Australia's National
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The ASKAP-CRACO Low Time Resolution Universe Survey (LOTRUN)

Survey scope and policies

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1 Introduction

The ASKAP-CRACO Low Time Resolution Universe Survey is a project with two aims: to demonstrate and validate the operation of the CRACO system as part of the ATNF National Facility, and to probe the Galactic radio sky at sub-second timescales. Like the Rapid ASKAP Continuum Survey, it is distinguished from the Survey Science Projects (SSPs) by being initiated and led from ATNF as an Observatory Project for the benefit of the user community.

The purpose of this document is to outline the technical and scientific scope of the project, as well as defining the data access and publication policy.

2 Survey technical and scientific aims

The LOTRUN survey design will be decided by the Observatory in consultation with the CRAFT and VAST Survey Science Teams (SSTs). Input from other SSTs may be considered. We provide a brief outline of the technical and scientific scope of the project below.

The primary role of LOTRUN is to robustly demonstrate and validate new national-facility capability for the benefit of the user community. The secondary aim is to enable high-impact science by exploiting a window of opportunity to probe new parameter space not necessarily well-covered by existing SSPs.

2.1 Technical scope

The CRAFT Fast Transient COherent upgrade (CRACO) records visibilities at millisecond time resolution with the primary aim of detecting and localising fast transients. It was developed by CSIRO S&A in collaboration with the CRAFT SST, who operate the instrument. CRACO comprises a compute cluster with 18 processing nodes, capable of ingesting high time resolution visibilities from the ASKAP hardware correlator, from baselines for the innermost 30 antennas of ASKAP. The processing nodes undertake low latency searches for transients in images formed from visibilities de-dispersed at approximately 1000 trial dispersion measures. Candidate events then trigger the existing ASKAP voltage buffer system which can then localise the transient with higher angular resolution (utilising all baselines), and higher spectral and temporal resolution, and with full Stokes polarimetry.

While CRACO was developed with the primary goal of being the next generation fast radio burst detection system for ASKAP, it was noted at the time of its proposal there would likely be additional scientific uses. Examples include studies of interplanetary or interstellar scintillation, techno-signature searches, visibility-based periodicity searches for exotic pulsars, space situational awareness, and high time-resolution studies of magnetospheric transients. To support these use-cases for the broader community, the CRACO team expended effort in 2024 to integrate CRACO into the National Facility operation of ASKAP. As part of this effort, the Observatory proposed a 200h survey to robustly test and validate the CRACO system in a National Facility context, and to probe the new scientific parameter space afforded by this system.

Specifically, the survey will provide the opportunity to robustly test:

- The ability of a general National Facility user to design and specify the parameters of an experiment using CRACO that can be successfully executed by the Observatory
- The interface between the CRACO system and the standard telescope monitoring and control software, ensuring user-requested CRACO observations can be successfully executed according to observing specification
- The feasibility and effectiveness of staging science-ready high-time resolution visibilities to Pawsey, and uploading limited 110ms resolution visibilities to CASDA
- Reliable provision of science-ready fundamental (e.g., 110ms visibilities) and higher-level data products (e.g. candidate lists or high-resolution visibility cutouts), to an end user

2.2 Scientific scope

ASKAP time-domain surveys have yielded an abundance of Galactic radio transients, including variable pulsars, stellar radio bursts, and sources of unknown nature. One recent class of interest are the so-called “long period radio transients” (LPTs; Caleb et al. 2022, Hurley-Walker et al. 2022), whose exceptionally bright, long-period coherent pulsed radio emission challenges established radio pulsar emission models.

Despite their high flux densities, these LPT sources have evaded discovery until now, because established neutron star radio emission models did not strongly motivate searches for such long-period pulsars, and these searches are technically challenging with single-pixel pulsar search observations. In addition, widefield radio imaging surveys have not typically probed the seconds-to-minutes timescales required to detect single pulses. However, the two time-domain SSPs on ASKAP, CRAFT (using the CRACO real-time fast-imaging backend), and VAST, have uncovered 9 of the 14 known examples of these sources (including new unpublished discoveries), placing ASKAP in a clear world-leading position for discovery of these sources. Both SSPs have also discovered several other examples of other Galactic radio transients, including Rotating Radio Transients (RRATs), long period and variable pulsars, and stellar radio bursts. In addition, both SSPs have discovered sources of unknown nature.

LOTRUN will fill a gap in the observing cadence and variability timescales that are currently probed by SSPs, exploiting a window of opportunity to extend ASKAP’s world-leading position in discovering LPTs and other transients. The broad strategy will be to observe several-hour-long tracks repeatedly, towards the inner Galactic plane ($-90 < l < 68$). This will provide a relatively complete, unbiased survey for long-period transient searches. The detailed observing strategy will be decided by the Observatory in consultation with the CRAFT and VAST teams.

