Census of stellar activity in the Milky Way

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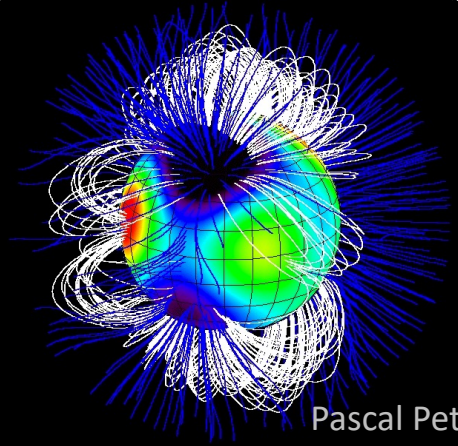
Image credits: P. Petit, NASA/ESA, Forbrich+16

Radio traces stellar atmosphere/ environment & magnetic field

Stellar structure & evolution



Atmospheric structure
Magnetic energy release
Rotation evolution

Impact on environment

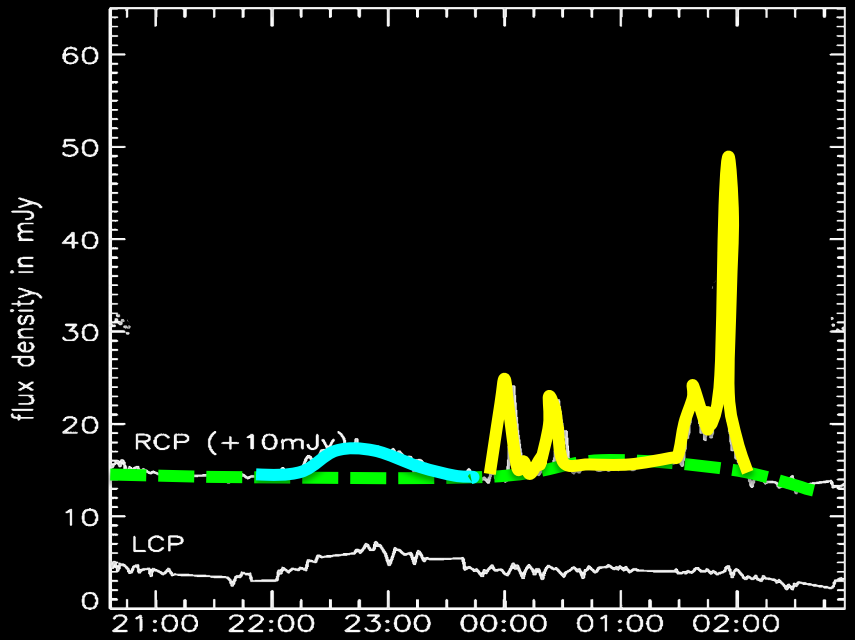
Space weather – impact on planets

- Particle acceleration
- Eruptions
- Stellar winds
- Star-planet interaction

DSA-2000 will detect quiescent & transient stellar emission

Quiescent emission

- Discover new types of radio stars
- Statistical studies of stellar radio activity
- Stellar mass loss



