



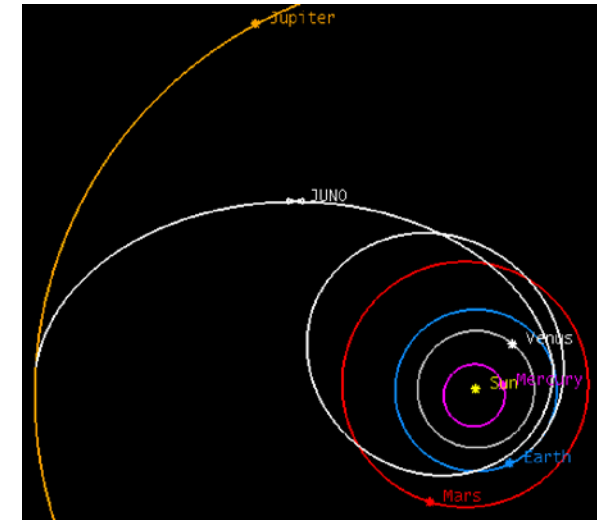
# Status of the Juno Mission

## Background: Earth-based support campaign

Glenn Orton  
Jet Propulsion Laboratory  
California Institute of Technology

# Juno Mission Status (high-level as of 2014 July 17)

- Outer Cruise phase of mission, with Jupiter Orbit Insertion (JOI) just under 2 years away.
  - Launch was nearly 3 years ago, 8/5/11.
  - Earth Flyby gravity assist was 10/9/13 (during the government shutdown if you're wondering why you didn't hear much about it!). See:
    - <http://www.jpl.nasa.gov/news/news.php?release=2013-360> (Earth approach movie story and video)
    - <http://www.jpl.nasa.gov/video/?id=1262> (Hi Juno video)
    - <http://missionjuno.swri.edu/media-gallery>
    - [http://www.msss.com/junocam\\_efb/efbimg.html](http://www.msss.com/junocam_efb/efbimg.html)
  - JOI will be 7/5/16. End of Mission is 10/16/17.
  - Current geometry:
    - Sun range = 3.2 AU, Earth range = 4.2 AU.
    - Approaching solar conjunction in early August.
  - Spacecraft/instrument activities and mission status:
    - Spacecraft subsystems and instruments are healthy.
    - Lessons from safing events after Earth Flyby and in March are being applied to JOI and orbital plans.
    - Most instruments were exercised at Earth Flyby, and are now on near-continuously (fields and particles solar wind measurements) or periodically (for calibrations).
- Status of orbital plans:
  - Will refine initial orbit plans starting late 2014, and then 11-day science orbit plans.
  - Considering a trade involving alternative capture orbit and science orbit periods.
  - Instrument observations of Jupiter and its environment will start ~ January 2016.



# Trajectory Event Times

Orbit	Event	Time (UTC)
Cruise	TIP [1]	08/07/2011 17:16:20.6
	DSM1 [2]	09/28/2012 21:28:54.8
	EFB	10/12/2013 17:55:34.5
0 JOI	JOI-6days	07/28/2016 00:28:54.8
	PJ0 [3]	08/03/2016 00:45:19.3
1 PRM	AJ0	09/10/2016 21:42:10.3
	PJ1 [4]	10/19/2016 18:15:59.3
	AJ1	10/25/2016 05:53:55.2
2 Cleanup	AJ1	10/25/2016 05:53:55.2
	PJ2	10/30/2016 17:33:21.8
	AJ2	11/05/2016 05:07:25.6
3 MWR	AJ2	11/05/2016 05:07:25.6
	PJ3	11/10/2016 16:42:09.7
	AJ3	11/16/2016 04:21:56.0
4 GS	AJ3	11/16/2016 04:21:56.0
	PJ4	11/21/2016 16:02:17.8
	AJ4	11/27/2016 03:43:15.1
5 MWR	AJ4	11/27/2016 03:43:15.1
	PJ5	12/02/2016 15:22:24.7
	AJ5	12/08/2016 03:02:55.3
6 MWR	AJ5	12/08/2016 03:02:55.3
	PJ6	12/13/2016 14:42:29.9
	AJ6	12/19/2016 02:24:15.6
7 MWR	AJ6	12/19/2016 02:24:15.6
	PJ7	12/24/2016 14:02:40.7
	AJ7	12/30/2016 01:42:27.7
8 MWR	AJ7	12/30/2016 01:42:27.7
	PJ8	01/04/2017 13:22:45.9
	AJ8	01/10/2017 01:01:33.9
9 GS	AJ8	01/10/2017 01:01:33.9
	PJ9	01/15/2017 12:42:53.0
	AJ9	01/21/2017 00:23:36.6
10 GS	AJ9	01/21/2017 00:23:36.6
	PJ10	01/26/2017 12:03:01.1
	AJ10	01/31/2017 23:43:00.3

Orbit	Event	Time (UTC)
11 GS	AJ10	01/31/2017 23:43:00.3
	PJ11	02/06/2017 11:23:08.1
	AJ11	02/11/2017 23:03:43.4
12 GS	AJ11	02/11/2017 23:03:43.4
	PJ12	02/17/2017 10:43:13.3
	AJ12	02/22/2017 22:21:47.4
13 GS	AJ12	02/22/2017 22:21:47.4
	PJ13	02/28/2017 10:03:20.7
	AJ13	03/05/2017 21:43:21.8
14 GS	AJ13	03/05/2017 21:43:21.8
	PJ14	03/11/2017 09:23:26.8
	AJ14	03/16/2017 21:02:41.8
15 GS	AJ14	03/16/2017 21:02:41.8
	PJ15	03/22/2017 08:43:35.0
	AJ15	03/27/2017 20:25:55.4
16 GS	AJ15	03/27/2017 20:25:55.4
	PJ16	04/02/2017 08:03:41.9
	AJ16	04/07/2017 19:43:35.1
17 GS	AJ16	04/07/2017 19:43:35.1
	PJ17	04/13/2017 07:23:50.8
	AJ17	04/18/2017 18:54:41.6
18 GS	AJ17	04/18/2017 18:54:41.6
	PJ18	04/24/2017 06:24:06.1
	AJ18	04/29/2017 18:03:31.9
19 GS	AJ18	04/29/2017 18:03:31.9
	PJ19	05/05/2017 05:44:13.3
	AJ19	05/10/2017 17:25:06.1
20 GS	AJ19	05/10/2017 17:25:06.1
	PJ20	05/16/2017 05:04:19.8
	AJ20	05/21/2017 16:45:06.4
21 GS	AJ20	05/21/2017 16:45:06.4
	PJ21	05/27/2017 04:24:25.4
	AJ21	06/01/2017 16:05:01.4
22 GS	AJ21	06/01/2017 16:05:01.4
	PJ22	06/07/2017 03:44:31.4
	AJ22	06/12/2017 15:23:38.8

