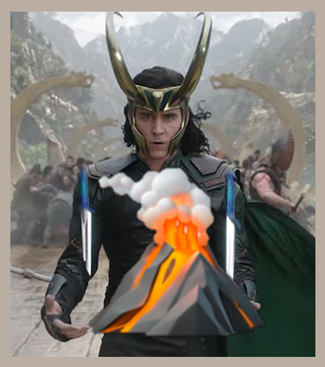

Io's Loki Volcano: An Explanation of Its Tricky Behavior and Prediction for the Next Eruption

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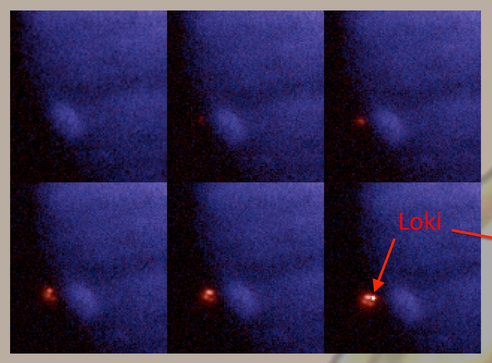
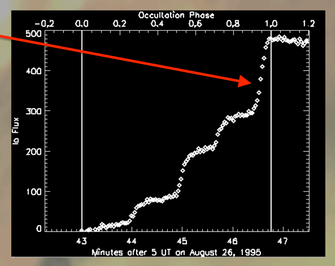
Loki

- Powerful, Large (200 km across), active since Voyager
  - When active, accounts for >15% of Io's total heat flow
  - Brightest volcano on Io, easily observed in ground-based observations
  - Observations from Hawaii's IRTF



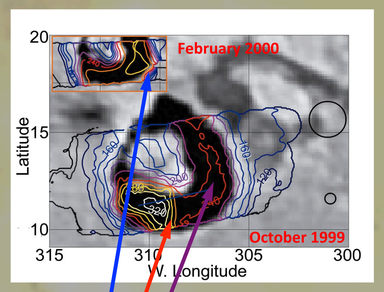


Occultation lightcurves

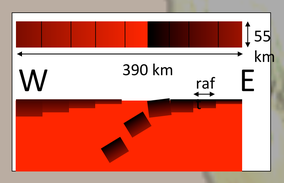
1. Used to measure Loki brightness in Rathbun/Spencer program
2. For each image, total brightness of Io becomes one point on curve
3. Each step in curve represents at least one volcano
4. Timing gives volcano location
5. Height gives volcano brightness

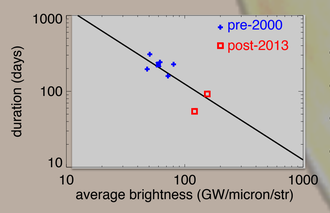
Propagating overturn wave caught in the act!

- Galileo PPR temperature measurements
- According to the ground-based data, the earlier brightening ended ~1/99, the later brightening began ~9/99
- Lava temperatures and ages consistent with ground-based eruption start times



Temperature	Approximate age
290 K	100 days
330 K	45 days
250K	300 days





Lava lake overturn model

(Rathbun and Spencer, 2006)

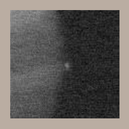
- Assume simple rectangular lava lake
- Every day, some length of surface overturns
- Length determined by velocity of propagating overturn front
- Age calculated as function of time & length
- Age → temperature → blackbody brightness
- Brightness = f(velocity)
- While observed durations and brightnesses all fit the model line, more recent eruptions (red) in substantially different location

Porosity changes (Rathbun et al., 2002)

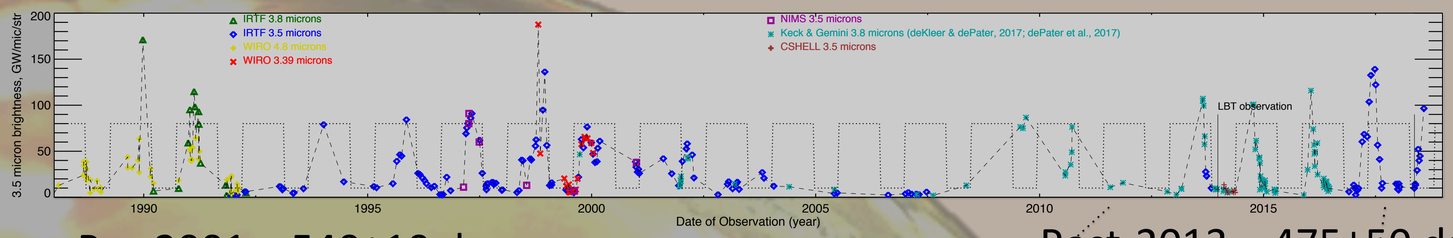
- In Hawaiian lava lakes, porosity decreases nearly exponentially with depth.
- As crust cools and thickens, less porous material is added, increasing density until crust becomes gravitationally unstable and sinks.
- At 540 days, the crust is less than a meter thicker than it is at 475 days.
- A small change in porosity of the lava could account for the small difference in thickness required for the crust to sink.

What can groundbased data do for you?

