DK-Proposal 27

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The Greenland ice cap as an astronomical site

Place:
Summit or northern central ice cap

Disciplines:
Astronomy, Meteorology and climate, Space physics

Motivation:
The central part of the Greenland ice cap offers unique possibilities for conducting astronomical research, comparable to what is the case for Dome-C in Antarctica. The main advantages which pertain directly to astronomical research are
A) The temperature is sufficiently low that the precipitable water vapor is significantly lower than even the driest equator-near observing sites. As a consequence completely new bands open up in the infrared and in the microwave regions, bands which are crucial for the study of the early universe and star and planet formation.
B) As the Arctic night lasts for 100-150 days, it is possible to record long uninterrupted time series of data. Such data are crucial in the study of a wide range of variable celestial sources, such as pulsating stars and supernovae. It has in practice been found that such time series are impossible to obtain from a network of equator-near sites.
C) A dominant component of the thermal micro turbulence above established astronomical sites is due to the jet stream. This is not the case for the polar regions, and the presence of katabatic winds may led to a further altitude depression of the level where thermal micro turbulence occurs. With a smaller distance to the dominant turbulent layers, the amplitude of scintillation (twinkling of stars) is very significantly reduced.
D) The ground level wind speed at summit is low, with a median value about 2.5m/s. This implies that the time scale on which the optical disturbances, as induced thermal micro turbulence, is much slower than at established observatories, where the jet stream with wind speeds an order of magnitude higher may dominate the variation. For adaptive optics, which is an advanced technology to compensate for these disturbances, this implies that the system may operate at much lower speed. This is a very significant technological advantage. The lower altitude of the dominant turbulence,as discussed under C), does also have the very important advantage for adaptive optics, that the required reference star can have a larger separation to the celestial object of interest.
E) The ice cap is extremely flat. Combined with the ultra-low water vapor content in the atmosphere, this makes the ice cap the ideal site for a large microwave interferometer.

F) In the arctic night, the OH emission lines are not excited by the suns radiation. They are therefore comparatively weaker, resulting in a darker sky in the near-infrared wavelength region.

Research:
While the exact characteristics of the Greenland ice cap as an astronomical site are not well known, it is clear that in some aspects it offers fundamental advantages over equator-near sites, even though it may not be exactly as outstanding as Dome-C on Antarctica. The Greenland ice cap will under any circumstances be complementary to any observing station in Antarctica, given that objects which are observable from Greenland are not observable from Antarctica. For a significant fraction of future astronomical observations the Greenland and Antarctic ice caps offers unique possibilities for establishing new major observational facilities. The alternative to this would be to deploy experiments in space. From a cost benefit analysis, ice cap based observatories win by a vary large margin, also because they are serviceable.

Characterization of the site:
The focus on the project is entirely on characterizing the site (Summit) in terms of its astronomical properties. For this purpose it is intended to implement a turbulence profiler, continuously observing Polaris. This instrument will be fully autonomous, have one moving part, no consumerables besides power and will, if possible, transmit data at a very low bandwidth requirement. Additionally, the precipitable water vapor content will be measured using the GPS technique. It is assumed that parameters such as temperature and wind speed will be recorded by an on-site meteorological station. Recording the turbulence profile, the precipitable water vapor and the temperature and wind speed during one arctic winter will give a sufficient basis, upon which decisions to deploy larger experiments on the ice cap can be taken. Notably it will become clear in exactly which aspects the Greenland ice cap offers the largest advantages and it will also become possible to design 10-20m IR adaptive optics telescopes optimized for the site. Such a telescope can potentially challenge projects such as the multi-billion dollar Next Generation Space Telescope (now known as the James Webb Space Telescope).