Vancouver 2010

skepticamp

be the candle in the dark

An informal, community-organized conference borne from the desire for people to share and learn in an open environment. Everyone from casual skeptics to the experienced participate, give talks, and get to know each other.

Completely Free

vancouver.skepticamp.org

10am-6pm
Saturday, March 20, 2010
Victoria Learning Theatre (Room 182)
Irving K. Barber Learning Centre
1961 East Mall, UBC, Vancouver

http://vancouver.skepticamp.org/

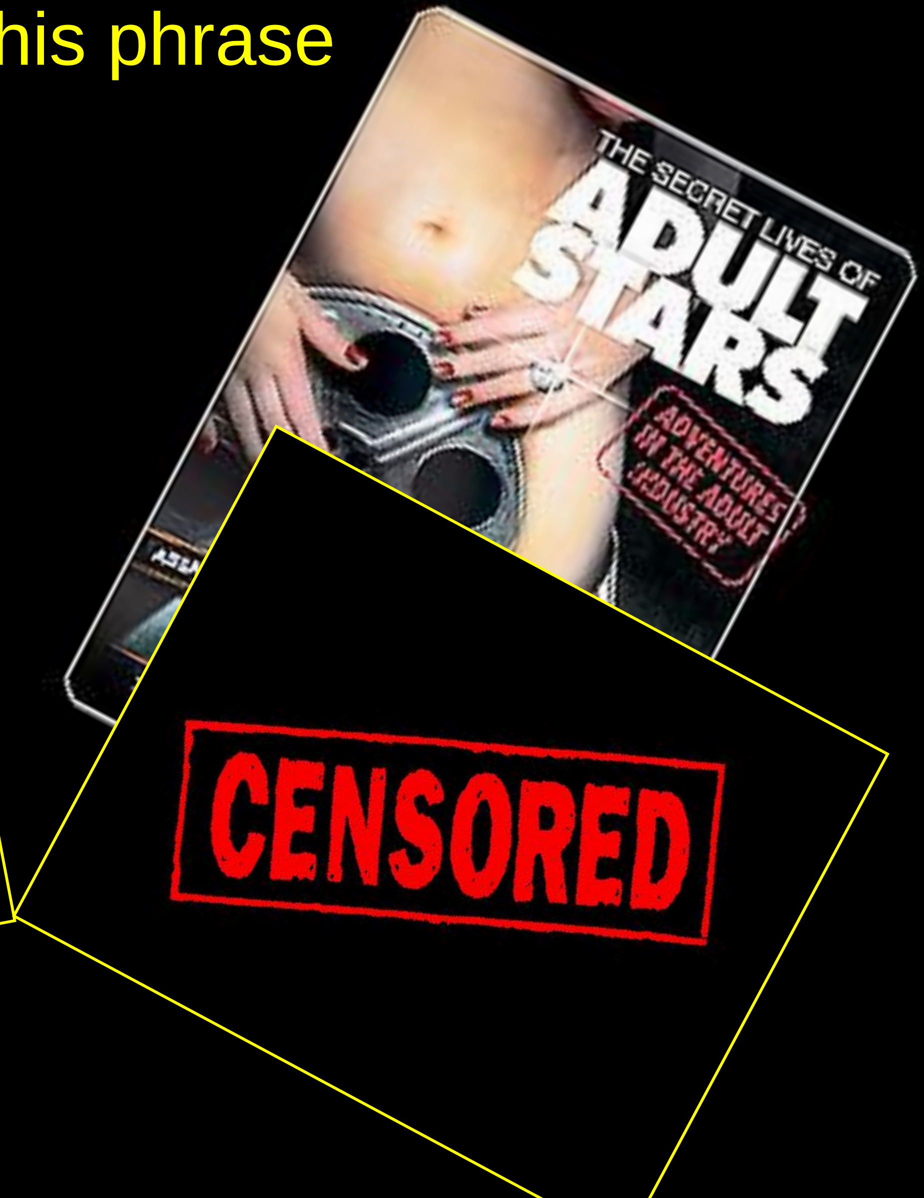
Happy belated birthday, Albert!

Albert Einstein was born on
14 March 1879 in Ulm, Germany

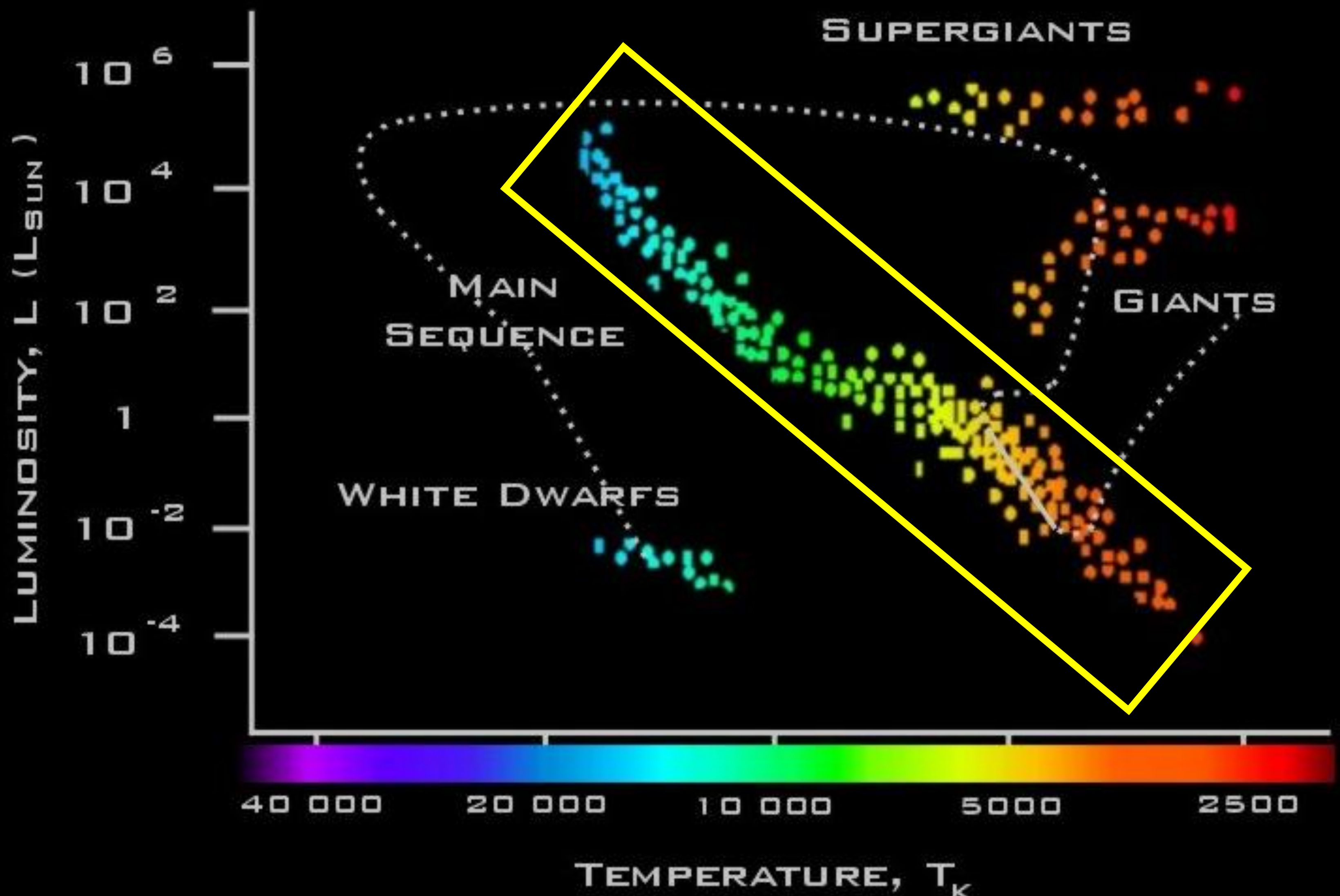
The adult lives of stars

The adult lives of stars

Be careful if you Google this phrase

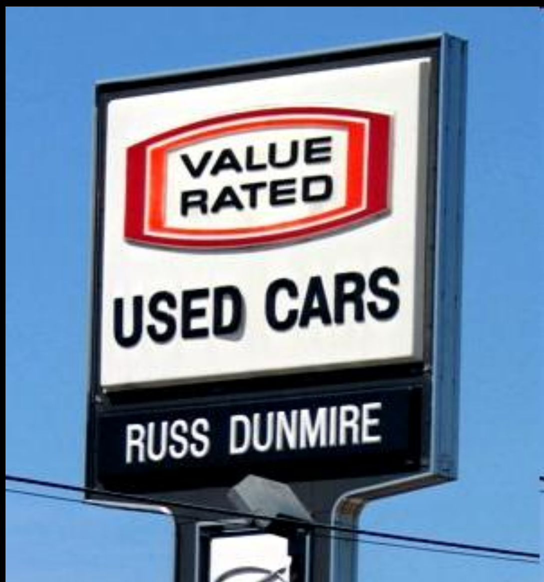


The adult lives of stars



The adult lives of stars

The user car lot



Do I have a deal for you!

The adult lives of stars

The user star lot

In some ways, stars are like cars

Astronomical prices guaranteed!

The adult lives of stars

<u>The user star lot</u>

In some ways, stars are like cars

Trust me!

The adult lives of stars

Massive stars = sports cars

Hot massive stars are bright and attract attention across great distances

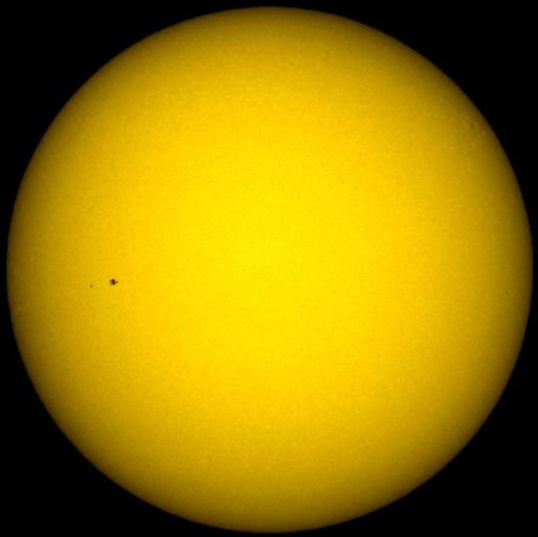
The adult lives of stars

Massive stars = sports cars

Hot massive stars are bright and attract attention across great distances but they’re not very fuel efficient

The adult lives of stars

Solar-mass stars = economy cars



2009 model Sol

Stars of moderate mass
are moderately bright
and much more fuel efficient

The adult lives of stars

M dwarf stars = hybrid super-economy cars

The lowest-mass stars
are hard to notice
unless they're very close by

The adult lives of stars

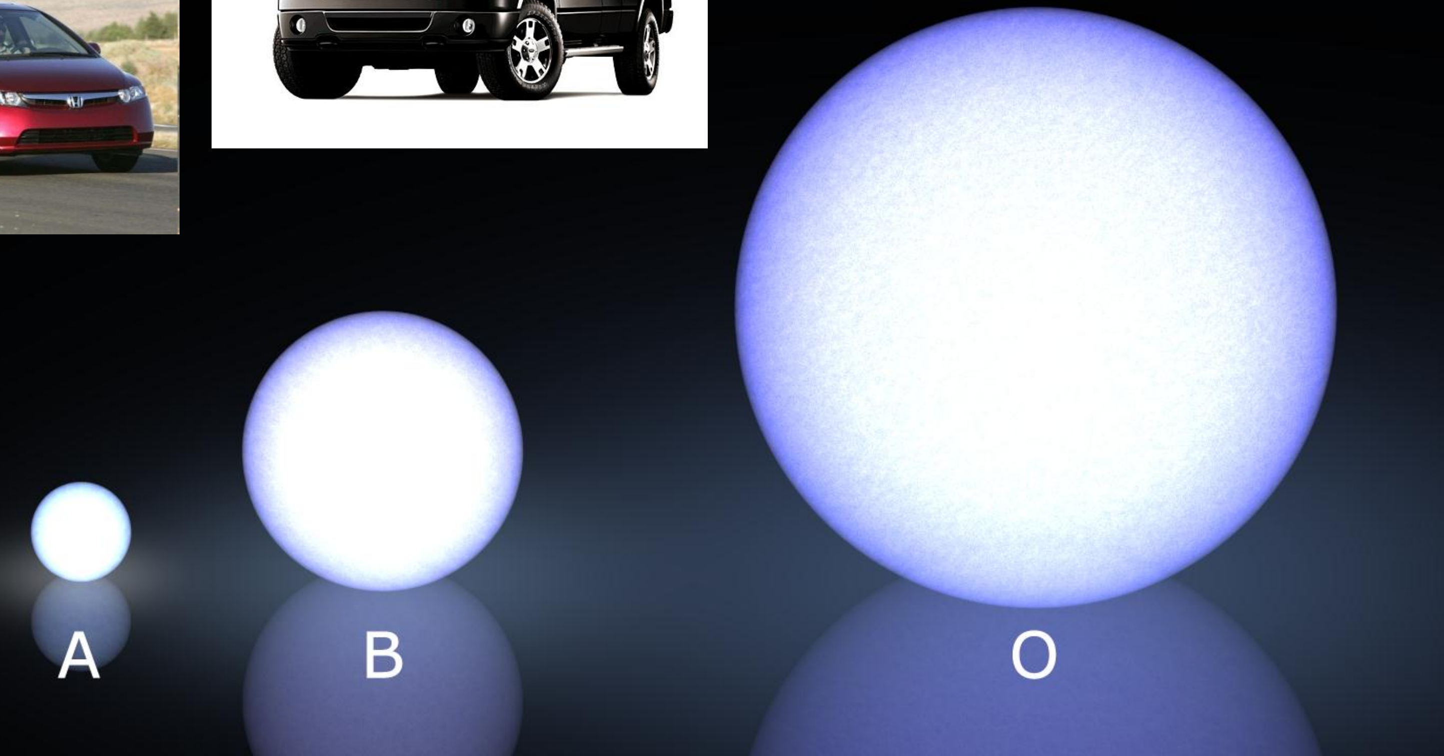
M dwarf stars = hybrid super-economy cars

