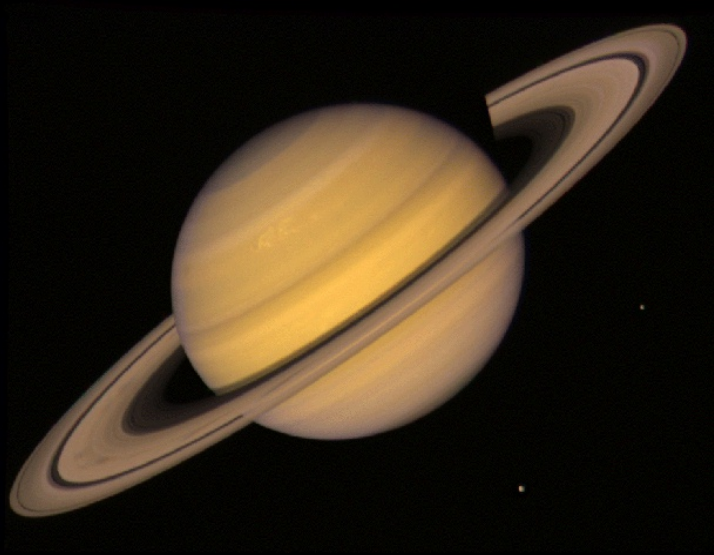
Light Scattering in Saturn's Rings and the Azimuthal Asymmetry



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Azimuthal Asymmetry

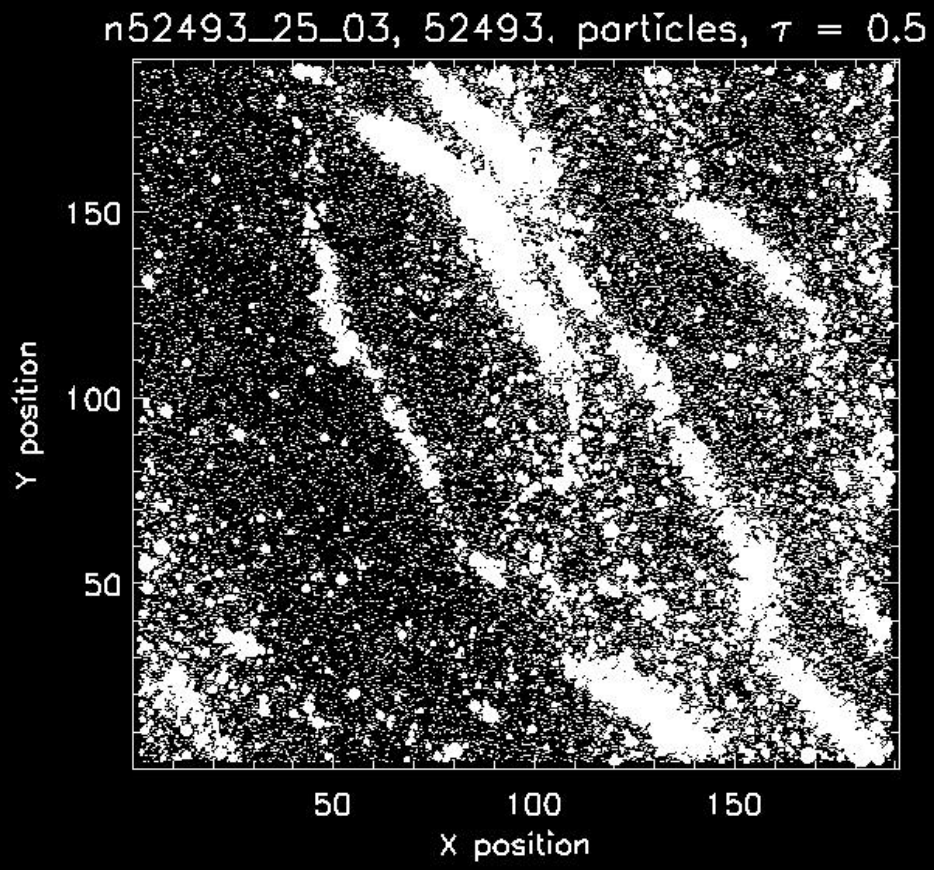
- First observed by Lyot (1929)
- Approximate 30% quadrupole brightness variation along azimuth of A ring
- Many models proposed, but probably due to mutual shadowing between wakes
- Effect more pronounced on dark side of rings
  - Multiple scattering?
- We approach problem with coupled numerical N−body and light−scattering methods

