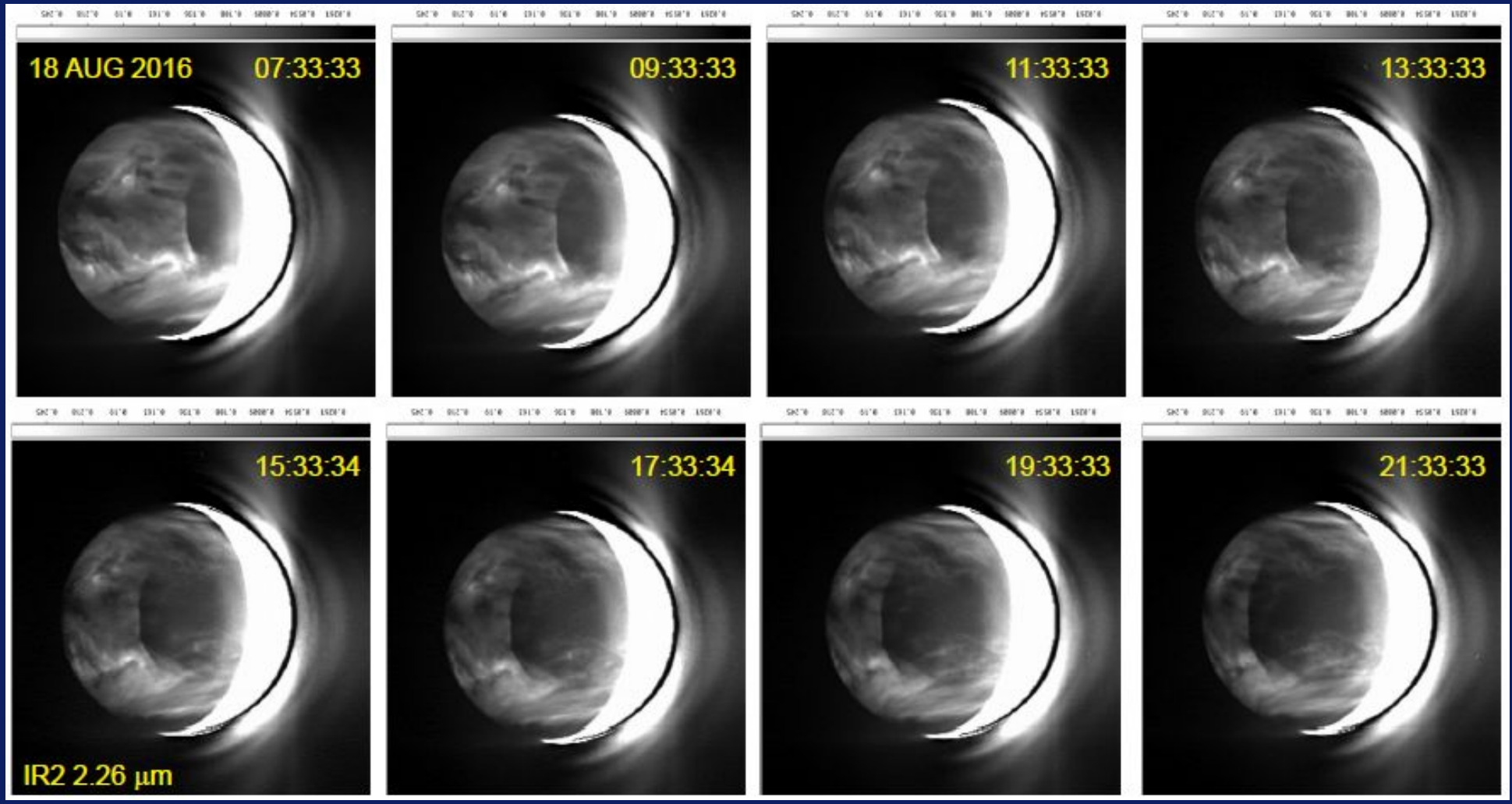
Enormous cloud cover as seen by Akatsuki/IR2 on the night-side disk of Venus



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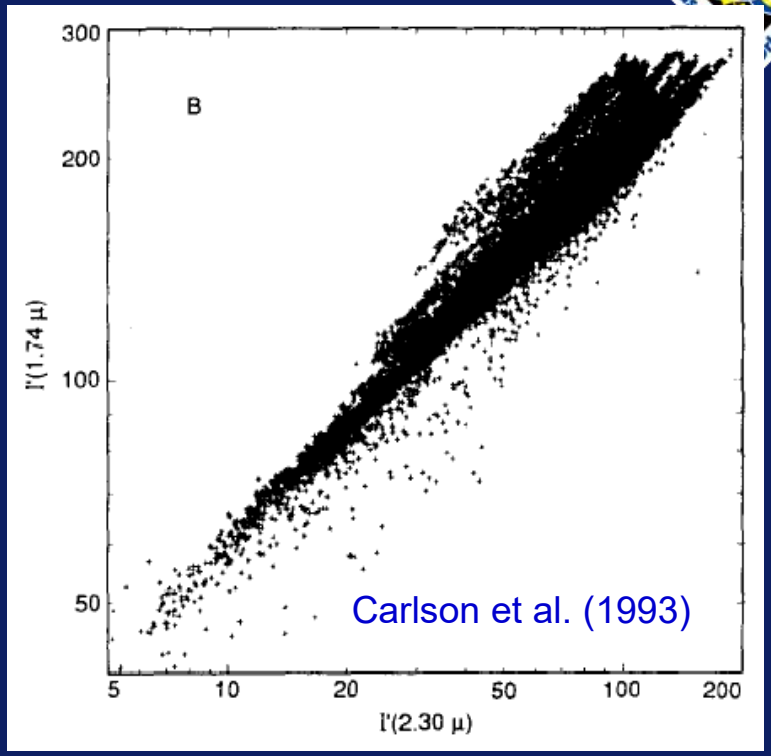
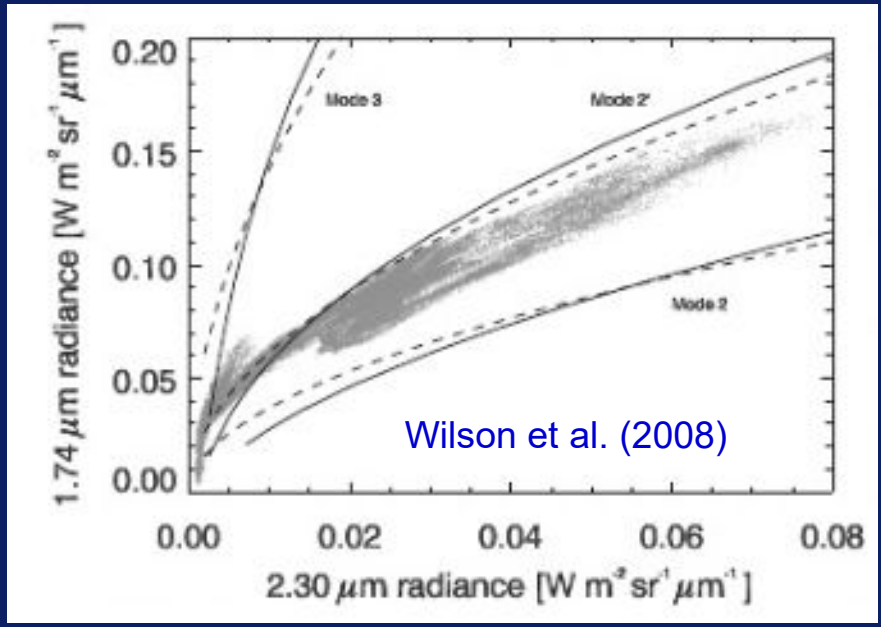
Introduction: Night-side clouds

- Combination of 2.26-μm & 1.735-μm Akatsuki/IR2 images of Venus' night-side disk can be used to diagnose the cloud particle size. Carlson et al. (1993) demonstrated this from Galileo/NIMS flyby data acquired in January 1990.
- NIMS data, as plotted in radiance (2.3 μm) vs. radiance (1.74 μm) plane, exhibit obvious "branching" which are interpreted as regions of different particle sizes (figure on the right). Venus Express/VIRTIS data were also used for similar study (Wilson et al., 2008).
- However, it has been difficult to extract such "branching" from IR2 2.26/1.735-μm pairs. This problem needs to be solved before the analysis with radiative transfer model (RTM) starts.
- In this paper, we show (for the first time) clear "branching" in IR2 data (though preliminary) and discuss its implication.