Orbit	Event	Time (UTC)
23 GS	AJ22	06/12/2017 15:23:38.8
	PJ23	06/18/2017 03:04:34.8
	AJ23	06/23/2017 14:43:49.2
24 GS	AJ23	06/23/2017 14:43:49.2
	PJ24	06/29/2017 02:24:41.3
	AJ24	07/04/2017 14:05:22.3
25 GS	AJ24	07/04/2017 14:05:22.3
	PJ25	07/10/2017 01:44:45.9
	AJ25	07/15/2017 13:24:58.5
26 GS	AJ25	07/15/2017 13:24:58.5
	PJ26	07/21/2017 01:04:50.4
	AJ26	07/26/2017 12:46:23.0
27 GS	AJ26	07/26/2017 12:46:23.0
	PJ27	08/01/2017 00:24:55.2
	AJ27	08/06/2017 12:04:06.6
28 GS	AJ27	08/06/2017 12:04:06.6
	PJ28	08/11/2017 23:45:00.2
	AJ28	08/17/2017 11:25:33.6
29 GS	AJ28	08/17/2017 11:25:33.6
	PJ29	08/22/2017 23:05:03.8
	AJ29	08/28/2017 10:45:13.3
30 GS	AJ29	08/28/2017 10:45:13.3
	PJ30	09/02/2017 22:25:10.5
	AJ30	09/08/2017 10:07:08.2
31 GS	AJ30	09/08/2017 10:07:08.2
	PJ31	09/13/2017 21:45:13.8
	AJ31	09/19/2017 09:24:30.6
32 GS	AJ31	09/19/2017 09:24:30.6
	PJ32	09/24/2017 21:05:12.9
	AJ32	09/30/2017 08:45:37.0
33 Extra	AJ32	09/30/2017 08:45:37.0
	PJ33	10/05/2017 20:25:16.8
	AJ33	10/11/2017 08:10:33.4
34 Deorbit	AJ33	10/11/2017 08:10:33.4
	PJ34	10/16/2017 19:29:24.5

[1] Launch is ~ 58-64 min earlier than TIP, i.e., ~ 08/07/2011 16:15.  
 [2] DSM2 is 2 days after DSM1, 09/30/2012 21:28:54.8.

[3] JOI starts 08/03/2016 00:28:54.8 (duration = 32:49 min = 1969 s).  
 [4] PRM starts 10/19/2016 17:58:54.8 (duration = 34:09 min = 2049 s).



# • Juno Mission Orbit Plan

- **Jupiter Orbit Insertion (JOI)**
  - Orbit 1 lower apojove
  - Orbit 2 “cleanup orbit”
  - Orbit 3 MWR orbit (remote sensing)
  - Orbit 4 gravity orbit
  - Orbit 5 MWR orbit (rem. sensing)
  - Orbit 6 MWR orbit (rem. sensing)
  - Orbit 7 MWR orbit (rem. sensing)
  - Orbit 8 MWR orbit (rem. sensing)
  - Orbit 9 gravity mapping orbit
  - ...
  - Orbit 32 gravity mapping orbit
- 2016 July 5
- perijove 2016 August 3
- perijove 2016 October 16
- perijove 2016 November 10
- perijove 2016 November 21
- perijove 2016 December 2
- perijove 2016 December 13
- perojove 2016 December 24
- perijove 2017 January 4
- perijove 2017 January 15
- perijove 2017 September 24



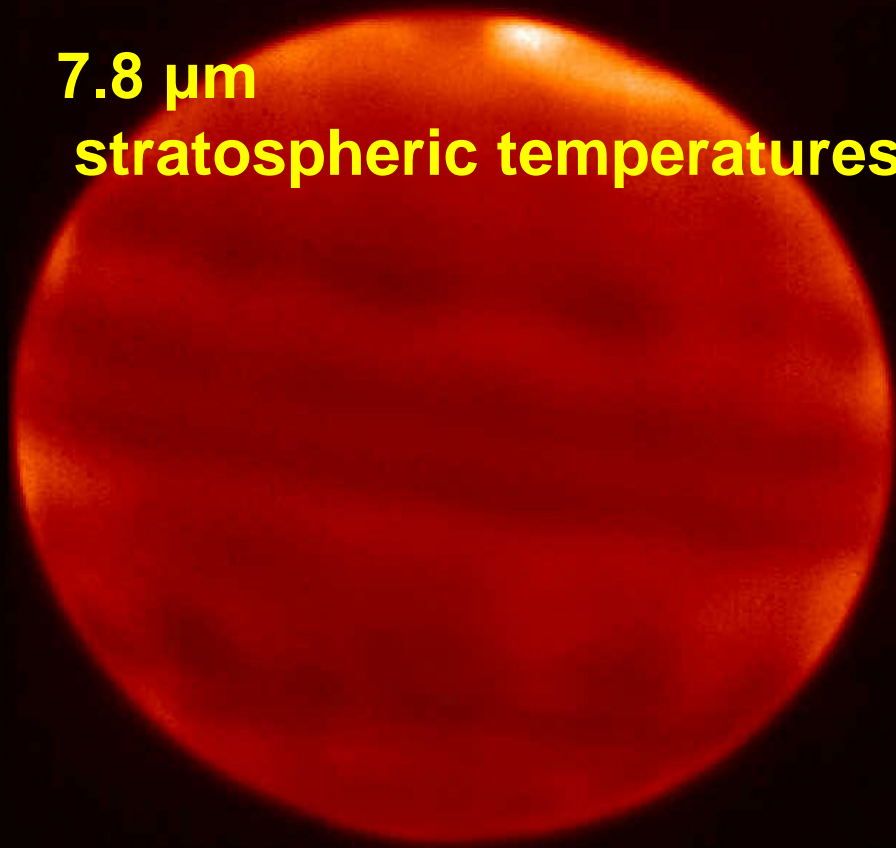
# What does Juno need in remote-sensing support?

