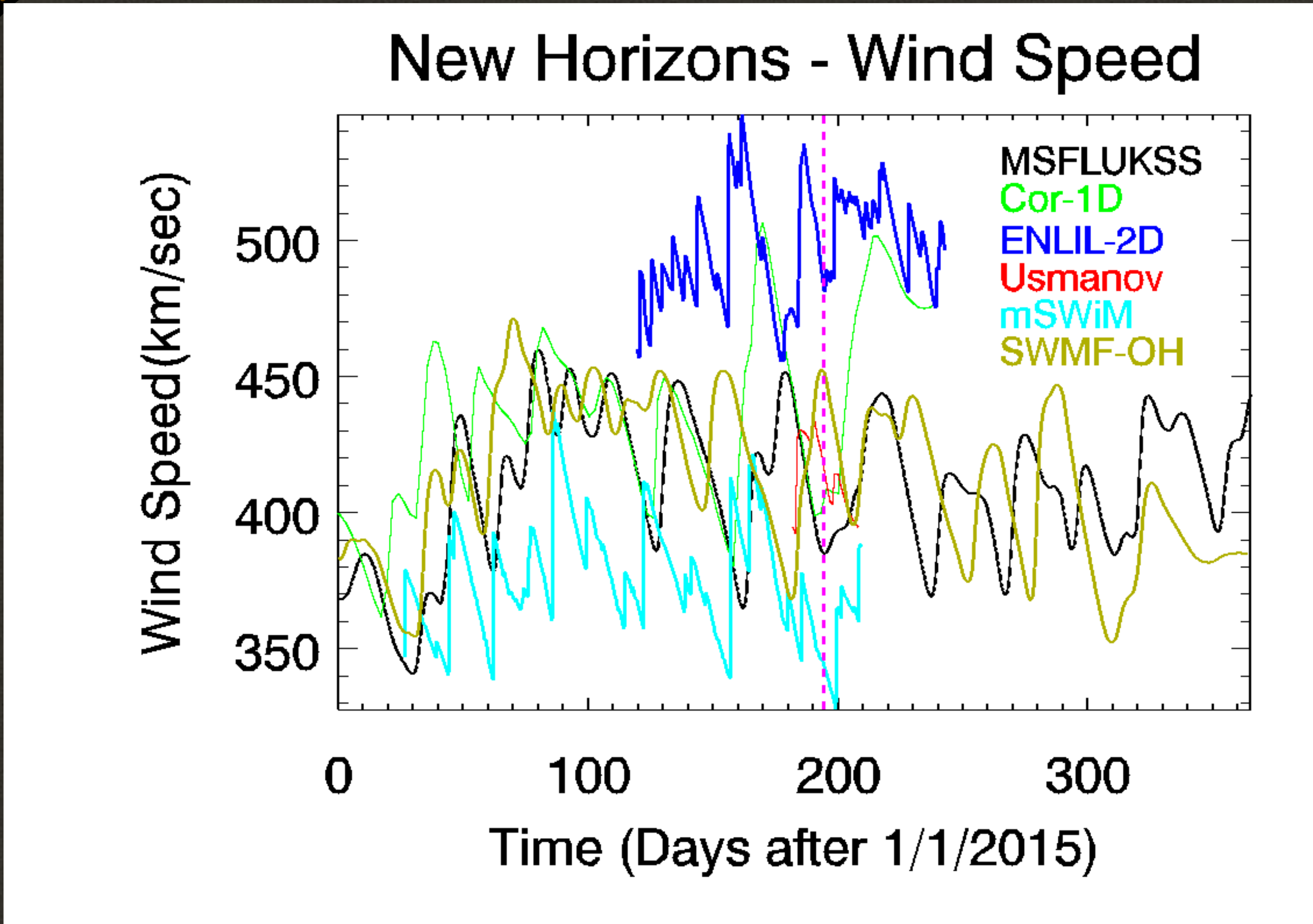
Some Initial Thoughts

- (A) Having a solar wind monitor would be very beneficial for the auroral studies we are talking about
- (B) Propagating solar wind from the Sun or from 1AU is being done, but it is challenging
- A + B = people in the MOP community have been very enthusiastic about solar wind propagations
  - Propagations have been used for many auroral studies at Jupiter, Saturn, Uranus
  - Most users have tried to take into account limits of the propagations
  - Care is needed so that the propagation results are not used incorrectly or with too much confidence
  - To me, the overall result of the use of propagated solar wind is what I could call "limited success"
    - Strong correlations have been very difficult to come by
    - On the other hand, some correlations have been found although they have been mostly been stated with caveats and limited confidence
- Using more than one model is a good idea
  - Thus far attempts to do this have not been "confidence boosting"

Various Solar Wind Prediction Models - I

- New Horizon's Challenge @ Pluto
  - All were pretty bad
  - Interstellar neutrals are a major player – this is a major difference for Jupiter
  - Models used in the
    - MSFLUKSS
      - 3D MHD-plasma/kinetic-neutral code
      - Historical application is to the global, large scale heliosphere
      - Inner boundary: Magnetograms, @Sun ??
    - Cor-1D
      - 1D, gasdynamic
      - Has been applied only to the large scale heliosphere
      - Inner boundary: 1AU
    - ENLIL-2D
      - 2D (3D?)
      - Inner boundary: 20Rs
      - CMEs empirically inserted
    - Usmanov
      - 3 fluid MHD
      - Inner boundary: Magnetograms, @Sun
    - mSWiM
      - 1.5D, MHD
      - Very well validated for Jupiter
      - Takes into account all rotational issues
      - Inner boundary: 1AU (Earth, STEREO A, STEREO B)
    - SWMF-OH
      - 2D MHD + interstellar neutrals
      - Inheritance from 3D model of Merav Opher, with application to the global, large scale heliosphere
      - New, used only for the New Horizons challenge
      - Inner boundary: 1AU (Earth)

New Horizons Challenge – One Example



Various Solar Wind Prediction Models - II

- Models that have been applied to Saturn and Jupiter by the MOP community
  - mSWiM
    - 1.5D, MHD
    - Very well validated for Jupiter
    - Takes into account all rotations associated with imperfect alignment of the source and target
    - Inner boundary: 1AU (Earth, STEREO A, STEREO B)
    - Has been used extensively by the MOP community and there are many examples of "good" ways to use the model without overstepping
  - Miyoshi
    - 1.5D, MHD
    - Propagation is very similar to mSWiM
    - Inner boundary: 1AU (Earth)
    - Does not perform the same full rotations that mSWiM does (???)

