The Juno Mission

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Europlanet Workshop on Juno Ground-Based Support from Amateurs

ROADMAP

- Summary of Science Goals
- Payload
- Logistics of Trajectory and Orbit Insertion
- Orbit Plans and Timeline
- Earth-Based Supporting Observations
  - Professional planned / requested support observations

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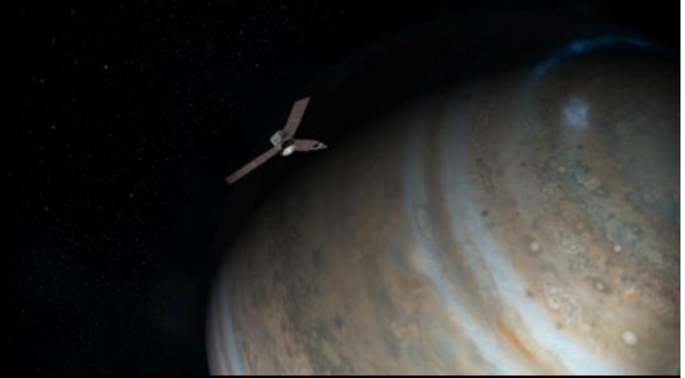
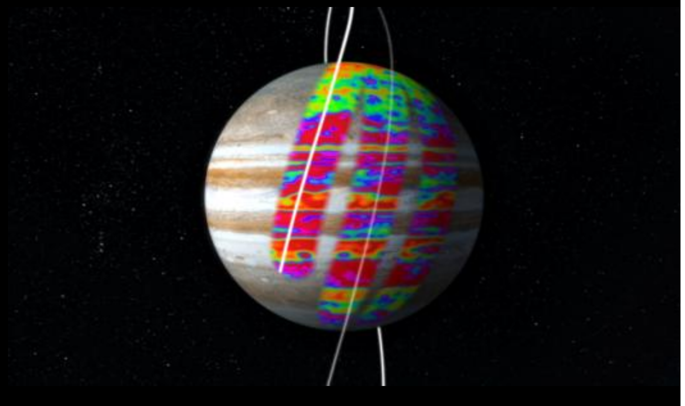
  - Professional planned / requested support observations
  - Amateur contributed observations (see the next talk!) ☺

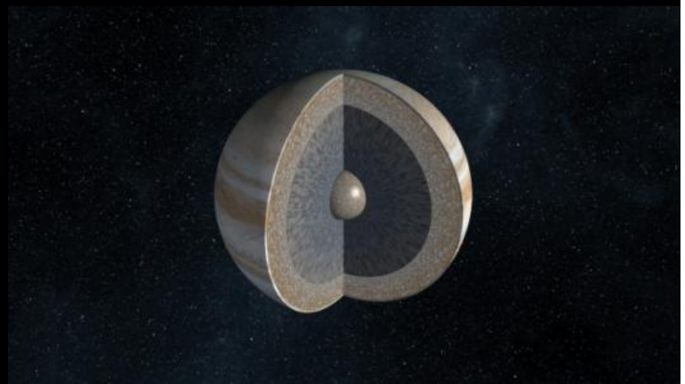
Juno's Overarching Science Objectives



Juno will improve our understanding of the history of the solar system by investigating the origin and evolution of Jupiter.



To accomplish this goal, the mission will investigate Jupiter's **Origin, Interior, Atmosphere and Magnetosphere.**



What we learn from Juno also will vastly improve our general knowledge of how giant planets form and evolve, shaping the evolution of planetary systems everywhere.

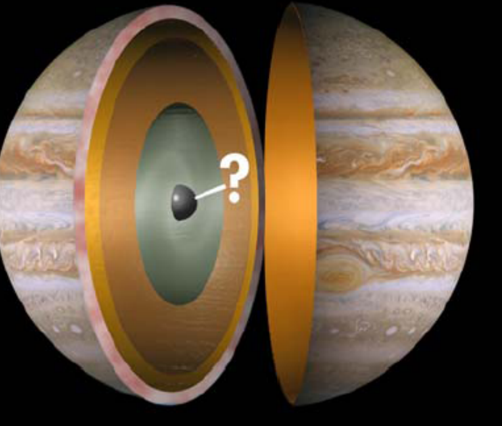
Juno's Specific Science Objectives

Origin

Determine O/H ratio (water abundance) and constrain core mass to decide among alternative theories of origin.

Interior

Understand Jupiter's interior structure and dynamical properties by mapping its gravitational and magnetic fields

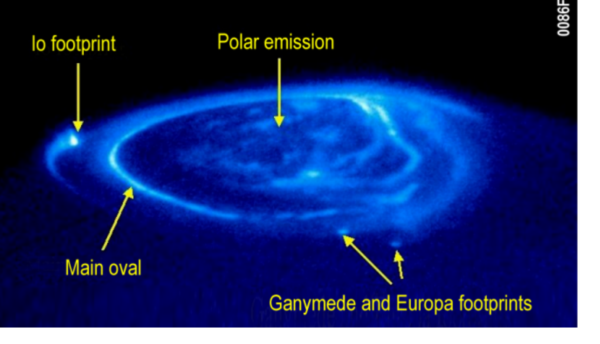


Atmosphere

Map variations in atmospheric composition, cloud opacity and dynamics to depths greater than 100 bars at all latitudes.

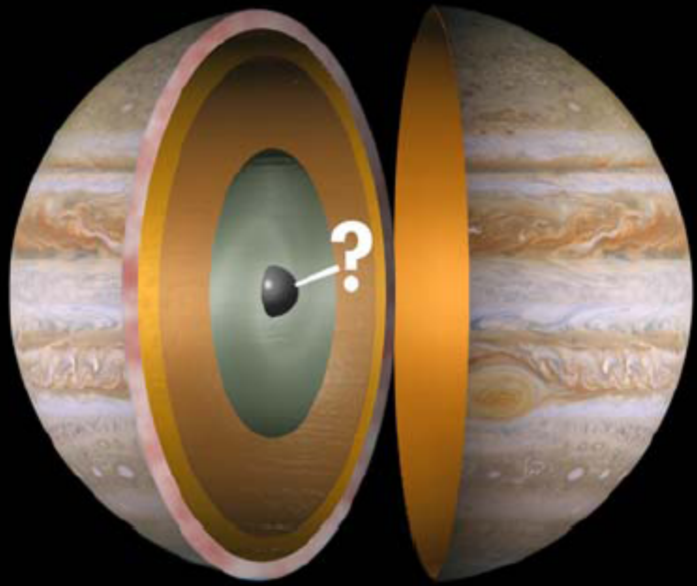
Magnetosphere

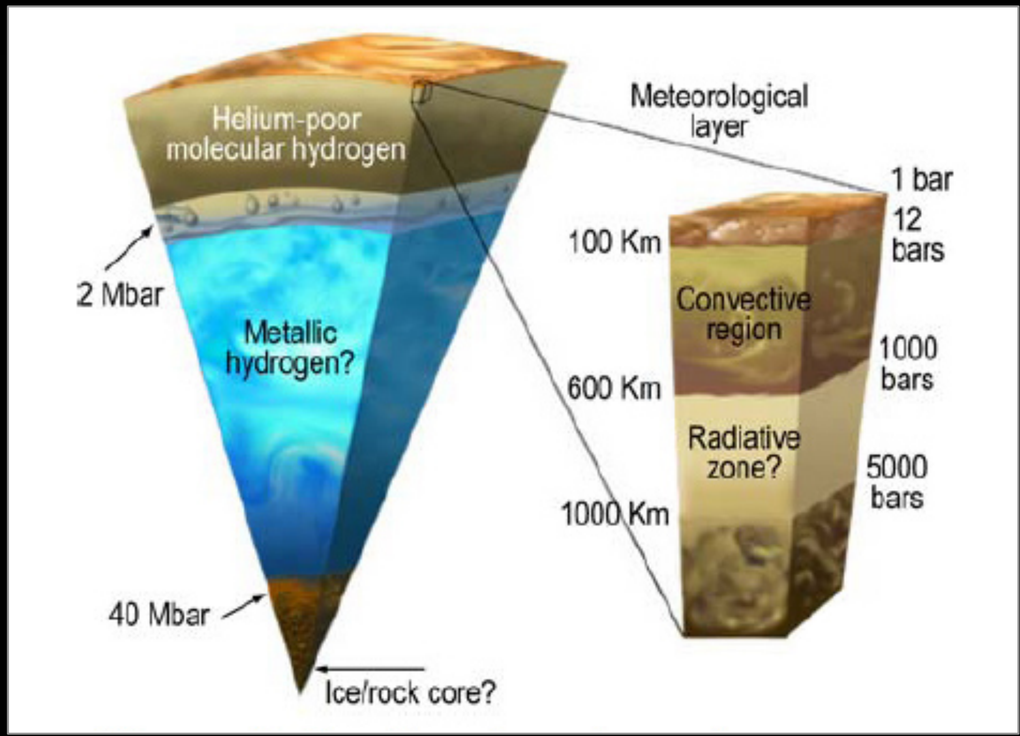
Characterize the three-dimensional structure of Jupiter's polar magnetosphere and auroras.



Probing the deep interior from orbit

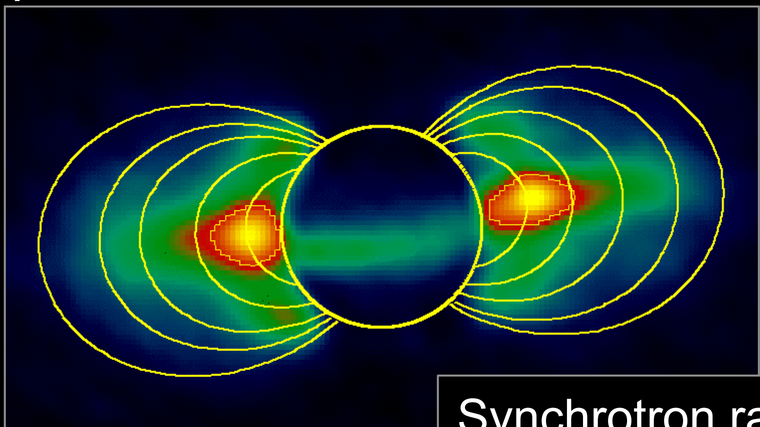
Juno maps Jupiter from the deepest interior to the atmosphere using microwaves, and magnetic and gravity fields.

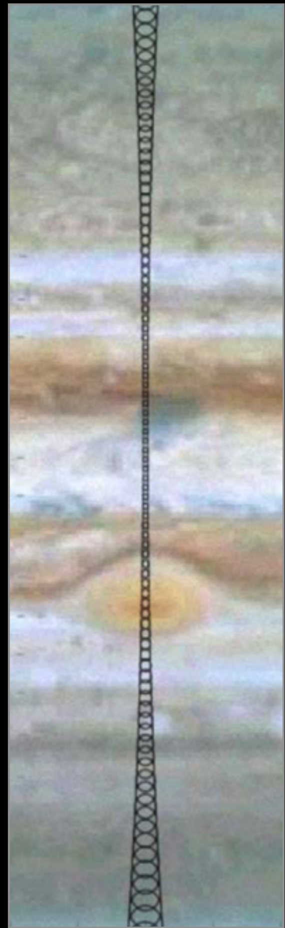


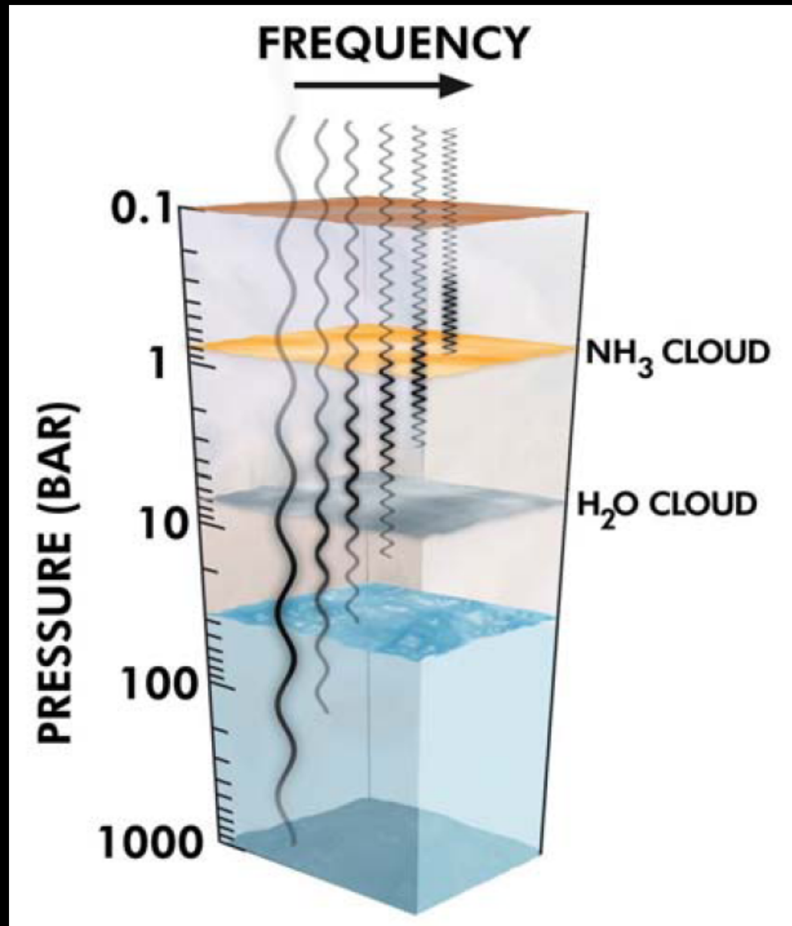


Sensing the deep atmosphere (Pt1)

