The Transient Universe with The Square Kilometre Array

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On behalf of the SKA Transients Science Working Group
Extreme Astrophysics

- Collapsing stars, relativistic remnants
- Extremes of density, pressure, gravitational curvature
- Searchlights shining over cosmological distances – counterparts to LIGO events?
Two flavours of radio transients

Incoherent synchrotron emission
- Relatively slow variability
- Brightness temperature limited
- Associated with all explosive events

Find these (mostly) in images

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

Find these (mostly) in time series

Early branch in classification pipelines
Exploring parameter space (and an interesting trend of brightness temperature with luminosity..)

Cordes et al. …. Pietka, Fender & Keane (in prep)
The SKA Transients
Science Working Group

- **Goal:** optimise SKA for transients and variables
- **Chairs:** Fender and Macquart
- **Core membership:** Trott, Bignall, Stappers, Law, Deller, Chatterjee, Murphy, Corbel, Hessels, Paragi, Karastergiou, Woudt, Rupen
- **Advisors:** Keane, Hallinan, Buitink, Swinbank, Armstrong, van Leeuwen, Miller-Jones, Lazio, Siemion, Kuulkers, Perez-Torres, Morrisson

Open to requests to join from community
First wide-field searches for transients using SKA pathfinders

- First SKA-style wide-field (pseudo-)automatic transient searches have been carried out by LOFAR and MWA

Bell et al. (2014), Stewart et al. (in prep), Broderick et al. (in prep), Fender et al. (in prep)
LOFAR Transient

~10 Jy ~10 minute transient at 60 MHz

Discovered a year 'late' | Doesn't repeat | No optical counterpart

From radio alone could be anything from flare star to scattered FRB

Implies ~100s/day with SKA-Low

→ highlights the need for early discovery and rapid response

(Stewart et al. *in prep*)
Predicted rates for SKA (assuming 100% efficient commensal)

**Tidal Distruption Events**
GHz (MID & SURVEY): ~1 / week

**Fast Radio Bursts**
GHz (MID & SURVEY: ~ 1 / day)
MHz (LOW): lots?? none??

**Low frequency**
“Stewart” transients
MHz (LOW): 100s/day?
Top two recommendations from the Transients SWG for the SKA1 design:

- Commensal Transient Searches
- Rapid (robotic) Response to Triggers
Commensal Transient Searches

- Single highest priority for Transients
- Increases rate of events by at least one order of magnitude
- Cost to implement much less than scale of re-/de-scopes being currently considered (30%)
- Not implementing is more damaging than scrapping an entire SKA1 component
- Politics are surmountable
MeerKAT commensal system design

Armstrong et al. (in prep)
REAL TIME SYSTEM

POST-OBSERVATION (slower, deeper)

All daytime observations will have simultaneous optical images from MeerLICHT
In an ideal world...

Telescope monitors sky...
Software finds new transient source!

Interesting?
Appropriate follow-up?

Analyse / re-evaluate / feedback (IA)

radio
X-ray
Robo-AMI: the world's first robotic radio telescope

Timescale from *Swift* detection of first photon to observing command sent to follow-up telescope: **30s**

**AMI** on-target typically **4min**

Staley et al. (2013)  
Anderson et al. (2014)
Robotically following every *Swift* trigger delivers surprises and discoveries (as well as GRBs..)

Gamma-ray flare from DG Cvn – nearby (8pc) extremely young (30 My) dM43e+dM4e binary. Huge energy release associated with magnetic activity.

**First time** a radio flare has been associated with such a superflare

A robotic SKA transient mode would deliver breakthrough science
Transients supports SKA$_1$ VLBI and higher frequencies

SKA1-VLBI important for localisation and – for nearby sources – spatially resolving structure

Higher frequencies (at least to 5 GHz) give better localisation as well as earlier and more peaked light curves
The SKA will find many radio variables and transients, which will lead us to the sites of the most extreme astrophysics in the universe.

Such events lead to new physics, a better understanding of feedback over cosmic time, and can act as searchlights over cosmological distances.

The current design provides the collecting area and frequency coverage (at least by SKA$_2$) to revolutionise this area.
However, the scientific yield for transients and variables could be increased by an order of magnitude or more by including commensal and (robotic) rapid-response modes.

Implementation of these modes would demonstrate a commitment to flexibility, would be a very minor cost change compared to those currently being discussed, and should be incorporated into the revised design ASAP or we risk losing >90% of this science.