

Project Summary

Early in 2009 at Big Bear Solar Observatory (BBSO), first light engineering observations of the Sun were made with our 1.6 m clear aperture, off-axis telescope - the NST (New Solar Telescope). The NST will be the most capable, largest aperture solar telescope in the US until the 4 m off-axis ATST (Advanced Technology Solar Telescope) comes on-line in the middle of the next decade. Here we propose, in collaboration with Matt Penn of the National Solar Observatory (NSO) and Thomas Ayres of the University of Colorado (CU), to develop the Cryogenic InfraRed Spectrograph (CIRS) spanning 1.0 to 5.0 μm for the NST. This system is essential for the NST to achieve its scientific potential of probing for the first time the fundamentals of the Sun's atmosphere with its dynamic magnetic field, the origin of space weather, while providing valuable experience and risk reduction for the ATST project. CIRS will be a substantial improvement over the two current solar IR spectrographs – one operating at the National Solar Observatory (on the McMath-Pierce telescope) and the other at Institute for Astronomy (Mees Solar Observatory, University of Hawaii), both of which are based on warm optics except for the detectors and order sorting filters. CIRS will be a significant advance, particularly for high-spatial and high-cadence and high Zeeman sensitivity observations of the Sun's atmosphere from the photosphere through the chromosphere, as well as observations of dimmer targets such as sunspot umbrae and off-limb features.

CIRS will be located on the NST at Big Bear Solar Observatory on Big Bear Lake in the San Bernardino mountains of California. CIRS is a complex cryostat. Construction of the dewar and the incorporated camera system will be handled by an outside vendor specializing in cryogenic instrumentation. BBSO personnel will be responsible for initial design and specification of the dewar and construction of the optical interfaces outside the dewar. These will include image stabilization hardware (correlation tracker), image control and positioning systems (image rotator and scanner), and overall opto-mechanical interfaces that interrupt the Coudé light path and feed light to CIRS. BBSO will perform the final integration of CIRS and will develop the control systems and data acquisition hardware and software.

Spectral observations of the photosphere and chromosphere utilizing the largely unexplored near-infrared (NIR) are crucial for solving many long-standing problems in solar astronomy, especially the disparity among of magnetic field measurements in visible and infrared spectral lines and the origin of the solar chromosphere. The infrared spectrum beyond 1 μm is not only fertile ground for photospheric magnetic diagnostics, but also allows a unique window into the chromosphere lying atop the photosphere. The transition region between the near-equilibrium photosphere and solar corona is complex: the chromosphere is at once host to the coldest material in the whole solar atmosphere ($T \sim 3500$ K, as seen in off-limb emissions of 4.6 μm the carbon monoxide, CO, lines), and very hot gas ($T \sim 10^4$ K, associated with ionizing shocks).

High spatial resolution polarimetry at NIR wavelengths requires large aperture telescopes. Here, we propose for funding to develop CIRS for the NST for observations at the Gregorian focal plane.

In sum, we directly address the two criteria required in an NSF proposal:

(1) Intellectual merit: CIRS will be the only fully cryogenic IR solar spectrograph, which will enable the NST to provide the community unique data on the solar magnetic field illuminating the fundamental character of our dynamic star, while probing the origins of space weather. Over the next decade, NSO will build and begin operating the ATST, the flagship telescope for the solar community. CIRS will be a significant testbed for the more complicated IR spectrograph(s) planned for the ATST. After the ATST is on-line, the NST will continue to be an essential telescope in making campaign-style observations.

(2) Broader Impact: The development of the proposed CIRS system continues our decade long tradition of training the next generation of scientists who build instruments. The resulting data will be used in many PhD theses. Our data will be open to the scientific community, and a substantial portion of observing time on the NST will be open to the community.