SKA Transients Science Working Group

Headline science and requirements

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Advisors: Evan Keane, John Swinbank, James Miller-Jones, Joe Lazio, Andrew Siemion, Gregg Hallinan, Richard Armstrong

[Europe 8, Australia 7, South Africa 2, USA 5]

Transients and the SKA “Key Science Programmes”

– are the original KSPs still valid points of reference?

– Transients relates to parts of several of the original KSPs but should not be bundled merely as “exploration of the unknown” which seems to be a 'soft' design consideration

– *Astronet*, UK Astronomy advisory panels, etc. all list *Extreme Astrophysics* as one of their top priorities

– LOFAR, ASKAP, MeerKAT all approved Transients as Key Science

Two flavours of radio transients

Incoherent synchrotron emission

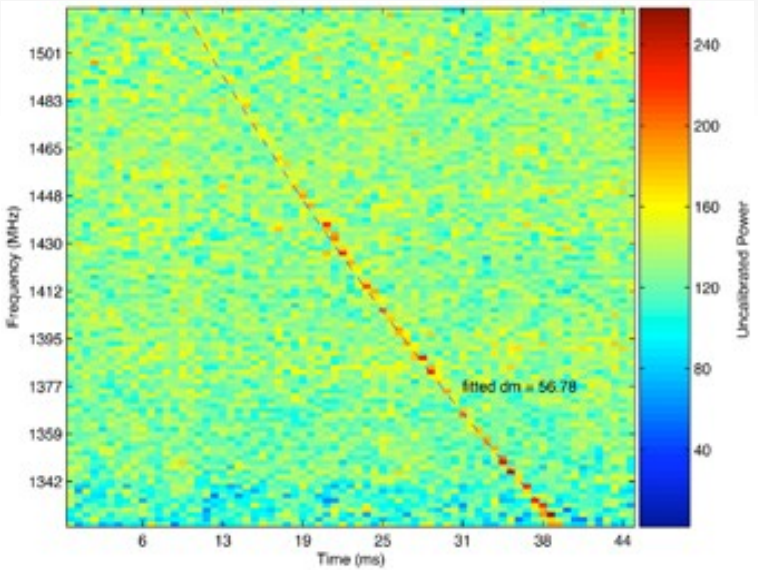
Relatively slow variability
Brightness temperature limited
Associated with all explosive events

Find these (mostly) in images

Early branch in classification pipelines

Coherent emission

Relatively fast variability
High brightness temperature
Often highly polarised
Sometimes very steep spectra



Find these (mostly) in time series

Transients science

Extreme environments and Astrophysics

Testing relativity

Lighthouses to huge distances

All of these are 'killer science' if *Nature/Science* and national reviews are anything to go by