## Supplemental spectral observations

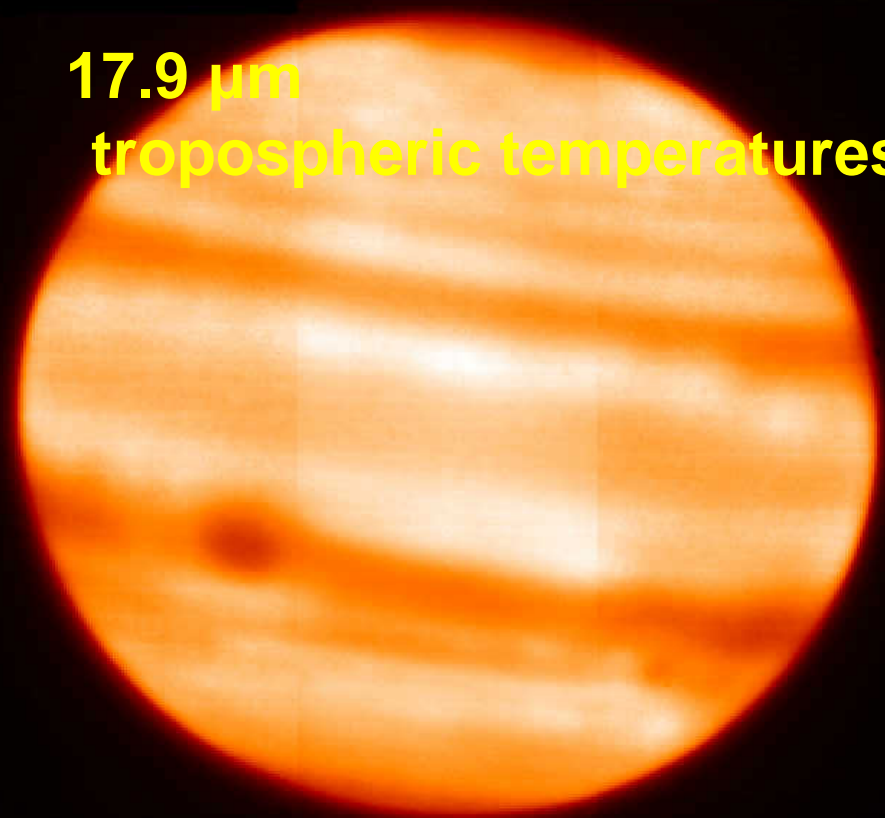
- JIRAM – 2-5  $\mu\text{m}$  (near-infrared spectrum)
- MWR – 1.3-50 cm (microwave spectrum)
- UVS – 70-205 nm (ultraviolet spectrum)
- JUNOCAM (public-outreach CCD camera)
- **Missing:**
  - **Mid-IR (thermal)**
    - Temperatures in the upper-troposphere and stratosphere
    - Clouds at the ammonia-ice condensation level
    - Composition in the upper troposphere



**7.8  $\mu\text{m}$   
stratospheric temperatures**



**17.9  $\mu\text{m}$   
tropospheric temperatures**



**Subaru/COMICS observations of Jupiter**

**2013 February 27**

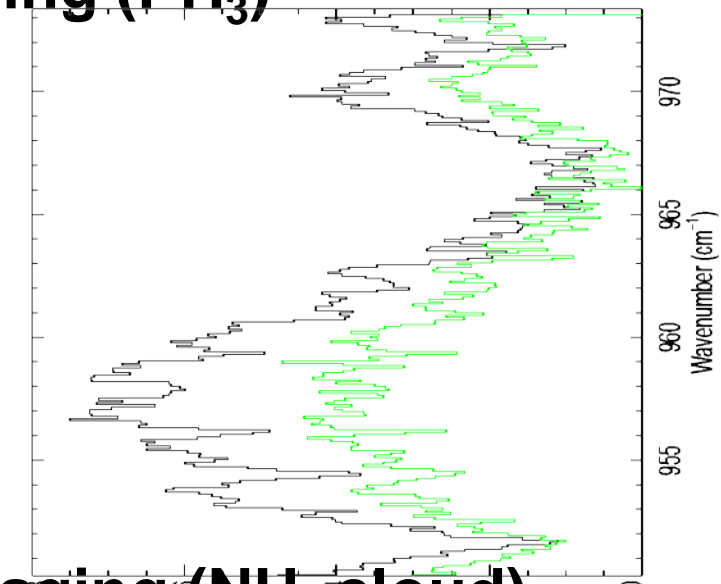
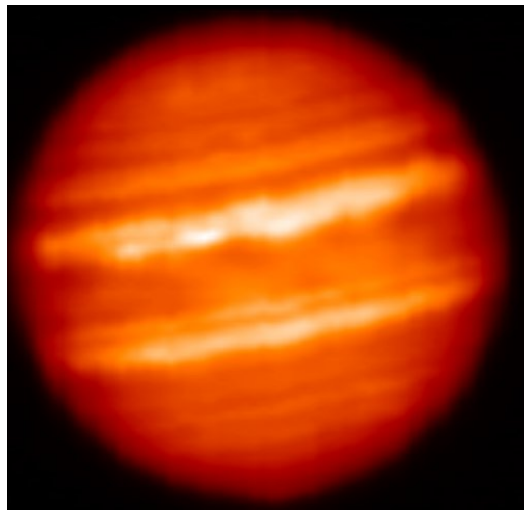


# Difficulty with Mid-Infrared Support

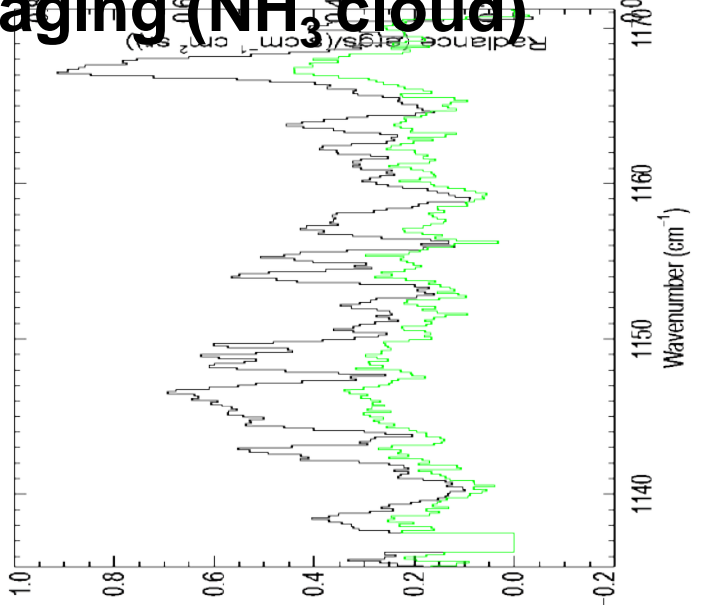
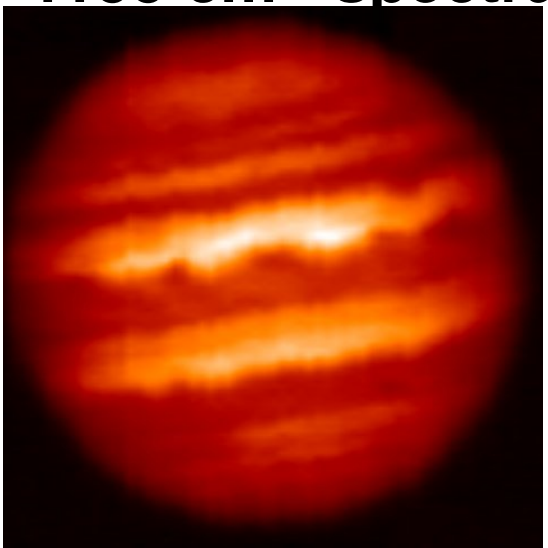
- Mid-infrared facility instruments have become rare
  - Keck Long-Wavelength Spectrometer decommissioned in 2004
  - Gemini South TReCS, Gemini North Michelle, unplugged for financial reasons
  - VLT VISIR, down for refurbishment, performed worse after returning, so down again
- Functioning, COMICS at the 8-m Subaru Telescope
  - Extremely good data, both imaging and spectroscopy
  - Recent policy change, “as a non-Japanese PI, you are at a disadvantage”
- Functioning, CanariCam at the 10.4-m Gran Telescopio Canarias
  - Slow beginning, proposals accepted to observe Jupiter for the first time; collaboration with the University of the Basque Country group in Bilbao, Spain
  - Not a low-water-vapor site, so what’s possible will remain to be tested
- Non-facility instruments
  - TEXES, a high-resolution scanning mid-infrared spectrometer, operating mostly at the IRTF, occasionally Gemini North
  - CELESTE, operating at Kitt Peak
  - Smaller telescopes mean worse diffraction limits, closer to 1.8” than the 0.4” at 8-10 meter-class telescopes.

