The Planet-Disk Connection

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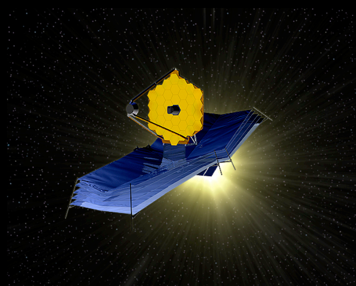
GSFC Missions and Centers

JWST

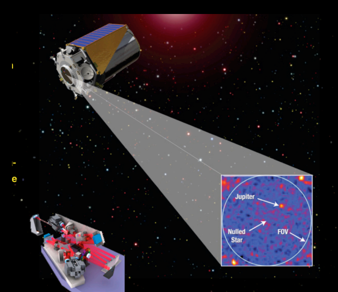


EPOXI

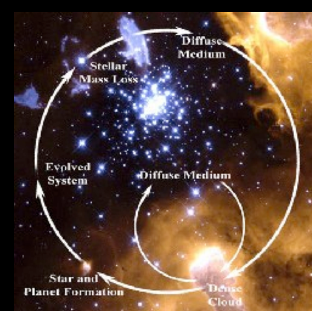
THEIA/TPF/NWO

FKSI

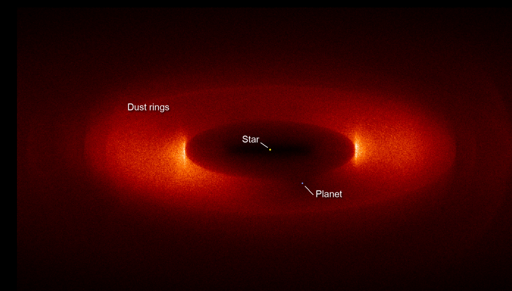
EPIC



Center for Astrobiology



Theory



Opportunities

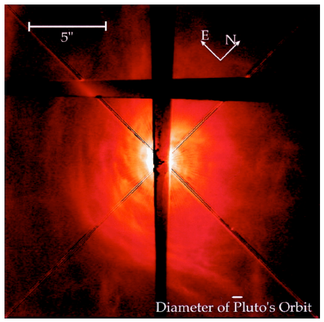
Graduate Student Research Program
http://fellowships.hq.nasa.gov

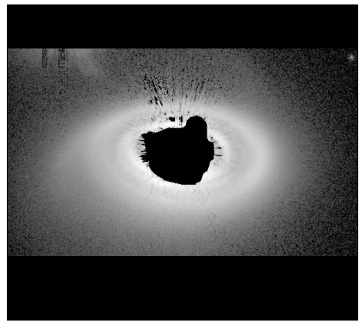
NASA Postdoctoral Program
http://nasa.orau.org/postdoc/

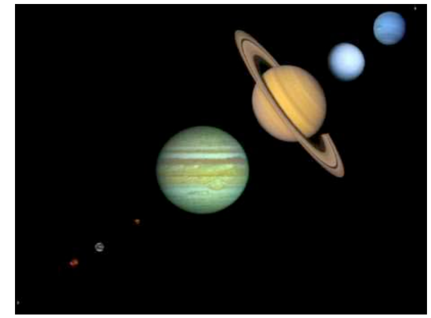
Sagan Fellowships
http://nexsci.caltech.edu/sagan/