The lowest-mass stars
are hard to notice
unless they're very close by

but boy, do they go a *long way*
on a single 'tank' of hydrogen

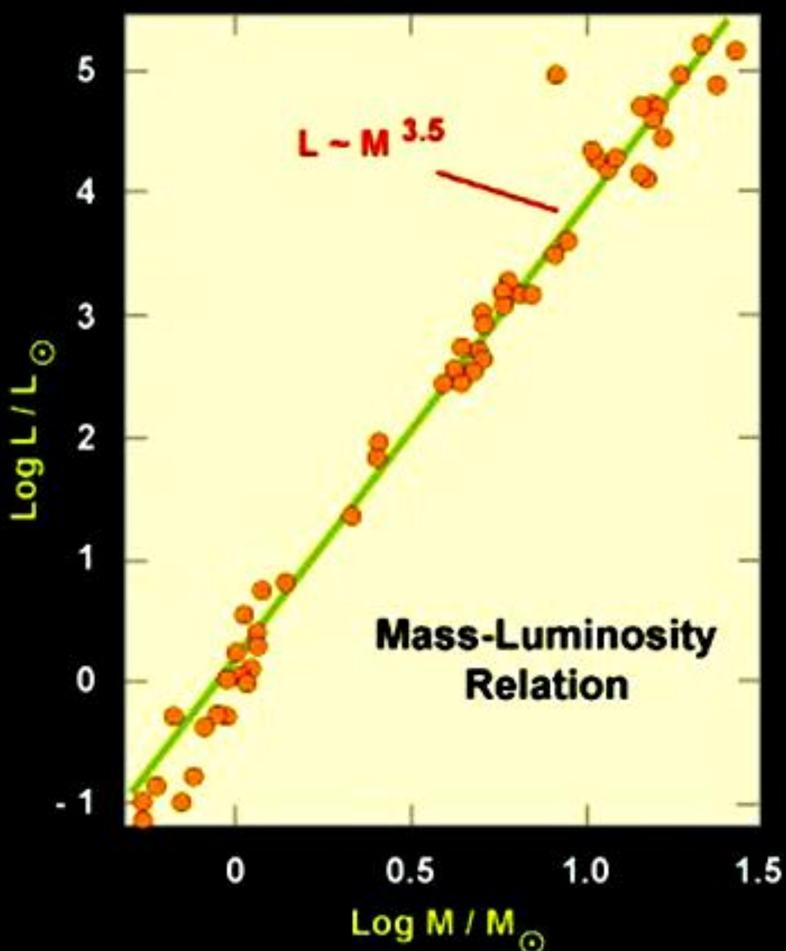
The adult lives of stars

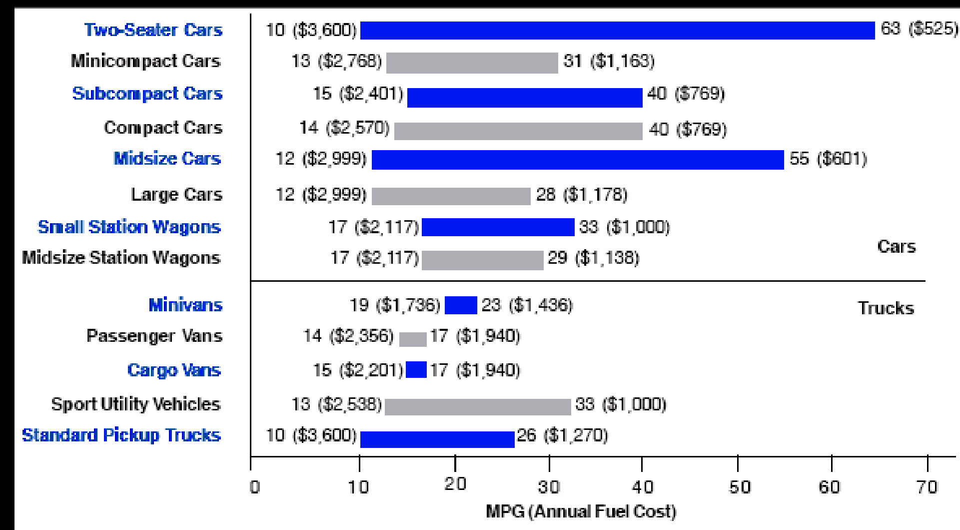
The showroom floor



The adult lives of stars

Main sequence energy generation

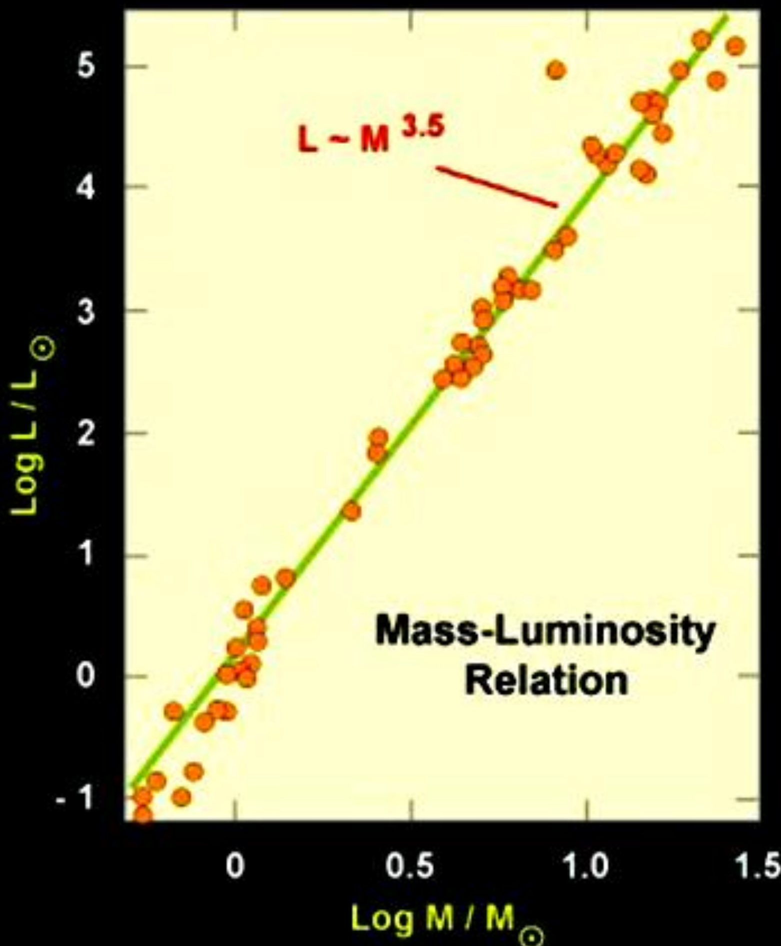


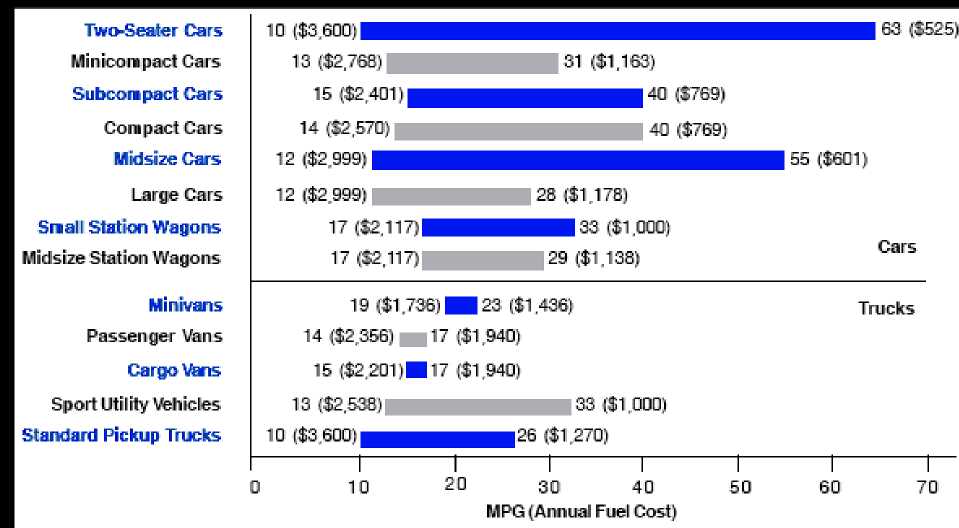


The mass-luminosity relation is the stellar equivalent of automobile fuel efficiency

The adult lives of stars

Main sequence energy generation

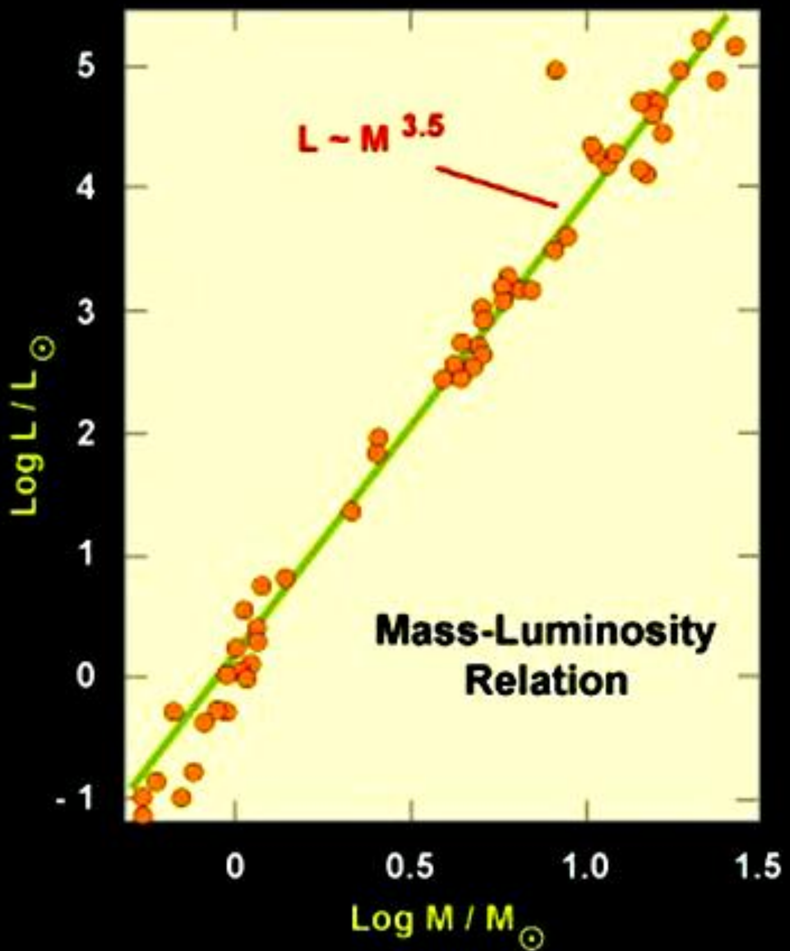




The number of Joules per second a star produces per kilogram tells you how long that star will shine

The adult lives of stars

Main sequence lifetime

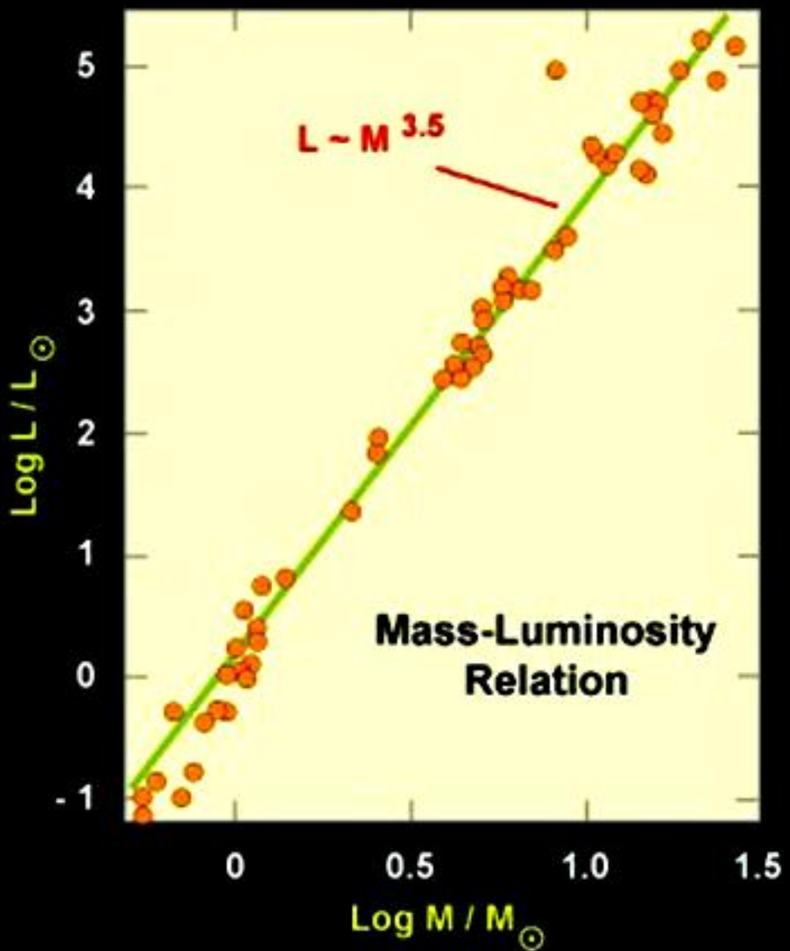


mass-luminosity relation

$L / L_{Sun} \sim (M / M_{Sun})^{3.5}$

The adult lives of stars

Main sequence lifetime



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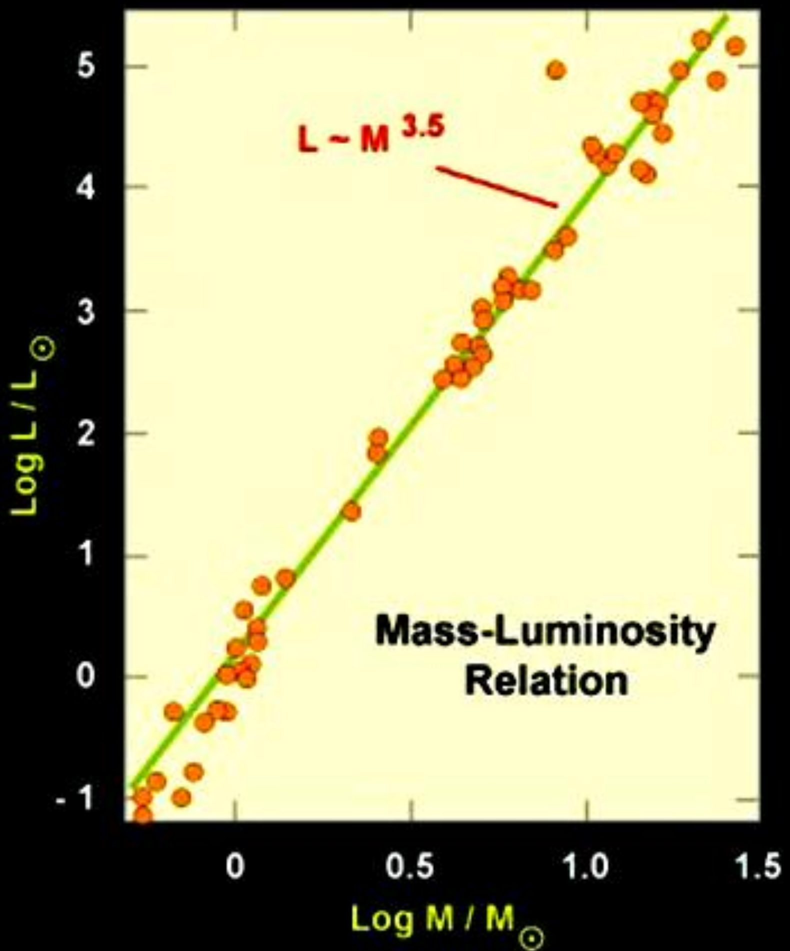
$L / L_{Sun} \sim (M / M_{Sun})^{3.5}$

total energy = luminosity × time

$t / t_{Sun} \sim (E / E_{Sun}) / (L / L_{Sun})$

The adult lives of stars

Main sequence lifetime



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This time *t* is the age of the star if it shines at constant luminosity *L*

The adult lives of stars

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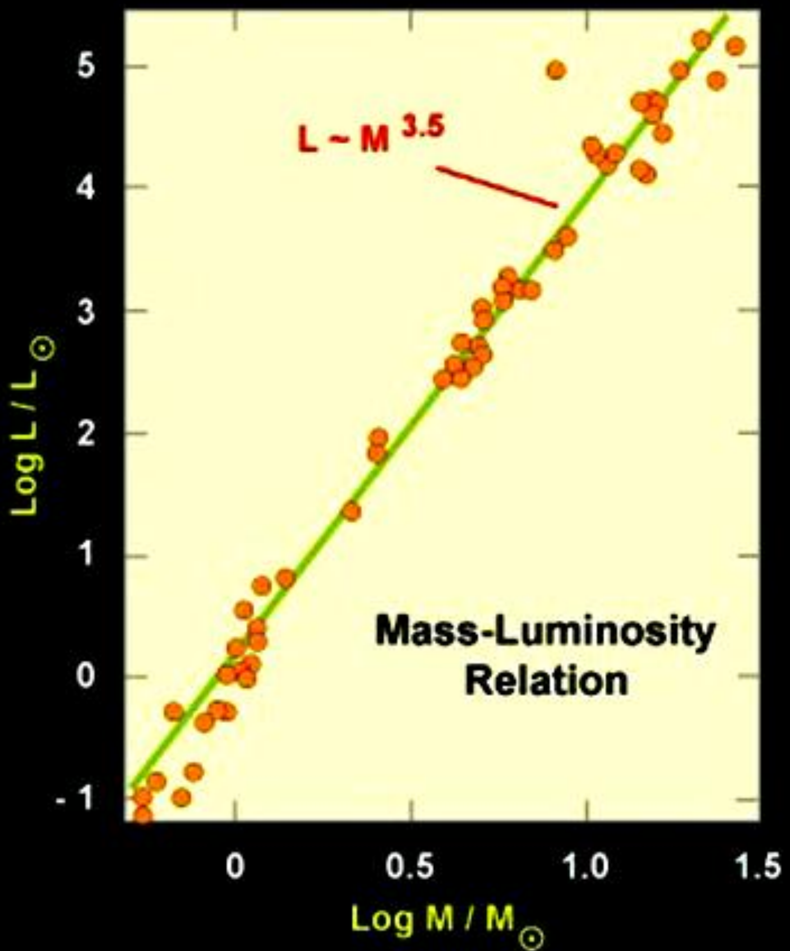

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The adult lives of stars

Main sequence lifetime

$$t / t_{Sun} \sim (E / E_{Sun}) / (M / M_{Sun})^{3.5}$$

How does a star produce energy?