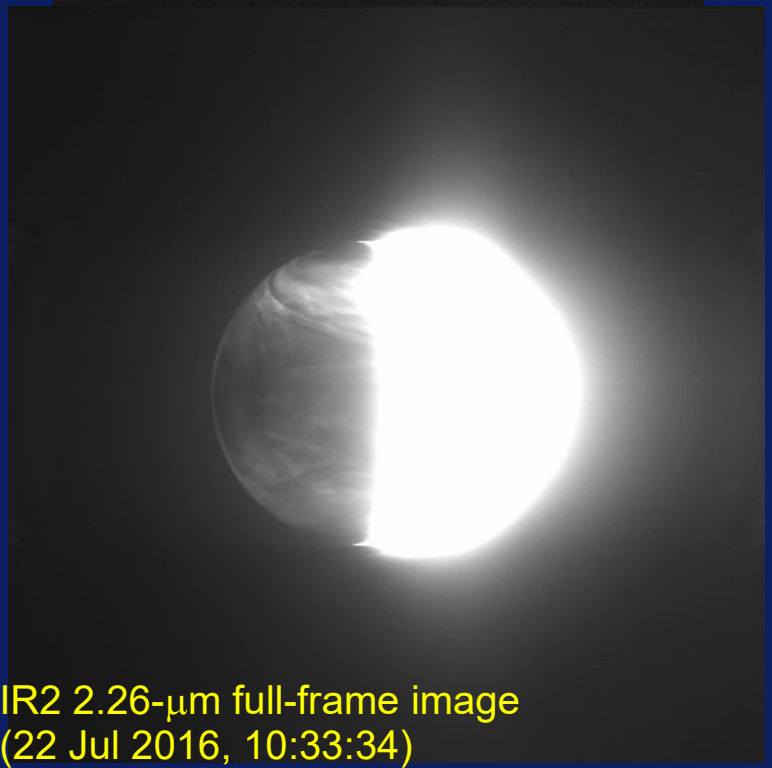




Reasons of no “branching” in IR2 data

1. Contamination from the day-side:
   This was found soon after the night-side imaging started in Venus orbit. Extended tail of the point-spread function (PSF) blurs the intense day-side crescent, causing the light contaminates the nigh-side disk (Satoh et al., 2018). Solution has been developed by using image deconvolution (Vun et al., in preparation).
2. Possible non-linearity (not conclusive yet):
   During 16 h of continuous observation, the later images tend to darken compared to the earlier images. Increasing detector temperature may raise the floor of usable dynamic range, possibly pushing it to a range where non-linearity is noticeable.
3. Alignment of two images:
   Previous analyses of “branching” were done with spectrograph data (NIMS and Venus Express/VIRTIS). They assure the radiance in two bands are from exactly same position. IR2 images, on the other hand, need precise alignment of two images.

IR2 pre-flight image of city lights (H band)



IR2 2.26-μm full-frame image (22 Jul 2016, 10:33:34)

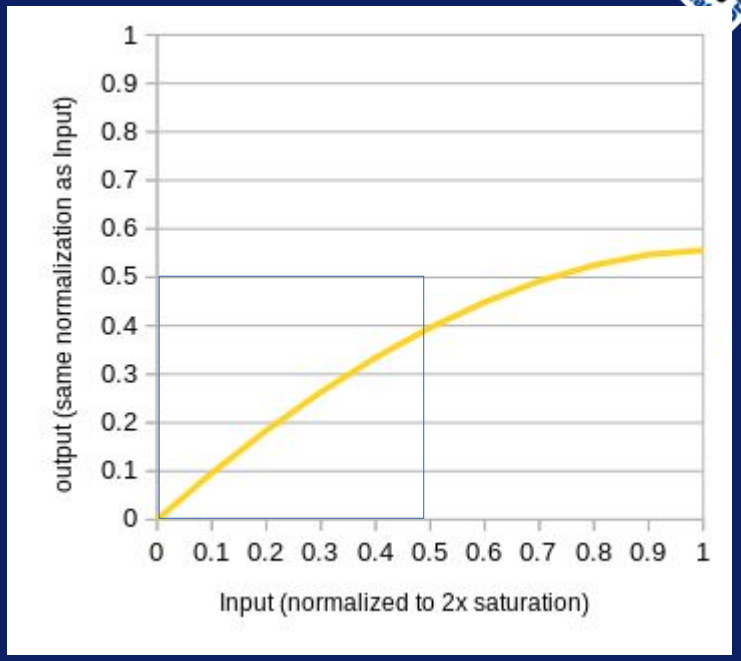
Modeling non-linearity of IR2

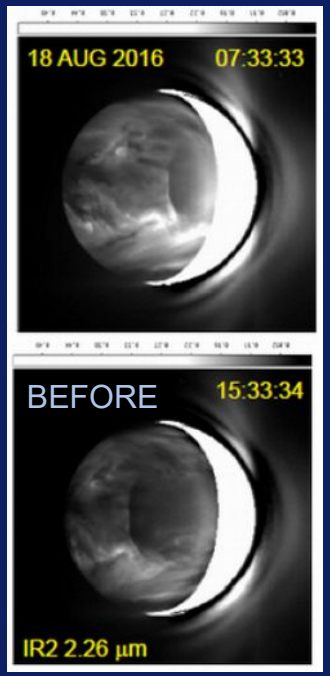
- A preliminary formula is introduced to describe possible non-linearity of IR2 data:

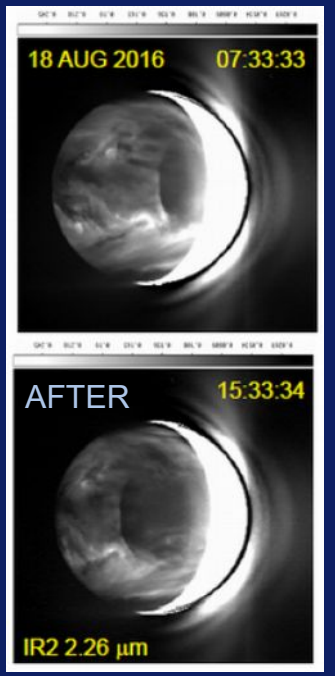
$$y = \frac{1}{k+1}\left[1-(1-x)^{(k+1)}\right]$$

where *x* and *y* are input and output, respectively, and *k* is a coefficient to describe degree of non-linearity.

- Input, *x*, is normalized to twice the full-well of IR2 detector (10^6 e^-).
- Output, *y*, is normalized to possible maximum count (twice the full-well divided by a conversion factor, 70 e^- / ADU).
- The coefficient, *k*, is set to 0.8 through some experiments.
- Example images processed with the above formula are shown on the right. Left column shows “darkening” of 15:33 image compared to 07:33 image, while right column, with non-linearity correction, shows less “darkening”.







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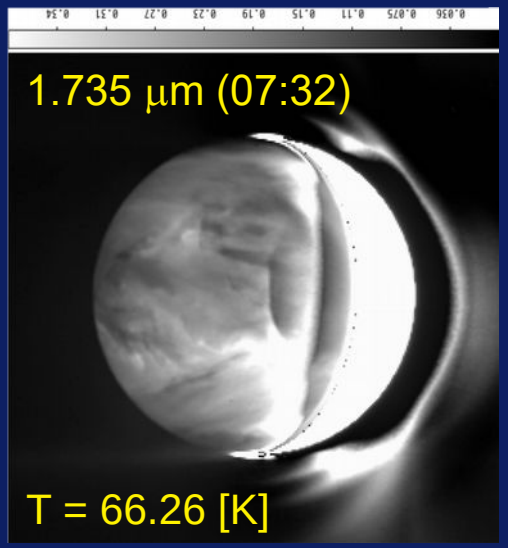
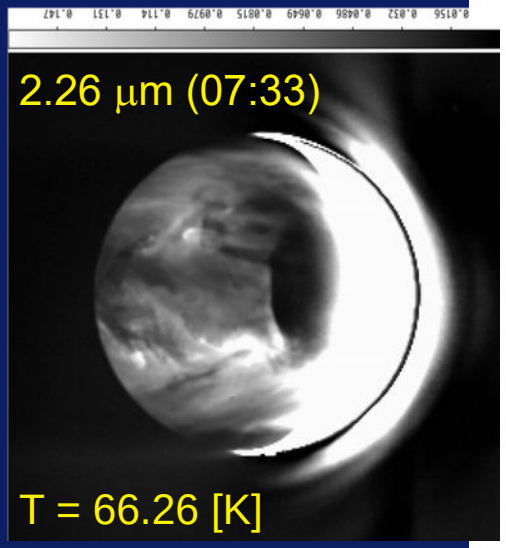
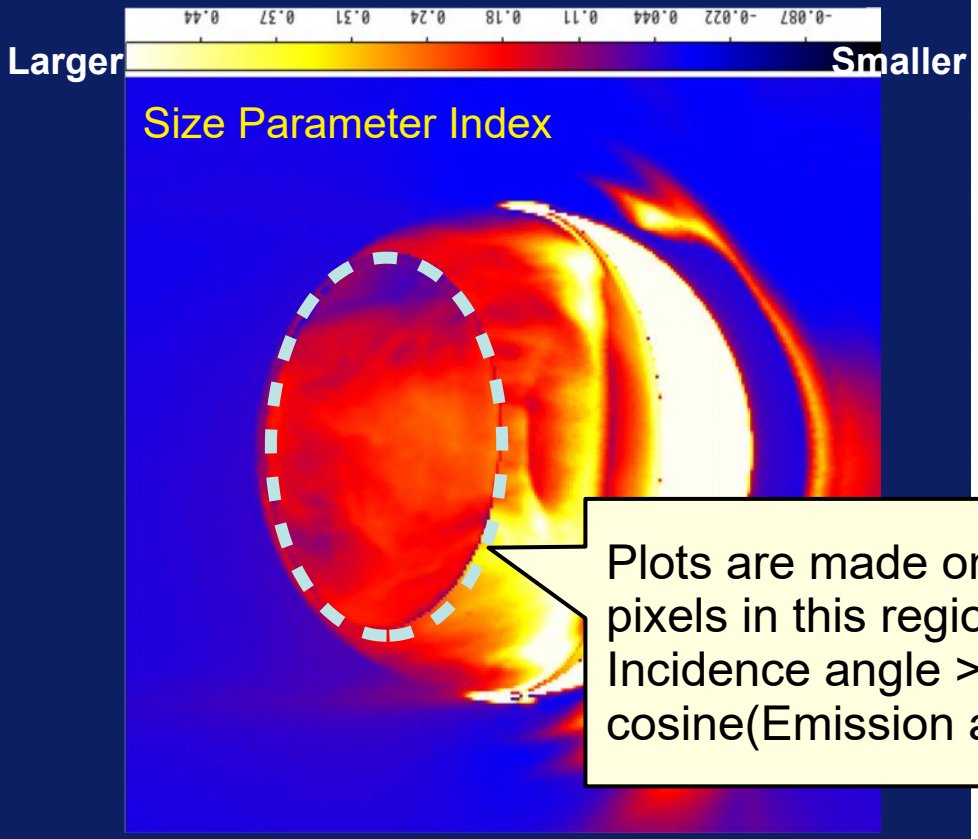
Examining Aerosol Size Parameter Index (07h)

