Exploring Saturn's Narrow Ringlets with Cassini Radio Science

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Mission San Jose High School and Leland High School

18 October 2025
Fifteenth Annual Fall-Term MIT PRIMES Conference

Saturn's Rings

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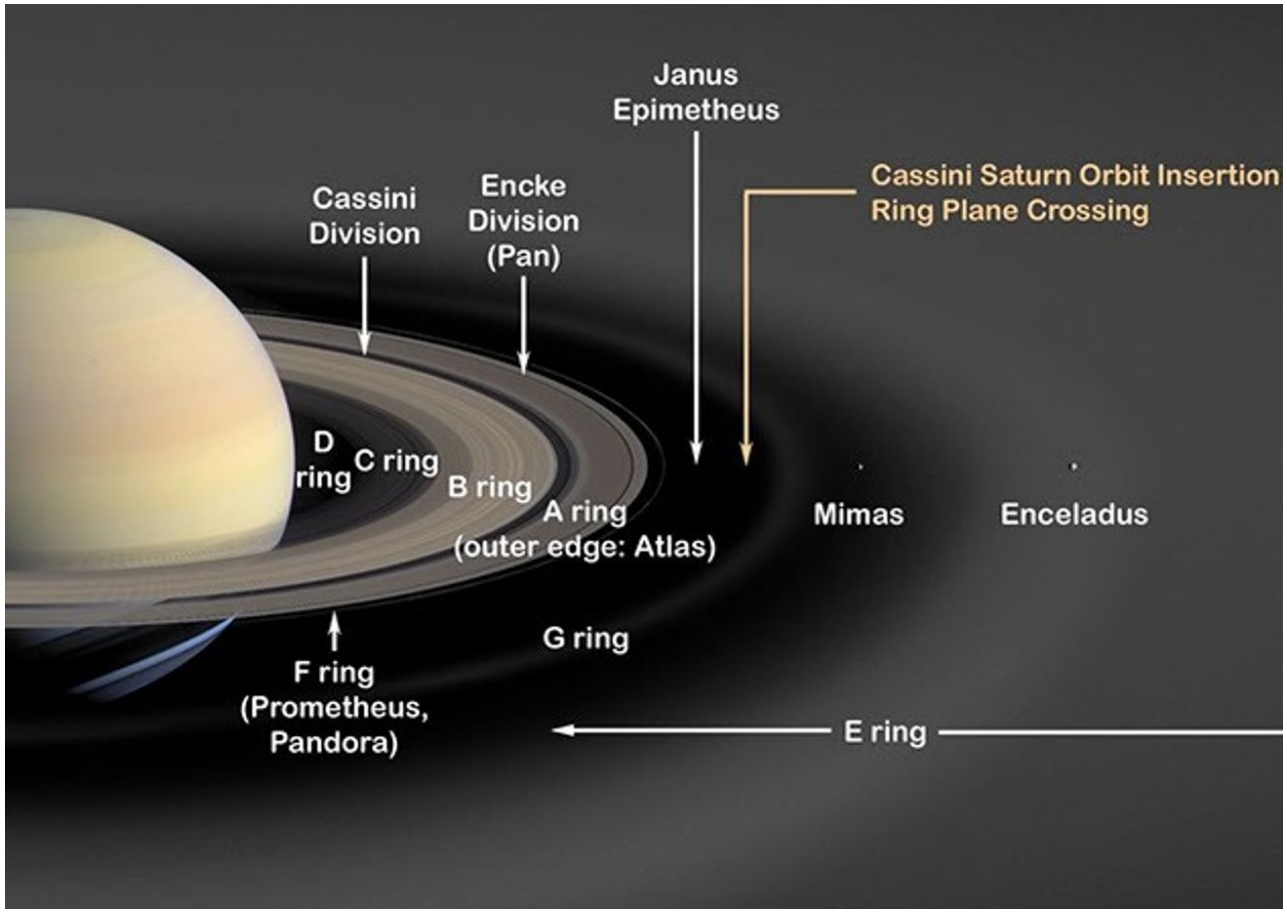
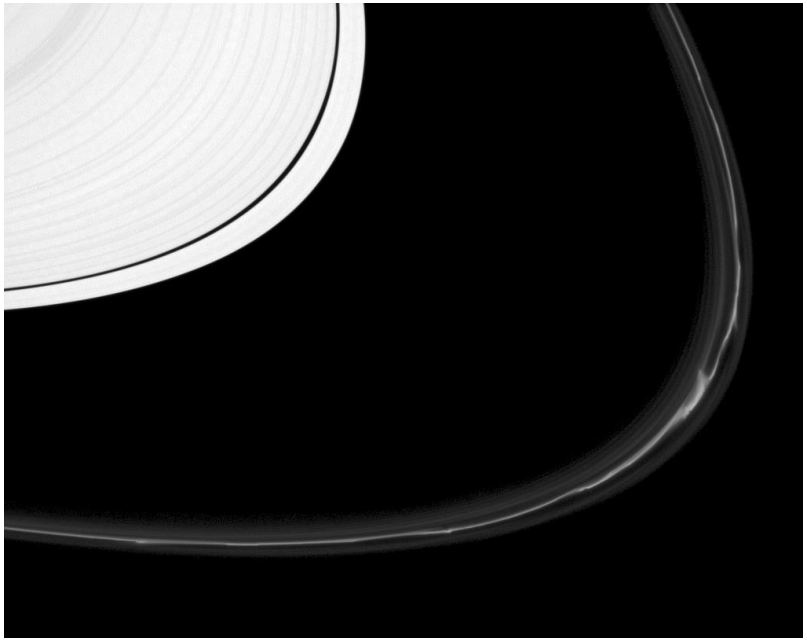


