LOFAR2.0 Large Programmes

Jason Hessels - LOFAR2.0 Project Scientist

LOFAR Family Meeting - Olsztyn, Poland - June 12th, 2023



Scope of LOFAR2.0 Large Programmes





- 70% for Large Programmes would mean ~21,000hrs available.
- The Eols requested ~42,000hrs, so commensality (or not accommodating all requests) is critical. Allocations are possibly 1+2+2 years. Calls for more limited-scope proposals will
- continue.

- 5-year programme running from about 2025-2030
 - (early, shared-risk + first 4 years of operation).
- 70% observing efficiency means ~30,000hrs
- available in ~5 years (best case scenario).

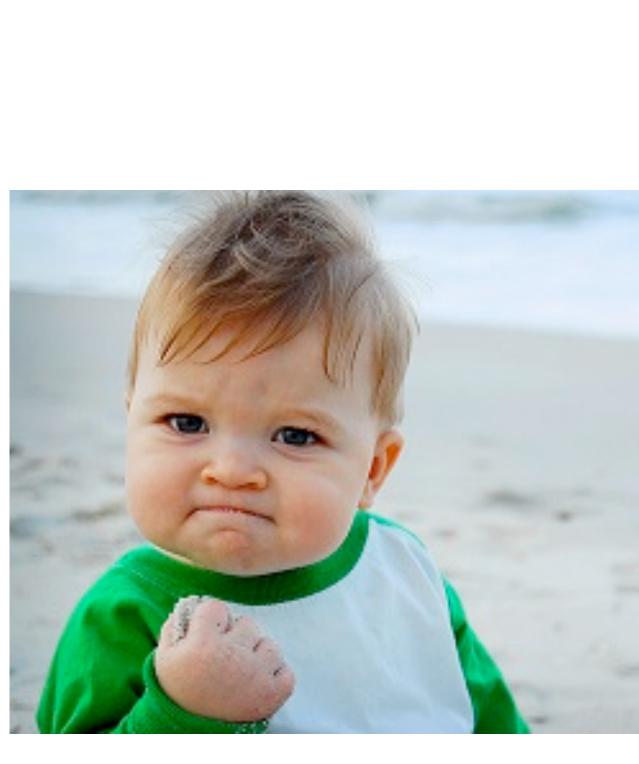






LOFAR2.0 Large Programmes **Success Criteria**

- Scientific impact
 - Publications, citations, theses, prizes, grants
- Technical impact
 - Techniques, software
- Community impact
 - Partner countries & institutes, support ECRs, develop SKA leadership roles
- Accessibility & legacy
 - Data reuse, distilled data products
- Visibility
 - Make LOFAR better known to other astronomers, policy makers, the public



Sphere and Space OFAR 2.0.

a Morosan, Nataliya Porayko, Mario M. Bisi, jej Krankowski, Gottfried Mann, Jasmina rina Tiburzi, and Christian Vocks

acceleration of particles, the expulsion of plasma into the ly affecting the conditions of the ionosphere. However, the

schnology at Earth is still subject to investigation. With the sin our understanding of the Sun-Earth system, including space-based observing technology. By using LOFAR 2.0 will be targeted at the Sun, heliosphere and ionosphere.

eliosphere

anetary Scintillation (IPS)

e scintillation of a compact radio source due to densit ns in the solar wind) is commonly used to observe the ind throughout the inner heliosphere. The combination tu and remote sensing instrumentation available to such observations is unprecedented over the next , and must be taken full advantage of. Significant es in the analysis of IPS measurements, playing to the strengths of LOFAR, have been made recently, paving ay to a more fundamental understanding of the ring solar wind turbulence, and how that may be ted with the larger-scale density structure seen in white light imagery. In addition, solar activity is ing towards an expected maximum in a few years time, ated with an evolution of the global solar wind structure creasing chances of CMEs. Taken together, this ents an enormous opportunity to exploit the capabilities AR2.0 in this arena.



ructure (vertical stripes) seen in a 15-of the passage of a CME in May 20.