Juno's Microwave Radiometer measures thermal radiation from the atmosphere to as deep as 1000 atmospheres pressure (~500-600km below the visible cloud tops). Determines water and ammonia abundances in the atmosphere all over the planet

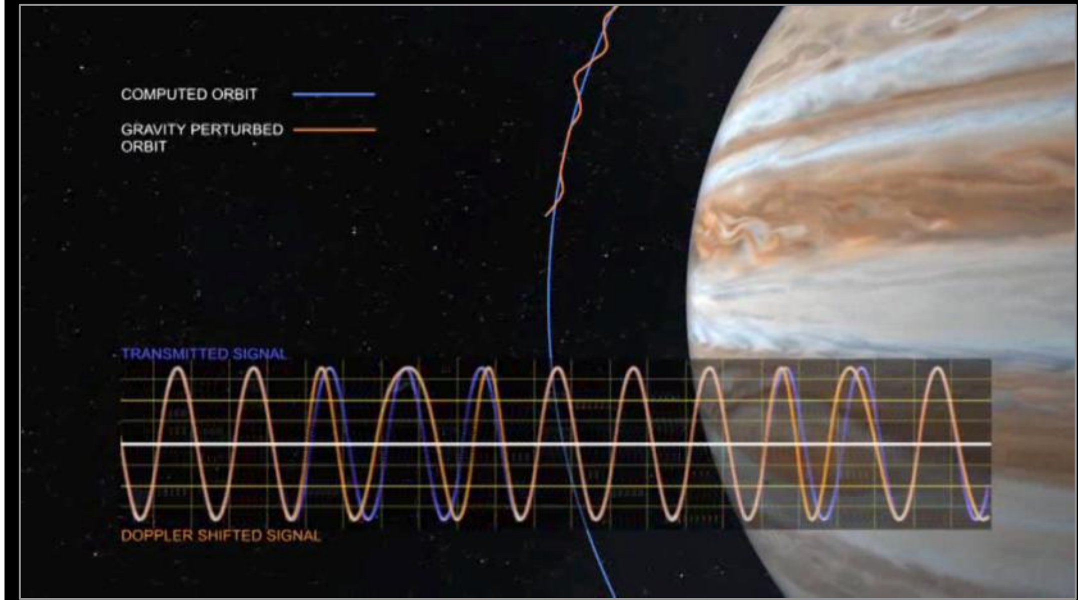






Synchrotron radio emission from the radiation belts makes this kind of measurement impossible from far away on Earth

Mapping Jupiter's gravity



Tracking changes in Juno's velocity reveals Jupiter's gravity (and how the planet is arranged on the inside).

Precise Doppler measurements of spacecraft motion reveal the gravity field.

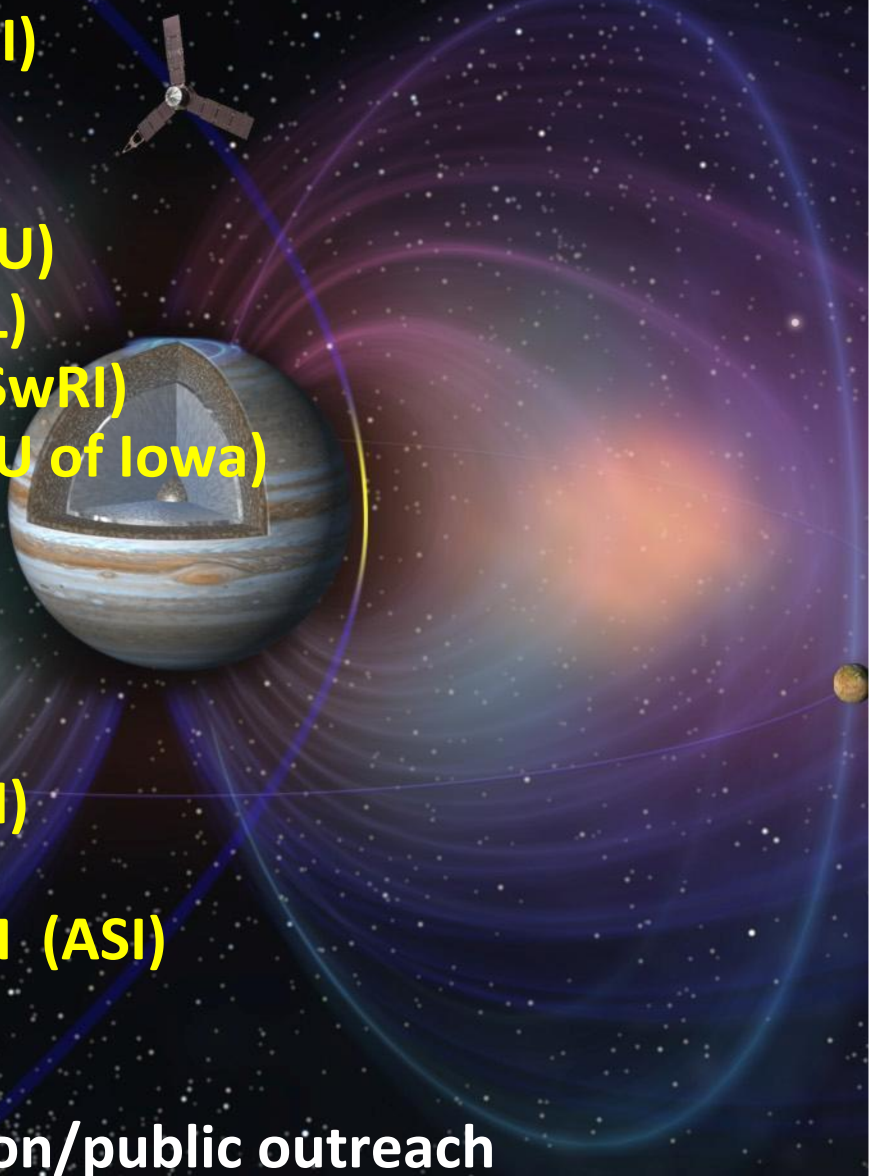
Tides provide further clues.

Juno Payload

Gravity Sensing:
X and Ka Band Gravity Science (JPL/ASI)

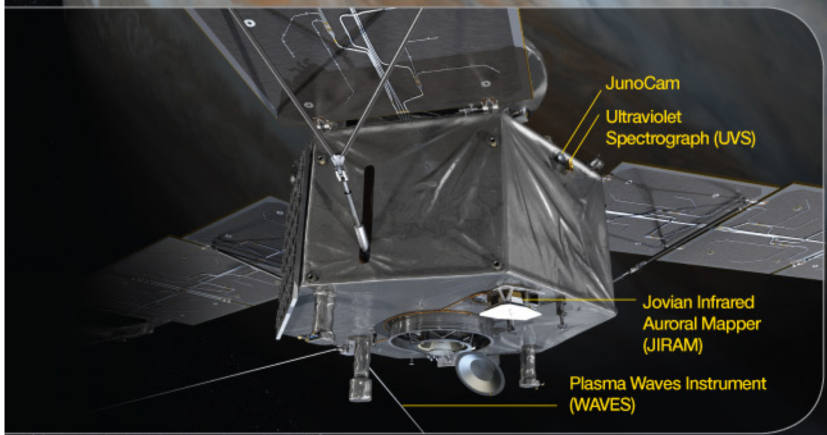
Particle/Field Experiments:
Magnetometer— MAG/ASC (GSFC/DTU)
Energetic Particle Detectors—JEDI(APL)
Jovian Auroral Distributions — JADE (SwRI)
Plasma Wave Measurement - Waves (U of Iowa)

Remote Sensing Instruments:
Microwave Radiometer— MWR (JPL)
  λ = 1.37 – 50 cm
UV Imaging Spectrograph— UVS (SwRI)
  λ = 68-210 nm
Near-IR Camera/Spectrometer –JIRAM (ASI)
  λ = 2-5 μm
CCD Camera - JunoCam (MSSS)
  R,G,B and 890-nm filters – education/public outreach



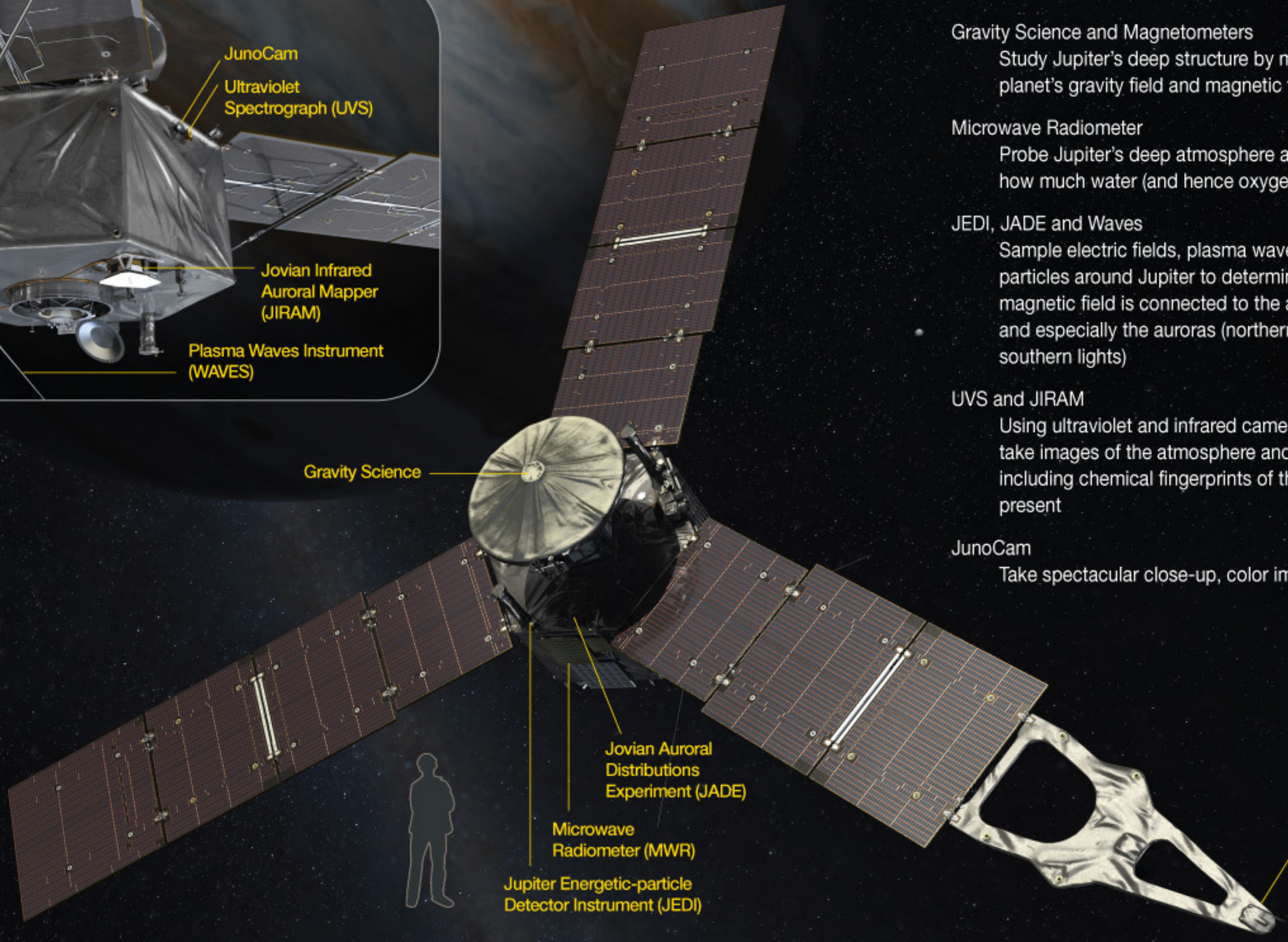
Juno Spacecraft

National Aeronautics and Space Administration



SPACECRAFT DIMENSIONS

Diameter: 66 feet (20 meters)
Height: 15 feet (4.5 meters)



Juno's Instruments

Gravity Science and Magnetometers
Study Jupiter's deep structure by mapping the planet's gravity field and magnetic field

Microwave Radiometer
Probe Jupiter's deep atmosphere and measure how much water (and hence oxygen) is there

JEDI, JADE and Waves
Sample electric fields, plasma waves and particles around Jupiter to determine how the magnetic field is connected to the atmosphere, and especially the auroras (northern and southern lights)

UVS and JIRAM
Using ultraviolet and infrared cameras, take images of the atmosphere and auroras, including chemical fingerprints of the gases present

