# Determining the depth of the Great Red Spot with Juno gravity measurements

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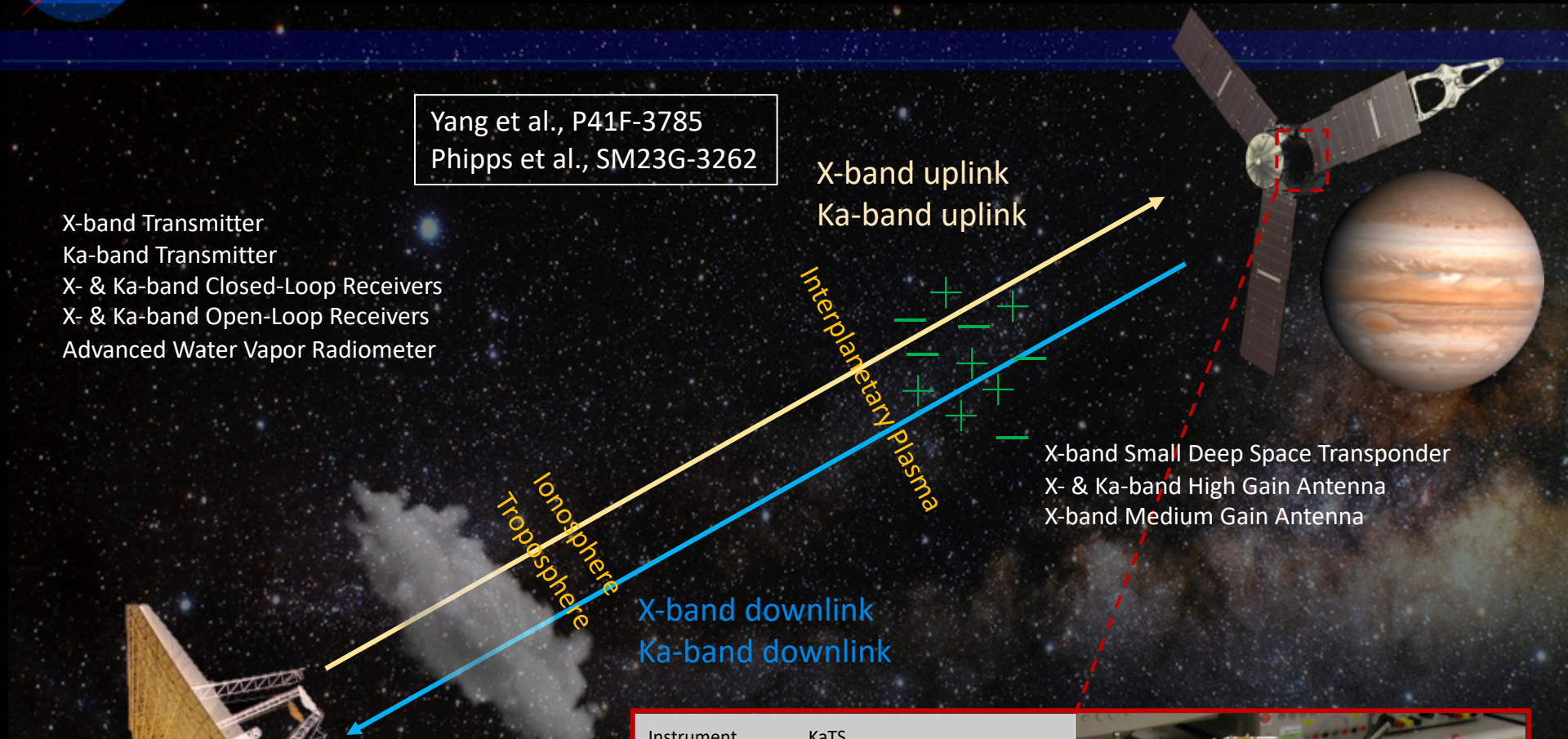
# Juno Gravity Science Instrument

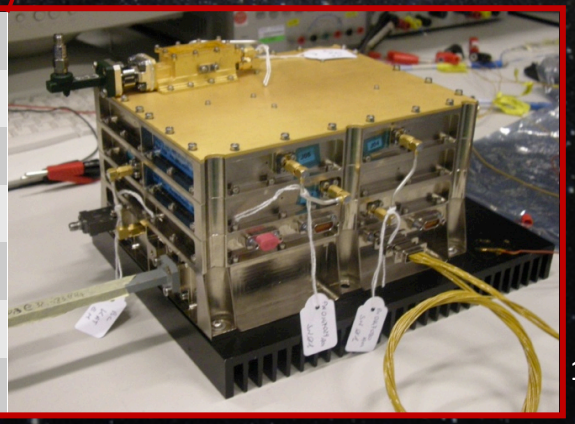
Yang et al., P41F-3785
Phipps et al., SM23G-3262

X-band Transmitter
Ka-band Transmitter
X- & Ka-band Closed-Loop Receivers
X- & Ka-band Open-Loop Receivers
Advanced Water Vapor Radiometer