Ir Dispersion Measure and Rotation Measure r emission is modified by the action of the trave red plasma, that can induce four kinds of effect: ation, scattering, scintillation. The study in lead to the inference of parameters se modifications can lead to the ini is to the e With LOFAR2.0 to the ature thanks to the possibility LBAs and HBAs simultaneous

Expression of Interest LOFAR2.0 Dark Matter eXperiment (LoDMaX) Aritra Basu¹ (abasu@tls-tautenburg.de), Dominik J. Schwarz² (dschwarz

The nature of dark matter (DM) remains elusive, and various types of matter including particles beyond the Standard Model and massive objects have been put forward as its candidate. Although DM are not visible directly, depending on their nature, they can manifest through indirect processes or via the effects they have on electromagnetic radiation. Many of these processes leave measurable imprints on astrophysical scales, and radio continuum observations using LOFAR2 0 can play a

 The LoDMax large programme will systematically hunt for dark matter using LOFAR2.0's state-of-the-art capabilities.

 LoDMax will focus on detecting ultralight axion-like particles (ALPs) and QCD axions through signatures of birefringence, stimulated de-

cay and axion-photon conversion, and decay products of annihilating weakly-interacting massive particles (WIMPs) LODMaX will also foster imaging-synergy with beamformed-based Eols

to search for exotic sterile neutrinos and primordial black holes. • The parameter space that LoDMaX will probe can not only compete with dedicated DM search experiments, but potentially improve the search dramatically

> Candidates of dark matter (adapted from Bertone & Tait, 2018, Nature, 562, 51). The shaded circles show the candidate space LoDMaX will explore. The dashed circles indicate further potential tar ets that can be explored brough simultaneous imaging of beamformed data DMaX will coordinate with

high energie

• A 1

 Alternatively, signatures of WIMPs can be indirectly detected via an physical searches when they annihilate via various channels produce -rays and e-e+ pairs. So far, astrophysical searches have cons y-ray observations of nearby dSph galaxies using the Fen LAT satellite and the HESS.

 An entirely new approach are radio-frequency searches which to when they give rise to synchrotron emission in the prese of magnetic fields. For WIMP masses in the GeV-TeV range and u magnetic fields, this emission peaks near $\sim 100 \, \mathrm{MHz}$ Using deep imaging capabilities of LOFAR2.0, LODMAX will target D

rich systems that are devoid of star-formation, such as, dSph and ea type ellipticals. A combination of LBA+HBA observations using international stations will allow LoDMaX to effectively reduce backg source confusion and constrain old (> 10⁸ yr) CREs.

QCD axion conversit Max will probe in search for ultralight ALPs via differential birefringence. A single lens detected by the LOFAR2.0 can improve the exclusion

bounds by more than an order of magnitude compared to dedicated axion search experiments like CAST. In comparison, it will require observations of ~ 100 lenses by the VLA. **Middle:** Parameter space expected to be probed by LOFAR2.0 HBAs and LBAs (in gray) through deep observations of about 40 DM-rich systems to search for spectral-line emission due to Pri-DMAX will probe a complementary parameter space towards lower m_a compared by factures effects of lab based OCD avion searches and improve the evolution ve efforts of lab-based QCD axion searches and improve the exclusion

X towards WIMP annihilation signal through deep observations (~. bounds by more than an order of magnitude. compliment direct WIMP searches, 6

...some of the 20 Eol postore

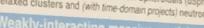
searched through several lab-based experiments, e.g., the XENONthe CRESST and the EDELWEISS.