Strengths and Weaknesses

- 3D
  - Initiated near the sun using magnetograms
  - 3D model for a 3D structure
  - Inherently steady state models of a single solar rotations
  - CMEs can be added in empirically (ENLIL, SWMF-EAGLE)
  - Lower spatial resolution
- 1.5D
  - Initiated at 1AU (ACE/Wind, STEREO A, STEREO B
  - 1D spatial model for a 3D structure
  - Inherently time dependent
  - CMEs “included” if observed at the 1AU spacecraft
  - Higher spatial resolution
  - Applicable only what 1AU spacecraft and target are aligned

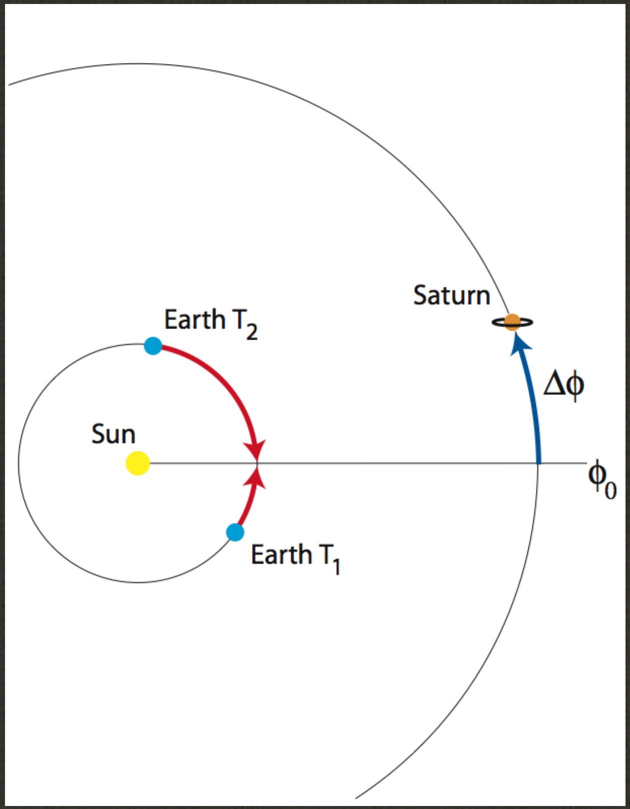
MICHIGAN SOLAR WIND MODEL (mSWiM)

mswim.engin.umich.edu

Zieger and Hansen (2008) Statistical validation of a solar wind propagation model from 1 to 10 AU, J.Geophys.Res., doi:10.1029/2008JA013046.