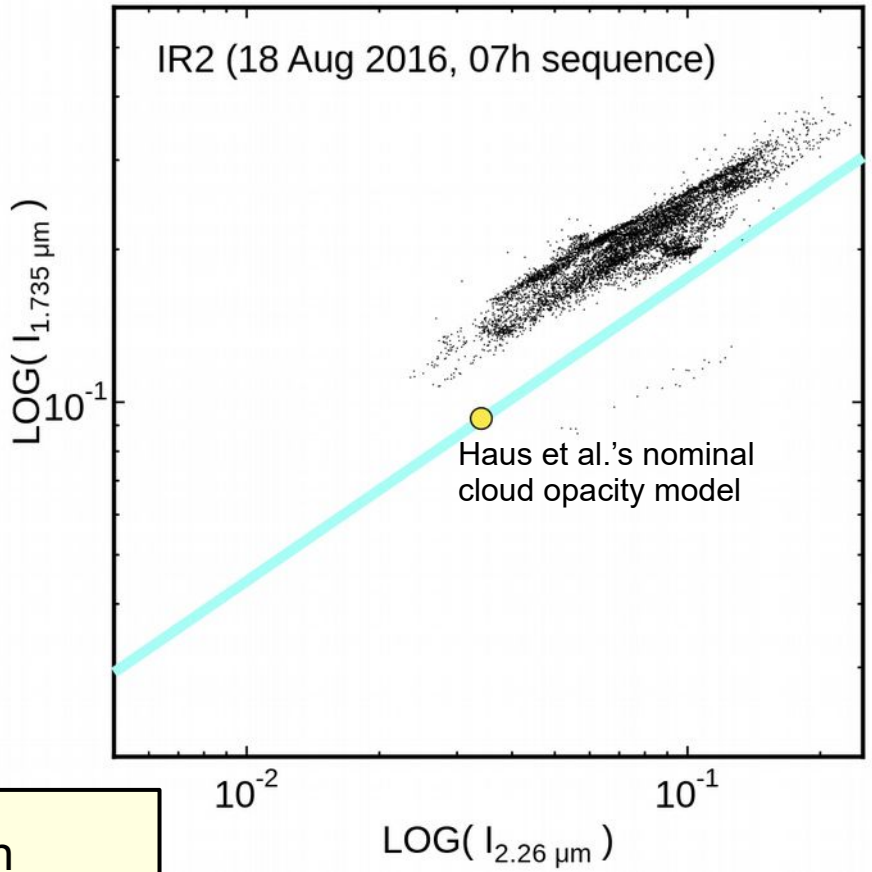






Plots are made only with pixels in this region:
Incidence angle > 130°, and
cosine(Emission angle) > 0.2

Shown in light blue is theoretical computation with Haus et al.'s cloud model. Slope in log-log scale is 0.598, while Carlson et al.'s value was 0.53.



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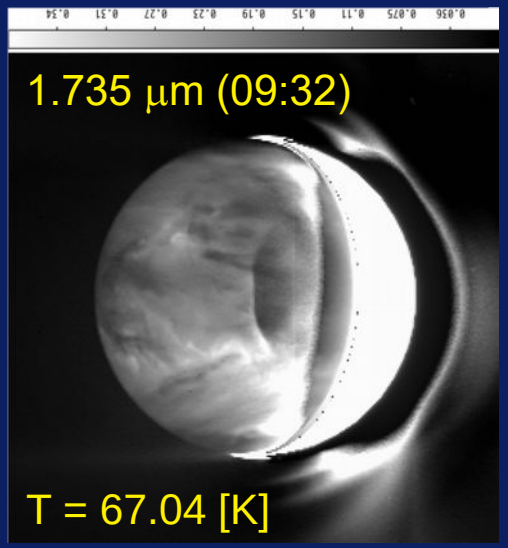
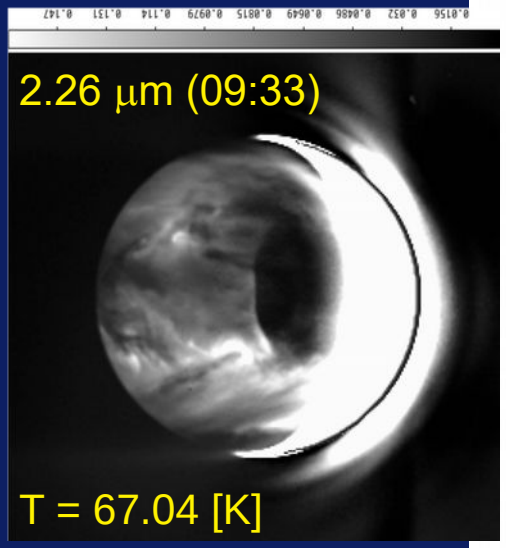
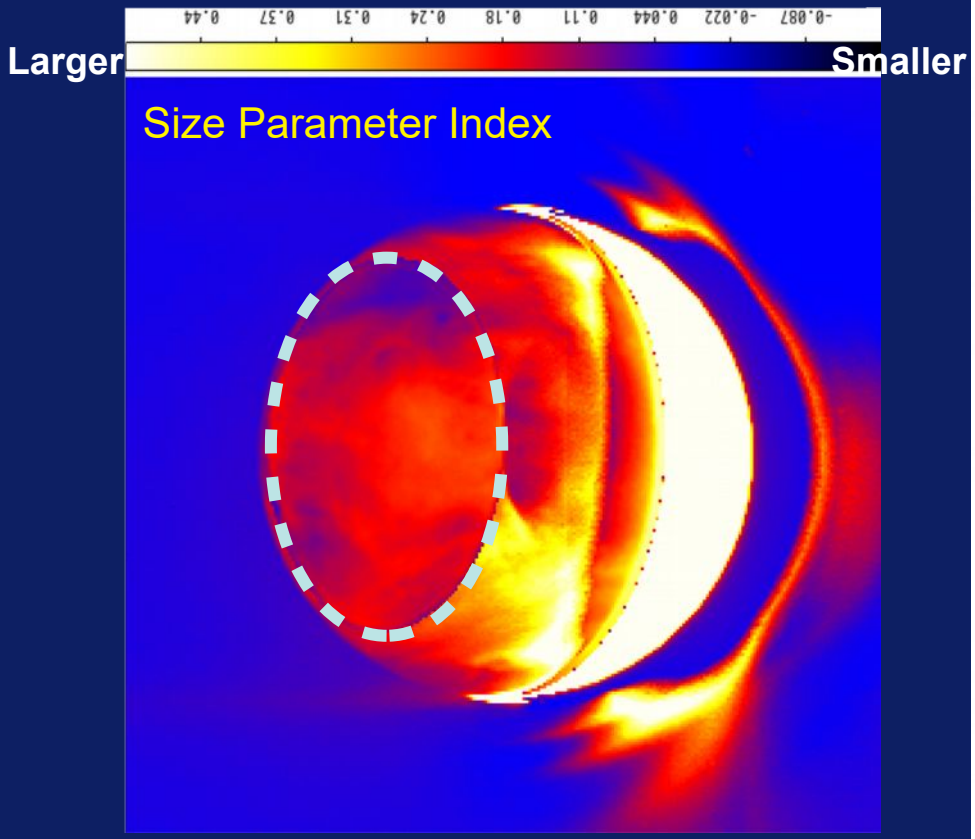
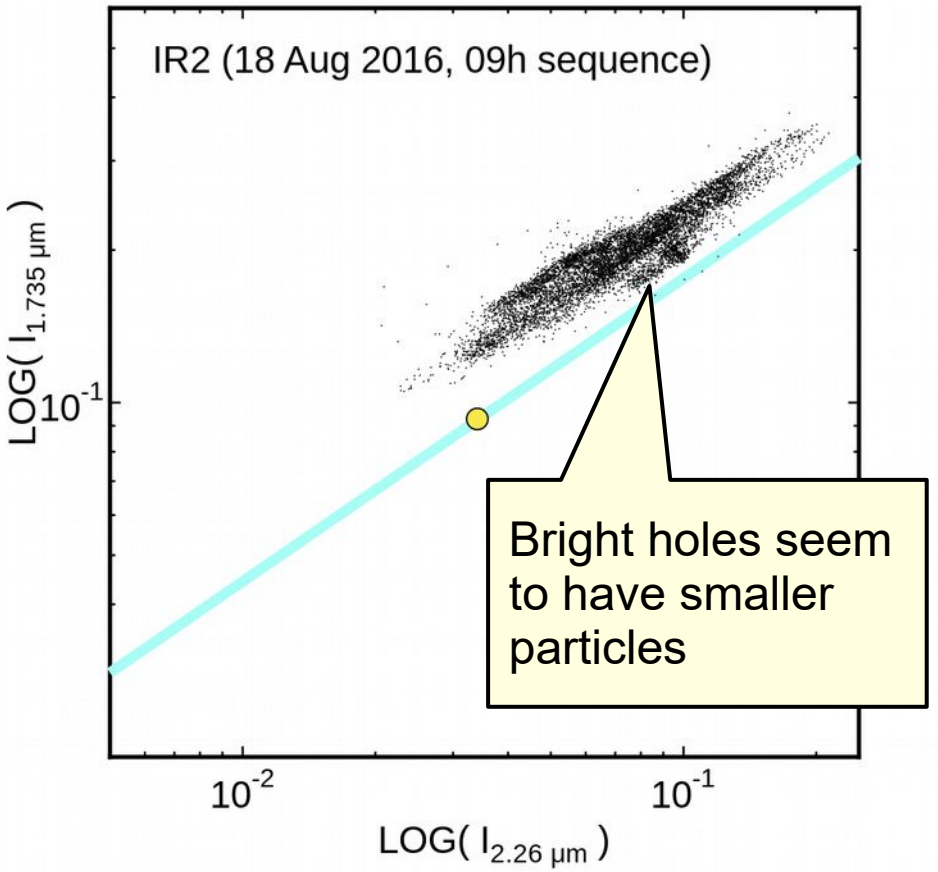
Examining Aerosol Size Parameter Index (09h)









