Memo 3: LFT3 100 light year star catalog

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1 Introduction

In this memo, we compile a list of unique nearby stars that will be used as the primary technosignature targets by the Lunar Farside Technosignature and Transient Telescope (LFT3, ref WHITEPAPER). Given the relatively limited collecting area of LFT3 compared to Earth-based telescope facilities, we chose to probe meaningful Equivalent Isotropic Powers (EIRPs) of nearby star systems (within roughly 100 light years), as this maximizes the scientific return of the mission. The scientific impact of this survey leverages LFT3's access to an RFI-free environment that is orders of magnitude better than the best Earth-based facility. This distinction allows LFT3 a unique place in the global effort to search for techno signatures and answer the question "Are we alone?".

In this memo, by combing together published catalogs of nearby star systems, we aim to create a more 'complete' catalog of all stars within 100 light years, and by observing these targets with LFT3 we aim to create volume complete (or close to volume complete) technosignature survey of nearby stars, which can be used as a reference dataset with future deeper surveys. The primary difficulty is in identifying the unique stars in the catalog such that no duplicates persist and none are overlooked.

This document is structured as follows. In Section 2, we give a summary of the parent catalogs used in this memo, along with the method used to combine them. In Section **??**, discuss our final results and also perform a statistical analysis to quantify the possible number of stars lost during the cross-matching process. We provide the final combined 100 light-year catalog in Section 4.

2 Data and Methods

We create our final catalog of nearby stars using five parent catalogs of nearby stars, namely, the Recons catalog of 100 nearby star systems, the Recons red dwarf catalog, the Isaacson catalog, and the 100 light-year catalog. The individual catalogs are summarized below.

Recons 100 catalog This is a complete volume catalog put together by the REsearch Consortium On Nearby Stars (RECONS)[1] to understand the Sun's nearest neighbors. As this catalog covers objects as big and bright as large stars to small and dim objects like brown dwarfs, this is the most volume complete knowledge we have of our neighborhood within 10 parsecs of the Sun.

Recons red dwarf catalog Due to the comparatively less luminous nature of stellar dwarfs, they are harder to find. After the original 10 parsec sample of stars was published by RECONS, they later identified 49 new members within 10 parsecs (3), most of which are red dwarfs, and where later added to their original catalog of nearby stars.

Recons M dwarf catalog As previously mentioned, this catalog of approx. 500 M dwarf stars was later identified by Recons to lie within 15 parsecs (4).

Isaacson catalog This is a list of stars put together for *Breakthrough Listen's* search for technosignatures using the Automated Planet Finder, Parkes Telescope, and Green Bank Telescope (2). This catalog aimed to explore stars of all spectral types for the technosignatures. Although this catalog is not a volume-complete catalog, it attempts to explore all spectral types for techno signatures with minimal selection bias (compare to other similar searches). Stars within about 100 ly are used from this catalog.