Narrow Ringlets

- Gravitational interactions cause many interesting F ring properties
- Particle sizes in narrow rings differ widely from other regions



"Jets" and kinks in the F ring.

Cassini Radio Science Subsystem

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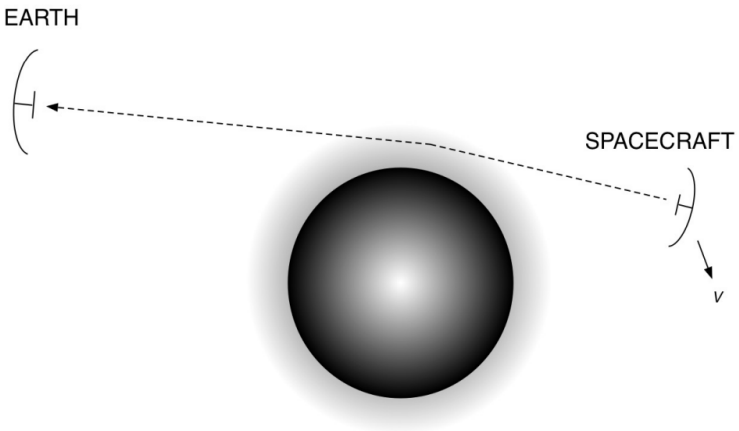
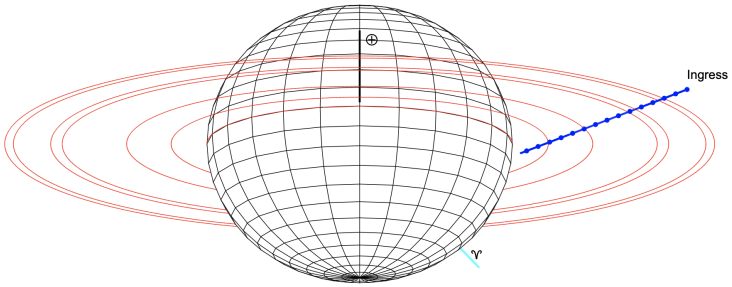
- The Cassini space probe launched in 1997 and orbited Saturn for 13 years
- The Radio Science Subsystem (RSS) transmitted 3 wavelengths of radio signals from Cassini to Earth

Method of Observation: Radio Occultations



Geometry of a radio occultation.



Occultation track for Rev 028.

Reconstruction Integrals

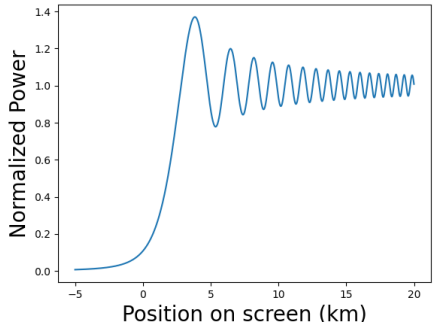
- The power of the signal alone cannot show the shape of the obstacle due to diffraction
- Thus the DSNs measure both amplitude (power) and phase of the waves they receive from Cassini