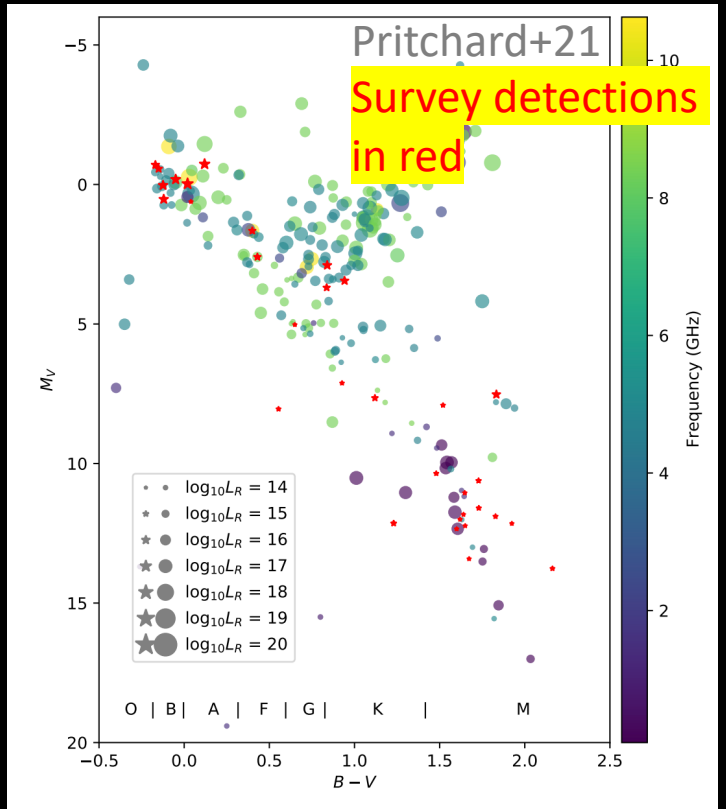
Benz+98: 8 GHz light curve of M dwarf

Transient emission

- Weird events (flares & space weather)
- Targets for follow-up (star-planet interaction)

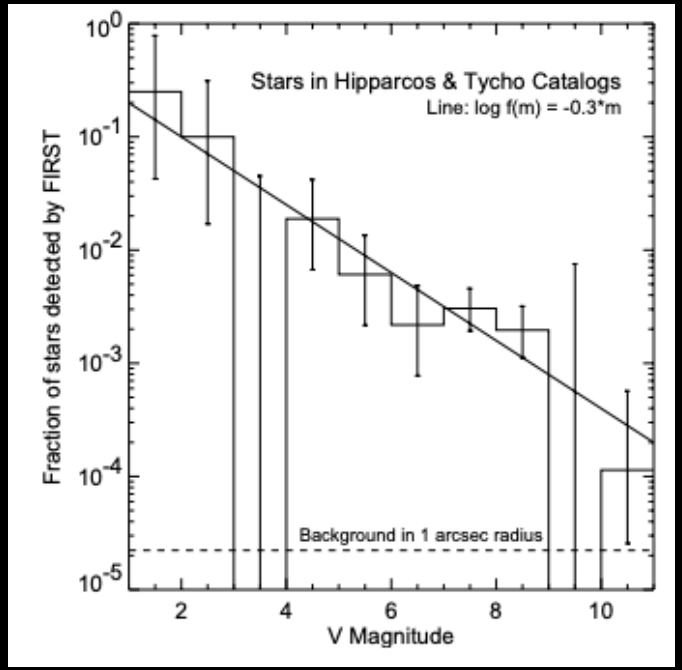
Quiescent: DSA-2000 will massively expand the number of radio-detected stars

- ASKAP all-sky survey (RACS) - 0.7-1 GHz, RMS of 250 uJy – selected >6% circ. pol. stars (need Stokes I & V)
- Detected 33 stars (23 previously not known as radio stars)
  - Half M/K dwarfs, half binaries or magnetic massive stars
- DSA 0.5 uJy probes ~20x farther → 20,000 – 400,000 stars ($N \sim d^2 - d^3$)
  - Compare to a few hundred known so far



Quiescent: DSA-2000 will massively expand the number of radio-detected stars

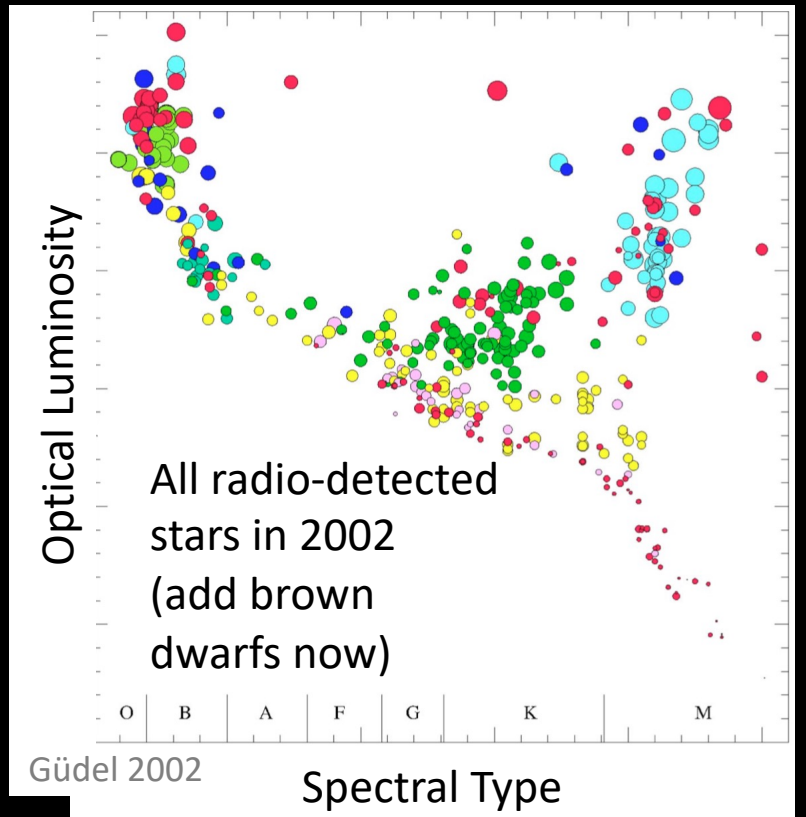
- VLA FIRST survey (5000 deg^2, 0.7 mJy flux density limit, 1.4 GHz) – Stokes I
- 26 stellar radio sources (~1/2 magnetic binaries, other assorted)
  - Few M dwarfs – due to mag limit on optical matching?
- Scale to DSA-2000 (3 uJy limit, 30000 deg^2?) → >=1400-20000x more sources → 40,000-600,000 stars