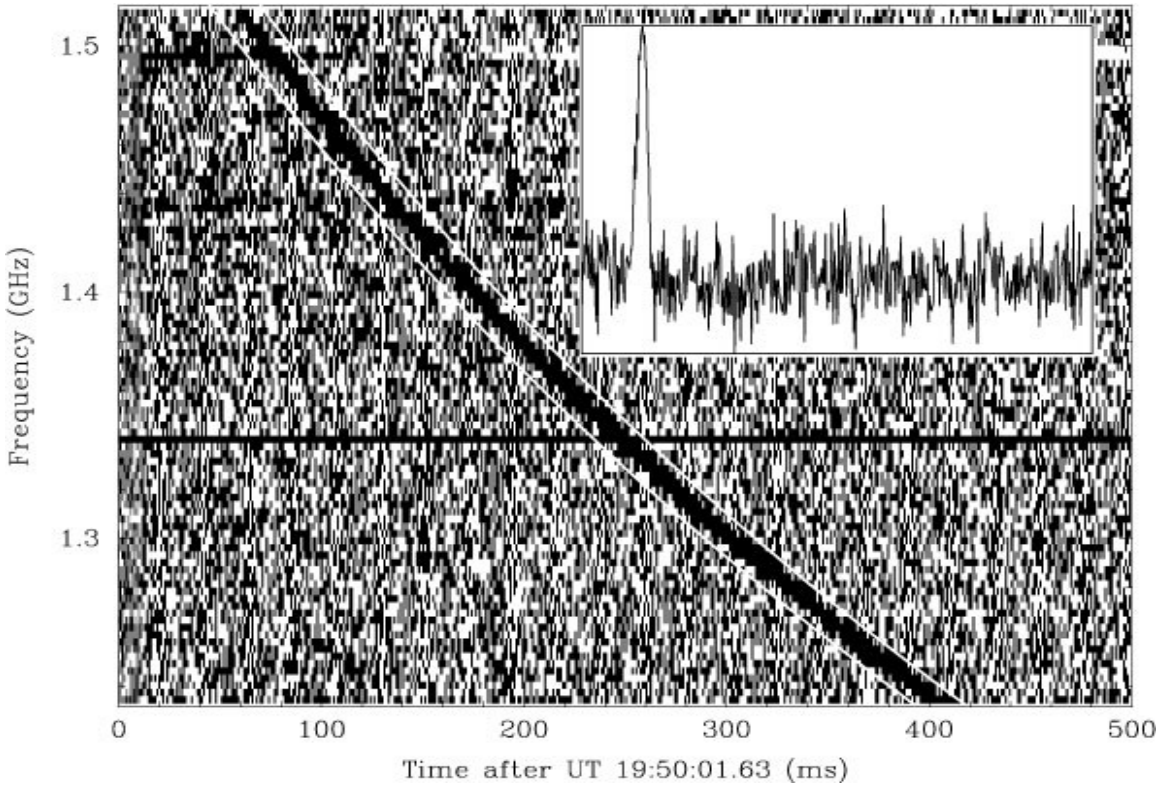
Pulsars: discovered as unexpected astrophysical transients

GRBs (and their afterglows): largest cosmic explosions, visible to ~EoR, huge multiwavelength coordinated effort → **100s** of Nature papers...

Supernovae: Ia → cosmology. Optical surveys finding many new classes.

Coherent bursts

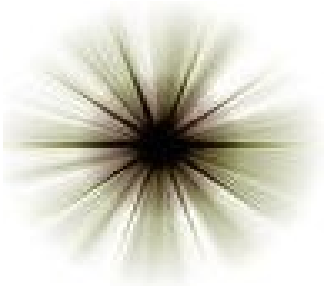
FRBs: potentially unmatched as cosmic probes of the IGM

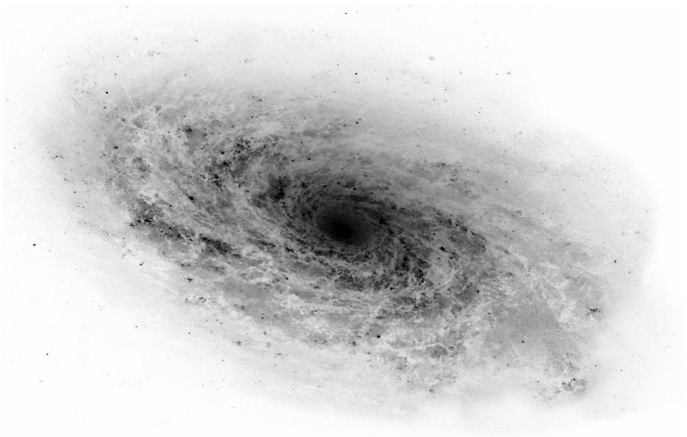


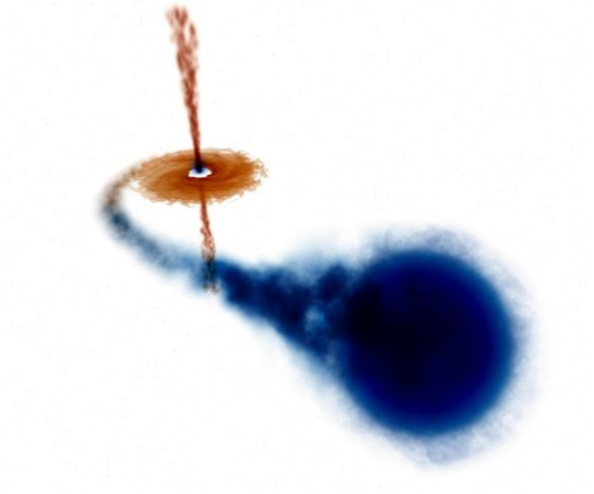
Bursts from extrasolar planets?