Forward Diffraction Integral

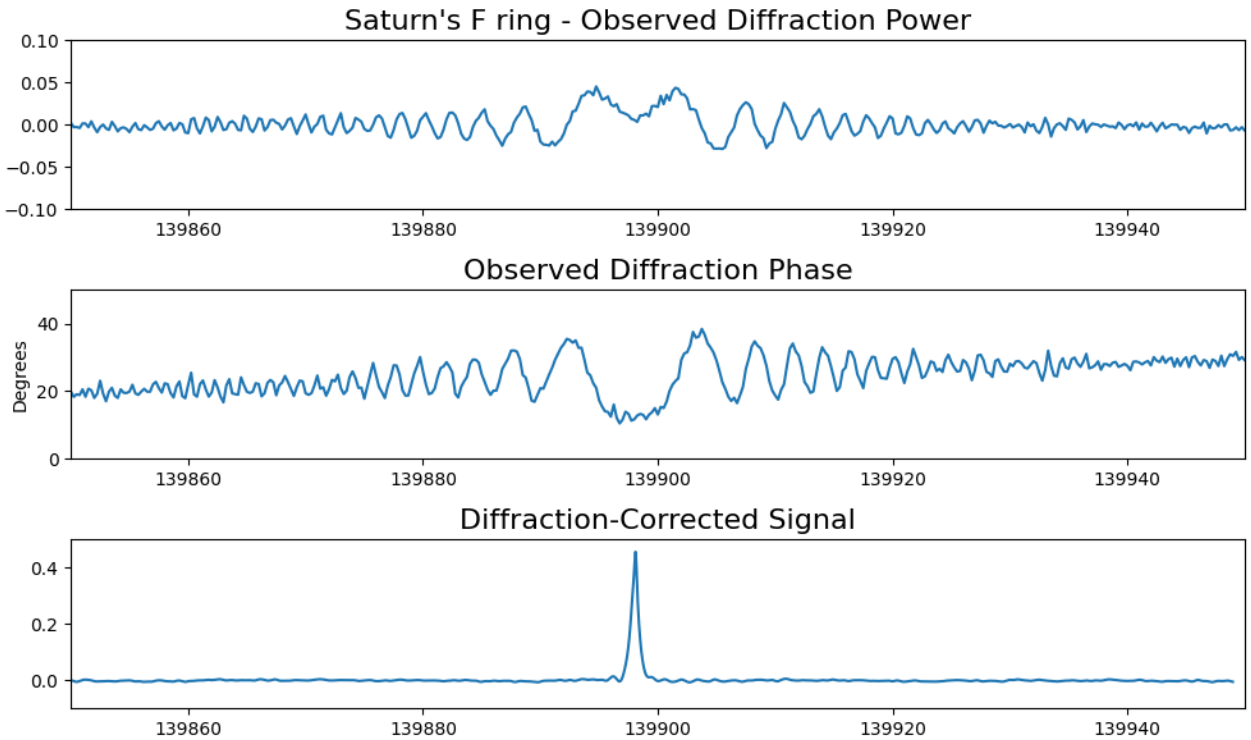
$$\hat{T}(\rho_0) = \frac{\mu_0}{i\lambda} \int_0^\infty \rho T(\rho) \int_0^{2\pi} \frac{e^{i\psi(\rho_0,\phi_0;\rho,\phi)}}{||\boldsymbol{R_c} - \boldsymbol{\rho}||} \mathrm{d}\phi \mathrm{d}\rho$$

- It is possible to reverse this integral to recover the "density" of the rings

Overcoming Diffraction



Diffraction due to a straight edge.

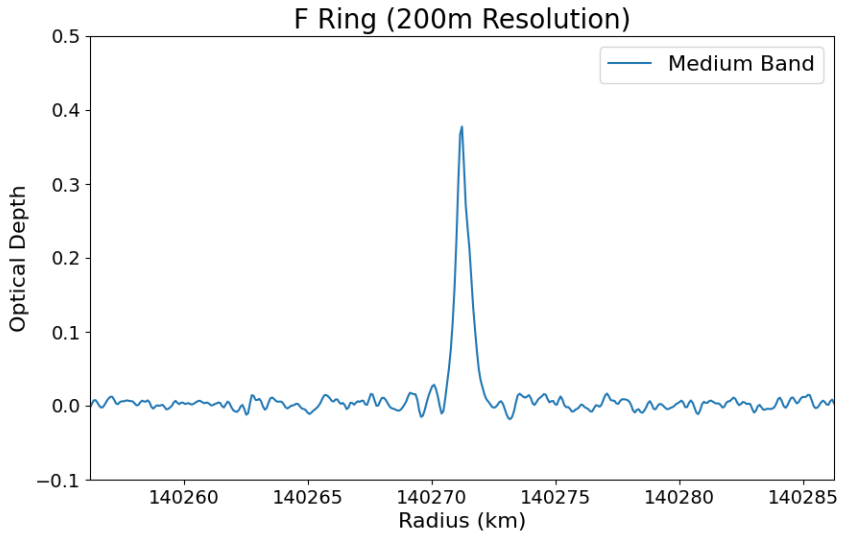


Optical Depth Profiles

Optical depth is directly proportional to how much ring material there is, making it a more useful measure of ring density:

Optical Depth

$$\tau(\rho) = -2\mu_0 \ln(|T(\rho)|)$$



X band optical depth profile of the F ring.