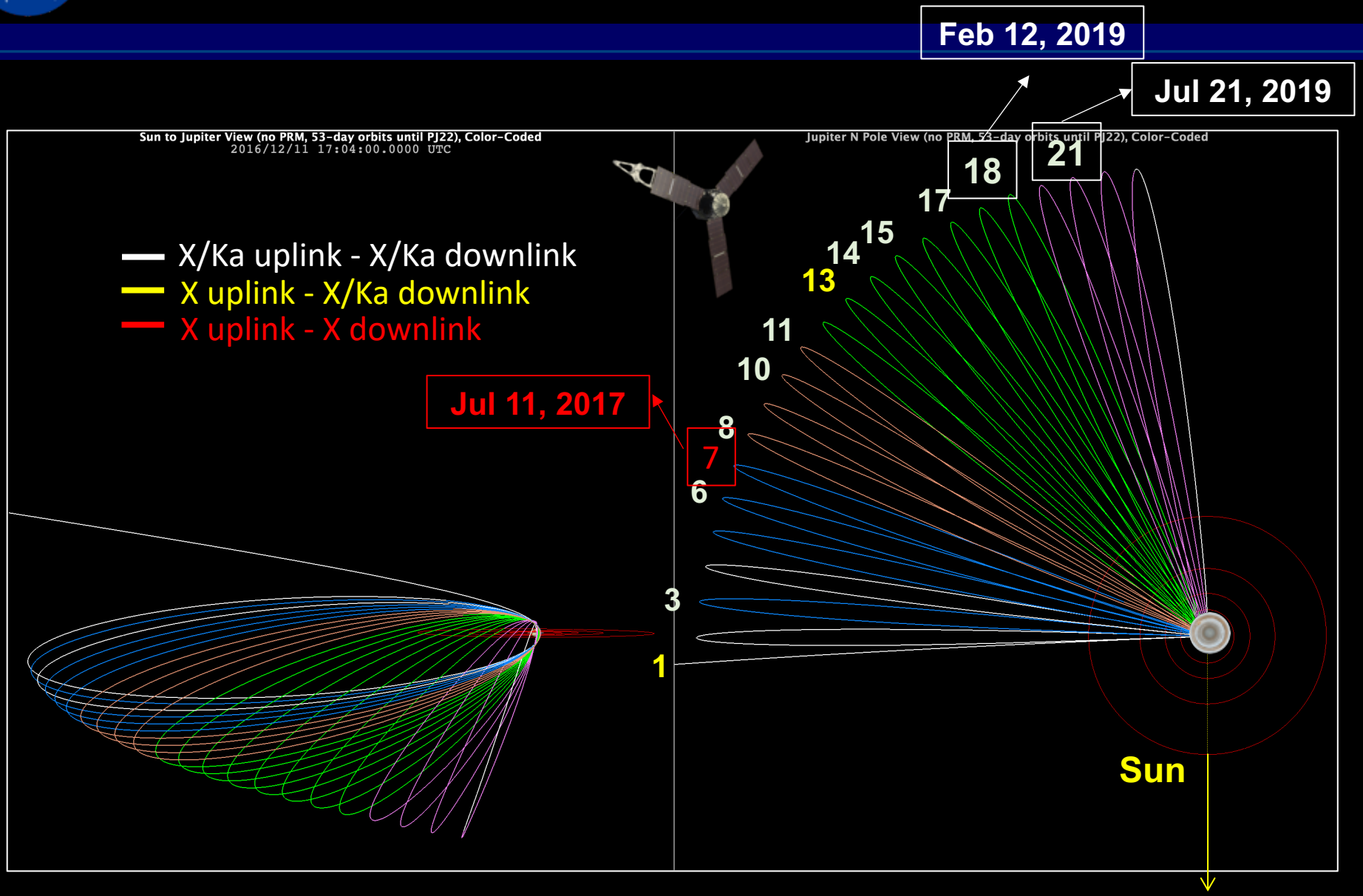



X-band Small Deep Space Transponder
X- & Ka-band High Gain Antenna
X-band Medium Gain Antenna

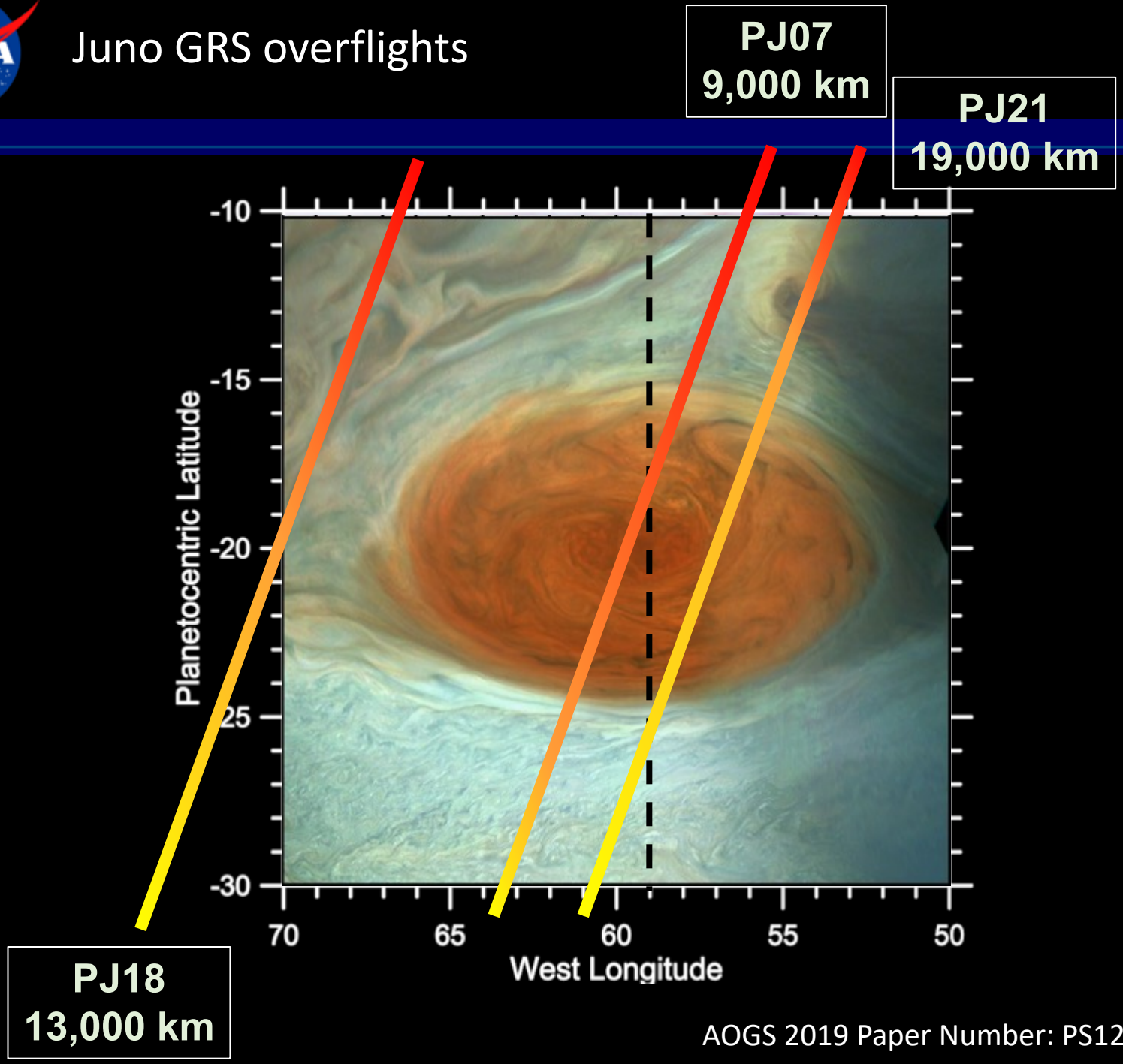
| | |
|---|---|
| Instrument | KaTS |
| Manufacturer | Thales Alenia Space - Italy |
| Allan Deviation | $4 \times 10^{-16}$ @ 1000s |
| Observables | 2-way Doppler |
| Link | Ka/Ka (34Ghz up / 32.5 GHz dn) |
| Tracking Station | DSS25 34m BWG – Goldstone |
| Allan Deviation | $< 10^{-14}$ @ 1000s end to end |



