NEPHEX: NEPHELOMETER FOR MEASURING CLOUD PARTICLE SIZE AND DENSITY IN PLANETARY ATMOSPHERES. M. P. Garrett[1], V. Jha[1], A. M. Cook[1], B. White[1], A. Dave[1], L. Hyde[2], A. Colaprete[1], [1]NASA Ames Research Center, Moffett Field, CA (matthew.p.garrett@nasa.gov), [2]US Geological Survey, Menlo Park, CA

Introduction: The size distribution of particles present in planetary clouds and hazes yield important clues to the mechanisms of atmospheric evolution, dynamics, and climate. While it is possible to observe these clouds and hazes from afar, telescopic measurements or orbiting satellites cannot fully penetrate the depths of an opaque atmosphere, nor can they easily discern the elevations at which features occur.[1] Therefore, measurements taken at different levels within that atmosphere, such as by a descent probe, are ideal. Here we propose a compact nephelometer that uses backscattered laser light to measure particle size distributions within an atmosphere.

Other nephelometers have been used to measure planetary atmospheres before, namely on the Pioneer 13 mission to Venus, and the Galileo spacecraft to Jupiter. In the case of the Pioneer Venus Multiprobe, LEDs were used as a light source, as space flight-ready lasers could not be obtained at the time.[2] This, along with other technical limitations from that era, meant the instrument could only measure optical depth, providing no further information about the makeup of the hazes which it measured. The Galileo nephelometer used a laser source, and did measure particle sizes, but was a much larger instrument: 4.4 kg in mass and requiring an 11.3 W power source.[3]

We are developing a laser backscatter nephelometer that is roughly 1.7kg in mass, operates at 5.3W, and is contained in a 10cm cube, is roughly 1/40 of the volume of the Galileo nephelometer.

The nephelometer is sensitive enough to apply dynamic light scattering principles to the backscattered light, allowing for a calculation of particle sizes. This method would be especially interesting and precise for a planet like Venus, where hazes are known to form layers with distinct, multimodal particle sizes.[4]

Instrument Design: The instrument consists of two laser light sources, a pair of photodiodes to detect backscattered light, a pair of photodiodes with bandpass filters to collect reference data, a pair of beamsplitters to divert laser light into a reference beam and measurement beam, and a controller to pulse the lasers and record data. (See Fig. 1 and Fig. 2)

Light Sources: we use a 1550 nm and a 785 nm Matchbox series laser, from Integrated Optics. Having lasers at two different wavelengths adds to redundancy, in case of hardware failure, but most importantly, permits characterization of particles over a wider range of sizes, due to differences in scattering coefficient at each wavelength.

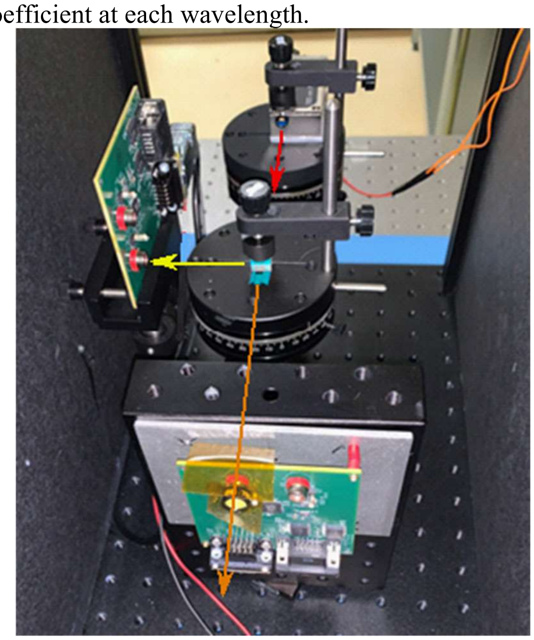

Figure 1: Optical table prototyping with one laser. The laser beam (red arrow) passes through the beamsplitter cube, with 30% of the light directed to the reference sensor (yellow arrow), and 70% of the light directed to perform measurements (orange arrow.) The reference board on the left side of the photo confirms function and laser output intensity. The sensor board in foreground detects backscattered light as the measurement beam backscatters off atmospheric particles.

