AST s309L

„Exoplanets and Extraterrestrial Life“

Second Summer Session

9 July – Aug 10, 2012

M,T,W,Th,Fr 1:00-2:30 pm
BUR 112

Michael Endl

Office: RLM 16.328

Tel: (512) 471 8312

Email: mike@astro.as.utexas.edu

Web:

http://austral.as.utexas.edu/michael/teaching/2012/AST_s309L.html

Did you ever wonder about one (or more) of the following questions:

- are we alone in the Universe?
- do other stars have planets too?
- is there current or past life on Mars?
- how many Earth-like planets do we know?
- what are the basic requirements for life as we know it?
- what kind of stars have planets?
- can we communicate with alien civilizations?
- how do we search for planets orbiting other stars?
- is there a liquid subsurface ocean on Jupiter's moon Europa?
- when did life first emerge on Earth?
- is our Solar System special?
- how can we probe atmospheres of planets in other star systems?
- can we detect life on other planets?

- **GOAL OF THE COURSE:**
  At the end of the course you will have a basic understanding of the astronomical techniques to detect and characterize exoplanets. You will also have an overview of the properties and statistics of exoplanets and their host stars. And you will have knowledge about astrobiological topics like what life is, how life works, what habitats of alien life we can imagine, and about the Search For Extraterrestrial Intelligence (SETI).
- **Textbooks:**
  No textbook, the slides for each class will become available (as pdf files) and represent the basis of this class. There will also be handouts.
- **Exams:**
  There will be a written exam at the end of each week (5 in total) about the 4 previous classes. Students can drop (or miss) one of the 5 exams. There will be 1 homework per week. Final grade will be the average based on the 4 written exams, the 5 homeworks and attendance (75% exams, 20% homework and 5% attendance).

- **Grade: 100-90=A, 89-80=B, 79-70=C, 69-60=D**

SCHEDULE:

Week 1: Exoplanets I: (Observational Techniques)

Week 2: Exoplanets II: (Results)

Week 3: Exoplanets II & Astrobiology I: (life on Earth)

Week 4: Astrobiology I & II: (life in the Solar System)

Week 5: Astrobiology III: (life in the Universe)

Books:

Exoplanets:

„*Planet Quest*“, Ken Croswell

„*Toward Other Earths*“, Alan Boss

„*The Crowded Universe*“, Alan Boss (2009)

Extraterrestrial Life:

„*Lonely Planets*“, David Grinspoon (2004)

„*The Living Cosmos*“, Chris Impey (2007)

„*The Eerie Silence*“ , Paul Davis (2010)

Resources

The Extrasolar Planet Encyclopaedia (Jean Schneider): www.exoplanet.eu (note www.exoplanets.eu sends you to the Geneva Planet Search Program)

- In 7 languages
- Tutorials
- Interactive catalog (radial velocity, transits, etc)
- Online histrograms and correlation plots
- Download data

ASTs309L

Resources: The Nebraska Astronomy Applet Project (NAAP)

http://astro.unl.edu/naap/

This is the coolest astronomical website for learning basic astronomy that you will find. In it you can find:

1. **Solar System Models**
   Basic Coordinates and Seasons
3. The Rotating Sky
4. Motions of the Sun
5. **Planetary Orbit Simulator**
6. Lunar Phase Simulator
7. Blackbody Curves & UBV Filters
8. Hydrogen Energy Levels
9. Hertzsprung-Russel Diagram
10. **Eclipsing Binary Stars**
11. Atmospheric Retention
12. **Extrasolar Planets**
13. Variable Star Photometry

I really like astronomy,
but I **hate** math…

Let's review…

Basic Mathematics Review I

Units: Always use units to describe a quantity.

``Car travelling at a speed of 70'' is incomplete information.

``70 miles per hour'' or ``70 kilometers per hour''

Wrong: 12 feet/second x 1 minute =?

Right: 12 feet/second x 60 seconds = 720 feet

Metric system:

1 meter ~ 40 inches

1 kilogram ~ 2.2 pounds

Scientific notation:

$100 = 10^2$

$10 = 10^1$

$1 = 10^0$

$0.1 = 10^{-1}$

$0.01 = 10^{-2}$

$10^3 \times 10^6 = 10^9$

$10^5 / 10^{-19} = 10^{-14}$

$7 \times 10^{24} / 2 \times 10^{36} = (7/2) \times (10^{24} / 10^{36}) = 3.5 \times 10^{-12}$

ASTs309L

Basic Mathematics Review II

Simple (really simple) equations

$3\ (a^2 + 4)=87$

$a^2 + 4= 87/3 = 29$

$a^2 = 29 - 4 = 25$

$a = 5$ or -5

Circle has 360°

1° = 60’ or 60 arc minutes

1’ = 60’’ or 60 arc seconds

Common in astronomy:

1 billion = 1000 millions

1AU = 1.496×10^{11} m

1 ly = 9.46×10^{15} m = 63,200AU

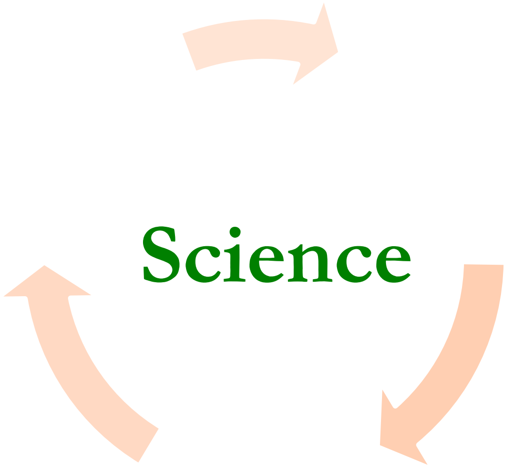
1pc = 3.09×10^{16}m = 206,000AU

$M_{\odot}=1.99\times10^{30}$ kg

$R_{\odot}=6.96 \times 10^{5}$ km

Scientific Theory and the Scientific Method

-Theories must be testable and independently reproduced
-Theories must be continually tested: if one observation does not agree with the theory, this has to be modified or replaced
-Theories should be simple: least number of terms and constants to explain a phenomena (e.g. Newton's law)
-Theories should be elegant: theories should explain more than one phenomena (e.g. motivation to derive the Grand Unification Theory)



NOT a science: Astrology

NOT a scientific theory: The Universe was pink with green polka dots before the Big Bang

A new science:

Astrobiology

- Sometimes called “exobiology” or “bioastronomy”
- Literally means *the study of life in the universe*
- Trying to answer the age-old questions *“Are we alone?”*
- The discovery of life elsewhere can be regarded the single most profound discovery in human history

A new science:

Astrobiology

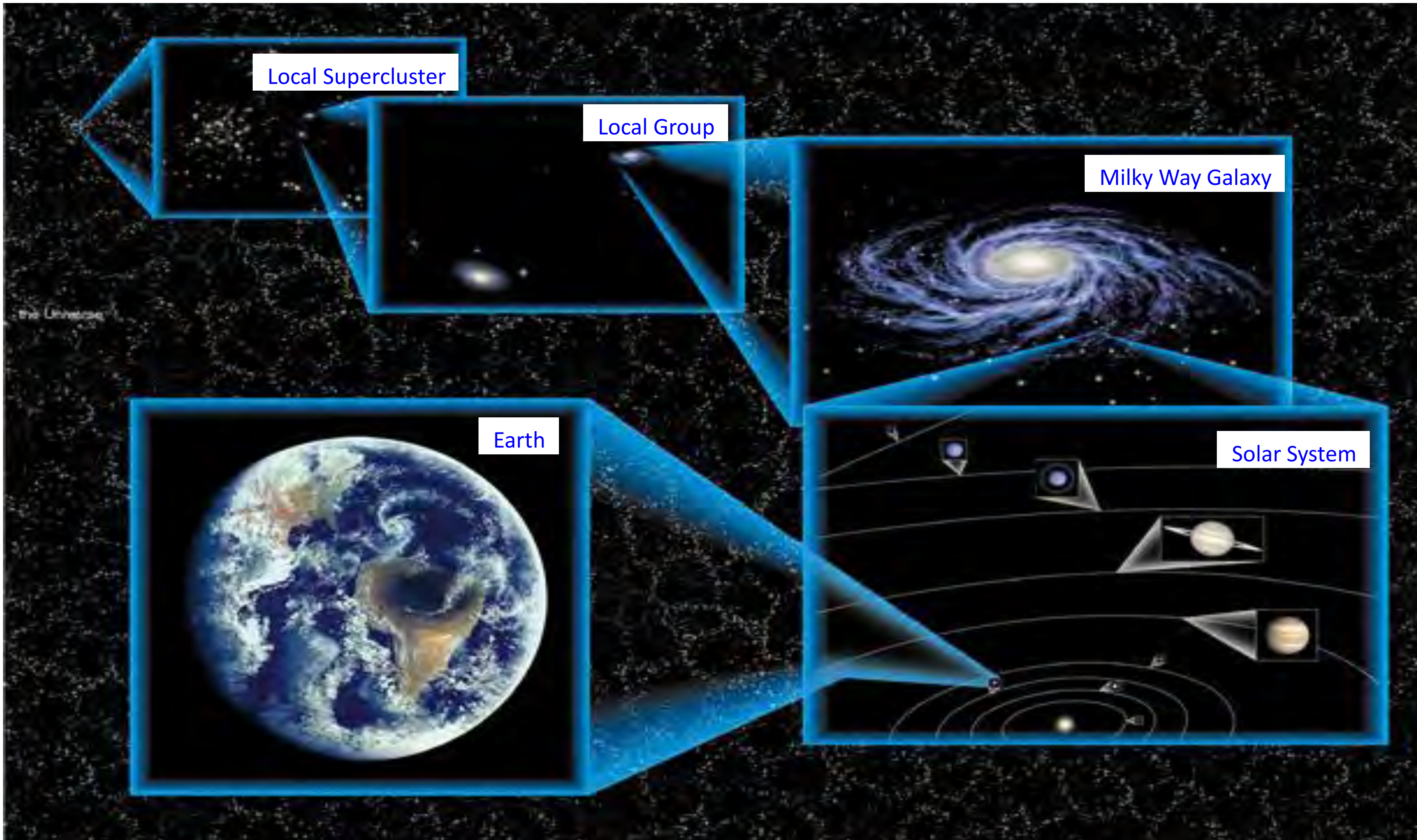
Just over the past 10-20 years:

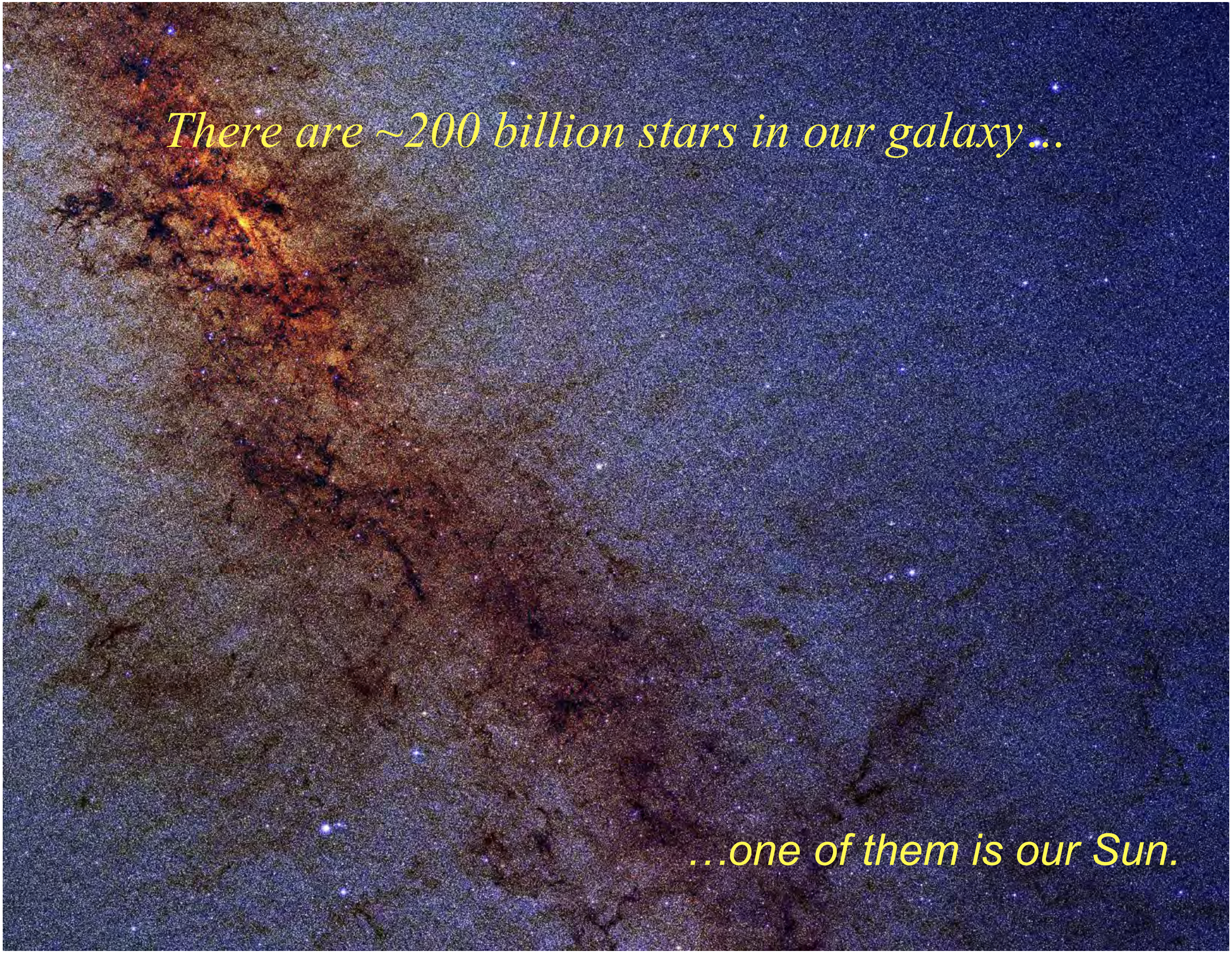
- The “astro” part discovered a large sample of exoplanets and is making excellent progress toward finding potential habitats for alien life.