Synchrotron emission

Tracer of all astrophysical explosions: Calorimeter of relativistic kinetic feedback







Probe of black hole populations

Maximise The Science

Concept of Operations Section 2.6
"*The primary success metric for the SKA Observatory will be the significance of its role in making fundamental scientific discoveries and facilitating overall scientific progress, expressed as high impact, peer-reviewed scientific papers using SKA data.A8 Additional success metrics such as the total number of users, etc., will also be developed and measured.*"

-- all of these metrics will be greatly enhanced by commensal analysis of data and public release of alerts.

Making the SKA a 21st century telescope:

commensal searches and rapid response

Predicted rates

Will the transients be rare, manageable or a deluge?

LSST – a SKA contemporary – anticipates finding N transients / night

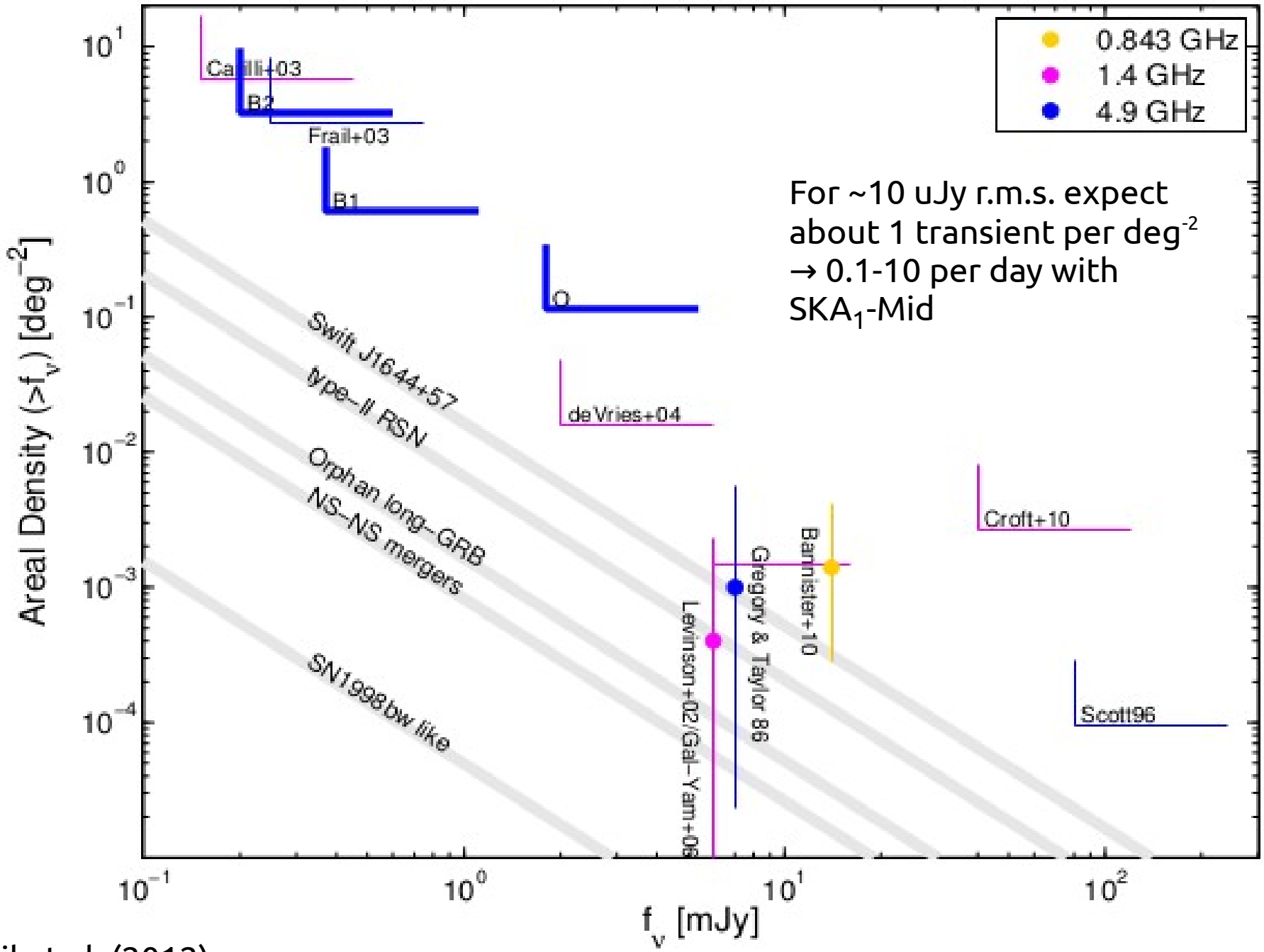
Predicted rates: GHz

We know there are interesting transients here, but rates not very well determined