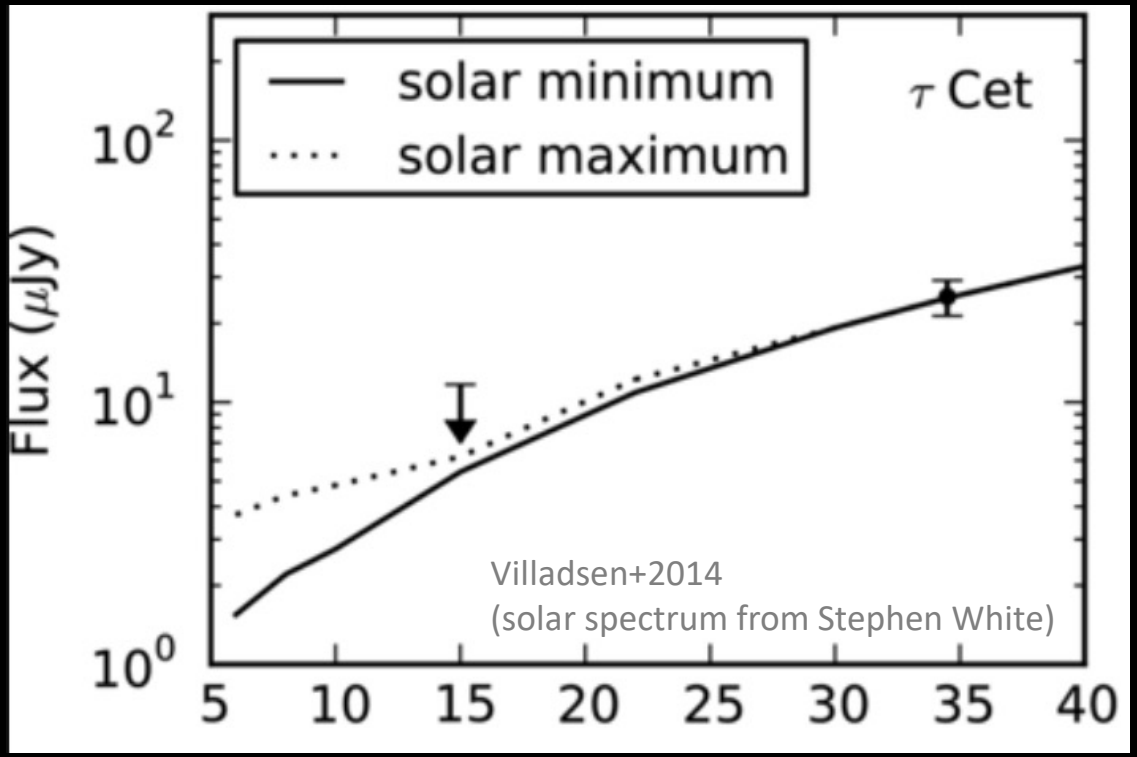
Helfand+99

Quiescent: DSA-2000 will detect new classes of radio stars

- Radio stars so far are extreme compared to Sun:
  - Extreme magnetic activity
  - Massive star winds
  - Giant star photospheres
- Solar twins are not detected at GHz freqs