- The “biology” part discovered “alien” life-forms here on Earth: extremophiles can survive and thrive in conditions previously thought impossible (this opens up a completely new parameter space for life in the universe)

ASTs309L

Our place in the Universe:




There are ~200 billion stars in our galaxy…
…one of them is our Sun.


Are there other planets in the universe?
Is there another Earth out there?

Some planets were known to the ancients who watched them move against the night sky.

Mercury, Venus, Mars, Jupiter, and Saturn were the "Wandering Stars."

"Planet" comes from the Greek word for "wanderer."

ASTs309L

A quick tour of our solar system

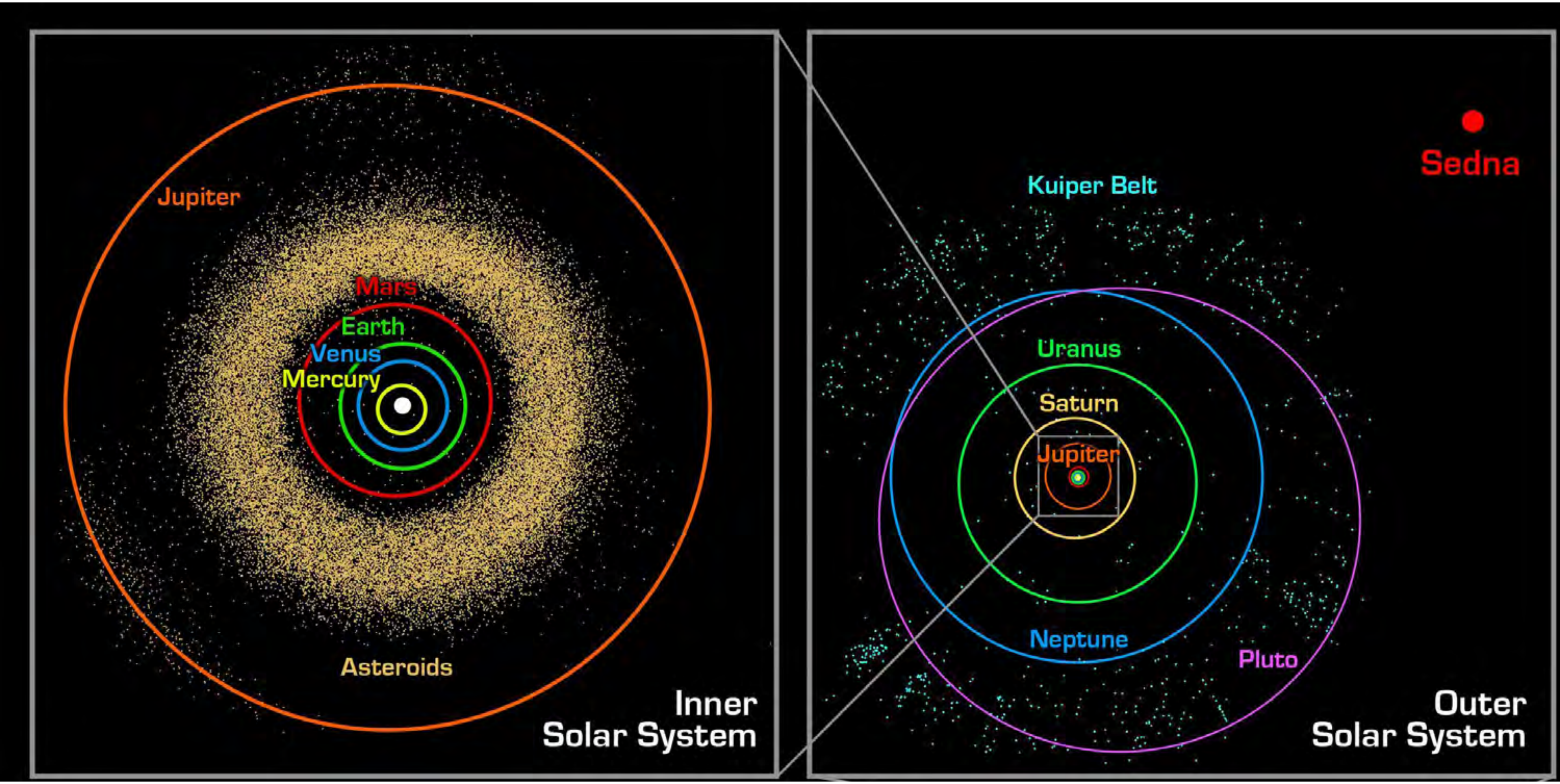
A good source for this is:

http://www.nineplanets.org

and

http://solarsystem.nasa.gov

The Structure Of Our Planetary System:

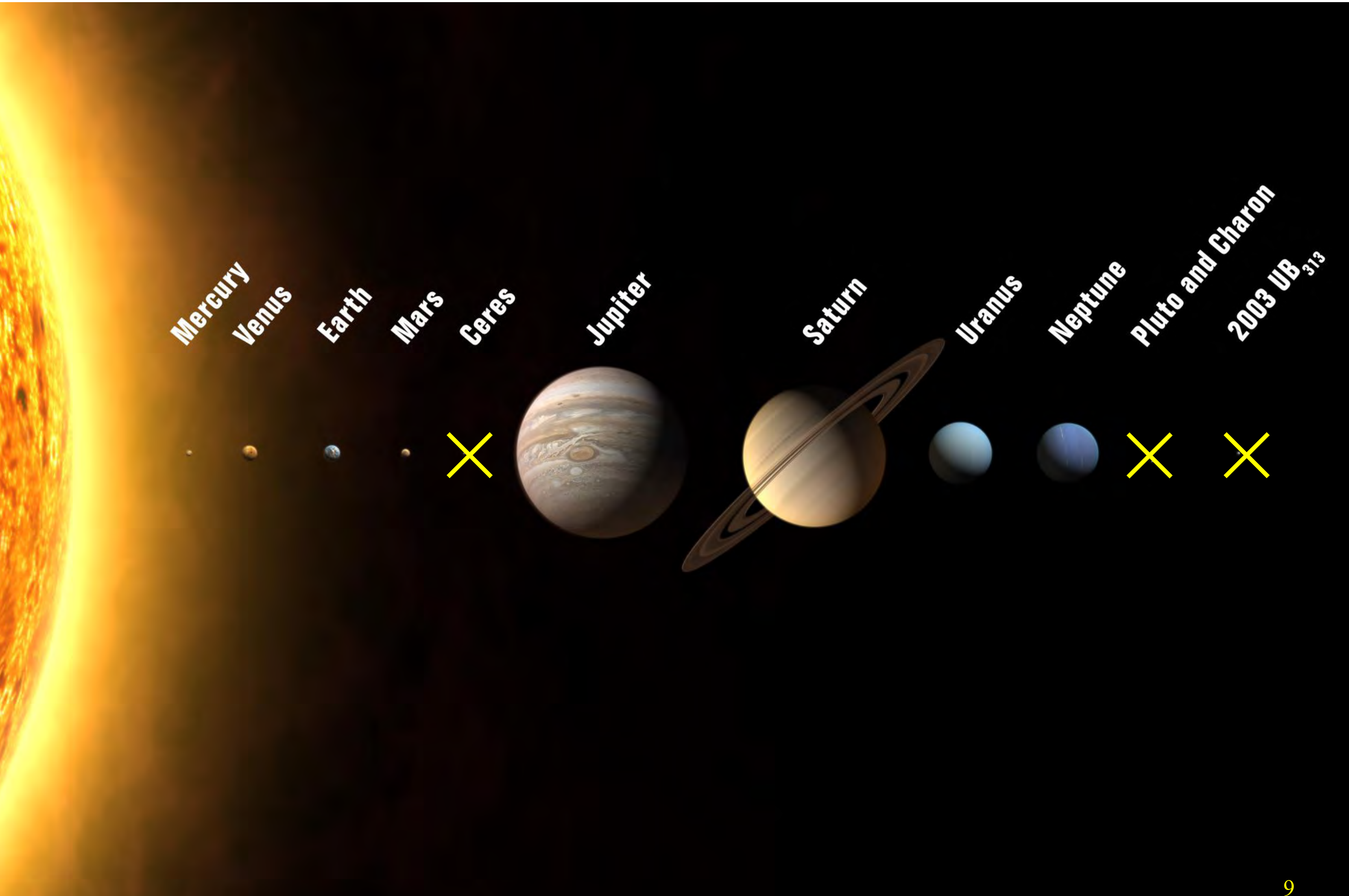


2006 IAU Definition of a Planet

1. is in orbit around the Sun,
2. has sufficient mass to assume hydrostatic equlibrium (a nearly round shape), and
3. has „cleared the neighborhood" around its orbit.

If a non-satellite body fulfills the first two criteria it is termed a „dwarf planet“. Originally, the IAU wanted to consider all dwarf planets as planets.

Under the new definition Pluto is no longer a planet, but rather a **dwarf planet**.