1% of mJy-level sources at 1 GHz are significantly (>25%) variable

At 5 GHz, tidal disruption evens may dominate (Frail et al. 2012)

Radio transients



For ~10 uJy r.m.s. expect about 1 transient per deg^{-2} → 0.1-10 per day with SKA$_1$-Mid

Frail et al. (2012)

Predicted rates: GHz

Assuming commensal searches, otherwise order of magnitude smaller

Probably of order **1** *interesting new image-plane transient* per day (plus a whole bunch of sources you're monitoring, plus a stack of AGN variability)

Only really tested to ~mJy sensitivity

CHILES will test to ~uJy depth (albeit in a narrow field)

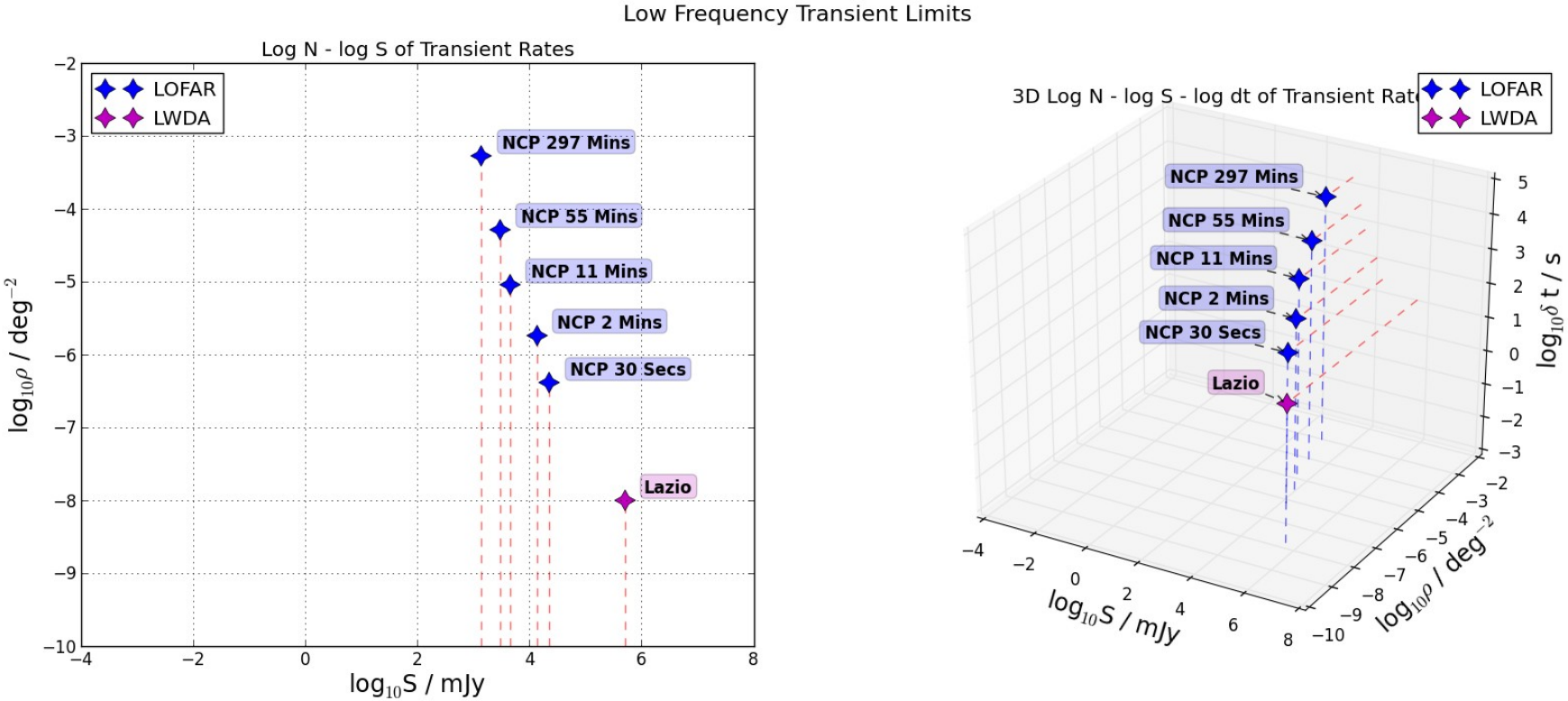
Predicted rates: MHz

Less clear

Transients reported, and pulsars of course detected

Best image-plane rate estimates probably from LOFAR (still being established)

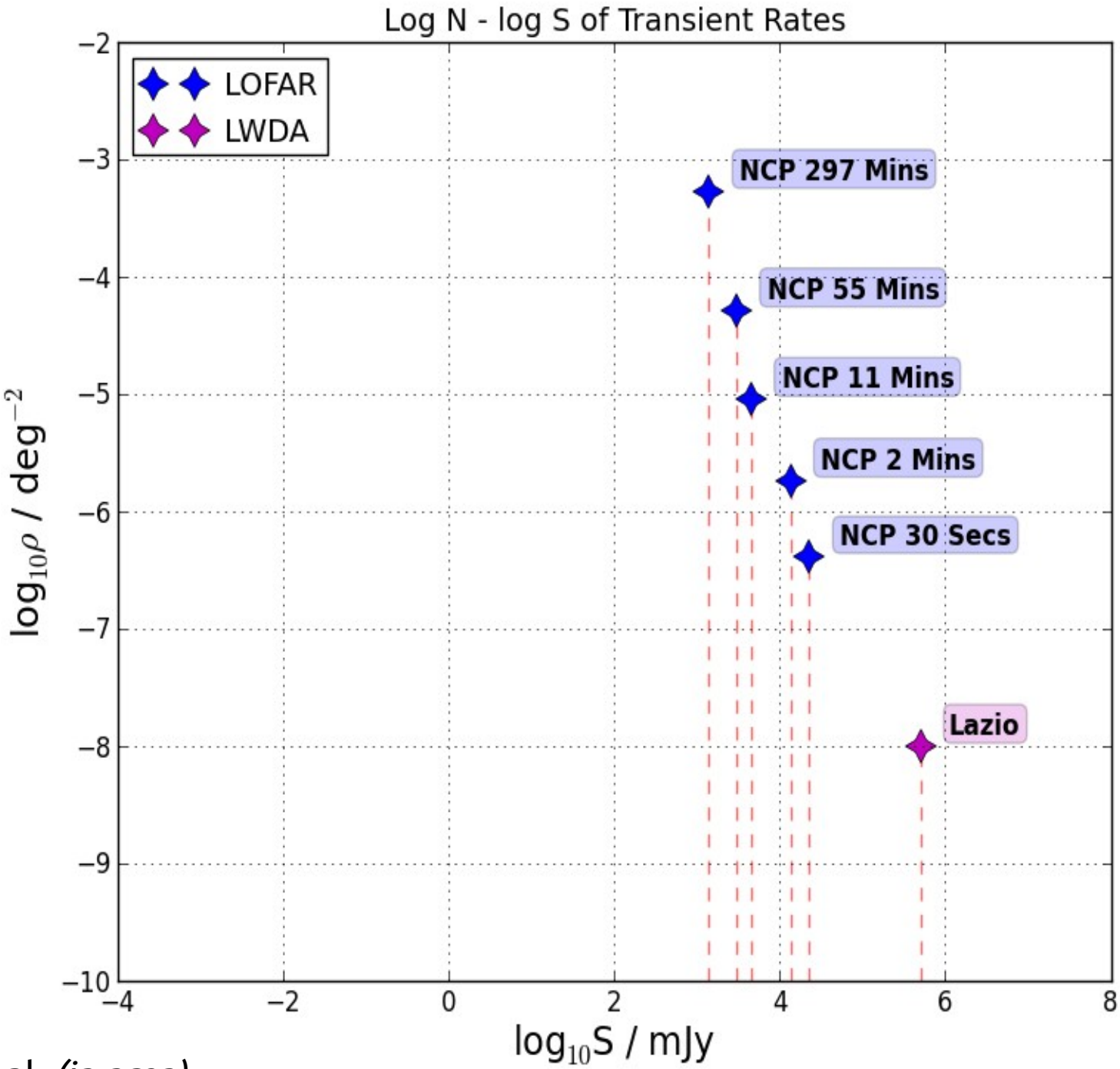
FRBs: could be a lot, depends on spectrum and scattering