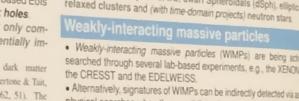
rticles (ALPs) are a generalization of that idea

iny interaction between the electromagnetic and the ALP fer gives rise to observable phenomenon, such as, achromatic birety gence and conversion of ALPs into photons, the Primakotf effect X will target strong gravitational lenses to robu differential birefringence $[O(1^{\circ}-10^{\circ})]$ due to ultra-light ALPs / V) between the lensed components the The Primakoft effect is expected to give rise to spectral-line to feature with characteristic line-width Δt

(000 kHz). At LBA+HBA frequencies, LooMax will target hearer QCD axions with $m_a = 0.35 - 1.5 \, \mu {\rm eV}$ \bullet Using 64 ch/SB (rms $\sim 6.2\,\text{mJy}/\text{12.21}\,\text{kHz}$ near 140 MHz), 1/

observe DM-rich systems, like, dwarf Spheroidals (dSph), elliptice relaxed clusters and (with time-domain projects) neutron stars



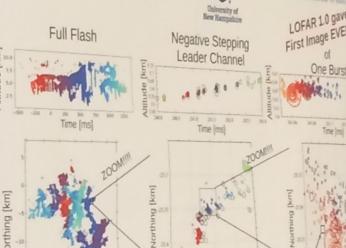


the Cherenkov Telescope Array collaboration to compliment direct WIMP-searches at

LOFAR2.0

LOFAR Family Meeting June 2022 in Köln

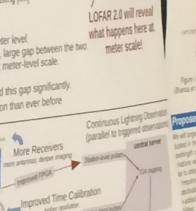
Expression of Interest Lightning Imaging with LOFAR 2.0 Brian M. Hare*, Stijn Buitink, Joseph Dwyer, Ningyu Liu, Olaf Scholten, and Sander ter Veen *b.h.hare@rug.nl university of groningen ASTRON



Fasting km Easting [km] SCIENCE: Lightning plasma modeling works at sub-meter level. Measurements are at 10 m resolution. Thus, large gap between the two. meter scale

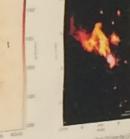
Goal is to close gap and measure plasma at meter-level scale. Figures above show LOFAR 1.0 has reduced this gap significantly. LOFAR 2.0 will let us push to higher resolution than ever be

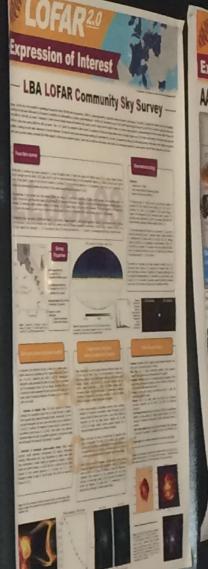
LOFAR 2.0 UPGRADE



Expression of Interest











LOFAR2.0 Large Programmes



Low Frequency Array

LOFAR

LOFAR

LOFAR is the largest and most sensitive radio telescope operating at low radio frequencies, between 10 and 240 MHz. It consists of antenna stations geographically distributed across Europe and driven in software by powerful station-level computing to produce a highly flexible and agile observing system. With a sensitivity more than 2



