Condensates and Clouds in Exoplanetary Atmospheres: Some Lessons from our Solar System

*Tristan Guillot[1,2]

1. Observatoire de la Cote d Azur, 2. JSPS/University of Tokyo

We will soon enter a new era for exoplanetary research: That of the characterization of exoplanetary atmospheres. With instruments such as JWST, Ariel and a growing number of instruments on ground-based observatories of different sizes, we can expect to learn much about the composition, structure and atmospheric dynamics of these planets. Before we can attempt to identify potentially habitable worlds, we must first make sense of these observations and understand their implications in terms of structure, dynamics and formation mechanisms. The lesson from our Solar System is that planets and planetary atmospheres are complex systems, full of surprises and far from being fully understood. Proper caution should be exercised when analyzing spatially unresolved observations of exoplanets often at a single epoch.

Most of the complexity can be tied to the presence of condensating species and the formation of clouds. The case of water in Jupiter is a particularly striking example: While water should be entirely in vapor form below about 5 to 7 bars, the Galileo probe has found its abundance to be extremely low down to 22 bars into the planet. Juno microwave observations indicate that ammonia is depleted relatively globally except near Jupiter's equator and the analysis of the mechanisms behind this indicates that water should follow suit: Thus the low abundance of water measured in hot spots but also throughout the north equatorial belt in Jupiter is probably not an indication of a low water abundance in the planet but instead of its settling to deeper regions than anticipated by classical models. In this case, the high molecular weight of water compared to hydrogen is a key factor to consider. This mechanism should be prevalent in exoplanets and brown dwarfs with hydrogen atmospheres, as long as they are cool enough to contain abundant condensing species.

On the other hand, exoplanets may be considered as unique laboratories to learn about the compositions and structure of planets in general. For example, water does not condense in hot Jupiters - measurements of its abundance may therefore provide a more reliable estimate of a global, bulk value in the deep interior. The observation of water clouds and atmospheric dynamics in temperate hydrogen planets will be invaluable to further understand the physics of planetary atmospheres in general.

Keywords: Exoplanets, Giant planets, Planetary Atmospheres, Composition, Clouds