The adult lives of stars

Main sequence lifetime

$$t / t_{Sun} \sim (E / E_{Sun}) / (M / M_{Sun})^{3.5}$$

How does a star produce energy?

Through thermonuclear fusion of H to He for most of its life

How much energy does this produce?

$$E = \Delta M c^2$$

where ΔM is the total amount of mass destroyed

The adult lives of stars

Main sequence lifetime

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The total amount of hydrogen fuel available to a star is proportional to its total mass

$$\Delta M = b M$$

where b is the fraction of mass consumed

The adult lives of stars

Main sequence lifetime

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The adult lives of stars

Main sequence lifetime

$$t \,/\, t_{Sun} \sim (M \,/\, M_{Sun})^{-2.5}$$

The adult lives of stars

Main sequence lifetime

$$t / t_{Sun} \sim (M / M_{Sun})^{-2.5}$$

B2 dwarf

If a star is
10 times the mass of the Sun
it will be able to shine for
only $10^{-2.5}$ ~ *0.003 times as long*

The adult lives of stars

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M8 dwarf

If a star is
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$(0.1)^{-2.5} \sim$ *300 times as long*

The adult lives of stars

<u>*Main sequence lifetime*</u>

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The total lifetime of the Sun is estimated to be about *10 billion (10^{10}) years*

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B2 dwarf

lifetime ~ *30 million years*

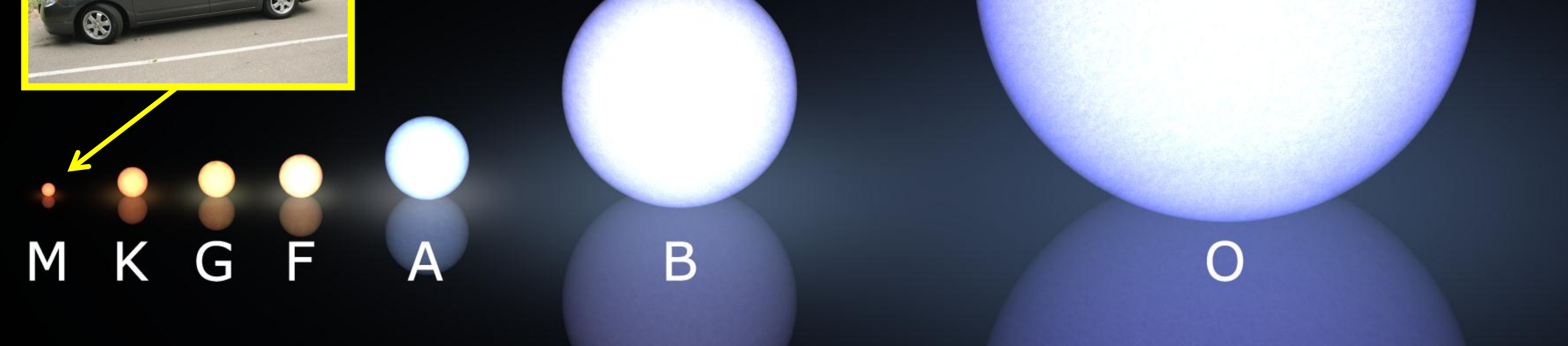
If a star is *1 tenth the mass of the Sun* it will be able to shine for $(0.1)^{-2.5} \sim$ *300 times as long*

M8 dwarf

lifetime ~ *3 trillion years*

The adult lives of stars

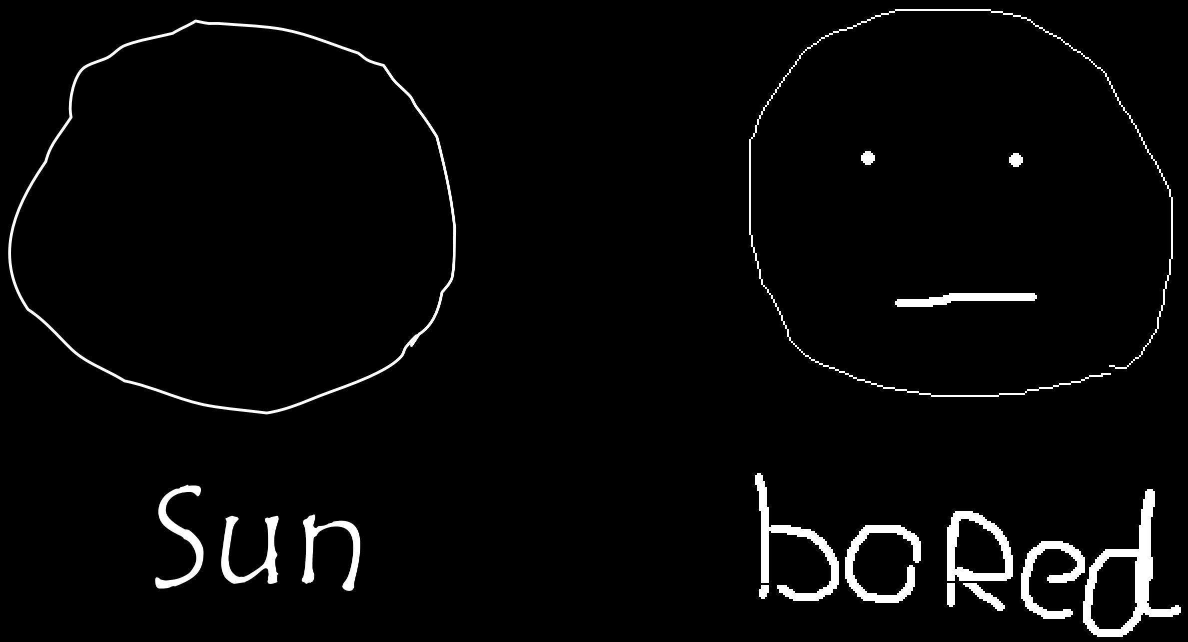
An M dwarf lasts a <u>*long*</u> time on a single tank of hydrogen



The adult lives of stars

A stable, "boring" life on the main sequence

While on the main sequence
stars are in hydrostatic equilibrium
so changes are slow and subtle



The adult lives of stars

A stable, "boring" life on the main sequence

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As hydrogen in the stellar core
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For example, the Sun has been very slowly increasing
in radius and in luminosity during its main sequence life

The adult lives of stars

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For example, the Sun has been very slowly increasing
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In 4½ billion years since the Sun was born
it has increased in luminosity by a few tens of per cent
and it will continue to brighten for the remainder of its life

The adult lives of stars

The Faint Young Sun Paradox

Astronomers know that the Sun has been gradually increasing in luminosity over the history of the Solar System so that the Earth must have been cooler in the past

The adult lives of stars

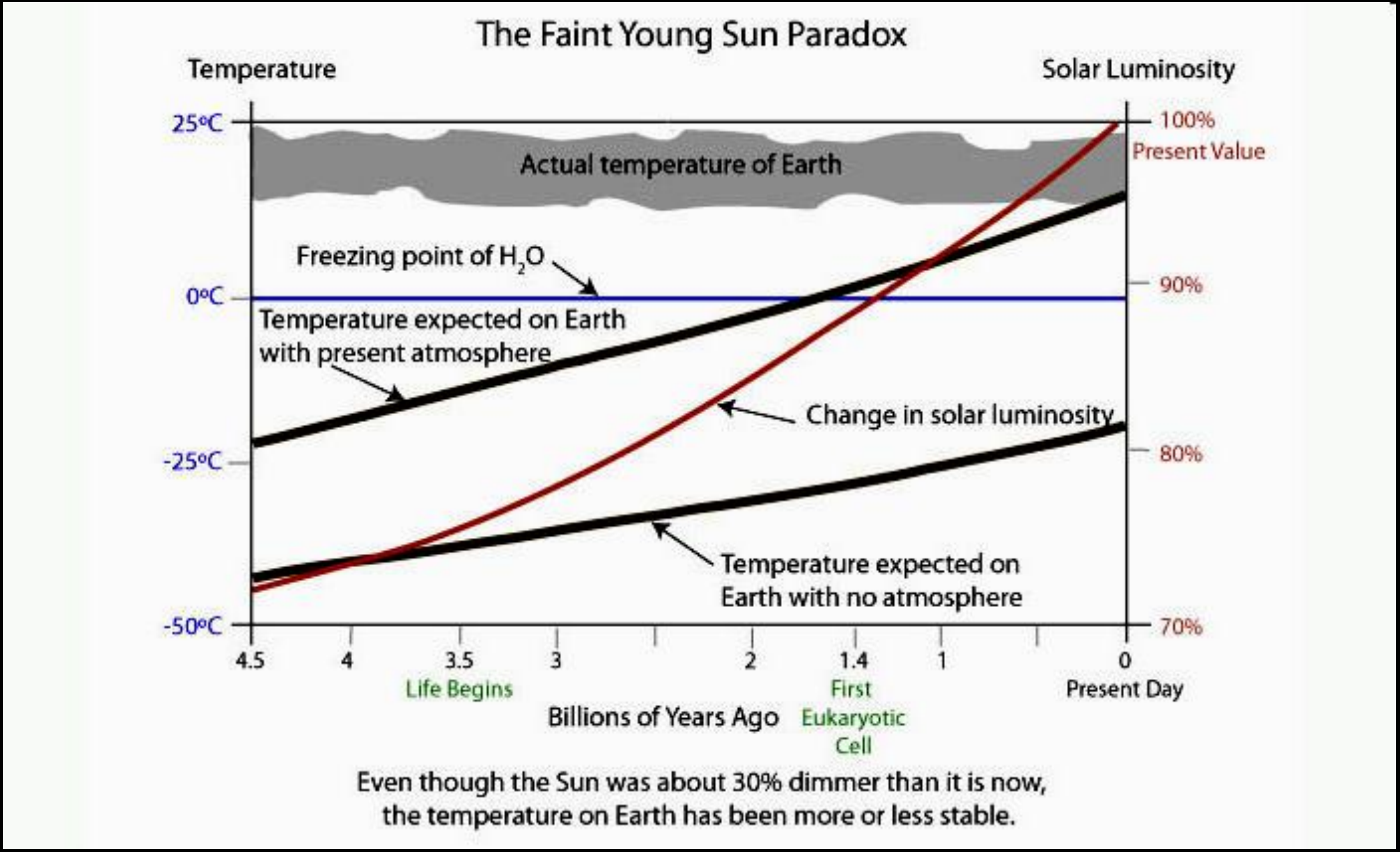
The Faint Young Sun Paradox

Astronomers know that the Sun has been gradually increasing in luminosity over the history of the Solar System so that the Earth must have been cooler in the past

But evolutionary models of the Sun predict that the solar luminosity was low enough in the past that the Earth should have been frozen over at the time when we know liquid oceans first appeared on our planet's surface

The adult lives of stars

The Faint Young Sun Paradox



The adult lives of stars

The Faint Young Sun Paradox

It is unlikely that the models of solar evolution are wrong by enough to resolve the paradox

The details of the Earth's primordial atmosphere and the early Greenhouse Effect are more promising ways to explain the Earth's relatively stable temperature history

The adult lives of stars

The past – Earth's first oceans

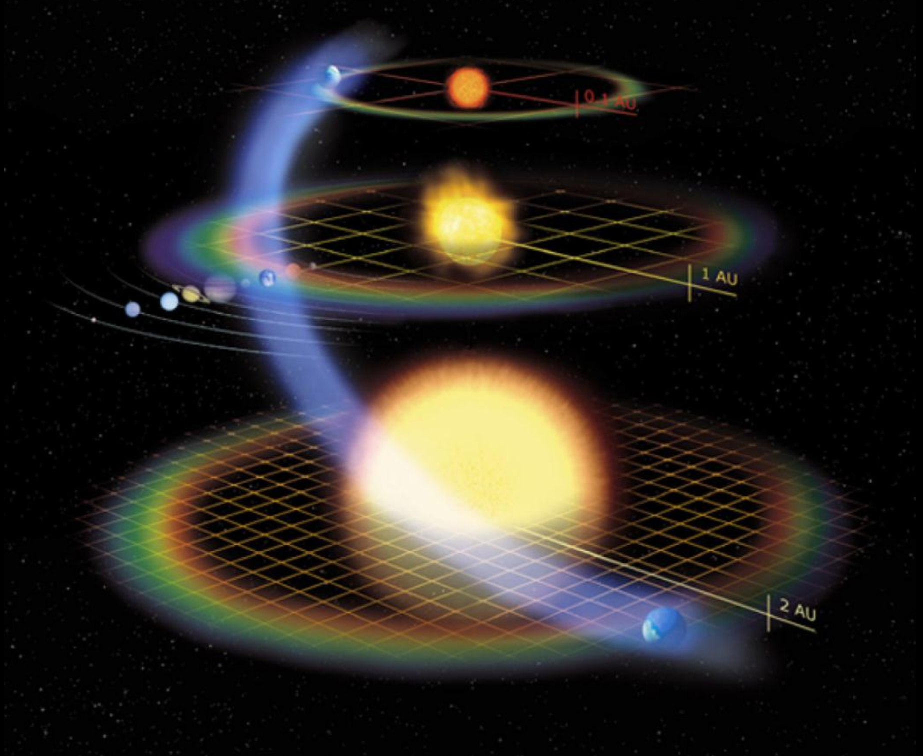
Results announced today
show that analysis of sandstones
in North Greenland confirm that oceans
formed on Earth about 4 billion years ago

http://www.cbc.ca/technology/story/2010/03/15/tech-geology-ancient-ocean.html

The adult lives of stars

The future

Even before the Sun exhausts its core hydrogen fuel supply it will continue to expand and to brighten slowly