Mie Scattering Theory

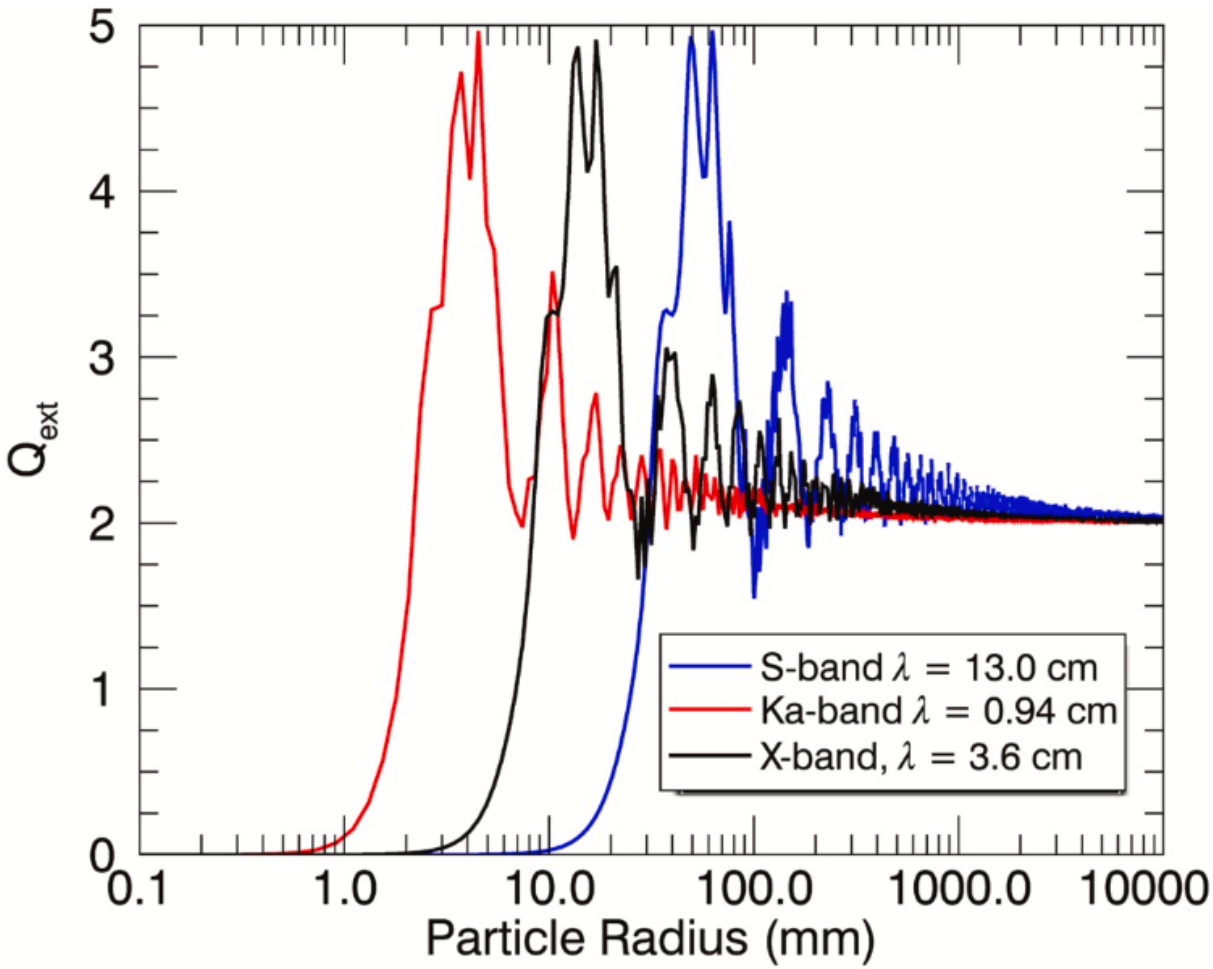
- Optical depth at a given wavelength can be determined from the sizes of particles in the ring
- Size distribution $n(a) = n_0 \left(\frac{a}{a_0}\right)^{-q}$; $a_{min} < a < a_{max}$

Optical Depth

$$\tau(\lambda) = \int_0^\infty \pi a^2 Q_{ext}(a, \lambda) n(a) \mathrm{d}a$$

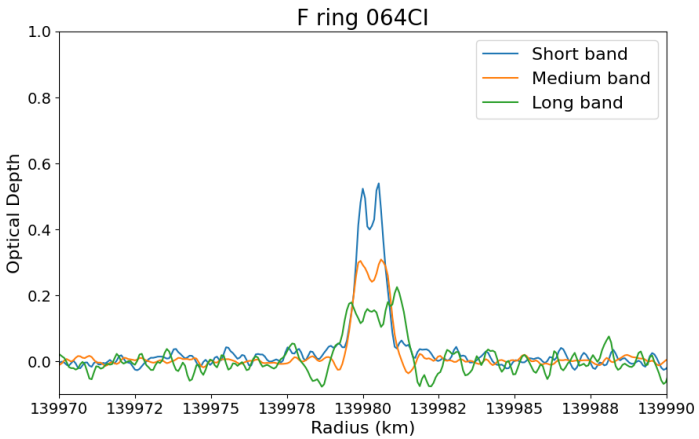
- Comparing the optical depths of pairs of wavelengths allows us to make conclusions about particle sizes