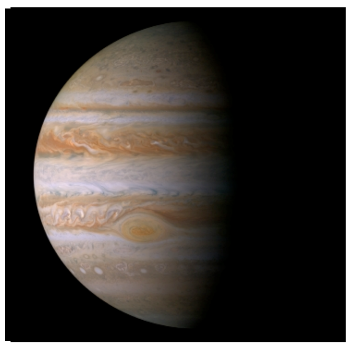
Time

0My 1Myr 5Myr 10Myr 1 Gyr









Jennifer Wiseman

Hannah Jang-Condell

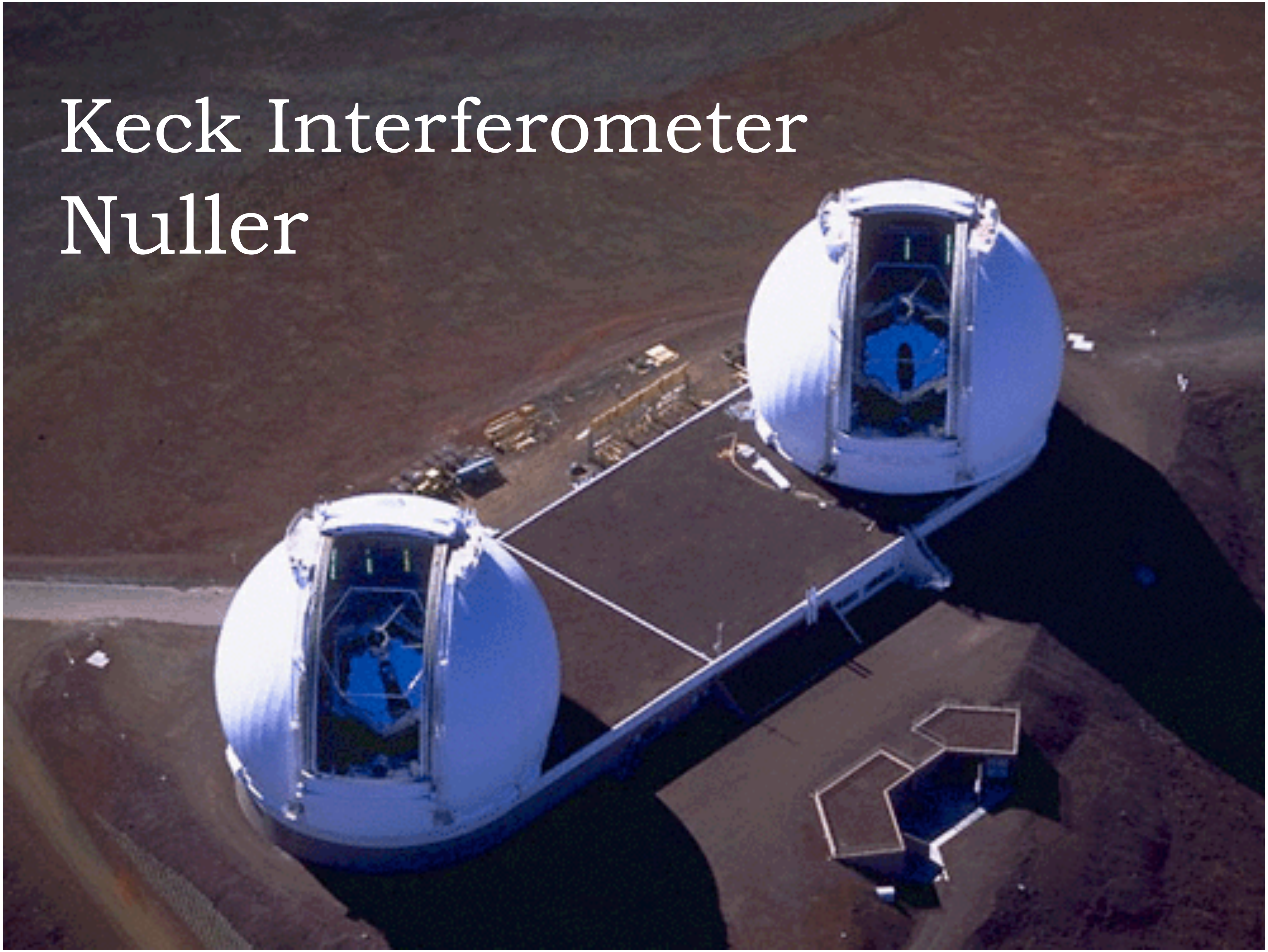
Thayne Currie

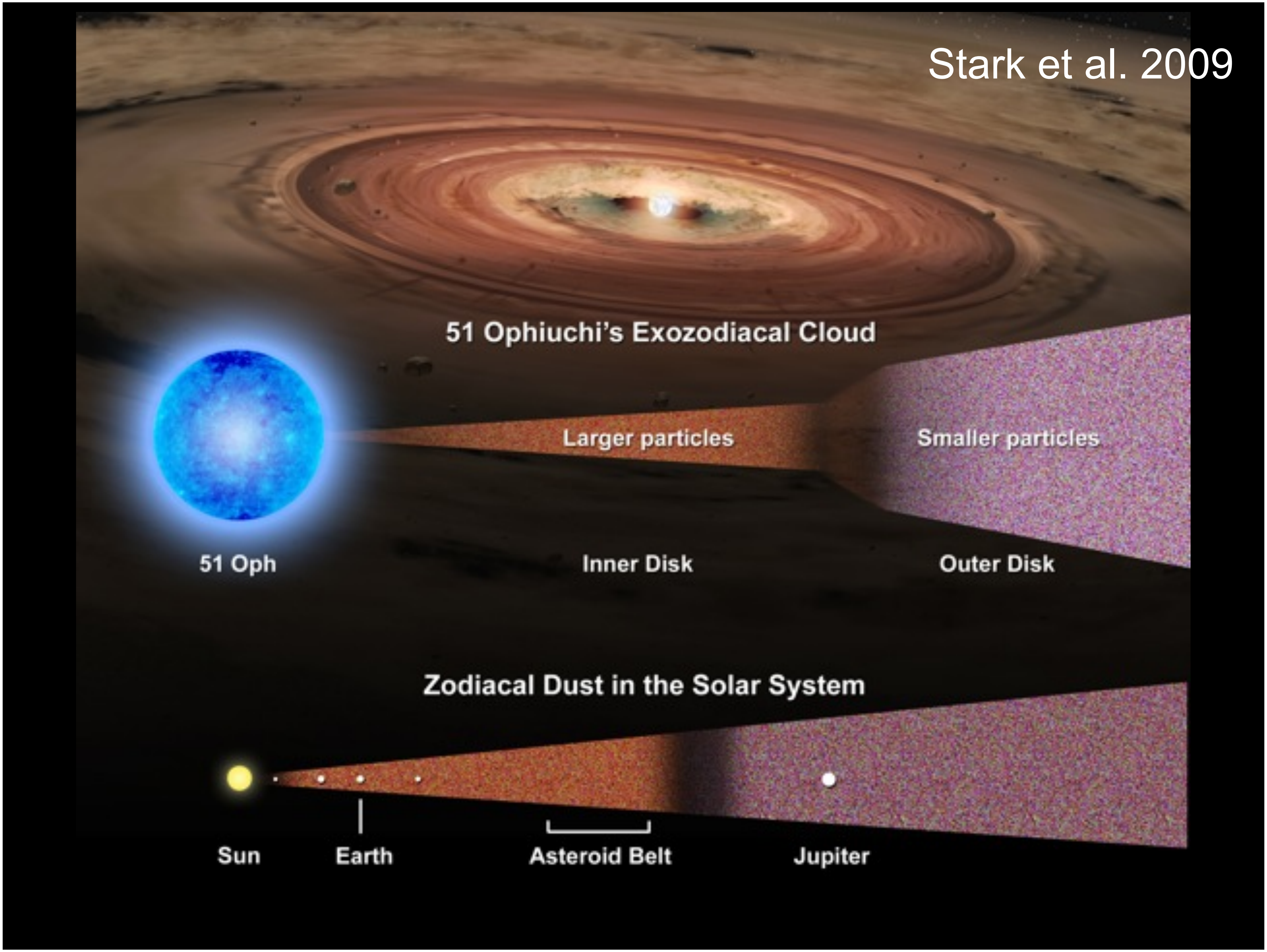
Katya Verner

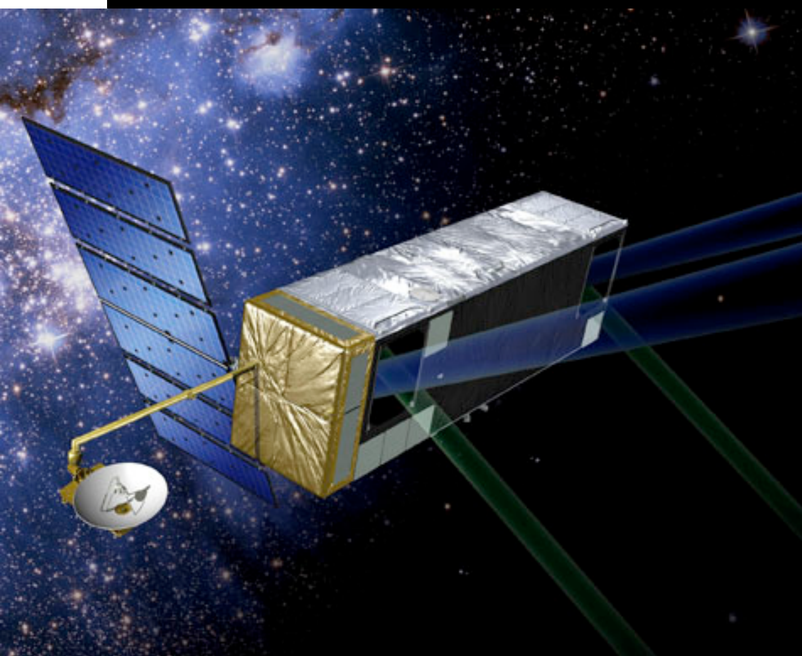
Christopher Stark and John Debes

Brian Jackson

Keck Interferometer Nuller

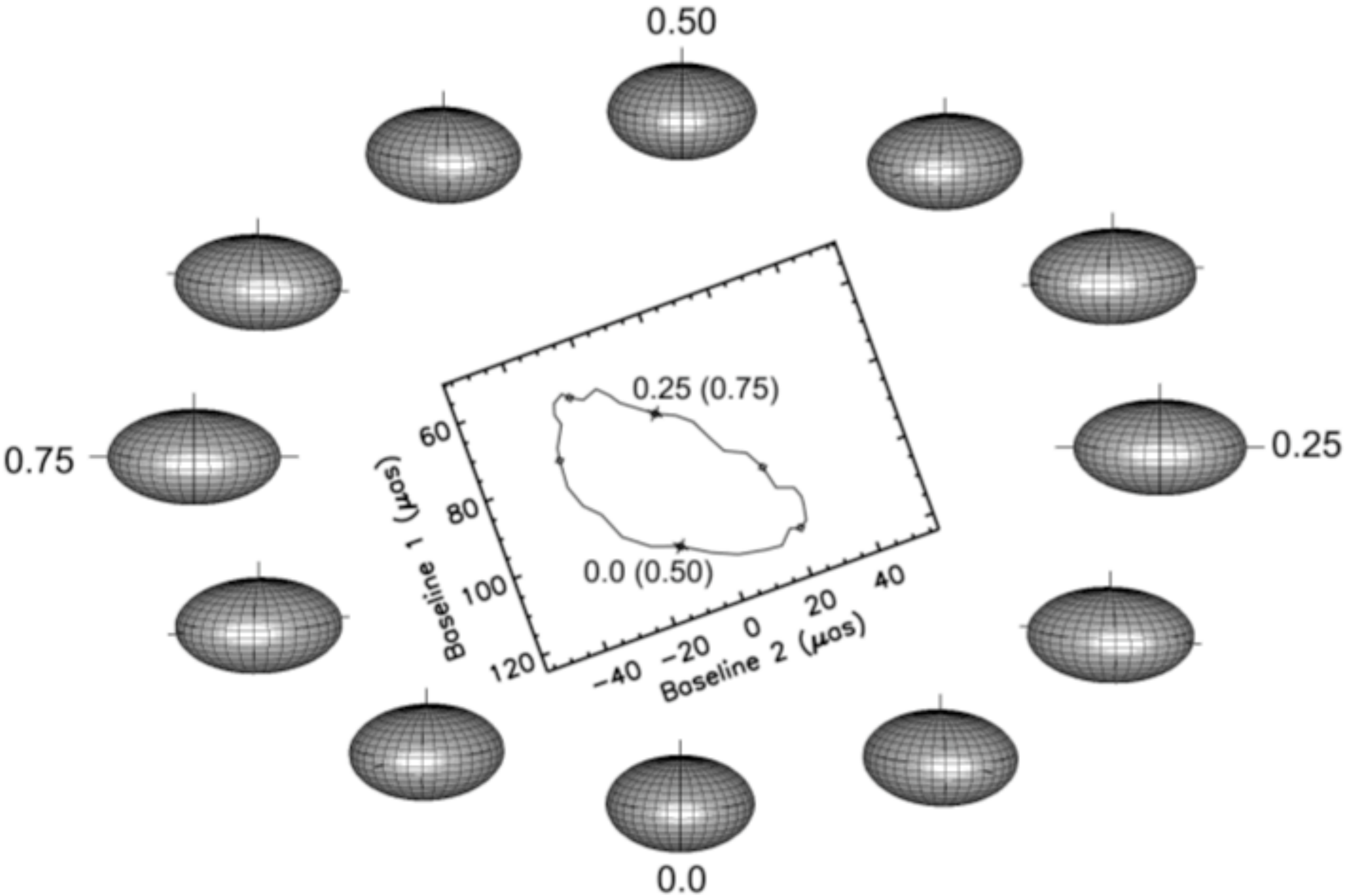



Stark et al. 2009
51 Ophiuchi's Exozodiacal Cloud
Larger particles
Smaller particles
51 Oph
Inner Disk
Outer Disk
Zodiacal Dust in the Solar System
Sun
Earth
Asteroid Belt
Jupiter