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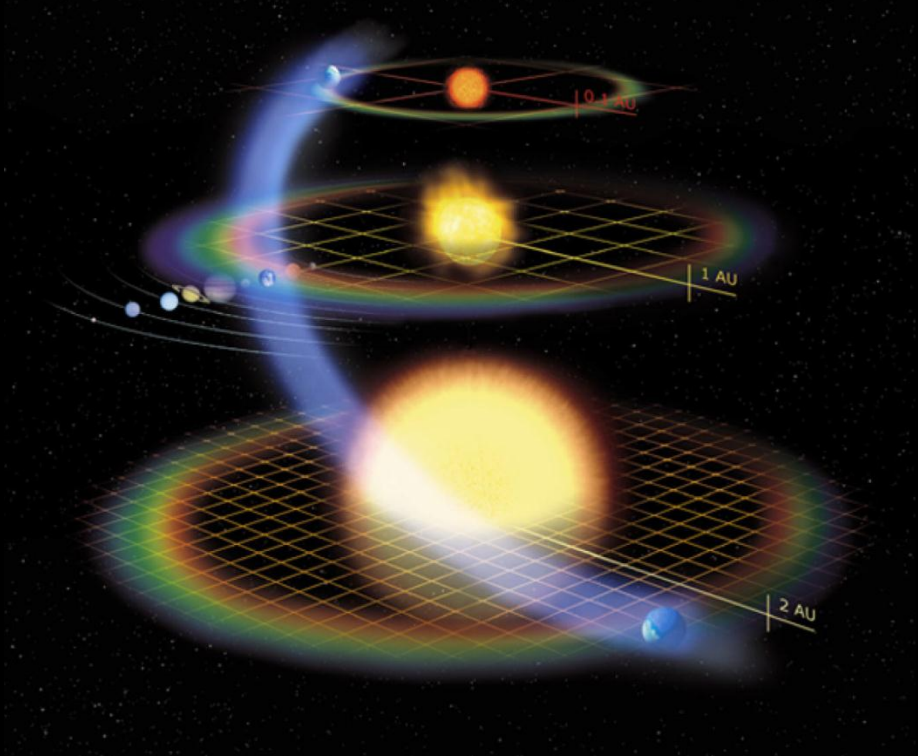
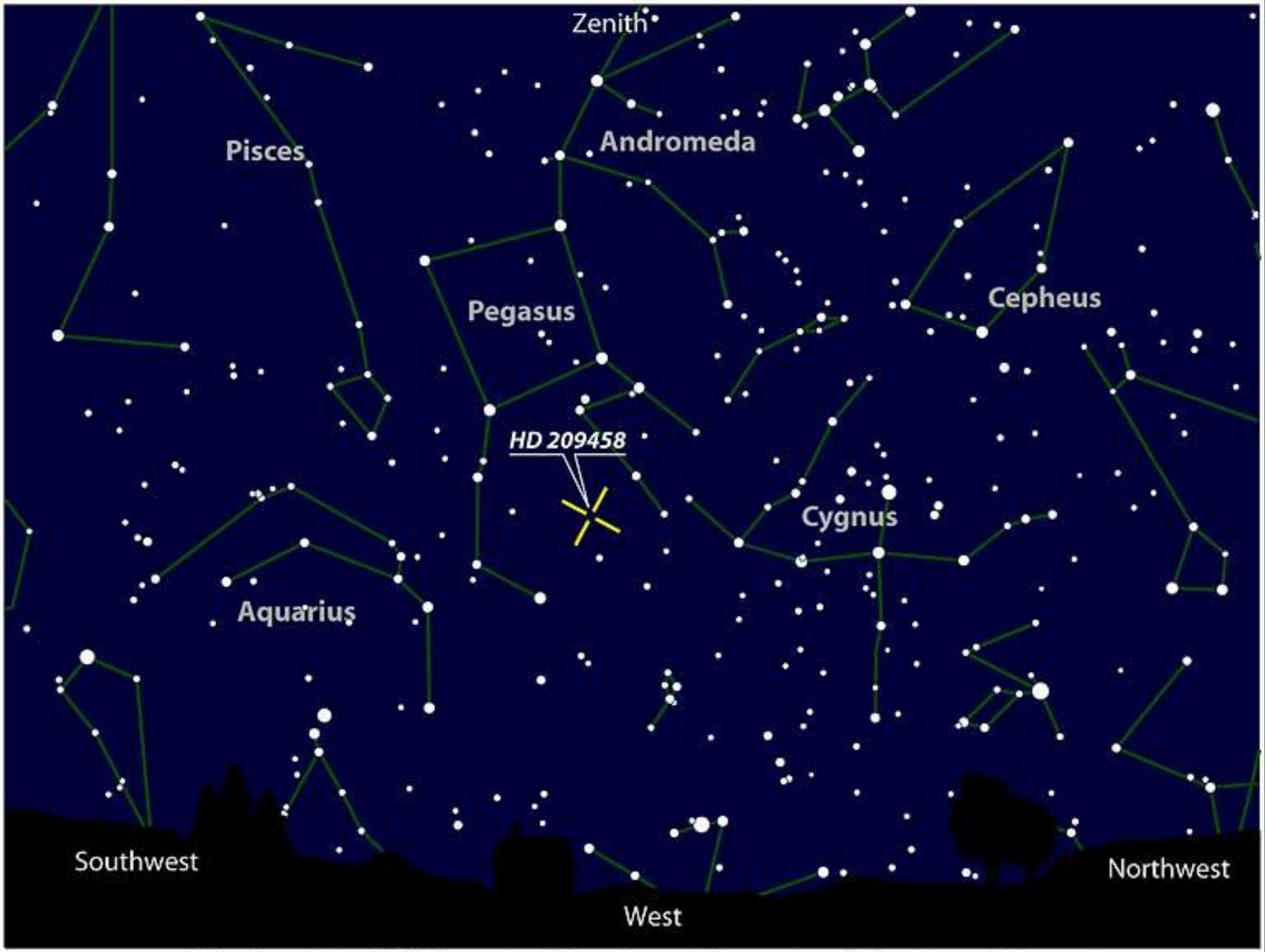


This will cause the Earth's surface temperature to rise

In a few 100 million years to a billion years or so the oceans will boil away

Questions?

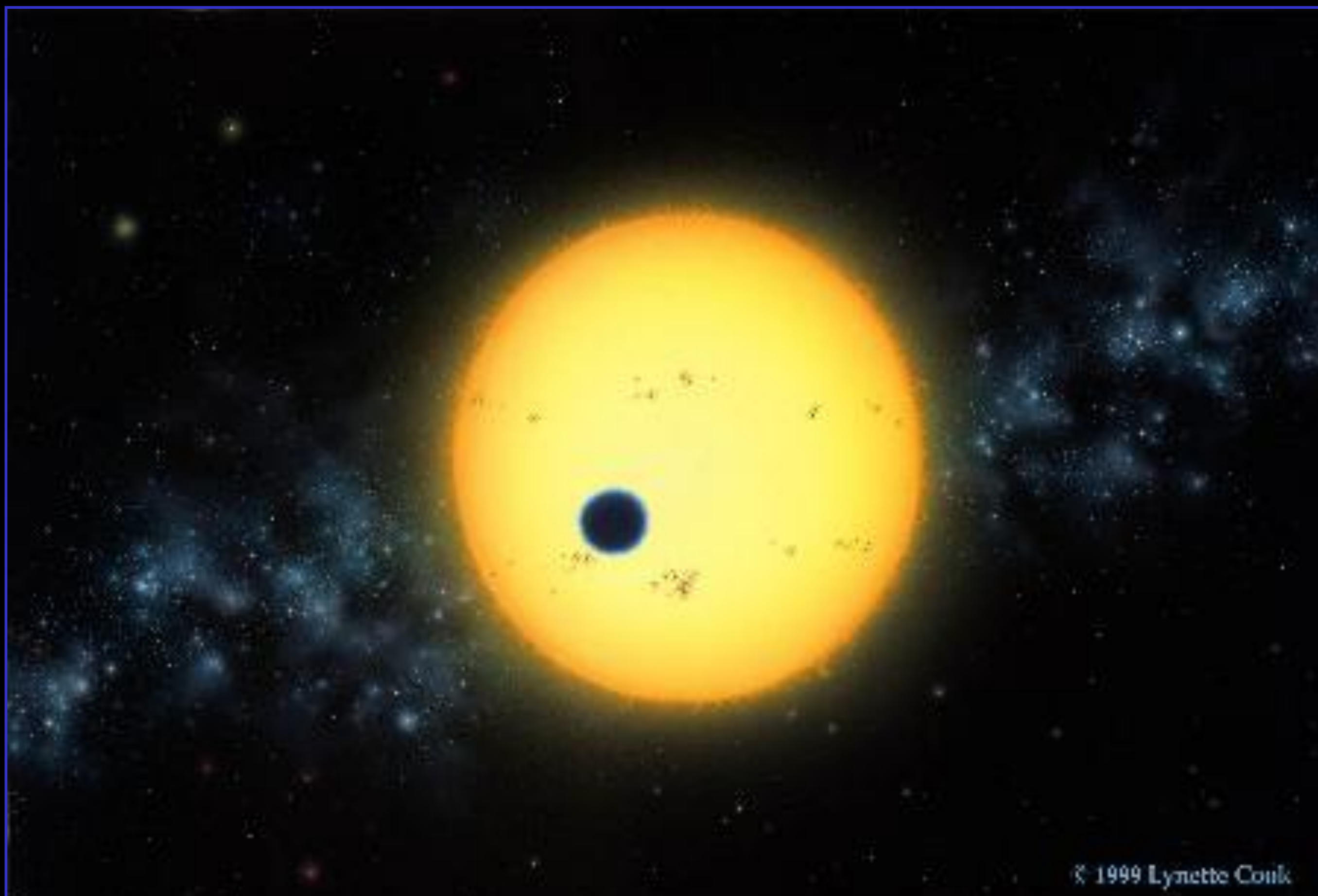
Travelling on the MOST transit system



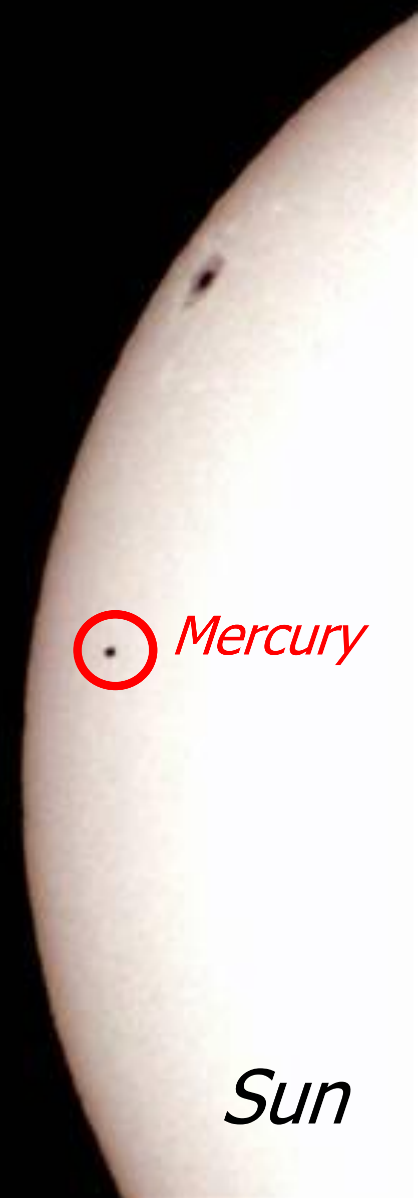
The sky at about 9:00p.m. local time in early December, facing toward the west

HD 209458

Transiting exoplanet



artist's conception



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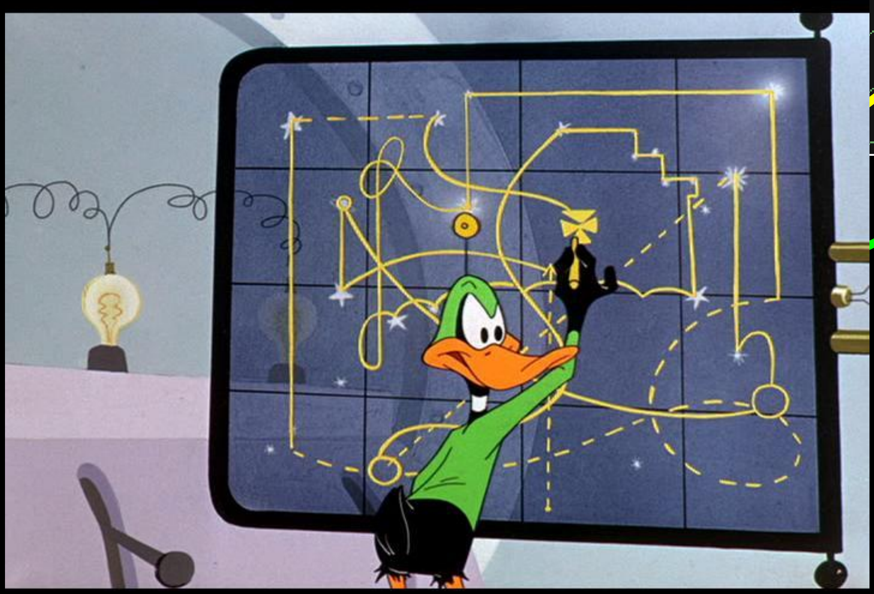


Position: RA = 22 03 10.8
Dec = +18 53 04
Distance: 47 pc ~ 153 ly
Constellation: Pegasus

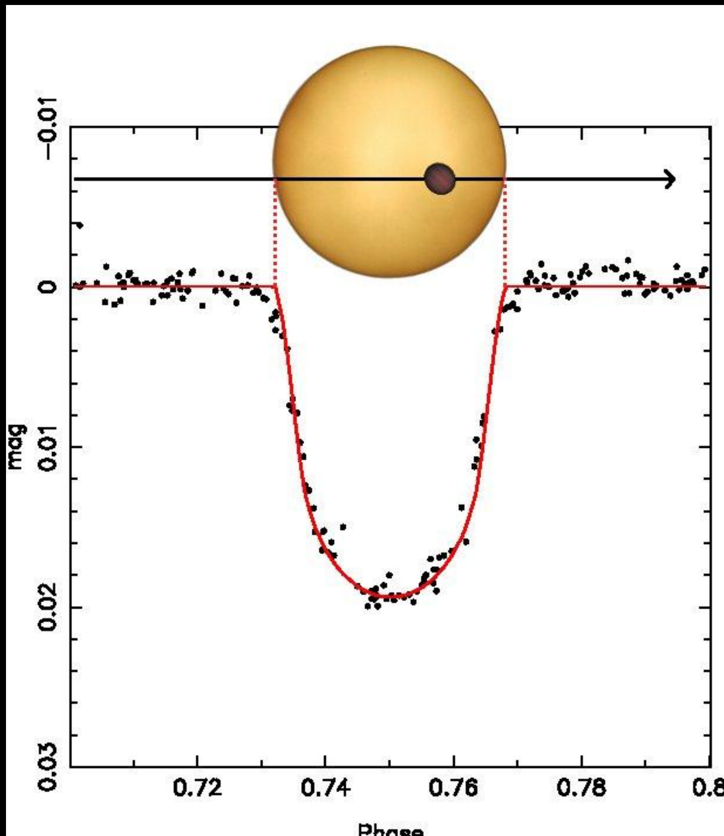
Star

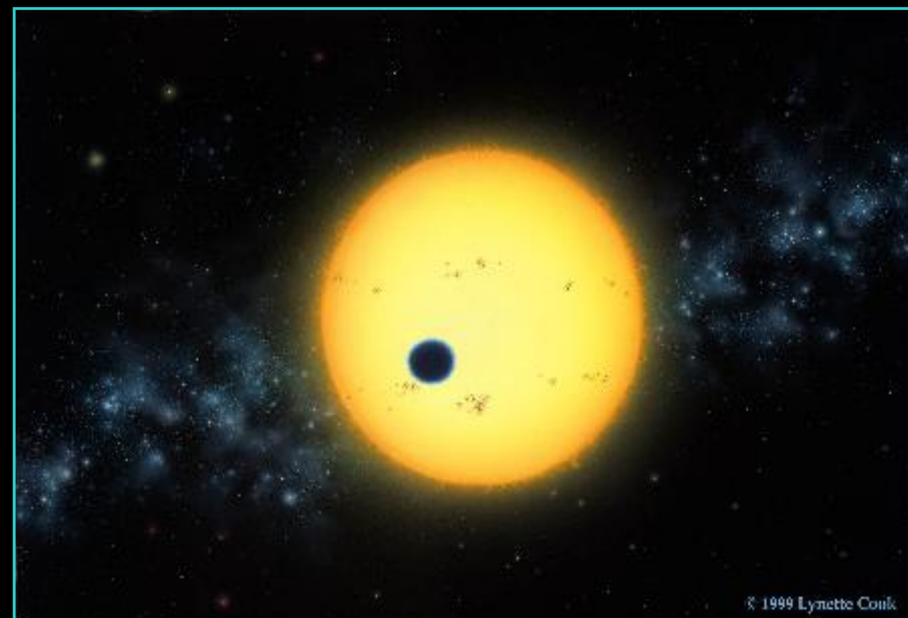
Magnitude (Star): V=7.64
Spectra Class: G0 V
Temperature: 6000 K

Planet

Orbital Period: 3.52 days
Semi-major axis: 0.046 AU
Eccentricity: 0
Mass: 0.68 × Jupiter
Radius: 1.35 × Jupiter

