Looking to the Future: the rest of the planets

Heidi B. Hammel
AURA, Washington, DC
Looking to the future of ...

Models, Laboratory Measurements, Archives

Atmospheres in our Solar System

Exoplanet atmospheres: space-based telescopes
Exoplanet atmospheres: ground-based telescopes

But FIRST – community assessment poll
Community Assessment of Exoplanet Characterization Parameters

Aki Roberge, Kunio Sayanagi, Everett Schlawin, Jacqueline Radigan, Heidi Hammel
Assess on two 5-level rating systems

**Difficulty of Determination**
- 5 = Possible for most planets
- 4 = Possible for some planets
- 3 = Possible for few planets
- 2 = Not against the laws of physics
- 1 = Warp drive

**Theoretical Importance**
- 5 = Crucial
- 4 = Important
- 3 = Useful
- 2 = Nice to have
- 1 = Irrelevant

**Implementation:** google poll will be established – stand by
Parameter Categories

- Orbital
- Stellar
- Basic Physical Parameters (mass, radius, bulk composition)
- Surface Properties
- Interior Properties
- External Factors
Orbital Parameters

- semi-major axis
- eccentricity
- obliquity
- inclination
- rotation rate
Stellar Parameters

- stellar spectrum
- stellar age
- stellar variability
- stellar winds
- stellar metallicity
Basic Planet Parameters

• mass / gravity
• radius
• bulk composition
Surface Properties

- planet reflected spectrum
- planet thermal spectrum
- planet transmission spectrum
- Bond albedo
- surface ocean fraction
- atmospheric composition
- clouds vs. hazes
- Wind Speed
Interior Properties

- magnetic field
- plate tectonics
- volcanic activity
- interior heat flux
- tidal heating
- interior density structure
External Factors

- impact rate
- impact history
- rings
- moons
- interplanetary dust
Assess on
two 5-level rating systems

**Difficulty of Determination**
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Models, Laboratory Measurements, Archives
Atmospheres in our solar system
your cat wants one, trust me

The solar system cat hat

http://geekologie.com/2013/06/omg-he-needs-that-solar-system-hat-for-y.php
Atmospheres in our solar system

Start with the outer solar system

(because I just happen to have this slide already handy)

((been showing it for the past decade, in fact))
Solar System Exploration: Giant Planets

Past

1975: Pioneer 10, Voyager 1, Voyager 2
1985: Voyager 2
1995: Voyager 2, Pioneer 11

Present

2005: Cassini, Galileo, New Horizons
2015: Juno, Cassini

Future

2025: Saturn Probe, New Frontiers
2035: Juice, Orbiter?
exploring atmospheres in our solar system with spacecraft

Current Mars Missions

- MAVEN
- India’s Mars Orbiter Mission
- Trace Gas Orbiter
- ExoMars Rover

US Discovery
- InSight
- Mars2020

US Flagship

Functioning and/or selected
Selected but some uncertainties
Notional or much uncertainty

Ground- and space-based telescopic observations

- 2015
- 2020
- 2025
- 2030
- 2035

- 2015
- 2020
- 2025
- 2030
- 2035

more Mars?
Other SS Atmospheres – NOTIONAL 6/28/2013

<table>
<thead>
<tr>
<th>Year</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
<th>2035</th>
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<td>US Flagship</td>
<td>Cassini</td>
<td>JUICE</td>
<td>Ice Giant?</td>
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<tr>
<td>US New Frontiers</td>
<td>Juno</td>
<td>NH Pluto</td>
<td>Saturn Probe?</td>
<td>Titan?</td>
<td>Venus In Situ Explorer?</td>
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<td>Akatsuki</td>
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<tr>
<td>US Discovery</td>
<td>Venus?</td>
<td>Titan?</td>
<td>Ice Giant (using warp drive)?</td>
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Ground- and space-based telescopic observations

- Functioning and/or selected
- Selected but some uncertainties
- Notional or much uncertainty
exploring atmospheres of exoplanets with spacecraft
Exoplanet atmospheres from space – NOTIONAL 6/28/2013

- Hubble
- Spitzer
- Kepler RIP

2015

2020

- TESS
- transit photom
- CHEOPS
- PLATO
- transit photom
- EXCEDE
- disks

2025

- JWST

2030

- WFIRST
- AFTA/NRO

2035

- super-duper (UVOIR?) mega-telescope to characterize exo-earths with:
  - coronograph?
  - occulter?
  - interferometry?
  - TBD?
exploring atmospheres of exoplanets with ground-based telescopes
**exoplanet atmospheres from the ground – NOTIONAL 6/28/2013**

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**Precision Radial Velocity machines such as:**
- HARPS (La Silla),
- HARPS-N (TNG),
- ESPRESSO (VLT),
- YOUR FAVE HERE...

**Radial Velocity such as:**
- SpEX (IRTF),
- FIRE (Magellan),
- NESSI (Magdalena Ridge),
- YOUR FAVE HERE...

**Imaging and/or spectra on 5- to 10-m telescopes such as:**
- GPI (Gemini),
- Spheres (VLT),
- Palm1640 (Palomar 5-m),
- HiCIAO (Subaru),
- YOUR FAVE HERE...

**Transits:**
- Next Generation Transit Survey,
- NESSI (Magdalena Ridge) small-telescope transit observations;
- YOUR FAVE HERE...

**OMG SO MUCH OTHER STUFF:**
- microlensing,
- polarization with PlanetPol,
- zodi and disks with ALMA and LBTI,
- YOUR FAVE HERE...

**super-duper extremely large telescopes (ELTs) with:**
- E-ELT + EPICS (imaging)?
- GMT + SuperHARPS (RV)?
- TMT + IRIS (IFU = spectra)?
Looking to the future for Solar System planets
Looking to the future for exoplanets, the future’s so bright you gotta wear shades