Polarimetric Remote Sensing of Planetary Systems
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**Polarimetric Method: Direct Detection and Characterization**

**What Polarization Reveals**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Application</th>
<th>Spectral</th>
<th>Temporal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unpolarized</td>
<td>High</td>
<td>Low</td>
<td>None</td>
</tr>
<tr>
<td>Linear</td>
<td>Partially polarized</td>
<td>Strong/weak</td>
<td>None</td>
</tr>
<tr>
<td>Circular</td>
<td>Molecular</td>
<td>High</td>
<td>UV</td>
</tr>
<tr>
<td>Resonant</td>
<td>Near-IR</td>
<td>UV</td>
<td>UV</td>
</tr>
</tbody>
</table>

**Characterization**
- Reflected light is linearly polarized by planetary bodies upon scattering by atmospheres or surfaces, unique for the reflecting body (UV, optical and near-infrared)
- Changes in the scattering properties of objects cause changes in the polarimetric signatures
- Changes can be caused by seasonal events, episodic processes such as collisions and impacts, surface/terrestrial changes

**Our Solar System**
Our diverse solar system exhibits all flavors of polarization:
- Atmospheric (e.g. Venus, Mars, Titan, Titan)
- Planetary rings (e.g. Saturn, Saturn)
- Cometary activity (e.g. Halley, Halley)

**Observed Polarization of our Solar System**

<table>
<thead>
<tr>
<th>Object</th>
<th>LP</th>
<th>EP</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun</td>
<td>Yes</td>
<td>No</td>
<td>Changing rapidly</td>
</tr>
<tr>
<td>Mercury</td>
<td>Yes</td>
<td>No</td>
<td>Changing moderately</td>
</tr>
<tr>
<td>Venus</td>
<td>Yes</td>
<td>No</td>
<td>Changing slowly</td>
</tr>
<tr>
<td>Mars</td>
<td>Yes</td>
<td>No</td>
<td>Characteristic color change</td>
</tr>
<tr>
<td>Saturn</td>
<td>Yes</td>
<td>No</td>
<td>Changing</td>
</tr>
<tr>
<td>Europa</td>
<td>Yes</td>
<td>No</td>
<td>Changing</td>
</tr>
<tr>
<td>Titan</td>
<td>Yes</td>
<td>No</td>
<td>Changing</td>
</tr>
<tr>
<td>Halley</td>
<td>Yes</td>
<td>No</td>
<td>Changing</td>
</tr>
</tbody>
</table>

**Polarization of outer Planets**
- Atmospheric polarimetry: small (e.g. Titan) and large (e.g. Jupiter)
- Variable due to changing morphology of clumps, and other dynamic processes (tides) and external (solar)
- Spectroscopic polarimetry: plumes in methane torus (Jovian and Saturnian)

**Atmospheres: Venus**
- Very dense atmosphere, complete and variable cloud system
- Fast and evolved air, planetary rotation and temperature change
- Linear polarization due to spherical plumes (Venus, Earth)
- Observatory using XUV, UV, visible, and near-infrared

**Comets**
- Polarization measurements: genuine perihelion (e.g. Comet Halley, Comet Hale-Bopp)
- Thermal variations in the nucleus of Comet Halley (1985-1986)
- Near-IR polarization sensors (e.g. Hubble Space Telescope)

**Life on Earth: Clues to Habitability**
- The Red-Eye Effect
  - Ozone layer exhibits strong absorption in the red (aerosol)
  - Circumstellar point

**SUMMARY: SCIENCE DRIVERS**
- Solar-magnetospheric phenomena
- Identification of compositional species in comet, atmospheres, -H2
- Atmospheric processes and surface properties
- Terrestrial climate
- Oceanic evolution

**SUMMARY: NEEDED OBSERVATIONS**
- Linear Polarization: detection of reflected and thermal components
- Atmospheric processes: polarimetric observations of reflection
- Differential Polarization: detection of changes in atmospheres and surface properties
- Circular Polarization: sensitivity to biologic activity necessary for life

**SUMMARY: PARALLEL DEVELOPMENTS**
- Need new/parallel developments:
  - Observation: polarimetric UV-NIR of solar system objects in space
  - Need to study full-sky images on function of planetary objects
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