## 2013 February 1-11

### 960 cm<sup>-1</sup> spectra and imaging (PH<sub>3</sub>)



### 1155 cm<sup>-1</sup> spectra and imaging (NH<sub>3</sub> cloud)





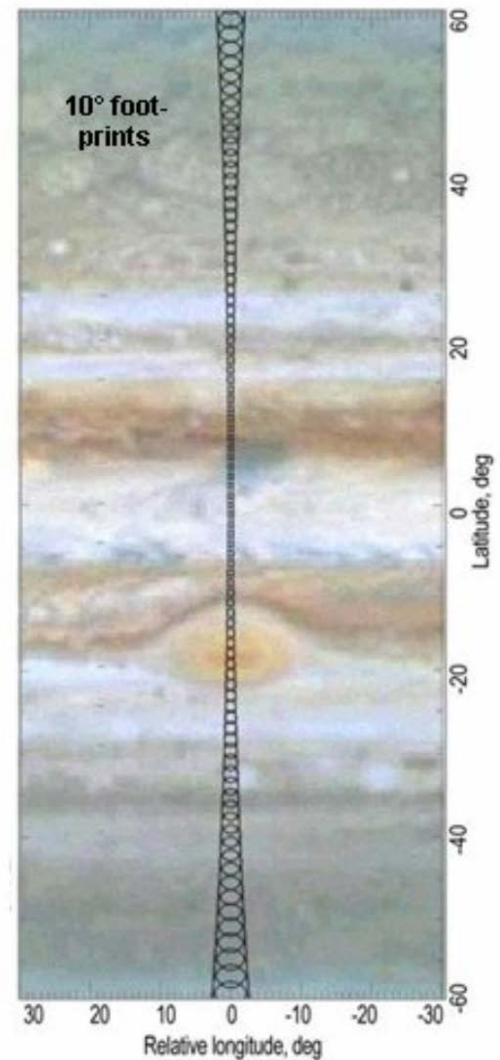
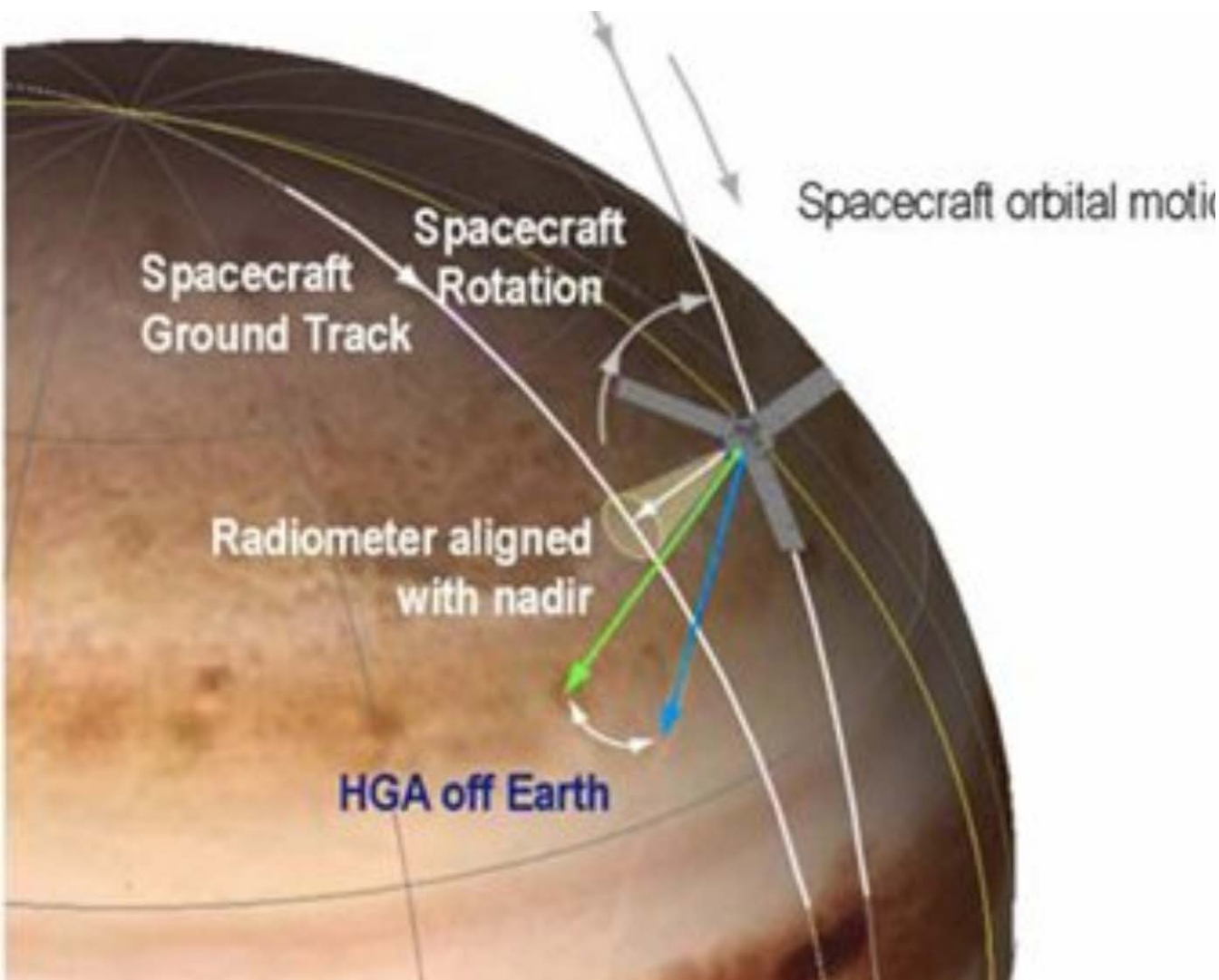


# What does Juno need in remote-sensing support?

- Contextual observations over the globe



# Track of MWR and JIRAM Sensing





# What does Juno need in remote-sensing support?

- Contextual observations over the globe
  - Are those narrow regions JIRAM, MWR sensing a part of wave structure
  - Are they representative of global-mean properties?