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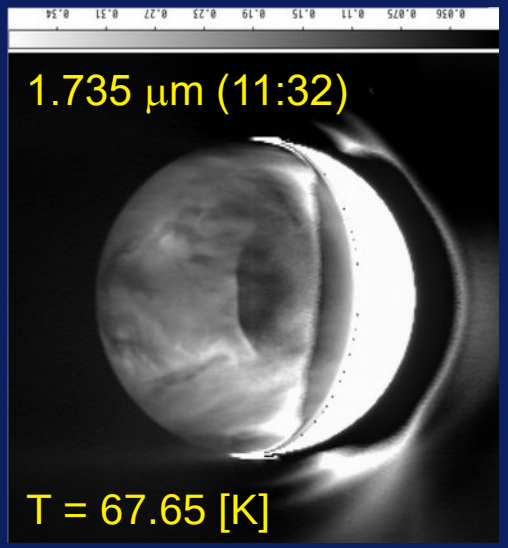
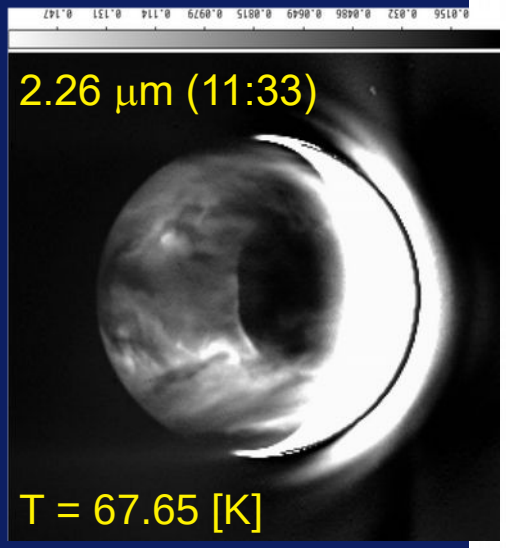
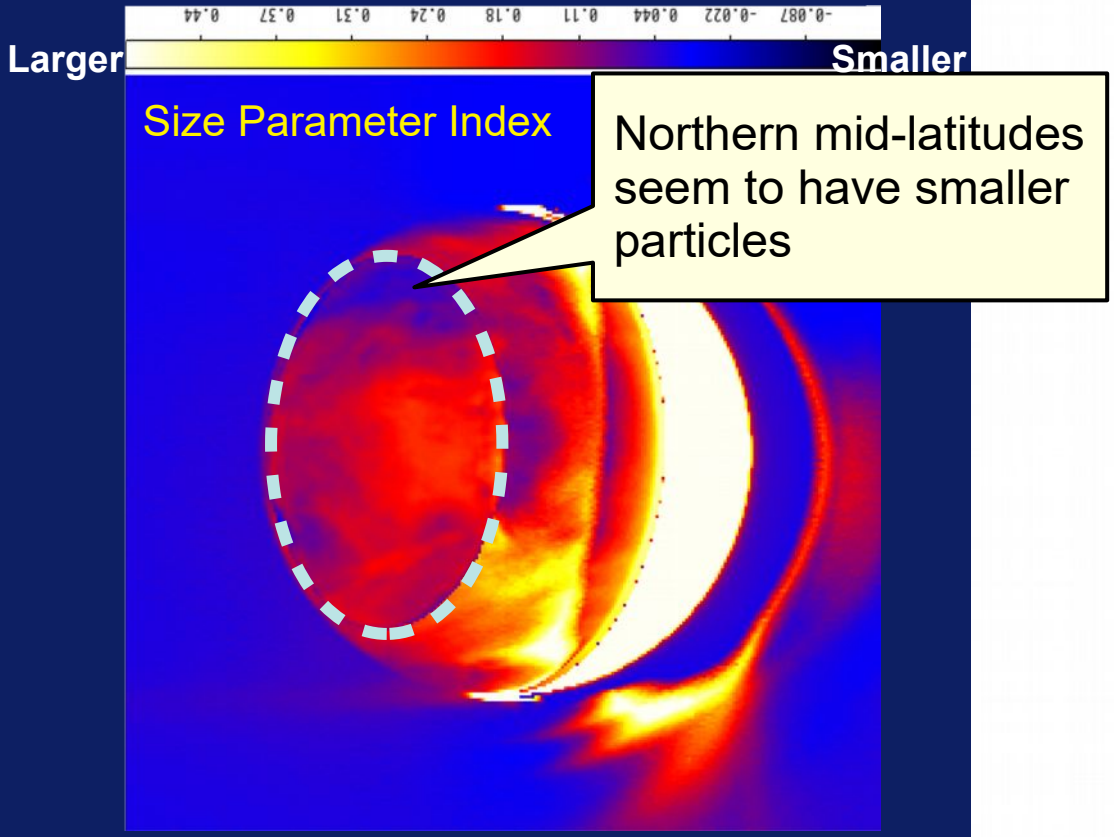
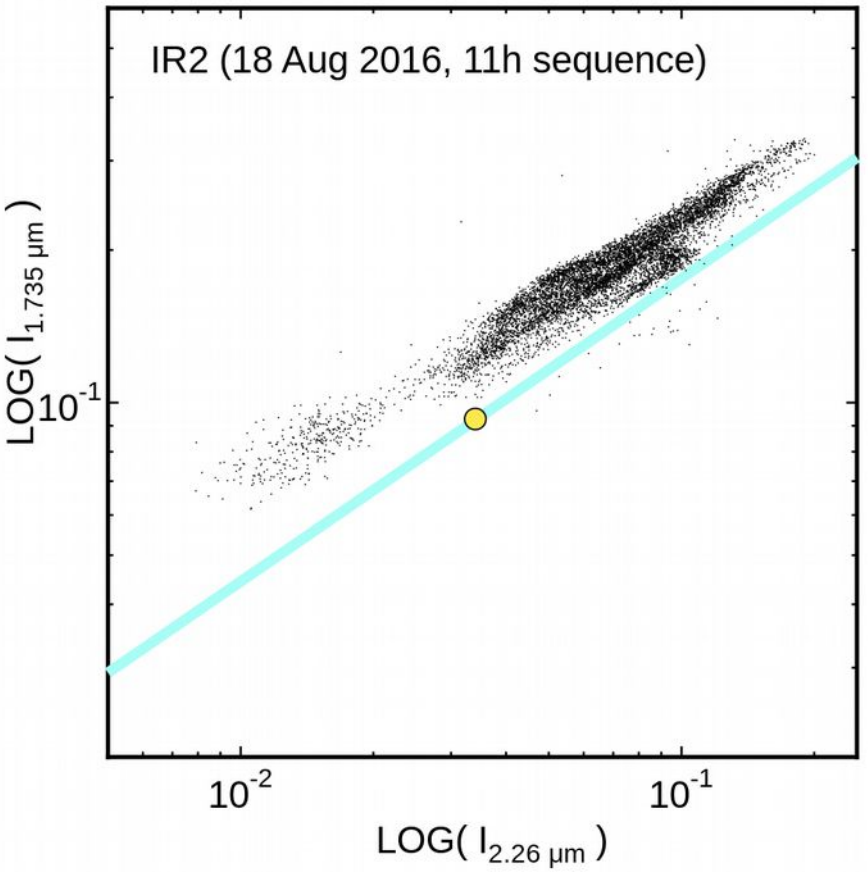
Examining Aerosol Size Parameter Index (11h)









