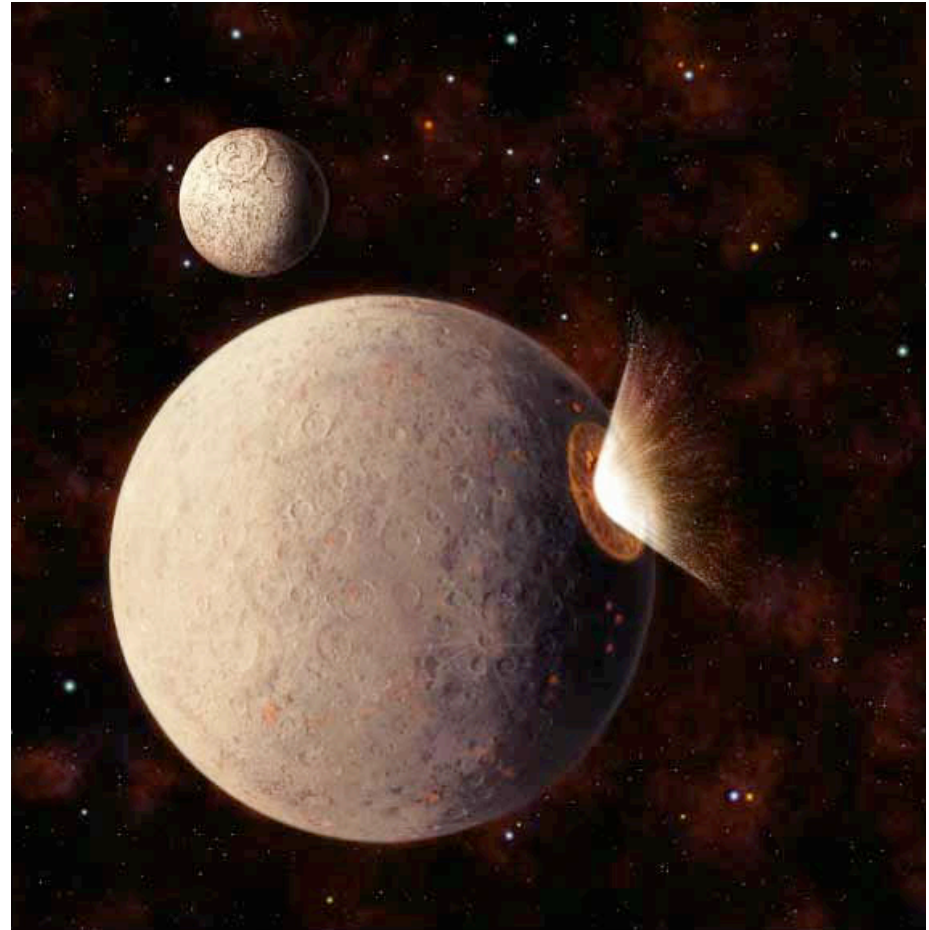


# The Chaotic Early Solar System

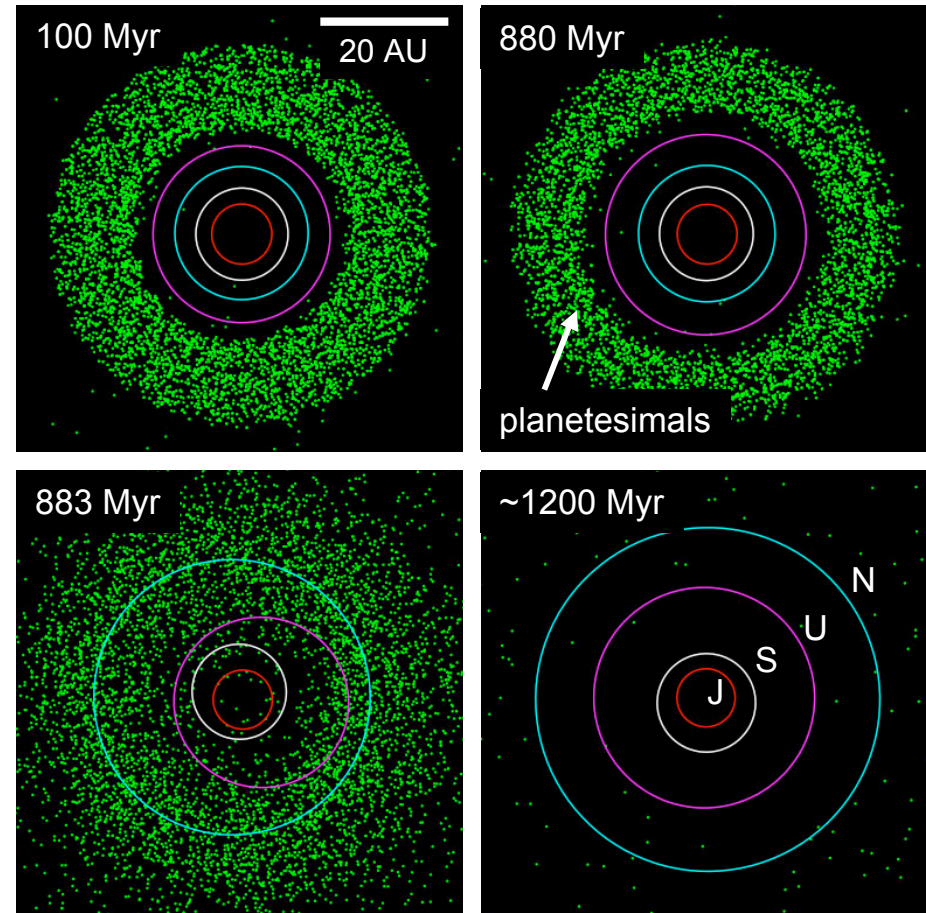
- Recent computer models are challenging earlier views that planets formed in an orderly way at their current locations
- These models suggest that the jovian planets changed their orbits substantially, and that Uranus and Neptune could have changed places
- These chaotic motions could also explain a 'spike' in the number of impacts in the inner solar system ~3.8 billion years ago