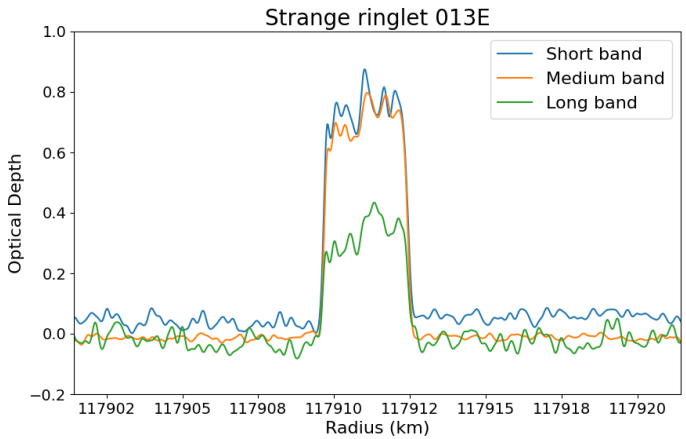
Comparing Optical Depths



Extinction efficiency versus particle radius for the Ka (short) band, X (medium) band, and S (long) band.

Comparing Optical Depths





Optical depth profiles of the F ring and Strange ringlet on all 3 bands.

- Proportionality constant n_0 can be determined from $\Delta\tau$
- The remaining degrees of freedom are a_{min}, a_{max}, and q

Constraining Particle Sizes

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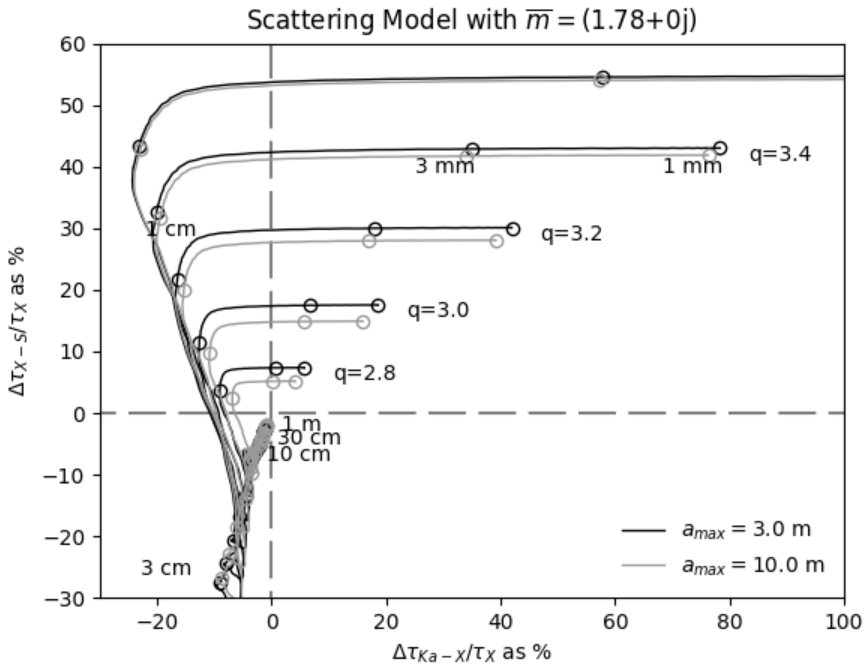
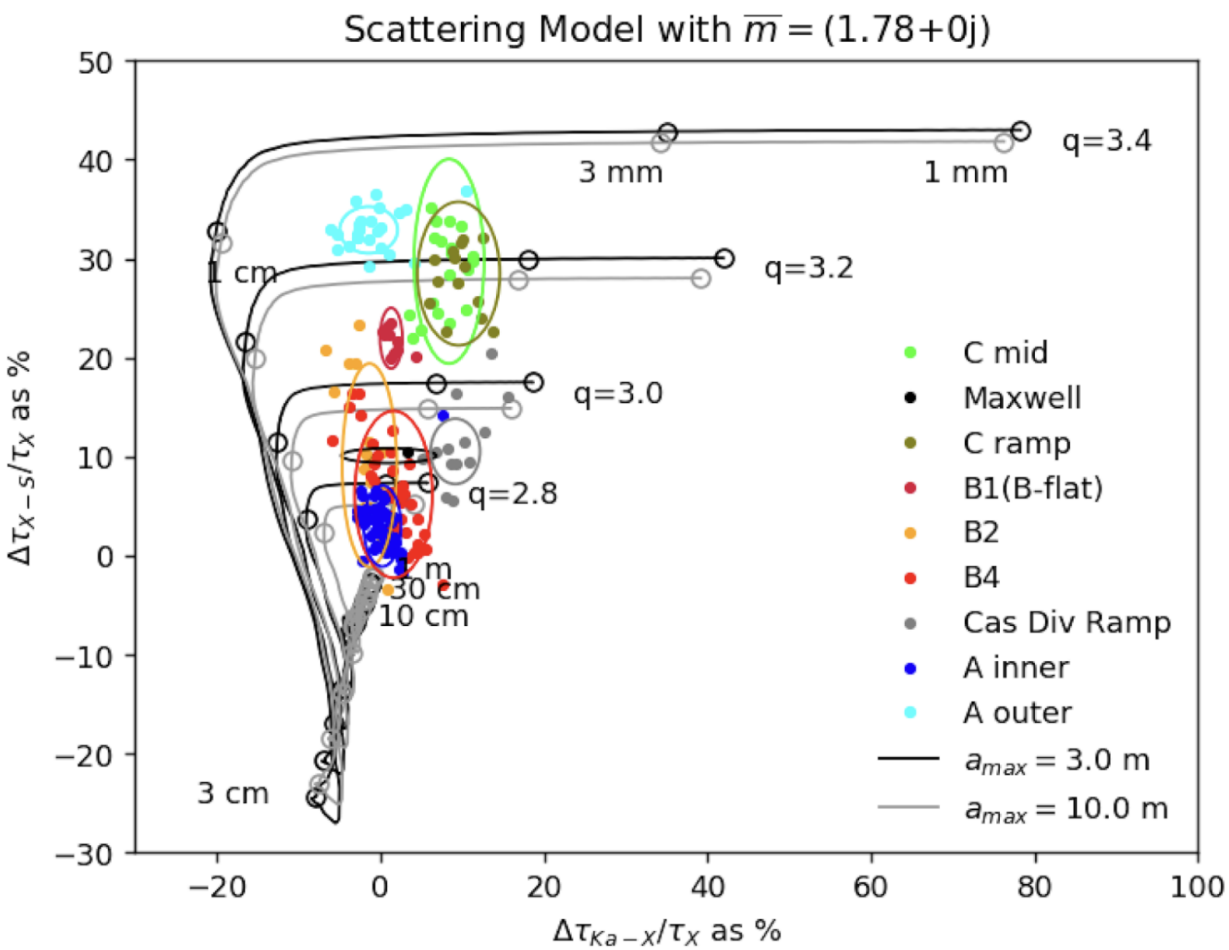
- Values of q and a_{max} determine curves for differential optical depth
- Plotting short/medium differential opacity with medium/long differential opacity significantly constrains q, a_{min}, and a_{max}