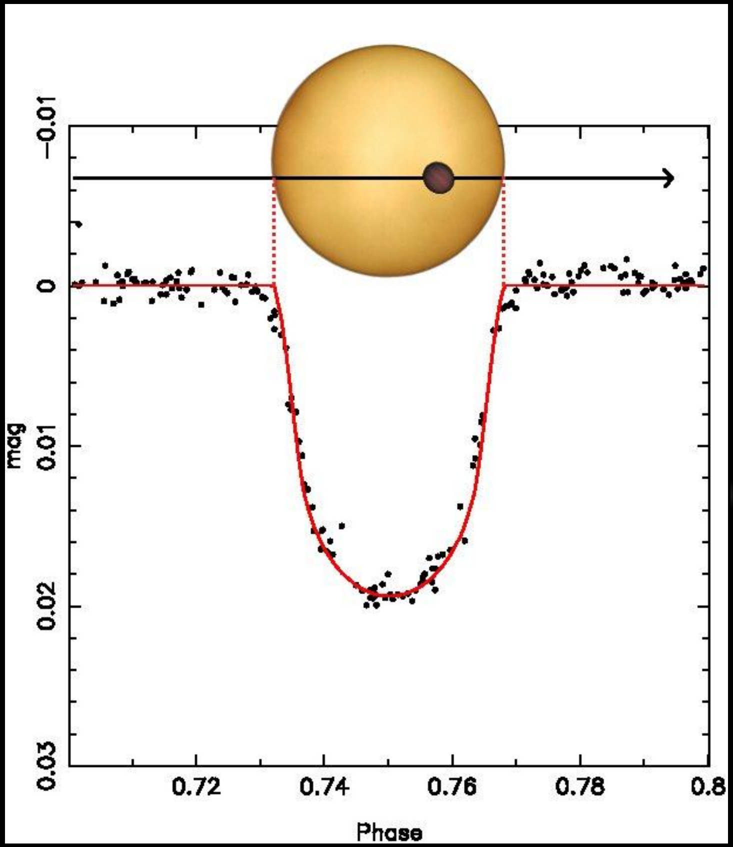
HD 209458





- ✓ measurement of the transit of the giant planet by MOST

HD 209458



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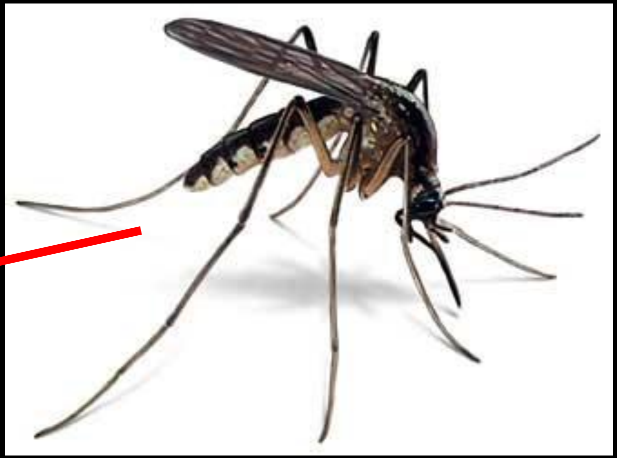
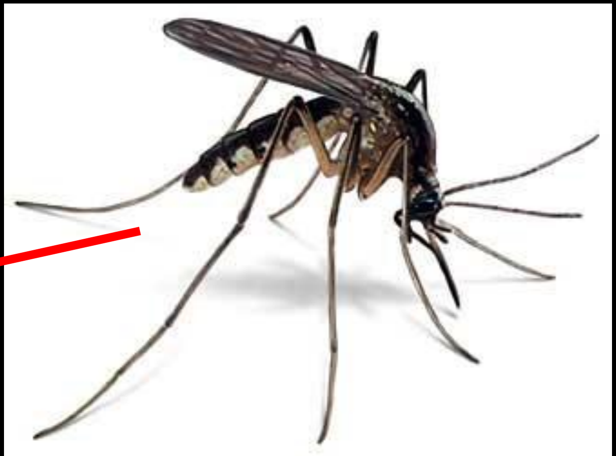
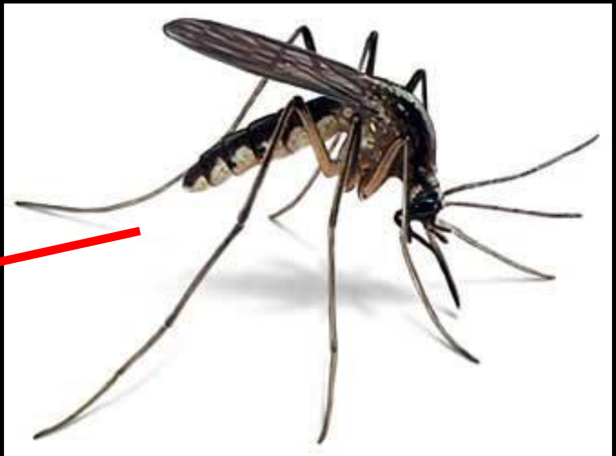


Imagine trying to see a mosquito disappearing behind a 400-Watt streetlamp.



Imagine trying to see a mosquito disappearing behind a 400-Watt streetlamp.

Not at the street corner, nor a few blocks away…



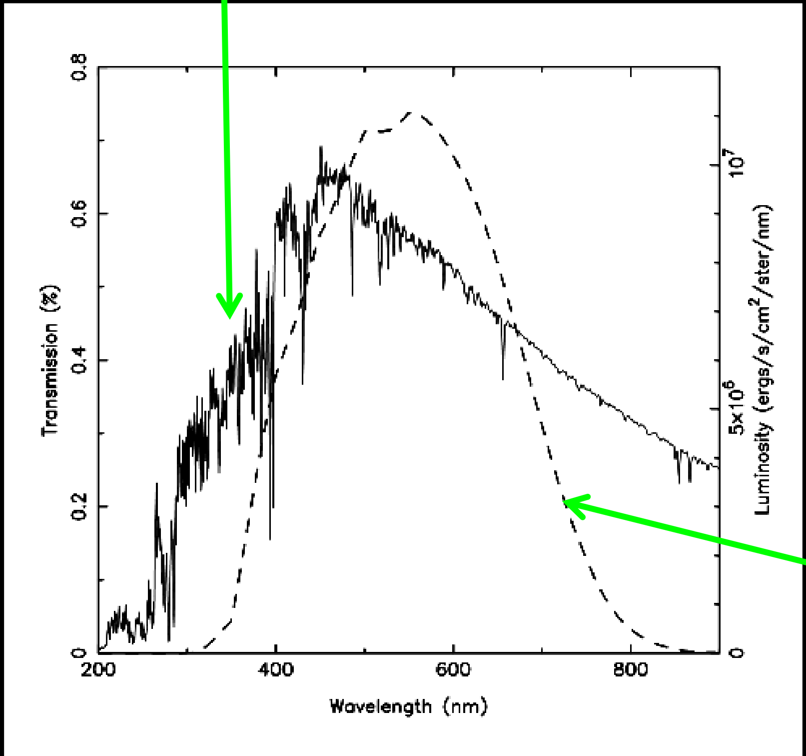
Imagine trying to see a mosquito disappearing behind a 400-Watt streetlamp.

Not at the street corner, nor a few blocks away…
but ***1000 km*** away.

Albedo

- ✓ Photon scattering & molecular absorption are the dominant mechanisms that determine the reflected spectrum of an exoplanet

G0V star



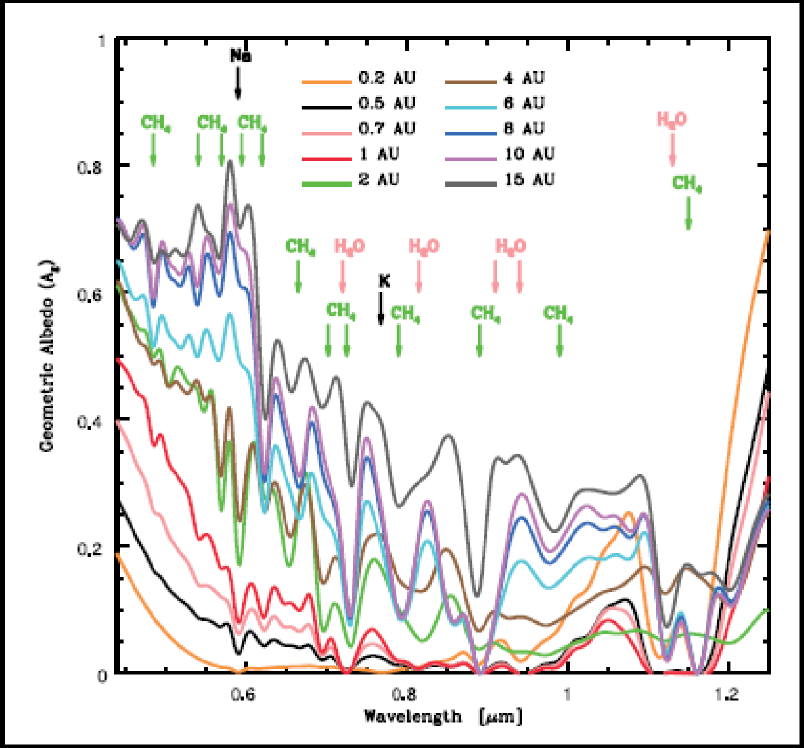
MOST instrument throughput

Albedo

- For wavelengths $\lambda < 600\ nm$
  Rayleigh scattering dominates

  a large fraction of incident light can be reflected outwards

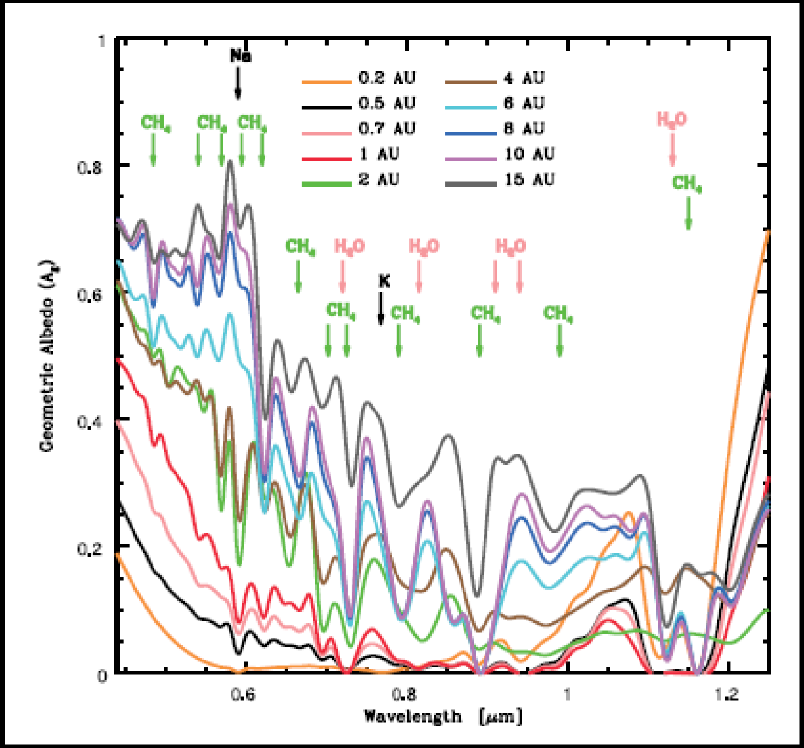
- For wavelengths $\lambda > 600\ nm$
  photons are absorbed deep in the exoplanet's atmosphere



Albedo

- ✓ Strong UV flux produces haze darkening planet in the blue
- ✓ Cloud formation is still speculative

Particle size and composition?



Albedo

Albedo, Bond Albedo

Bond Albedo

"Let a sphere *S* be exposed to parallel light. Then its albedo A is the ratio of the whole amount of light reflected from *S* to the whole amount incident on it" (*Bond 1861)*

$$A_B = A_g\, q$$

Geometric albedo

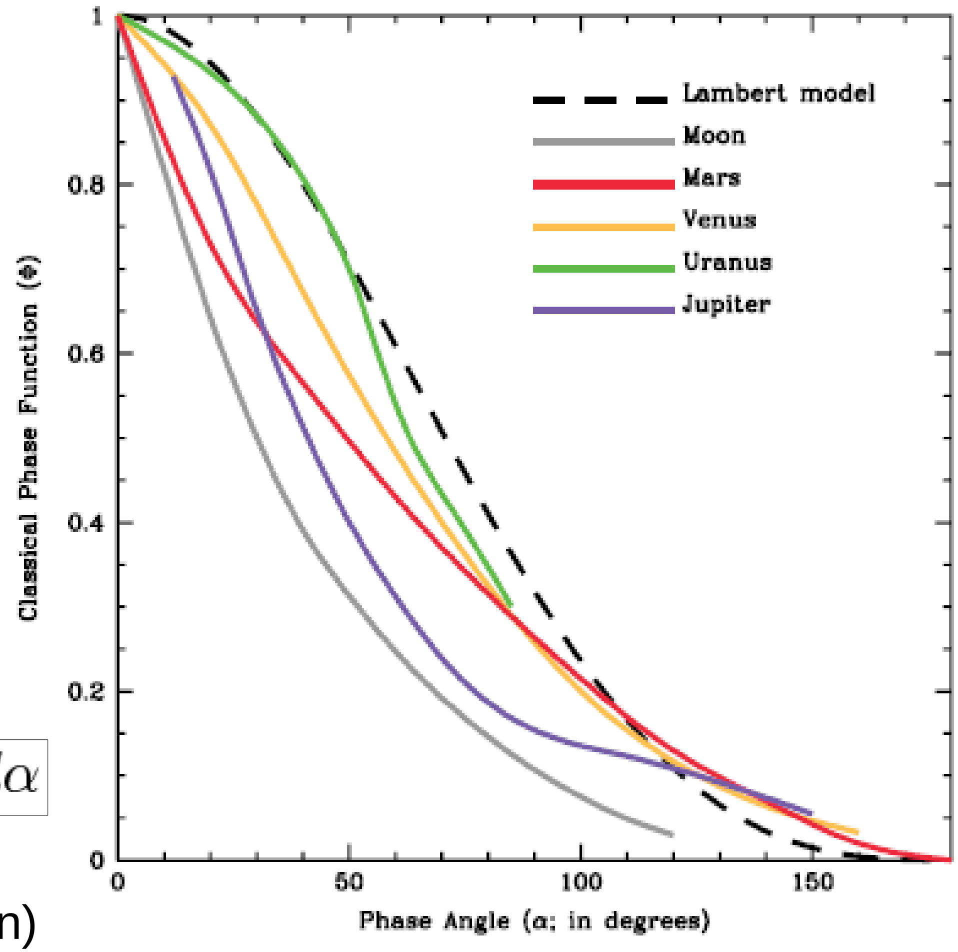
Phase integral

$$\frac{F_P}{F_*} = A_g \left(\frac{R_P}{a}\right)^2$$

$$q = 2\int_0^{\pi} \phi(\alpha)\, sin\alpha\, d\alpha$$

Phase function (Lambertian)

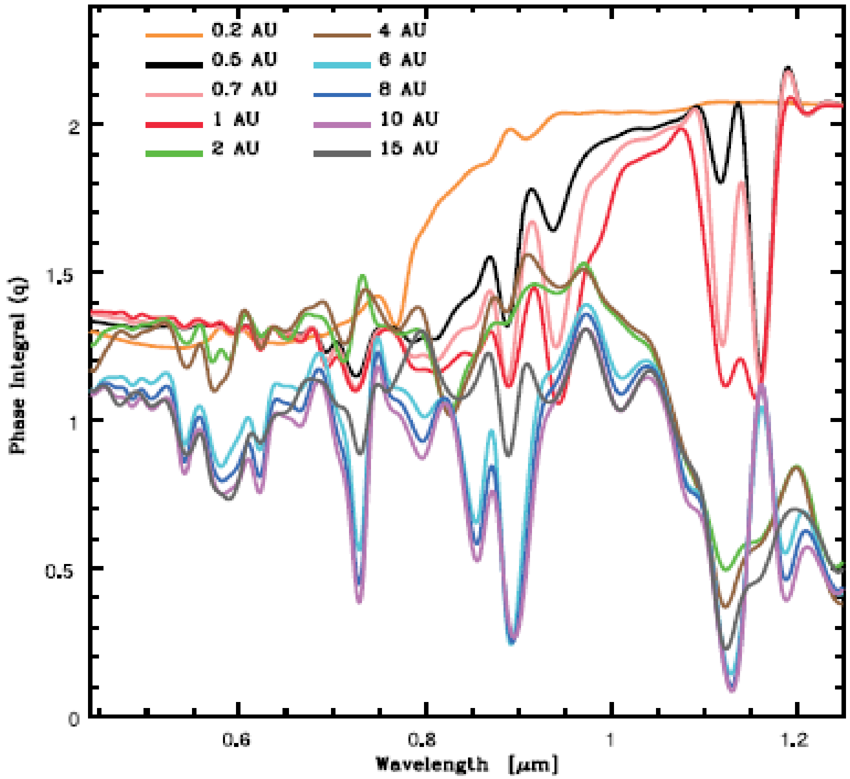
$$\phi(\alpha) = \frac{1}{\pi}(sin\alpha + (\pi - \alpha)cos\alpha)$$