Results from LOFAR search for transients in NCP MSSS observations at 60 MHz

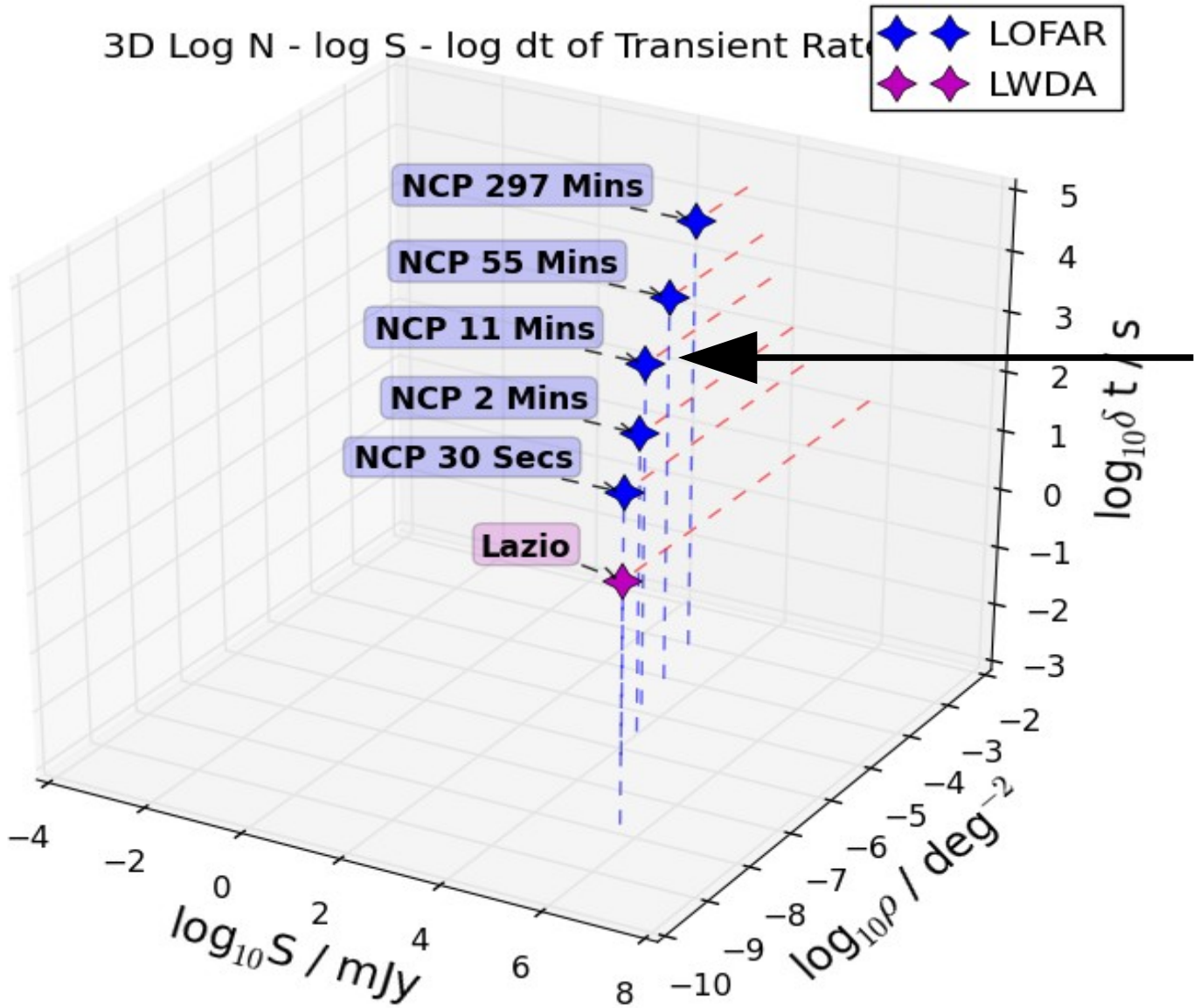
Stewart et al. *(in prep)*

Low Frequency Transient Lim



Stewart et al. *(in prep)*

ansient Limits



Detection not limit (maybe)