Previous Results: Other Ring Features



F Ring

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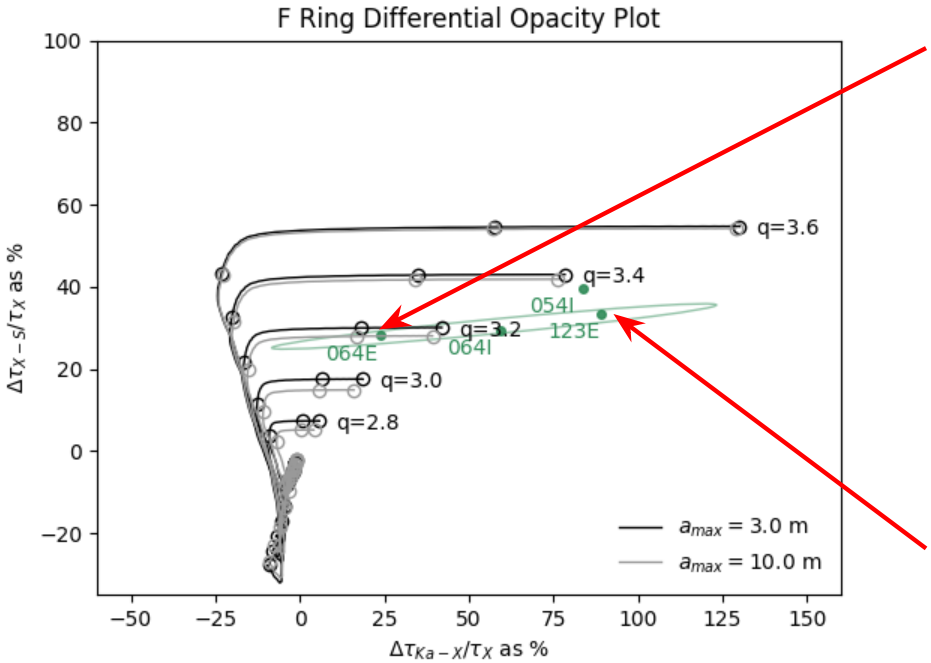

