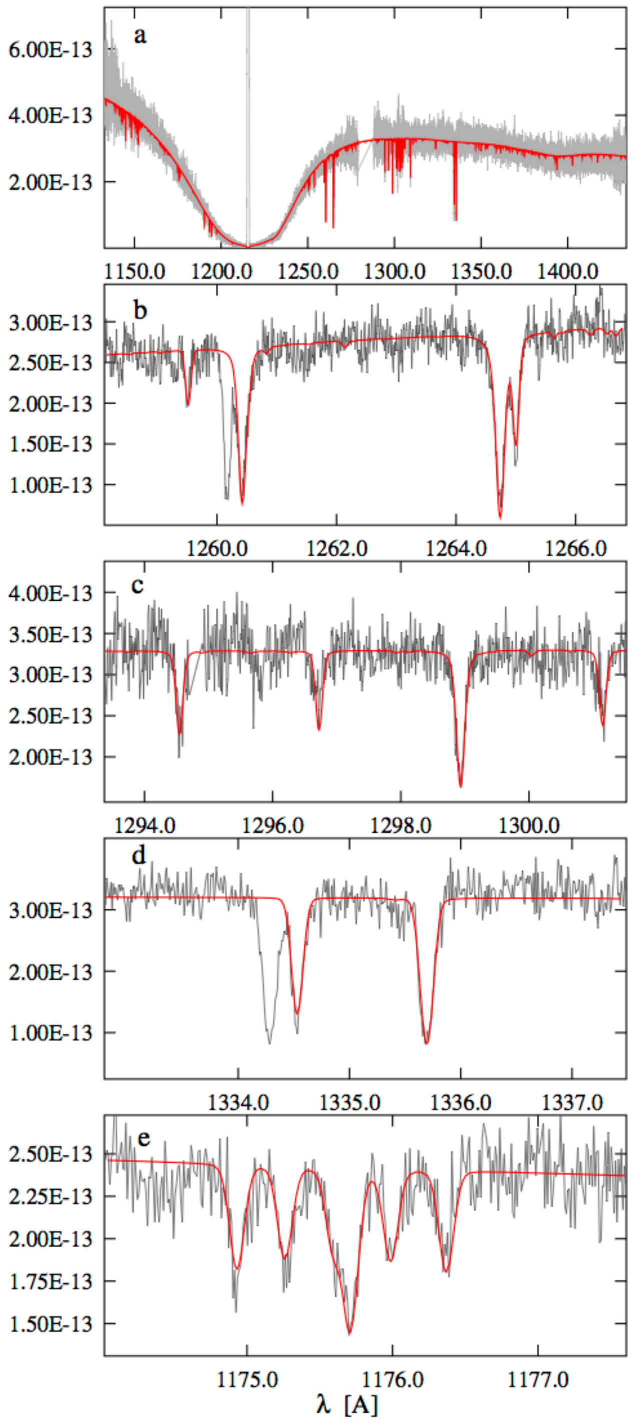
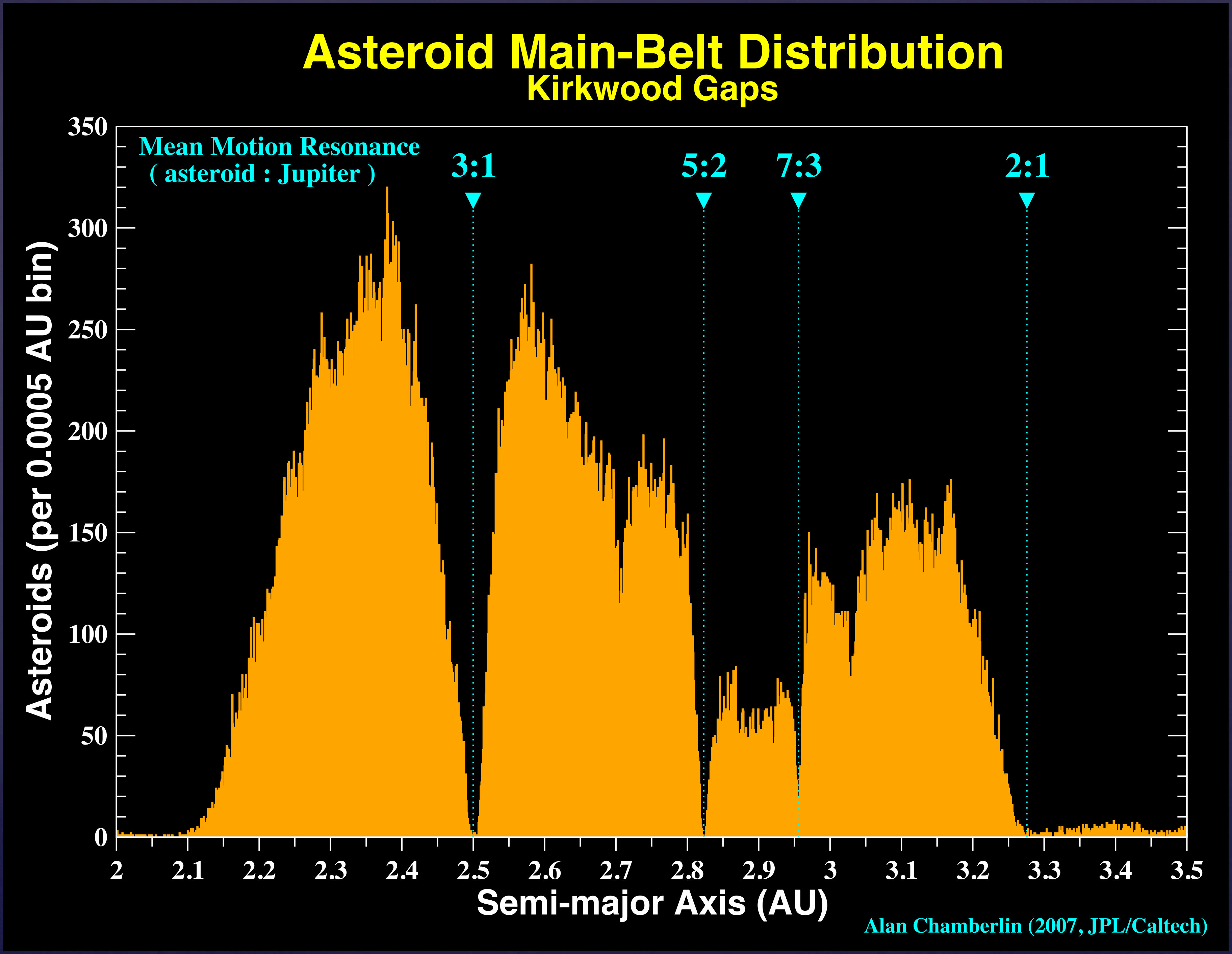
Dusty White Dwarfs and the Late Stages of Planetary Systems