JunoCam
Take spectacular close-up, color images

For more information:
missionjuno.swri.edu &
www.nasa.gov/juno

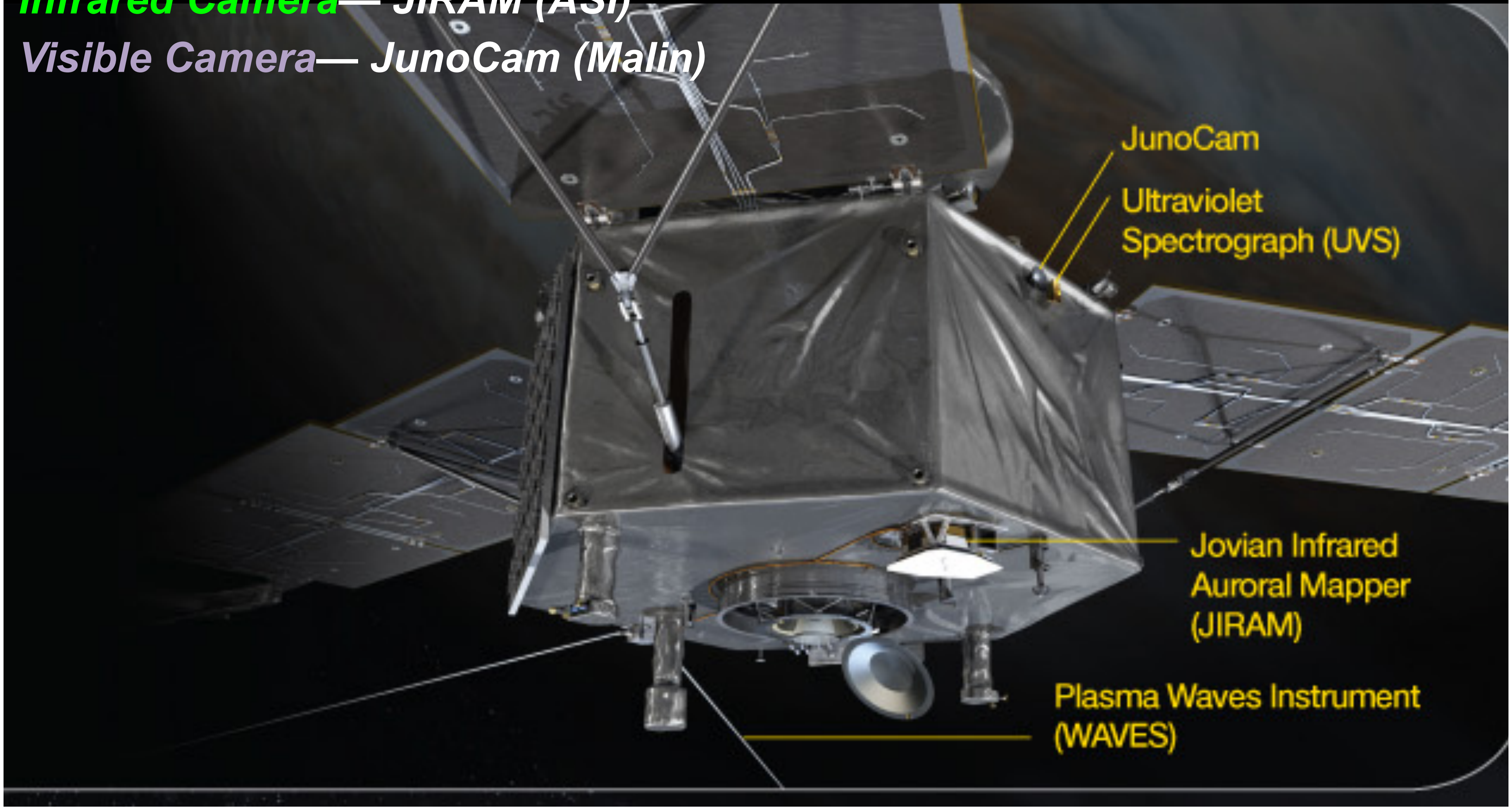
National Aeronautics and Space Administration

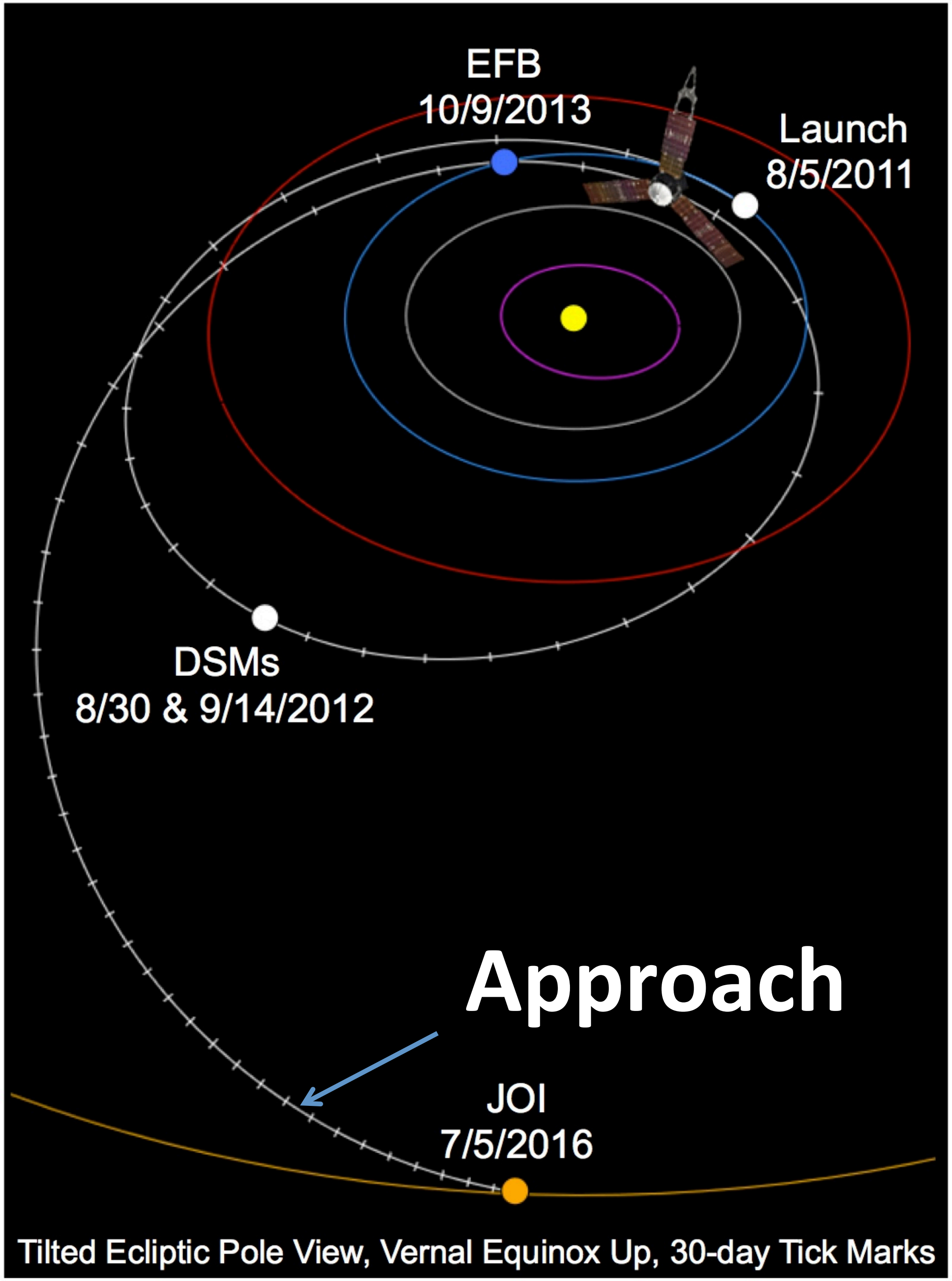
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

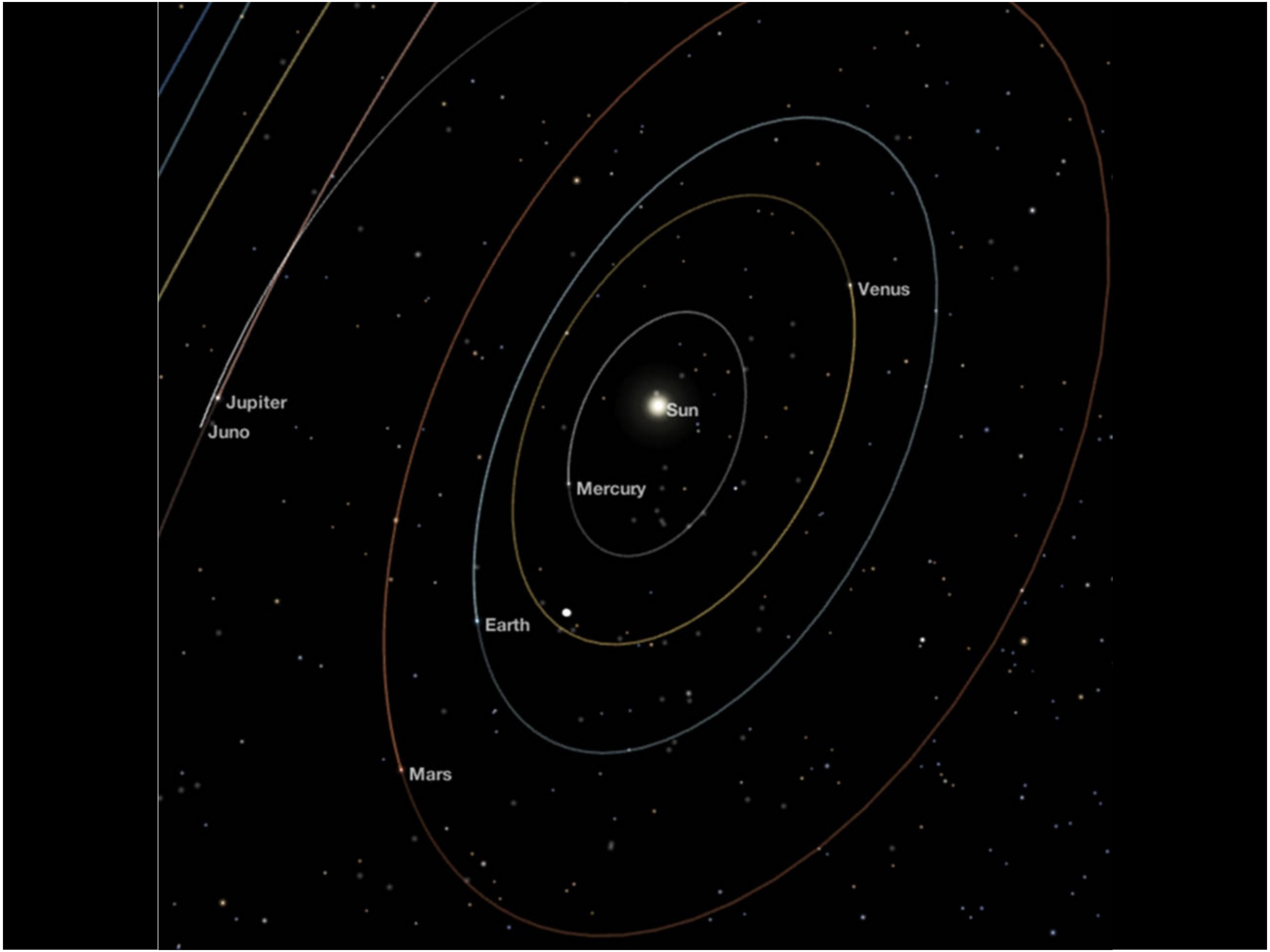
www.nasa.gov

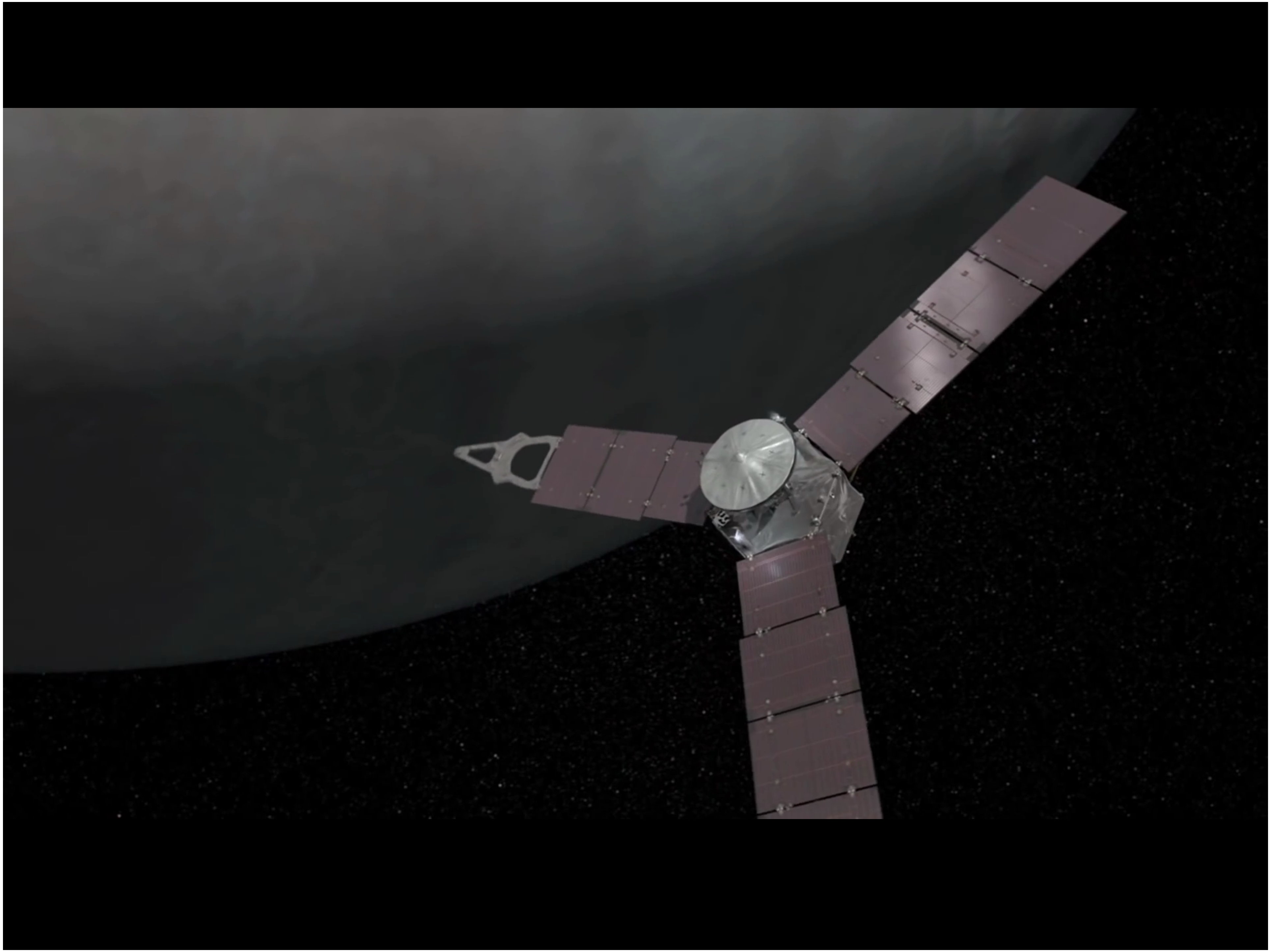
key remote-sensing instruments:

***Microwave Radiometer*— MWR (JPL)**
***UV Spectrometer*— UVS (SwRI)**
***Infrared Camera*— JIRAM (ASI)**
***Visible Camera*— JunoCam (Malin)**

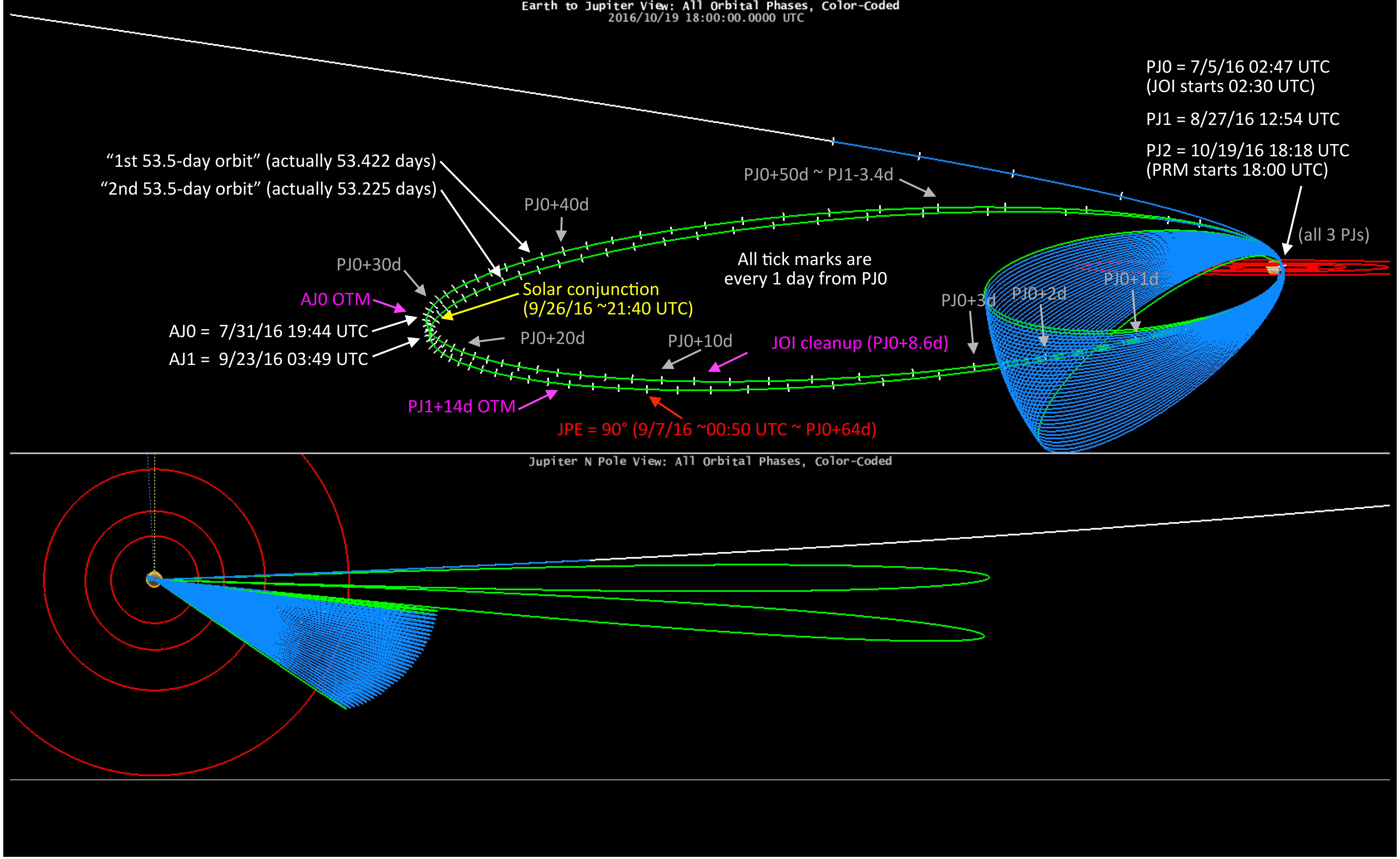


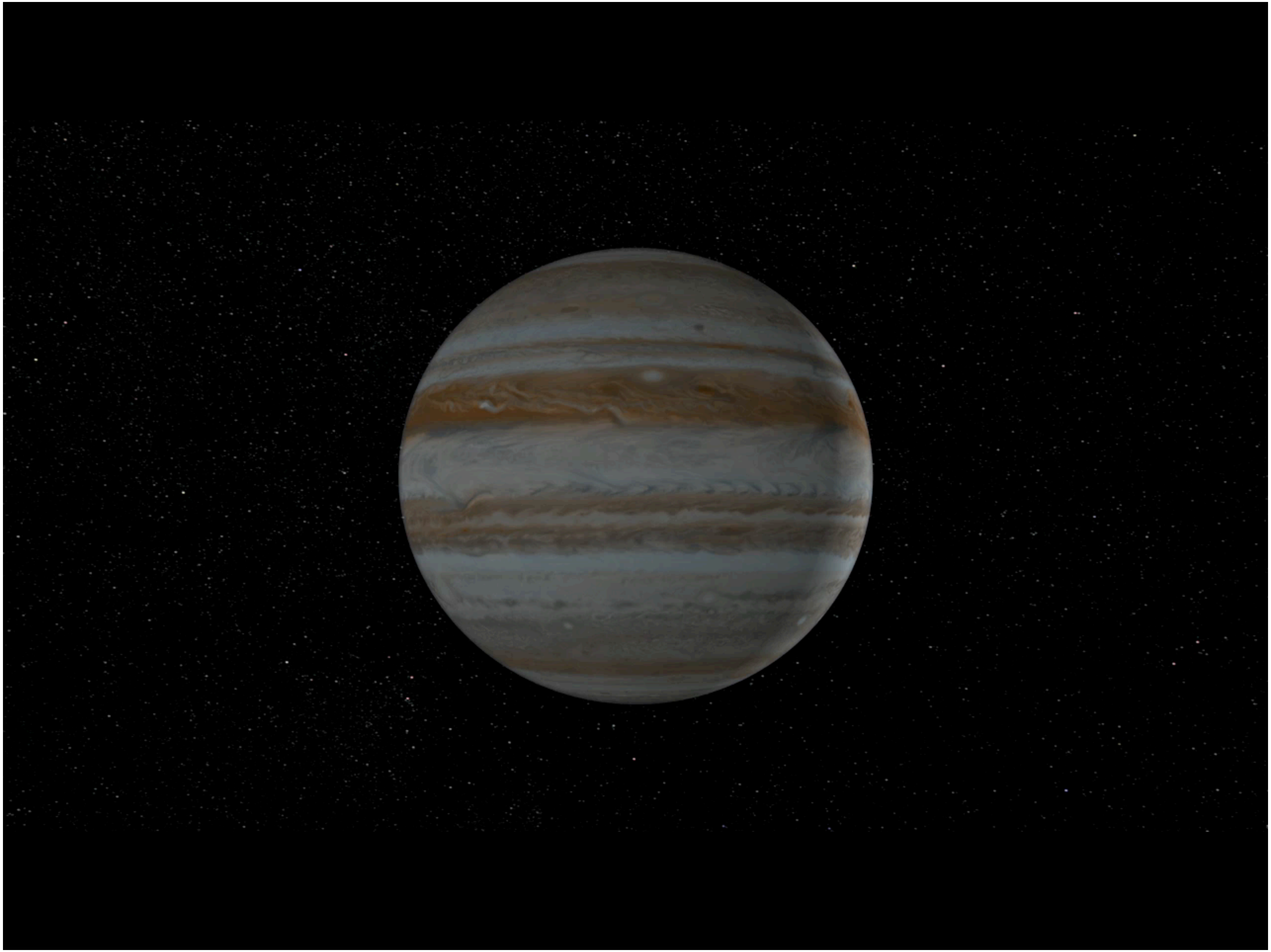

EFB
10/9/2013
Launch
8/5/2011
DSMs
8/30 & 9/14/2012
Approach
JOI
7/5/2016
Tilted Ecliptic Pole View, Vernal Equinox Up, 30-day Tick Marks