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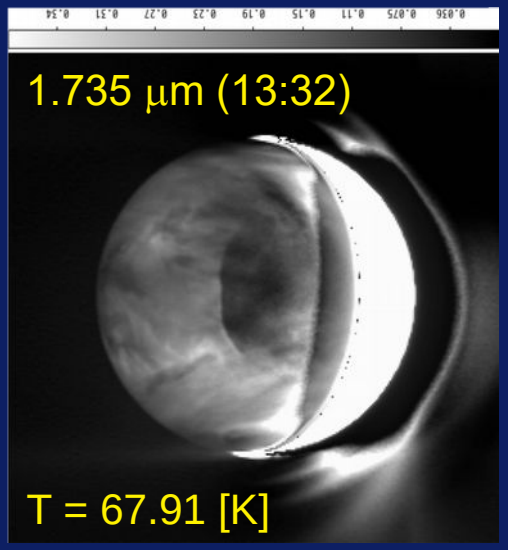
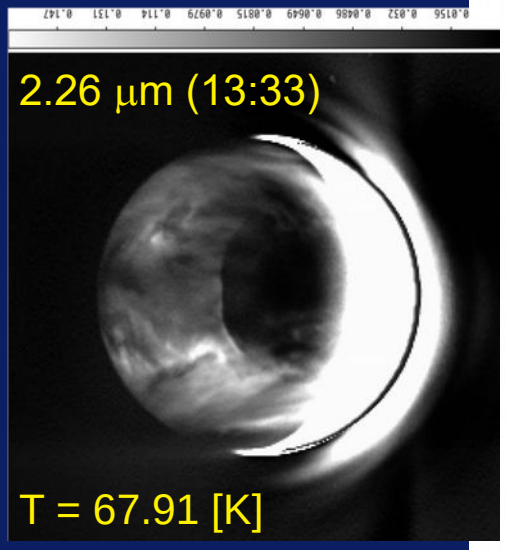
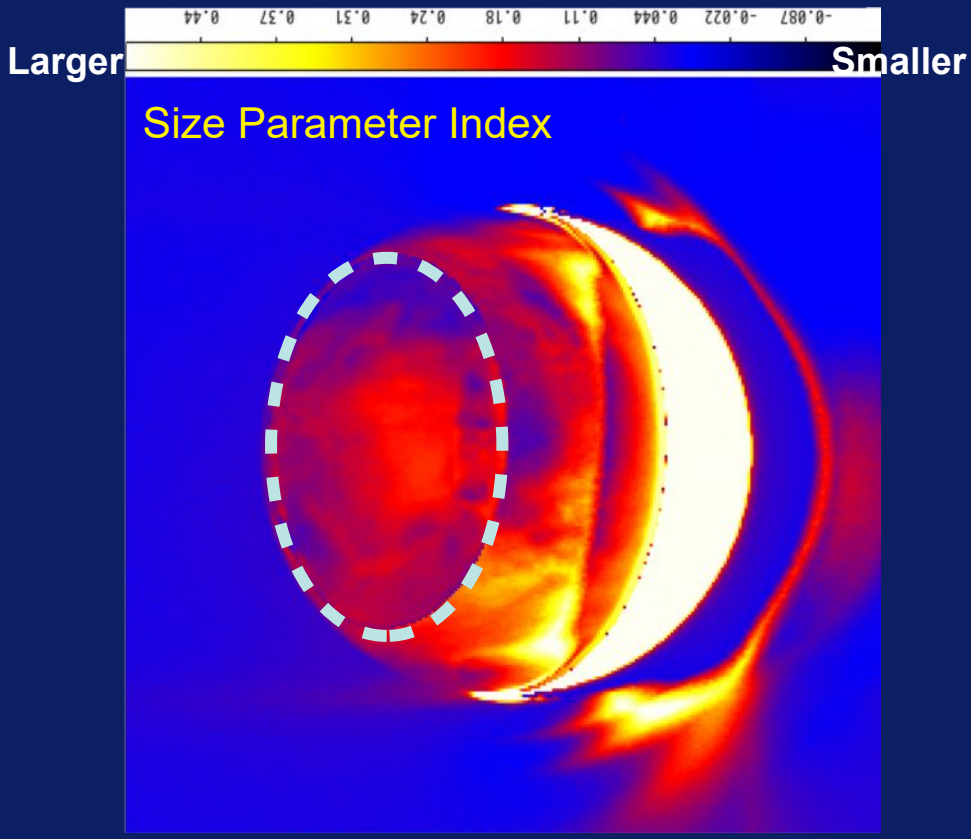
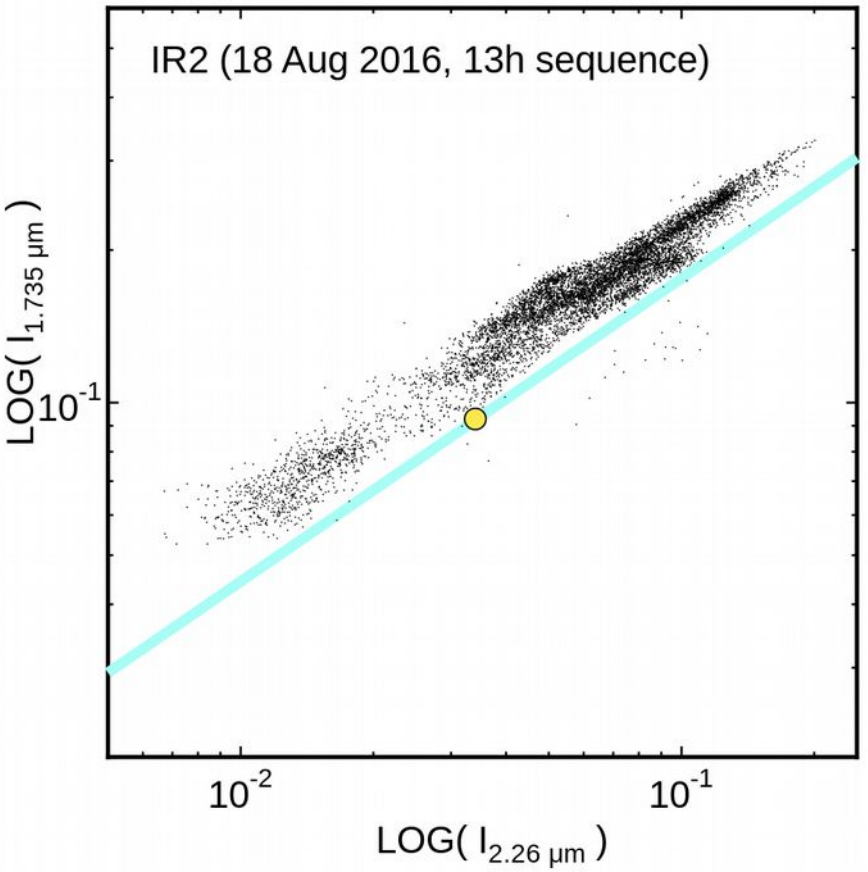
Examining Aerosol Size Parameter Index (13h)