Justin Ely



- Dusty and Metal-enriched WD
  - ~1% Dusty, excess emission in the IR
  - ~25% Metal absorption lines in the UV
- Elemental abundance consistent with terrestrial planets
- Thought to be caused by tidally disrupted asteroids
- Provides a probe of the surviving planetary system if the disrupting mechanism is understood

White Dwarf Observations


Asteroid Main-Belt Distribution
Kirkwood Gaps
Mean Motion Resonance
(asteroid : Jupiter)
3:1
5:2
7:3
2:1
Asteroids (per 0.0005 AU bin)
0
50
100
150
200
250
300
350
2
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3
3.1
3.2
3.3
3.4
3.5
Semi-major Axis (AU)
Alan Chamberlin (2007, JPL/Caltech)

Inner Mean Motion Perturbation (IMMP)

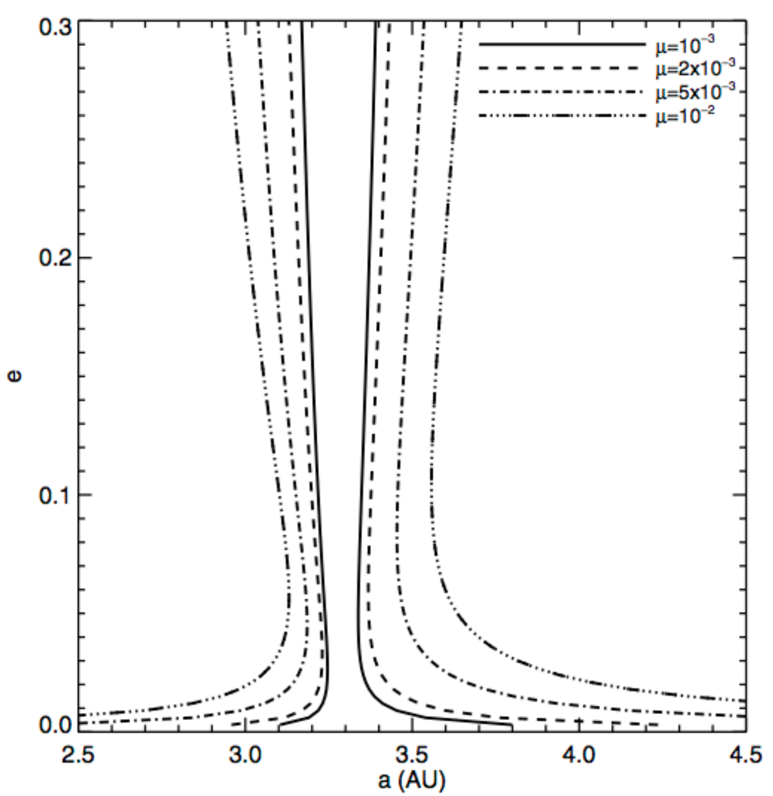
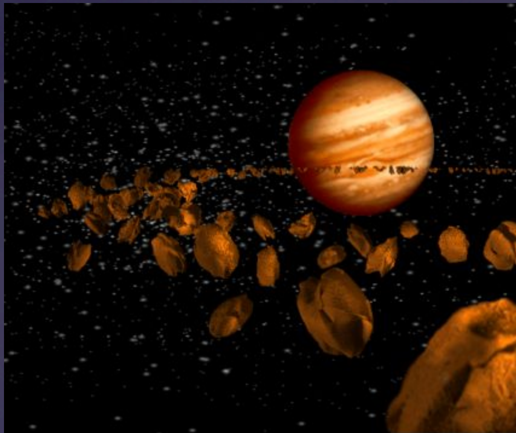


Figure 1. Evolution of the libration width about the 2:1 resonance as a function of mass lost from the central star (or as a function of planet mass ratio). The libration width grows under increasing mass ratio, creating regions that can trap planetesimals. These planetesimals are later perturbed out of the resonance on long timescales.