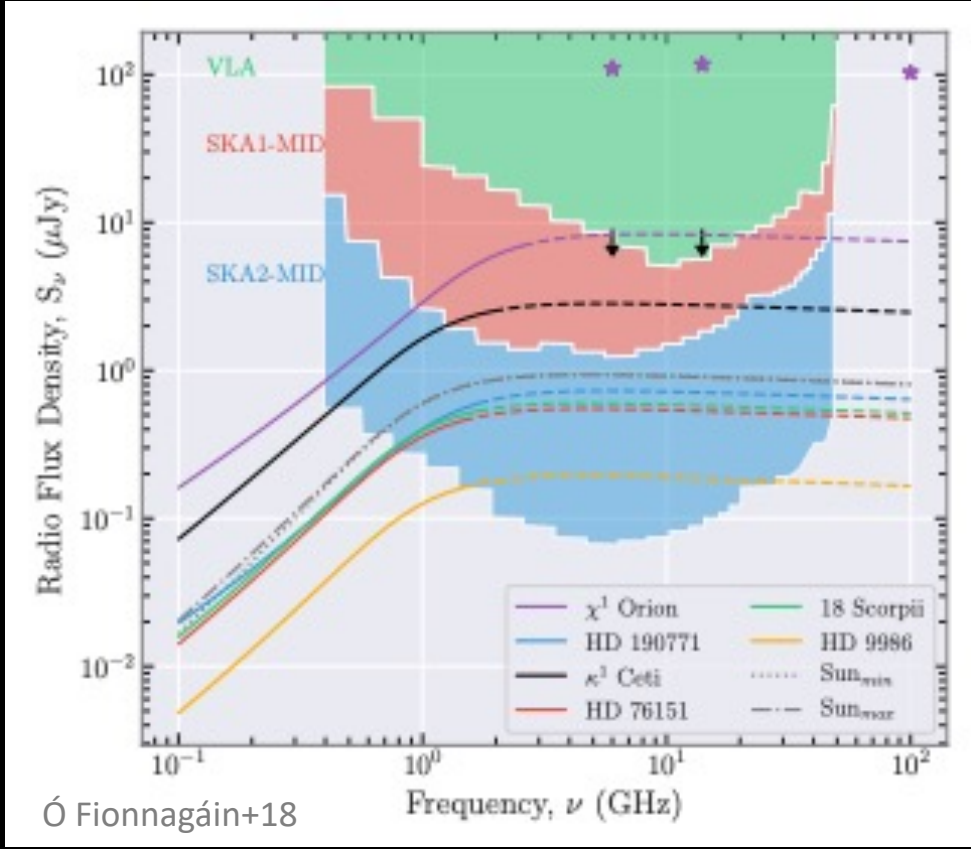
Quiescent: DSA-2000 will detect the nearest Sun-like stars



Sun at a few pc:

- Flux at uJy level
- 0.7-2 GHz flux comes from corona above sunspots, traces magnetic activity cycle

Quiescent: DSA-2000 will constrain stellar winds



Ó Fionnagáin+18

A couple nearby young Suns would have detectable winds (modeled at left), and more active/dense winds will be detectable

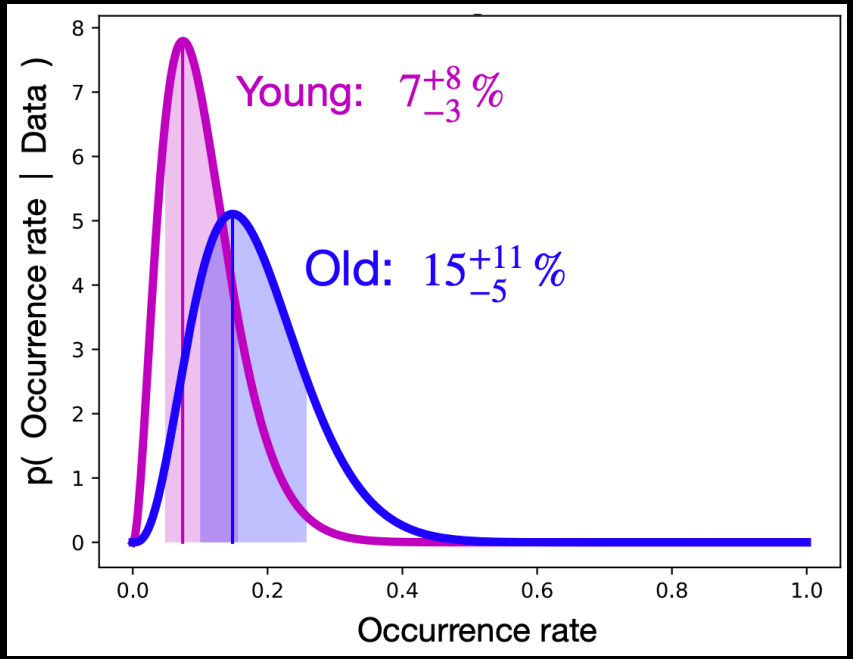
Massive winds: optically thick surface high → measure mass loss rate

