Incoherent transient radio emission from stellar-mass compact objects

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on behalf of

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for the SKA transients WG
Synchrotron transients

Primarily explosive events or outflows

Known source classes:
- **X-ray Binaries (BH, NS, WD)**
- **Ultra Luminous X-ray sources (ULX)**
- **Isolated black holes and IMBH**
- Magnetar outbursts, gamma-ray binaries
- **Supernovae (SNe)** ⇒ Perez-Torres, Wang
- Active Galactic Nuclei (AGN) ⇒ Croft
- Tidal disruption events (TDEs) ⇒ Donnarumma
- Gamma-ray bursts (GRBs) ⇒ Burlon
- Some **nova**e (usually thermal) ⇒ Rupen

See also talk by W. Yu
Motivations

Accretion: the most powerful source of energy in the Universe!

Whenever you have accretion, you always see ejection (or disk wind)!!

Nature of the existing fundamental coupling? Is it universal along the mass scale? How does it depend on the nature of the compact object?

Synchrotron flares from stellar mass compact objects: a unique laboratory with associated variabilities accessible with our lifetime.

Astrophysics in extreme environments: density, temperature, gravity, velocity, ...!

Jets: Composition? Formation? Energetics? Feedback on their environment?

Existence of intermediate mass black holes? Seeds of supermassive BHs? EOR?
Similar physics across the entire mass scale?

Despite very different classes of objects, they will share similar requirements in term of SKA specificities.
Incoherent synchrotron processes

Shock-accelerated electrons and magnetic fields

Important frequency evolution. Become optically thin later at lower frequencies (+lower flux also).
**Accreting black holes**

Do quiescent BHs host radio jets?

What fraction of the liberated accretion power do they carry away?

Accretion/ejection coupling and the broad-band emission?

Nature of very faint outbursts ($<10^{35}$ erg s$^{-1}$)?

**SKA** will probe a significant fraction of whole outburst duration for almost all BHs in our Galaxy.

All flaring transient BHs accessible in the local Universe (possibly also up to Virgo @ 15 Mpc).

See also talk by W. Yu

Corbel et al. 2013
Connexion with NS and WD?

**NSs and WDs:** Is the *accretion-ejection coupling* universal?

How does it depend on depth of potential well, the presence of an event horizon, a stellar surface, a boundary layer, B field?

Measurements of **jet kinematics:** pattern speed = bulk motion?

Jets in NS dominated by Poynting flux?

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**AQL X-1**

**Miller-Jones et al. 2010**

**Koerding et al. 2008**
Novae

Thermonuclear runaway on WD surf.
Possible progenitor of Type 1a SN
Collimated bipolar outflows in RS Oph, V959 Mon, ... Novae = an heterogeneous pop?

Nature and energetics (mass, KE, geometry) of novae outflow during outburst?
Currently: only detection of novae with significant circumstellar material or those nearby.

Fraction of novae with jets?
→ SKA1-Mid census!
Ultra-luminous X-ray sources

Luminosity $>10^{39}$ to $10^{40}$ erg s$^{-1}$

Are these stellar-mass BHs accreting at/above Eddington?

Probe accretion and ejection at Eddington rates.

Spin measurements?

Feedback effect on surroundings (EoR)?

SKA1-Mid: possibility to study these flaring events up to Virgo

Middleton et al. 2013

A transient ULX in M31
Intermediate mass black holes

Bridging the gap in mass scale?

Is there evidence for massive BHs (HLX-1)?

Fundamental Plane to get BH masses (Merloni et al. 03)

Growth of quasars in early Universe

A flaring IMBH?

Needs sufficiently high resolution

Plotkin et al. 2012

Webb et al. 2012
Isolated nearby black holes

Likely $10^8$ isolated stellar mass BHs in our Galaxy. Accretion from surrounding ISM (Maccarone 2005).

35,000 in a sphere of radius 250 pc around us (Fender et al. 2013)

Identification of small fraction (10s mJy): high proper motions (up to 100 mas/yr)
Black holes in globular clusters

**Globular clusters**: XRBs factories, but BHs ejected?

Not true anymore with possible recent BH detections (Maccarone et al. 07, Strader et al. 12, Chomiuk et al. 13)

Theory: maybe more massive BH?

New accretion laboratories and new constraints on BH formation mechanisms

BHs merger in a cluster? Prospect for GW!

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*SKA1-Mid will significantly increase the current sample*

Fig. by J. Strader
IMBH in globular clusters

Globular clusters have been suggested to host a population of IMBHs.

Radio surveys are more efficient in finding quiescent accreting (IM)BHs.
Resolution important for:

- Probing jets in XRBs, incl. proper motions (origin of jet formation?),
- Identification of multi-wavelength counterparts in crowded regions,
- Reducing confusion (detect a 100 mJy IMBH flare in the central region of a galaxy),
- High precision astrometry: distance, parallaxes → BH spin, XRBs formation, ...

As explosive events, almost all transients will be point-like except at VLBI resolution

Muxlow et al. 2010
SKA Requirements
SKA1-Mid will be the best array for the synchrotron transients.

Highest freq. needed in the initial deployment of SKA1-Mid: B4 (2.8–5.2 GHz) or B5 (4.6–13.8 GHz) instead of B3 (1.7–3.0 GHz). Transients self-absorbed at lower freq.

Good polarisation purity needed.

Simultaneous operation at two ≠ freq. (or sub-arrays) + well sampled light-curves (multi-beaming or sub-arrays) → Key for modeling physical parameters of the synchrotron explosions/flares.

Multi-wavelength coordination is a key addition for synch. transients.

Capability to respond to internal/external triggers on timescales of hours/days is crucial!
Why high frequencies?

Higher frequency capability improves science yield:

- Peak emission is brighter,
- Peak emission appears earlier,
- Allow to probe larger volume of space,
- Self-absorption/absorption in the surroundings has less effect,
- Resolution is higher,
- Extended emission is filtered out better.

VLBI capabilities of the SKA is crucial for imaging, astrometry and reducing confusion in crowded regions (GC, external galaxies, ...
Access to all SKA data for commensal searches:

- SKA can act as an «all-sky» radio monitor,
- Sensitivity and Wide FOV here (esp. SKA1-Low and Sur).

Traditionally, this role was devoted to X-ray ASM:

- X-ray selection bias

Public release of information on transients.

A lot of synergies with planned MW facilities (LSST, SVOM, ...).
Grazie