The choice of laser wavelengths is due to several considerations. First, the light sources should be at wavelengths where chemicals in the atmosphere are not strongly absorbing. Particulates in the clouds of Saturn, for example, are expected to be largely crystalized ammonia compounds, whereas the hazes of Venus are purported to be sulfuric acid and sulfur oxides. While these have strong absorbing features in the far infrared, there is very little interaction in the NIR. Second, the light sources must be of a wavelength where Mie scattering is dominant, in order to maximize backscatter, and to more easily interpret the data. The expected particle diameters in both Saturn and Venus, for example, range roughly from 0.1 μm to 10 μm.[1,5] Mie theory at our chosen wavelengths dominates scattering within this entire particle range.[6] Lastly, compact, modulated lasers of these wavelengths are readily available commercially.

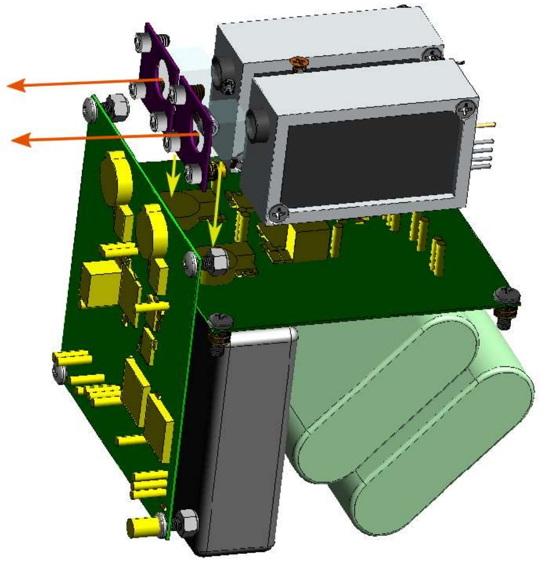

Figure 2: NephEx assembled for balloon flight. The reference board is now oriented horizontally below lasers, while the sensor board is oriented vertically in front of lasers. Lens holders (purple) allows for alignment optics. A beamsplitter directs 30% of beam to the reference board (yellow arrows), and 70% of beam towards the sampling area (orange arrows.) Also shown are boxes containing the laser controller (a BeagleBone Black) and a power source (18650 batteries).

Scattering detection mechanism: The Beaglebone Black modulates both lasers at a desired sampling frequency. Signals from the photodiodes are sent through a transimpedance amplifier, with gain for the two backscatter diodes set to be approximately 100 times higher than gain for the reference diodes, to accommodate the difference in light intensities. The photodiodes are fitted with bandpass filters centered at either 1550nm or 785nm, so that they only detect light from their corresponding laser, and to remove the effects of noise from an ambient light. In the case of balloon flight, intensity signals are sent to the Beaglebone Black SD card for later retrieval. In the case of space flight, the Beaglebone Black will be replaced with custom hardware, and signals will be relayed via telemetry.

Initial results: We have tested the nephelometer using aerosolized water droplets and chalk dust, as these are straightforward materials to obtain, and are within the expected size range of atmospheric particles. An example of these results is shown in figure 3. In this sample data, four instances of chalk dust were released into the path of the measurement beam over a short period, and fluctuations in backscatter intensity were recorded.

This shows that even in its simplest configuration, the nephelometer is successful in detecting light scattered off atmospheric particles, and in detecting the fluctuations in intensity that will be necessary for particle size analysis.

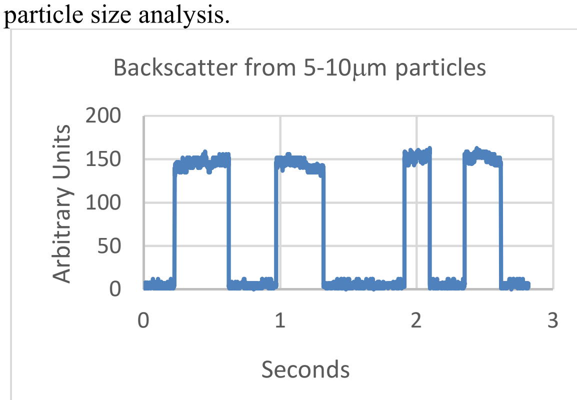

Figure 3: Data showing backscattered 785nm light from chalk particles (size range 5-10μm.) Maxima indicate the presence of particles. Minima show the range of ambient noise in the lab environment.

Near-term development work: More lab-based sampling shall be performed on different sized particles within the 0.1μm – 10μm range. Optics to better align the backscatter with the sensor photodiode, and to filter out noise will be explored.

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