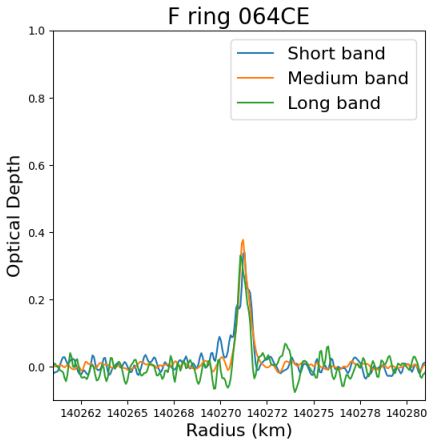

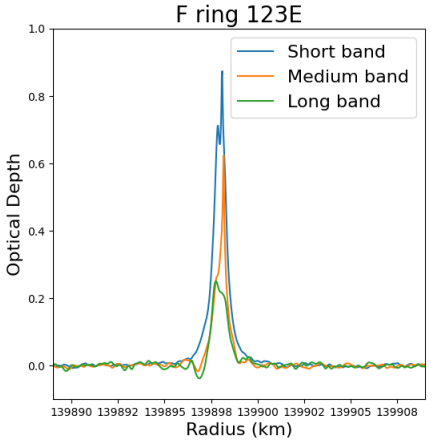

Strange Ringlet

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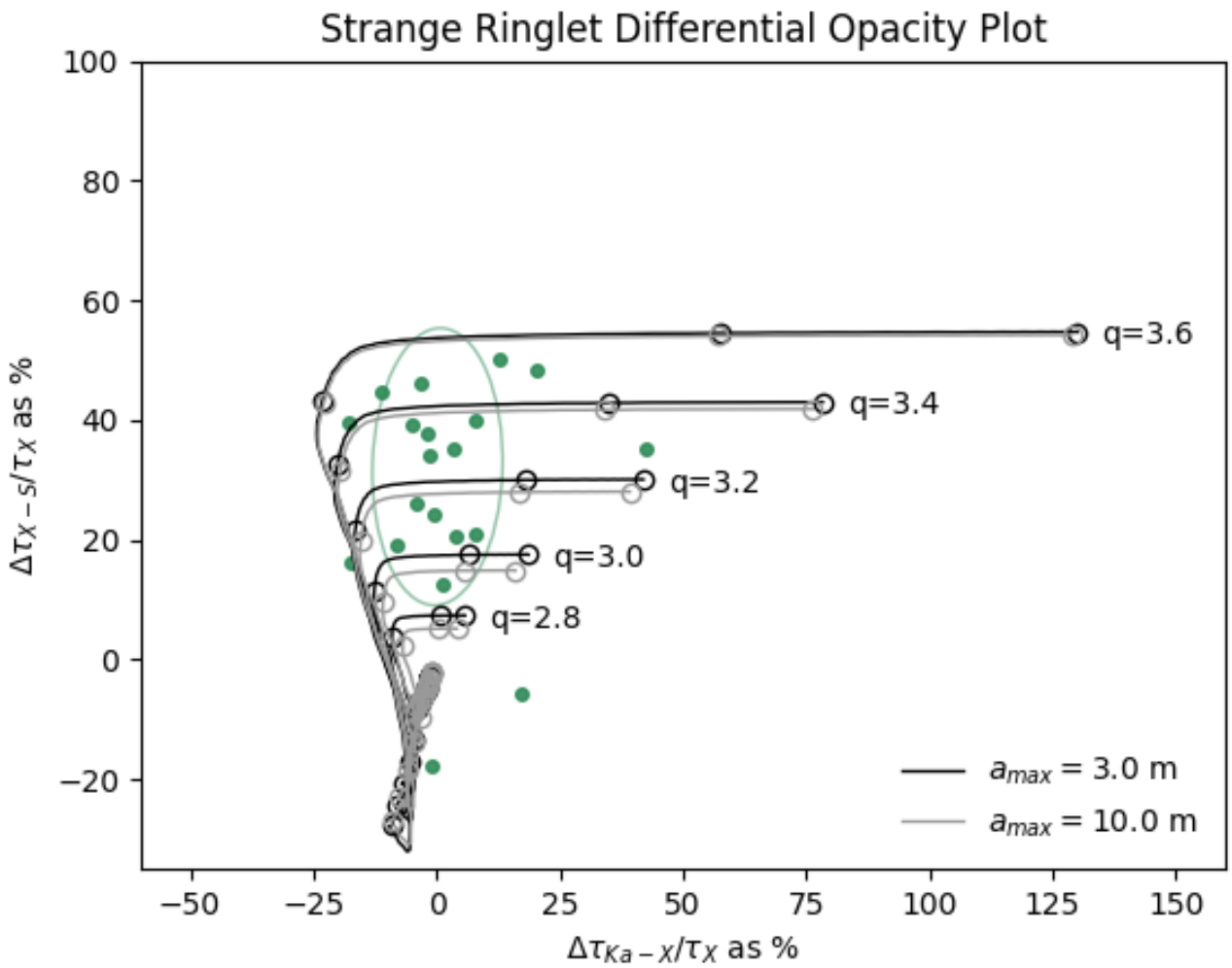
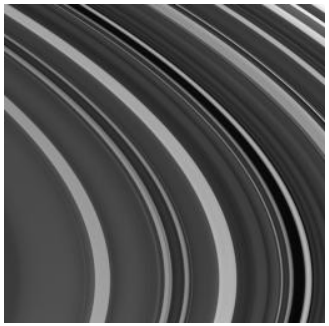
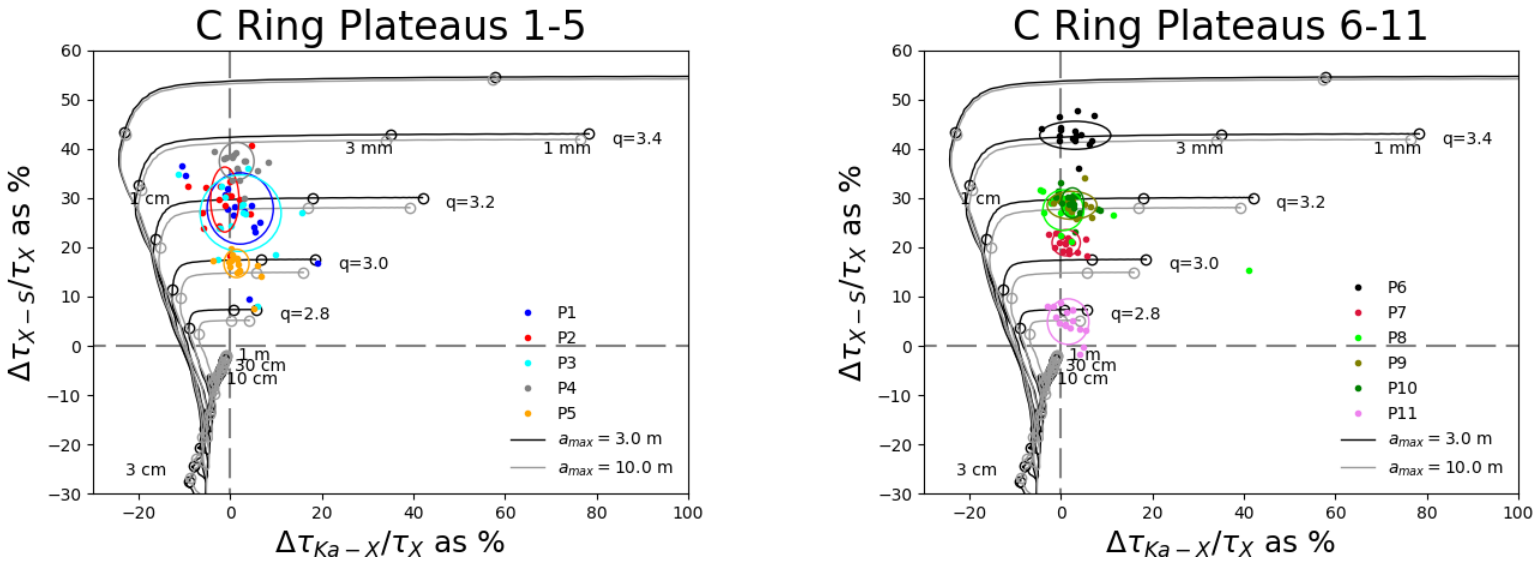