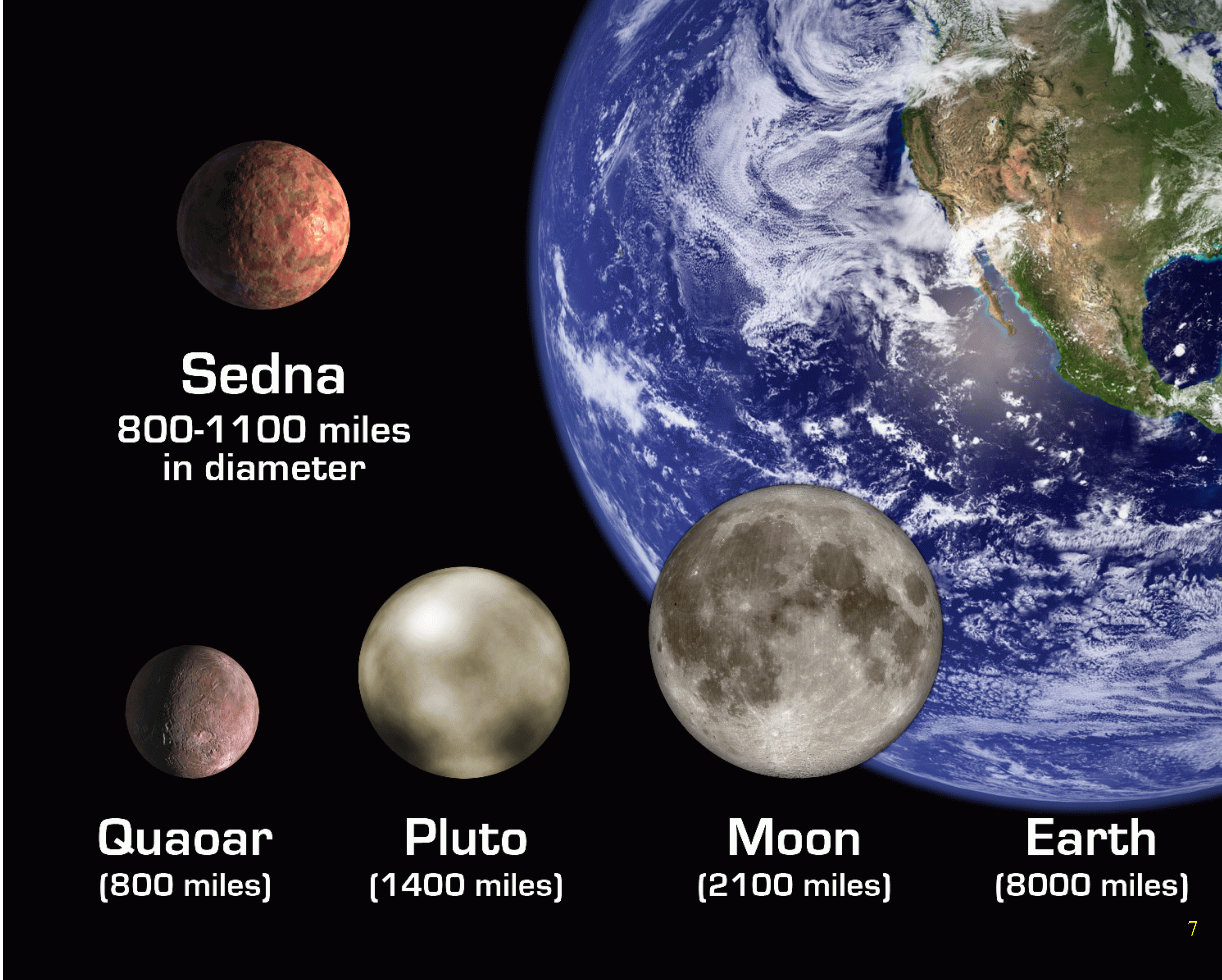

Mercury
Venus
Earth
Mars
Ceres
Jupiter
Saturn
Uranus
Neptune
Pluto and Charon
2003 UB313

Pluto before 2006

Pluto at the IAU 2006

Pluto today

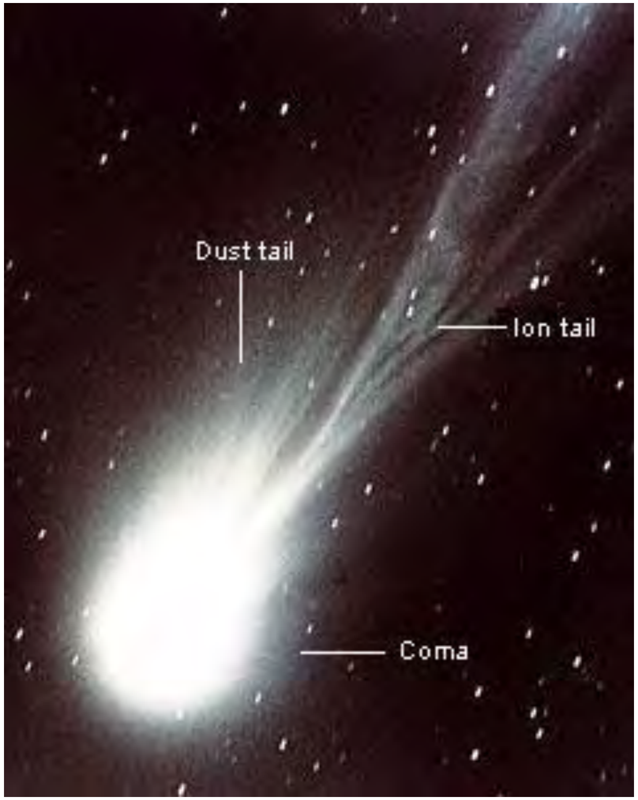
Completing the Census: Satellites


Sedna
800-1100 miles
in diameter
Quaoar
(800 miles)
Pluto
(1400 miles)
Moon
(2100 miles)
Earth
(8000 miles)