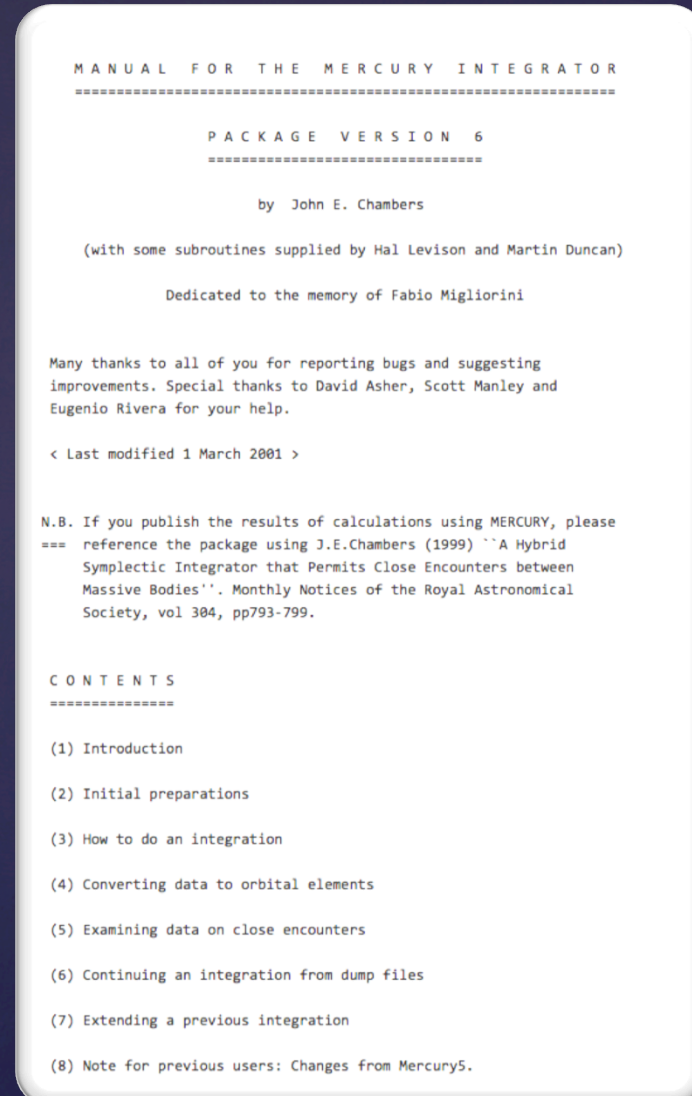
- Planetary systems with at least 1 dominant giant planet possess remnant asteroid belts
- Libration width around resonance grows during mass loss
- Over time these bodies are disrupted into star-crossing orbits

Simulation Parameters



- Central WD .54 Solar Mass
- Masses of .1, 1, 10x Jupiter Mass
- Semi-major axis of 1, 2, 3x Jupiter a
  - 3x semi-major axis not able to begin due to lack of system resources
- 250Myr integration timescale
- 2000 bodies each

- Mercury6 Integration software



M A N U A L   F O R   T H E   M E R C U R Y   I N T E G R A T O R

P A C K A G E   V E R S I O N   6

by John E. Chambers

(with some subroutines supplied by Hal Levison and Martin Duncan)

Dedicated to the memory of Fabio Migliorini

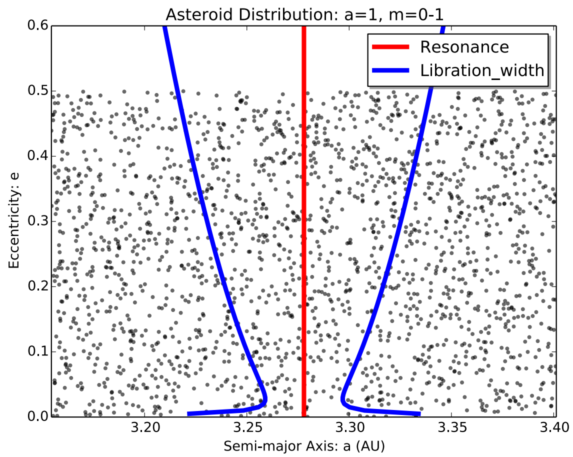
Many thanks to all of you for reporting bugs and suggesting improvements. Special thanks to David Asher, Scott Manley and Eugenio Rivera for your help.