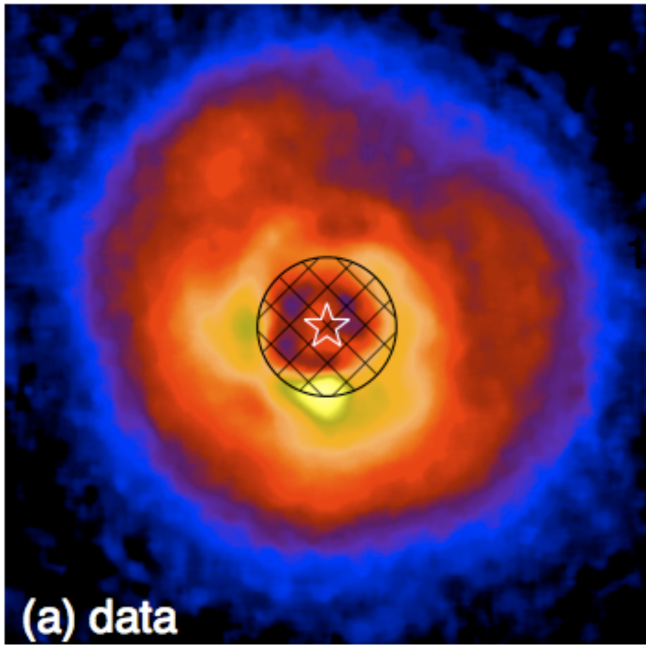


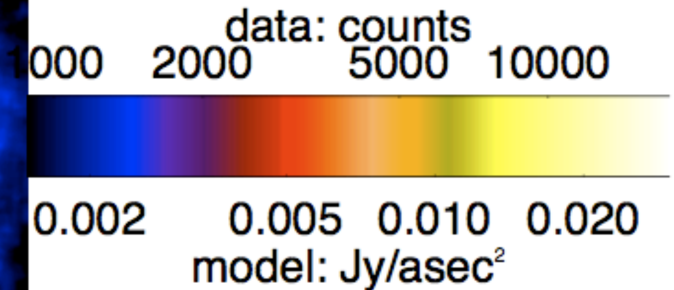
SIM
Planetquest

Jianyang Li et al. 2009



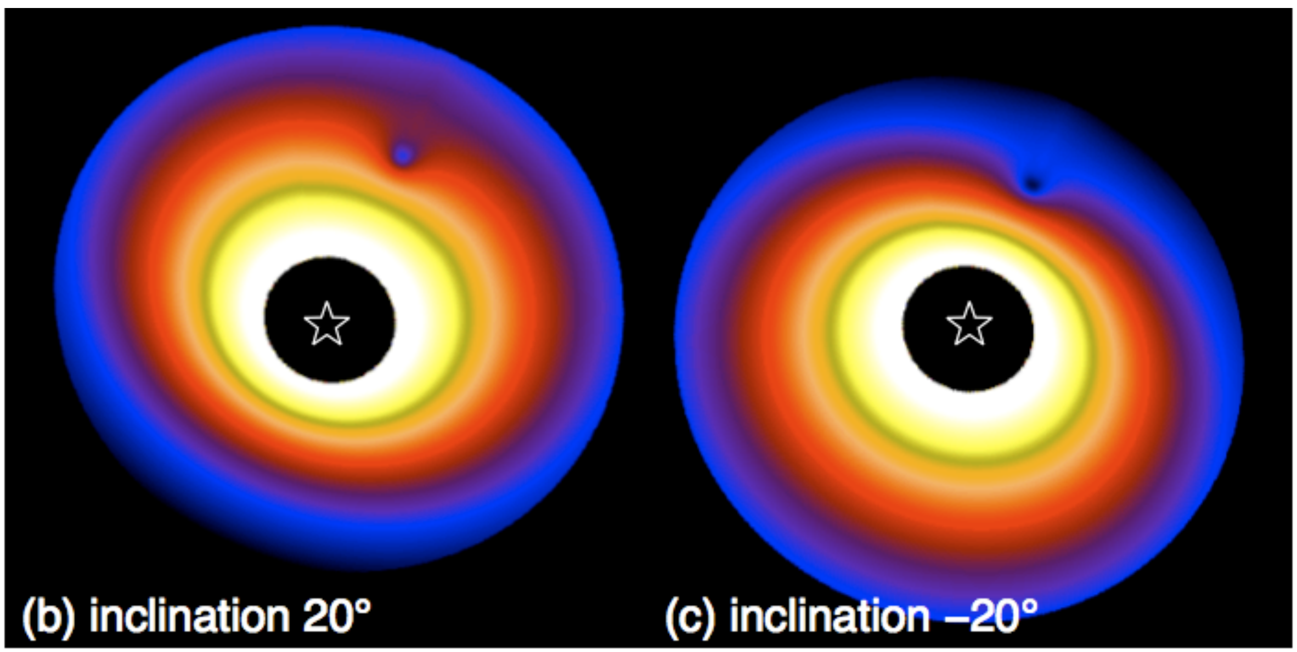
AB Aurigae



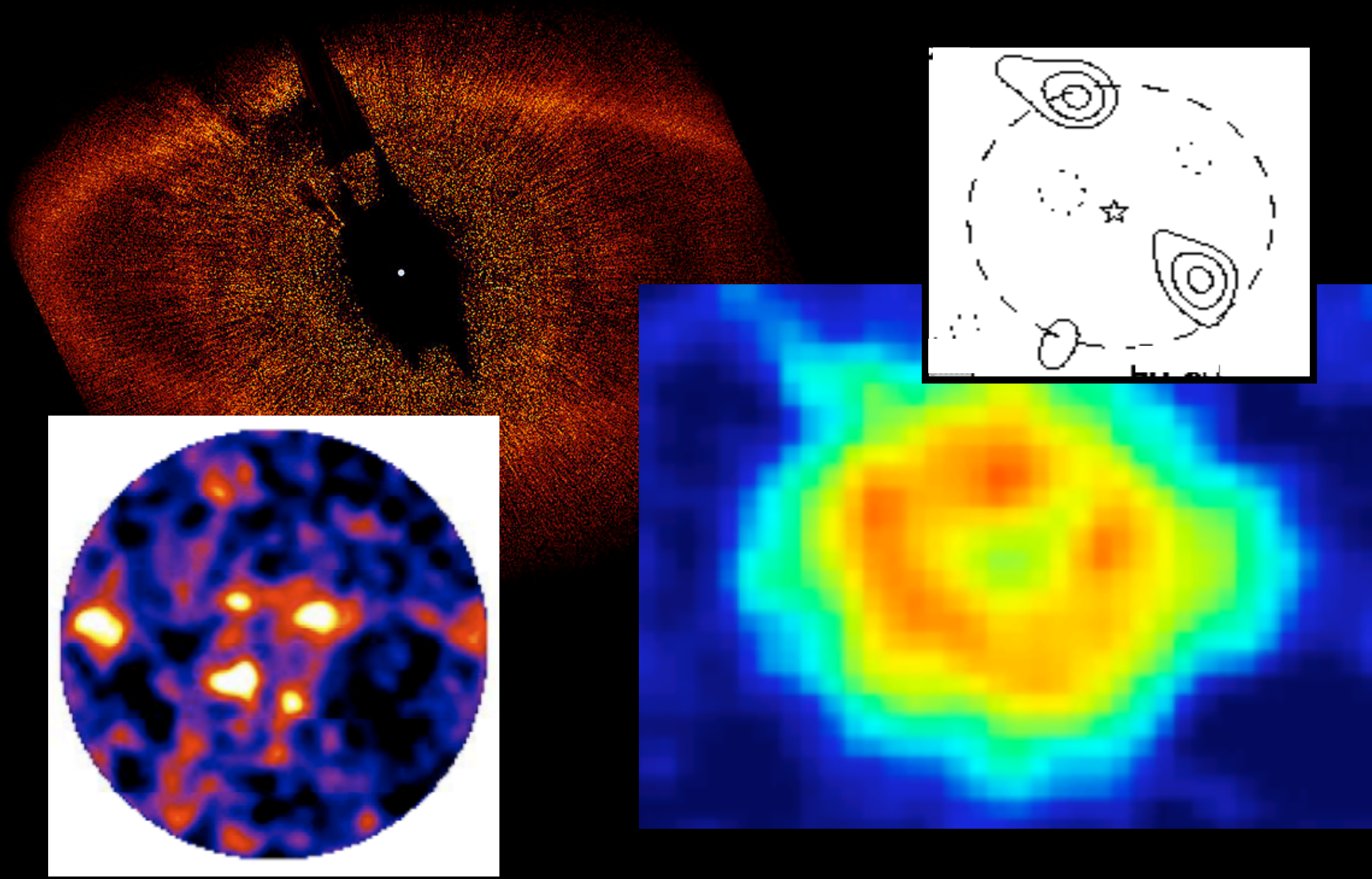


Oppenheimer et al. 2008

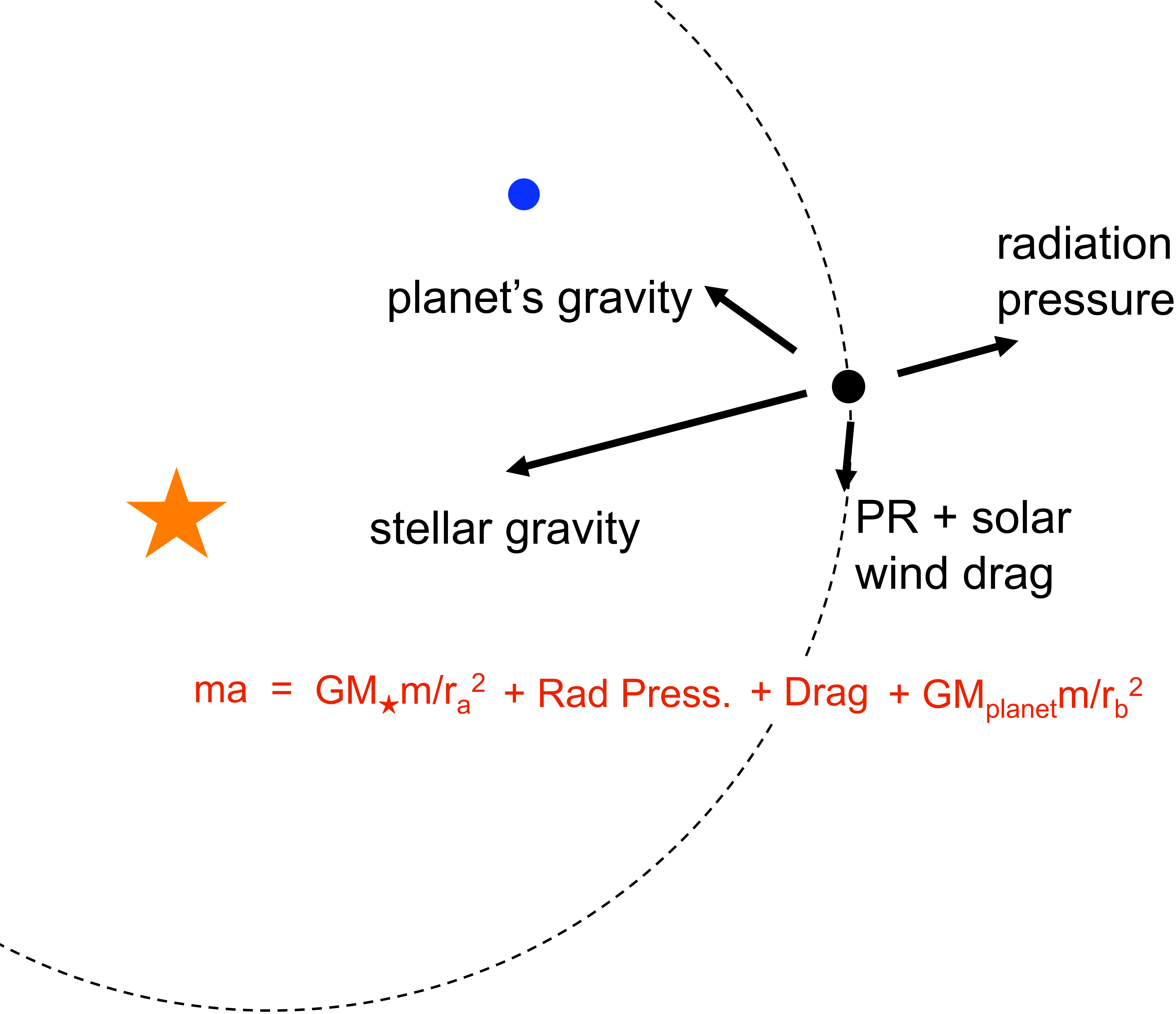
144 AU = 1"