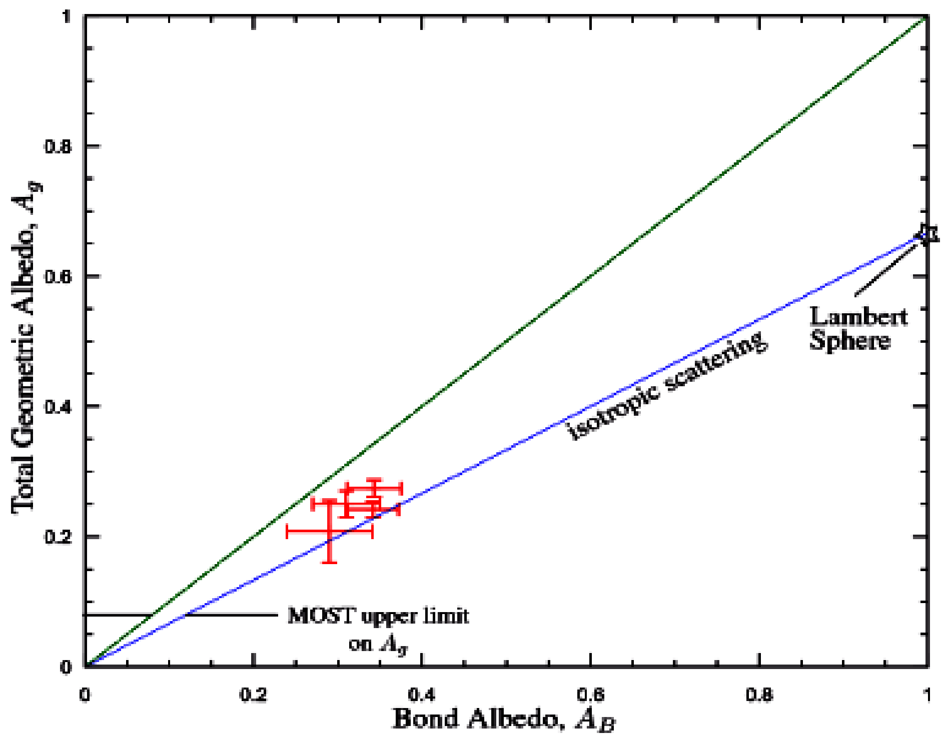


Sudarsky et al. 2005

Bond Albedo

Phase function

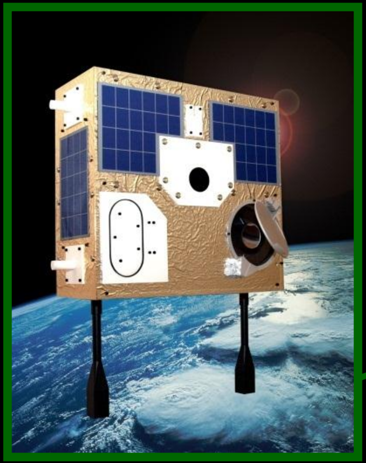




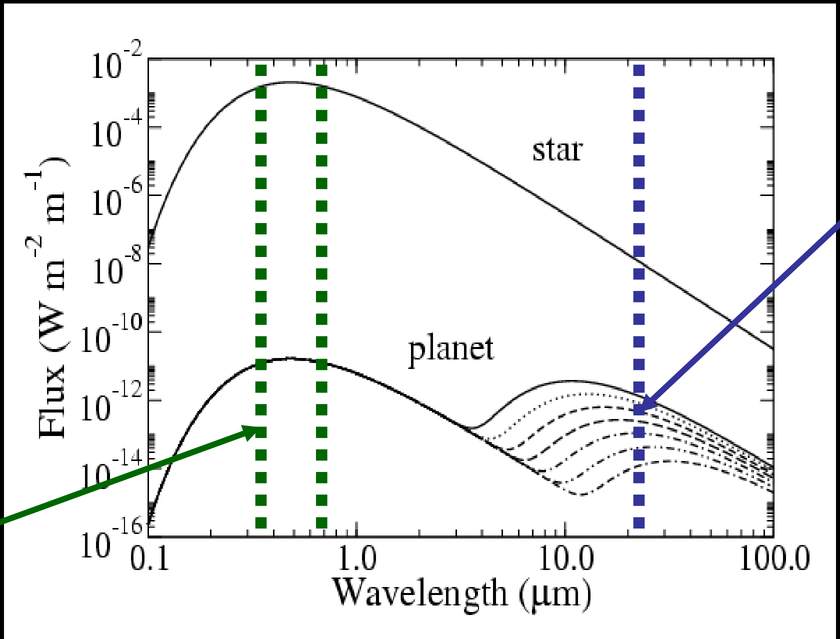
Treating the phase function of the planet as an isotropic scatterer gives an upper limit on the Bond Albedo

HD 209458

MOST
optical



Rowe et al. 2008
Astrophysical Journal



Spitzer
infrared

Deming et al. 2005
Nature 111, 111

HD 209458

MOST
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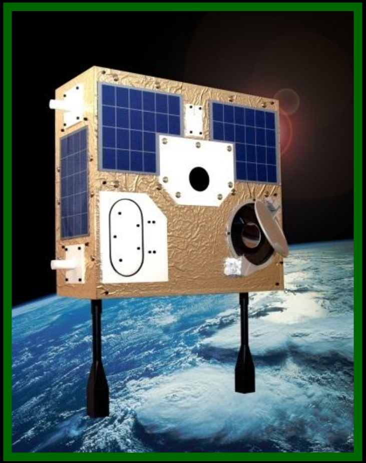

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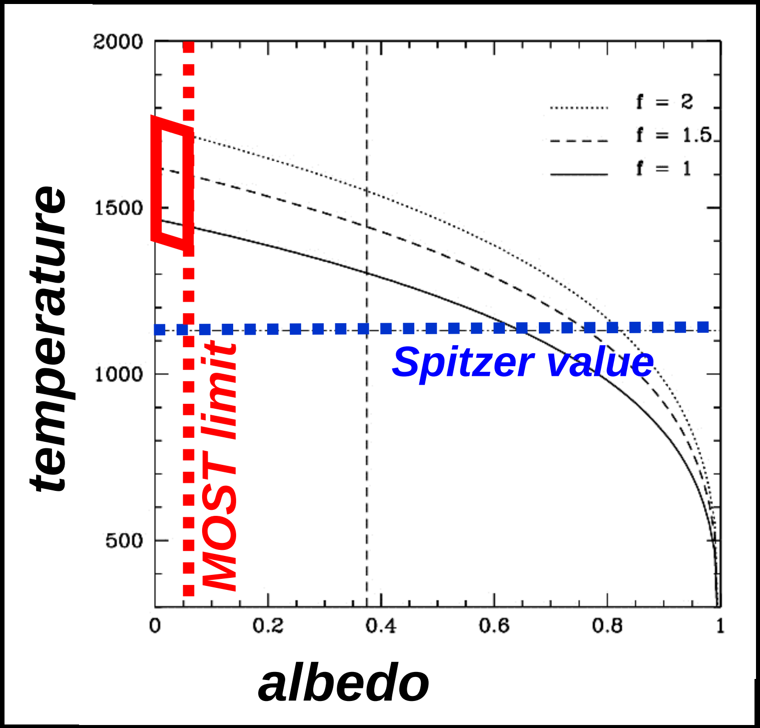
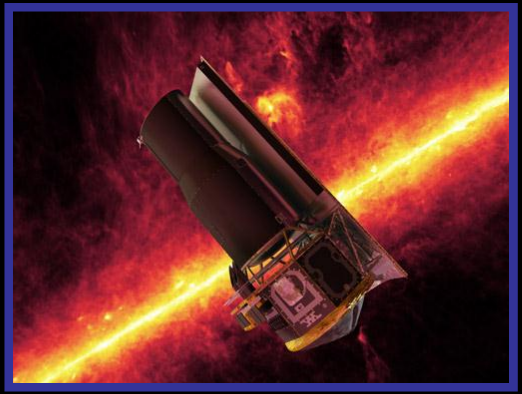
models of planet atmosphere





Spitzer
infrared

Deming et al. 2005
Nature 111, 111

HD 209458

Best fit parameters:

albedo = *0.04 ± 0.04*

stellar radius :