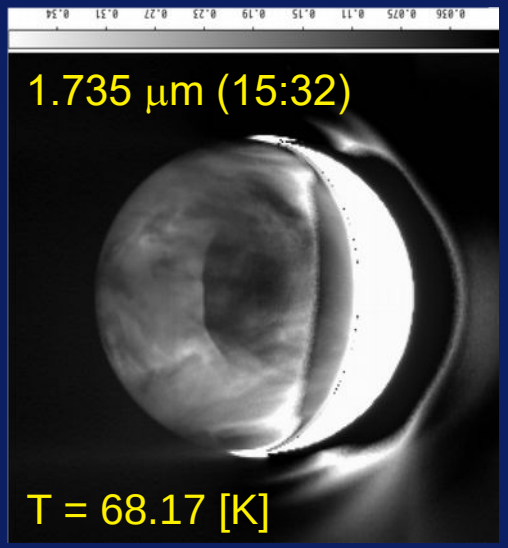


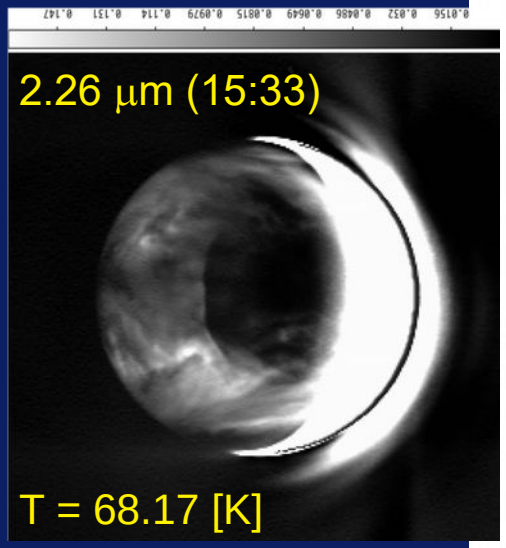


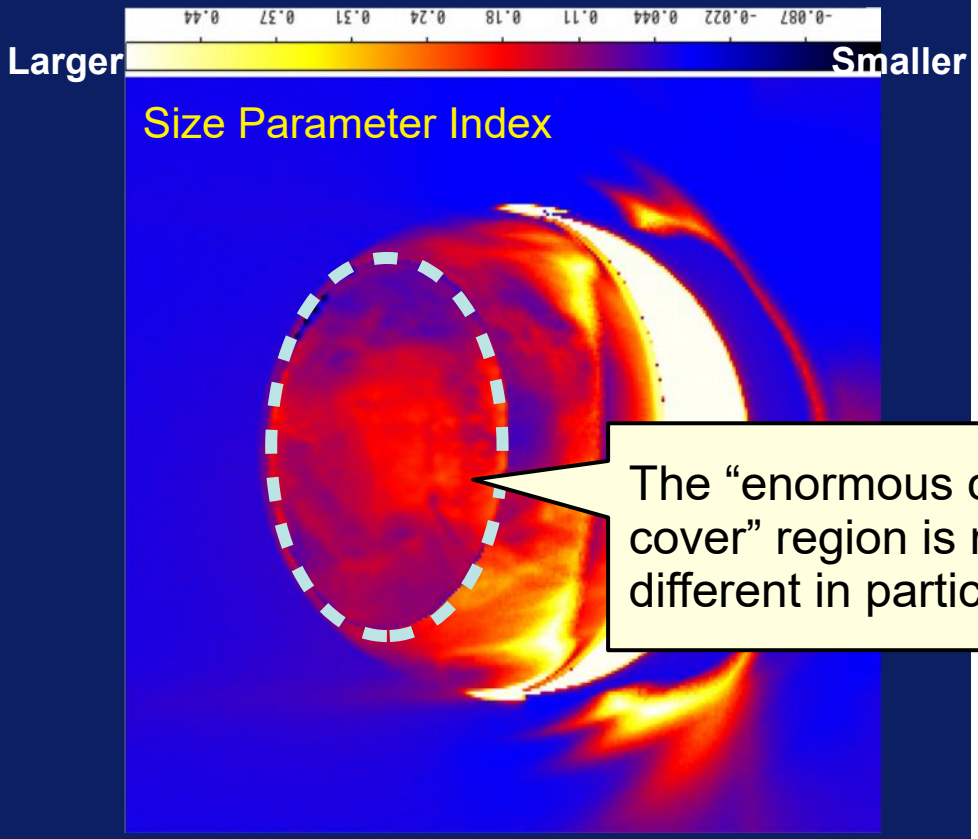




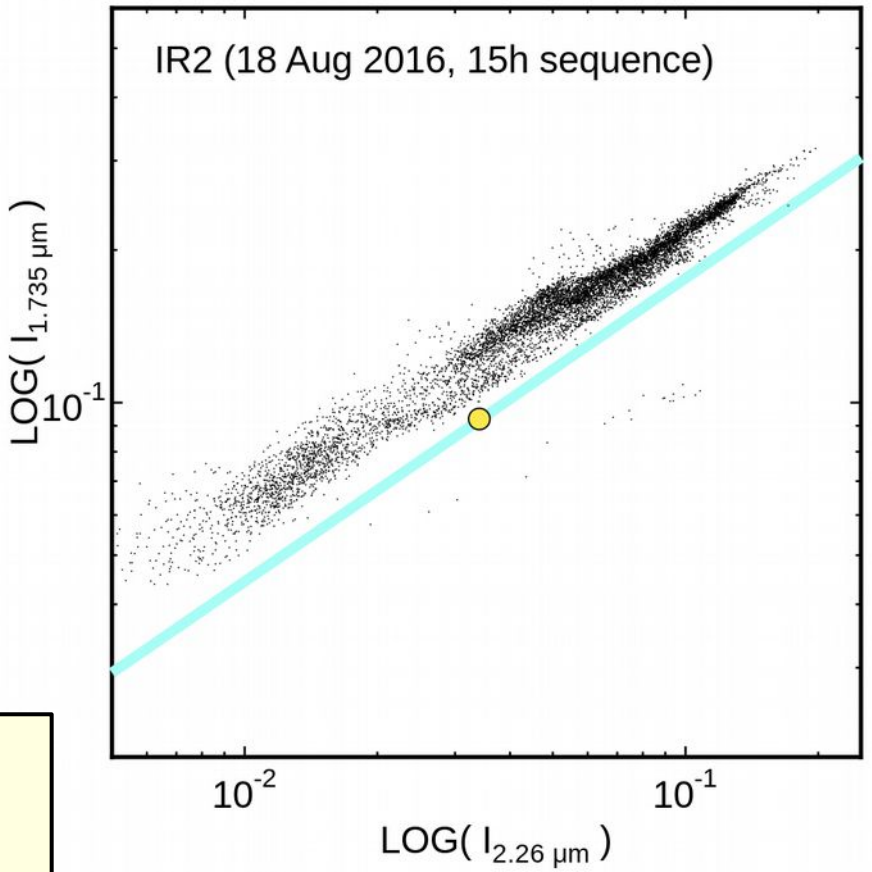
Examining Aerosol Size Parameter Index (15h)







The “enormous cloud cover” region is not so different in particle size.



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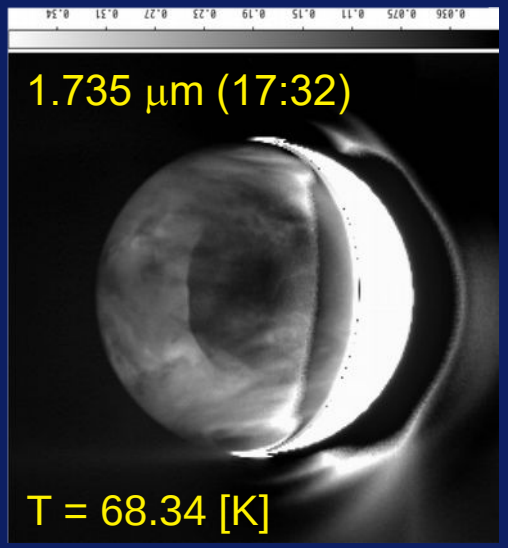
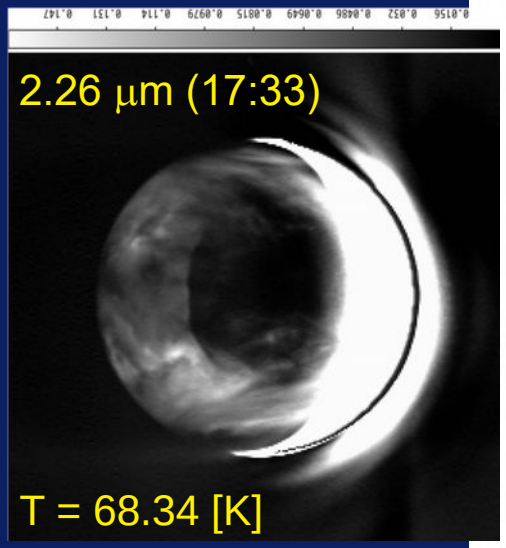
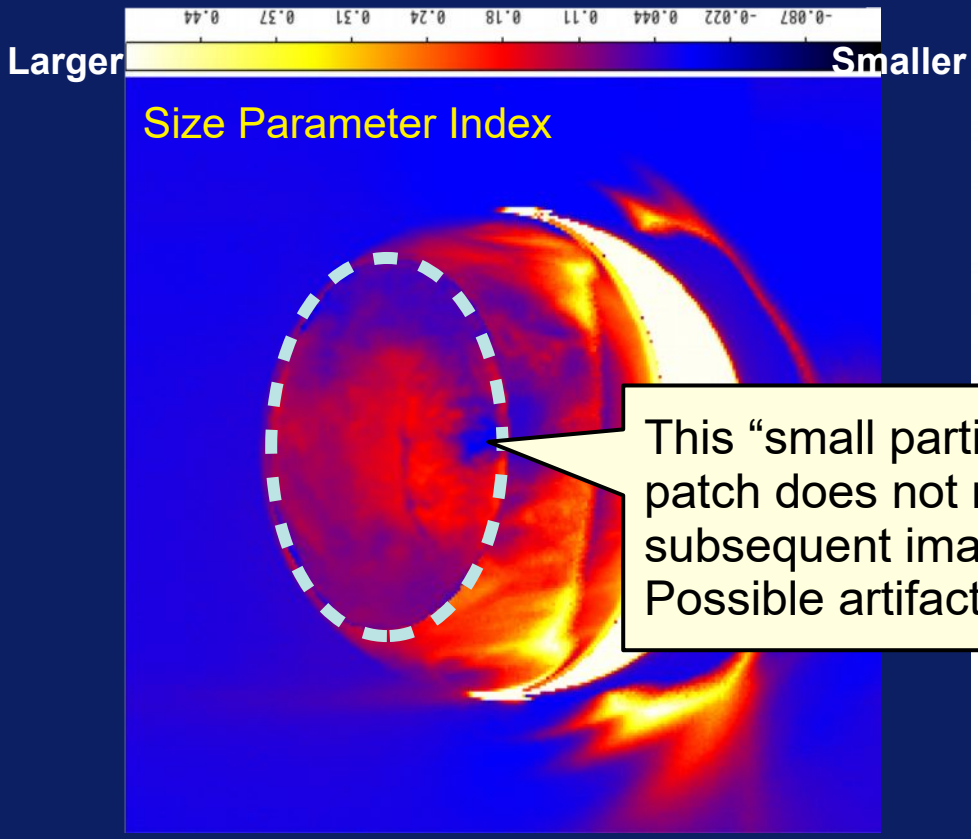
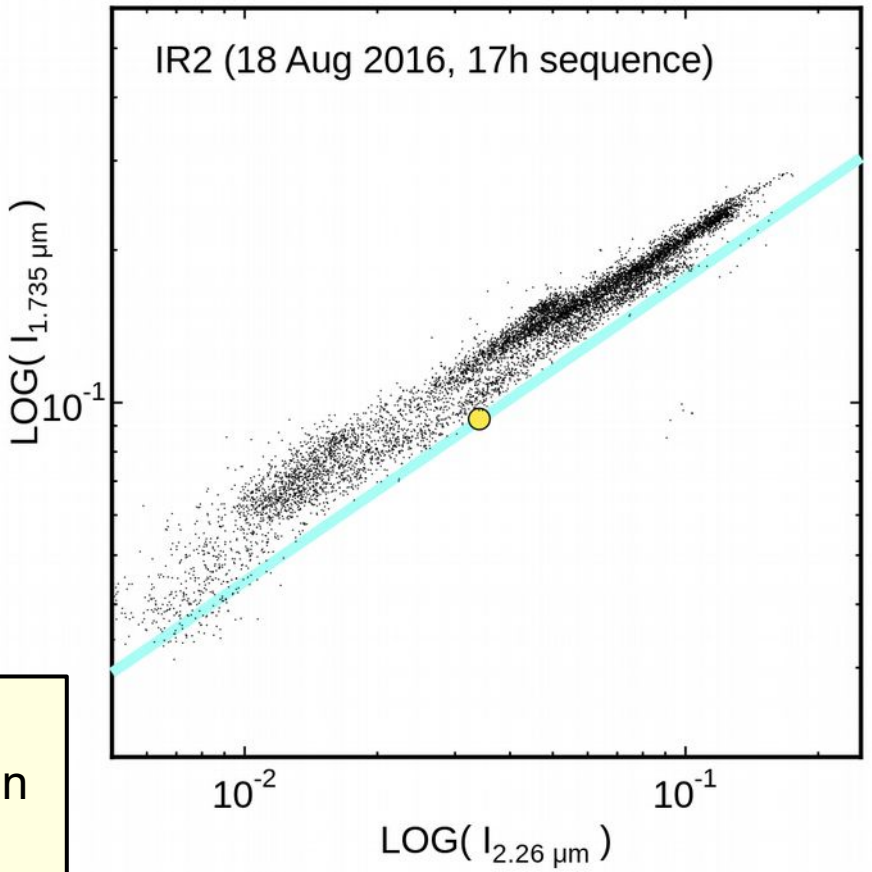
Examining Aerosol Size Parameter Index (17h)







This “small particles” patch does not rotate in subsequent images. Possible artifact.