## **Junocam:**

**Has no scientific-grade calibration and will be taking images depending on the 'votes' of the general public.**

**This is good for the public, including amateur astronomers but not optimal for the science team, who would prefer imaging along the spacecraft track.**

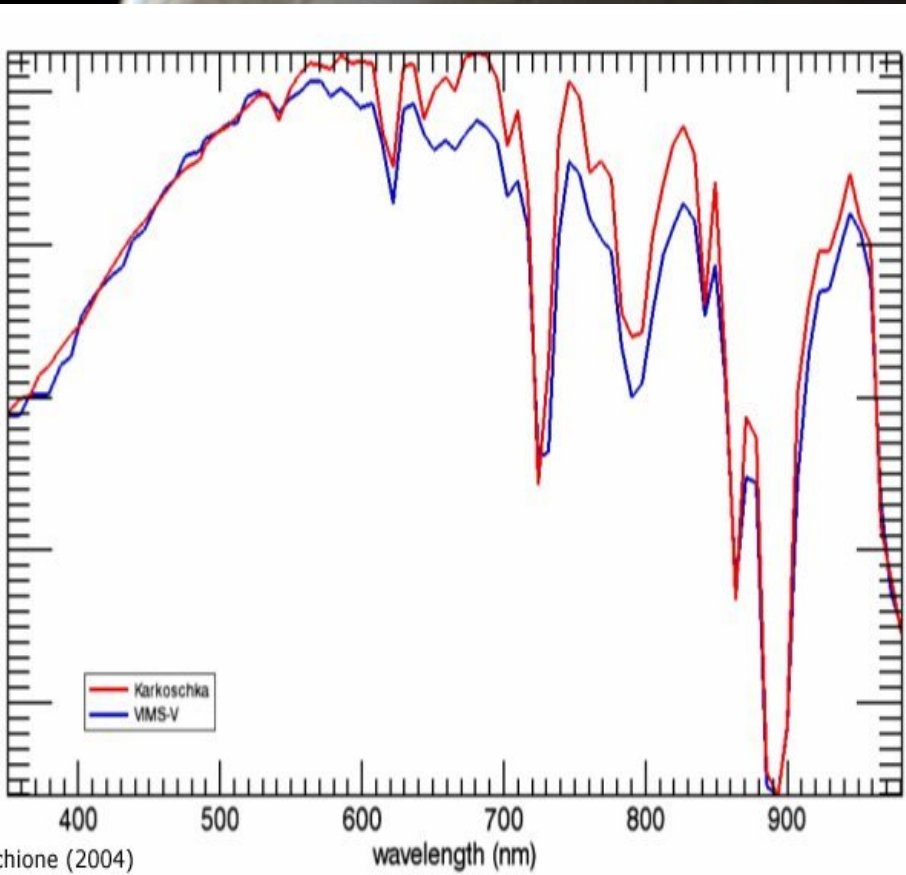
**This is a simulation of a Junocam image 72 hours before perijove.**



**Junocam has 4 filters:  
B ,G, R and 890-nm ('methane')**

**These sense what the human eye can see, but the G and R filters aren't particularly useful for understanding cloud structure because they sense sunlight reflected from clouds in and out of bands of gaseous methane.**

**The 890-nm filter will be more useful in this sense. But it would be good to resolve reflection spectrally in the various bands and the continuum between them.**



# What does Juno need in remote-sensing support?

- Contextual observations over the globe
  - Are those narrow regions JIRAM, MWR sensing a part of wave structure
  - Are they representative of global-mean properties
- Context in time
  - What has been the evolution of these features?
  - What is the relationship between the properties detected in the upper atmosphere and the deeper atmosphere?





# Example: Jupiter's "Faded" South Equatorial Belt



**2009:**

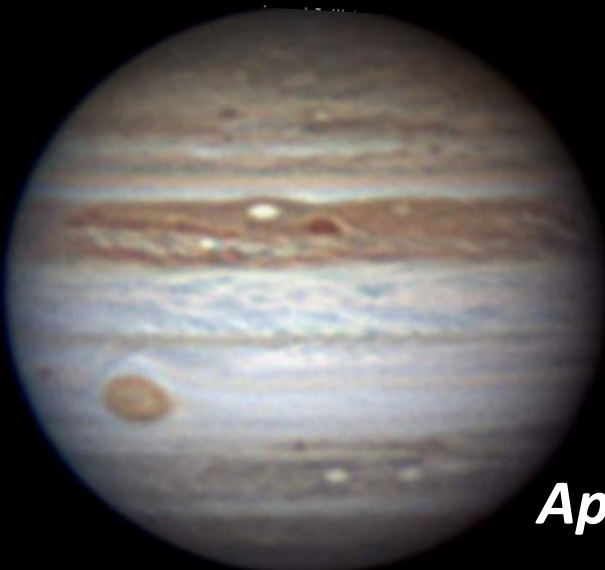
**July 23**



**October 20**

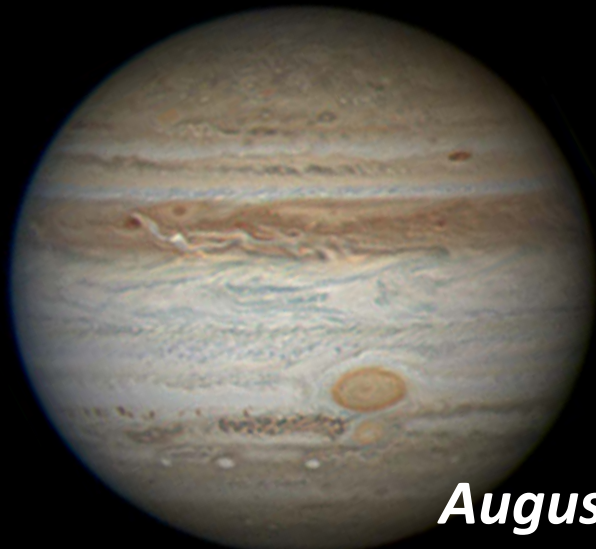


**November 7**



**2010:**

**April 19**



**August 30**

**A. Wesley images**



**Juno Project**



# Imaging of an SEB Fade – seeing through near-infrared eyes

**20 July 2009**

**6 August 2009**

**27 August 2009**

SEBn  
SEBs

GRS

**25 June 2010**

**5 September 2010**

*- SEB “fade” as early as mid-2009 in the deep atmosphere*

GRS →

GRS →

↑  
Oval BA

**IRTF/NSFCam2 imaging 2009-2010**



Juno Project





# Professional Ground-Based Support



- Prominent, consistent group: University of the Basque Country, Bilbao, Spain (Agustin Sanchez-Lavega, Ricardo Hueso, Santiago Perez-Hoyos)
  - Vigorous program of multi-filtered CCD imaging
  - Using “lucky imaging”, similar to amateurs
  - But retain photometric quality of data and multiple narrow-band images
- Recent contact by Caltech group working on AO imaging: Ten Milli-ArcSec (TMAS) project
  - Not working out
  - Try their Robo-AO group (Palomar 60”)
- Need to get ground-based multi-filtered CCD observations from a station that complements the Spanish one.
  - NMSU (Chanover and students)
  - Royal Thai Observatory (telescopes in Thailand, Chile and Australia)
  - U. Hawaii (2.4-m with CCD), but needs U. Hawaii PI
  - Hard to find suitable stations, not many professional astronomers do ground-based CCD narrow-band filtered photometric imaging any more