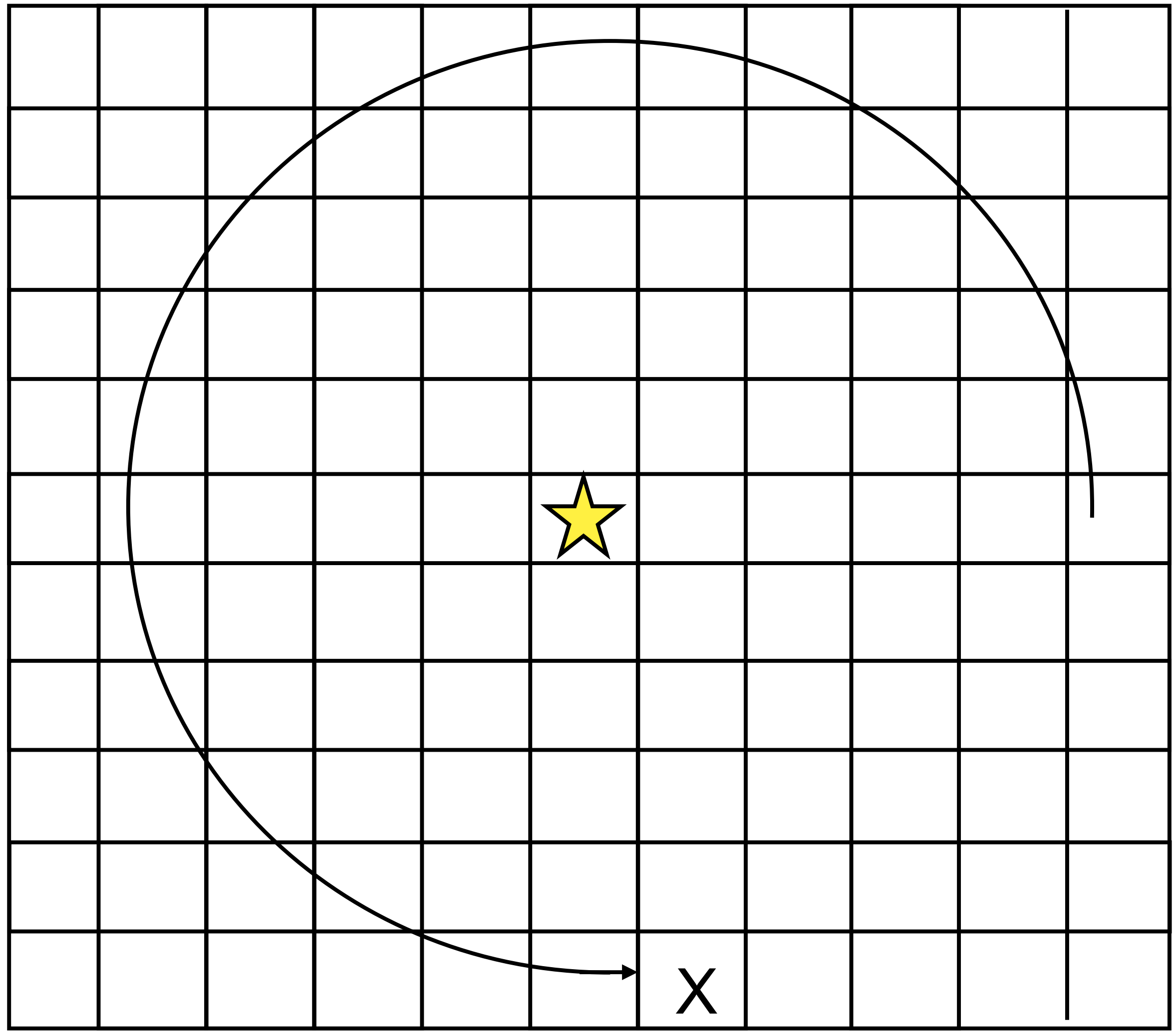


Jang-Condell & Kuchner 2009

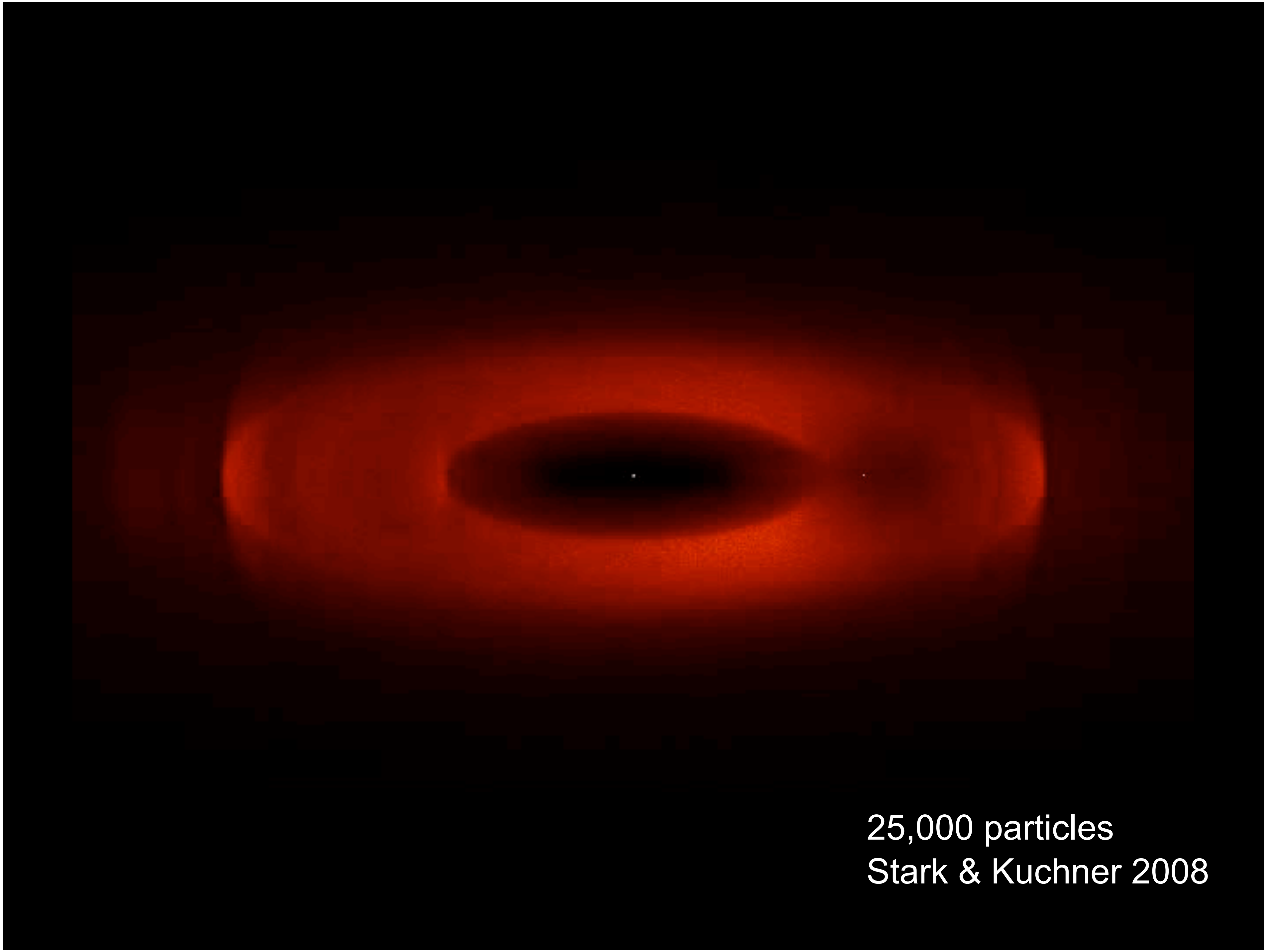


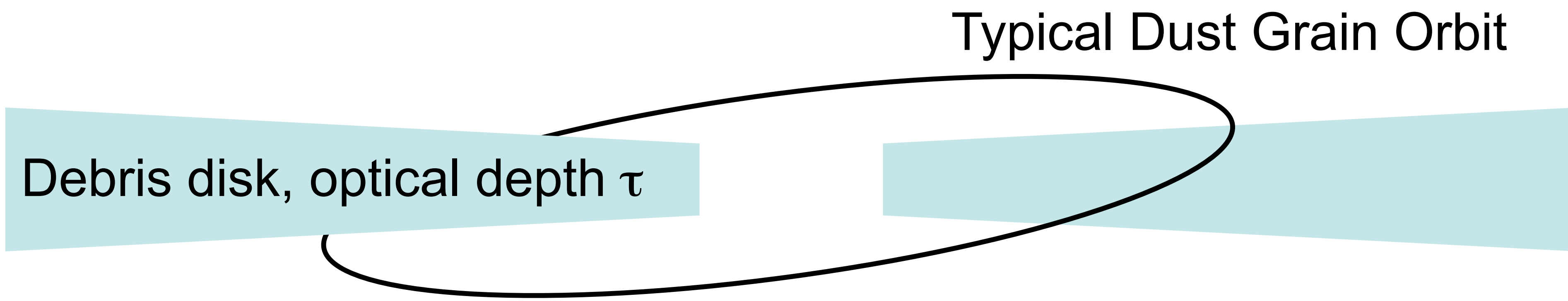
Collisional Grooming Model


planet's gravity
radiation pressure
stellar gravity
PR + solar wind drag
ma = GM★m/ra2 + Rad Press. + Drag + GMplanetm/rb2



e.g. Jackson & Zook (1989), Dermott et al. (1994), Wyatt (1999), Liou & Zook (2000), Wilner et al. (2002), Quillen & Thorndike (2002), Moro-Martin & Malhotra (2005), Reche et al. (2008), Debes et al (2009)


25,000 particles
Stark & Kuchner 2008



$$T_{Collision} \sim T_{Orbit} / (2\tau)$$

$$\eta_0 \sim T_{PR}/T_{Collision}$$

Stark & Kuchner 2009

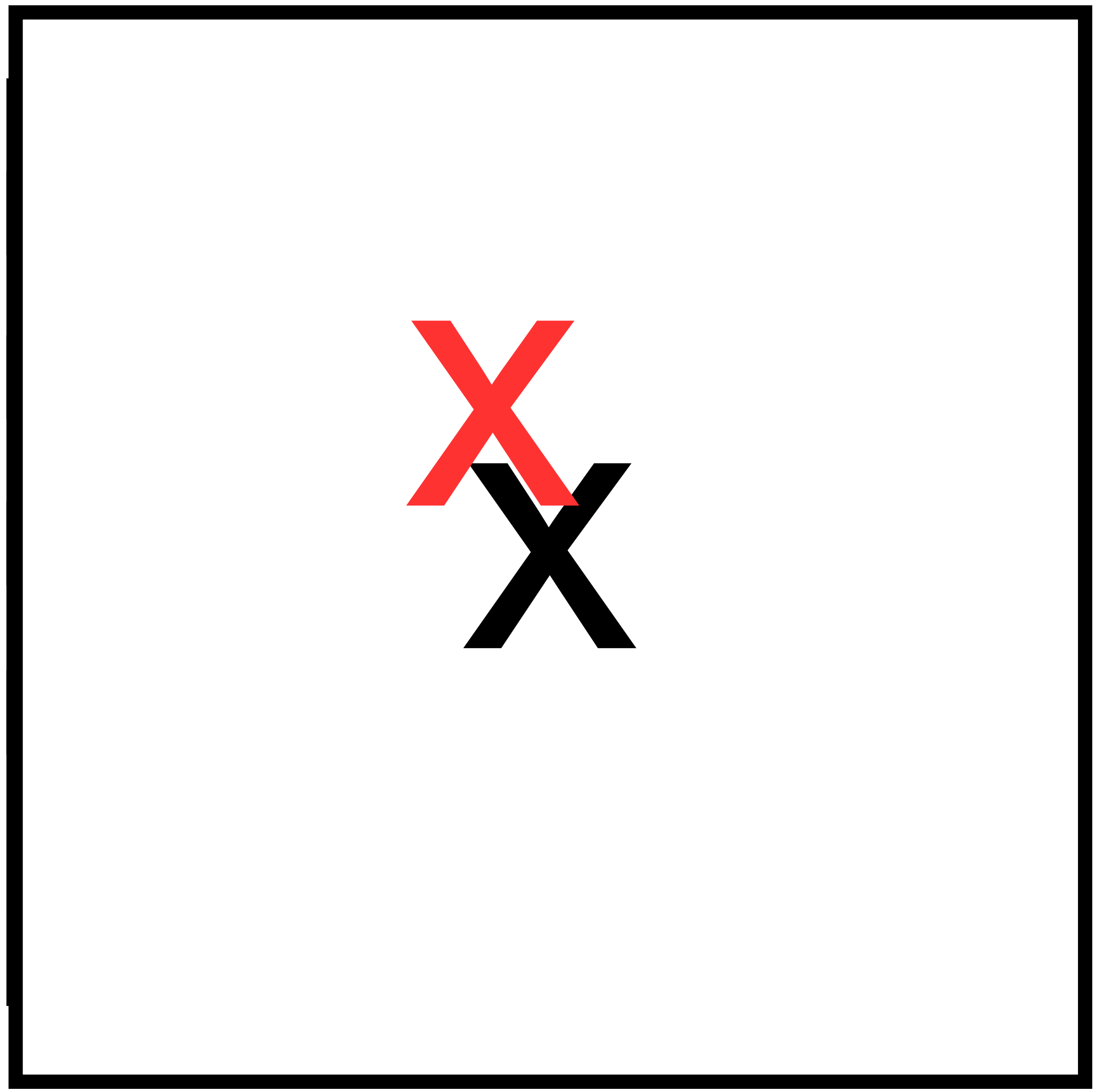
Simultaneously solve:

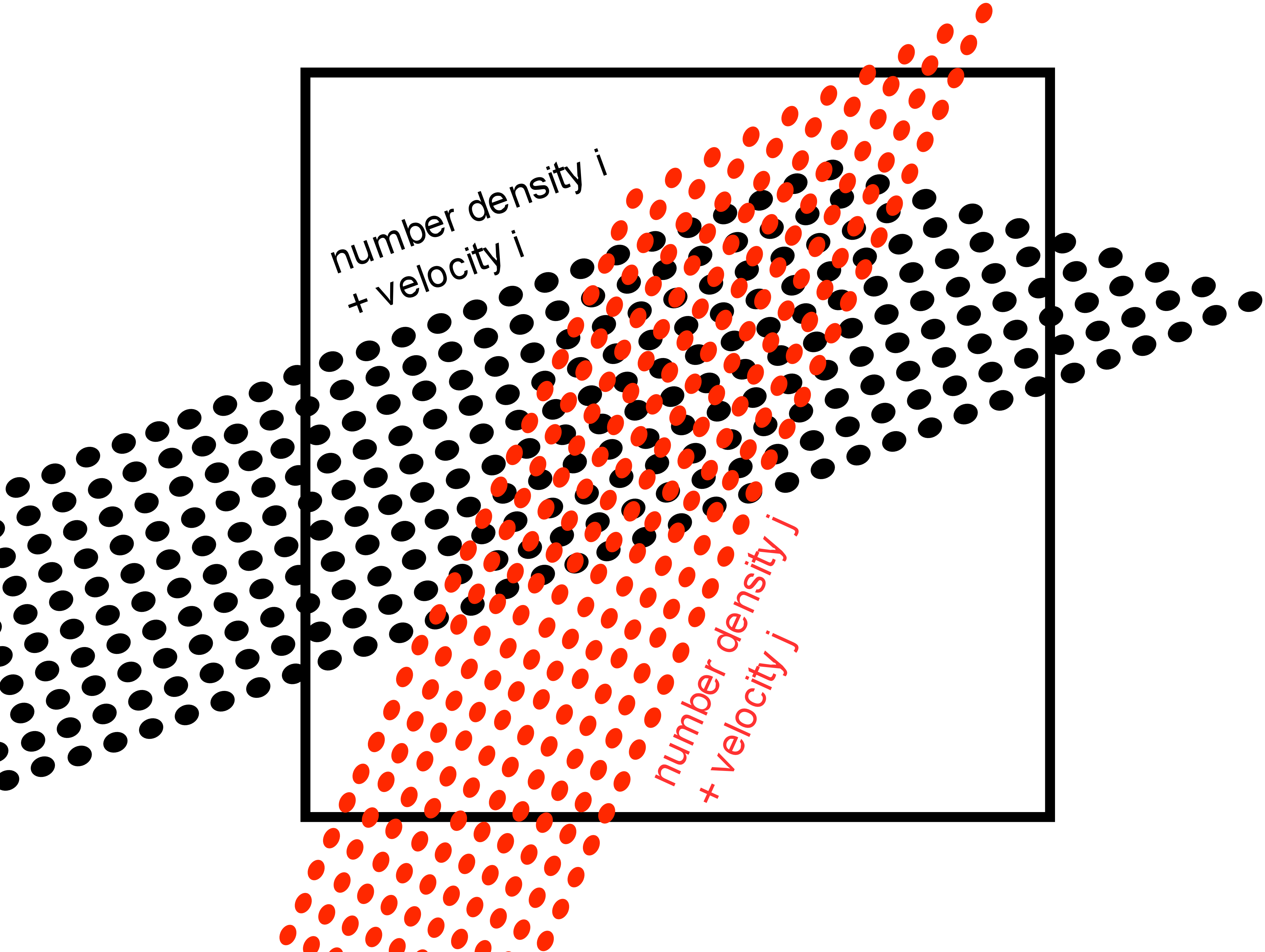
$$F = ma$$

Dynamical equation

$$\nabla \bullet (\rho \vec{v}) - \frac{\partial \rho}{\partial t} = \left. \frac{d\rho}{dt} \right|_{coll}$$

Mass Flux equation


X
X


number density i
+ velocity i
number density j
+ velocity j

$$\text{collision rate } i = \sum_{i \neq j} n_i \sigma_i \left| \Delta v_{ij} \right|$$