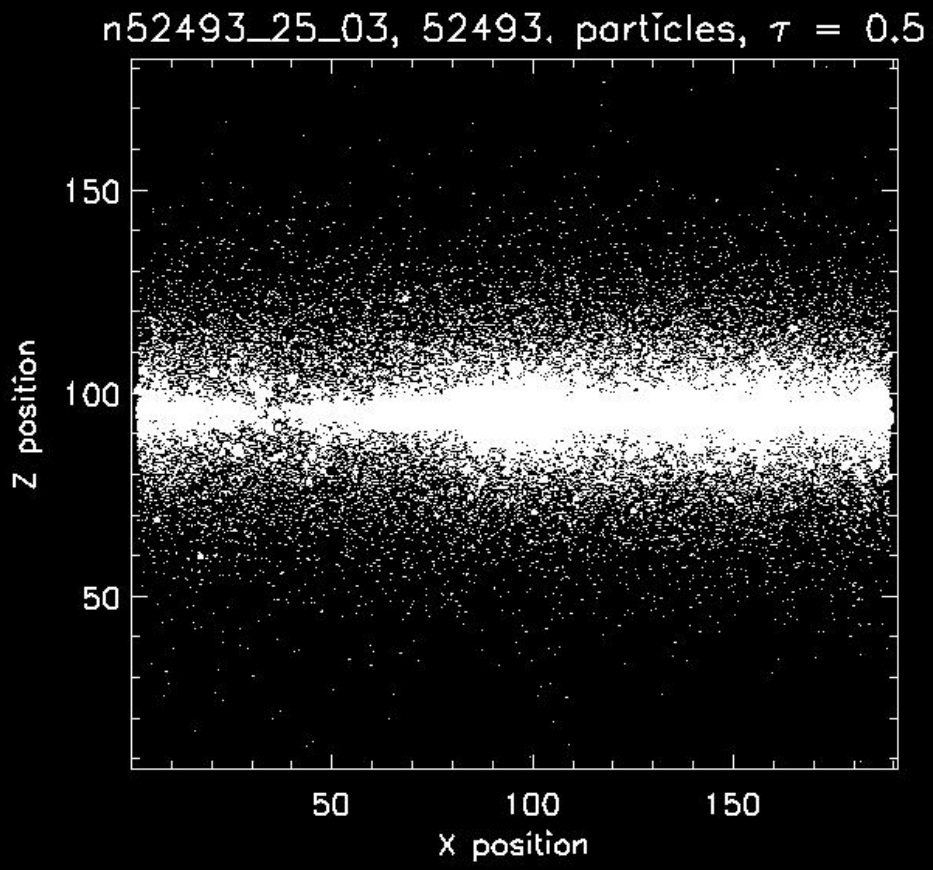
Gravitational particle modeling

- Tracks wakes in rings
- 3D N−body gravitational/collisional simulation, 64−processor Beowulf
- Periodic boundary conditions, ’sliding patch’ model
  - n = 200,000
  - r = 0.2 −2 m
  - 2 km x 2 km
  - $\tau = 0.5$
  - Coefficient of restitution