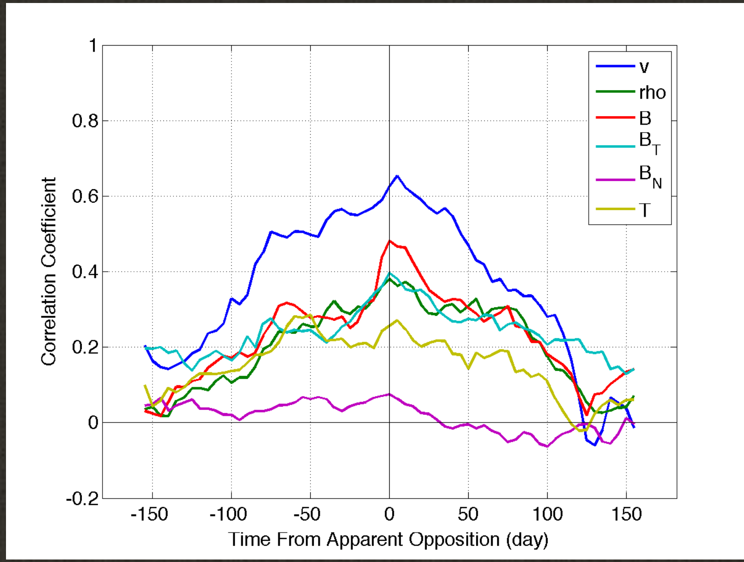
Review of mSWiM Propagation Method

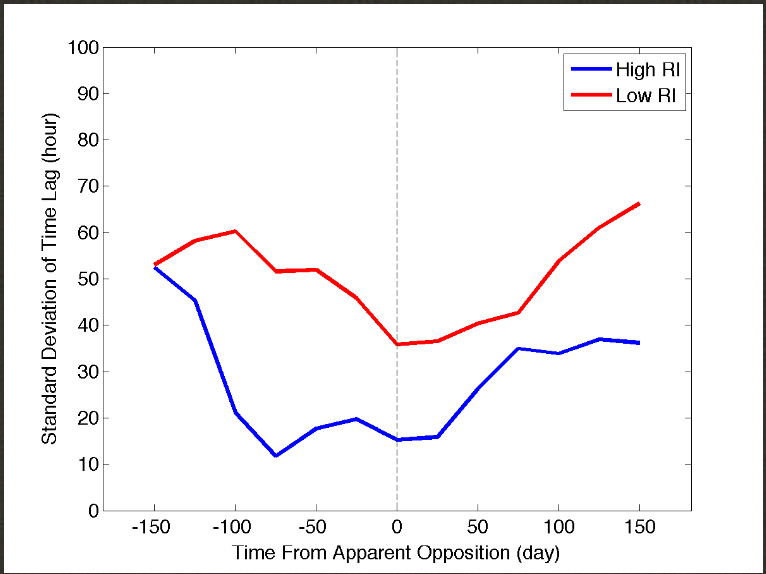
- Michigan Solar Wind Model
  - 1.5D ideal MHD
  - Solved along a line in the inertial frame at a fixed helioecliptic longitude
- Input: Inner Boundary
  - Time-dependent n, v, T, B mapped from near Earth
  - ISEE3, Wind, ACE, Omniweb, STEREO A/B
  - 1hr averages work well
- Output:
  - n, v, T, B as a function of heliocentric distance and time
  - Mapped "trajectories" at planets (Jupiter, Saturn) or spacecraft (Pioneer, Voyager, Cassini)
- Advantages:
  - Computationally inexpensive (1 year is modeled in 2 hours)
  - High spatial resolution (grid converged)
  - Shock steepening handled self-consistently (better than ballistic propagations)
- Limitations:
  - Drastic simplification of the real 3D problem
  - Method clearly works best when the Sun-Earth-Object are aligned
  - The radial magnetic component cannot change in time
  - We essentially assume a steady state solar corona for the rotations



Review of Propagation Accuracy

- Years with high recurrence index:
  - Error estimates of shock arrival times between 15 and 20 hours within ±75 days from apparent opposition
- Years with low recurrence index:
  - The errors are significantly higher, 40-45 hours within ±75 days from apparent opposition
  - Include a systematic error of 15-20 hours
  - Predicted shock arrival times tend to be late





- Relatively good prediction efficiency within ±75 days from apparent opposition
- Best predictions for the solar wind speed
- The north component of the magnetic field (BN) is not predictable

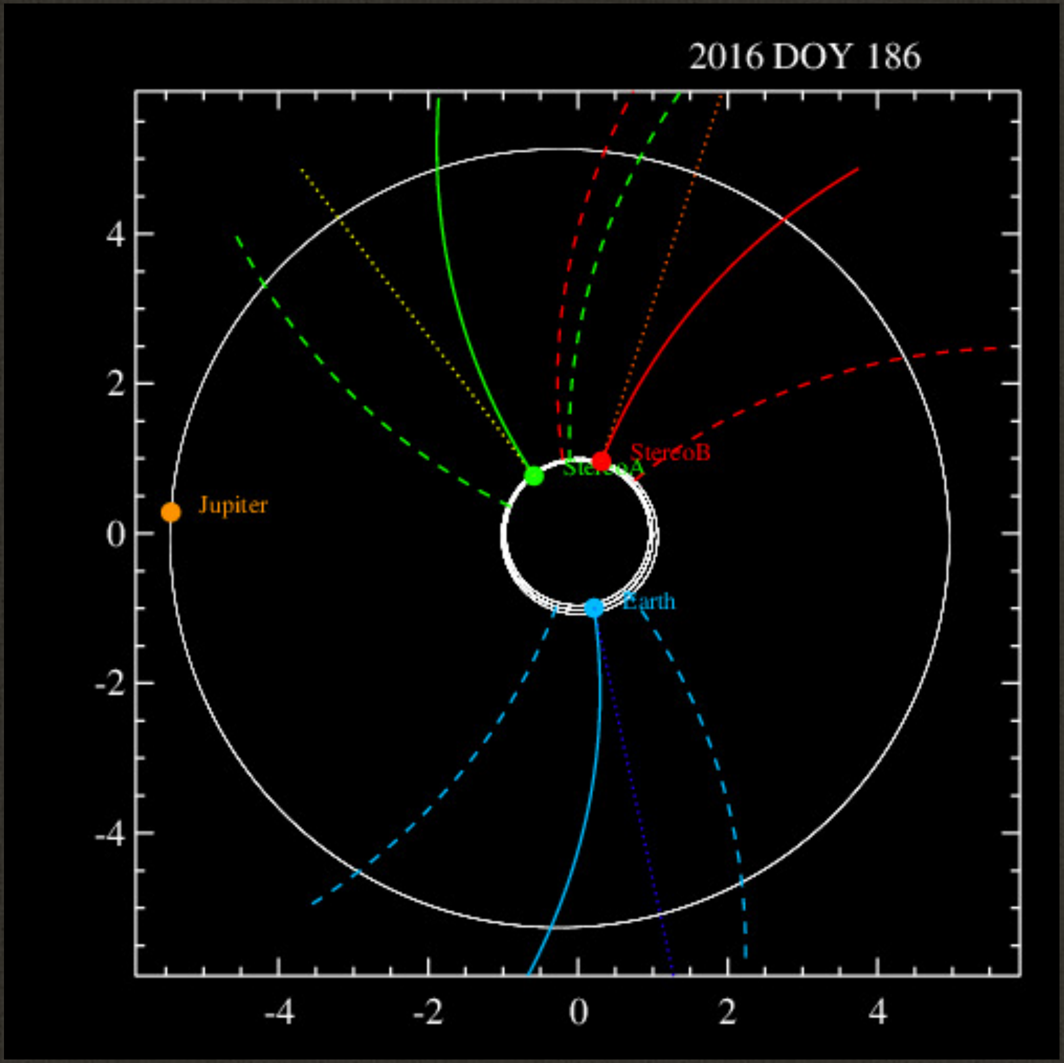
Things to Keep in Mind

- Things to keep in mind
  - In my plots and when I make suggestions:
    - ± 30 degrees (days) – optimal period
    - ± 60 degrees (days) – OK period
    - Outside of this window be careful
  - Caveat: if the Sun is in steady state, then mSWiM results should always be valid, irrespective of alignment (longitudinal separation)
  - Accuracy
    - See Zieger and Hansen (2008)
    - Shock arrival (12 hours is the best statistical estimate)
    - Correlation
      - Velocity and density are good
      - Bz is not predictable
  - Direct, event-for-event comparison is probably not the best usage for this kind of data set
  - Future prediction: limited to solar wind propagation time between Earth and Jupiter (~10 days)

