Moonrise

the surprisingly diverse array of moons in our solar system

Hubble Science Briefing
May 1, 2014

Bonnie Meinke, PhD
Inner Solar System

- Mercury: 0 moons
- Venus: 0 moons
- Earth: 1 moon
- Mars: 2 moons

Not to scale
Outer Solar System

>67

>27

>62

>14
Earth’s Moon: Our Celestial Partner

1. Why is Earth the only rocky planet with a substantial moon?
2. How does this benefit Earth?
3. How does this make the Earth suited for life?
Formation: a Giant Impact
Over time:
Moon moves out in its Orbit, Earth’s rotation slows
Over time:
Moon’s rotation slows until one side faces Earth at all times

This is known as “Tidal Locking”

Time it takes the Moon to rotate once on its axis = the time it takes to orbit Earth once
Benefits of Having the Moon

Environmental Stability
- Tides
- Meteor shield
- Axis Tilt

Development of Human Civilization
- Calendars
- Exploration stepping stone
Benefits of Having the Moon

Environmental Stability

Meteor shield

Tides

Circulate oceans, create tidal pools

Moon takes many hits for Earth

Axis Tilt

Keeps the axial tilt stable over geologic time scales, stabilizing climate
Tidal pools
Meteor Shield

Near Side

Far Side
Axial Tilt

Earth: 23°
Uranus: 97°
Venus: 177°
Mars has experienced big swings in tilt over short (~100,000 years) time scales.
Big swings in tilt drastically affect seasons and climate

Bigger tilt = hotter summers, colder winters
  = big shifts in ice caps

Smaller tilt = less seasonal variation
The Moon keeps Earth’s tilt stable over tens of millions of years.

Long term = tens of millions of years

Earth 23°

Short term = ~100,000 years

Mars 25°
Benefits of Having the Moon

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Development of Human Civilization
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Benefits of Having the Moon
Development of Human Civilization

Lunar calendars were used by many ancient civilizations

Calendars

Allows humans to test space technologies “close to home”

Exploration stepping stone
Benefits of the Moon

• Tides: regular schedule of water flow (tidal pool). Help circulate oceans
• Meteor shield: takes a lot of hits for us
• Maintains axial tilt: Our seasons and climates are stable
• Calendars: benefits civilization
• Stepping Stone for Human Exploration

Our Moon gives us a stable environment conducive to the development and long term survival of life
Moons across the Solar System

Do other moons provide stability for life?
Inner Solar System

Mercury  Venus  Earth  Mars
Inner Solar System

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Outer Solar System
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Selected Moons of the Solar System, with Earth for Scale

- Earth (Moon)
- Mars (Phobos, Deimos)
- Asteroid Ida
- Jupiter (Io, Europa, Ganymede, Callisto)
- Saturn (Mimas, Enceladus, Tethys, Dione, Rhea)
- Uranus (Puck, Miranda, Ariel, Umbriel, Titania, Oberon)
- Neptune (Proteus, Triton, Nereid)
- Pluto (Charon)
- Eris (Dysnomia)

Scale: 1 pixel = 25 km
Are any of these worlds “stable” enough?

Stability our Moon provides:
1. Circulation of water
2. Shield from impacts
3. Stable climate

Earth already has:
1. Shield from radiation:
   – Atmosphere
   – Magnetosphere
2. Water
3. Energy
   – from Sun
   – Internal heat
Atmosphere

- Hazy atmosphere
- Provides rain (liquid methane!)
- Protects from impacts
- Protects from certain radiation
- Stabilizes Climate

Saturn’s moon Titan
Magnetic Field

Protects against harsh radiation

• Ganymede has an *intrinsic* magnetic field (like Earth)
• Some other moons have *induced* fields due to their planet’s field

Jupiter’s moon **Ganymede**
Internal Heat produced by gravitational tug of planet

- Jupiter’s Io
- Saturn’s Enceladus
- Neptune’s Triton
- Jupiter’s Europa

Creates geologically active surface:
- Volcanoes
- Geysers
- Evolving surfaces
## Ideal candidates?

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The perfect combination:
1. Protection from radiation
2. Protection from impact
3. Stable “climate”
4. Warm enough for liquid water
Global subsurface ocean
Small subsurface ocean at south pole vents to surface via geysers
Moons are harbingers of Life

- **Earth’s Moon** helps maintain Earth’s life-friendly stable environment
- **Outer solar system moons** create small pockets of habitability safely tucked away under ice
As we continue our search for life elsewhere:

Should we adjust our definition of “Another Earth” to include “Another Moon”?

Should we be more concerned about exploring our own Europa?
Resources

• More general information about moons: http://en.wikipedia.org/wiki/Natural_satellite


• Amazing Space: “Myths vs. realities: Solar system” http://amazing-space.stsci.edu/eds/overviews/myths/solar_system.php

1. **Planetesimal**: solid objects thought to exist in protoplanetary disks. The building blocks of planets, usually >1 km in size.

2. **Giant Impact Hypothesis**: the idea that the Earth-Moon system was created when a Mars-sized object impacted proto-Earth. The planetary science community believes this is the best explanation of how the Moon formed.

3. **Tidal lock**: occurs when the one side of an astronomical body always face another, sometimes known as *synchronous rotation*.

4. **Obliquity**: Tilt of a planet’s axis relative to the plane of its orbit.