There are four SSPs that target the Galactic Plane, namely EMU, GASKAP-HI, GASKAP-OH, and VAST. The aims of LOTRUN cannot be achieved commensally to these SSPs because:

- CRACO cannot run commensally with the high frequency resolution “zoom” mode used by the GASKAP spectral line surveys;
- EMU only observes the Galactic plane in a single 10-hour epoch per field;
    - VAST Galactic pointings have shorter dwell time so are less suited to detect LPTs.

3 CRACO commissioning outcomes and National-Facility readiness

The CRACO system has been offered as a National Facility in a "shared risk" capacity throughout 2024. Specifically, data transfer from Skadi, the CRACO processing cluster on-site at the ASKAP Control Room to the acacia cluster at the Pawsey Supercomputing Centre has been demonstrated successfully. The ability of CRACO to be deployed according to user specification has been a success. Integration of the CRACO monitoring and control software with the central ASKAP monitoring and control software has begun, with visibility of CRACO status available at the time of scheduling, although the veracity of this status should be improved.

While excellent progress has been made in offering CRACO as part of the National Facility, some parts of its capability remain "shared risk" for users. In addition, some operational instabilities which compromise the ability to reliably complete observations have been identified. These include (but are not limited to):

- Currently, data is deposited temporarily to a staging area on acacia before it is deleted, meaning there is no means for long-term access to data or tracking data quality metrics. Movement and storage of data for user access is currently handled manually.
- Current calibration methods and observing constraints can lead on-line calibration to fail, leading to degraded real-time imaging quality. This reduces real-time sensitivity to transients, preventing triggers for dumping data and requests for a dedicated polarisation and gain calibration observations post-detection
- Correlator card and other system instabilities may cause the CRACO pipeline to fail while the main system may continue relatively unhindered.

With these in mind, we have established the following outcomes for the LOTRUN project, which will validate CRACO as a fully operational National Facility system.

3.1 Outcomes for the LOTRUN project

1. Requested CRACO data products along with necessary metadata and auxiliary data (e.g., calibration scans) are prepared and deposited to CASDA for long-term storage and user access via a centrally managed, automated process. Data quality metrics can be tracked and assessed as with other ASKAP data
2. The CRACO system runs reliably in National Facility mode with minimal manual intervention and accurate reporting, such that "shared risk" aspects are mitigated. This includes:
    a. The availability of a stable CRACO data recording capability for National Facility observations,
    b. CRACO National-Facility observations can be executed successfully to user specification (and within Observatory-placed constraints),
    c. Necessary calibration observations for on-line delay calibration and off-line processing are scheduled and executed

3. Improved two-way reporting between the CRACO and central ASKAP control system, ensuring any non-zero return status is passed automatically. This will ensure that any operational issues that affect either the CRACO system specifically, or the ASKAP system overall, can be identified, and rectified in a timely and sustainable fashion.
   Examples of relevant issues include sometimes-poor stability and status visibility of the CRACO backend, handling of degraded correlator cards, intermittent corruption of data from individual antennas, and CRACO stability issues affecting the broader telescope system.

LOTRUN observations will commence once the ASKAP Senior Systems Scientist is satisfied that LOTRUN Outcomes 1. and 2. are implemented. LOTRUN Outcome 3. will require longer-term development which will be implemented as the survey progresses. To assess progress, a checkpoint will be in place after 100 hours of observing, and any necessary improvements can be identified for the completion of the survey. If insufficient progress has been made, the LOTRUN project may be placed on hold by the ASKAP Senior Systems Scientist, ATNF Head of Science, or Head of Operations until sufficient progress has been made to implement the required changes.

4 LOTRUN Data products

The following data products will be provided to the community via CASDA.

CRACO data products

- Total-intensity visibilities at 110 millisecond time resolution and 1 MHz spectral resolution.
- Candidate lists and other outputs from high time resolution searches.

ASKAP correlator data products

- Full polarimetric visibilities at standard 10s, 1 MHz resolution, mosaicked images, selavy catalogues, and other standard continuum data products
- Individual per-beam continuum images in Stokes I, Q, U, V, and per-beam CLEAN model images for continuum subtraction in low latency fast imaging processing

To ensure all LOTRUN data products can be made widely available to the community promptly, tools will be developed to include CRACO data products in the CASDA ingest process prior to the survey commencing. In practice, this involves development of new tools within the ASKAP pipeline that will produce xml files encapsulating key information of CRACO data products for CASDA upload. CRACO data products and auxiliary files will be staged in the `askapbuffer` area on the Pawsey supercomputing system, where the descriptive xml files will be produced automatically. This effort will be led by the LOTRUN survey lead in collaboration with the ASKAP Head of Data Operations.

At 110 millisecond resolution, CRACO visibilities have a data rate of 27.2 GB per hour per beam which yields 980 GB per hour across all 36 beams. The visibilities will be segmented into 15-minute scans, each stored in a separate uvfits file approximately 244 GB in size which will be provided on CASDA.