→ one transient per 1000 deg^2 at a r.m.s. of 100 mJy

→ 0.1-10 per day with SKA$_1$-Low

Stewart et al. *(in prep)*

Predicted rates: MHz

Assuming commensal searches, otherwise order of magnitude smaller

Minimum **1** *interesting new transient* image-plane per day, could be considerably higher

Only really tested to ~ 100 mJy sensitivity
Better LOFAR data will test to ~1 mJy

FRB rate should be > 1 day^{-1} (caveat spectrum)

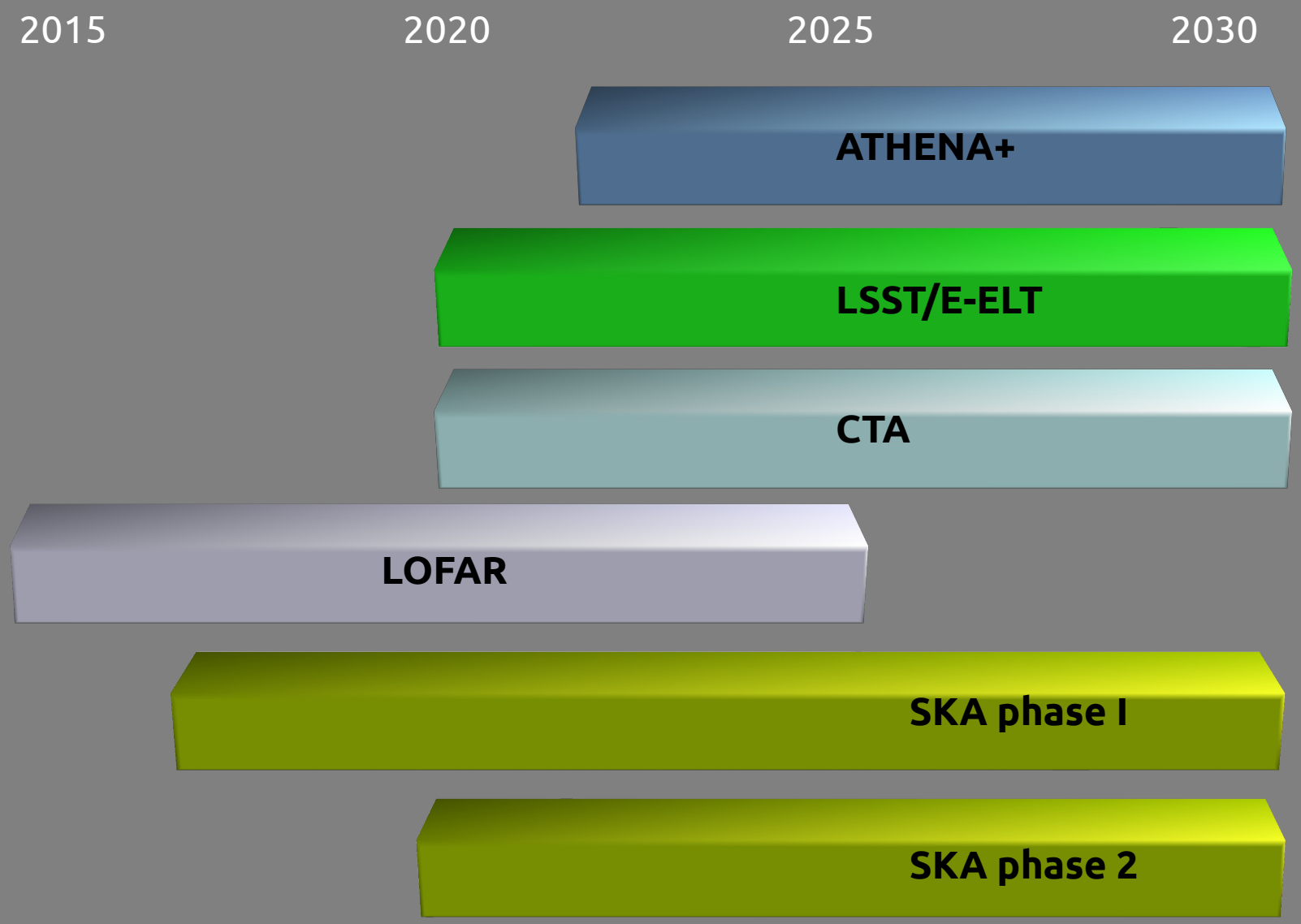
Multiwavelength

Don't forget to consider the environment SKA will be operating in

LSST → 10^6 transients/night
ATHENA+ → transients
LIGO → transients?
CTA* → transients

(* CTA is being designed for very rapid slew response to external alerts, despite there being far fewer UHE transients than radio transients!)

Synergies with other major facilities



NASA / LIGO / LSST / CTA / ++ all strongly support the push for commensal transient searches with SKA and confirm their communities would make use of them

LSU

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Gabriela González, Professor
Department of Physics and Astronomy
gonzalez@lsu.edu

Baton Rouge, January 18, 2014

Dear Professor Fender, Professor Braun,

I am the spokesperson of the LIGO Scientific Collaboration (www.ligo.org), a large international group of scientists dedicated to the search for gravitational waves with the LIGO interferometric detectors at Hanford, Washington and Livingston, Louisiana in the United States (www.ligo.caltech.edu).

The gravitational waves we will be detecting for the first time in the few years after we begin operating will originate in strong astrophysical events that are very likely to have counterparts in the electromagnetic spectrum, and we are fostering collaborations so we can chare transients in very short time scales, to enable follow up of all interesting events – see our latest call for collaborations in http://www.ligo.org/science/GWEMalerts.php.

For that reason, our community strongly support the inclusion of near-real-time commensal searches for all three components of the SKA. We are aware that the current SKA phase 1 baseline design does not have a concrete commitment to such a provision, but wish to urge the SKA Project Office to reconsider this. Adding a commensal transient search capability to all SKA phase 1 components would increase the rate of radio transient detection by the SKA an order of magnitude.

