Tackling the complexities of substellar atmospheres

10. - 14.2.2020 @ Oort

The **scientific goal** of this workshop was to bring together experts from four different sub- fields: in Solar System planets, the modeling and observation of transiting exoplanets, observation of directly imaged exoplanets and brown dwarfs. The idea was to formulate and discuss pressing problems and questions in the respective fields and propose methods and ideas on how to solve these issues.

Several major topics of interest emerged across the four different sub-disciplines:

- **Cloud modeling** proved to be of high interest as they appear in all substellar atmospheres, where different models and their benefits and drawbacks werepresented and also offered to the community (e.g. VIRGA by N.E. Bathalha, M.Marley)
- the **role of retrieval**, that is, inferring basic (atmospheric) planetary properties like temperatures, surface gravity and molecular atmospheric make-up with simplifiedmodels based on (incomplete) observational data was discussed. Here, the participation of members of the brown dwarf and directly imaging exoplanets community and transiting exoplanet community proved to be vital. The former two had experience with the interpretation of very detailed spectra, whereas the latter had pioneered techniques to interpret even very limited data. It was generally agreed on that it would be highly desirable to apply exoplanet retrieval techniques also to brown dwarf data and those of directly imaged exoplanets: a) this could lead to improvements of derived parameters for brown dwarfs and directly imaged planets and b) exoplanet experts could test their methods on more detailed data before JWST data becomes available for transiting exoplanets. Furthermore, it was agreed upon that the simplicity of retrieval methods can lead to unphysical results. The only safeguard is to perform in addition to retrieval sanity checks with complex models that take into account a more complete physical picture.
- It came out that there are **difficulties to compare observationally derived data**, e.g. cloud composition and molecular composition across the four different fields. It was revealed that the different observation techniques but also intrinsically different temperature structures lead to different regions of the substellar atmosphere to beprobed. Therefore, “temperature” in one case is not the same as “temperature” in the other.
- JWST was a major topic in the discussions, where we had the benefit to have several experts on site that led splinter session in how to plan observational proposals for their respective targets. Tools and resources were shared to facilitate proposal writing forJWST.
- Another topic of high interest was **variability** and their origin in substellar atmospheres: from the role of waves in the Solar System planets to observations of high variability in young brown dwarfs and their strong magnetic fields. It was also generally agreed upon that the physics in substellar objects operate with different age (internal temperature)and different irradiation conditions (effective temperature) across the four different area of expertise. Thus, insights in variability in one class of substellar atmospheres are complementary to other classes.

The format of the workshop and diverse set-up of participants was praised by many participants. It consisted of two days of keynote lectures to introduce the four fields. Furthermore, we held lightening card events on the first two days that allowed each participant to introduce their work and themselves to the other workshop participants. Keynote splinters were set up interactively on-site, where we gathered ideas and suggestions for possible sessions beforehand via a google document. The splinters were covering all the topics of interest and results were presented at the end of each day, when the splinter was held, to all participants. We also had two major “all-hand” discussion that lasted each 1 hour, during which all participants engaged in a respectful and lively matter.

Also a training session was held in the form of a “describe your favorite object” session to train (in particular early career) scientists in honing their skills to “pitch” a particular target of observation for proposal writing.

Furthermore, care was taken to ensure a gender balance in participants, and in having early career scientists alongside designated experts and leaders of their field. Last but not least, we gathered experts from the US, Europe and Chile. Unusually, seven of our eight keynote speakers where women and among those two were women of color. Overall about 40 % of the participants were women. About 50 % were early career scientists (master, PhD students and postdocs on their first term). This balance proved to be very beneficial to make the discussions lively and worthwhile for all participants.

Tangible outcomes were the following: Participant Ernst de Mooij initiated an observation proposal writing session after the workshop was concluded on the Lorentz site to investigate if high resolution spectroscopy, a technique that was pioneered in the atmosphere characterization of transiting exoplanets, could also be of use for the observation of brown dwarfs. Participant Leigh Fletcher offered to share opacity data that were gathered during Solar System space missions but were never made publicly available. Furthermore, Leigh Fletcher invited the participants to prepare themselves for white papers to justify the scientific benefit for a Solar System space mission to Uranus and/or Neptune and how such a mission would benefit their respective areas of expertise. Participant Kelle Cruz proposed to encourage/train people to use a repository of data and techniques, a “Shared data infrastructure” to be collected to prevent “loss of knowledge” that is prone to happen at the end of projects (like the data offered by Leigh Fletcher). It was proposed by Kelle Cruz to initiate a dedicated archive in particular for brown dwarfs and directly imaged planets, for which such an infrastructure is still lacking in the form of
e.g. “SIMPLE archive of directly imaged planets and BDs.”
It was further agreed on to investigate the possibility to have two follow-up workshops, directly based on this Lorentz Center workshop. One in the US (participant/organizer Jackie Faherty, Aspen) and one in Germany (participant Paul Mollière, Ringberg).

All talks were gathered in a common repository and are accessible to all participants also after the workshop. For all splinter sessions and the discussions notes and pictures of the blackboard were taken and collected in a google document. This documentation is available for future reference to all participants even after the workshop.

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