C Ring Plateaus



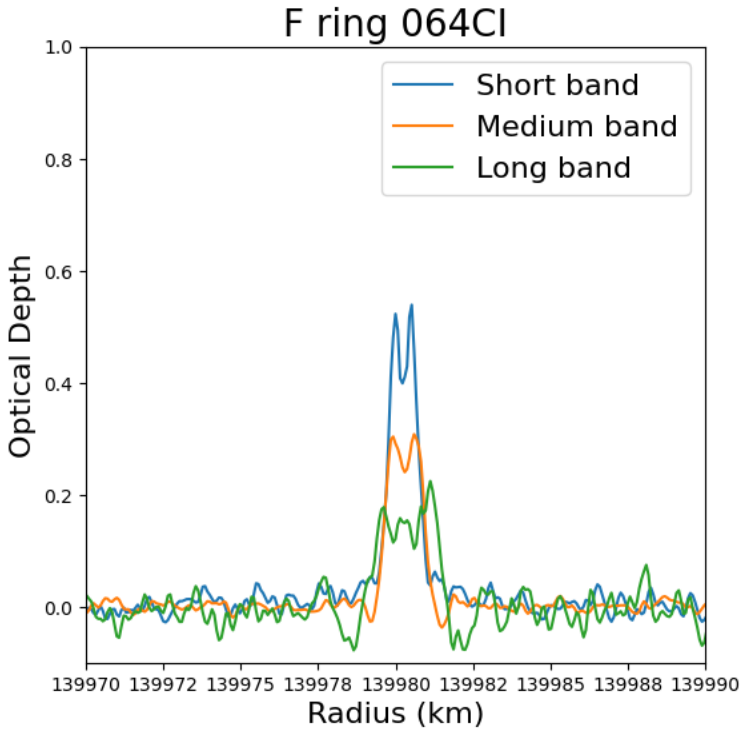
Plateaus are optically "bright" regions in the C ring.



2D differential opacity graph of C ring plateaus.

Concluding Remarks

- High resolution reconstructions allow us to analyze particle sizes in narrow ringlets
- The F ring is unique from other ring regions
- Most easily interpreted as an abundance of smaller particles



Acknowledgments

We would like to thank Professor Richard French and Dr. Ryan Maguire for their invaluable guidance and support through the research process. We also thank Dave Darrow for his feedback on our presentation, and the MIT PRIMES-USA program for this research opportunity.

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