[1] http://www.recons.org/

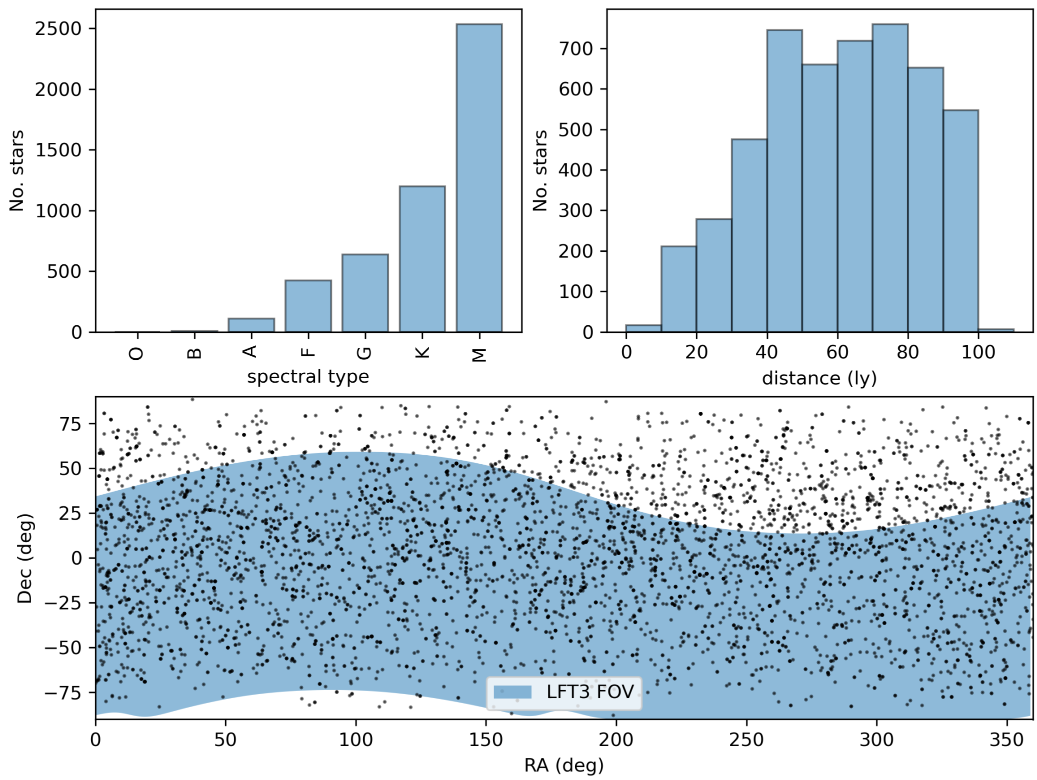

Figure 1: Distribution of the stars in the combined catalog. In the top-left panel we show the spectral distribution of the stars, and their distances from the Sun in the top-right panel. The bottom panel shows their distribution on the sky overlayed with LFT3's FOV (assuming a launch date of January 2028).

100 light year catalog The 100 light-year catalog was obtained from the ChView[2], a 3D interactive tool used to visualize our solar neighborhood. The back end of the tool uses star catalogs from the Gliese Catalog of Nearby Stars (CNS3)[3] and the Yale Bright Star Catalog [4]. From the ChView tool, we obtain 3721 stars that are within 100 light years.

2.1 Cross-matching catalogs

A new and more complete catalog of stellar objects within 100 light years was constructed by merging entries from the five independent parent catalogs. When combining catalogs, to unsure we only retain unique objects, we identify potential duplicates using three criteria: (i) angular separation of the sky less than 0.5°, (ii) identical spectral type (and the numerical subtype ranging 0-10) classification, and (iii) consistency in reported heliocentric distances within a tolerance of 5 light years. When two or more entries across catalogs satisfied these conditions, they were deemed to correspond to the same stellar object, and only a single representative entry was retained in the final combined catalog. The 0.5° angular separation criteria and the 5 light year distance tolerance criteria, are arbitrarily chosen conservative limits to remove duplicates, and they are large enough to account for proper motions and other sources of uncertainties.

Using the above method to combine catalogs, we estimate that about 2-10 stars would be lost due to them sharing similar spectral type, distance from Sun, and angular position on the sky, and is further discussed in Section 3.1.1.

[2] https://chview.nova.org/chview/

[3] https://heasarc.gsfc.nasa.gov/W3Browse/star-catalog/cns3.html#:~:text=The%20CNS3%20catalog%20contains%20all,van%20Altena%20(Yale%20University).

[4] http://tdc-www.harvard.edu/catalogs/bsc5.html

3 Discussion

3.1 Combined catalog

Our final compiled catalog had s total of 5076 unique stellar objects spanning upto 100 light years and uniformly spread across the celestial sphere. The distribution of these stars on the sky, their spectral types, and their distances from the Sun is shown in Figure 1. The names, astrometry, spectral types, and distances to the stars in the combined catalog is given in Section 4.

3.1.1 False positives

To assess the potential number of stellar entries excluded by our criteria used to combine catalogs (i.e, angular separation less than 0.5°, identical spectral type and subtype, and distance agreement within 5 light years), we constructed a synthetic stellar population representation of the local neighborhood. A spherical volume of radius 100 light years was populated with stars randomly distributed according to a local stellar density[5] of 0.0984 stars pc^{-3}. Spectral types were assigned to stars probabilistically on the basis of the literature values [6] using the relative abundances of the spectral classes in the solar neighborhood. A Monte Carlo approach was then employed to evaluate the frequency of chance coincidences that met the exclusion criteria, thereby providing an estimate of the number of genuine stars potentially lost during the catalog merging process. In Figure 2, we show the number of stars lost for different selection criteria used. For the criteria used in this memo, expect about 2-10 stars to be lost.