~~all 10^{22} particles~~

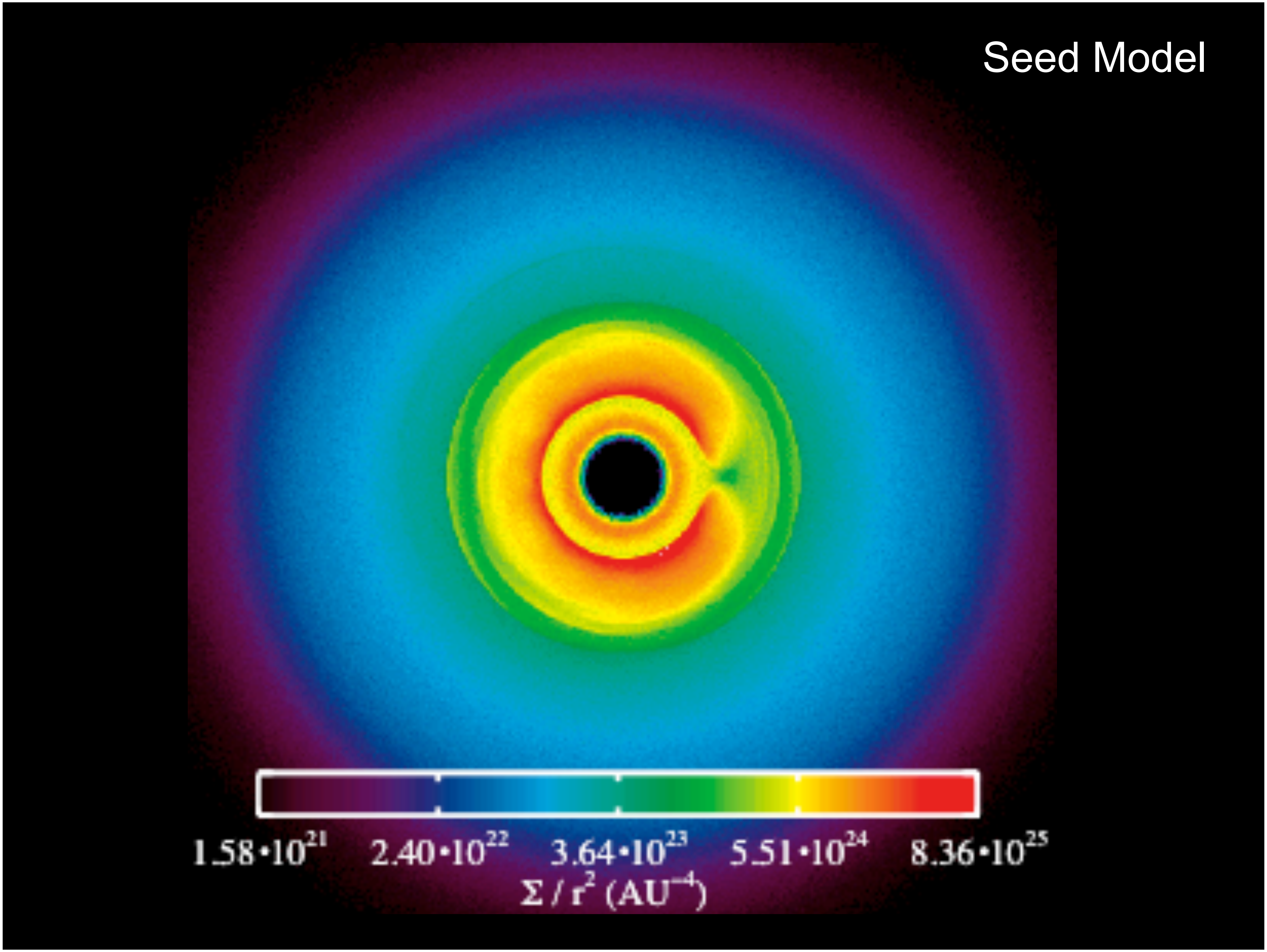
all 10^{5} streams

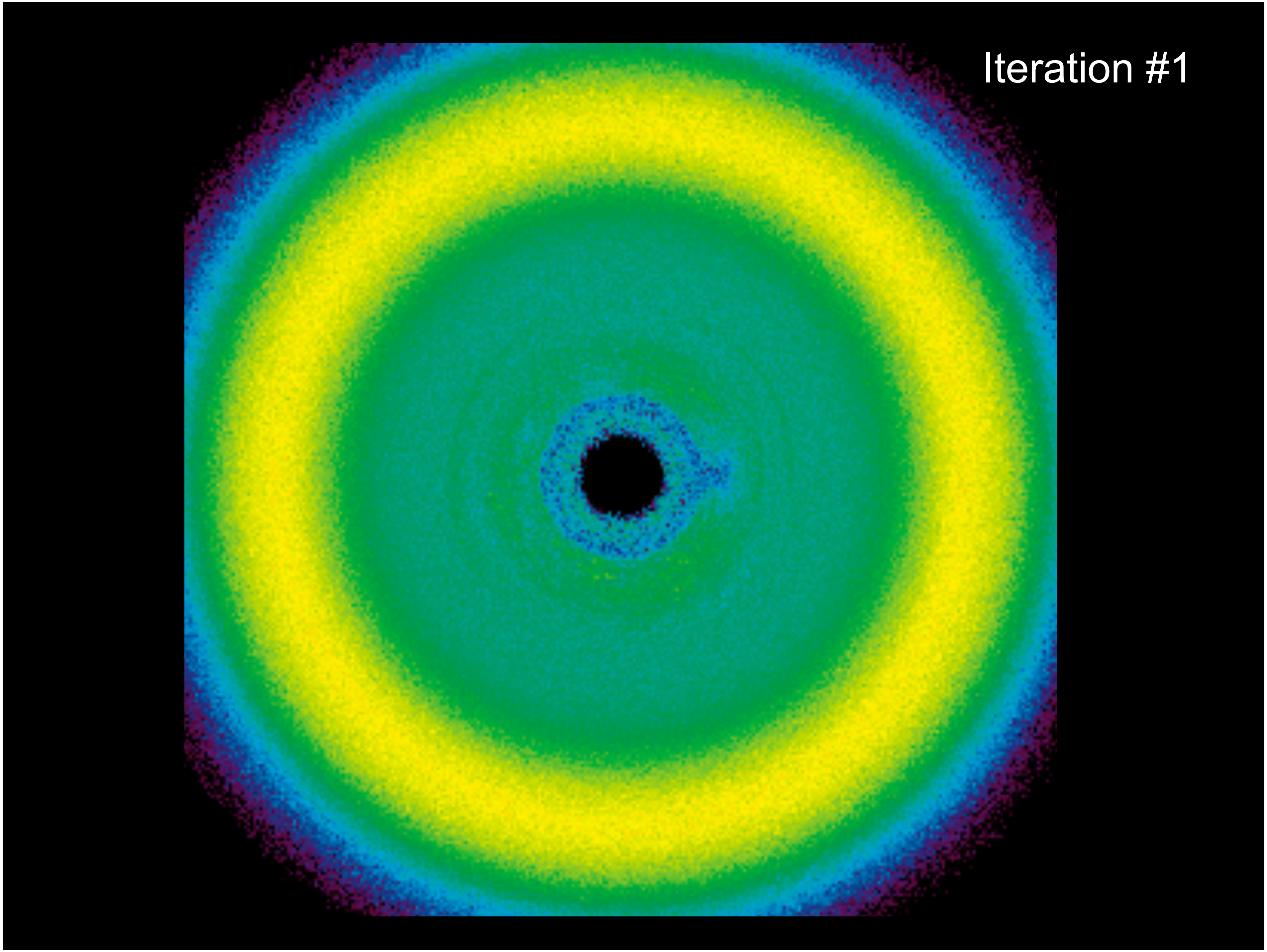
OK as long as collision time >> sampling time.

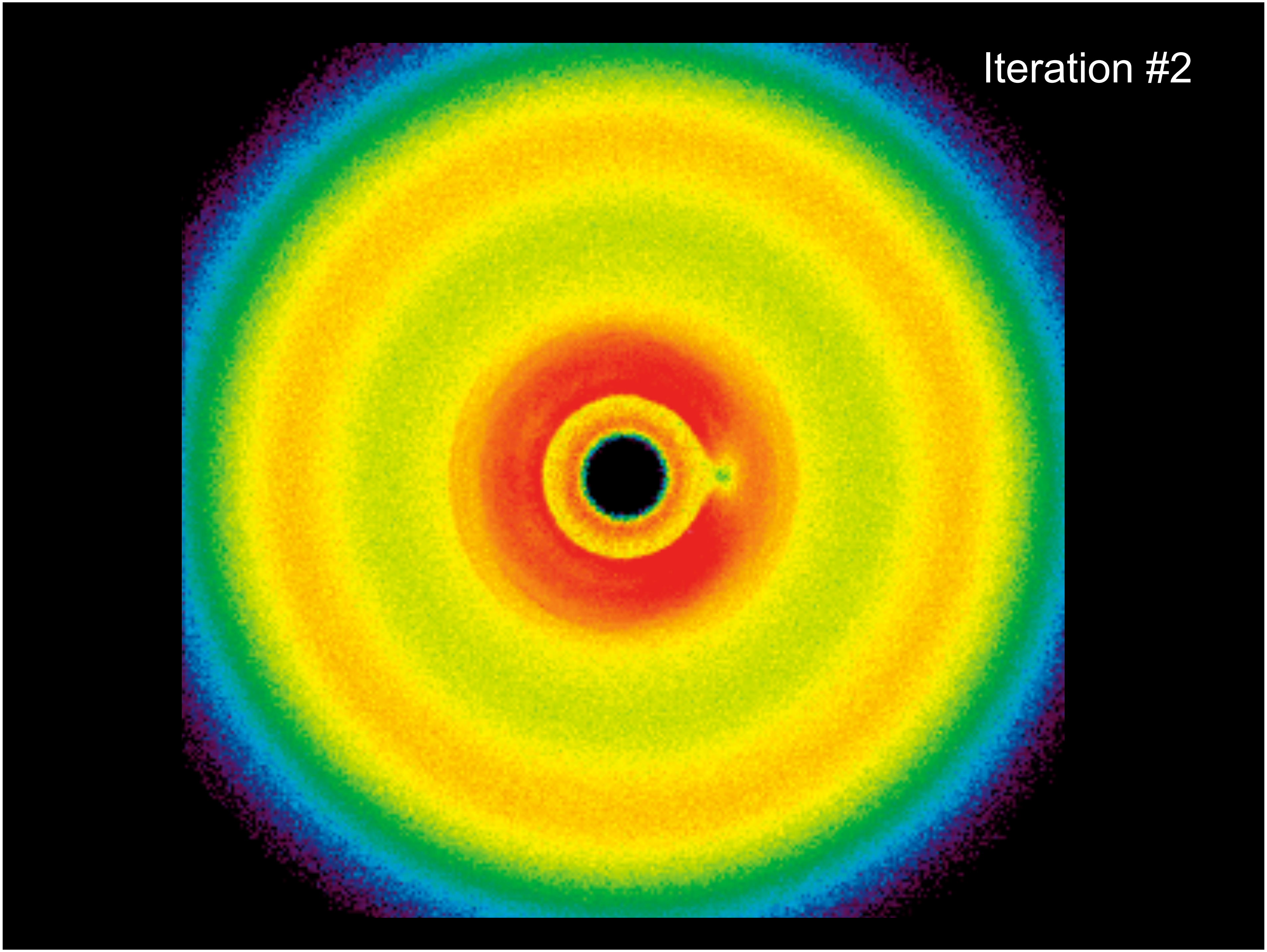
Collisional Grooming Algorithm

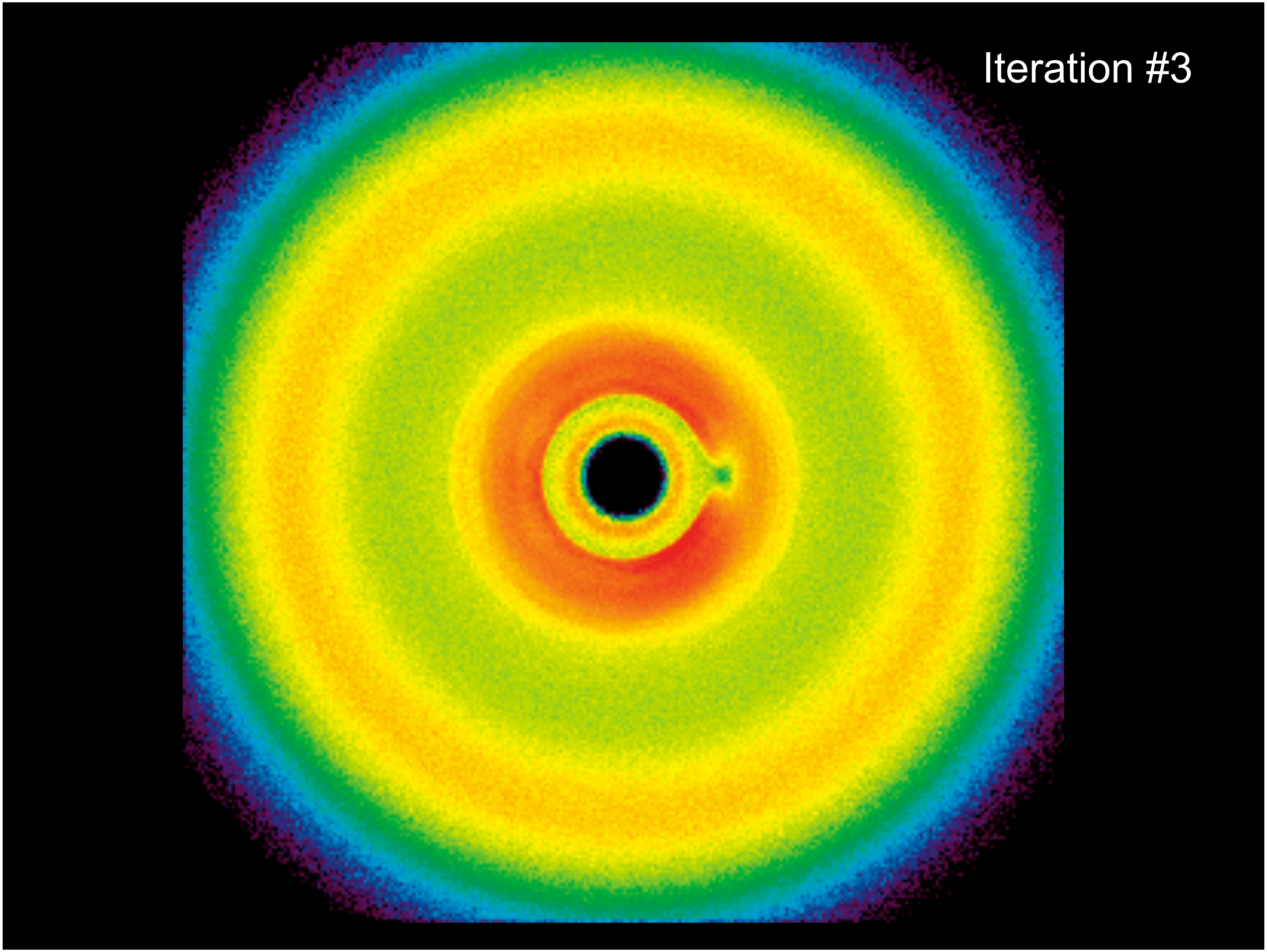
1. Integrate particle orbits.
2. Record positions and velocities in a histogram (distribution function).
3. Allow particle streams to interact with distribution function.
4. Update distribution function by weighting the streams.
5. Repeat 3-4 until the process converges.