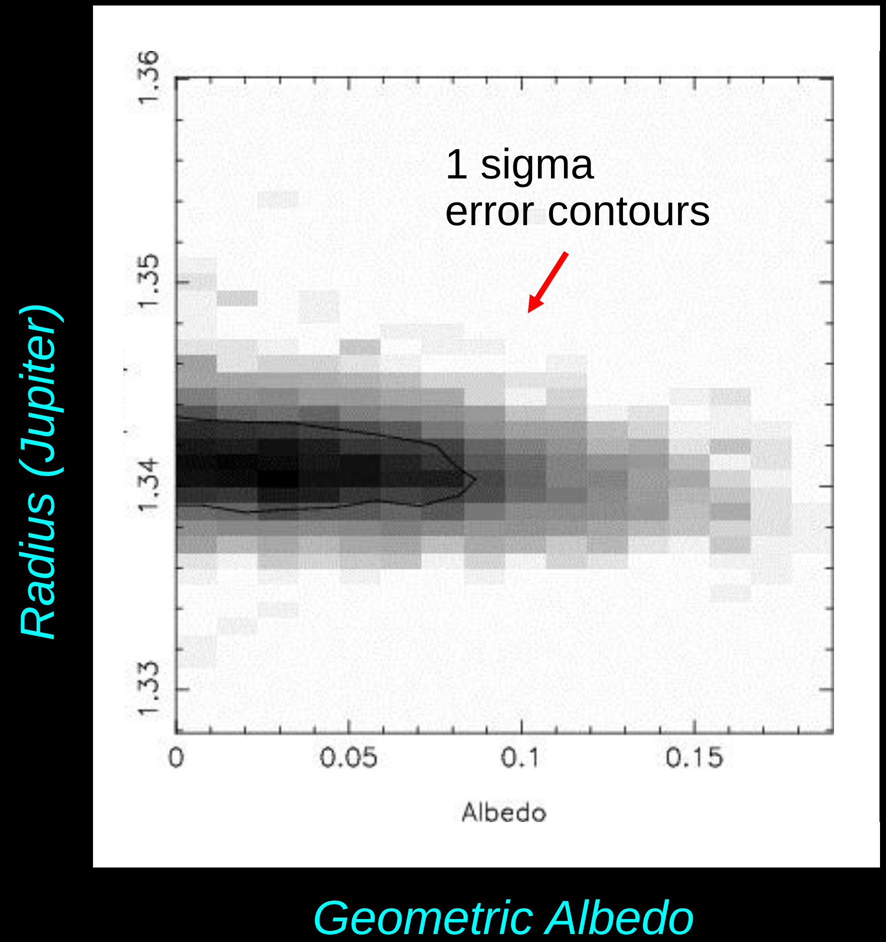
$1.339 \pm 0.001\ R_{Jupiter}$

stellar mass

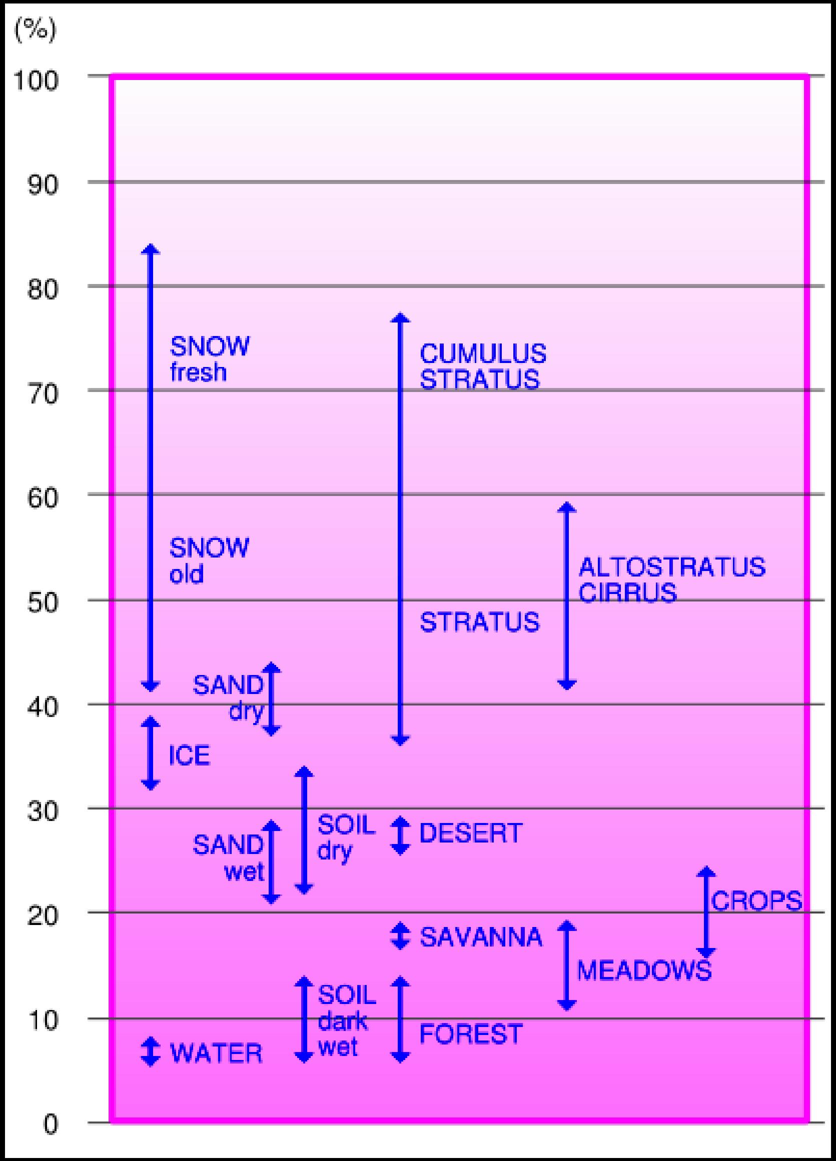
$1.084 \pm 0.005\ M_{Sun}$

$i = 86.937° \pm 0.003°$

$P = 3.5247489$ d

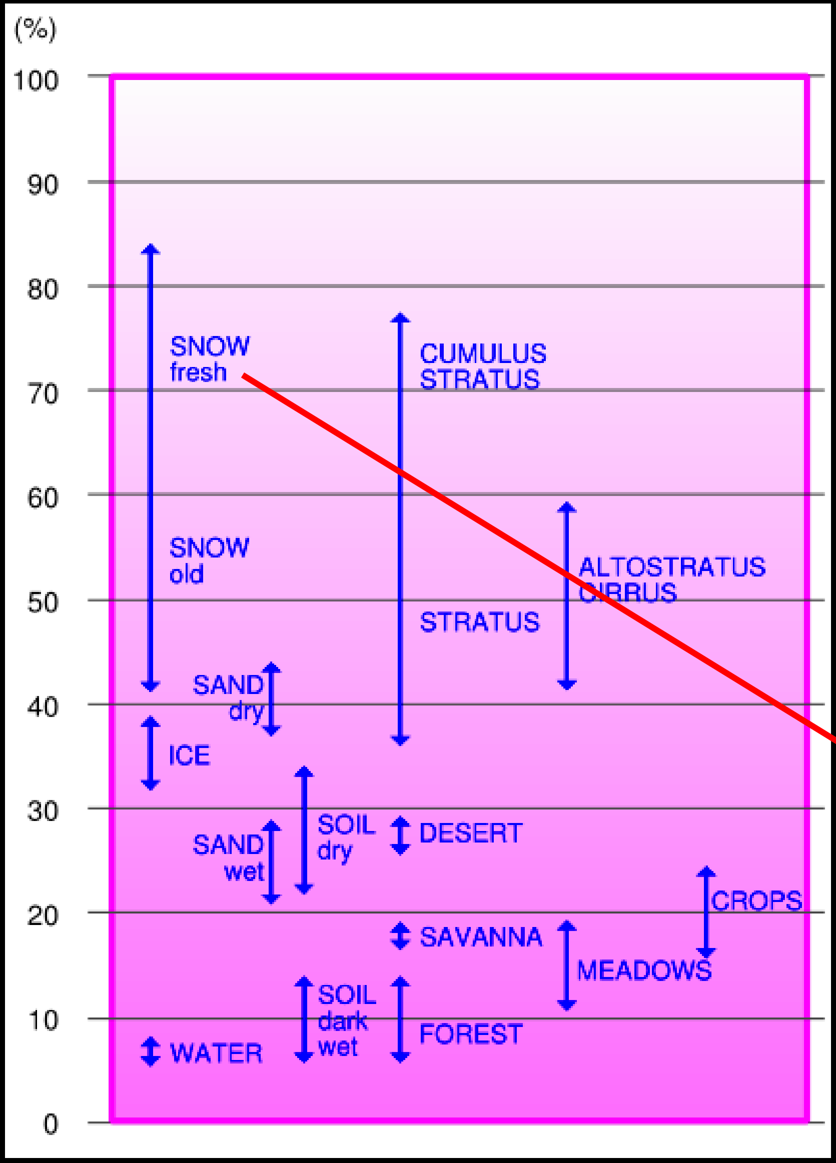


The Earth from space



albedo = *reflectivity* →

The Earth from space



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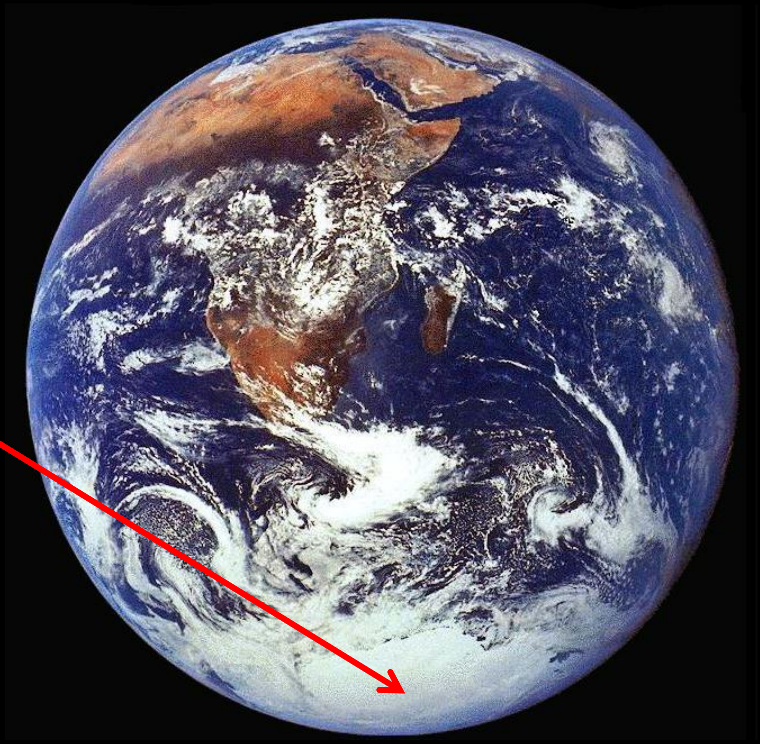

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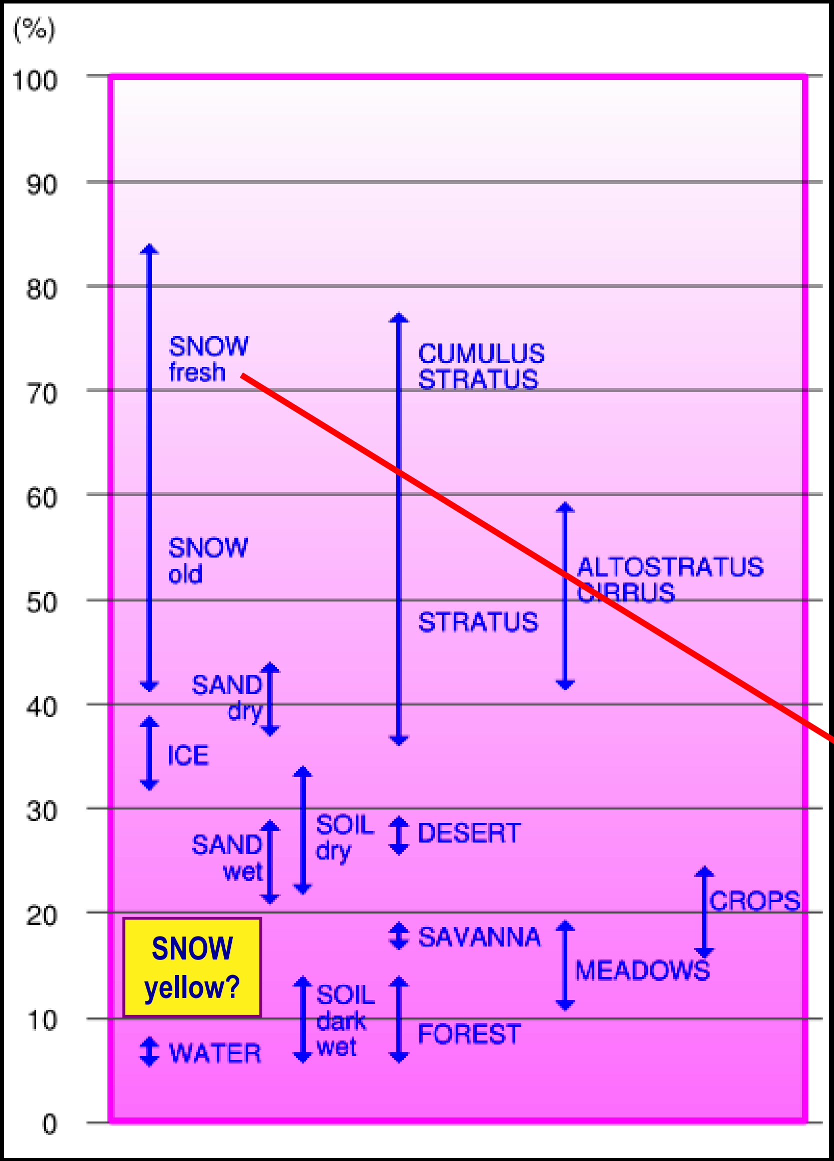
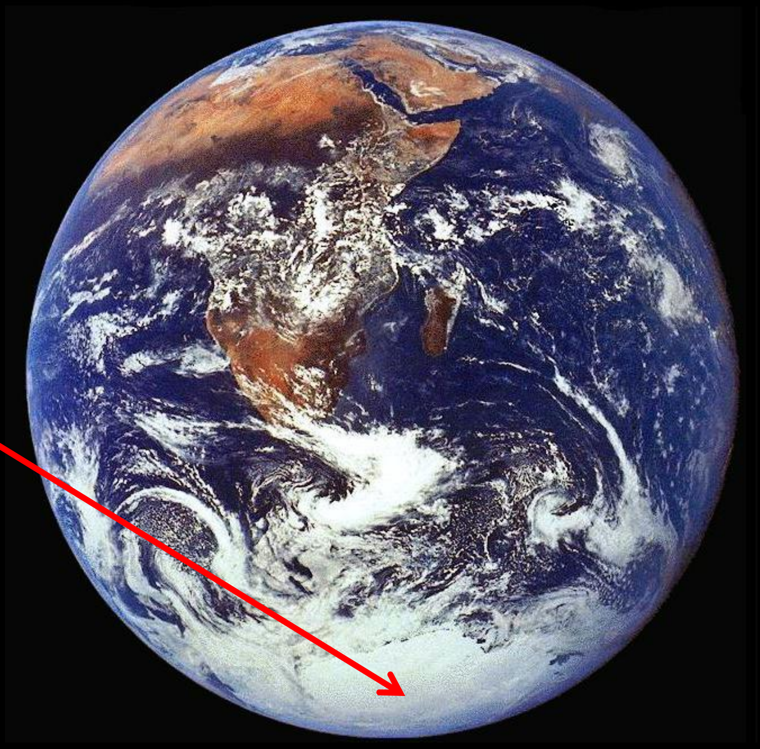
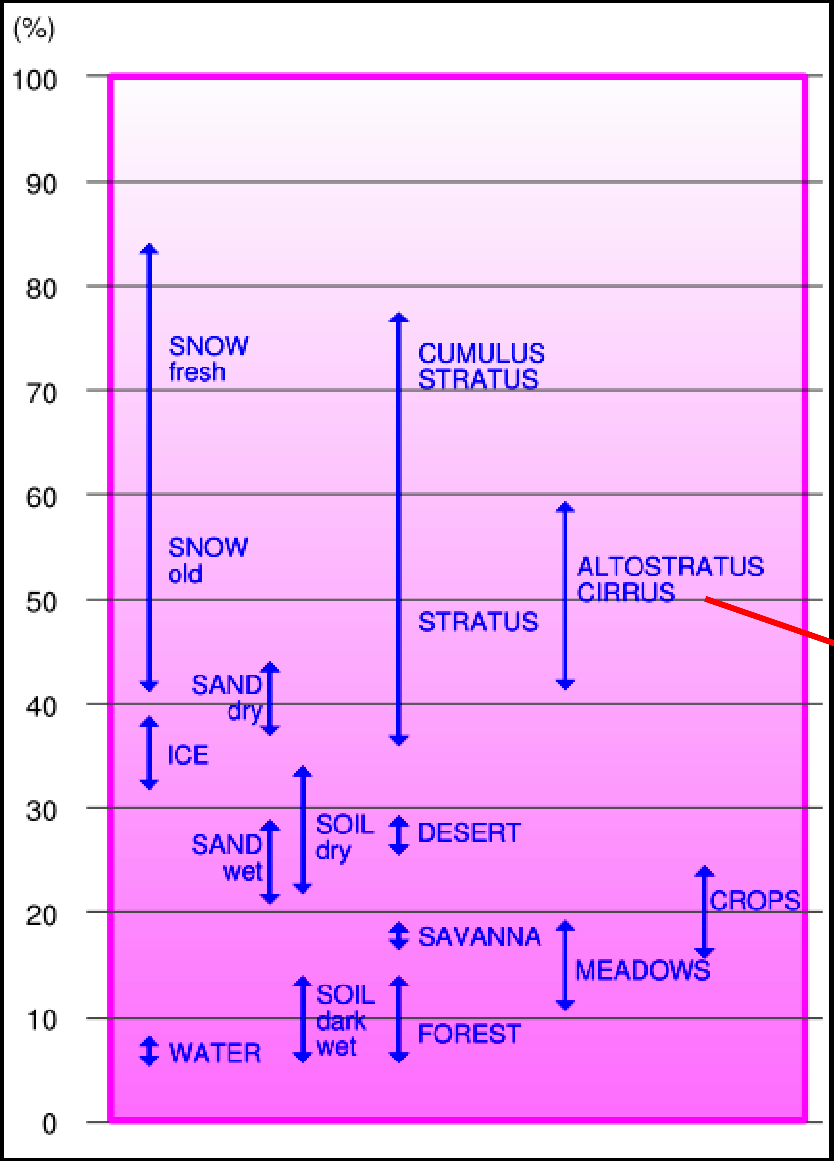


albedo = *reflectivity* →



The Earth from space



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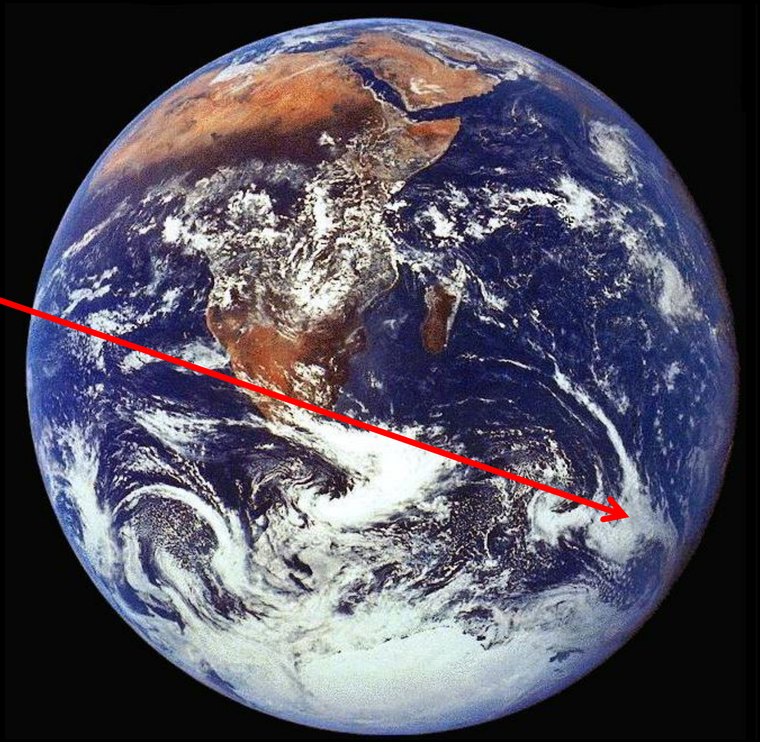
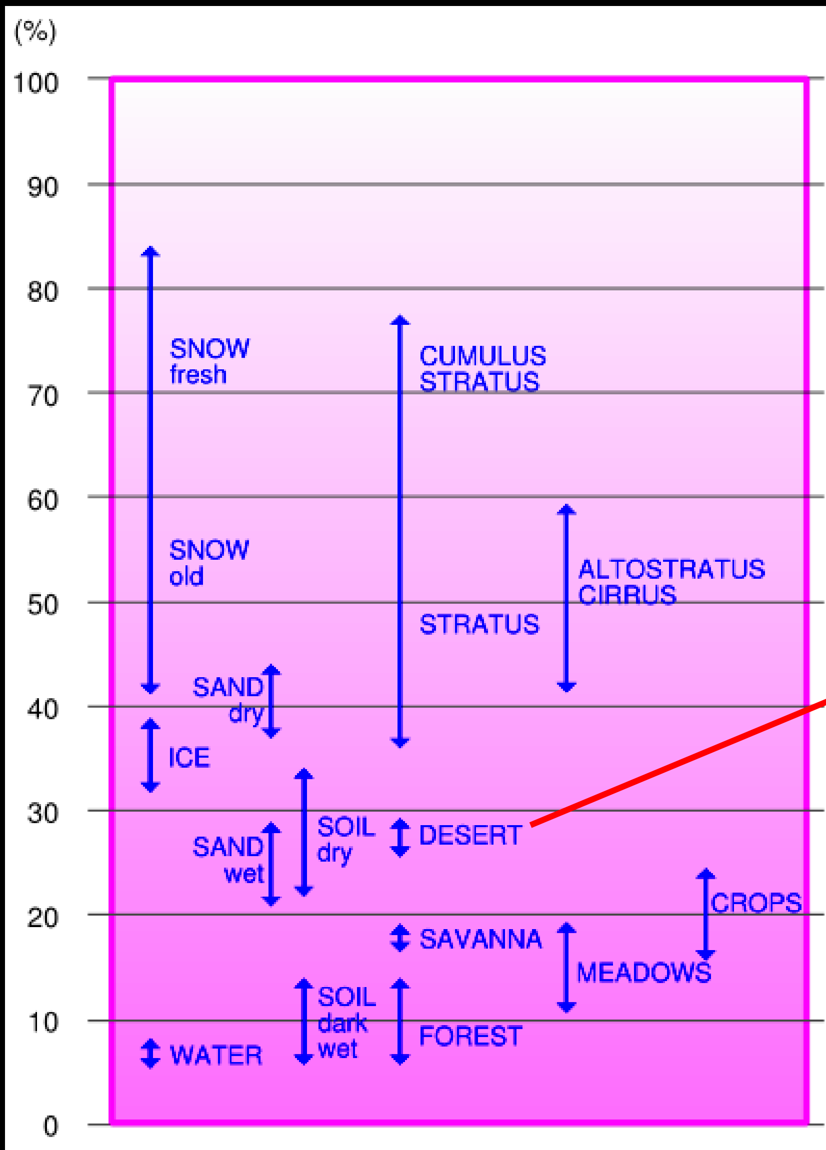
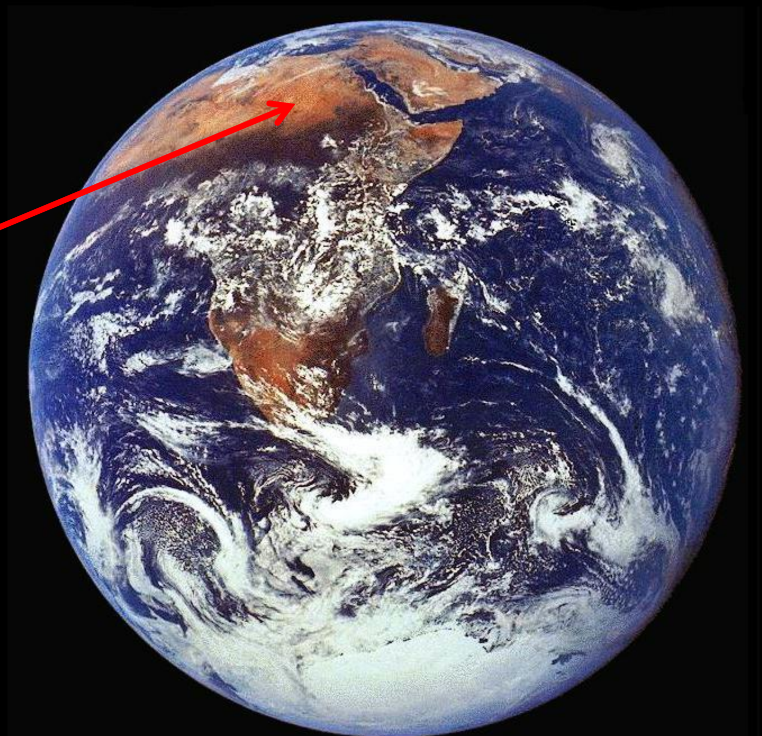