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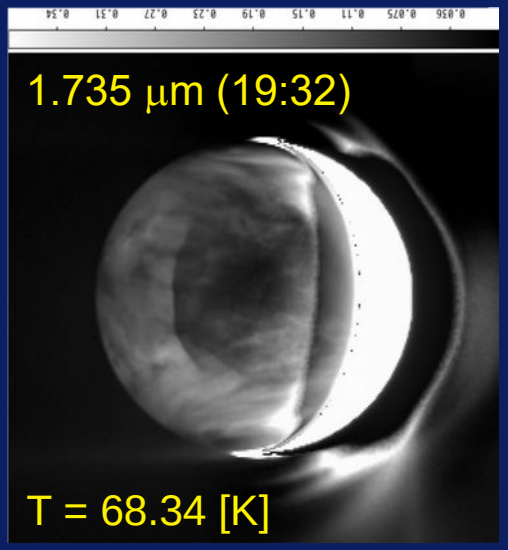
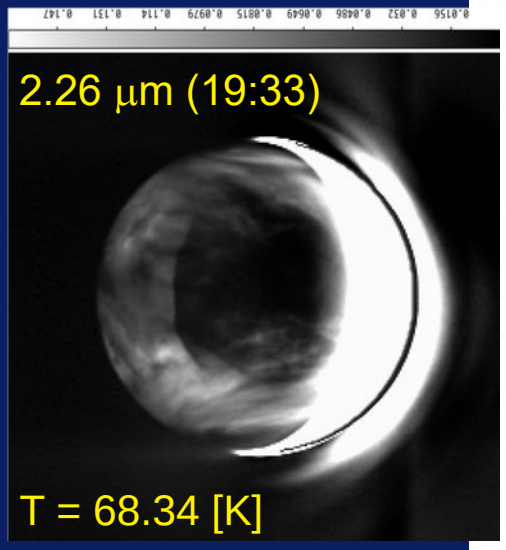
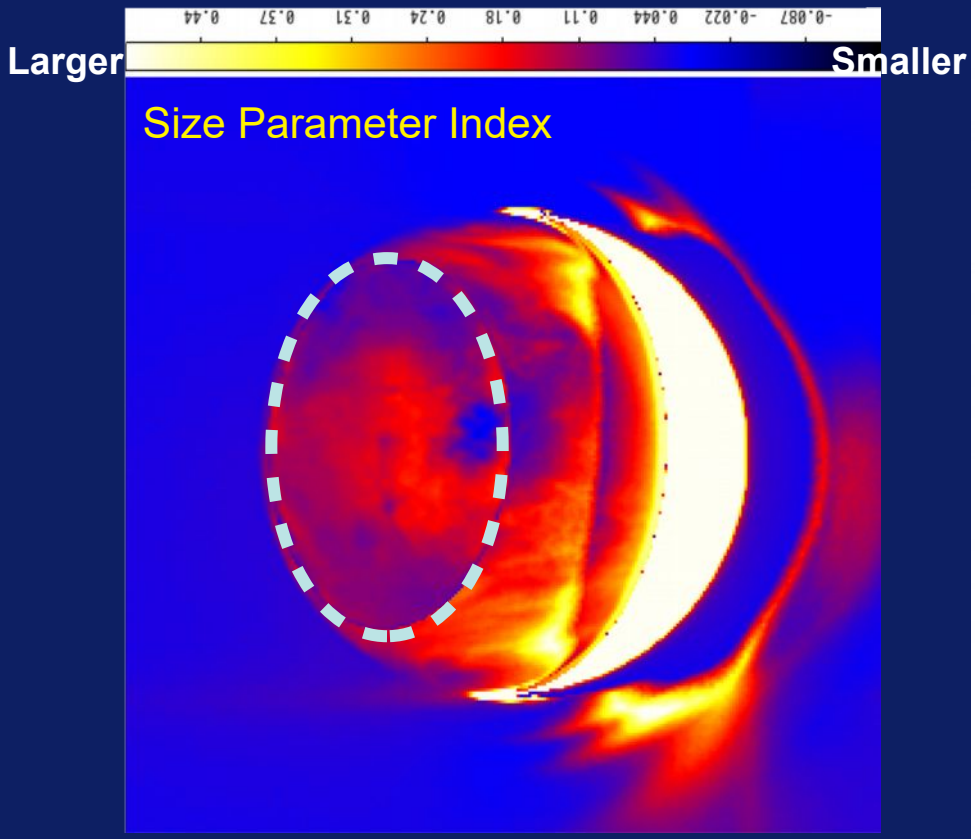
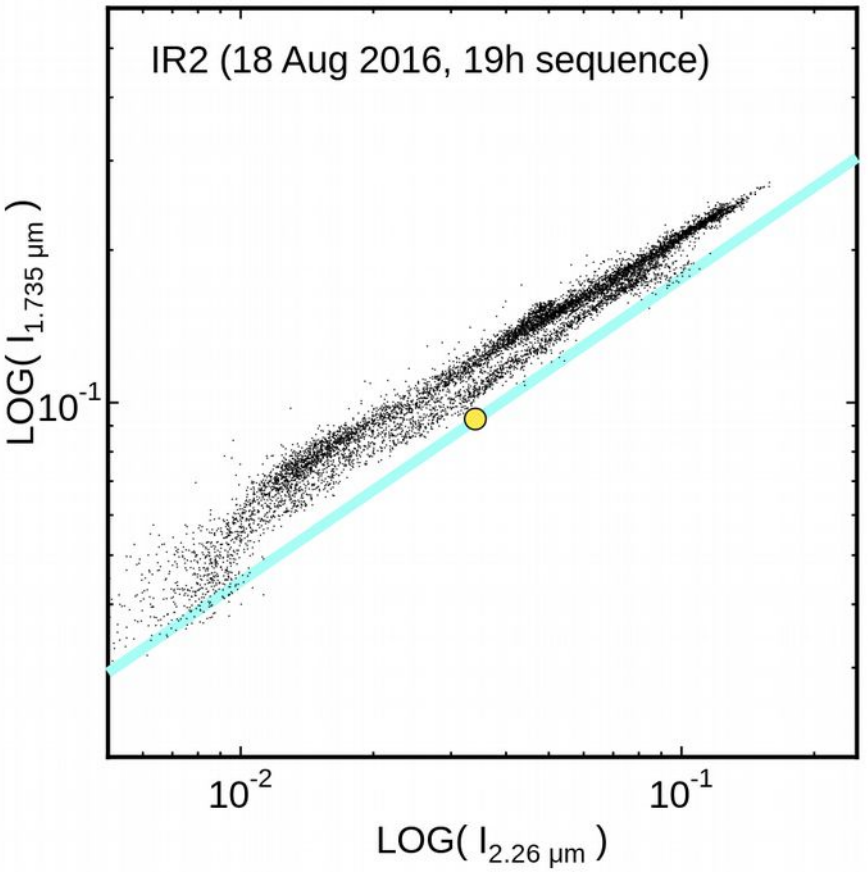
Examining Aerosol Size Parameter Index (19h)