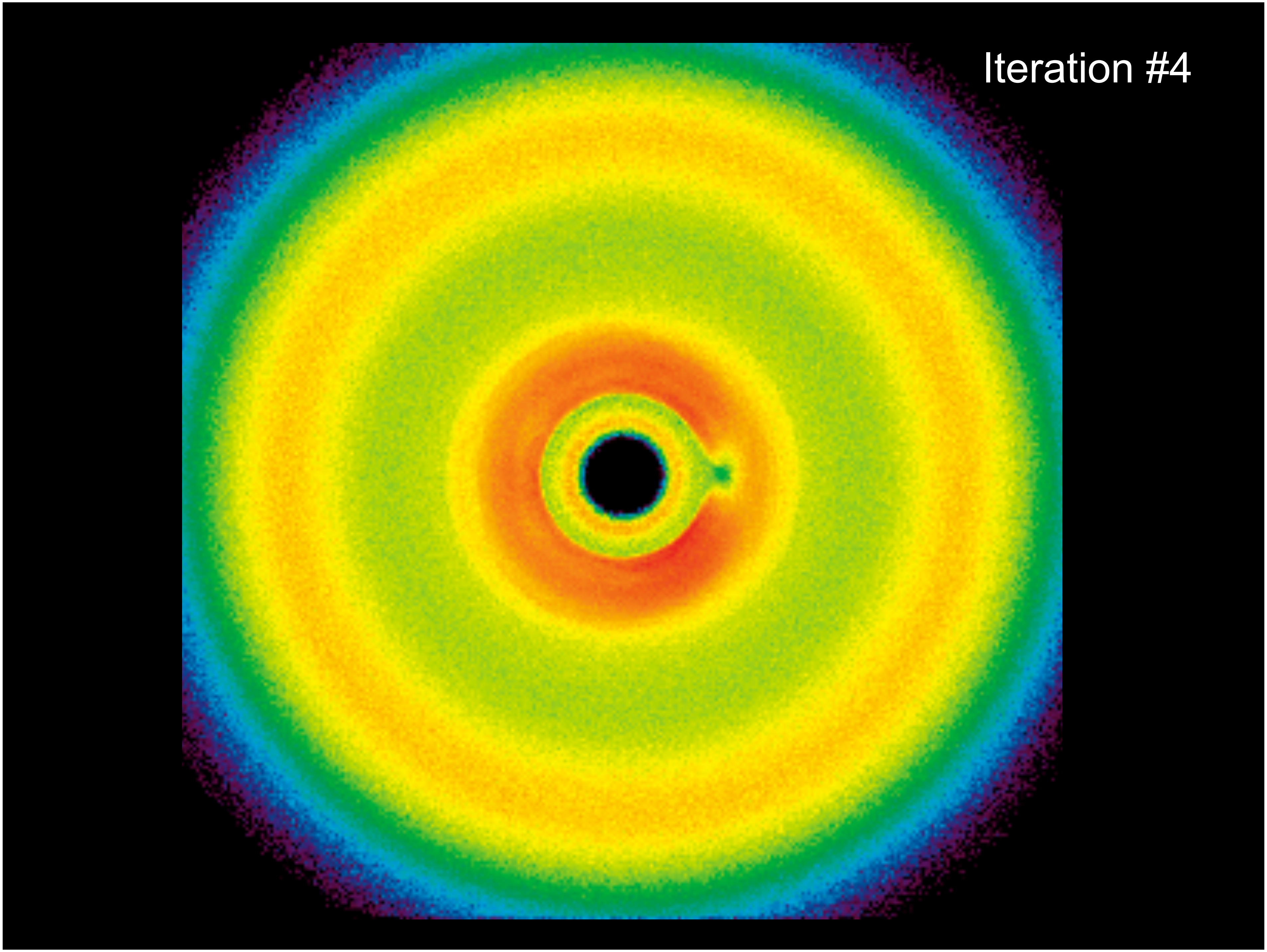
Christopher Stark's Thesis

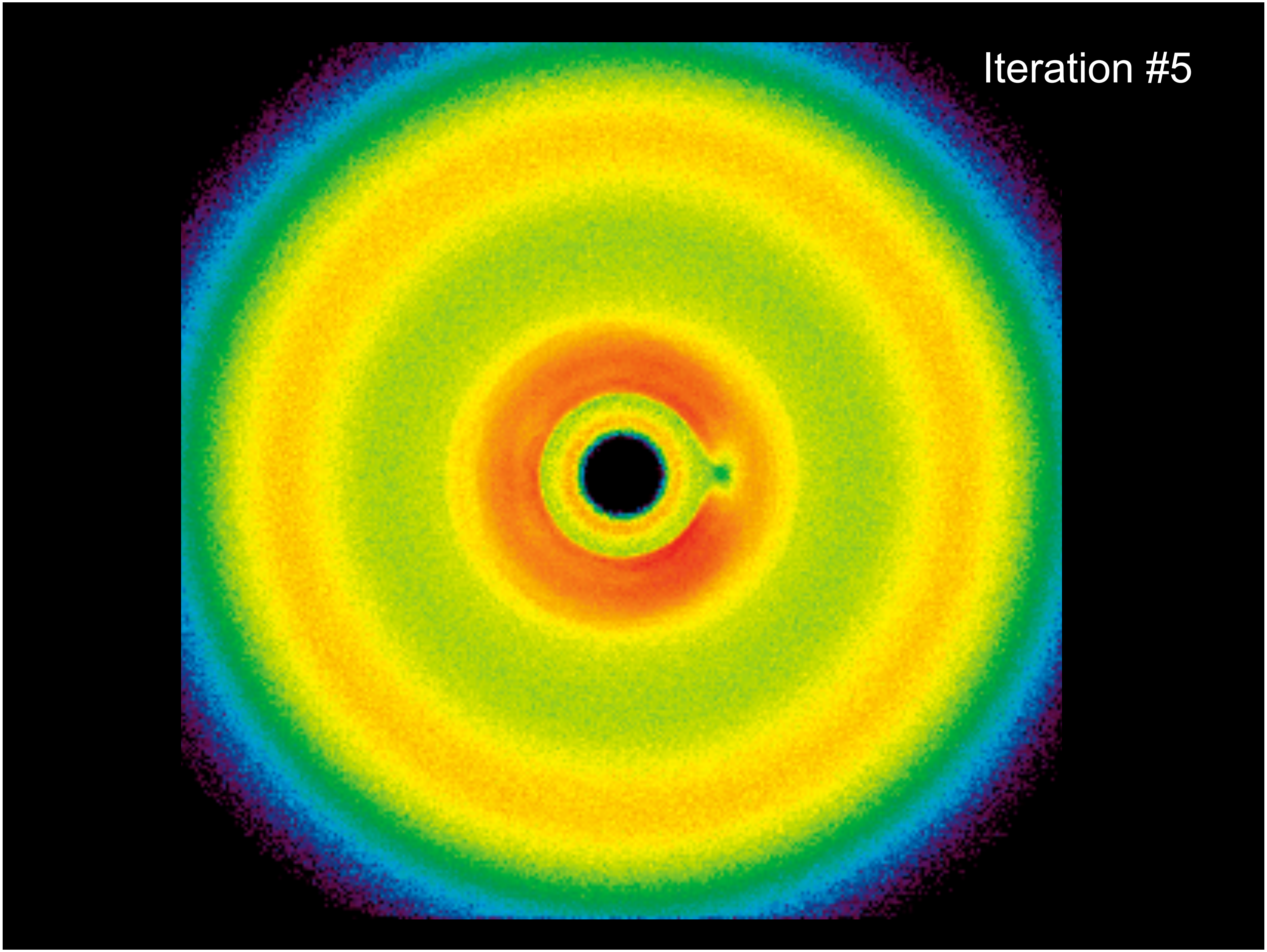

Seed Model
1.58•10^21
2.40•10^22
3.64•10^23
5.51•10^24
8.36•10^25
Σ / r^2 (AU^-4)