- Best practices
  - Averaging SW predictions over shock arrival error periods
  - Using data to attempt to co-locate (“shift”) prediction with data

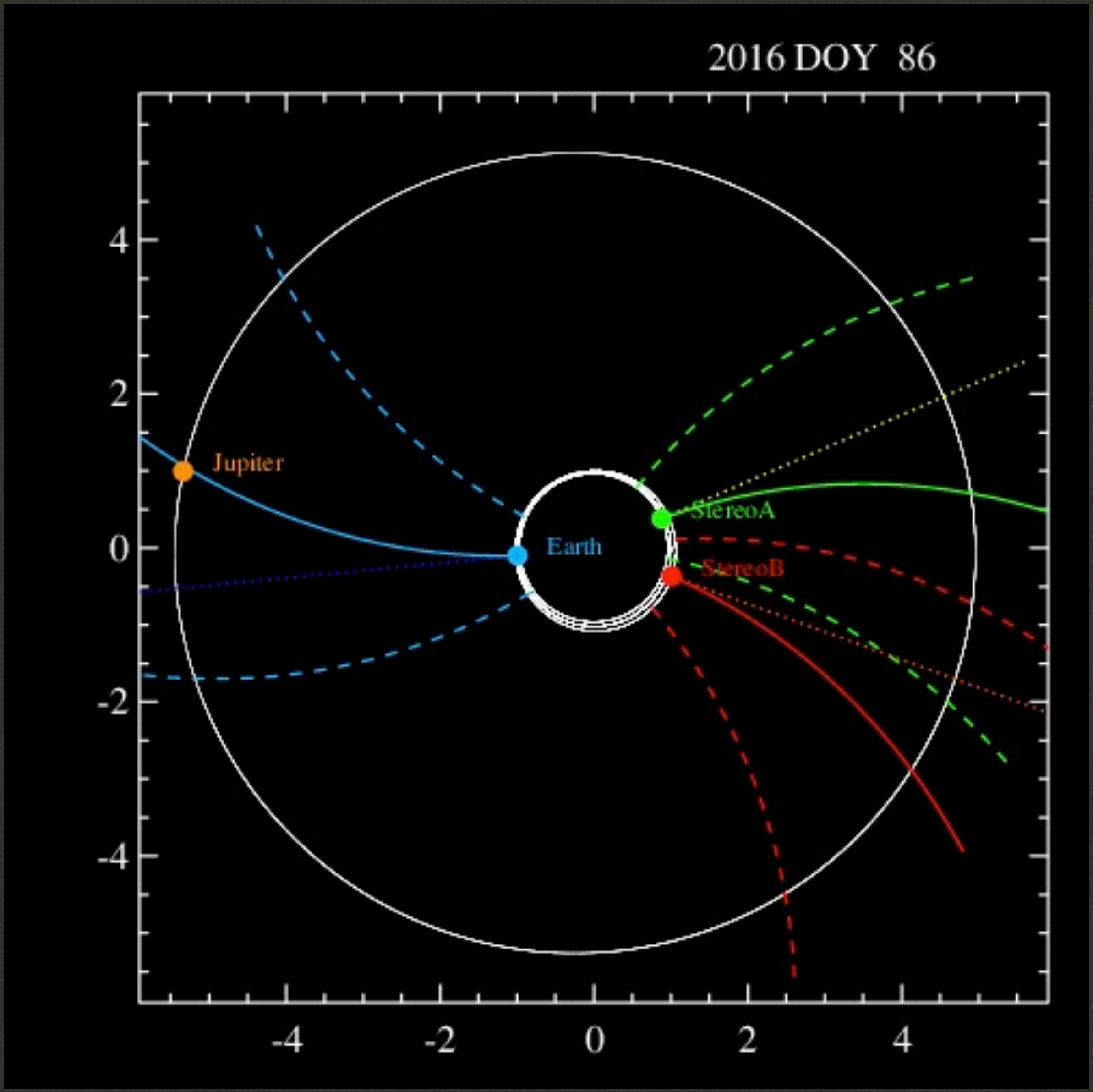
Solar Wind Propagation: The Movie

- Schematic only: does not indicate
  - Solar wind v
  - IMF
  - CIR
- Designed to indicate
  - Best days to use each propagation (solid line)
  - Period of good propagation (dashed lines, ± 30 days)
- Shows periods good for
  - Overlaps for cross correlations
  - Increased coverage