The LSC would very much like to establish a collaboration with SKA for the prompt follow up in radio of gravitational wave transients. We note that the Transients SWG are committed to transient detections being broadcast immediately to the worldwide astronomical community, providing a fantastic resource for multiwavelength and multimessenger studies of extreme phenomena. This is something we, and our community, would most certainly take advantage of.

Sincerely,

Gabriela González
Professor of Physics and Astronomy, Louisiana State University
Spokesperson, LIGO Scientific Collaboration

National Aeronautics and
Space Administration
Goddard Space Flight Center
Greenbelt, MD 20771

NASA

January 19, 2014

Dear Professor Fender, Professor Braun,

I am writing this representing/on behalf of the NASA Swift project for which I am the Principal Investigator. Our project strongly supports the inclusion of near-real-time commensal searches for all three components of the SKA. We are aware that the current SKA phase 1 baseline design does not have a concrete commitment to such a provision, but wish to urge the SKA Project Office to reconsider this. Our own project works heavily in the area of transients and variables, which have provided many key astrophysical advances and breakthroughs in the past decades (e.g. pulsars, gamma-ray bursts, microquasars, fast radio bursts).

Adding a commensal transient search capability to all SKA phase 1 components would increase the rate of radio transient detection by the SKA an order of magnitude. We note that the Transients SWG are committed to transient detections being broadcast immediately to the worldwide astronomical community, providing a fantastic resource for multiwavelength and multimessenger studies of extreme phenomena. This is something we, and our community, would most certainly take advantage of.

Best Regards,

Neil Gehrels

Chief, Astroparticle Physics Laboratory

Summary

Wide range of science

Potential for the biggest discoveries: maximise your field of view (beams) and time on sky (commensal searches, transient buffer boards)

Desperately needs not to have commensal searches and robotic designed out → headline request from Transients SWG

Design an ambitious 21st century telescope!