Iteration #1

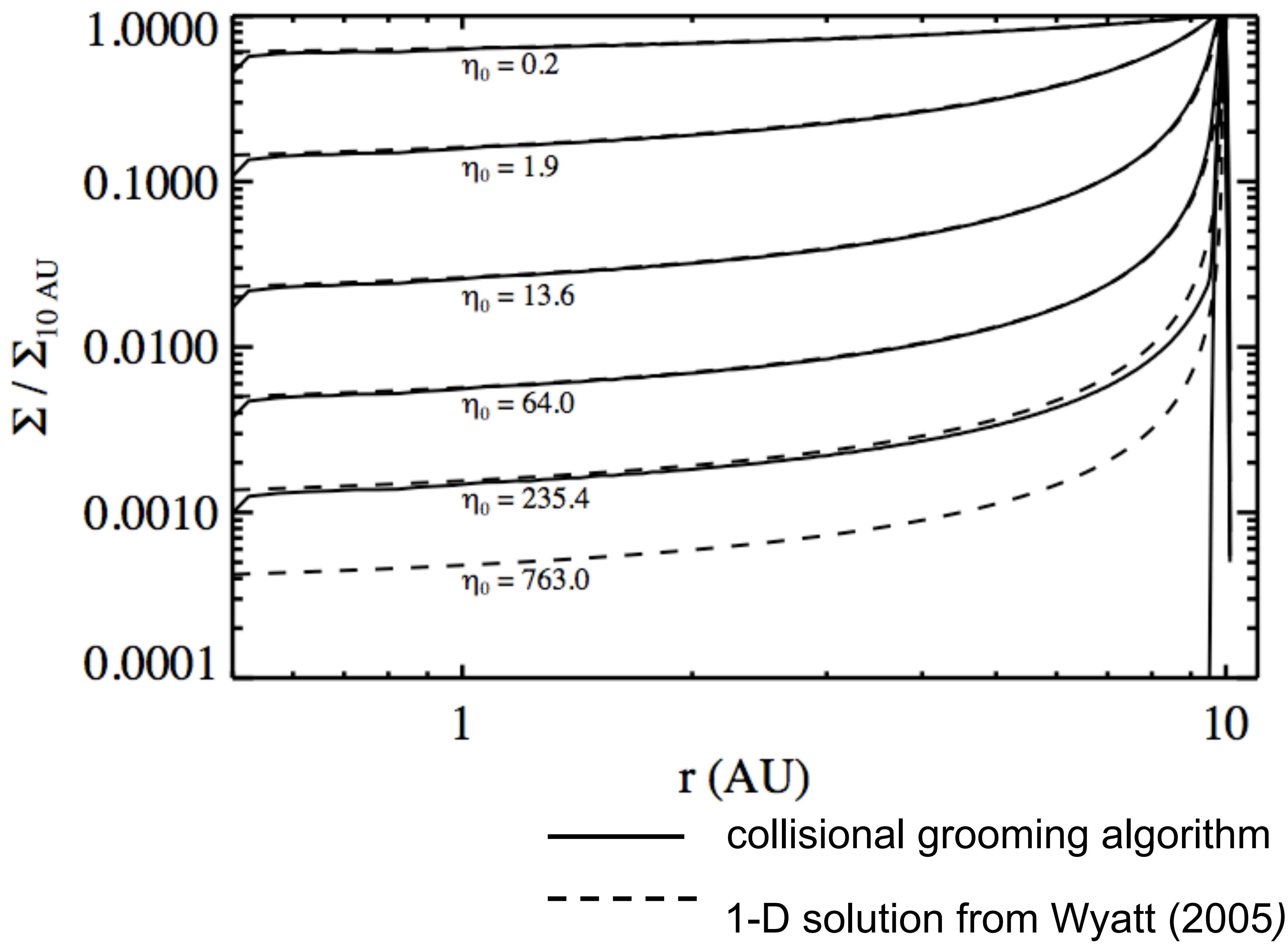

Iteration #2


Iteration #3

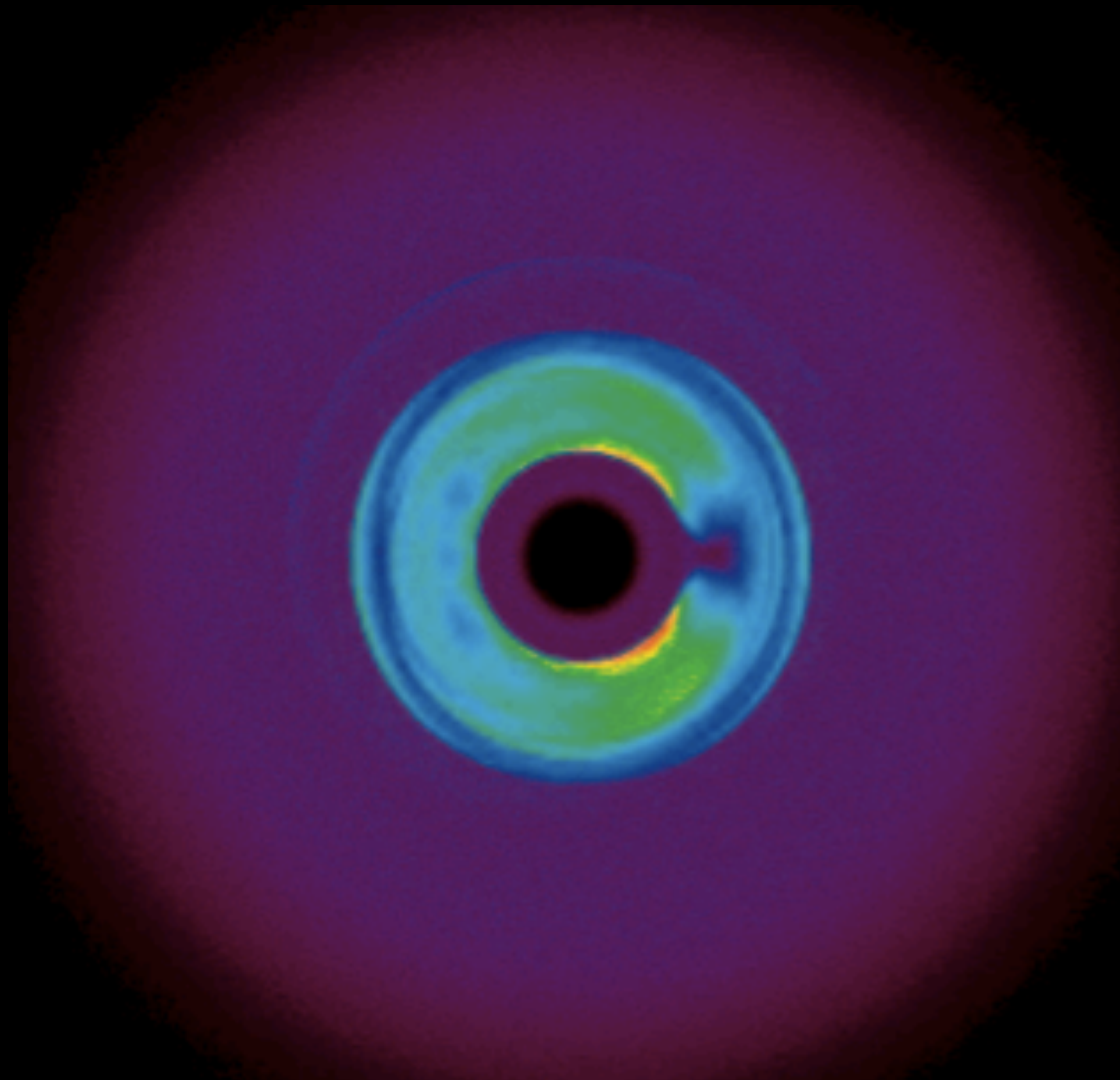

Iteration #4


Iteration #5

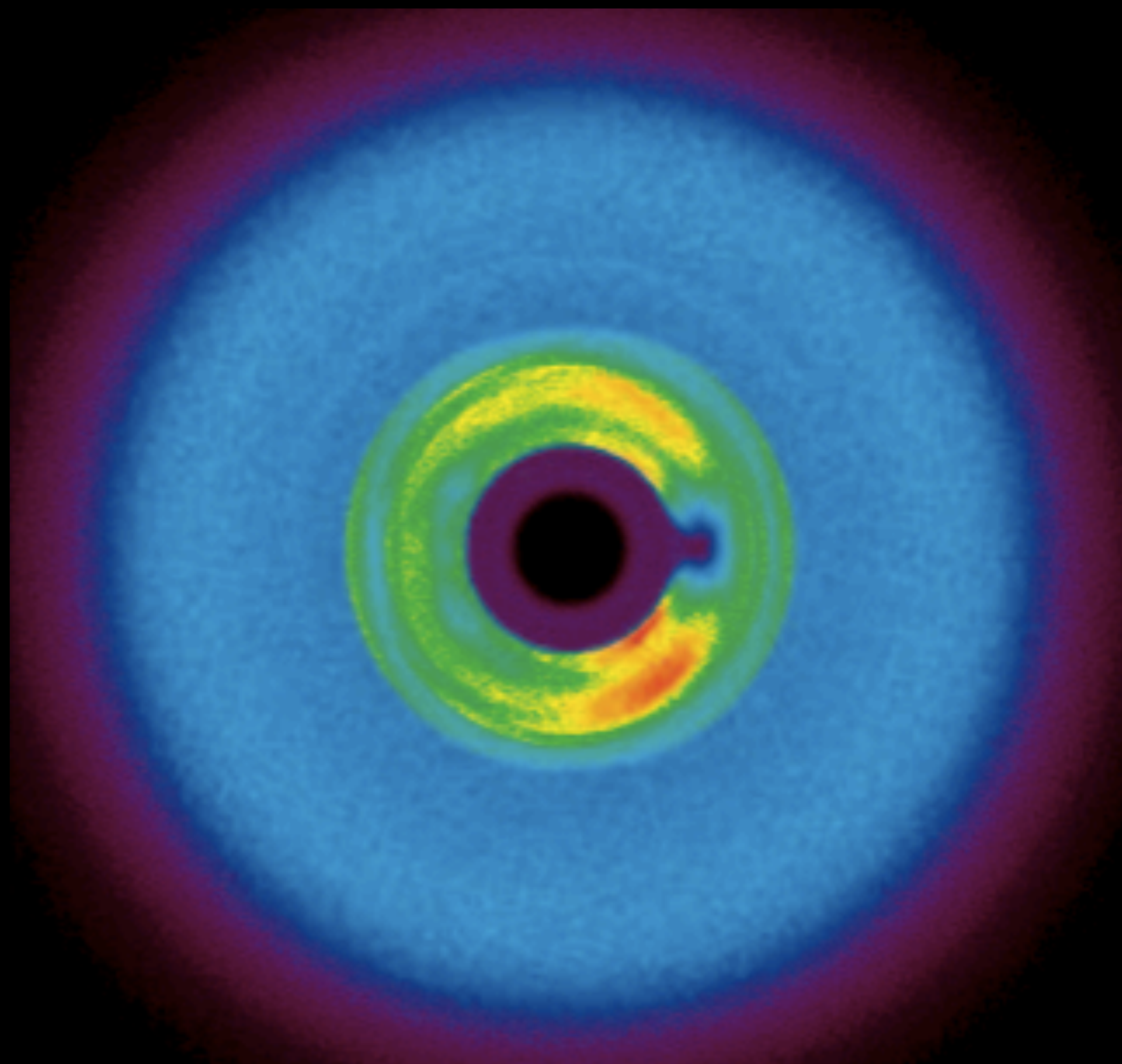
A Test of the Algorithm!