Dynamical simulation results

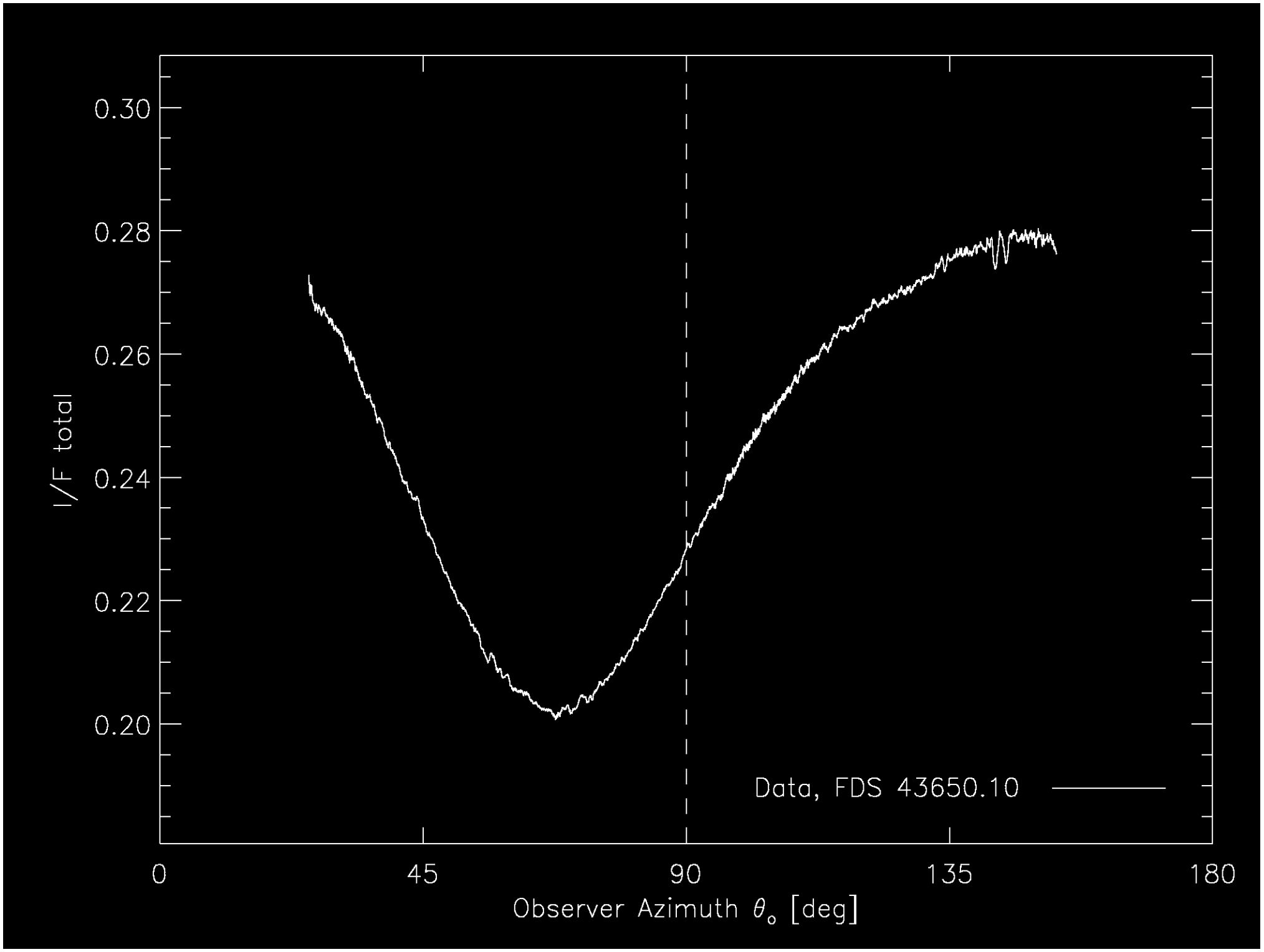
- Stable wakes created on 10−100 m spatial scales after ~ 10 orbits
- Largest particles are concentrated in wakes