www.lofar.eu

INFORMATION FOR SCIENTISTS \sim



Deadline: October 12th, 2023 at 12:00 UTC

LOFAR2.0 Large Programmes



Low Frequency Array

LOFAR

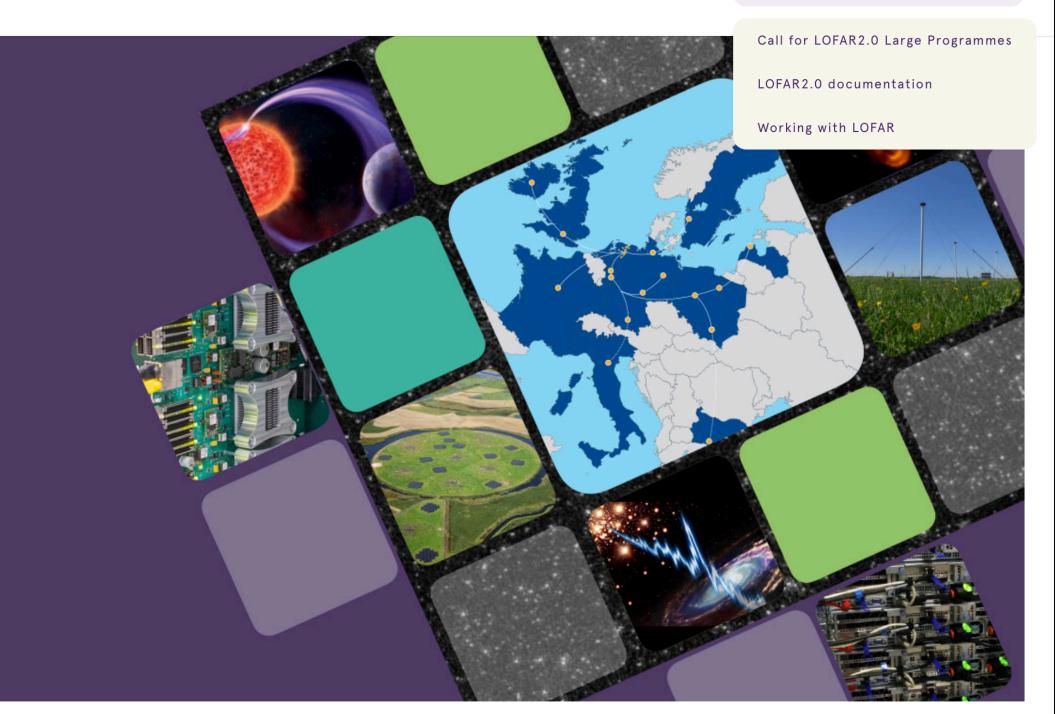
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INFORMATION FOR SCIENTISTS



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L2LPs: proposal template

- Deadline: October 12th, 2023.
- Workshops in the coming 4 months.
- Eol submission is *not* a pre-requisite.
- Find materials via <u>www.lofar.eu</u>
- Use this detailed template.
- Submit PDF via email:
- **lofar2-proposals@astron.nl** (also for questions).



3. nonths. equisite **.eu** Submission: LOFAR2.0 Large Programmes – Full proposal

(v230515) Template for LOFAR2.0 Large Programme proposals (replace with real title)

Jason W. T. Hessels^{1,2}, Anne Otherperson³

¹ASTRON – Netherlands Institute for Radio Astronomy ²Anton Pannekoek Institute for Astronomy, University of Amsterdam ³Advanced Institute

Abstract

In the Abstract, summarise your LOFAR2.0 Large Programme, its scientific goals and required observations.

Please use this LATEX template to prepare your LOFAR2.0 Large Programme proposal. In the final version, please remove the instructions and other extraneous text included in the template.

PAGE LIMIT: 20 pages total, including 1 page for the title and Abstract, also following the per-section limits. This limit does not include the reference list and you may also place full author lists at the end of the document. Please do not change the font-size, margins, or other aspects of the formatting in the LATEX template (but do remove the instruction text).

FIRST ANNOUNCEMENT: May, 2023. WORKSHOP: during the LOFAR Family meeting in Olstyn in June 12-16, 2023. See http://lfm2023.uwm.edu.pl/program. DEADLINE: October 12th, 2023.

SUBMISSION: Email a PDF, based on this template, to lofar2-proposals@astron.nl with title "LOFAR2.0 Proposal submission".

QUESTIONS?: Email lofar2-proposals@astron.nl with title "LOFAR2.0 Proposal question".

Keywords

Keyword 1, Keyword 2, Keyword 3, Keyword 4

Announcement (remove this section from final proposal)

LOFAR2.0 is a major upgrade to the Low-Frequency Array, offering simultaneous low- and high-band observing, increased field-of-view, and various other improvements to the sensitivity and operation of the telescope. A set of staged LOFAR2.0 test stations are helping to commission the new hardware and software, with a full system roll-out expected in 2024-2025, followed by early shared-risk observations and full operations thereafter.

