NephEx: A Nephelometer for Probing Planetary Atmospheres

Matthew Garrett, Khoa Ngo, Bruce White, Millan Diaz-Aguado, Vandana Jha, Amanda Cook, Arwen Dave, Tony Colaprete
NASA Ames Research Center

Background

The composition of planetary clouds and hazes is important to understanding planetary climate, atmospheric dynamics, and, for gas giants, planetary formation. Observations from orbit or from the planetary surface, such as satellite or ceiliometry, only give information about the outer edges of clouds. Instruments which can measure the interior of atmospheric structures, such as descent probe or balloon, are therefore ideal.

Similar instruments have been included on the Venus Pioneer Multiprobe (1978), and the Galileo Jupiter probe (1989). Modern technology allows us to build an improved instrument that is 1/40 of the volume and has half of the power consumption of these previous instruments, while yielding improved data.

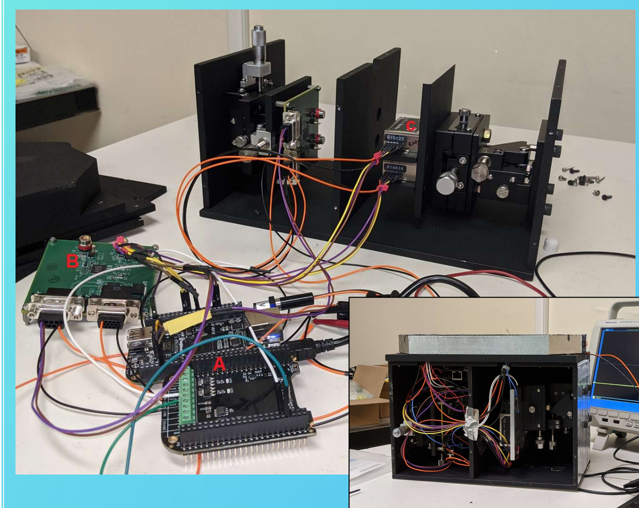

Figure 1. NephEx components wired together, ready for assembly. The prototype instrument consists of a Beaglebone Black controller (A), a custom-made circuit board with two photodiodes to sense backscattered light (B), and two infrared lasers (C). The inset shows the assembled instrument with side panel removed. Commercially available optical stages were used in the prototype, which are bulky, but easy to make on-the-fly adjustments during development stages. Replacing these with custom mounts will alone halve the instrument volume.

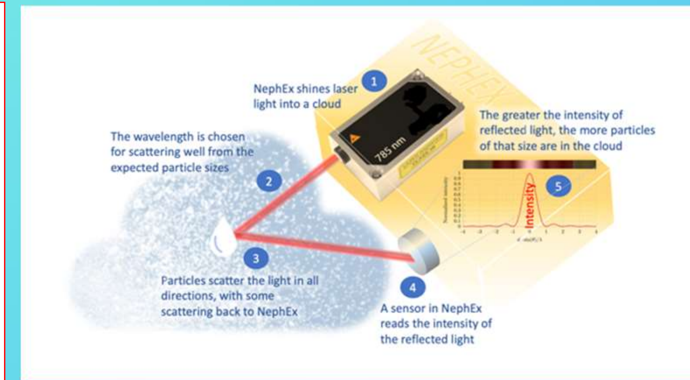

Figure 2. Basic working principle of NephEx. One of two lasers sends light into the atmosphere. That light scatters off atmospheric particles, with some of that light scattered backwards to its respective instrument sensor. The sensors are covered with a bandpass filter to only allow light of its respective laser wavelength to pass through. A larger signal indicates a higher concentration of atmospheric particles.

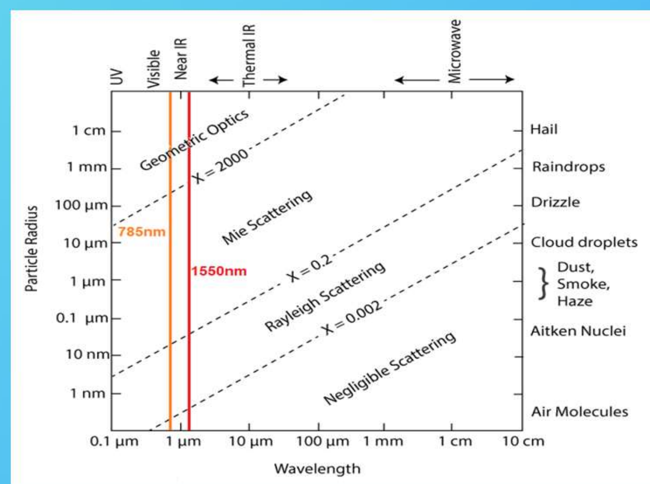

Figure 3. Dominant scattering wavelengths for different particle sizes. Our laser wavelengths of 1550nm and 785nm are shown in red and orange. Sensing with multiple wavelengths permits accuracy through a wider range of particle sizes, due to the differences in scattering coefficient. These specific wavelengths were chosen so that Mie scattering will be dominant for the expected particle sizes. (adapted from Cabrillo "Physics of the Atmosphere" 2014)

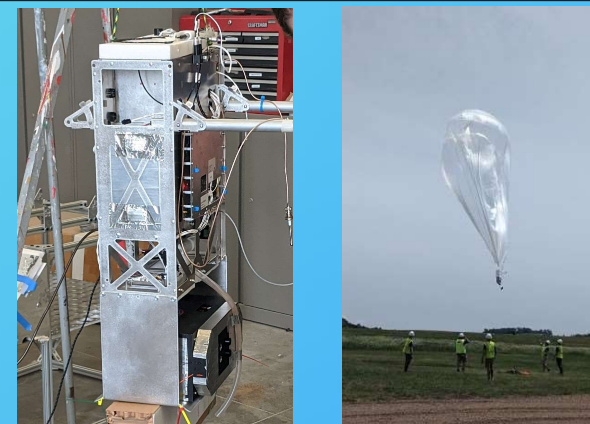

Figure 4. NephEx instrument mounted in preparation for balloon test, and during launch. NephEx was successfully tested in June 2021 on a weather balloon flight by Raven Aerostar. Successful testing of this instrument has brought the instrument to TRL-5 status.

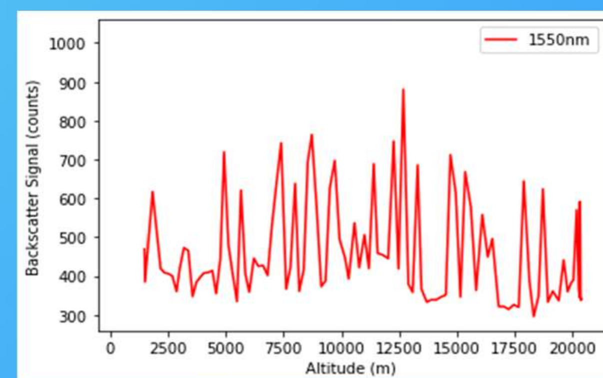

Figure 5. intensity of backscattered 1550nm laser light during weather balloon flight, as a function of altitude. The peaks show regions where the instrument passes through regions of atmospheric particles, such as clouds.

Future Work

Now that we have demonstrated successful in-atmosphere flight of the instrument, next steps involve the redesign of the sensor board to make it more compact, replacing the Beaglebone with a FPGA microcontroller designed specifically for NephEx, and re-testing in different atmospheric conditions.