# Support Observation Plans

- **Funding secured from Planetary Astronomy (now Solar-System Observations) for Juno-supporting thermal observations of Jupiter through pre-arrival (late 2015). A separate proposal will be submitted for direct “real-time” supporting observations and subsequent evolution (2016-2018).**
- **A proposal was submitted to SSO to do high-resolution spectral mapping observations in the 5- $\mu$ m window to support JIRAM observations (Bjoraker)**
- **A proposal was submitted to SSO to cover reflected sunlight, including AO-processed images in CCD and near-IR range (Baines, Orton, Stallard, and Chanover)**
- **A proposal was submitted to SSO to cover auroral-related stratospheric heating using high-resolution mid-infrared spectral mapping (Orton, Greathouse, *et al.* using TEXES)**





## Hubble Space Telescope support?

- Space-Telescope Science Institute-generated inquiry
- Why is there so little “proposal pressure” from the solar-system astronomical community
- Orton involved with ad hoc steering group, headed by Phil. Nicholson
- Possibility of mounting a Juno-support campaign
- Jupiter-observing proposals submitted for Cycle 22 (starting in the fall of 2014)
  - One accepted: Target of Opportunity if something again collides with Jupiter
  - Do we want additional pressure from the Juno mission?
  - Not just visible, but UV imaging and spectroscopy





“Amateur” observers continue to do astounding work



Juno Project



# “Amateur” observers continue to do astounding work



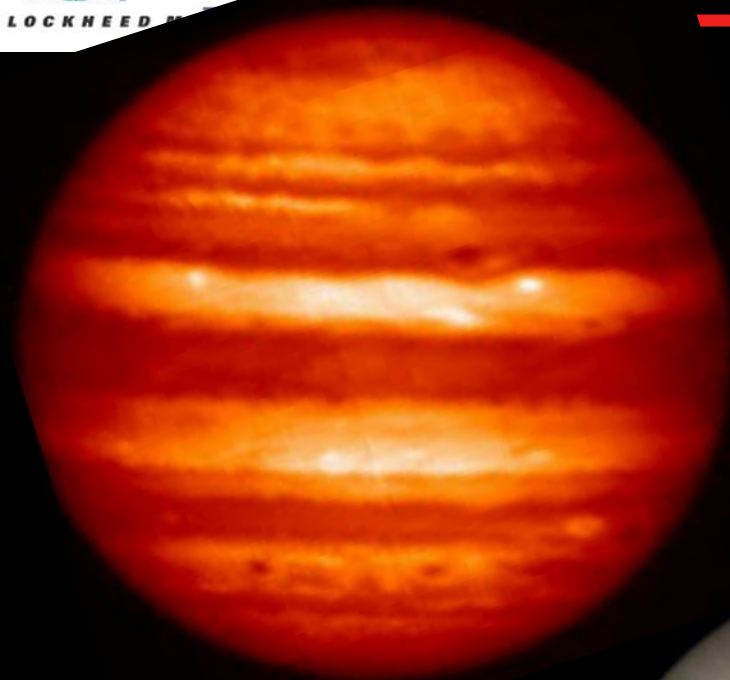
Damian Peach: Surrey, UK 14” backyard telescope