# Juno gravity orbits Aug 2016 – Jul 2019



# Juno GRS overflights

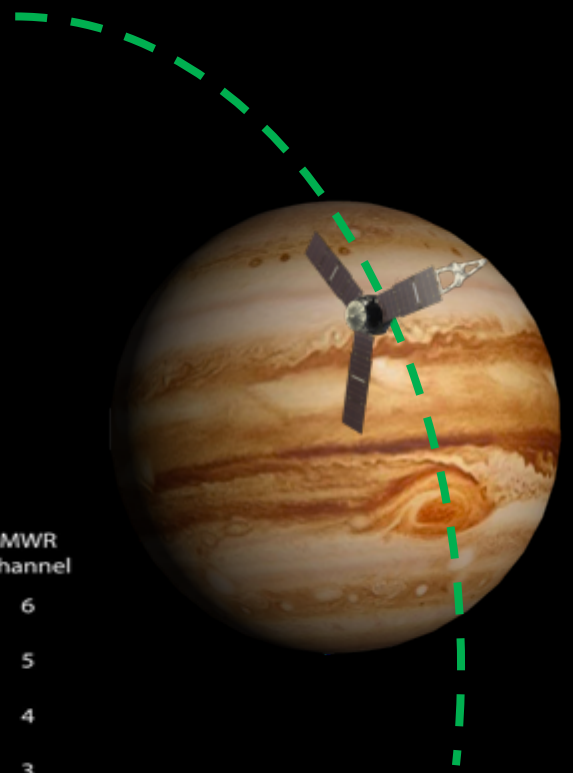


# PJ07 – MicroWave Radiometer observations

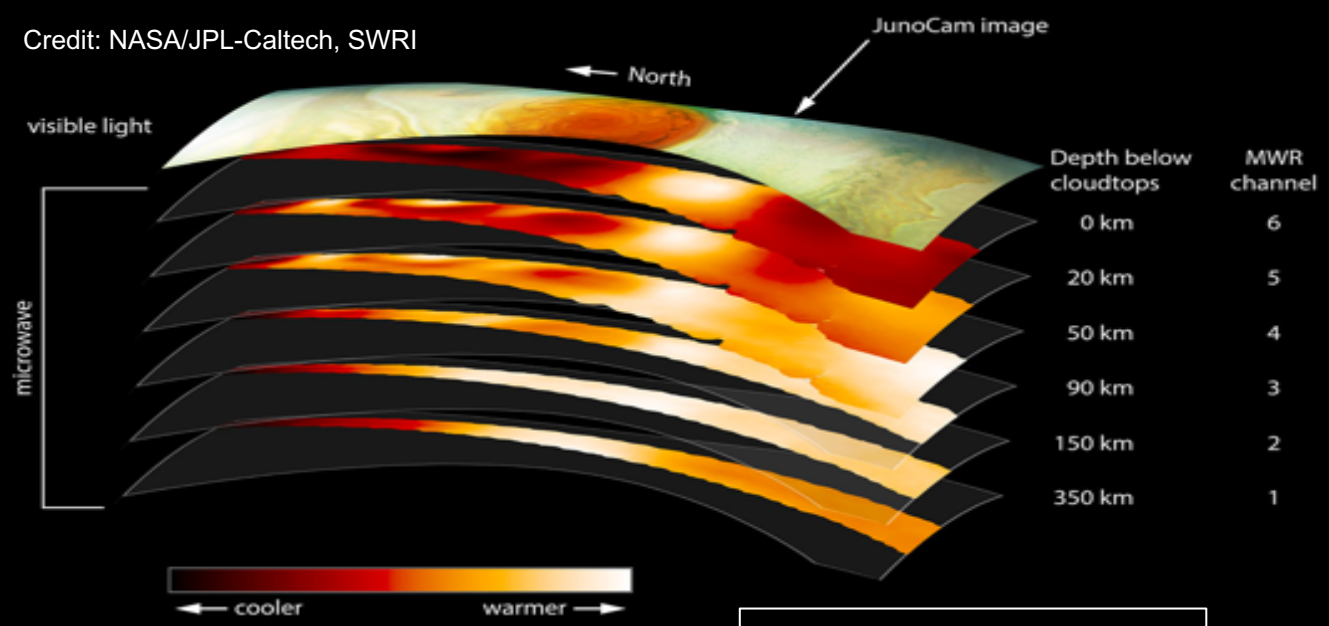
The GRS overflight during PJ07 occurred in July 2017. The spacecraft attitude was optimized for MWR observations.

