Habitability and Diversity

Manuel Güdel
Dept. of Astrophysics
University of Vienna

Radio Exploration of Planetary Habitability,
Palm Springs, May 8-12, 2017
Outline

- Not a summary
- No advice/guideline
- Biased view
- Incomplete and arbitrary
- Personal preference
- From your work and my fantasy
- Some curiosity and trivia
- No profound news
### Diversity of Planets

Same size, similar composition, similar orbit, similar amounts of CO$_2$, N$_2$, ... but:

<table>
<thead>
<tr>
<th>Stagnant lid, no plate tectonics or episodic plate tectonics?</th>
<th>plate tectonics</th>
</tr>
</thead>
<tbody>
<tr>
<td>no water</td>
<td>water oceans</td>
</tr>
<tr>
<td>slow rotation</td>
<td>rapid rotation</td>
</tr>
<tr>
<td>no dynamo (anymore?)</td>
<td>magnetic dynamo</td>
</tr>
<tr>
<td></td>
<td>Moon??</td>
</tr>
</tbody>
</table>
Diversity of Stars

<table>
<thead>
<tr>
<th></th>
<th>GI 65A</th>
<th>GI 65B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectral class</td>
<td>M5.5Ve</td>
<td>M6Ve</td>
</tr>
<tr>
<td>Mass</td>
<td>0.1225 M_☉</td>
<td>0.1195 M_☉</td>
</tr>
<tr>
<td>Radius</td>
<td>0.165 R_☉</td>
<td>0.159 R_☉</td>
</tr>
<tr>
<td>Rot. vsini</td>
<td>28.5 km/s</td>
<td>30.6 km/s</td>
</tr>
<tr>
<td>Rot. period</td>
<td>5.86 hr</td>
<td>5.45 hr</td>
</tr>
<tr>
<td>Metall. [Fe/H]</td>
<td>-0.03</td>
<td>-0.12</td>
</tr>
<tr>
<td>&lt;Bf&gt; Stokes I</td>
<td>5.2 kG</td>
<td>6.7 kG</td>
</tr>
<tr>
<td>B_{dip} strength V</td>
<td>0.3 kG</td>
<td>1.3 kG</td>
</tr>
<tr>
<td></td>
<td>complex, non-axisymmetric</td>
<td>axisymmetric dipole</td>
</tr>
</tbody>
</table>

Diversity of Stars

Important: Combining all information from all wavelengths

Consequences for space weather/planet interaction....
AND STELLAR SPIN-DOWN → feedback on stellar output and habitability
Who affects Whom?

tidal, magnetic, particles, radiation? Feedback loops?
Exchange of flows, energy, particles along connecting B?
The Full High-Energy Picture?

XMM, Chandra

10 keV – MeV electrons

thermal X-rays

nonthermal hard X-rays: \(e\)-bremsstrahlung

nuclear lines

pion decay

Lin+ 2002
Magnetospheres: Shields or Funnels?

It probably depends! Type of atmosphere, strength of magnetosphere, strength of stellar wind,....
Planetary Wind Processed by Stellar Wind and Radiation: Magnetic Fields Matter!

non-magnetic
Shaikhislamov+ 2016

magnetospheric
Khodachenko+ 2015
What Atmospheric Erosion?

boundary conditions, simultaneous operation, additional factors (dust/clouds/hazes? chemistry? lower atmospheres? magnetospheres/ionospheres?). Many non-thermal mechanisms.

stellar wind protons  planetary H atoms
ENAs moving away from / towards the star

Kislyakova et al. 2013

NASA, European Space Agency, Alfred Vidal-Madjar (Institut d’Astrophysique de Paris, CNRS)
To understand a planet and its habitability, the entire evolution of the stellar/planetary environment must be known!
Against Simplification – Nature Takes Freedom

Evolutionary diversity to guarantee habitability?

Tu, Johnstone, Güdel, Lammer 2015
Nature keeps **parameter space** and **evolutionary options wide open**, allowing it to accommodate many habitable planets in an extremely complex interplay of environmental factors such as radiation, winds, magnetic fields, particles, and planetary structure.
END