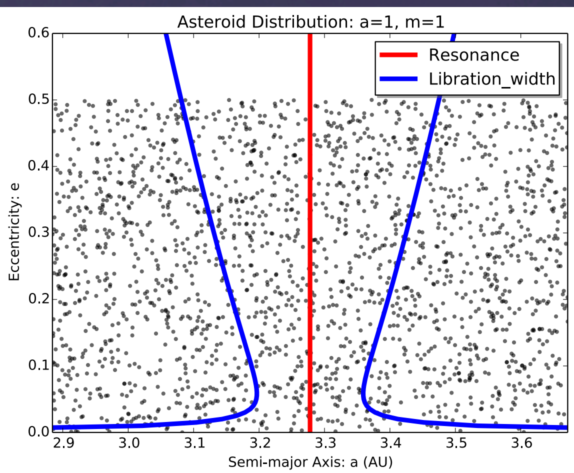
< Last modified 1 March 2001 >

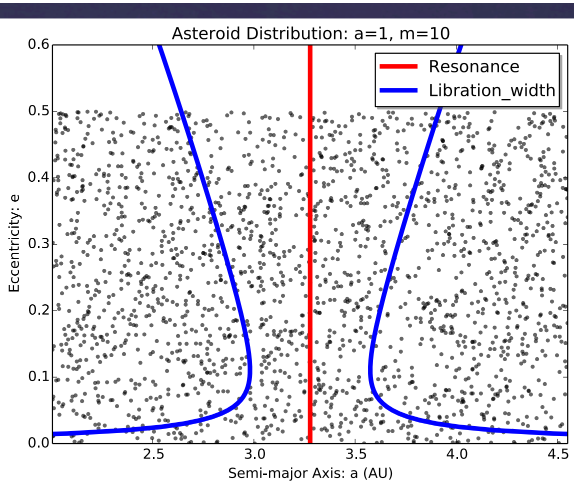
N.B. If you publish the results of calculations using MERCURY, please reference the package using J.E.Chambers (1999) ``A Hybrid Symplectic Integrator that Permits Close Encounters between Massive Bodies''. Monthly Notices of the Royal Astronomical Society, vol 304, pp793-799.

C O N T E N T S

Asteroid Distributions

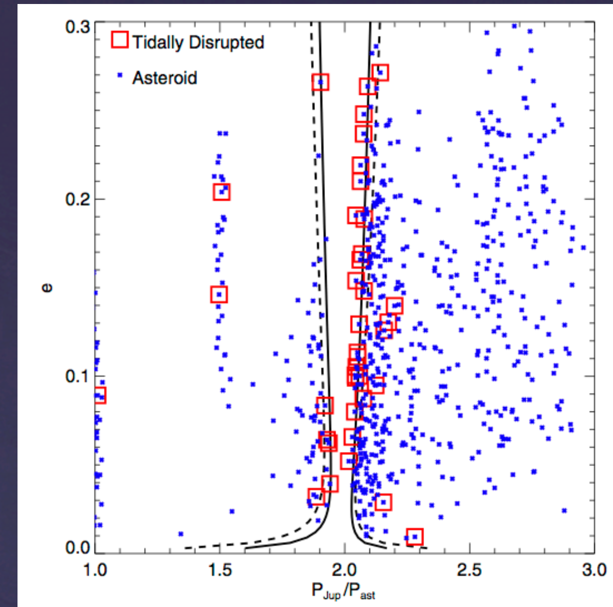




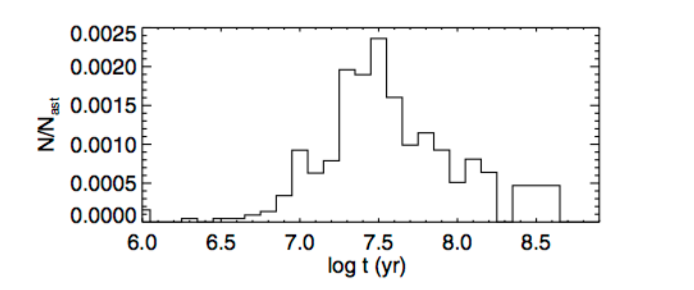


Design

- Evenly sample the 2x libration width of the 2:1 resonance
- Removes biases from initial condition
- Permits convolution of trail distributions with even distribution to determine behavior without more integration