ASTs309L

Comets


Comet McNaught 22nd Jan 2007


Dust tail
Ion tail
Coma


HMC COMPOSITE IMAGE
IMAGES 3416,3457,3475,3480,3491,3496,3500

ASTs309L

Debris Disks

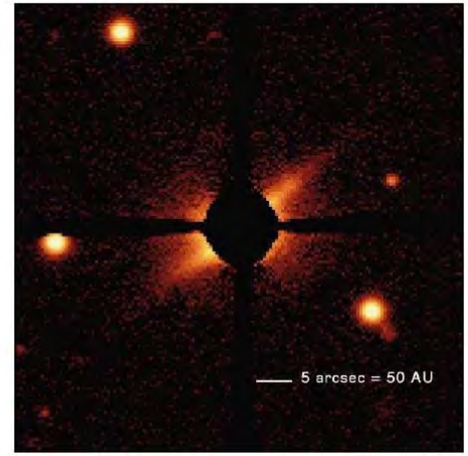
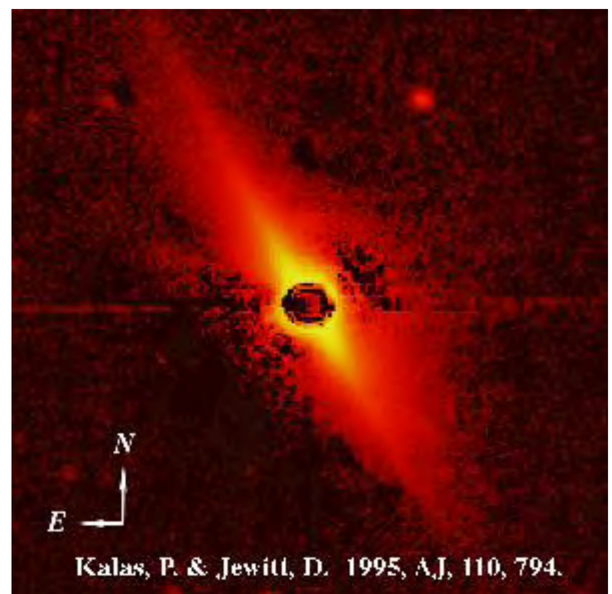


Fig. 1.— The disk surrounding AU Mic seen in optical scattered light. North is up, east is left, and each side of this false-color image corresponds to $60''$. The central dark region is produced by the $9.5''$ diameter focal plane occulting spot which is suspended by four wires and completely masks our direct view of the star. This image represents 900 seconds total integration in the R band and each pixel corresponds to 4 AU at the distance to AU Mic. Residual light evident near the occulting spot edge in the NE-SW direction is attributed to asymmetries in the point-spread function caused by instrumental scattering and atmospheric seeing.



Extrasolar Planets

Why Search for Extrasolar Planets?

How do planetary systems form?

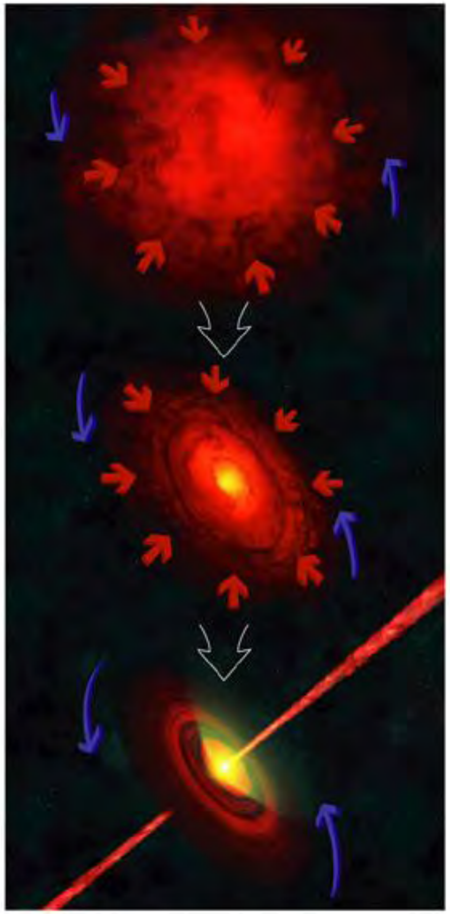
- Is this a common or an infrequent event?
- How unique are the properties of our own solar system?
- Are these qualities important for life to form?