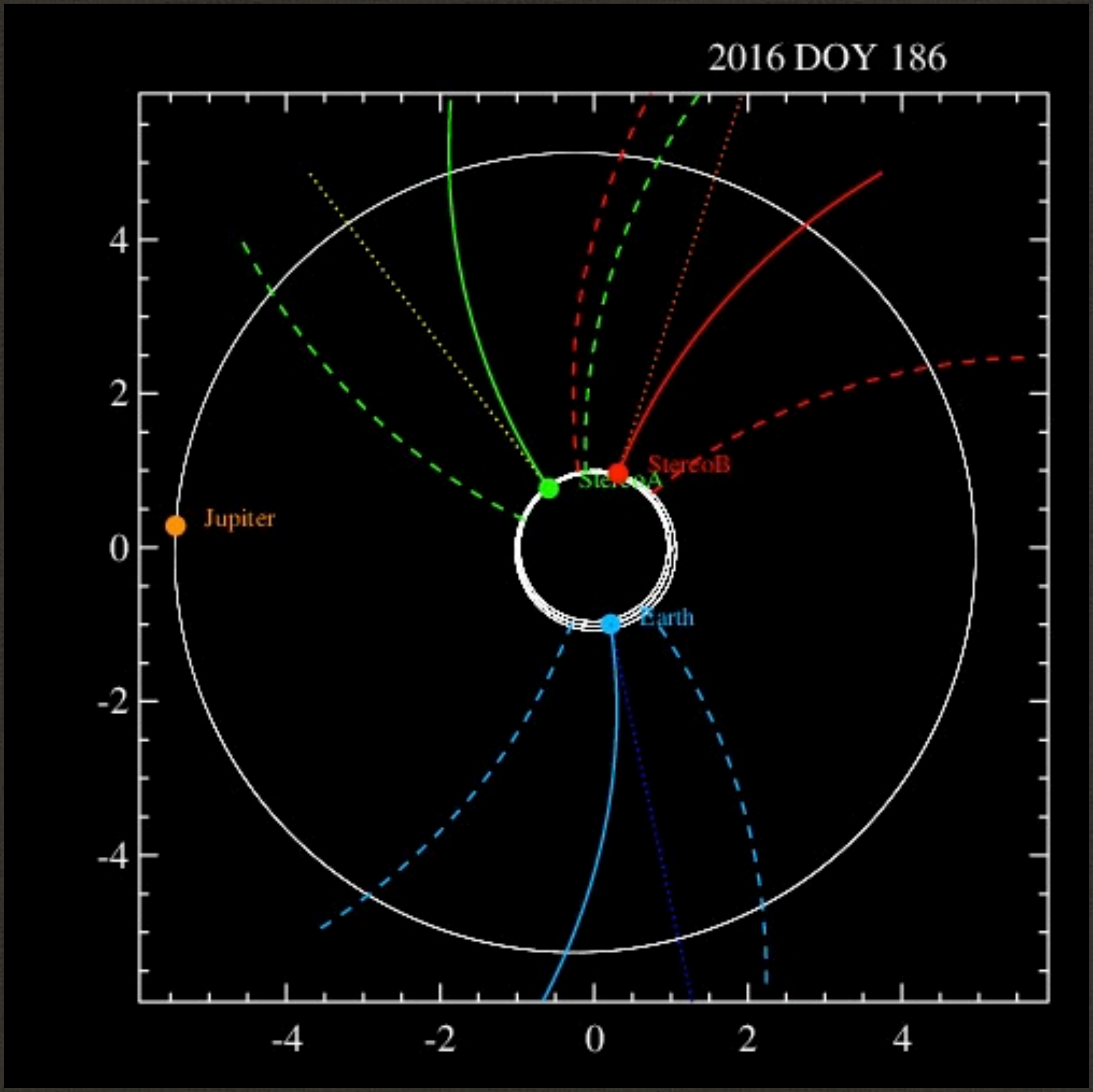


Green– STEREO A
Blue – Earth/OMNI
Red – STEREO B

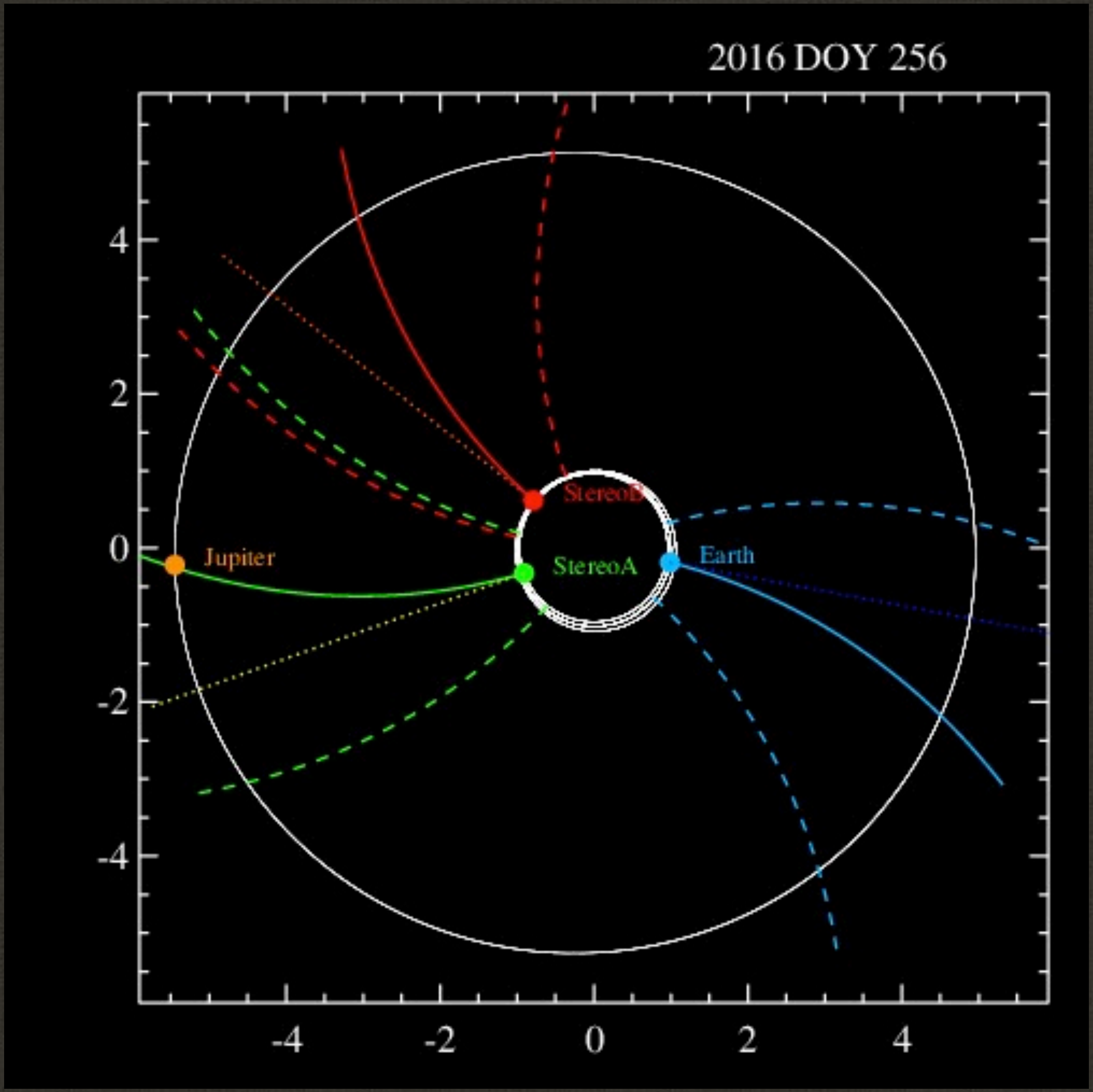
Earth - Jupiter Alignment - I