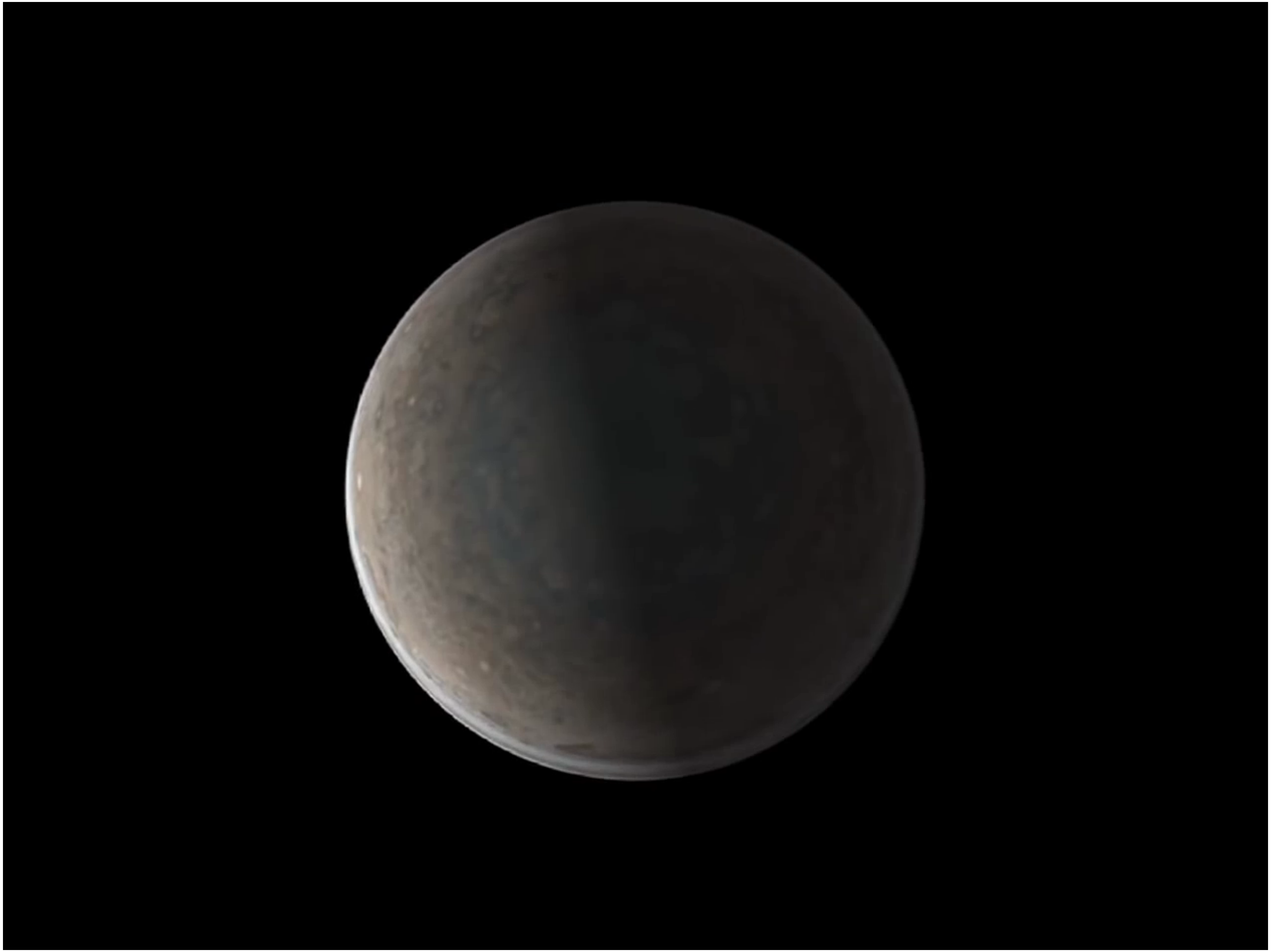

Venus
Jupiter
Juno
Sun
Mercury
Earth
Mars



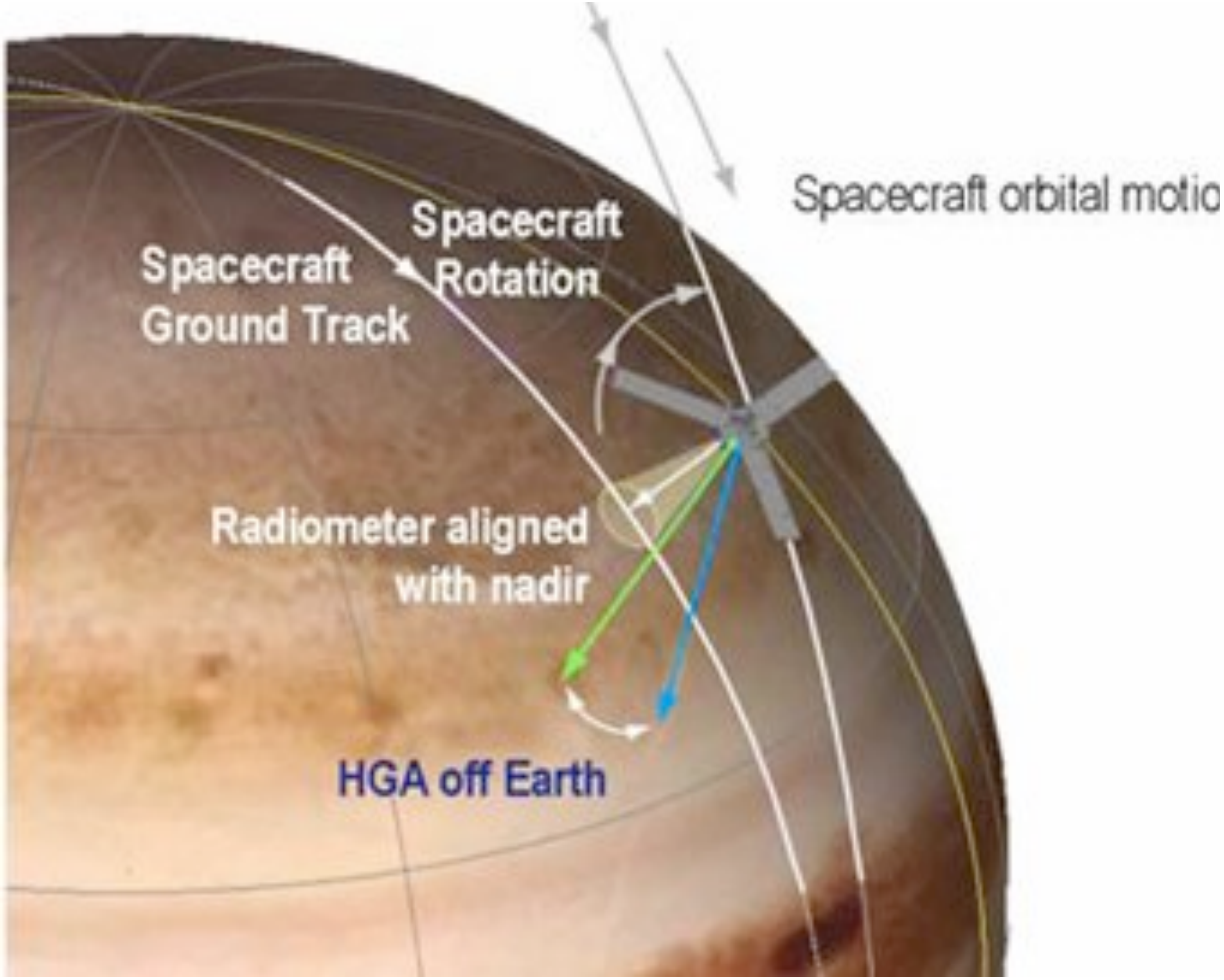
Following Jupiter Orbit Insertion (JOI), there are two ~53 day orbits, perijoves 0 and 1 (PJ0,PJ1)

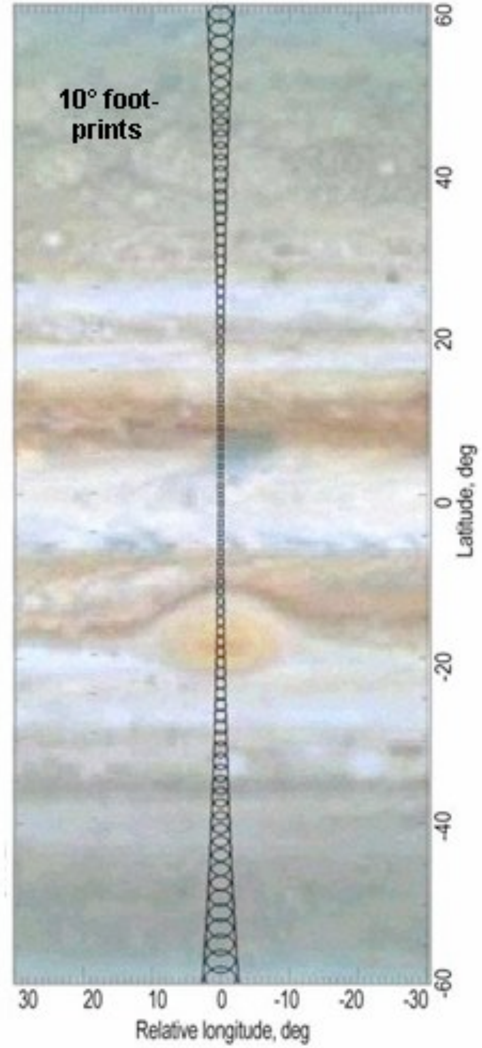




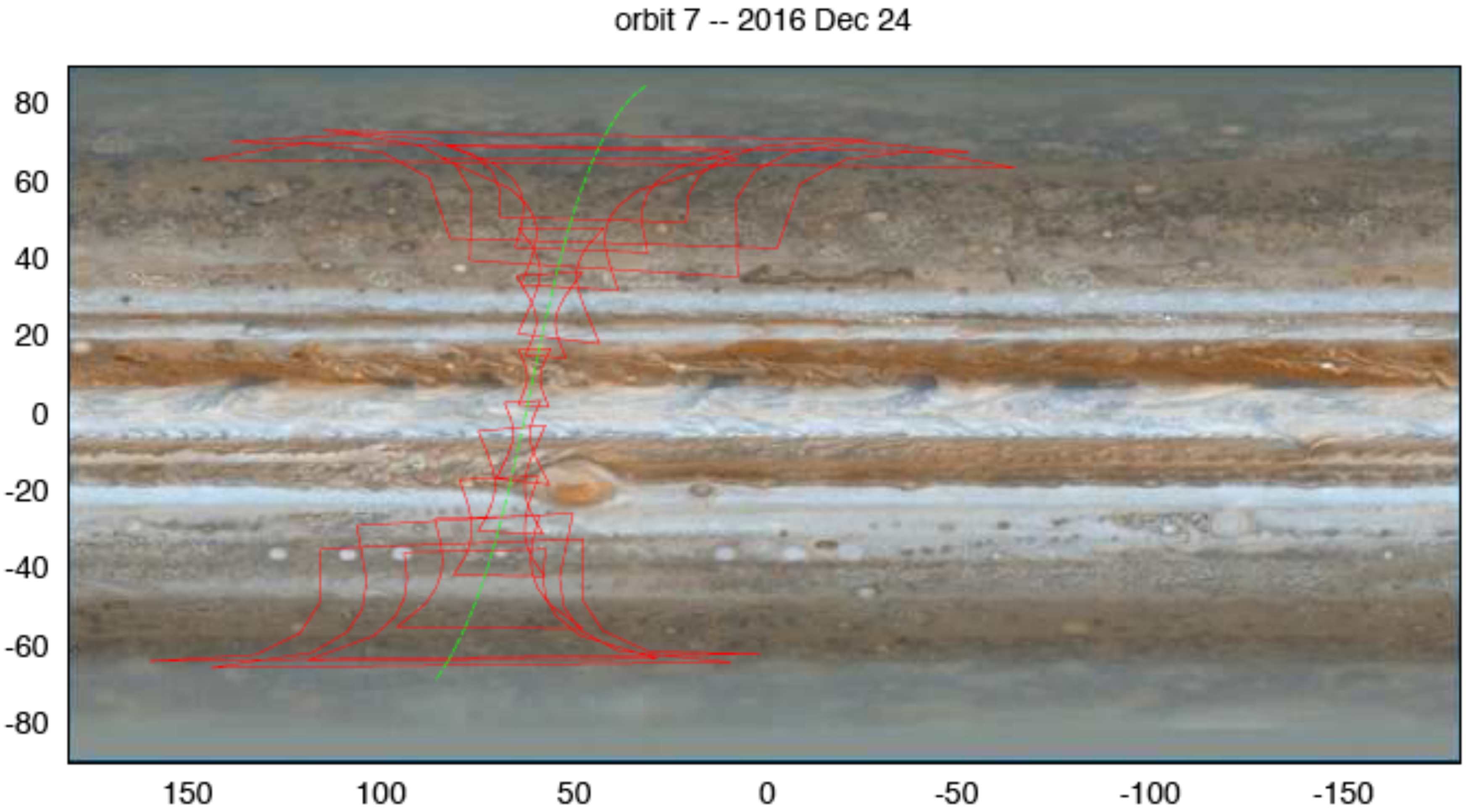


Track of MWR Sensing

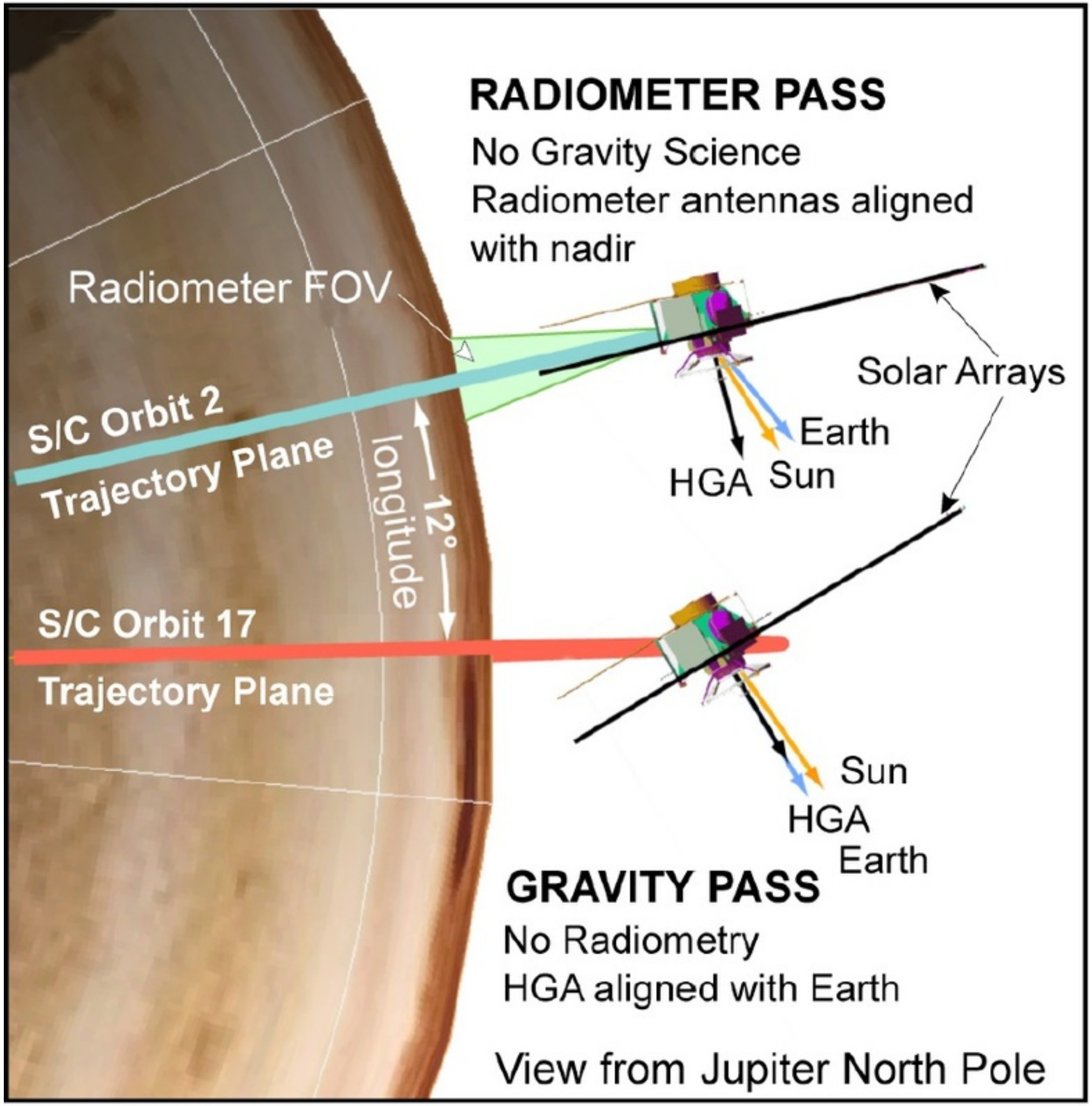




One longitudinal swath



- A pole-to-pole swath of images (15) is possible.
  - But this is not a requirement – EPO will select positions
- MWR orientation



MWR orbits have the spacecraft (S/C) oriented to point to nadir.