*The Moon and terrestrial planets were bombarded by planetesimals early in solar system history.*

# Cosmic Billiards

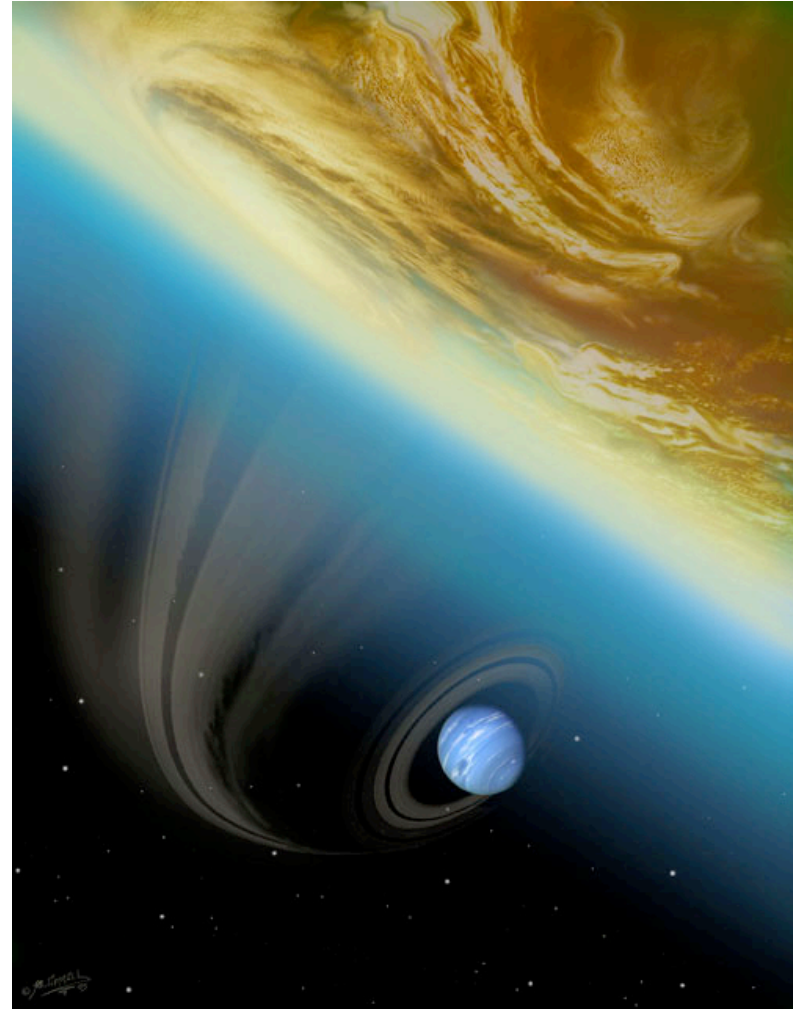
- The model predicts:
  1. After formation, giant planet orbits were affected by gravitational 'nudges' from surrounding planetesimals
  2. Jupiter and Saturn crossed a *1:2 orbital resonance* (the ratio of orbital periods), which made their orbits more elliptical. This suddenly enlarged and tilted the orbits of Uranus and Neptune
  3. Uranus / Neptune cleared away the planetesimals, sending some to the inner solar system causing a spike in impact rates



*The early layout of the solar system may have changed dramatically due to gravitational interactions between the giant planets. Note how the orbits of Uranus and Neptune moved outwards, switched places, and scattered the planetesimal population.*

# The Big Picture

- The current layout of our solar system may bear little resemblance to its original form
- This view is more in line with the “planetary migration” thought to occur even more dramatically in many extrasolar planet systems
- It may be difficult to prove or disprove these models of our early solar system. The many unexplained properties of the nature and orbits of planets, comets and asteroids may provide clues.



*Artist's depiction of Neptune orbiting close to Jupiter (courtesy Michael Carroll)*

# For more information...

## Press Releases

- Sky and Telescope - “Chaos in the Early Solar System”  
<http://www.skyandtelescope.com/skytel/beyondthepage/8594717.html>
- Science News - 02/14/09 - ‘The Solar System’s Big Bang’  
[http://www.sciencenews.org/view/feature/id/40390/title/The\\_Solar\\_Systems\\_Big\\_Bang](http://www.sciencenews.org/view/feature/id/40390/title/The_Solar_Systems_Big_Bang)
- Plan. Sci. Res. Disc. - 08/24/06 - ‘Wandering Gas Giants and Lunar Bombardment’  
<http://www.psr.d.hawaii.edu/Aug06/cataclysmDynamics.html>

## Images

- Impact on early Earth  
2006 Pearson Education Inc., publishing as Addison Wesley
- Computer simulation snapshots courtesy of Alessandro Morbidelli
- Jupiter/Neptune art courtesy of astronomy.com / Michael Carroll  
<http://www.astronomy.com/asy/default.aspx?c=a&id=3320>

## Source Articles (on-campus login may be required to access journals)

- Gomes et al., ‘Origin of the cataclysmic Late Heavy Bombardment period of the terrestrial planets’, *Nature*, **435**, p. 466 doi: 10.1038/nature03676, 2005.  
<http://www.nature.com/nature/journal/v435/n7041/abs/nature03676.html>
- Tsiganis et al., ‘Origin of the orbital architecture of the giant planets of the Solar System’, *Nature*, **435**, p. 459 doi:10.1038/nature03539, 2005.  
<http://www.nature.com/nature/journal/v435/n7041/abs/nature03539.html>

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