Following an earlier call for Expressions of Interest (EoIs), the International LOFAR Telescope (ILT) now solicits full proposals for LOFAR2.0 Large Programmes (L2LPs). Submission of a

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 ● 0000-0003-2317-1446 (J. W. T. Hessels); 0000-0000-000-1234 (A. Otherperson)

International LOFAR Telescope



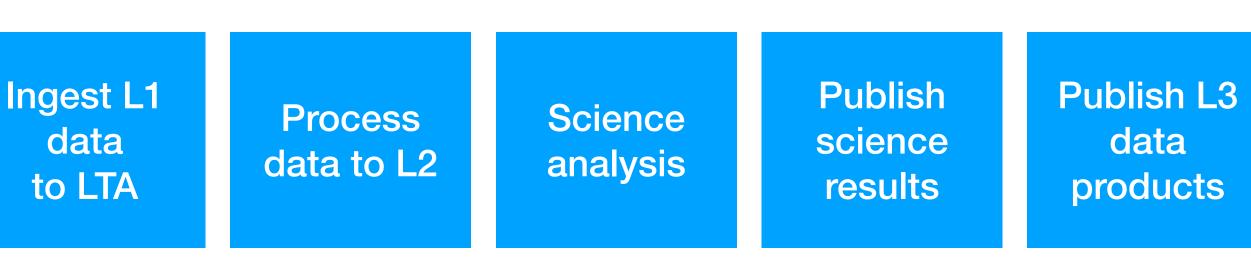
LOFAR2.0 Large Programmes

Schedule observations

Quicklook data checks

Preprocessing





L2LPs: evaluation

- Reviewed by experts, who consider:
 - Scientific merit & impact
 - Feasibility of observations & analysis
 - Strength & inclusiveness of team
 - Publication & dissemination plan
 - Useful open data products
- Final L2LP portfolio decided by ILT Board (considering the various Success Criteria).



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International LOFAR Telescope



L2LPs: background

- Short document summarising main changes between LOFAR and LOFAR2.0.
- See also van Haarlem et al. 2013 and Stappers et al. 2011 for basic system description.



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LOFAR2.0 Large Programme Proposals LOFAR2.0 compared to LOFAR: a short summary 2023-05-30

LOFAR2.0, see also the LOFAR2.0 White Paper, is a major upgrade to the LOw-Frequency ARray (LOFAR), offering simultaneous low- and high-band observing, increased field-of-view, and various other improvements to the sensitivity and operation of the telescope. A set of staged LOFAR2.0 test stations are helping to commission the new hardware and software, with a full system roll-out expected in 2024 – 2025, followed by early shared-risk observations and full operations thereafter. LOFAR2.0 will continue to be unique and world-leading, with an angular resolution > 10× higher than that of the planned Square Kilometre Array low-frequency component (SKA-Low), and also accessing the largely unexplored spectral window below 50 MHz.



Figure 1: International LOFAR Telescope.

The International LOFAR Telescope (ILT), see Figure 1, has previously been described in a general overview paper[1] and a paper specifically presenting beam-formed modes[2]. The goal of this short document is to summarise what new capabilities and improvements are offered by LOFAR2.0 compared to the previous system.