Gravity-Mapping orbits have the S/C oriented so the high-gain antenna (HGA) points directly at the Earth

MWR orbits are early in the mission to avoid radiation damage in later orbits.

MWR, JIRAM, JunoCAM and the UVS teams still plan to remain turned on during gravity-mapping orbits, so there may be some data obtained on GS orbits, but not at nadir angles.

Juno will concentrate remote-sensing plans on orbits 3, 5-8, but may get more useful data.

EVENT	DATE
JOI	2016 Jul 5
Orbit 1C	2016 Aug 27
Orbit 2 PRM	2016 Oct 19
Orbit 3 Cleanup	2016 Nov 2
Orbit 4 PJ	2016 Nov 16
Orbit 5 PJ	2016 Nov 30
Orbit 6 PJ	2016 Dec 14
Orbit 7 PJ	2016 Dec 28
Orbit 8 PJ	2016 Jan 11
Orbit 9 PJ	2017 Jan 25
Orbit 10 PJ	2017 Feb 8
Orbit 11 PJ	2017 Feb 22
Orbit 12 PJ	2017 Mar 8
Orbit 13 PJ	2017 Mar 22
Orbit 14 PJ	2017 Apr 5
Orbit 15 PJ	2017 Apr 19
Orbit 16 PJ	2017 May 3
Orbit 17 PJ	2017 May 17
Orbit 18 PJ	2017 May 31
Orbit 19 PJ	2017 Jun 14
Orbit 20 PJ	2017 Jun 28

EVENT	DATE
Orbit 21 PJ	2017 Jul 12
Orbit 22 PJ	2017 Jul 26
Orbit 23 PJ	2017 Aug 9
Orbit 24 PJ	2017 Aug 23
Orbit 25 PJ	2017 Sep 5
Orbit 26 PJ	2017 Sep 19
Orbit 27 PJ	2017 Oct 3
Orbit 28 PJ	2017 Oct 17
Orbit 29 PJ	2017 Oct 31
Orbit 30 PJ	2017 Nov 14
Orbit 31 PJ	2017 Nov 28
Orbit 32 PJ	2017 Dec 12
Orbit 33 PJ	2017 Dec 26
Orbit 34 PJ	2018 Jan 9
Orbit 35 PJ	2018 Jan 23
Orbit 36 PJextra	2018 Feb 6
Orbit 37 PJextra	2018 Feb 20
Orbit 38 Deorbit	2018 Mar 6

Remote-Sensing (MWR) Orbits
Gravity-Sensing (GS) Orbits

Professional Observations

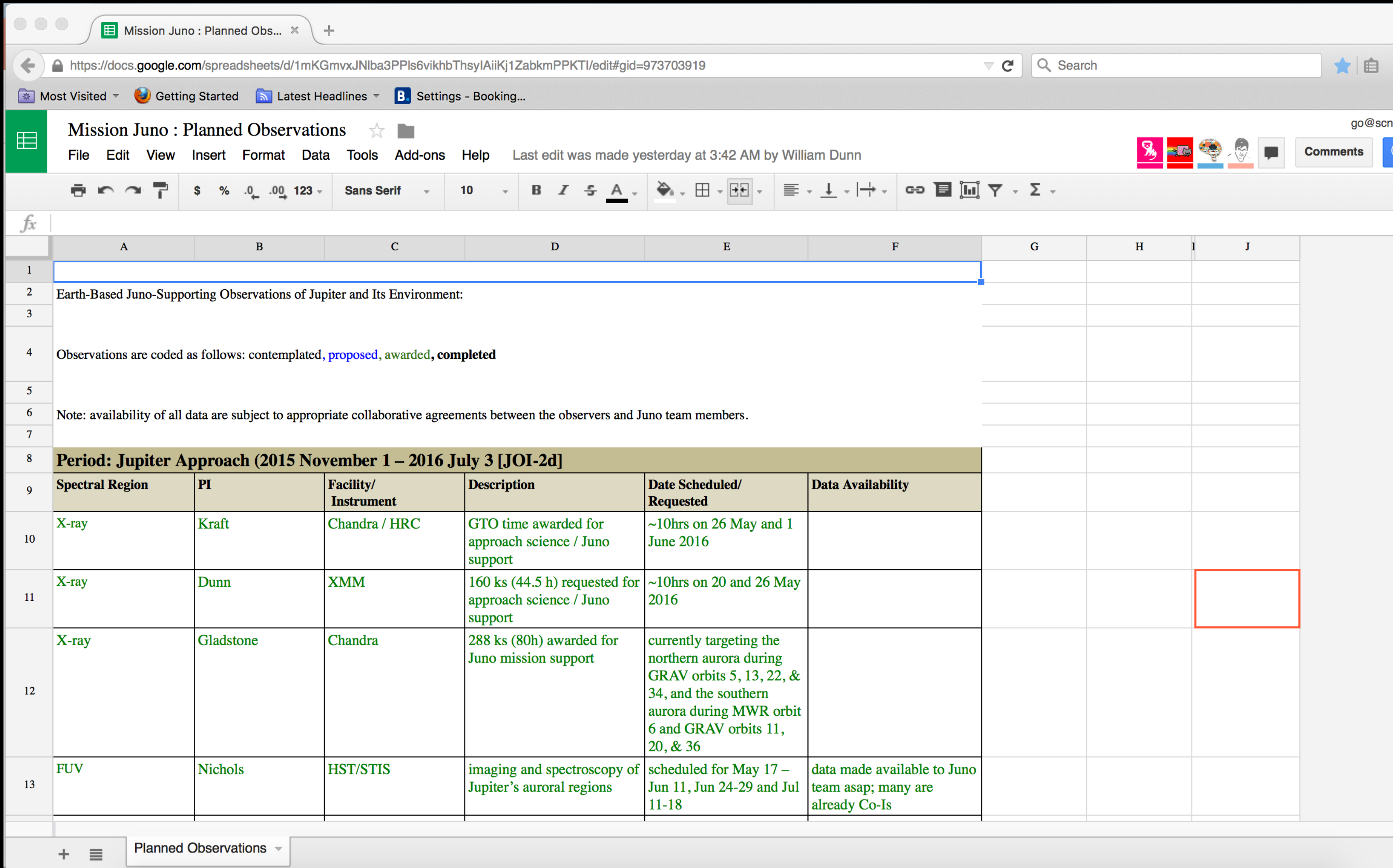
- X-ray observations
  - XMM (Dunn)
  - Chandra (Kraft, Gladstone)
- Ultraviolet observations
  - Exceed instrument on JAXA Hisaki satellite
  - HST STIS observations
- Visible observations
  - Calar Alto and Bilbao, Spain (Sanchez-Lavega et al.)
  - HST WFC3 (Wong et al., several PJs), HST WFC3 (OPAL program, but only ~PJ14
  - Apache Point spectroscopy (Chanover et al.)
  - VLT MUSE (Irwin et al.)
- Near-infrared observations
  - AO-stabilized imaging (Wong, Orton: Gemini; Conrad, Large Binocular Telescope)
    - Only stabilized via Galilean satellites (15-55" from the edge of Jupiter)
    - Not always available around critical PJ times
  - High-resolution, spatially resolved 5-µm spectroscopy (dePater, Bjoraker; Keck)
  - Quasi-continuous imaging (Orton; IRTF)
  - Challenge of PJ2 (Jupiter is 17^{o} from sun, barely accessible from the IRTF)
  - Intensive multi-spectral observations, including spectral scanning (IRTF)
  - High-resolution 5-µm observations (Bjoraker, IRTF)
  - Challenge of multiple requests for IRTF time
    - Neutral atmosphere imaging (SpeX, iSHELL guide cameras)
    - Io activity monitoring (SpeX, iSHELL)
    - Near-infrared auroral imaging (SpeX)
    - Near-infrared auroral spectroscopy (iSHELL)

Professional Observations

- Mid-infrared observations
  - TEXES at the IRTF
    - Three 10-day runs, to be timed as follows: (1) near PJ5 and on PJ4, (2) on PJ7 and (3) on/near PJ11,PJ12 (consortium: Greathouse, Fletcher, Sinclair, Encrenaz)
  - VISIR at the Very Large Telescope
    - Fletcher leading: 2-3 filter images on PJ4,PJ5; full filter sets for PJ7, PJ8, PJ9, PJ13*, PJ14*; partial coverage on PJ10-PJ12 (GRAV orbits)
    - Coverage only of sub-PJ hemisphere

      *Global Coverage
  - COMICS at Subaru*
    - Kasaba leading PJ8 (proposal submitted)
    - Orton leading via Keck exchange time using NASA mission support for PJ9 (proposal under review by Co-I's, required supporting letters from Bolton, Hasan @ NASA HQ in hand)
    - LBT: Some 10"x10" imaging mosaics simultaneous with near-infrared AO-guided imaging
  - Michelle at UKIRT
    - Tom Kerr (UKIRT staff time) leading. TBD: depends on schedule for Cassegrain configuration of the telescope.
- Microwave observations
  - Very Large Array (de Pater et al.) PJ2, PJ4, PJ5,PJ7, PJ8
  - Atacama Large Millimeter Array (de Pater et al.) several PJs

Mission Juno Planned Observations tool: up and active with 93 professional observers and 14 Juno investigators: https://www.missionjuno.swri.edu/planned-observations



Earth-Based Juno-Supporting Observations of Jupiter and Its Environment:

Observations are coded as follows: contemplated, proposed, awarded, **completed**

Note: availability of all data are subject to appropriate collaborative agreements between the observers and Juno team members.

Period: Jupiter Approach (2015 November 1 – 2016 July 3 [JOI-2d]

Spectral Region	PI	Facility/ Instrument	Description	Date Scheduled/ Requested	Data Availability
X-ray	Kraft	Chandra / HRC	GTO time awarded for approach science / Juno support	~10hrs on 26 May and 1 June 2016	
X-ray	Dunn	XMM	160 ks (44.5 h) requested for approach science / Juno support	~10hrs on 20 and 26 May 2016	
X-ray	Gladstone	Chandra	288 ks (80h) awarded for Juno mission support	currently targeting the northern aurora during GRAV orbits 5, 13, 22, & 34, and the southern aurora during MWR orbit 6 and GRAV orbits 11, 20, & 36	
FUV	Nichols	HST/STIS	imaging and spectroscopy of Jupiter's auroral regions	scheduled for May 17 – Jun 11, Jun 24-29 and Jul 11-18	data made available to Juno team asap; many are already Co-Is

Professional observations for Juno support

- Auroral observations during Juno’s approach phase and primary mission
- Contextual observations over the globe
- Context in time
- Observations in spectral regions not included in Juno instrumentation
  - Mid-infrared
    - Temperatures
    - Indirect tracers of vertical motions (clouds, abundances of condensable, disequilibrium gases)

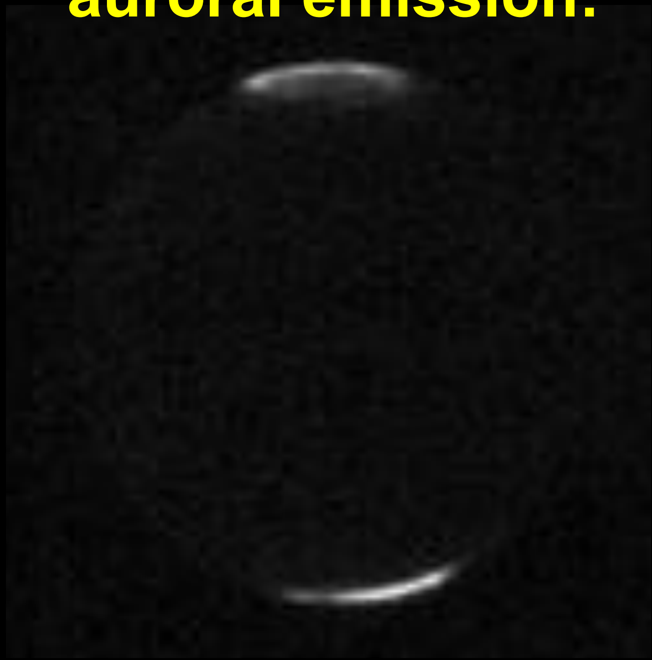
IRTF H_3^+ tracking: Evolution of Jupiter's auroral ovals while Juno particle and field instruments measure the properties of the impinging solar wind on approach