What it means for gravity science:

- X-band data only on MGA
- No dual-frequency calibrations for the Io plasma torus
- ~ 9,000km altitude

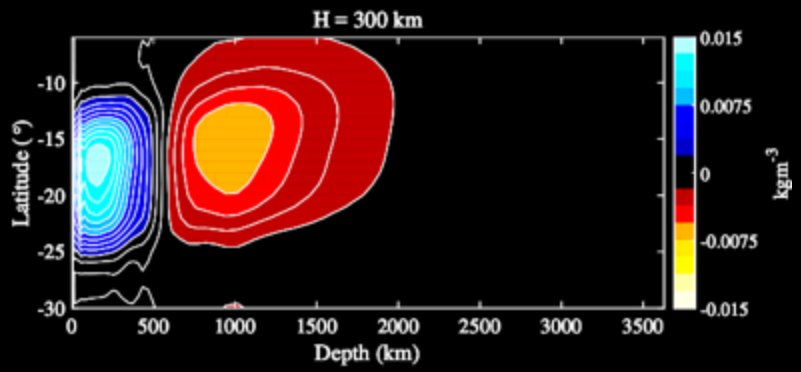


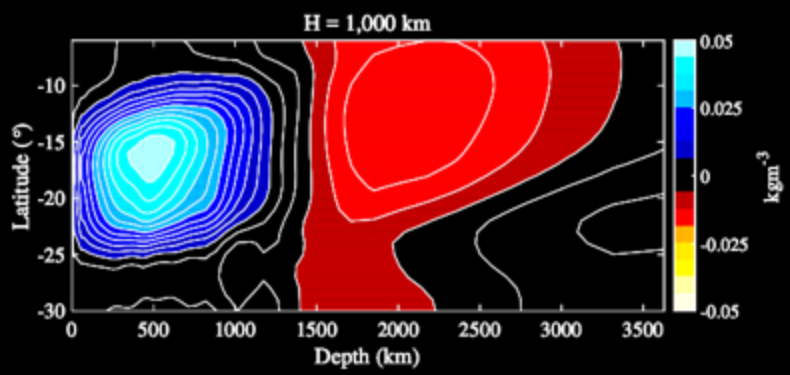
Credit: NASA/JPL-Caltech, SWRI

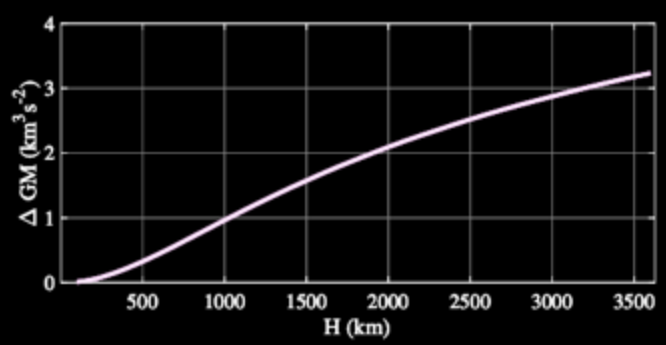



Cheng Li, July 2017

# Thermal wind balance and the GRS



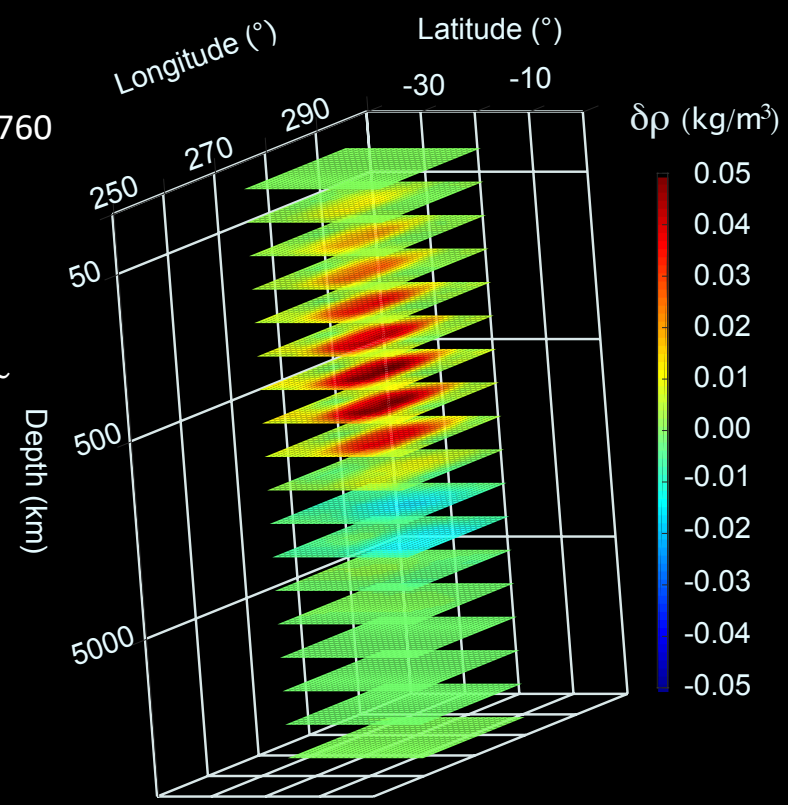

## H = 300km

- Mascon GM ~ 0.126 $km^3/s^2$
- Vertical separation ~ 760 km

## H = 1,000km

- Mascon GM ~ 0.965 $km^3/s^2$
- Vertical separation ~ 1,650 km

Relationship between scale height and mass anomaly