Telescope array

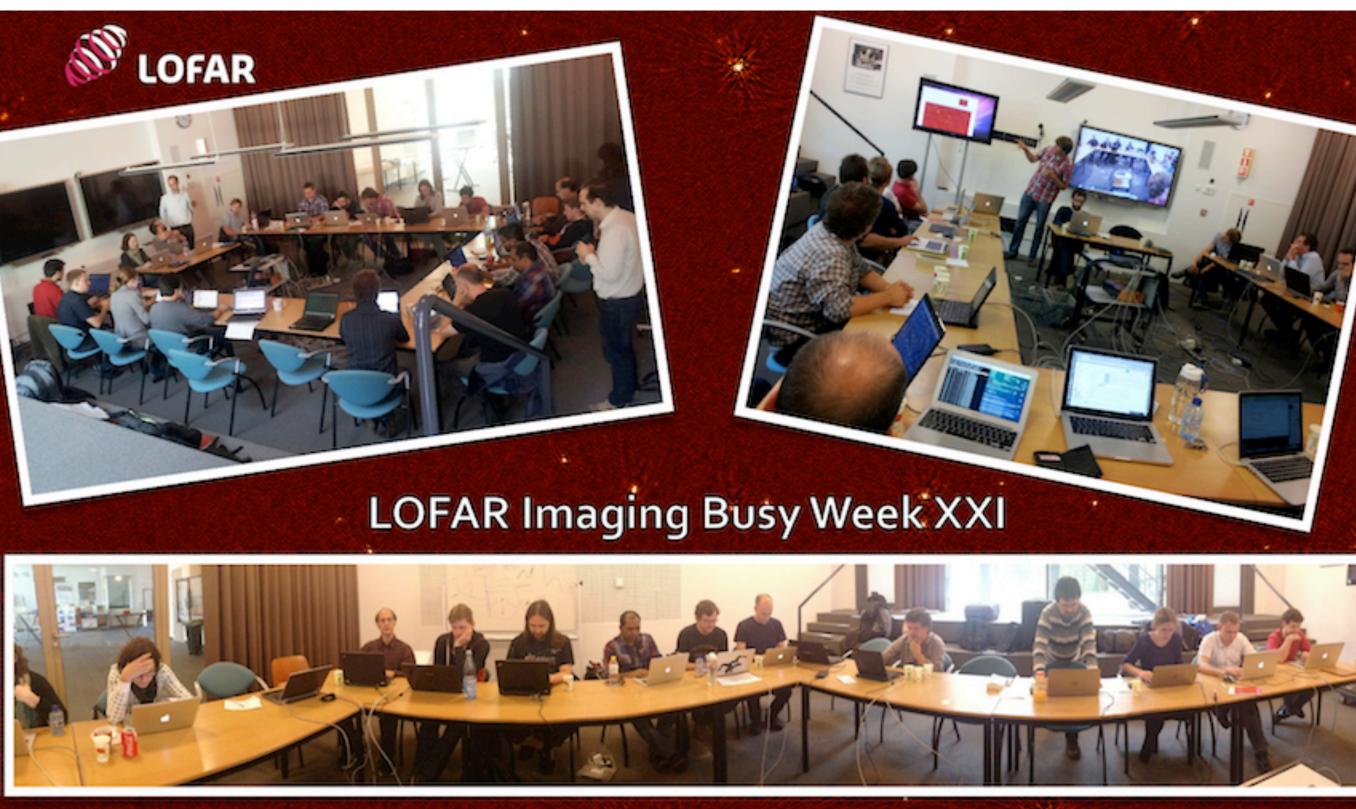
LOFAR is the world's largest and most sensitive low-frequency radio telescope (Figure 1). It stretches across Europe, from Ireland to Latvia, with a dense 'Core' and 38 stations distributed



