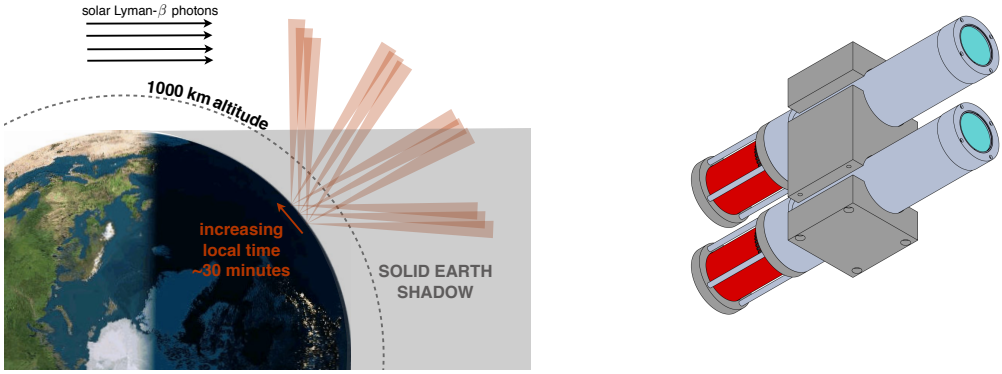
Photometer Array for Tomographic Hydrogen Sensing (PATHS)

Context

The earth's upper atmosphere is composed almost entirely of hydrogen (H) atoms, but of its density, spatial distribution, and temporal variability is very poorly known. Such knowledge is important for quantifying atmospheric evolution through gravitational escape as well as for characterizing the atmosphere's response to space weather, which can disrupt satellite signals used for communication and navigation.

One of the very few ways to measure H density is through remote sensing of the brightness of its optical emission known as "airglow", which is generated through the scattering of solar photons. Ground-based measurements of H airglow (at 656.3 nm, the "Balmer-alpha" emission) have been obtained routinely for decades, but their typically single-line-of-sight viewing geometry is insufficient to constrain the inverse problem of relating the measured emission intensity to the unknown H density. Instead, multiple viewing angles through a common volume would enable a tomographic formulation of the inverse problem and yield accurate H density estimation needed for atmospheric physics investigations.



(left) PATHS viewing geometry; (right) schematic of one binocular PATHS sensor

Problem Statement

The PATHS instrument is a novel ground-based photometer array that will measure the brightness of H airglow along multiple lines-of-sight simultaneously. Each sensor comprising the PATHS array is a doublet (binocular) optical assembly of dimension ~20 cm x 40 cm that will operate autonomously. The optical design of the sensor telescopes has been completed and a mass model replica will be provided. However, the instrument still needs a closed-loop pointing control assembly as well as operational software needed to steer the field-of-view.

This announcement of opportunity is targeting individuals with experience in robotics and/or control engineering to design and implement the pointing control assembly for one of the sensors comprising the PATHS array.

The project involves designing and implementing a PID controller that will interface with a pointing head motor to control its velocity and position. Both a 3D-printed mass model of the sensor and an off-the-shelf commercial pointing head mount and motor will be provided. The PID controller should allow the sensor to have two degrees of freedom in spherical coordinates and be able to point anywhere in the upper half plane – i.e., within 90 degrees from the vertical direction. The system will need to autonomously identify a fiduciary pointing direction ("home position") for calibration of the motor position. This can be accomplished through integration of a microcontroller, and various off-the-shelf components should be evaluated, with one to be selected and purchased for this purpose. The whole assembly should be controllable and user-friendly through simple commands, with pointing commands sent to the motor in terms of angular directions in the upper half plane (fractions of a degree). Housekeeping modes (e.g., directional calibration) and fail-safe modes should also be implemented.

Verification of this system will be developed during the proposal and design review of the class. A requirements and verification table along with a system block diagram will be the task of the students who choose to take this project for their Senior Design project.

Assistant professor Lara Waldrop must approve your design before any hardware purchases can be made. Purchases made without her consent will not be reimbursable. Candidates who are interested in this project should contact Prof. Waldrop (lwaldrop@illinois.edu).