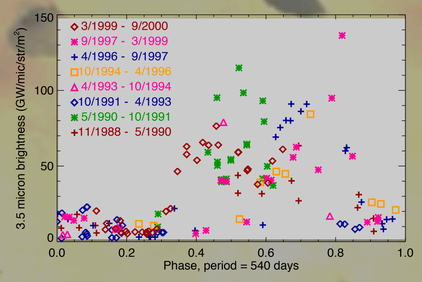
- Best data set to study temporal variability
- Detect bright outbursts
- Put spacecraft data in context
- We're currently working to put all our data on the PDS:
- ASCII tables with the data from occultation lightcurves – one for each night, along with PDS label information
- Software tools



Loki Brightnesses



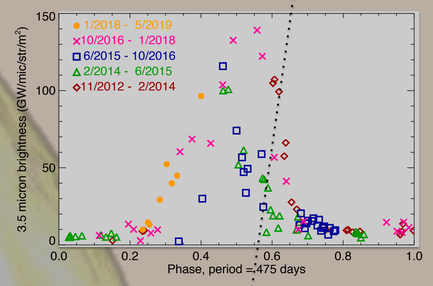
Pre-2001 – 540±10 days



Periodic Behavior

- Use Phase Dispersion minimization to determine periodicity
- 2001-2012: no discernable periodicity , but fewer observations

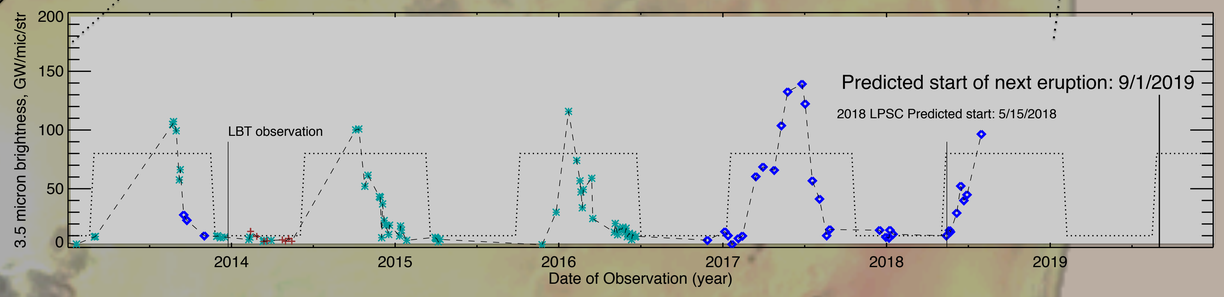
Post-2013 – 475±50 days



Prediction for next eruption

- At 2018 LPSC, predicted the next eruption in May, actual eruption began ~ May 15, 2018
- Based on the observed 470 day period, we predict the next eruption will begin **August/September 2019**

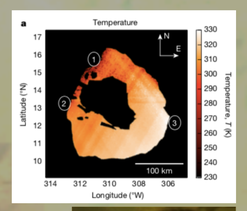
What's Loki doing lately?



LBT observations

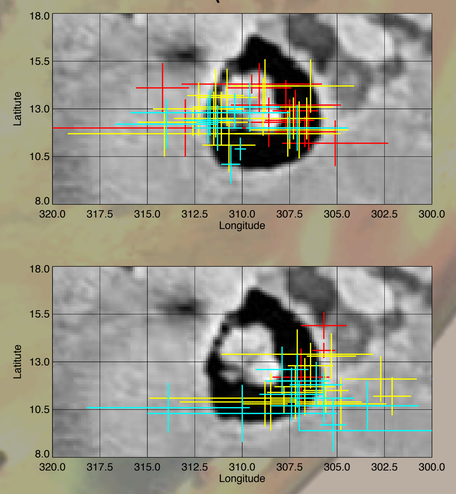
(Conrad et al., 2015 and deKleer et al., 2017)

- Obtained ~80 & 50 days after the end of a brightening
- Model predicts brightness of 160 GW/µm/str during the brightening and ~25 GW/µm/str 80-days after end
- Measured 4.6 µm brightness = 57.5 GW/µm/str
- Average 3.5 µm brightness measured ~10 GW/µm/str
- Consistent with ~0.5% cracks in surface with temperature > 500K



Hot spot locations

(from deKleer and dePater, 2017)



- Top panel shows locations between brightening events
- Red = just after event ends
- Teal = just before next event starts
- Bottom panel shows locations during a brightening event
- Red = first half of brightening
- Yellow = 3rd quarter
- Teal = last quarter

Conclusions

- Loki is again erupting periodically, but period changed from 540 to 470 days.
- The brightenings have a shorter duration & larger average brightness, consistent with a change in porosity in our model.
- We predict the next eruption (8-9/19), but predictions are dangerous when your volcano is named after a trickster God

Outstanding questions

- Why did Loki's period change? Why did the porosity of the lava change?
- Have the overturns changed direction (suggested by deKleer and dePater, 2017)? - No high resolution observations, only 3 positions measured in first ½ of brightening events.
- Could an influx of fresh magma into the lake explain change in direction & porosity?
- What is happening between brightening events? LBT observations suggest multiple bright regions, how does that affect locations from Keck/Gemini?