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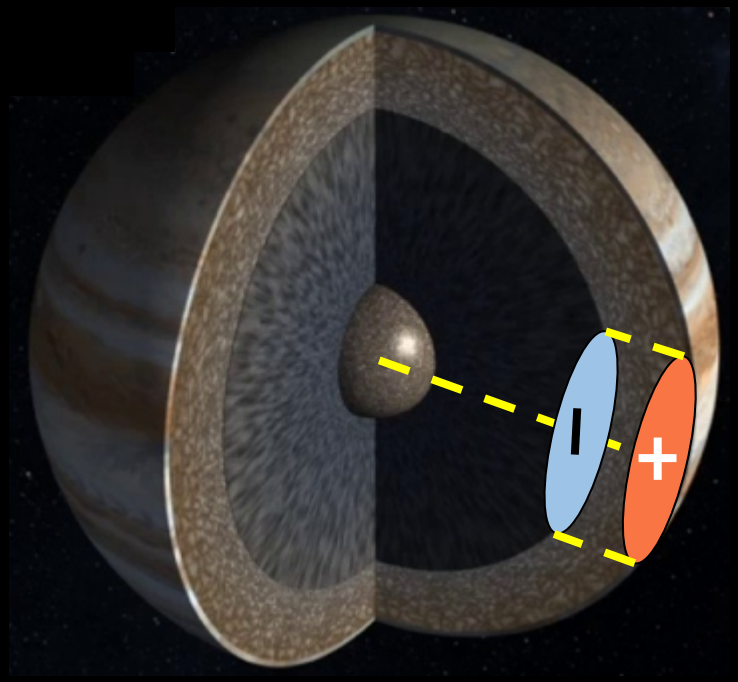
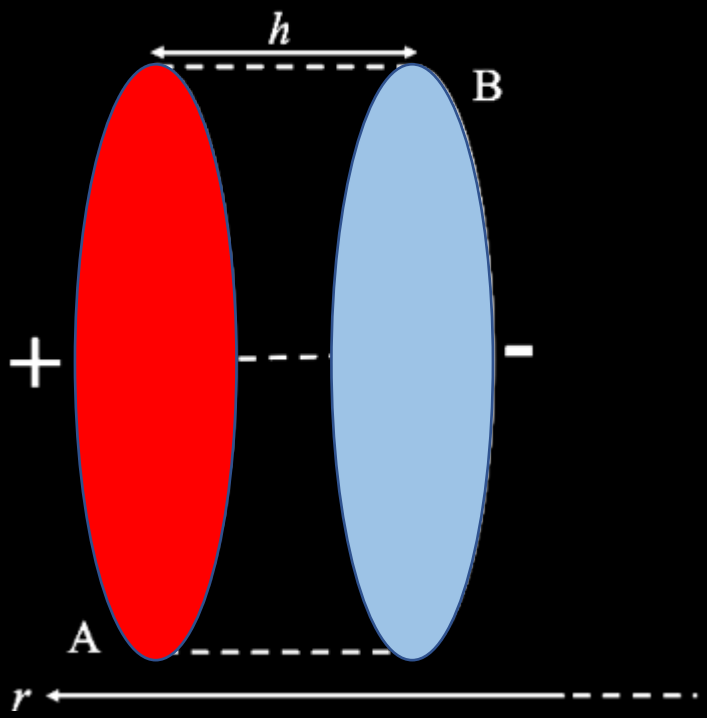
From Parisi et al., 2019, in review

# Method 1: Concentrated mass model for the Great Red Spot

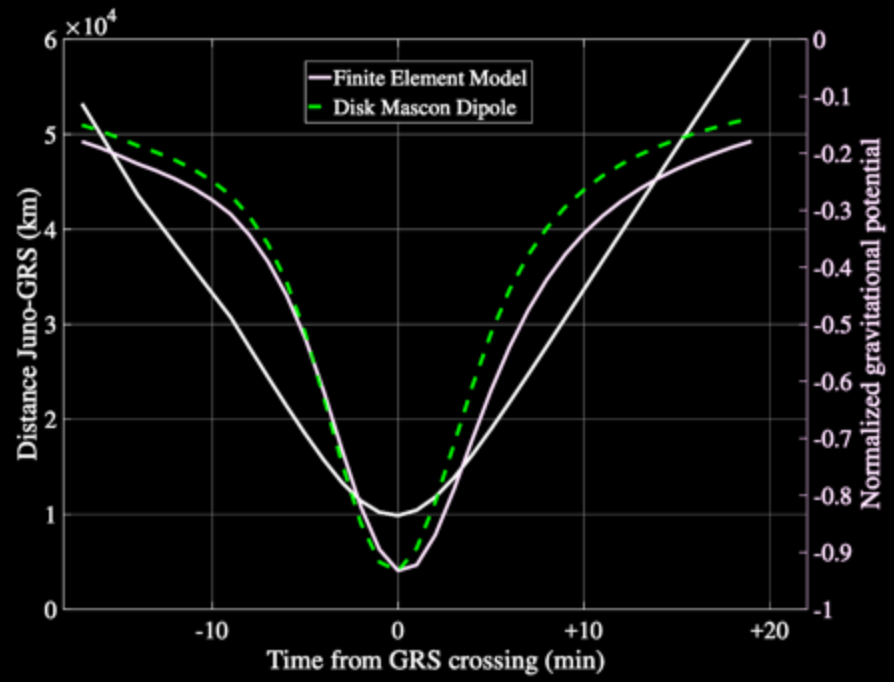
- One model used for the detection of the GRS depth consists of two thin circular flat disk mascons at different depth
  - With equal masses of opposite sign
  - Center of mascons at the GRS latitude and longitude
  - Radius of 8,000 km equal to longitudinal radius of GRS
  - Estimated mass varies depending on GRS depth