Weak winds: upper limit

Quiescent: DSA-2000 will enable statistical studies to determine causes of (sub)stellar radio emission

Many low-mass stars and brown dwarfs are currently detected by targeted observations (a few in surveys)

Only the most active objects are radio-detected (a small sample), limiting statistical studies



Kao & Shkolnik in prep

Example: Age does not affect occurrence rate of quiescent radio in brown dwarfs (surprising! but need to narrow the confidence intervals by deeper flux-limited survey)

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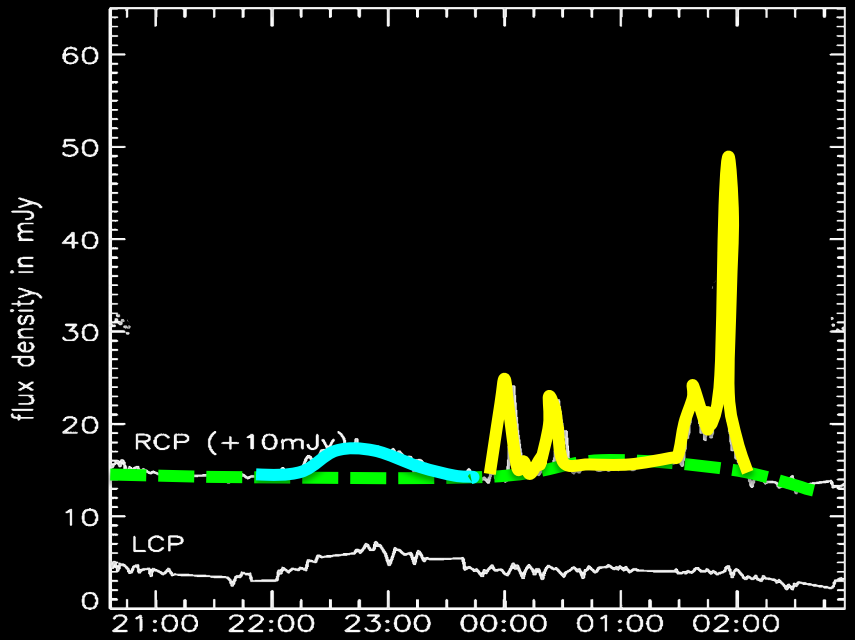