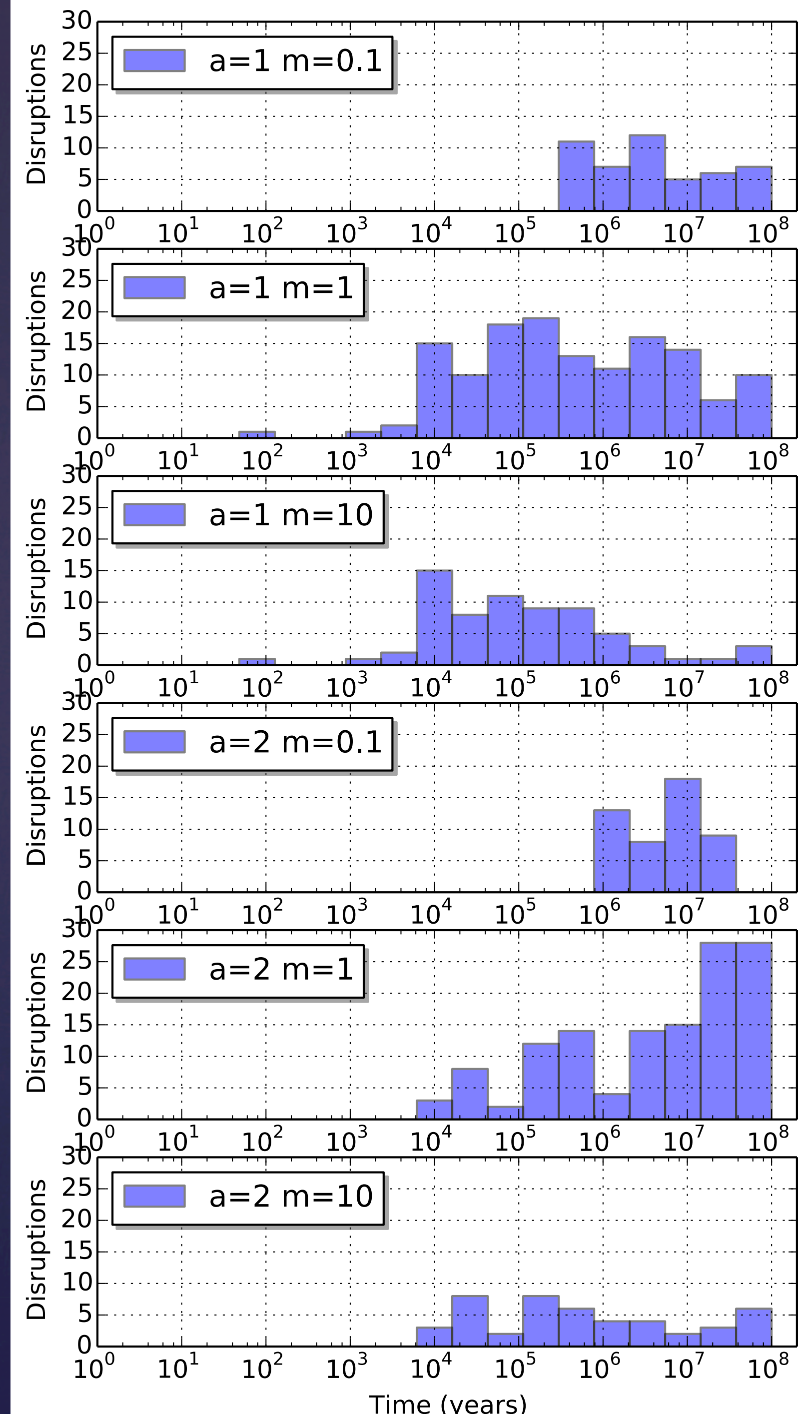
Sample asteroid belt distribution from Debes et al simulation