Up until now we have had only one laboratory to test planet formation theories. We need more!

Giordano Bruno (1548-1600)

Believed that the Universe was infinite and that other worlds exists. He was burned at the stake for his beliefs.

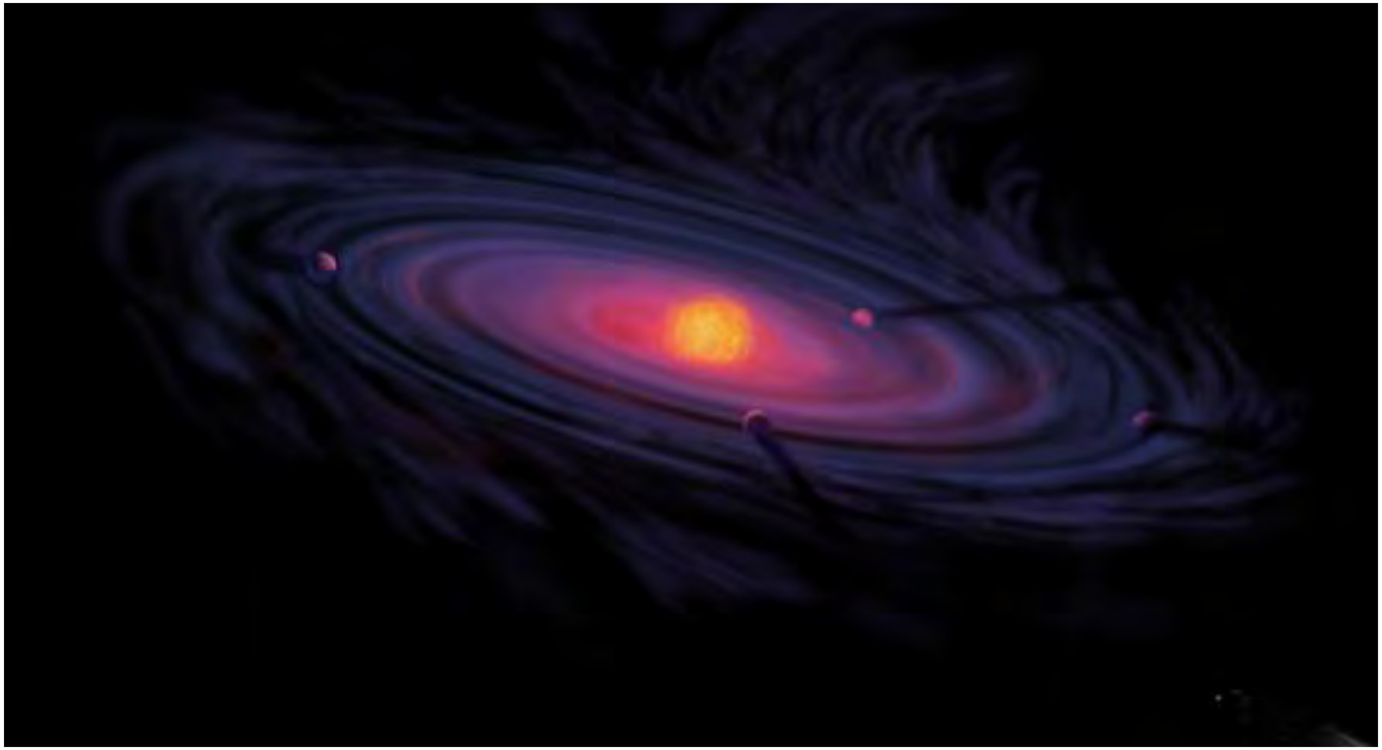
What kinds of explanetary systems do we expect to find?



The standard model of the formation of the sun is that it collapses under gravity from a proto-cloud

Because of rotation it collapses into a disk.

Jets and other mechanisms provide a means to remove angular momentum



The net result is you have a protoplanetary disk out of which planets form.

The net result is you have a protoplanetary disk out of which planets form (mostly) by a process called

accretion.

So how do we define an extrasolar Planet?

There is **no** official IAU definition of an exoplanet.

We can simply use mass:

Star: Has sufficient mass to fuse hydrogen to helium.

$$M > 80\ M_{Jupiter}$$

Brown Dwarf: Insufficient mass to ignite hydrogen, but can undergo a period of Deuterium burning.

$$13\ M_{Jupiter} < M < 80\ M_{Jupiter}$$

Planet: Formation mechanism unknown, but insufficient mass to ignite hydrogen or deuterium.

$$M < 13\ M_{Jupiter}$$

How to search for Exoplanets:

Indirect Techniques

- Radial Velocity (or Doppler Method)
- Astrometry
- Transits
- Microlensing

Direct Techniques

- Spectroscopy/Photometry: Reflected or Radiated light
- Imaging