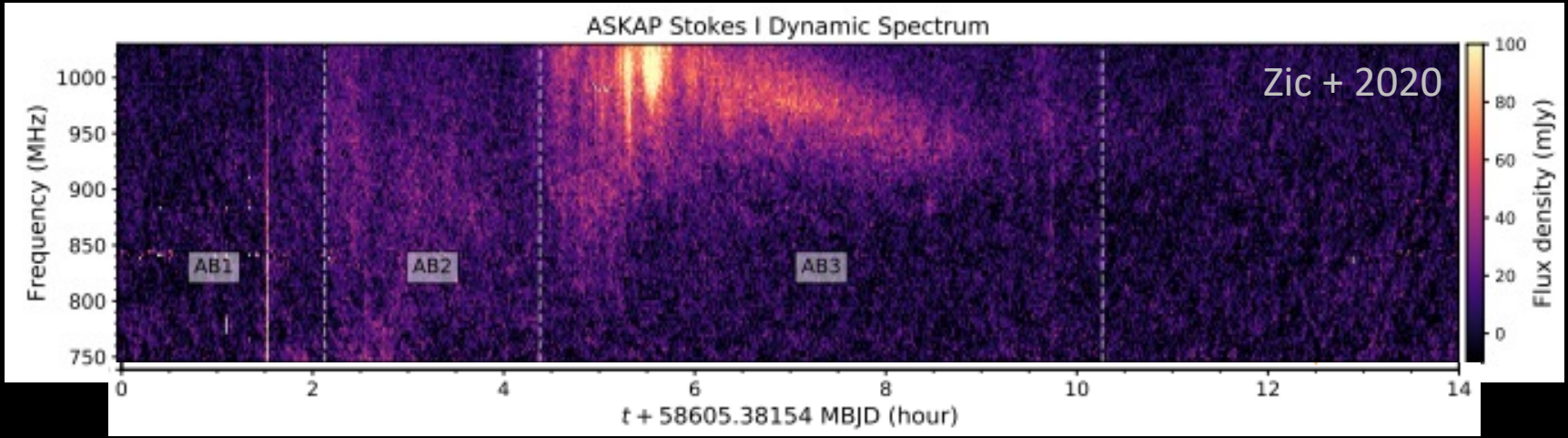
Benz+98: 8 GHz light curve of M dwarf

Transient emission

- Weird events (flares & space weather)
- Targets for follow-up (star-planet interaction)

Transient: DSA-2000 will detect novel/interesting stellar transients

Example 1: Solar Type IV-like **coherent** burst on Proxima Cen (CME-associated?)

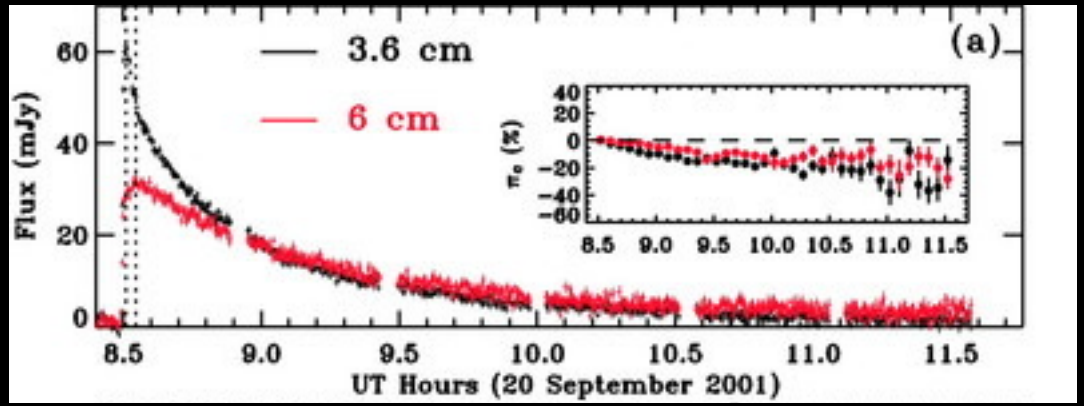


Time resolution (→ Tb), polarization → identify emission mechanism (coherent)

Structure in time-frequency plane → infer cause (coronal structure rearranging post eruption)

Transient: DSA-2000 will detect novel/interesting stellar transients

Example 2: Massive **incoherent** stellar flare on active M dwarf EV Lac



Osten+2005

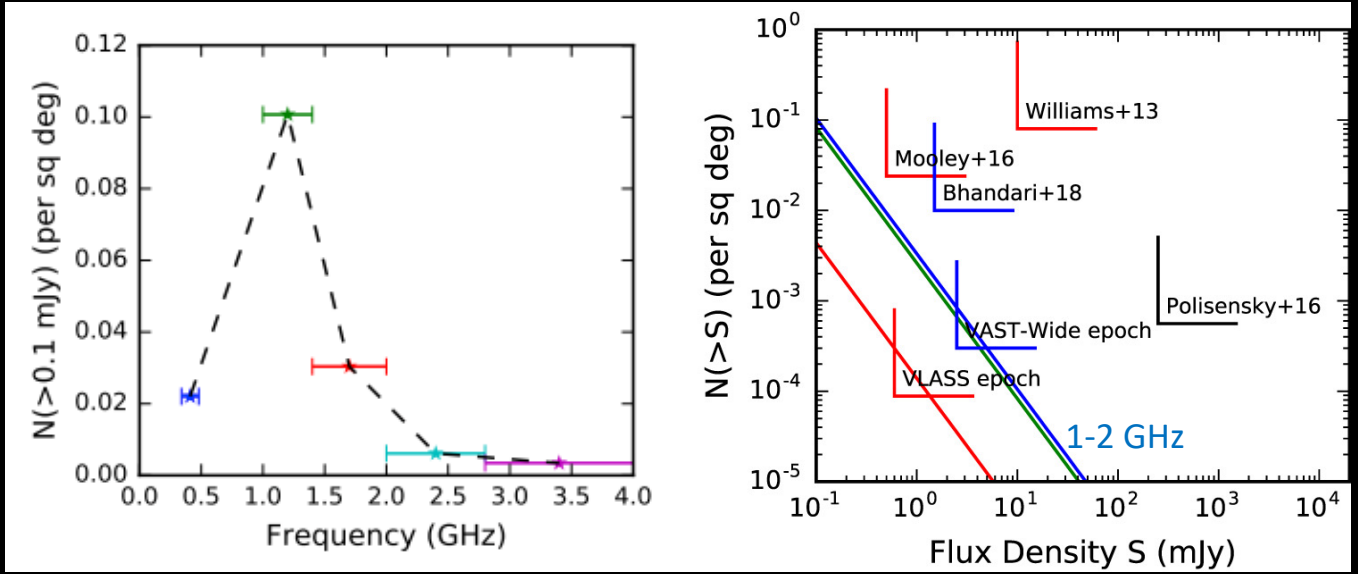
Incoherent radio flares: gyrosynchrotron (mildly relativistic) from accelerated e-'s → indicates huge amounts of particle acceleration in corona