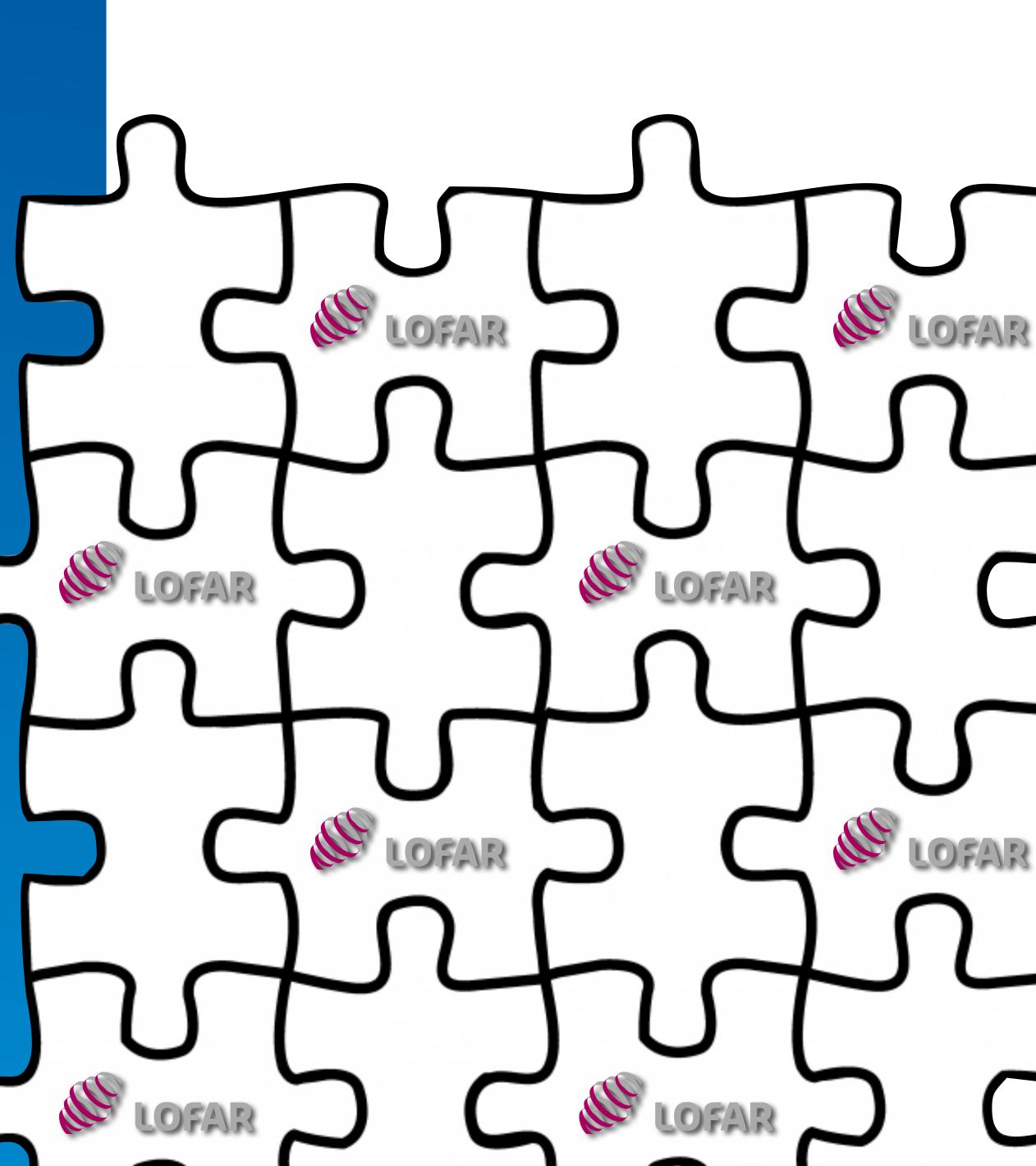
Putting the puzzle together

- Commensality in practice
- LTA and processing resources
- Running the observations
- Commissioning LOFAR2.0 \bullet









Synergies bases on:

- LBA + HBA simultaneous Simultaneous long baselines
- Commensal beam-formed observing (+ fast imaging)
- Commensal CRs, lightning
- Multiple science goals per survey field