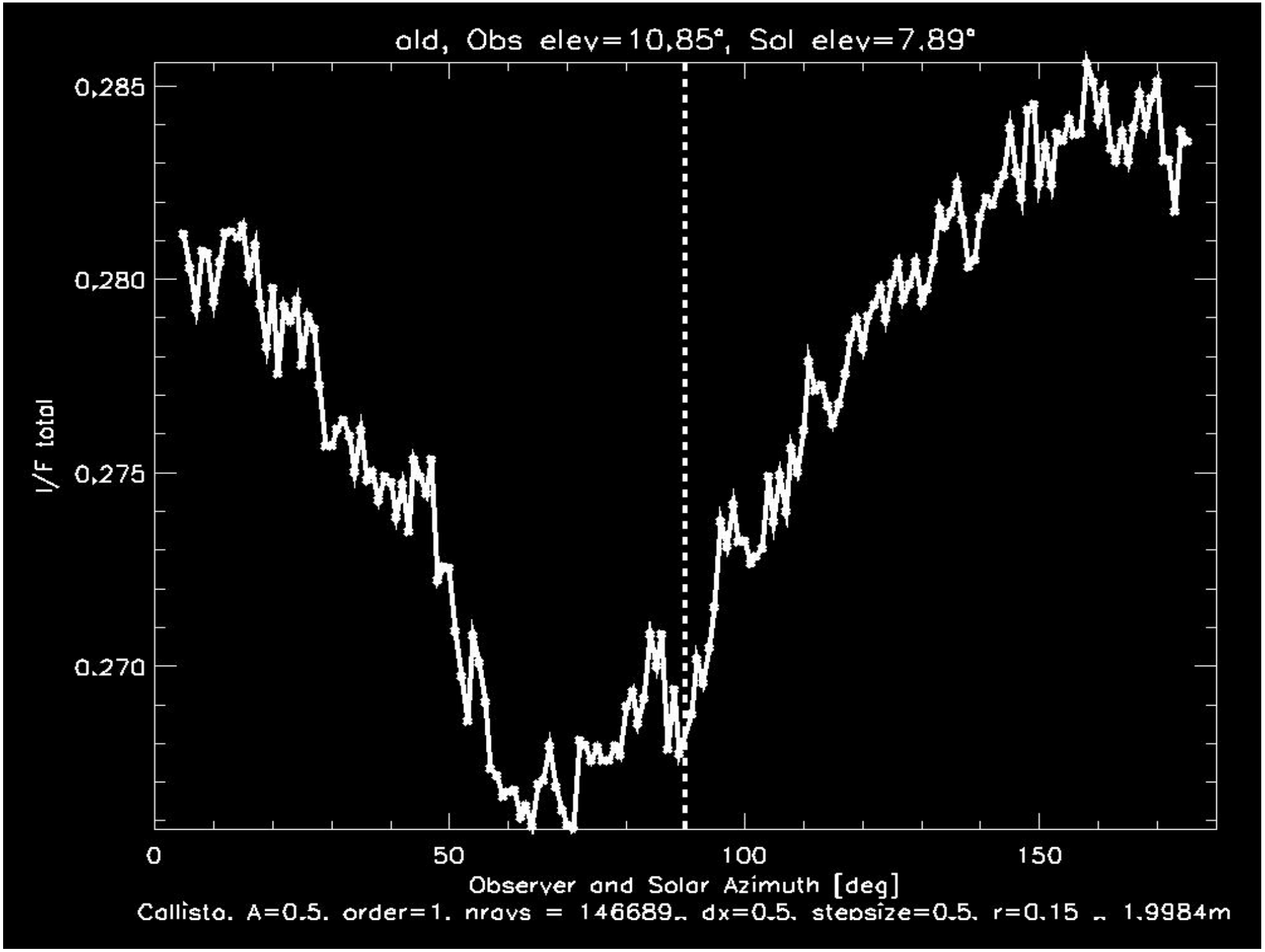




Light Scattering Model

- General purpose ray−tracing code follows light ray and its secondary, tertiary, etc rays as passes through box of particles.
- Uses arbitrary scattering order, phase function, source & observer positions.
- Includes sunshine, Saturnshine
- Typical runs are 50,000 particles, 10^7 rays


0.30
0.28
0.26
0.24
0.22
0.20
I/F total
0
45
90
135
180
Observer Azimuth θ_o [deg]
Data, FDS 43650.10


old, Obs elev=10.85°, Sol elev=7.89°
0.285
0.280
0.275
0.270
I/F total
0
50
100
150
Observer and Solar Azimuth [deg]
Callisto. A=0.5. order=1. nrays = 146689. dx=0.5. stepsize=0.5. r=0.15 . 1.9984m