From Parisi et al., 2019, in review

# Method 1: The approximation of the gravitational potential




| | GRS Perijove | Altitude ($km$) | $\sigma_{GM}$ ($km^3s^{-2}$) | | $\sigma_{GM}^{rel}$ (%) | | $\epsilon_{GM}$ ($km^3s^{-2}$) | | $\sigma_H$ ($km$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | H | | H | | H | | H | |
| | | | 300km | 1,000km | 300km | 1,000km | 300km | 1,000km | 300km | 1,000km |
| COV | PJ18 | 13,000 | 0.075 | 0.050 | 59.5 | 5.2 | 0.064 | 0.077 | 105 | 40 |
| | PJ18 & PJ21 | 13,000 & 19,000 | 0.054 | 0.037 | 42.9 | 3.8 | 0.004 | 0.074 | 70 | 30 |
| REC | PJ18 | 13,000 | 0.090 | 0.052 | 71.4 | 5.4 | 0.114 | 0.026 | 135 | 45 |
| | PJ18 & PJ21 | 13,000 & 19,000 | 0.057 | 0.034 | 45.2 | 3.5 | 0.030 | 0.133 | 75 | 35 |



From Parisi et al., 2019, in review

# Method 2: The Slepian approach

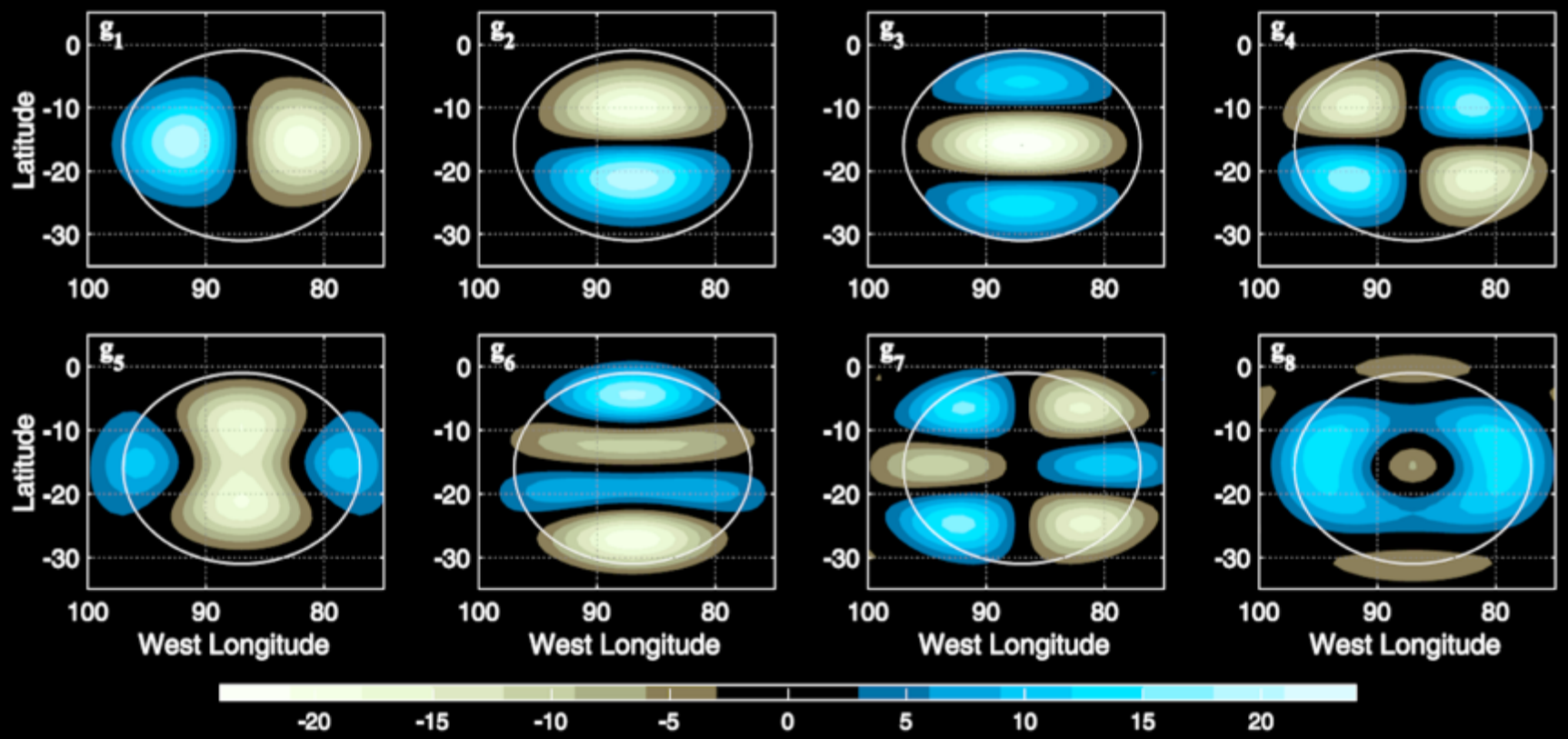
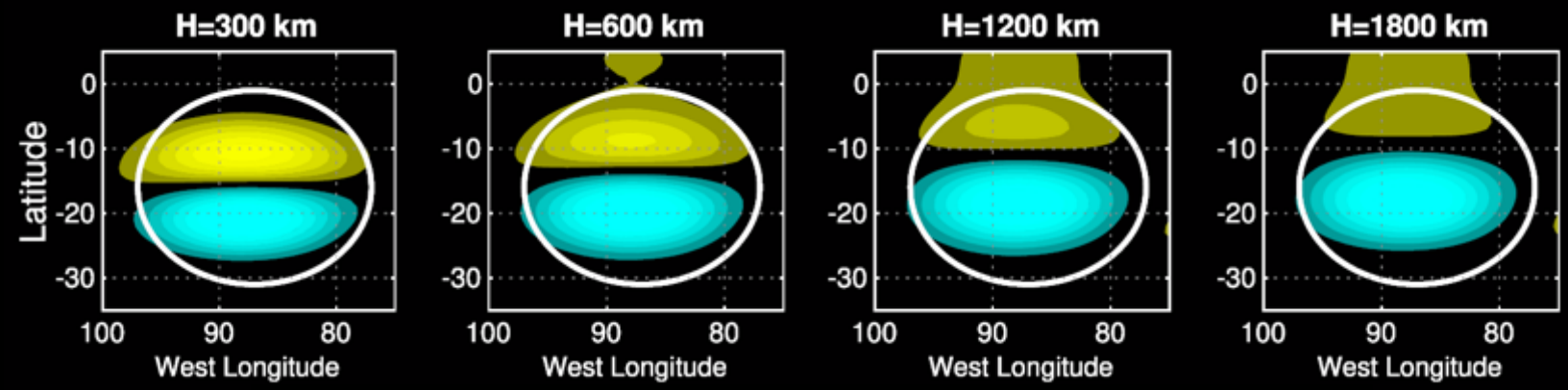
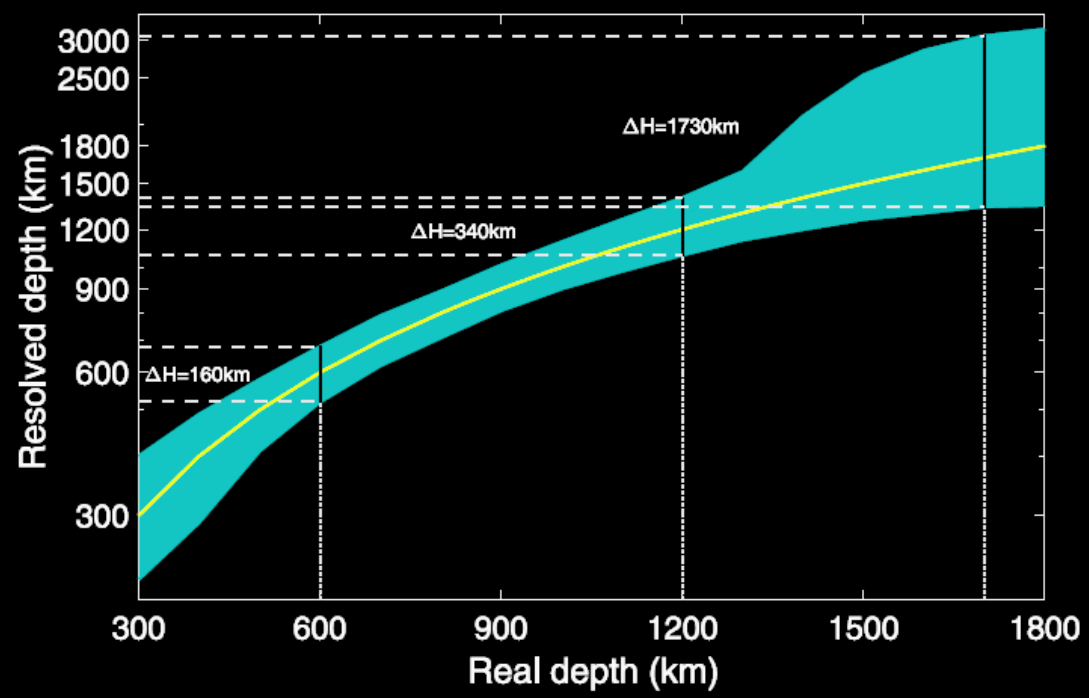