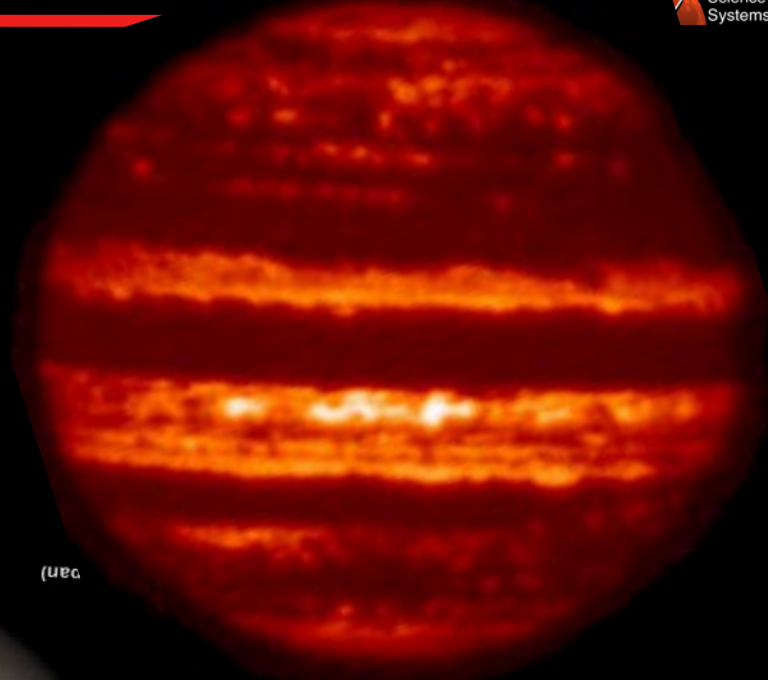


LOCKHEED MARTIN

# Example of contemporaneous multi-platform amateur and professional observations



2012 Aug 27, 8.6  $\mu\text{m}$   
Subaru, COMICS



2012 Aug 29, 4.8  $\mu\text{m}$   
IRTF, NSFCam2



2012 Aug 28, visible  
A. Kazemoto, Kyoto



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# Gemini North/NIRI

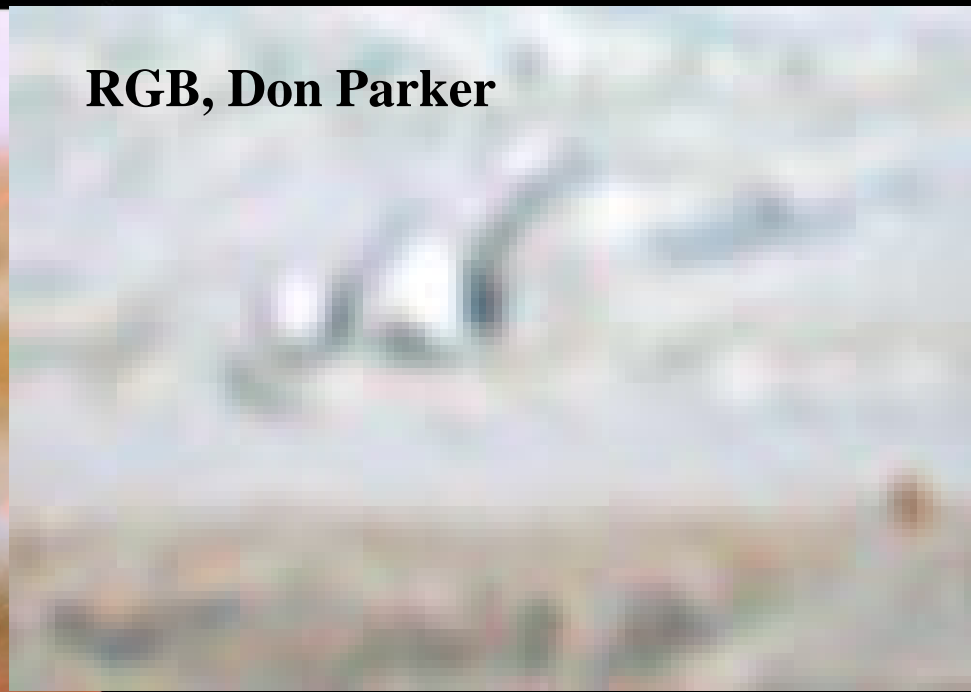
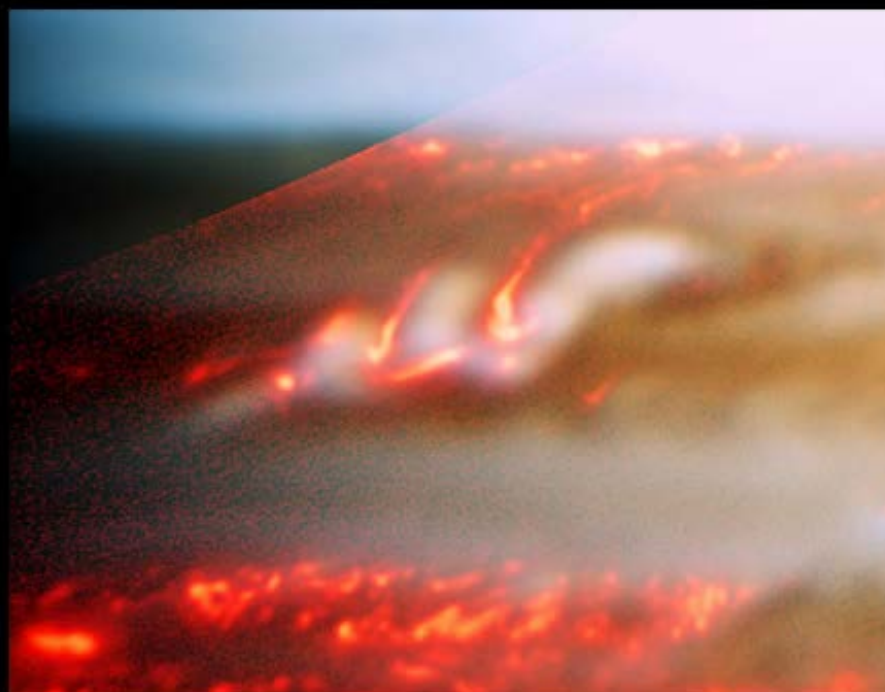
18 Nov 2010

2.12  $\mu\text{m}$

1.69  $\mu\text{m}$

4.68  $\mu\text{m}$

Another example, ~~coordinated~~ observations of a series of alternating upwelling (cloudy) and downwelling (clear) regions in the SEB 'revival' (re-darkening)