2016 January 30, 11:45 UTC

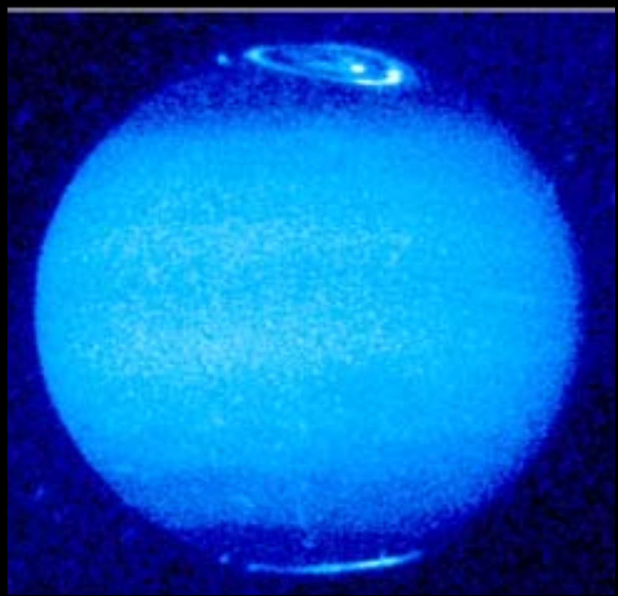
2016 January 29, 11:58 UTC

7.8 μm CH_4 emission: stratospheric temperatures

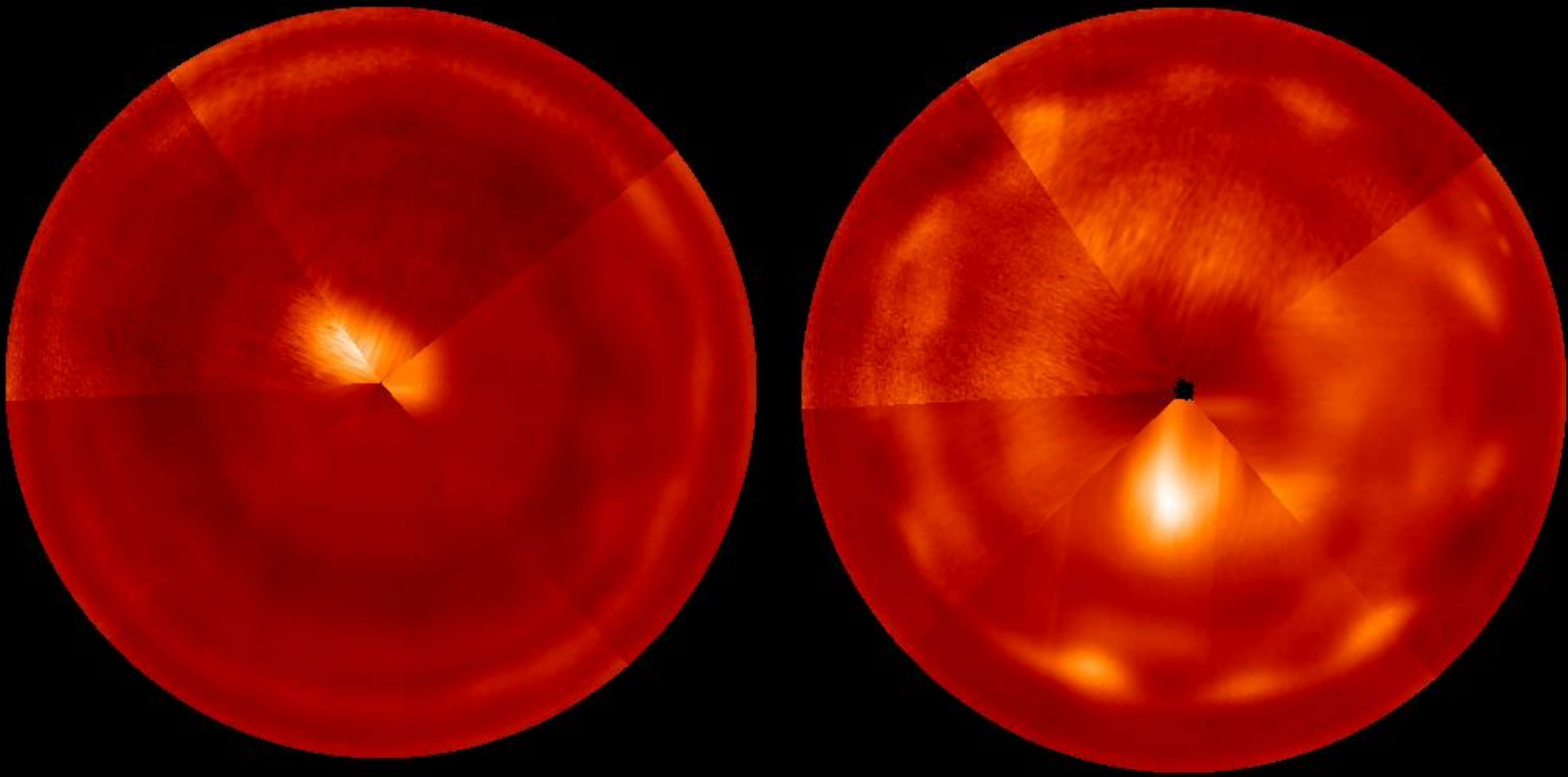
3.43 μm H_3^+ auroral emission:



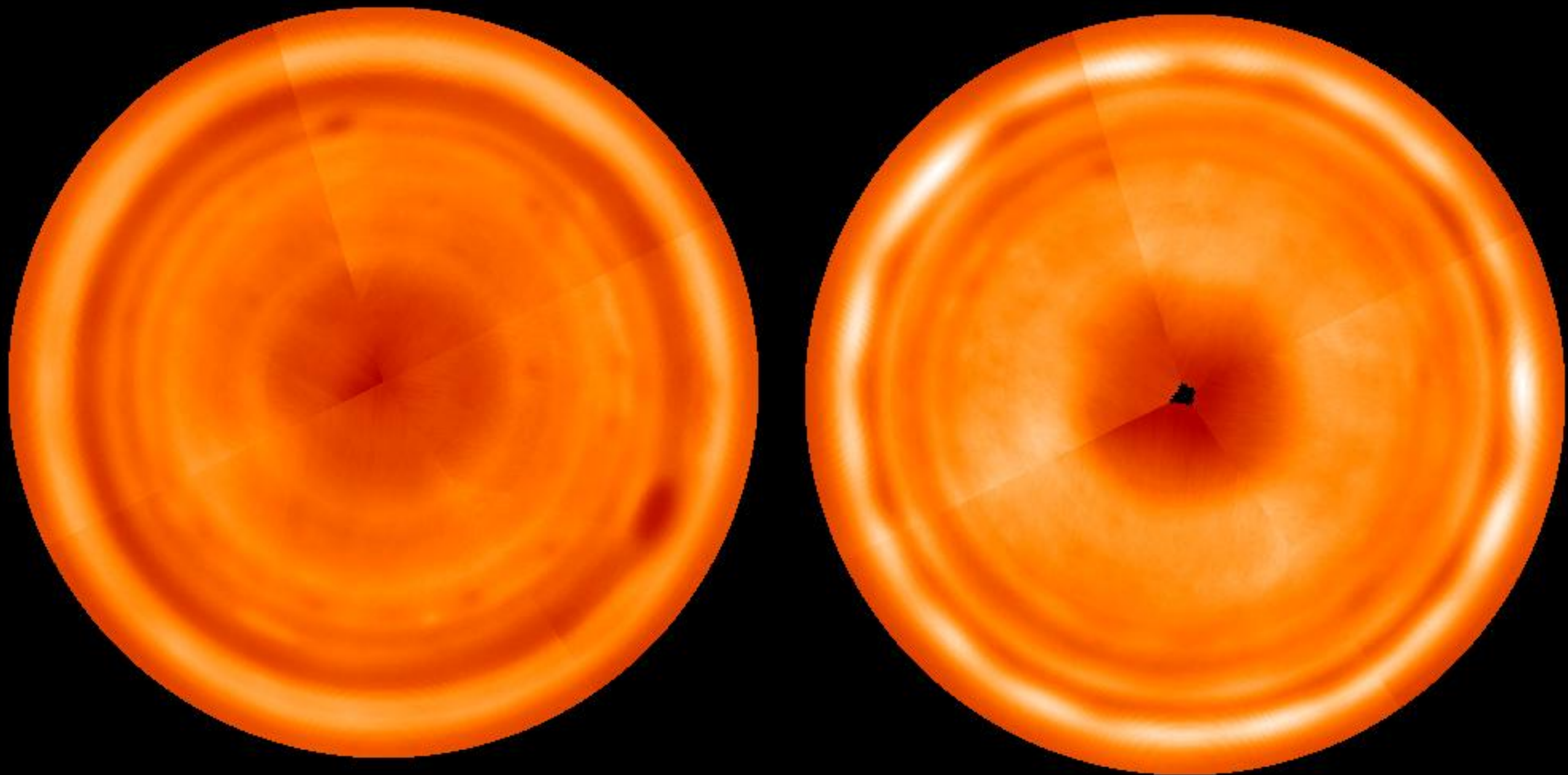
Ultraviolet emission
Hubble
Hisaki (unresolved)



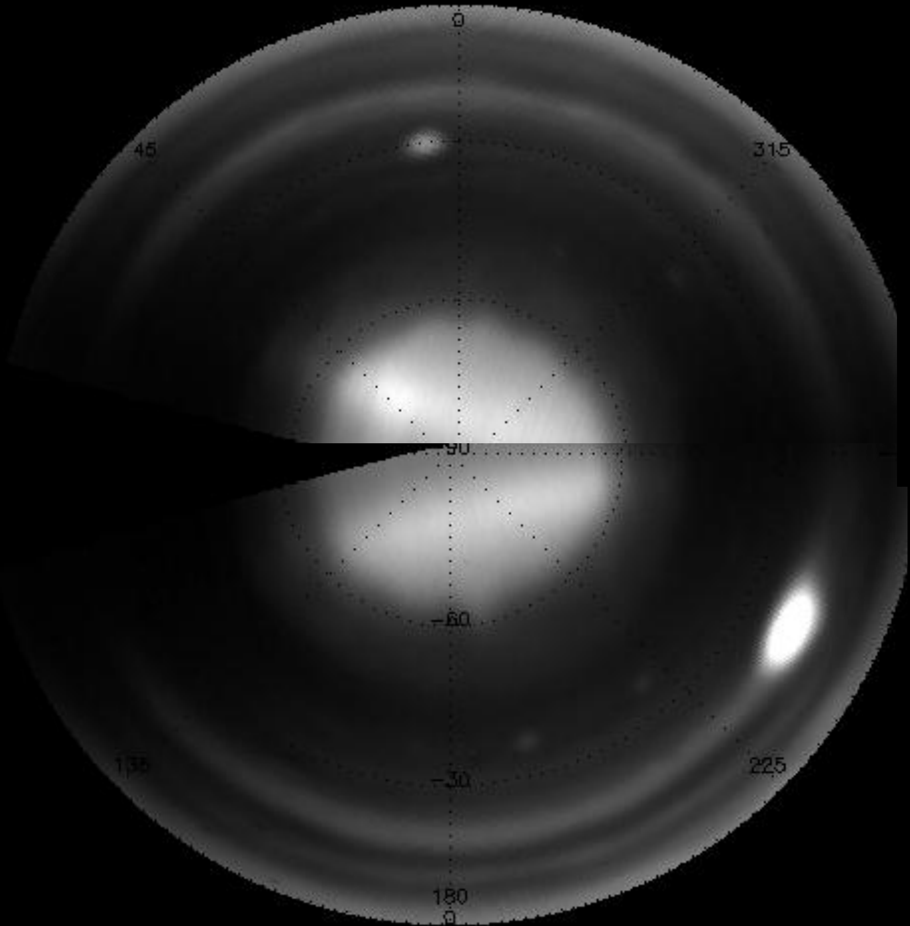
Jupiter: 2016 January 24-25 polar projections of composite 7.8-µm map
Subaru COMICS



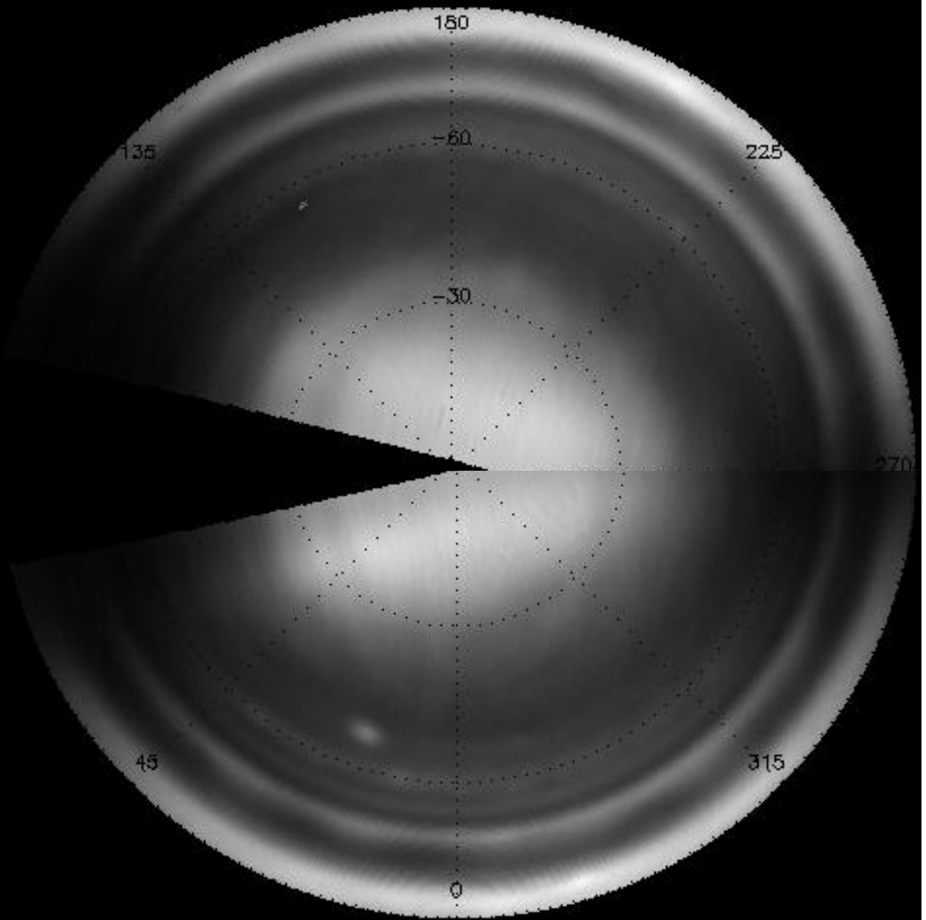
Jupiter: 2016 January 24-25 polar projections of composite 17.9-µm map