LOFAR2.0 Science White Paper





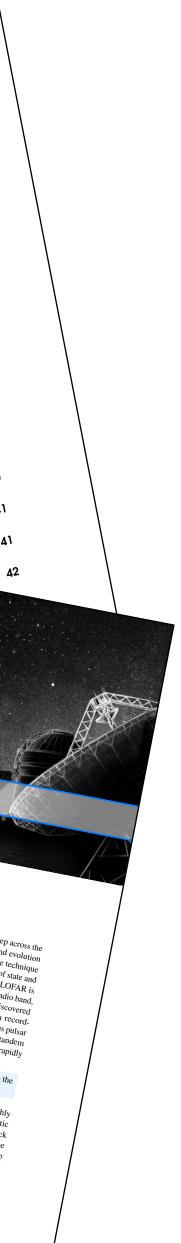
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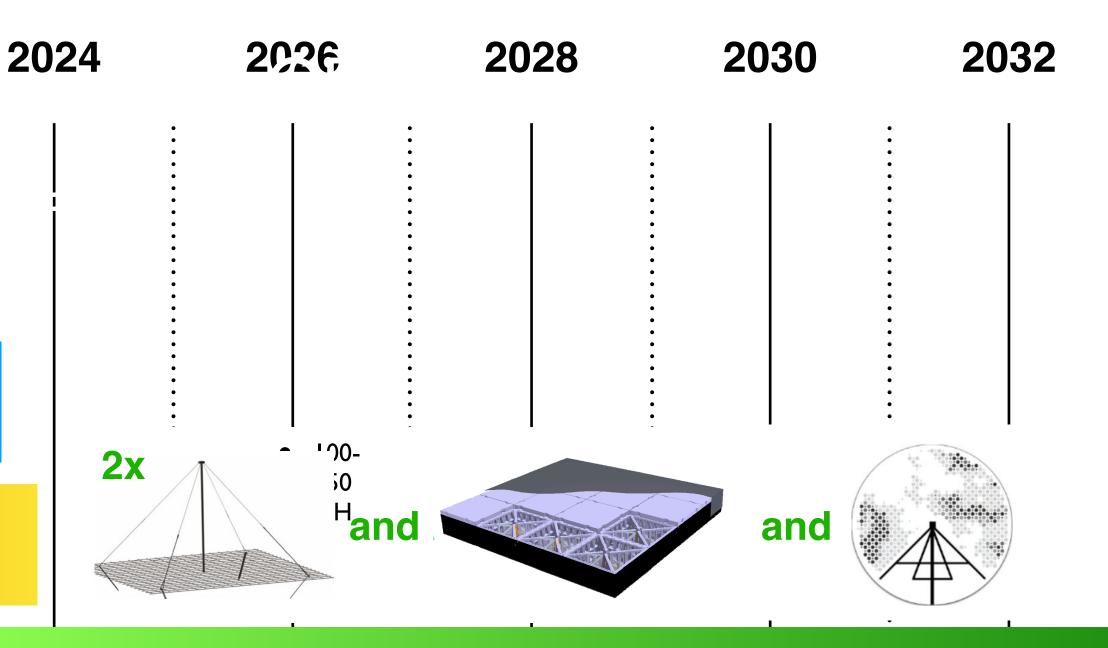
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	5.1 Pulsars	Contrast and
	Jason Hessels & Ben Stoppers	
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	sky like a cosnic lighthouse. These radio pulsations a of neutron stars, which are some of the most extreme of test Einstein's theory of gravity. Pulsars are exceptional a unique pulsar telescope because of its high sensitivity ac close to 100 radio pulsars to date <u>Gravita</u> of the most inter- breaking slow 23.5-sec pulsars to date <u>Gravita</u> of the most that is the cost of the sensitivity ac breaking slow 23.5-sec pulsars to date <u>Gravita</u> of the most that is the cost of the most external the test of the sensitivity ac the streaking slow 23.5-sec pulsars to date <u>Gravita</u> of the sensitivity ac the streaking slow 23.5-sec pulsars to date <u>Gravita</u> of the sensitivity ac the streaking slow 23.5-sec pulsars to date <u>Gravita</u> of the streaking slow 23.5-sec pulsars to date <u>Gravita</u> of the streaking slow 23.5-sec pulsars to date <u>Streaking</u> slow 23.5-sec pulsars t	e beams of radio waves that sween in the sween is to study the participation of the participation of the study t
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2018 2020 2022 **1**x 50 H<mark>O</mark>r LOFAR **DUPLLO Project**



Timeline



LOFAR2.0

Scientific & technical synergy

Square Kilometre Array