RGB, Don Parker



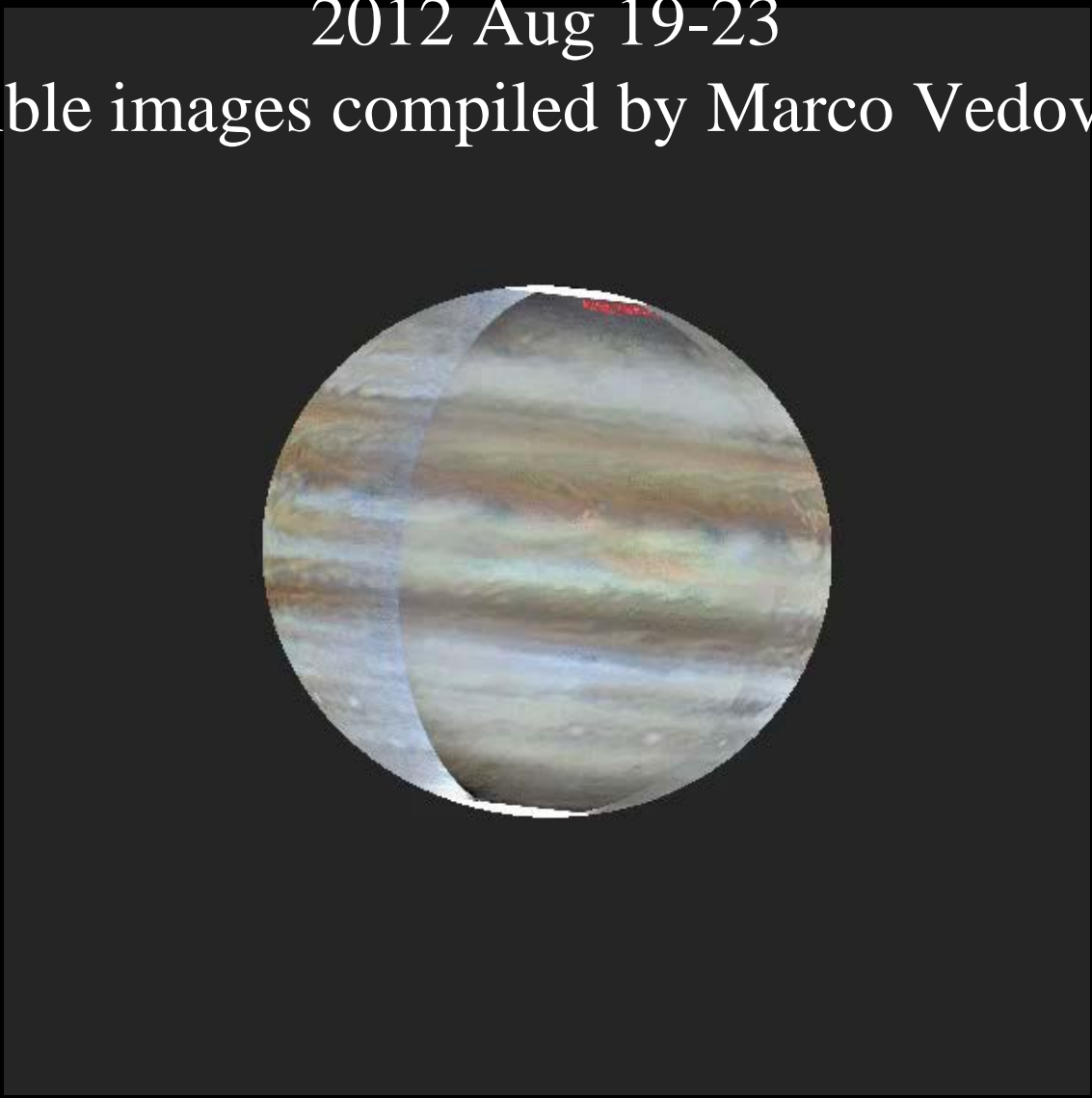
# Example of Professional-Amateur



## Comparisons:

2012 Aug 19-23

(visible images compiled by Marco Vedovato)



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# Wayne Jaeschke: full-daylight observation: 2013 April 9





# Amateur Involvement

- “Serious” amateur interest group, headed by Chris Go, Cebu City, Philippines





# Amateur Involvement

- “Serious” amateur interest group, headed by Chris Go, Cebu City, Philippines
- VPOL is best base of ground-based observations from the amateur community, curated by Univ. del Pais Vasco (Hueso, Sanchez-Lavega, Perez-Hoyos)
- We will need to triage input, most likely
- Convert jpeg, etc. to format that might retain some of the original photometric quality (automatic conversion) – see Bilbao group for their approach.





# Repositories of Amateur Observations



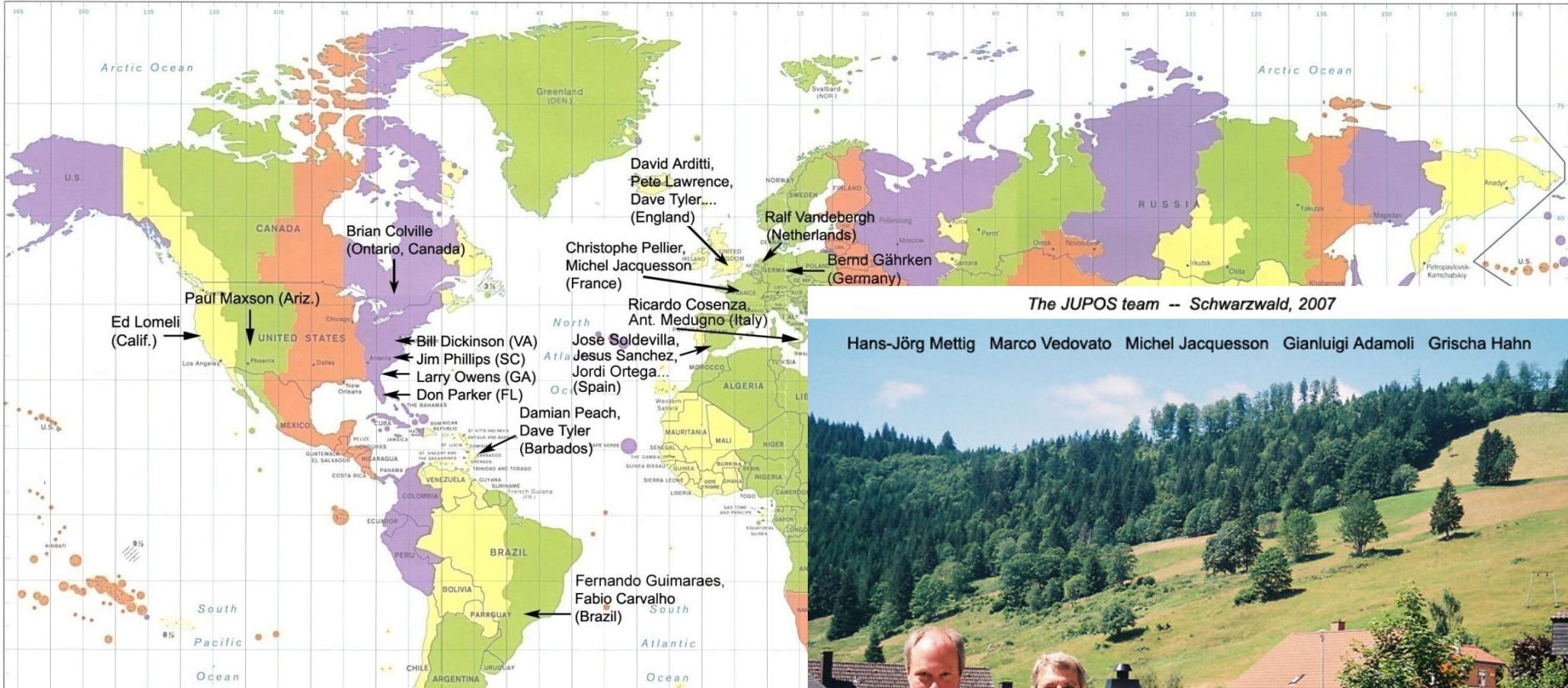
- **Planetary Virtual Observatory Laboratory**
- **British Astronomical Society, Jupiter section**, with narrative summaries supplied by John Rogers on a regular basis
- **Facebook groups:**
  - **Astronomy Planetary Imaging** (Freddy Willems)
  - **JPL\_SSI** (new group formed recently by Padma Yanamandra-Fisher) -





# Broader list of Jupiter observers around the world.

Standard Time Zones of the World



Stuart Stephens

# “Voyager 3”

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Lockheed Martin **astronautics**



**Bottleneck: a single person on Juno is responsible for coordination of science results and Earth-based support observations:**



**Juno Project**



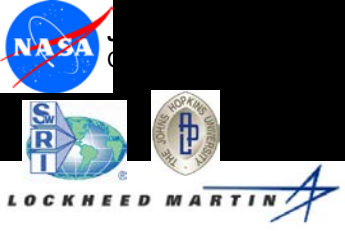


# astronomy **CS**

**Bottleneck: a single person on Juno is responsible for coordination of science results and Earth-based support observations:**

**Juno**  
**Glenn Orton**

Astronomy Planetary Imaging    About    Events    Photos    Files    Notifications



**So we have a lot to figure out and time is growing short. But I'm not discouraged.**

**One year before the Juno launch, when things didn't seem to be going on schedule, and people on the Juno project were getting worried, there appeared an invitation to the One-Year-To-Launch Party – to pick people's spirits up:**





# IF EVERYTHING SEEMS UNDER CONTROL -





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



**Juno Project**



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

**-Mario Andretti**



**Juno Project**