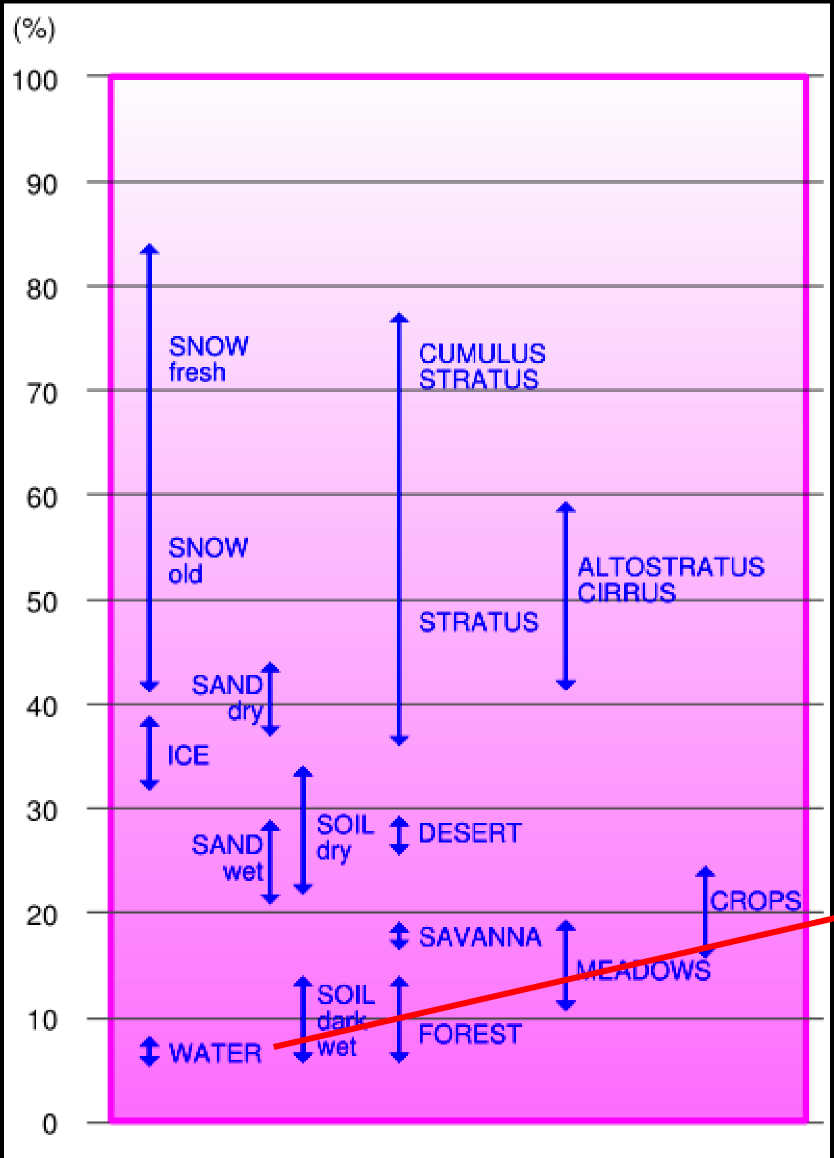
The Earth from space



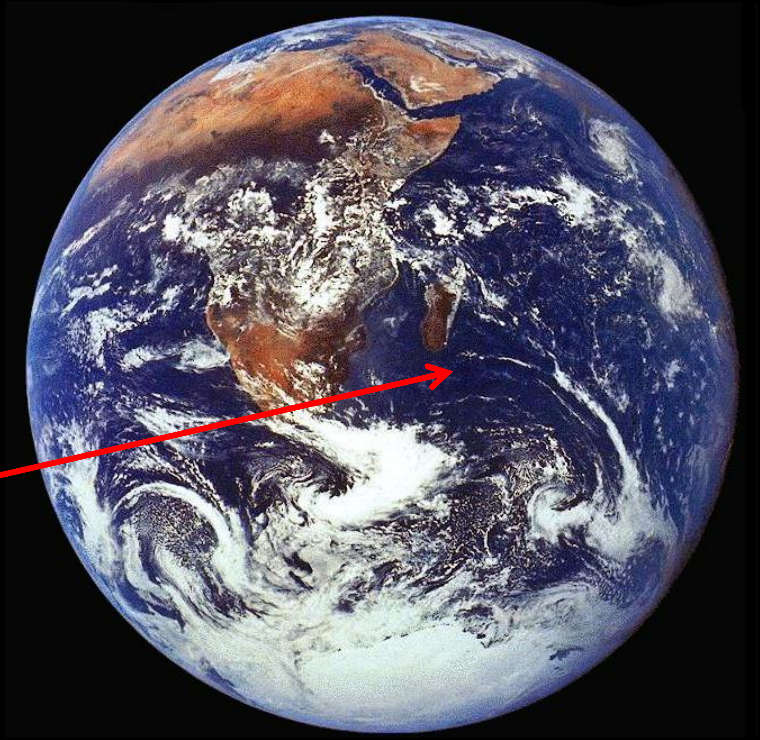
albedo = *reflectivity* →



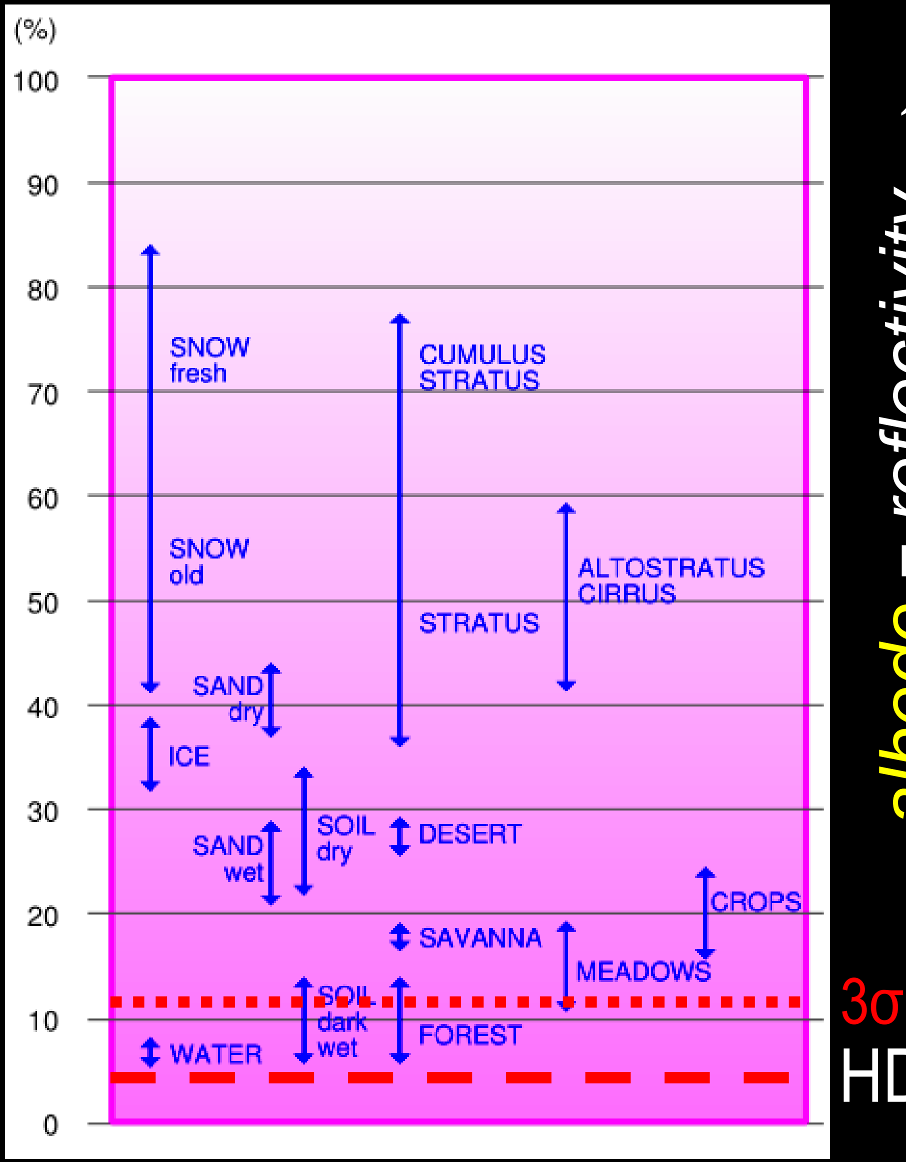
The Earth from space



albedo = *reflectivity* →

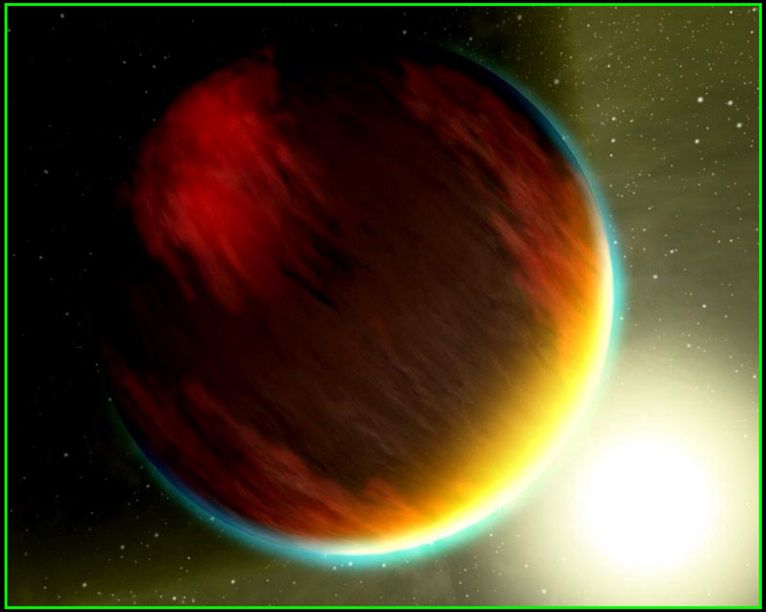


HD 209458 b from Earth

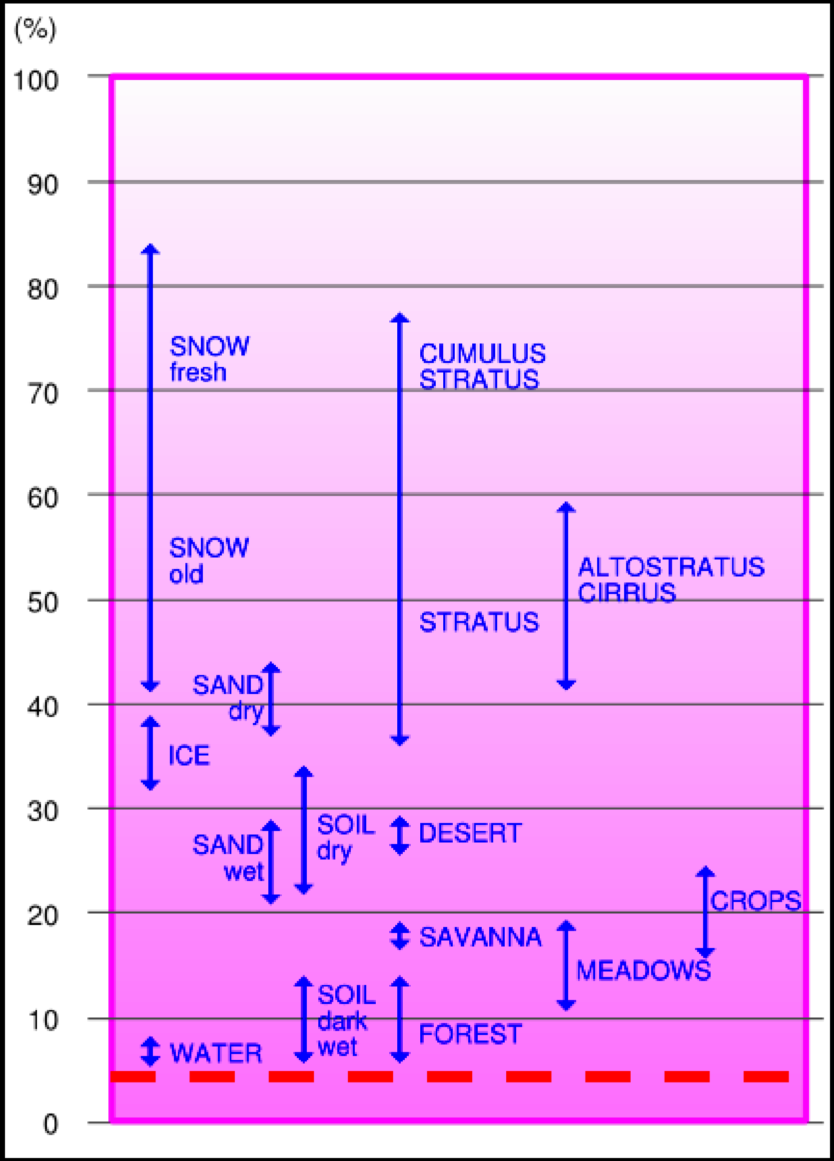


albedo = reflectivity →

artist's conception



HD 209458 b from Earth



albedo = reflectivity →

HD 209458b

Exoplanetometeorology

MOST data are helping us understand the weather and clouds on a planet you can't even see around a star 160 light years away!?!