This simulation does not explicitly account for binary stars, which may affect the estimated number of stars lost during cross-matching. To mitigate this, for all pairs of stars across catalogs that share the same spectral type, distance, and angular position on the sky, we employ the `SIMBAD`[7] API to retrieve all known identifiers for each source and retain both entries unless their names overlap across catalogs. This approach minimizes the likelihood of erroneously discarding binary components that share similar spectral type, distance, and sky position. We also note that, as the primary goal of this memo is to create a list of star systems for technosignature searches using LFT3, even if a star from a binary system is lost during cross-matching, it does not impact our study, as the star system would still get searched by LFT3 (regardless of it being a sole star binary system).

3.2 EIRP Limits on the star systems

Using the constraints from the LFT3 mission (such as mission life, field-of-view, sensitivity, etc.), we perform a first-order estimation of the Equivalent Isotropic Radiation Powers (EIRP) levels probed for these stellar objects. We do so in the following steps;

1. calculate the instantaneous FOV of LFT3. If θ is the FWHM of the beam at a given frequency, and n is the number of beams, then $FOV = n \times A_{beam}$ (where $A_{beam} = 2\pi[1 - Cos\theta]$)

2. using the instantaneous FOV, calculate what fraction (f) of the sky is seen by LFT3 at a given time ($f = FOV/4\pi$).

3. assuming all fields get equal observing time, we estimate what fraction of the total observing time (10 weeks of observing during lunar day, for the 20 week mission life) goes into observing a field/pointing ($exposure = 10weeks \times f$)

We do this calculation for different frequencies and show the total observing time per pointing is shown in the top panel of Figure 3. By stacking all the available observations per field, we determine the obtained EIRP limits (for a 1MHz bandwidth) as a function of distance in the bottom panel of Figure 3.

4 Catalog

The combined catalog can be obtained from (1). An animation of the final catalog (color-coded by spectral type) can be found in https://youtube.com/shorts/PH94zy0Ke8w.

[5] https://www.pas.rochester.edu/~emamajek/memo_star_dens.html?utm_source=chatgpt.com
[6] https://www.pas.rochester.edu/~emamajek/memo_star_dens.html?utm_source=chatgpt.com
[7] https://astroquery.readthedocs.io/en/latest/simbad/simbad.html

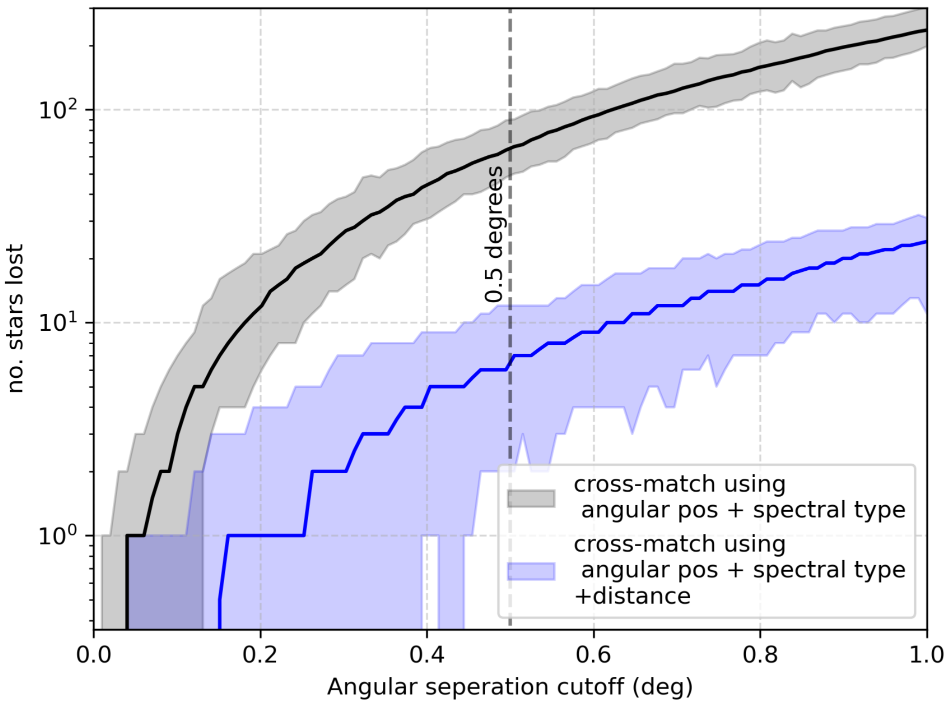

Figure 2: Potential number of stars lost during the cross-matching process, as determined from 1000 realizations of a synthetic solar neighborhood up to 100 light years. We show the number of stars that would be lost (on the y-axis) for different angular separation cutoff used on the x-axis. In the grey band we show the number of stars that would be lost when using only using the anguler separation and spectral type to cross-match stars across different catalogs. When distance tolerance is also used to cross-match, the number of stars lost during cross-matching reduced by many orders of magnitude, and is shown using the blue band in the above plot. As a vertical line we also show the 0.5° angular separation cutoff used in this work.