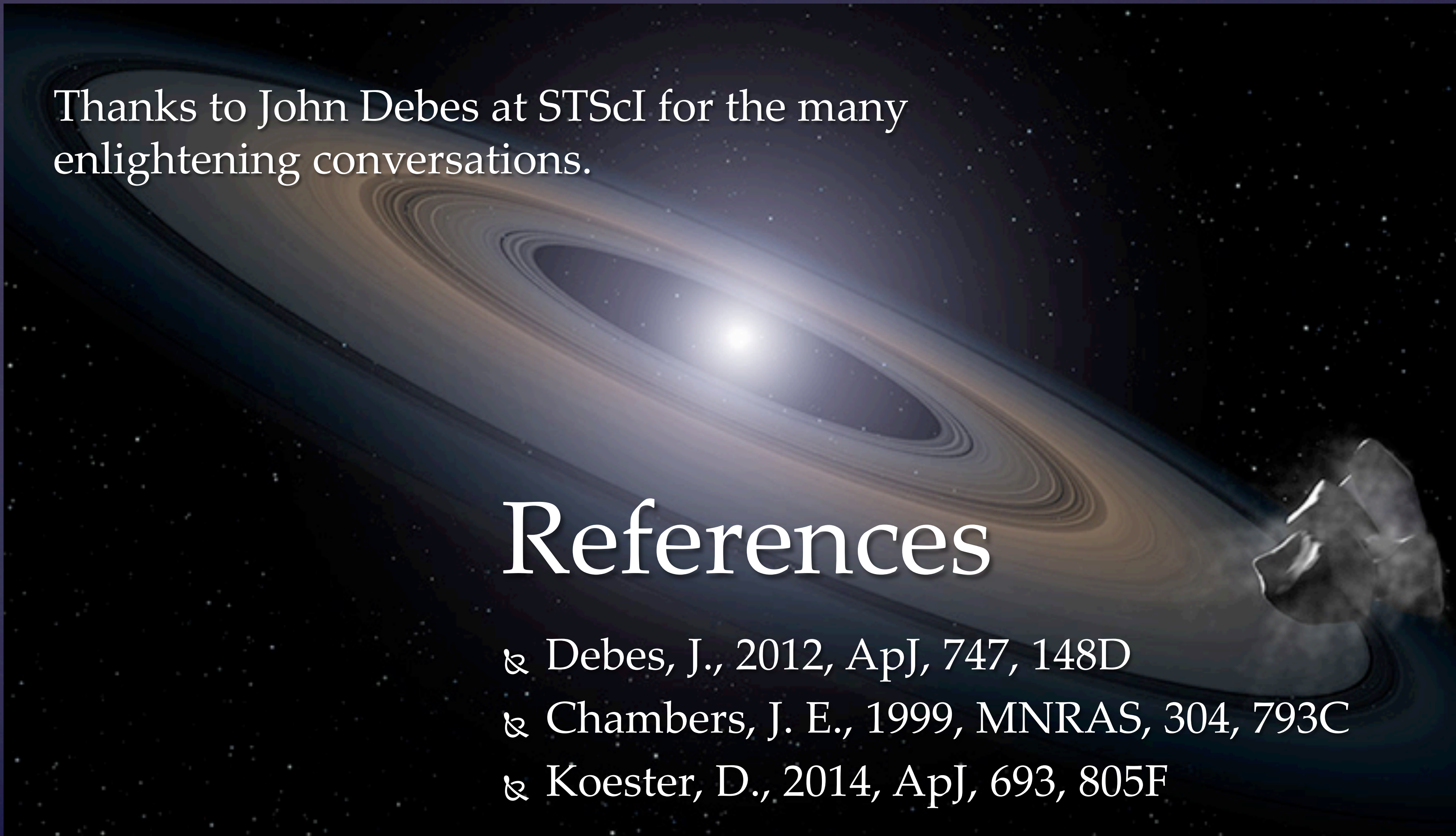


Debes et al. tidal disruptions from simulations. 10,000 bodies, solar system distribution.

- Low mass results in low efficiency at both semi-major axis
- Jupiter mass most efficient perturber at either semi-major axis
- Jupiter mass more efficient than 10x

Tidal Disruption Results





Thanks to John Debes at STScI for the many enlightening conversations.

References

- Debes, J., 2012, ApJ, 747, 148D
- Chambers, J. E., 1999, MNRAS, 304, 793C
- Koester, D., 2014, ApJ, 693, 805F