DSN-2000 survey may not catch full flare, but still exciting to catch megaflares!

Will find high-luminosity flares on more distant stars

Any DSN fields with simultaneous obs at other wavelengths?

Transient: DSA-2000 will detect large numbers of M dwarfs emitting coherent bursts



Villadsen & Hallinan 2019

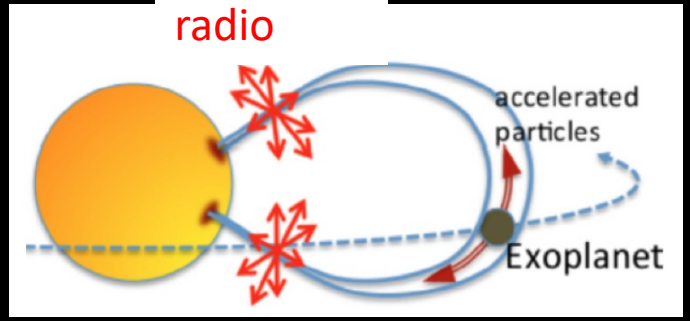
Highly active M dwarfs emit luminous coherent bursts ~1/4 of time at 1-2 GHz

Predict ~3 /deg^2 at flux of 10 uJy (1 epoch of survey)

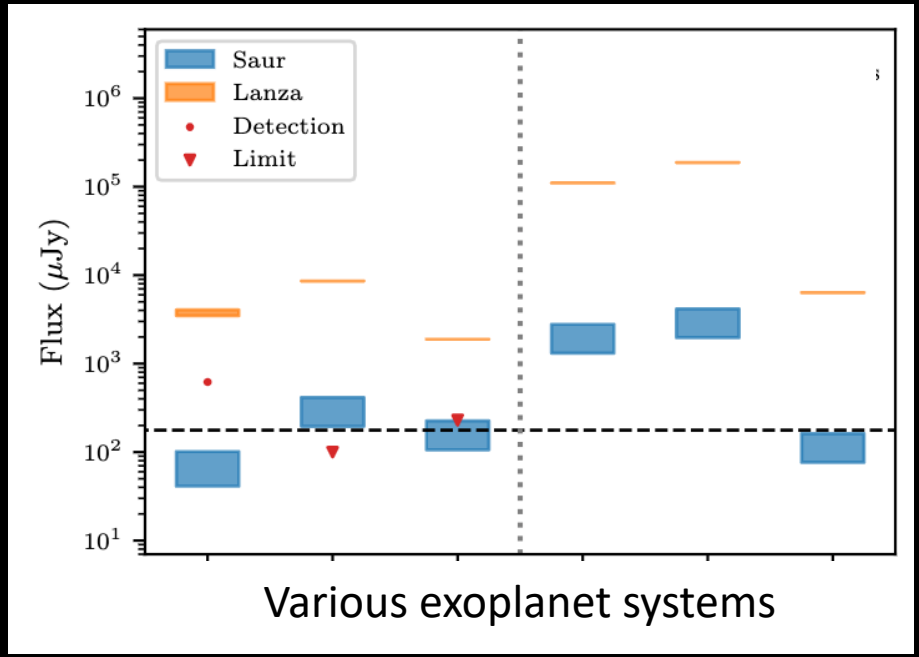
→ ~60,000 bursting M dwarfs in one epoch?