5 Data access and publication policy

LOTRUN data is collected for the benefit of the ASKAP SSTs and broader astronomical community, with the support of ASKAP Operations. LOTRUN data will be made public on CASDA as soon as their quality can be quantified and assured. Once the products uploaded to CASDA are fully validated, the LOTRUN products will be publicly and freely accessible to all.

Any simultaneous observations from other instruments coordinated with ASKAP LOTRUN observations must be taken under reciprocal access conditions – i.e., the data will be made publicly accessible promptly for the benefit of the broader astronomical community. Arrangements for simultaneous observations should be coordinated with the Head of ASKAP Science Operations and the LOTRUN Survey Lead. Failure to meet these conditions may result in the removal of the ASKAP schedule broadcast service.

The LOTRUN team will have access to the data prior to public release for the purpose of initial processing and validation of the data products. Other access to the survey data prior to public release is at the discretion of the Observatory and is granted with the express purpose of expediting quality control and subsequent public release. During this time, discoveries may be made and publication of these discoveries from the pre-release processing teams is encouraged, under the proviso that:

1. All publications arising from LOTRUN must follow the current ASKAP Publication Policy and ATNF publication guidelines. Note that Wang et al., 2025, PASA, 42, e005 is the relevant "key publication" describing the CRACO system. Publications arising from LOTRUN are therefore not required to have co-authorship opt-in based on historical contribution to the CRACO system.
2. Relevant science teams – particularly the CRAFT and VAST collaborations, or other relevant SSTs whose scientific domain substantially overlaps with the discovery – along with the ATNF Head of Science, are notified of the discoveries and publication plans. Members of any active sub-project with scientific cross-over within these SSTs should be invited to contribute to the publications. The ATNF Head of Science will advise if any publication has significant scientific overlap with other SSPs. Disputes will be referred to a panel consisting of the ASKAP Senior Systems Scientist, the Head of ASKAP Science Operations, and ATNF Heads of Science and Operations, which will rule on authorship.
3. Pre-release data should be processed, validated, and publicly released via CASDA for use by the community within 4 weeks of the observation. While discoveries may be made in initial processing of the data, scientific analyses used in publications must make use of publicly released data.
4. Contributions to data quality assessment will involve data processing and validation to ensure data is high-quality and science-ready upon release. We outline these checks below (Section 6), but detailed procedures and criteria checklist will be provided in a separate document.

Failure to follow these policies may result in access to pre-release data being withdrawn.

6 Data processing and quality assessment

Data processing for the survey will involve development of standard processing flows and outputs that can be deployed repeatedly on each epoch of LOTRUN. These outputs will be used to determine whether observing and data processing was successful, and which aspects (if any) failed. This framework will be adopted by the Observatory for future National Facility observations using CRACO or fast-imaging modes on ASKAP.

LOTRUN data quality assessment components

- Astrometric checks for both continuum and CRACO images. Astrometry errors within nominal levels given known issues and limitations of data
- CRACO calibration verification. Make sure Galactic fields do not execute without successful calibration. Practically this means observing an empty or calibrator field *prior* to executing survey observations for sufficient time to derive calibration solutions, which is typically 10-15 minutes.
- CRACO successfully operates in the chosen frequency band
- Radiometric checks: Accurate flux density scale, noise, and sensitivity at nominal levels
- Continuum image quality checks – no significant artefacts or calibration errors evident in the continuum images
- VASTER/fast imaging checks. Complex fields adequately modelled, self-calibrated, and uv-subtraction working. Model image does not contain significant un-physical features.
- Consistency checks between CRACO and standard correlator output, particularly in astrometry towards the phase centre and flux densities

6.1 The LOTRUN processing team

The LOTRUN Team consists of key members from within ATNF Science, and from within the CRAFT and VAST SSTs. These members will be responsible for coordinating observations with the Observatory and processing and validating data. Team members are chosen by the Observatory and by the relevant SST Primary Investigators (PIs). The survey will be managed by ATNF personnel indicated in boldface. External team members from relevant SSTs will contribute towards the processing and validation of data. Additional members may join the LOTRUN processing team with the approval of the LOTRUN survey lead, with the express purpose of assisting with data processing for validation and quality control.

LOTRUN Team members

- **Andrew Zic (ATNF Science; LOTRUN survey lead)**
- **Aidan Hotan (ATNF Science; ASKAP Senior Systems Scientist)**
- **Vanessa Moss (ATNF Science; Head of ASKAP Science Operations)**
- **Keith Bannister (ATNF Technologies; CRAFT/CRACO PI)**
- **Matthew Whiting (ATNF Science; Head of ASKAP Data Operations)**

- Ryan Shannon (CRAFT/CRACO PI)
- Ziteng (Andy) Wang (CRACO scientist)
- Yuanming Wang (CRACO & VAST scientist)
- Dougal Dobie (VAST survey scientist)
- Tara Murphy (VAST PI)
- David L. Kaplan (VAST PI)

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