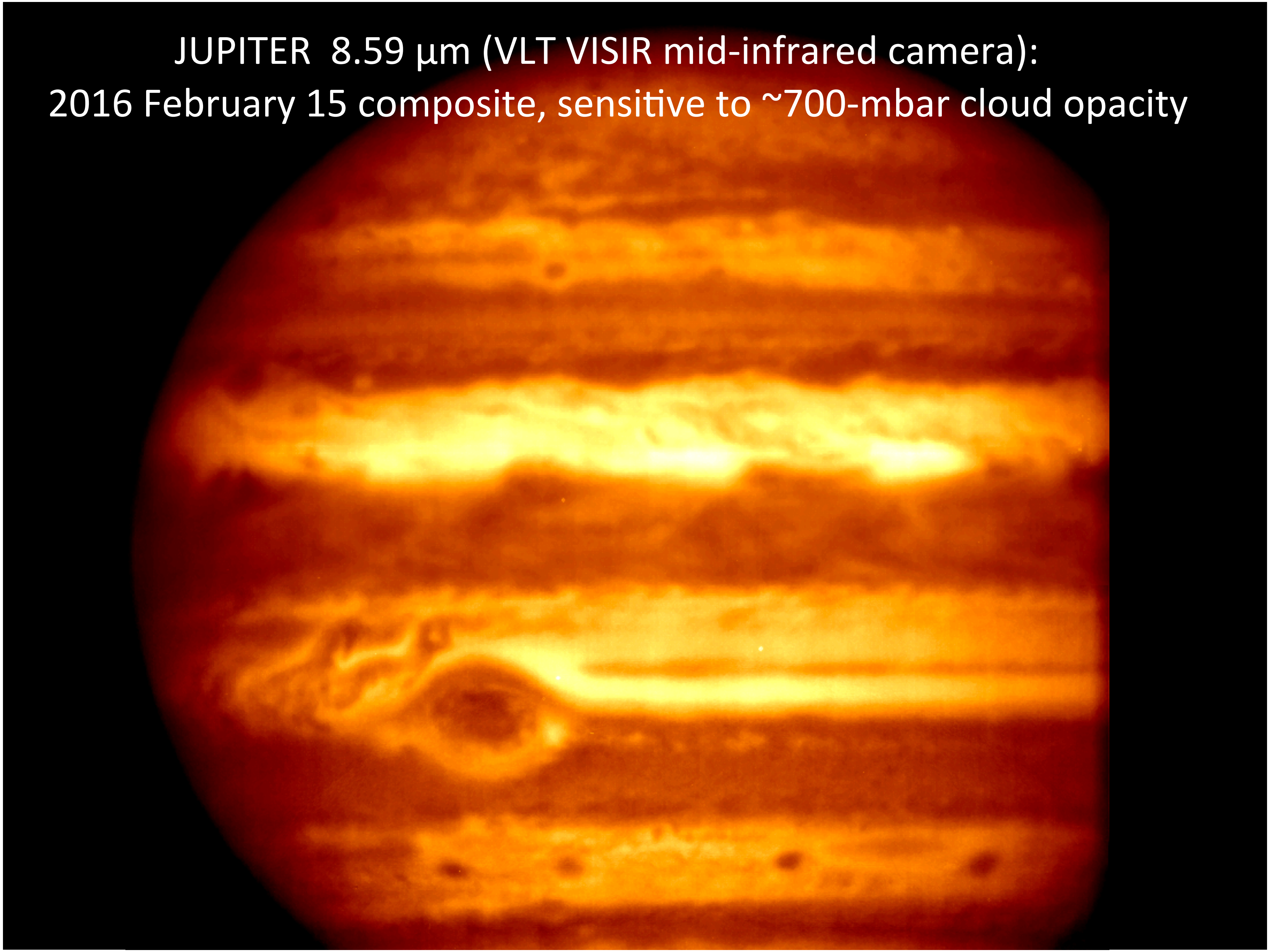
JUPITER 2.16 µm (IRTF SpeX guide camera)
2016 January 30-31 composite



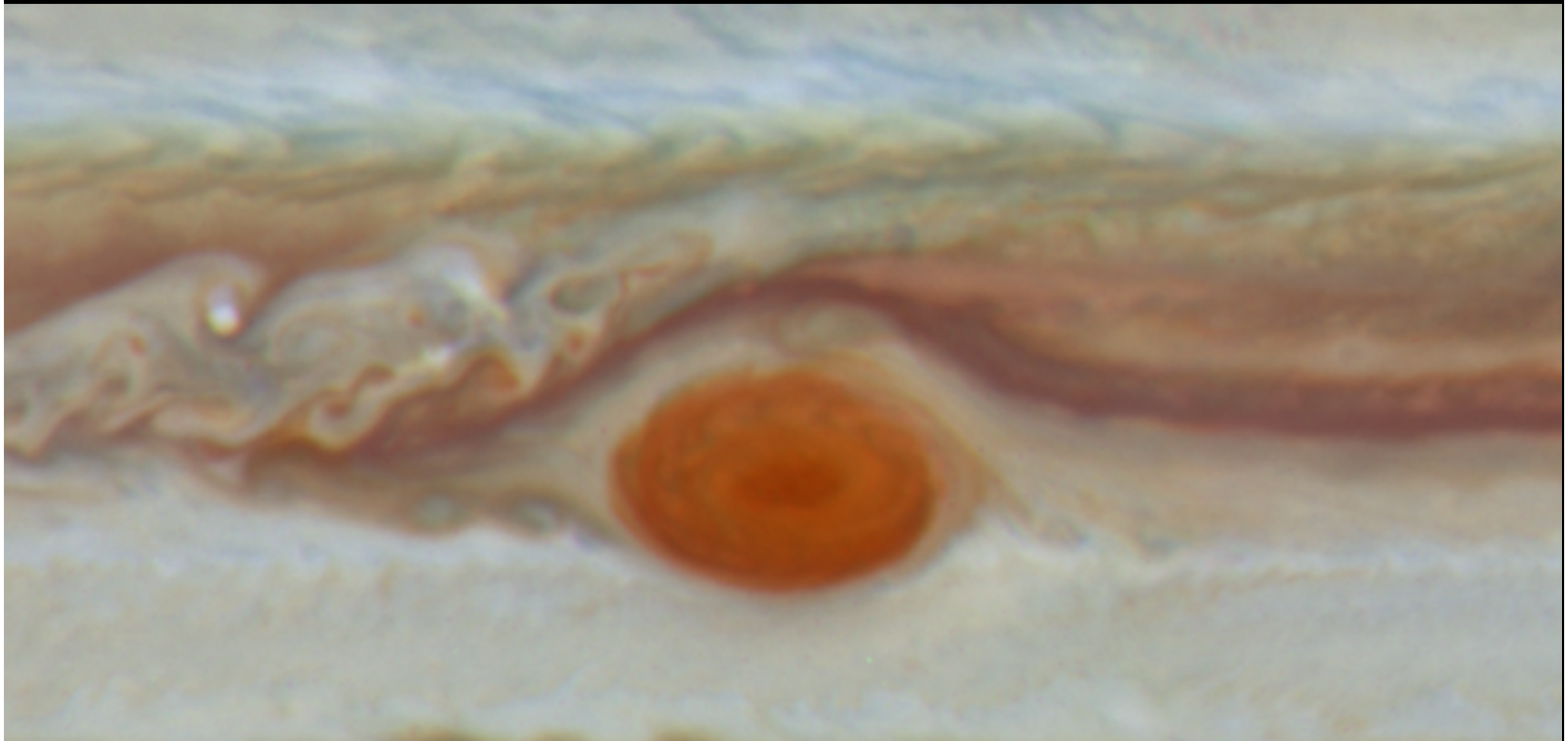
South Pole



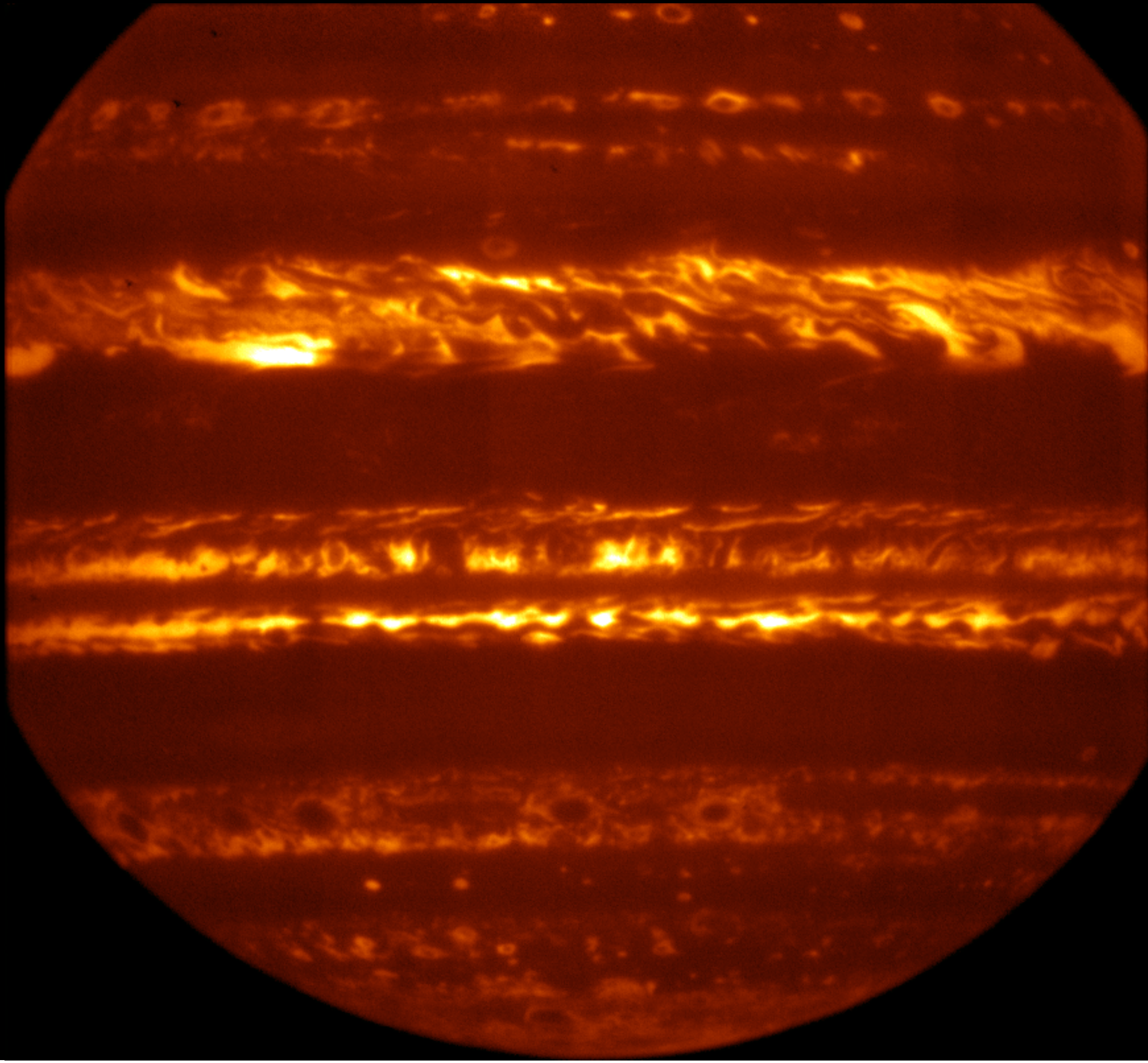
North Pole


JUPITER 8.59 µm (VLT VISIR mid-infrared camera):
2016 February 15 composite, sensitive to ~700-mbar cloud opacity

JUPITER color-composite (HST WFC3 camera; OPAL program):
2016 February 9 composite



M-band insertion test result for the VLT's VISIR (mid-infrared) experiment



Challenge of Proposal Preparations

- Very Large Array – February 1
- Subaru – March 8
- Keck (NASA time) – March 15
  - Spacecraft-support observations required letters from NASA HQ (Hashima Hasan) and Juno project (Scott referred them to me)
  - Orton writing/has written 3 detailed verification letters for Davies, Bjoraker, Stallard
- Keck (U. California time) – March 21
- Gemini – March 31
- Very Large Telescope – March 31
- Large Binocular Telescope – April 1
- Hubble Space Telescope (Cycle 24) – April 8
- Atacama Large Millimeter Array (ALMA) – April 21

IF EVERYTHING SEEMS UNDER CONTROL - YOU AREN'T GOING FAST ENOUGH.

IF EVERYTHING SEEMS UNDER CONTROL - YOU AREN'T GOING FAST ENOUGH.

-Mario Andretti

So let's move on as quickly as possible!

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