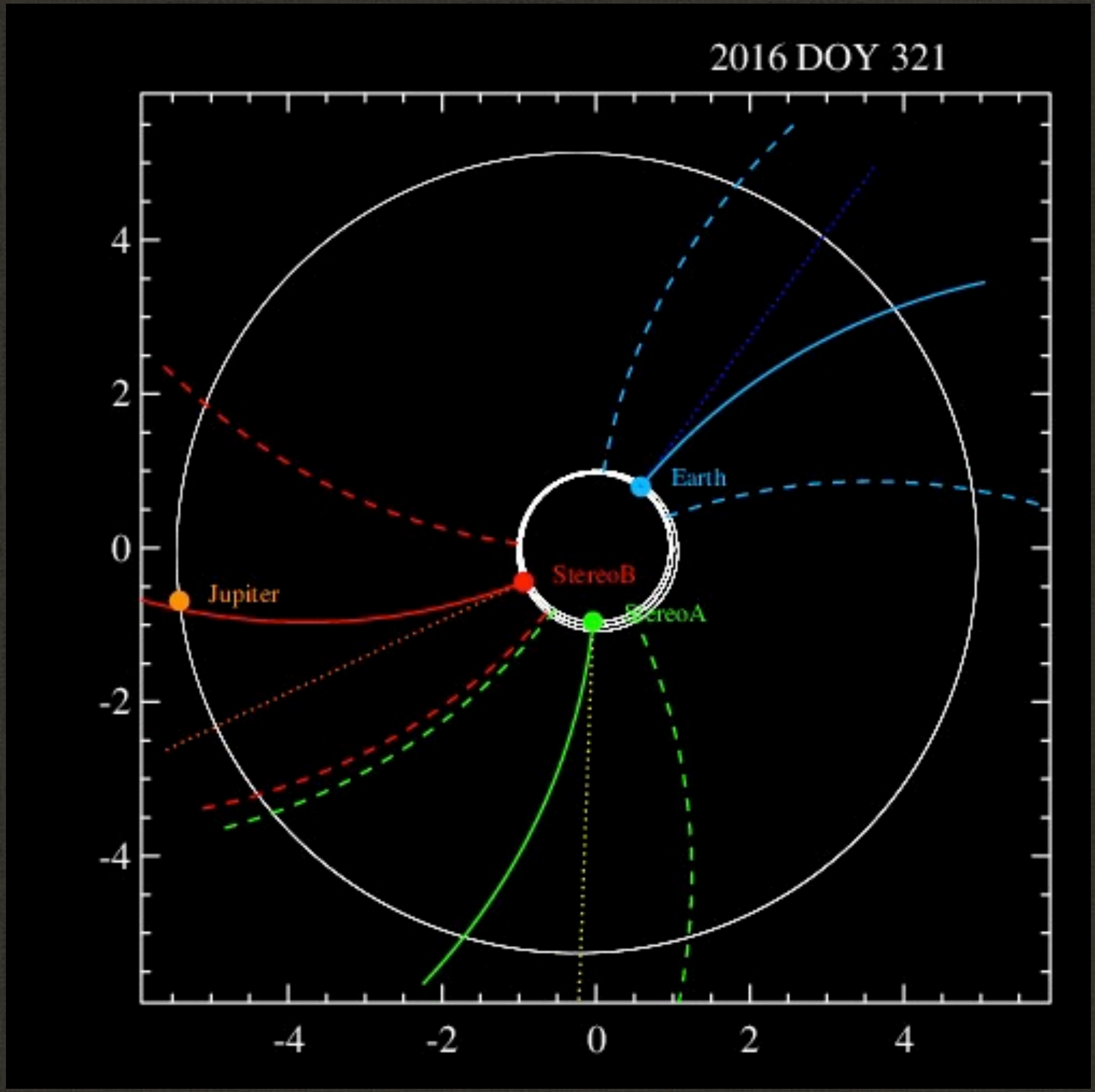
JUNO Arrival



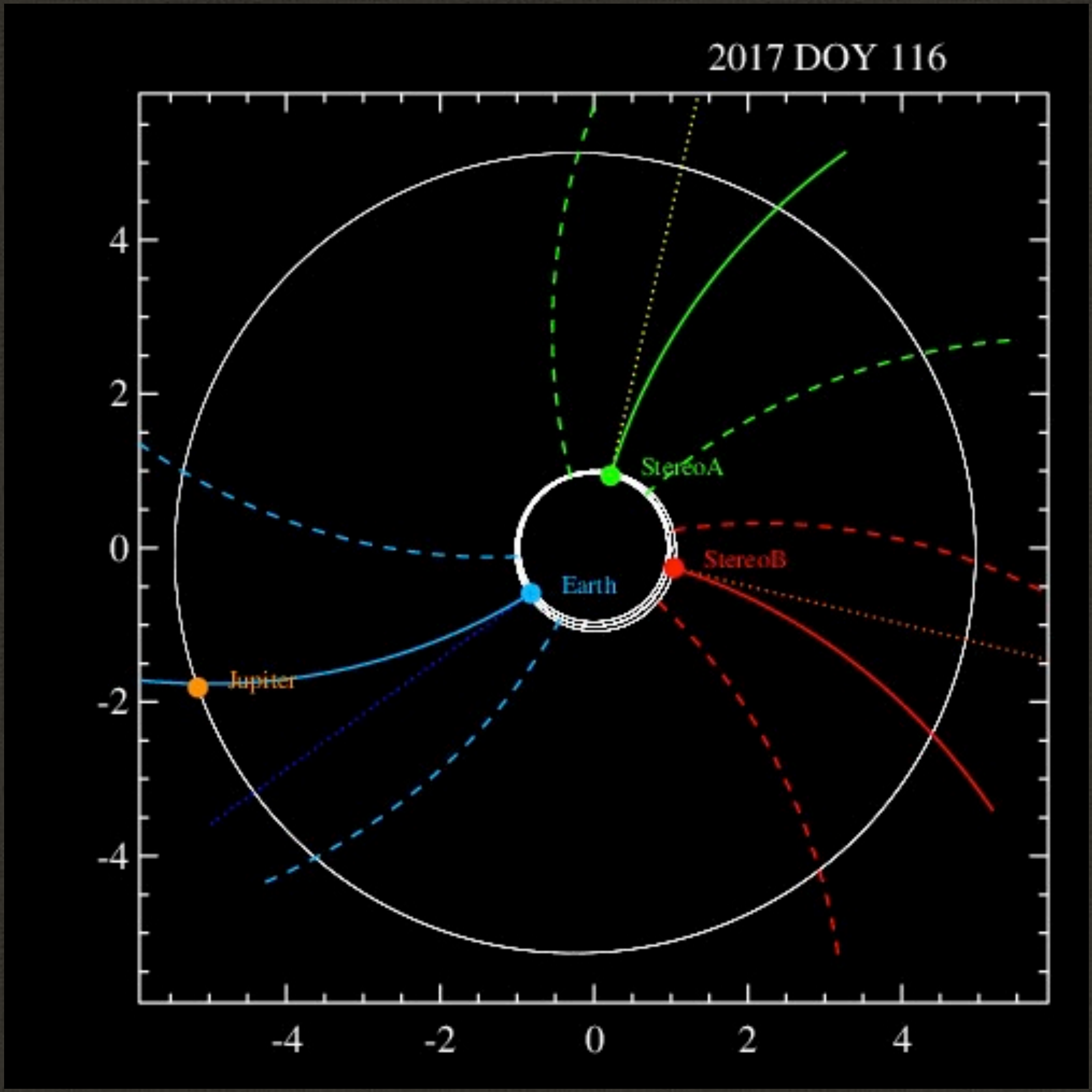
STEREO A – Jupiter Alignment



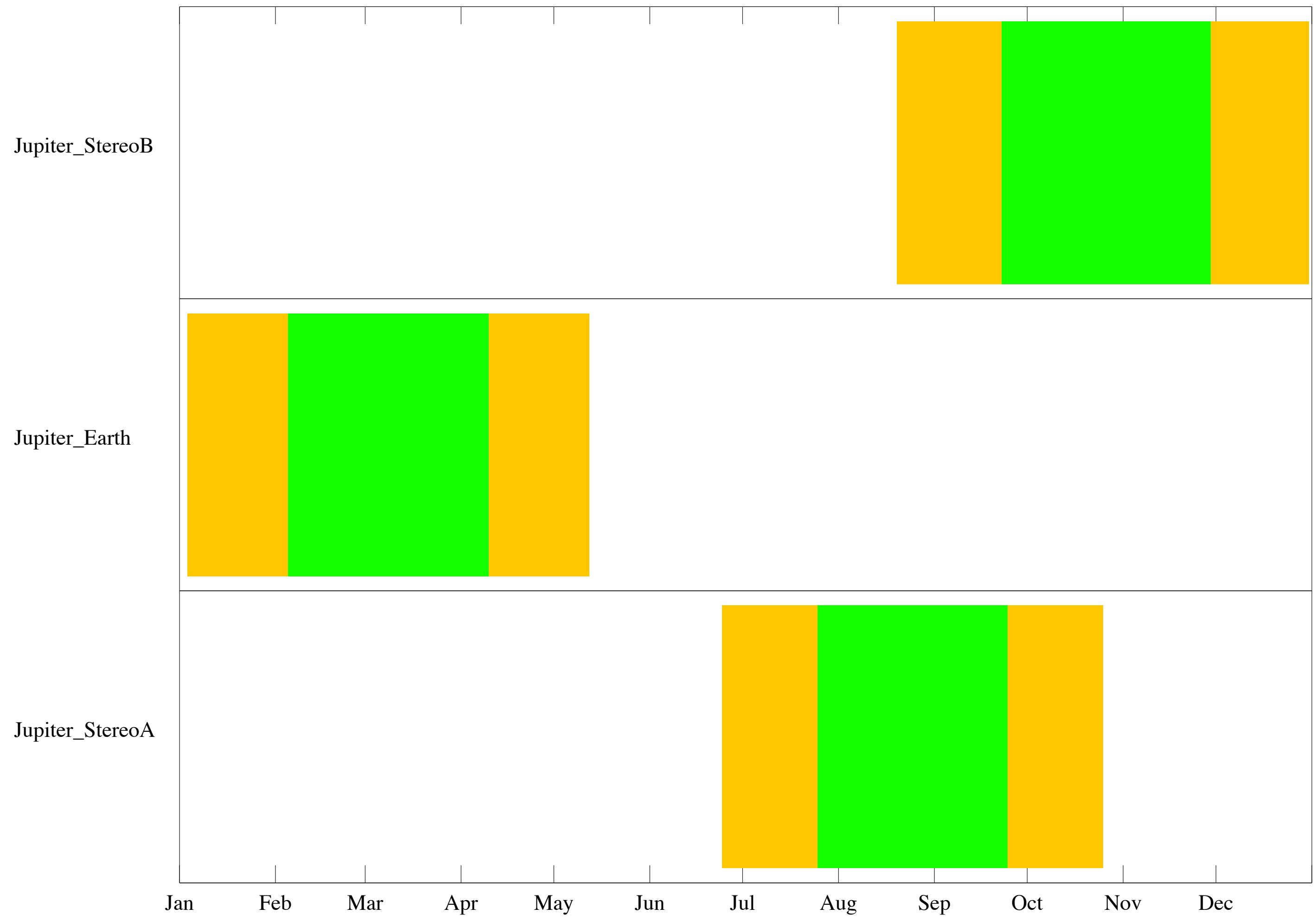