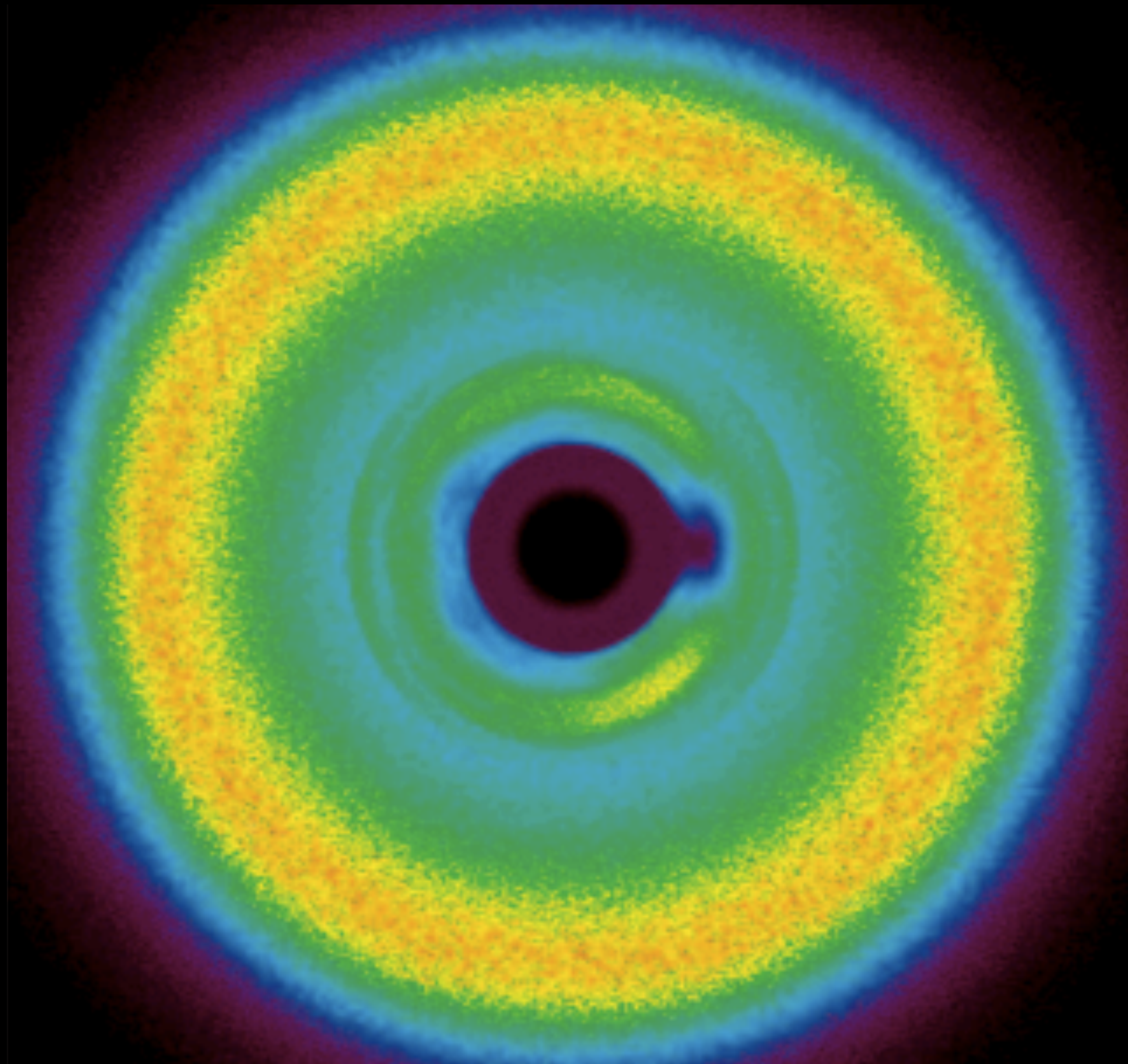
No Collisions

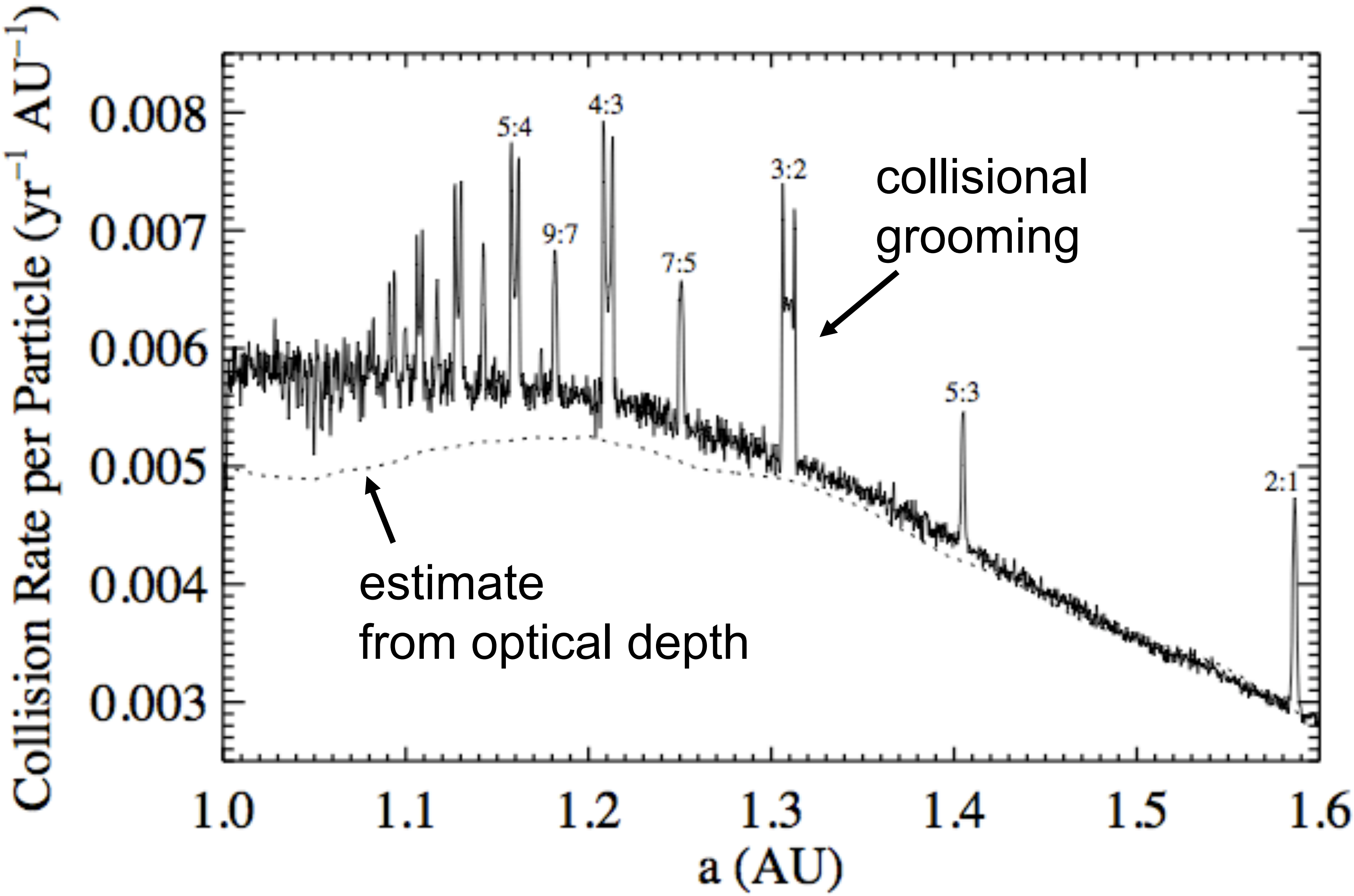


$t_{coll} \sim 10\ t_{PR}$

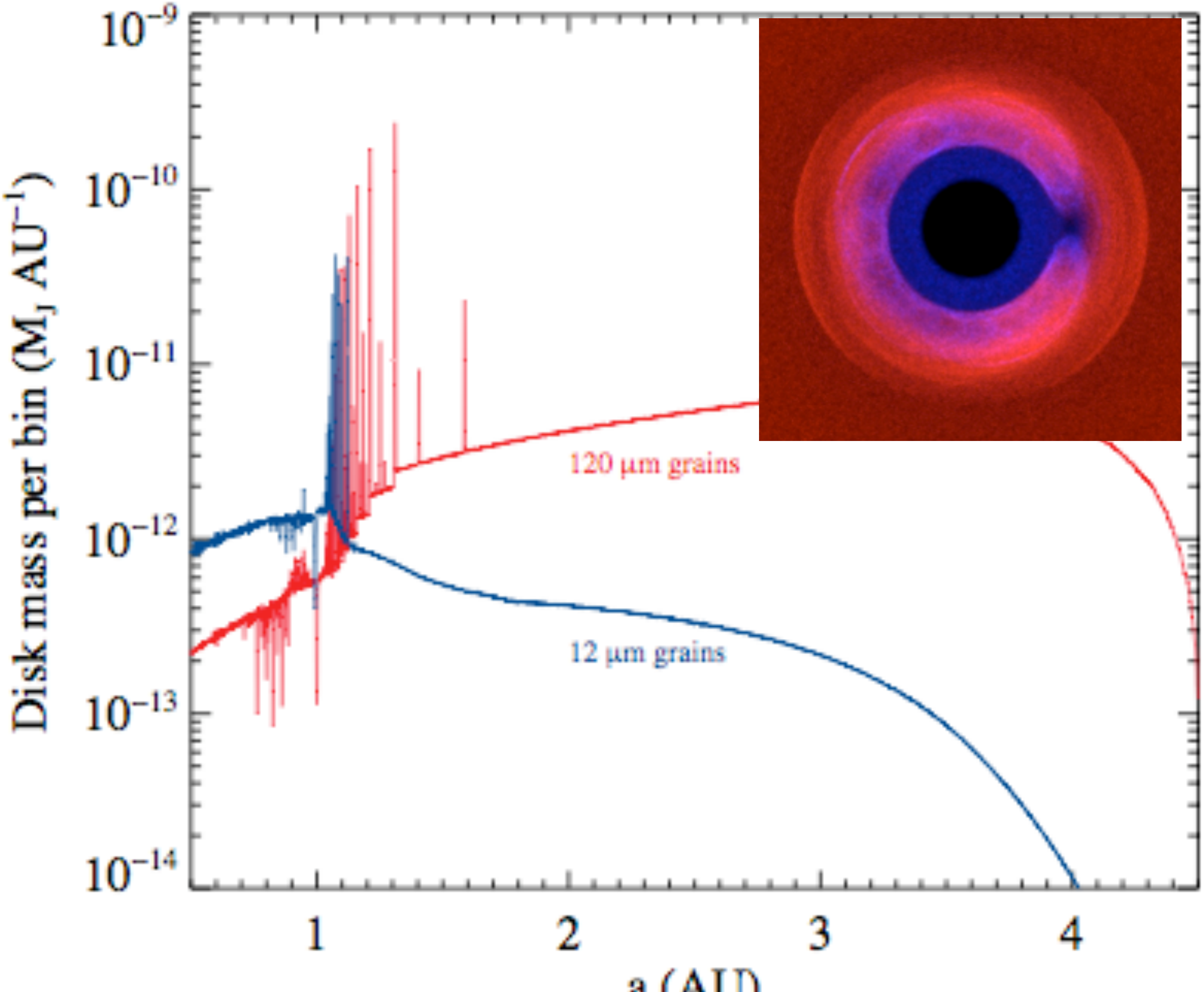


$t_{coll} \sim t_{PR}$





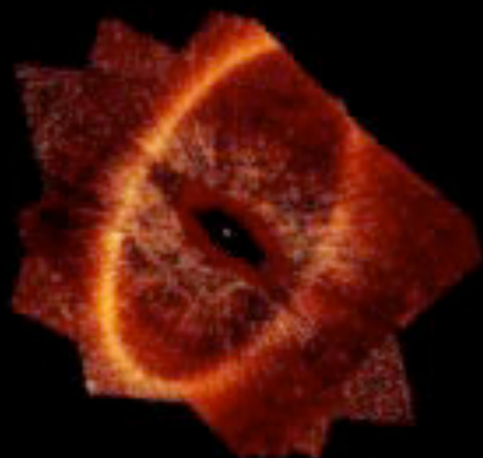
Collision Rate per Particle (yr^{-1} AU^{-1})
0.008
0.007
0.006
0.005
0.004
0.003
1.0
1.1
1.2
1.3
1.4
1.5
1.6
a (AU)
5:4
4:3
9:7
7:5
3:2
5:3
2:1
collisional
grooming
estimate
from optical depth

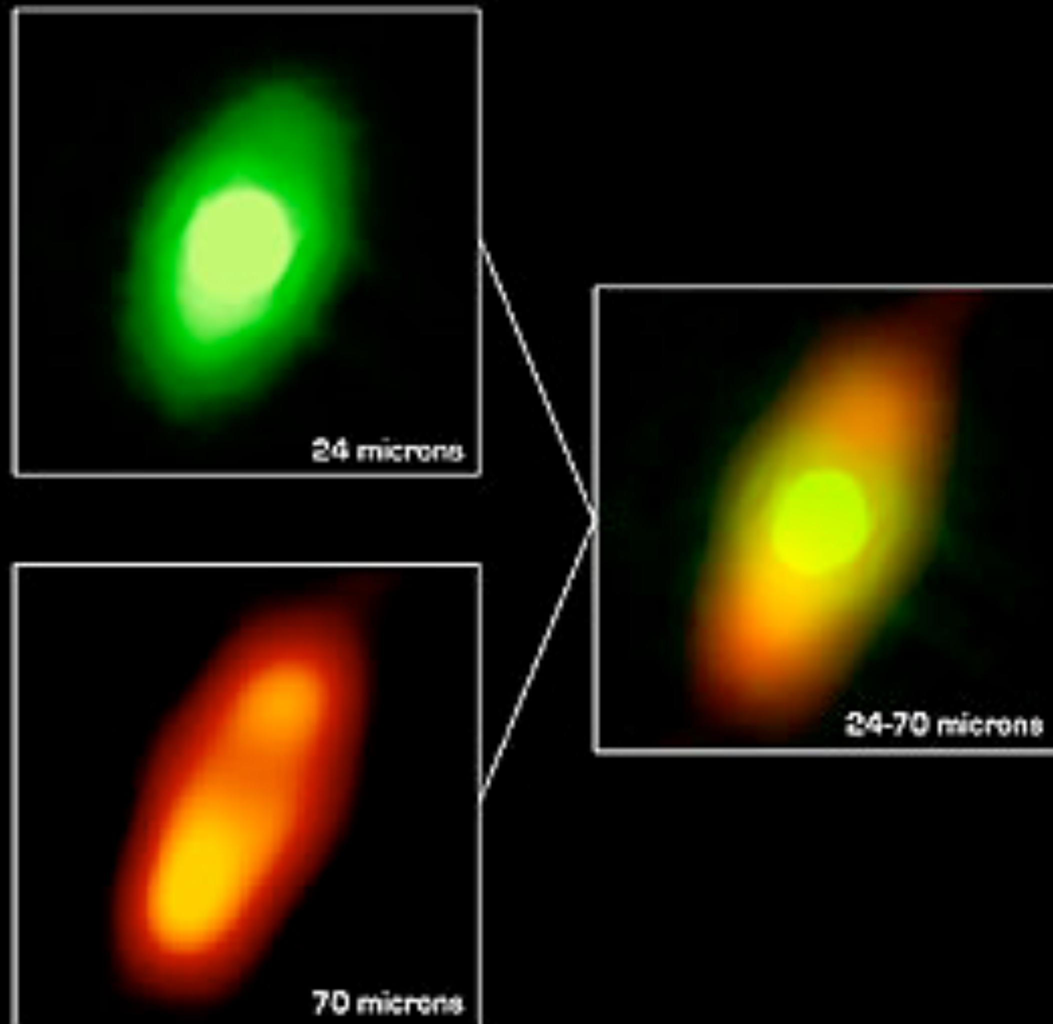


Disk mass per bin (M_J AU^{-1})
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
120 μm grains
12 μm grains
1
2
3
4
a (AU)

SPITZER

HST





Stapelfeldt et al. 2003

Solve:

$$F = ma$$ Dynamical equation