Light scattering results I

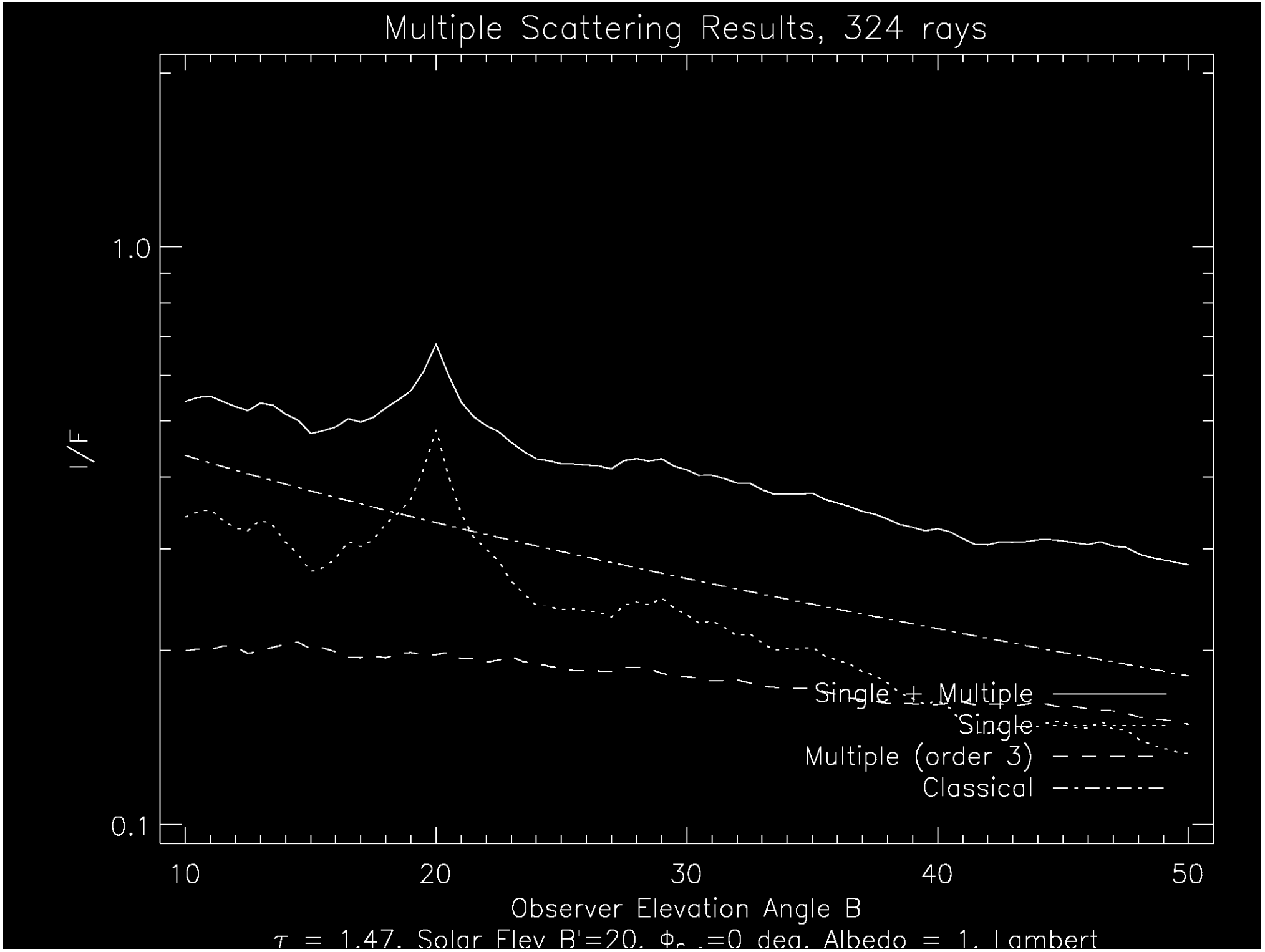
- We successfully reproduce position and shape of azimuthal asymmetry
- Our 7% p−p amplitude is low by factor of ~4
  - May be due to narrow size distribution, r = 0.2 − 2 m
  - Amplitude does not appear to be strong function of surface density or coeff. restitution
- Asymmetry is due to particles in interwake regions being shadowed by thick wakes

Light scattering results II: Other general purpose results

- Ring thickness
  - I/F of ring shown to depend on ring thickness
  - Direct measurement of ring thickness possible using scattering model
- Opposition effect
  - Reproduced. Initial runs suggest that opposition surge cannot be due entirely to shadowing between particles
- Numerical modeling of dark side of rings due to multiple scattering, Saturnshine

Conclusion

- Complete, numerical simulation of azimuthal asymmetry in optically thick rings due to collisional-gravitational wakes
- Magnitude of asymmetry still needs to be explored


Multiple Scattering Results, 324 rays
1.0
0.1
I/F
10
20
30
40
50
Observer Elevation Angle B
Single + Multiple
Single
Multiple (order 3)
Classical
τ = 1.47. Solar Elev B'=20. Φs-o=0 deg. Albedo = 1. Lambert