

Fermilab Laboratory Directed Research and Development, LDRD Preliminary Proposal

Project Title: Tianlai Data Analysis Center

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Supervisor/Line Management Approval: _____
Date

Lead Division/Sector/Center Approval: _____
Date

Project Summary (~150 words): Project objectives, novelty, relation to mission.

Neutral hydrogen in the universe produces copious numbers of radio photons via the hyperfine spin flip transition which produces a narrow line at a wavelength of 21cm. Mapping this line emission as a function of angle on the sky and frequency/redshift provides an alternative type of cosmological Large Scale Structure (LSS) survey to the traditional optical/IR photometric/spectroscopic surveys such as SDSS, DES, DESI, LSST. One advantage is that precise redshifts are automatically obtained in the imaging phase without need for spectroscopic followup. This type of survey has the potential of mapping LSS over the largest cosmological volumes, even extending to regions of the universe only visible before galaxies formed. Extending survey volumes is important as it decreases statistical errors on determinations of the dark energy equation of state and other cosmological parameters.

An interferometric array, Tianlai¹ is nearing completion in northwestern China. Tianlai's primary purpose is to test, refine, and implement the technique of intensity mapping of the 21cm line, *i.e.* to map out the line without need to resolve individual galaxies. The Tianlai collaboration, which the PI is a member of, would like to reduce and analyze the first year(s) of data at Fermilab. This would give Fermilab experience in what is likely to be an important technique in cosmological surveys over the coming decades at relatively little cost and risk.

¹ Tianlai is transliterated from Mandarin and means roughly "heavenly sound".

Project Work Plan (~200 words): Overview description the work to be performed, timescale, and approximate financial/personnel resources required.

The initial interferometer setup will map the 21 cm emission over the redshift range of $0.775 < z < 1.029$ and over 50% of the sky surveying more than 50 Gpc^3 . The telescope receives a complete data set every day as the earth rotates. Averaging over days reduces the noise of the map and a few years data is required to get an interesting map. At the telescope site the correlator data is culled and averaged to $\sim 2 \text{ TByte/day}$ of time ordered data (TOD). This is shipped to Beijing and we would like to copy this to Fermilab as well. At Fermilab the TOD would be calibrated, radio transients would be flagged/removed/deweighted, and the data would be combined to form an “average day’s” data or “calibrated data cube” (CDC $\sim 10 \text{ TByte}$). The CDC is further reduced by separating the foreground emission from the 21cm signal, finally producing a redshift space map (RSM $\sim 10 \text{ TByte}$). The RSM is the final science data product which can be analyzed to make maps of the universe and determine cosmological parameters.

The data reduction techniques, especially the large TOD→CDC reduction, is simple, embarrassingly parallel, linear in the data size and well suited to the Fermilab computer farms. The software is being developed by scientists on the project and a first version of the pipeline will be ready to go before Fall 2015. The large amount of data storage and handling requires computer resources and human effort. The details of how data would be transported to Fermilab are being discussed but will likely be via tapes shipped to Fermilab. Roser, Panagiotis and the PI have discussed the required resources and do not foresee that any new hardware would be required. We estimate the cost to handle/organize/inventory the incoming data and run jobs at $\sim \$75 \text{ k/yr}$. The data reduction effort will be ongoing throughout the two year LDRD period as data comes in, producing lower and lower noise maps.

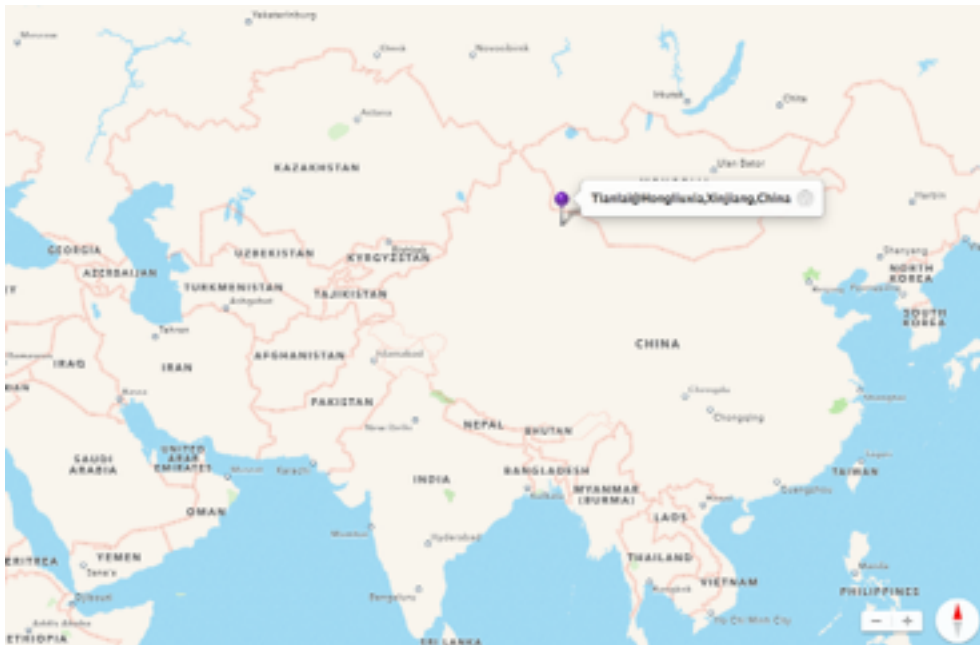
The computer professional effort will be overseen by the PI although other members of the collaboration from the US, China and France will be heavily involved in the data reduction and analysis.

Comments or Questions (optional).



Photograph of Tianlai telescope from early April 2015. In view is a 3 cylinder array (the main part of the project) and part of a 16 dish array. A person can be seen in the distance for scale.

The initial configuration of the cylinder array will have 96 dual polarization feeds all of which will be cross correlated. Each of the dishes will have a single dual polarization feed.



Location of Tianlai telescope