**Figure 2.** First eight Slepian functions ($g_1 - g_8$) defined for the region of the GRS (marked by the black ellipse).

From Galanti et al., 2019, ApJL

# Method 2: The Slepian approach

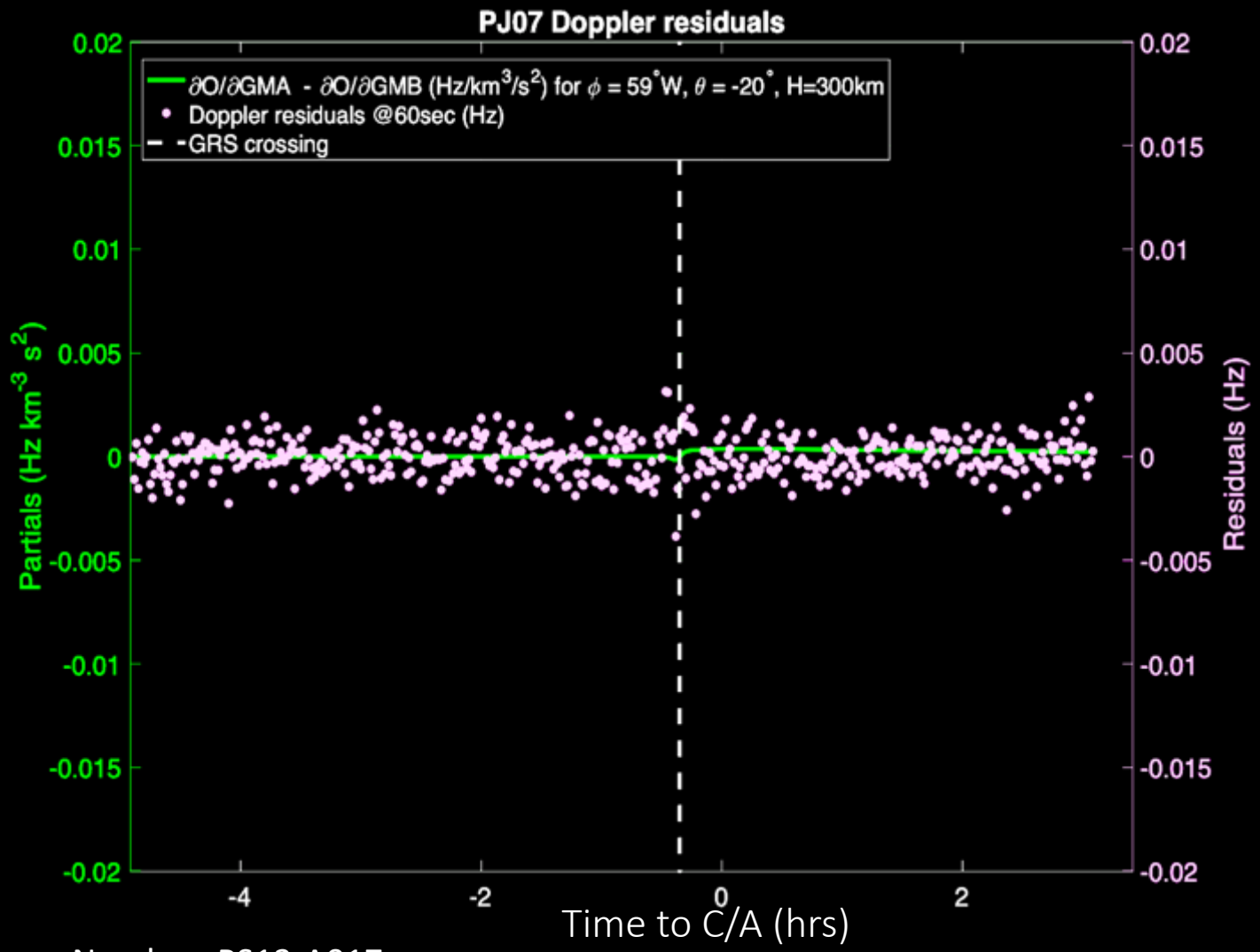



 From Galanti et al., 2019, ApJL

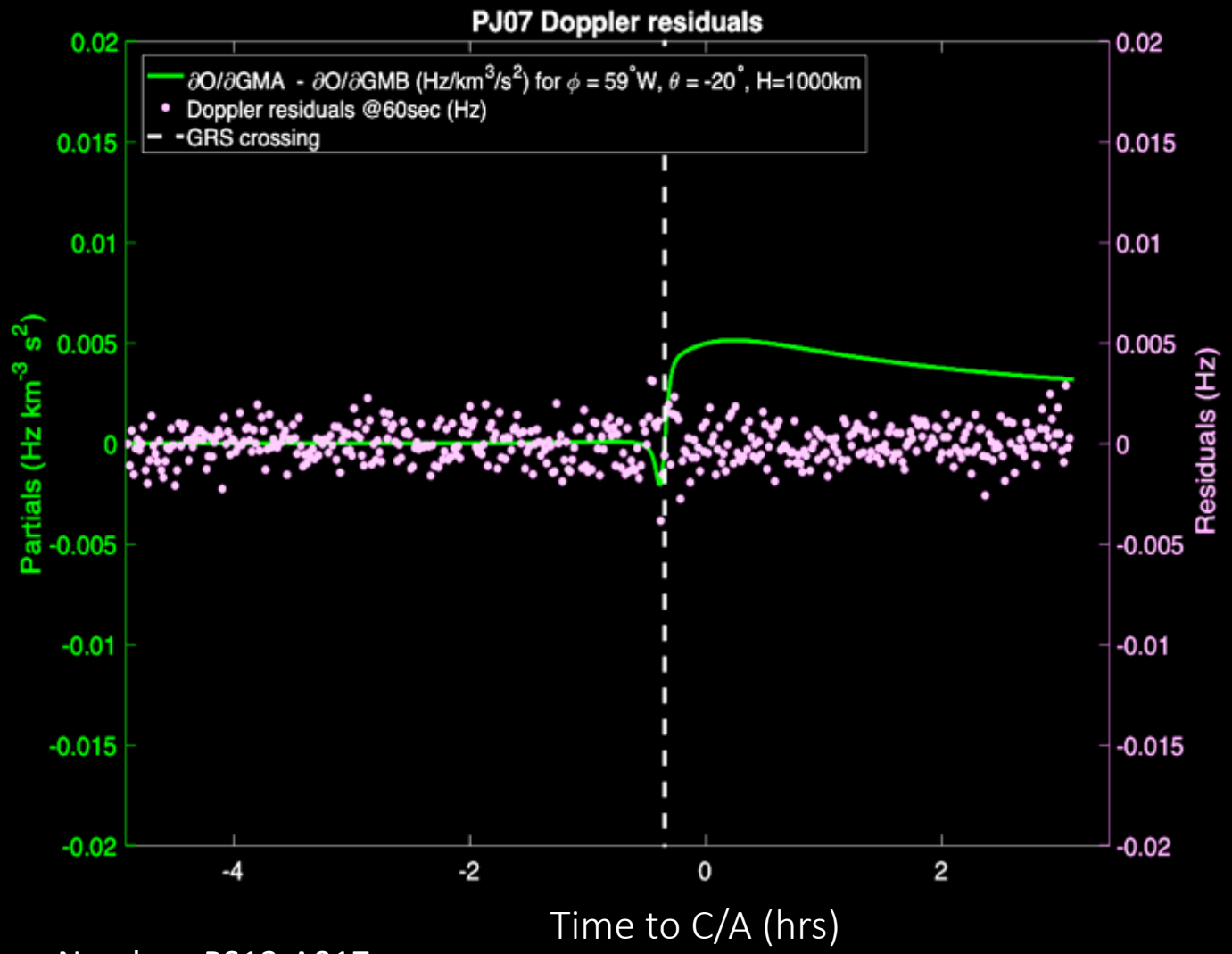
# Results from PJ07 (1)

PJ07 Doppler residuals versus GRS signature, for H = 300 km



# Results from PJ07 (2)

PJ07 Doppler residuals versus GRS signature, for H = 1,000 km



# Conclusions

- The gravity signature of the GRS is subtle and very precise measurements of the Jupiter gravity field are necessary for its detection
- We developed two methods for estimating the depth of the Great Red Spot: one looks at the mass anomalies, one looks at the gravity anomalies
- PJ07 data suggest that the GRS is no deeper than 1,000 km, consistent with MWR results
- PJ18 and PJ21 will be combined to confirm PJ07 results