Transient: DSA-2000 will identify candidate star-planet interaction systems for follow-up

Coherent radio (100% elliptical pol)

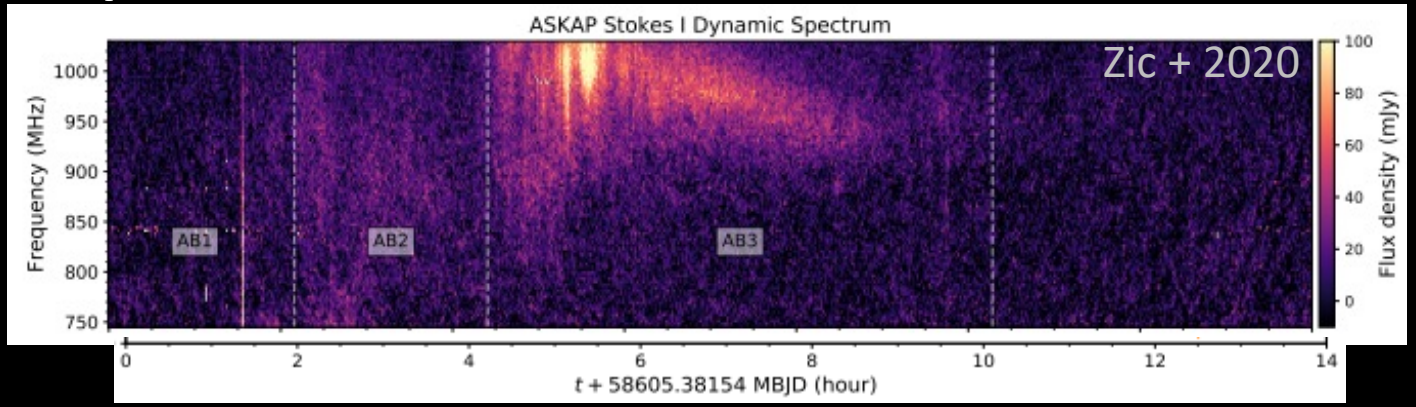


Model of Jupiter-Io system (blue) predicts close-in exoplanets should induce detectable coherent radio emission from star (no radio-detected systems have confirmed orbital modulation yet) → <u>measure planet B field</u>



Pineda & Villadsen, in prep

Stellar science needs: continuum, full polarization, time resolution



Continuum:

- 16 MHz channels good for most
- 1.3 MHz chans for studying “weird events”

Full polarization:

- Stokes I & V most essential, Q & U also valuable

→ Identify emission process

Time resolution:

- Transient events: light curve, dynamic spectrum
- ~1 s resolution good, ms can help

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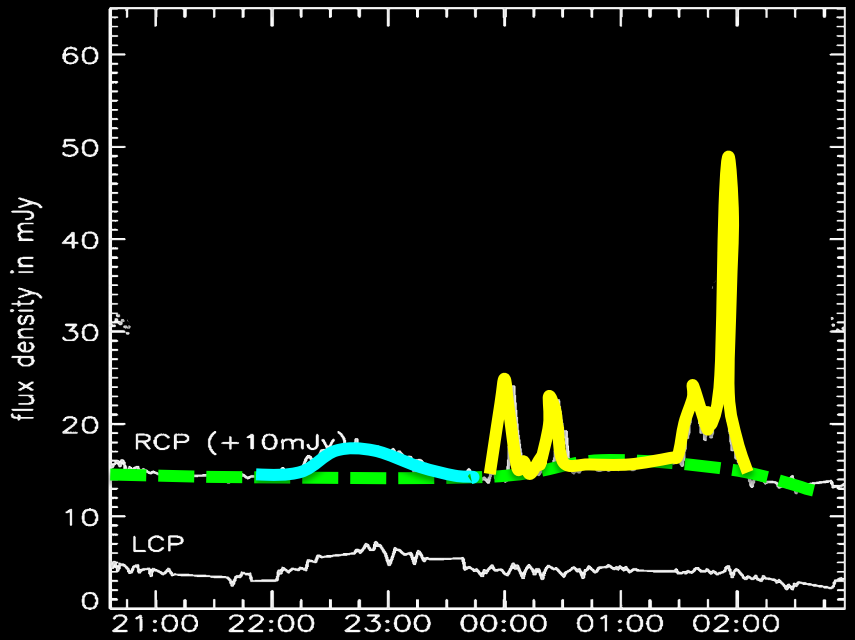

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