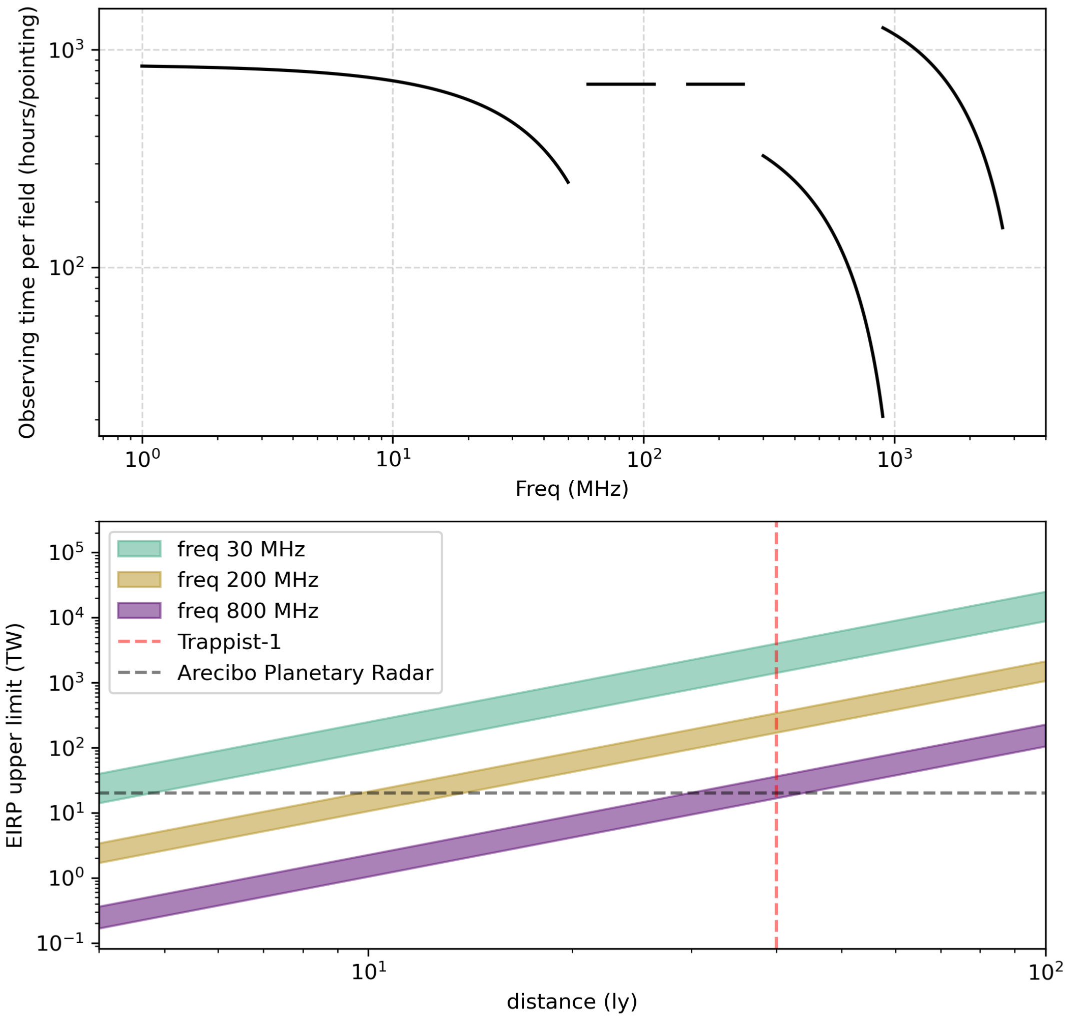

Figure 3: The top panel shows the total observing time (in hours) per unique pointing. LFT3 uses different types of antennas at different frequency, all of which vary very differently with frequency. Using the beam size and the mission life, we show the total observing time that goes towards each direction on the sky at a given frequency. Using the total observing time, estimate the EIRP limits that can be placed by LFT3 as a function of distance to the star system in the bottom panel. We note that in our most sensitive frequency band ($\sim 800\,\mathrm{MHz}$), LFT3 is capable of detecting an Arecibo Planetary Radar on the Trappist-1 star system.

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