STEREO B - Jupiter Alignment



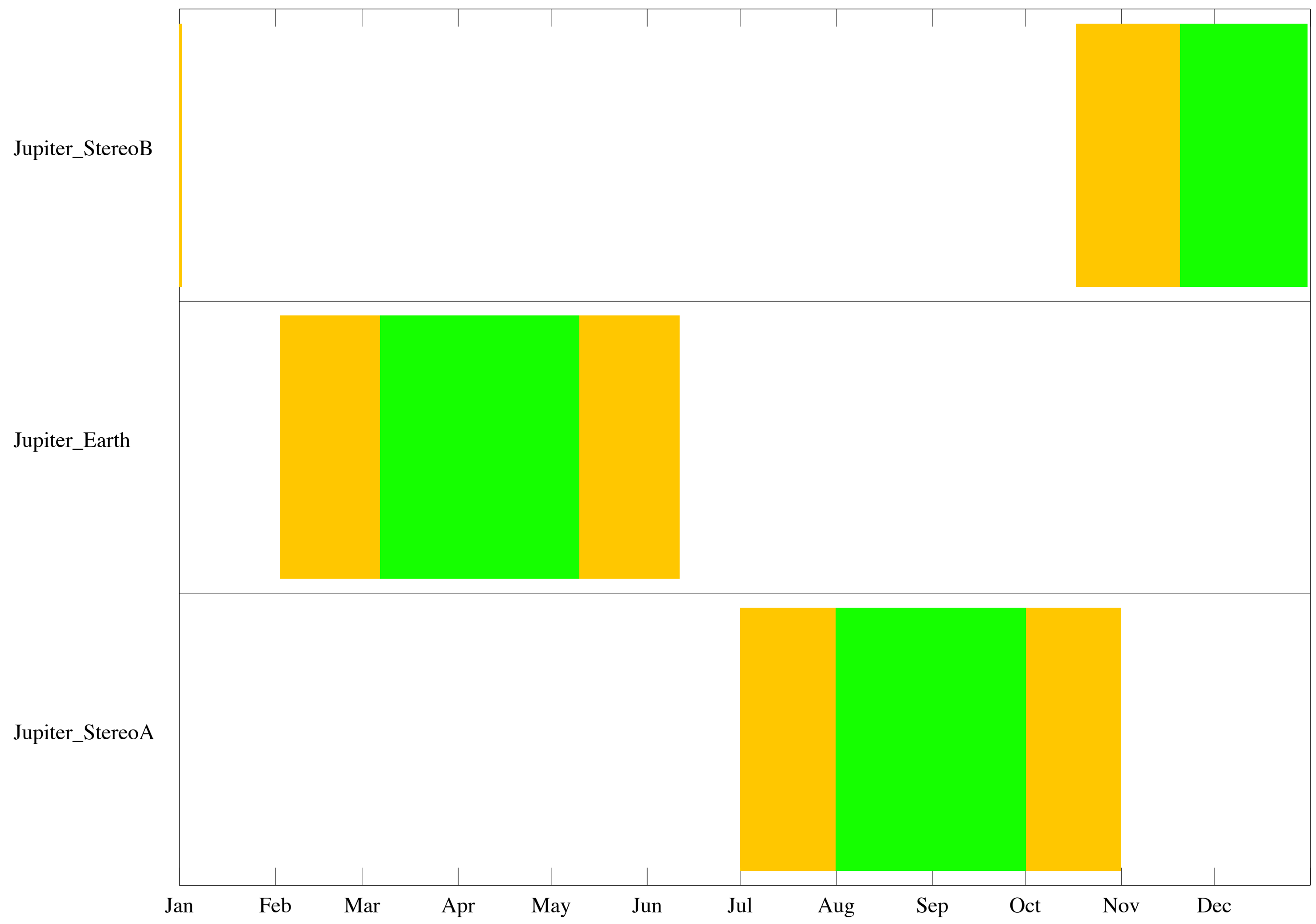
Earth-Jupiter Alignment - II



2016 Alignment Periods



2017 Alignment Periods



Ideal Study Periods

- Jan 1 – May 1, 2016 (Earth/ACE/Wind)
- July 1 – November 1, 2016 (STEREO A)
- February 1 – June 1, 2017 (Earth/ACE/Wind)