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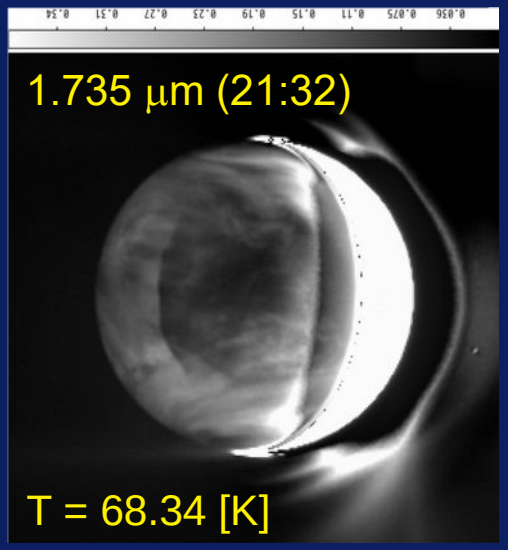
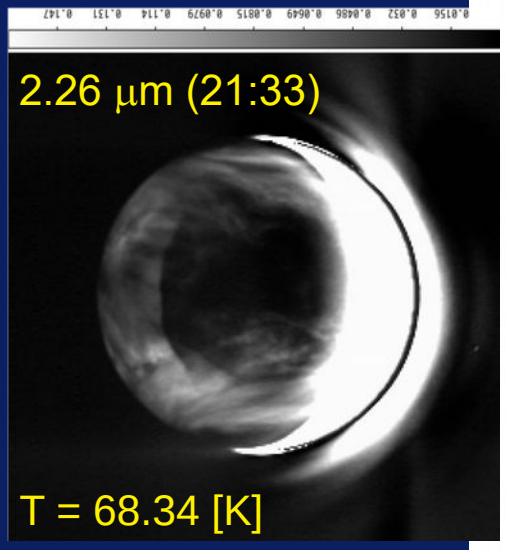
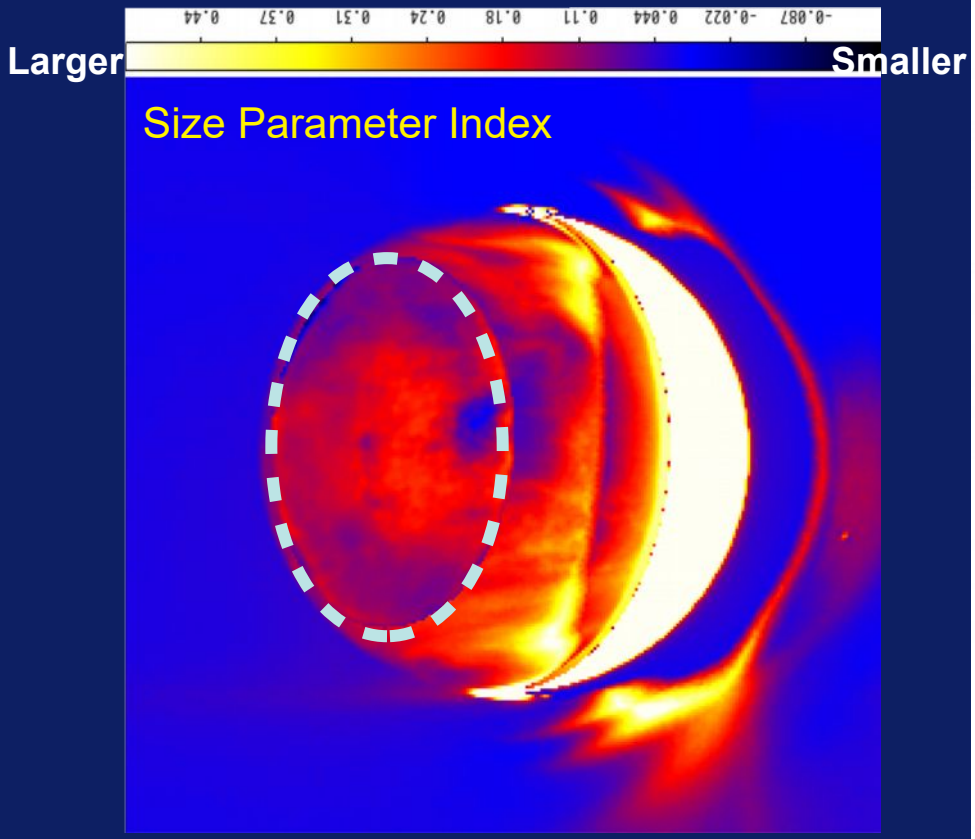
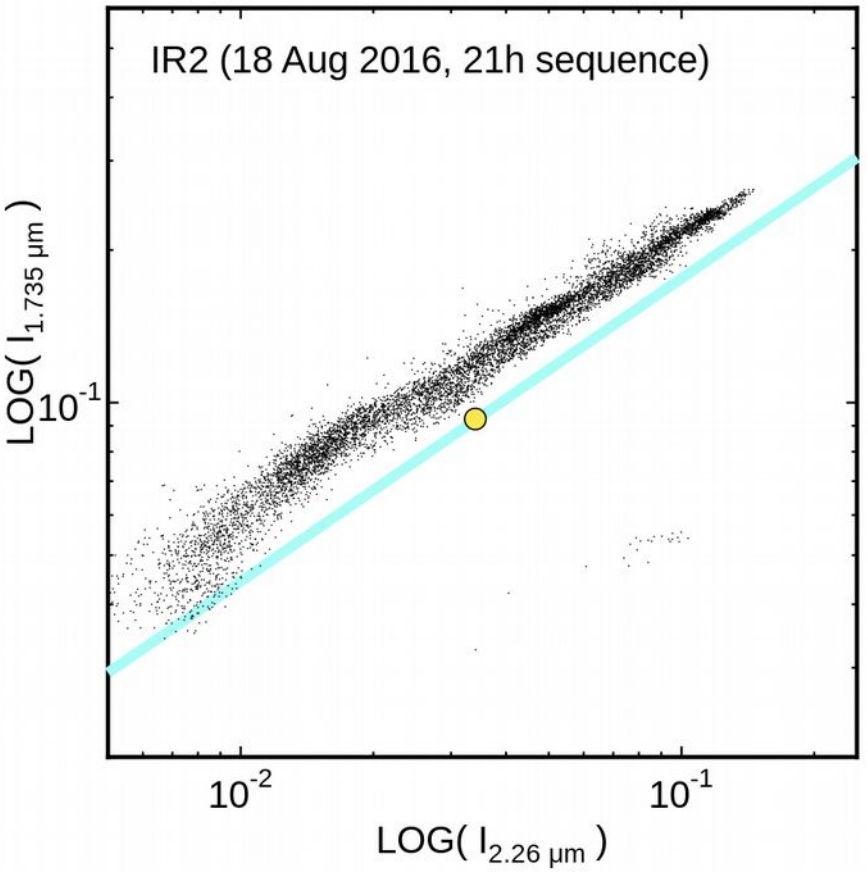
Examining Aerosol Size Parameter Index (21h)



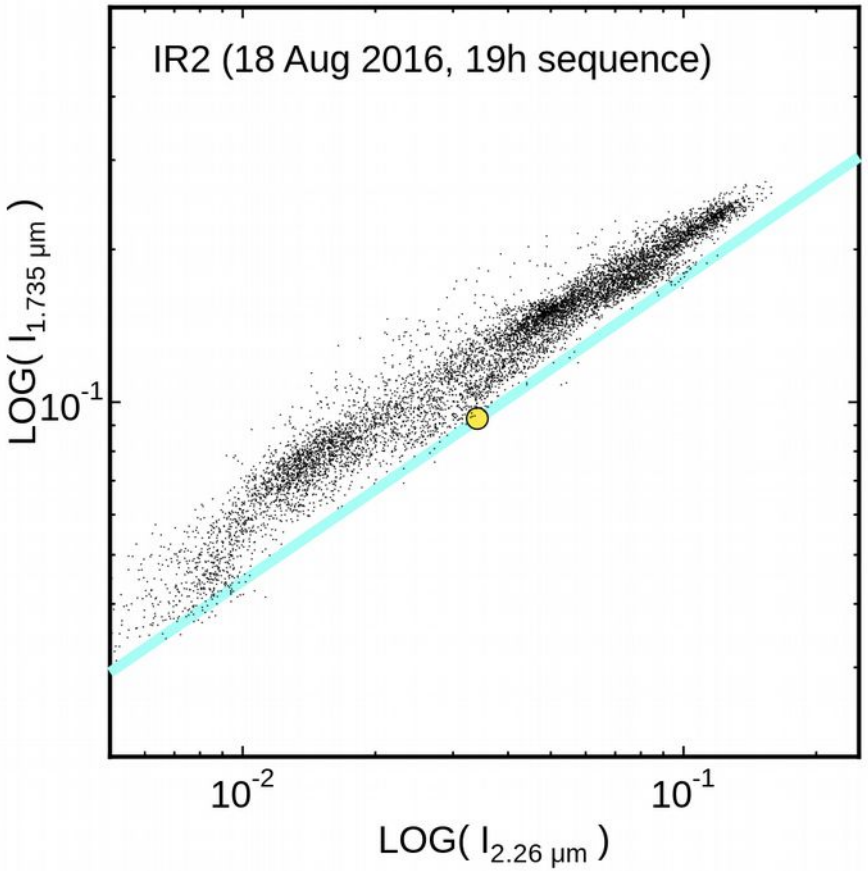






Alignment of 2.26/1.735-μm images

- "Branching" is most clearly seen in 18 Aug 2016 19h data.
- The plot on the right is made by intentionally mis-aligning two images (1.735-μm data shifted by +1 pixel in both X and Y). It is obvious that this small amount of mis-alignment completely washes out the "branching".
- This demonstrates the importance of precise alignment between two images. And, explains why "branching" was easily seen in NIMS and VIRTIS data which were acquired with spectrographs (no alignment problem in different wavelengths).



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Summary and Future Works

- For the first time ever, “branching” of radiance plot from IR2 data is clearly indicated. This has been possible with three careful processes: (1) correction of non-linearity; (2) restoration of night-side radiance by deconvolution; (3) precise alignment of 2.26- and 1.735-μm images. The reason why it has been difficult to see “branching” in IR2 data is explained.
- Obtained “particle size index” maps include consistently-rotating features which would have high levels of confidence. There are features that do not rotate in a sequence of images which may likely be artifacts. The enormous cloud cover region is not very different as far as particle size is concerned.
- In summary, this study provides a more robust basis than before to start RTM analyses of night-side clouds.
- It is planned to measure possible non-linearity using the proto models of IR1 and IR-AE at the laboratory (scheduled for early June). Better correction of non-linearity would (hopefully) be a possibility after that.

References:

Carlson, R. W., et al., *Planet. Space Sci.* **41,** 477-485 (1993).

Wilson, C. F., et al., *J. Geophys. Res.* **113,** E00B13, doi:10.1029/2008JE003108 (2008).

Satoh, T., et al., *Earth, Planets, Space* **69,** 154, doi:10.1186/s40623-017-0736-x (2017).

Vun, C. W., et al. (in preparation)

Haus, R., et al., *Planet. Space Sci.* **117,** 262-294 (2015).