The Power of RMS Observations for Answering Fundamental Stellar Questions

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An attempt to cover 4 decades of wavelength in (<)20 minutes. . ..

- focus on two key decadal survey questions:
  - how do rotation and magnetic fields affect stars?
  - (planetary habitability)
  - time-domain astronomy
- key techniques/advances:
  - wide bandwidths: drifting radio bursts
  - time variability
  - sensitivity improvements

cool half of HR diagram at radio wavelengths dominated by nonthermal processes

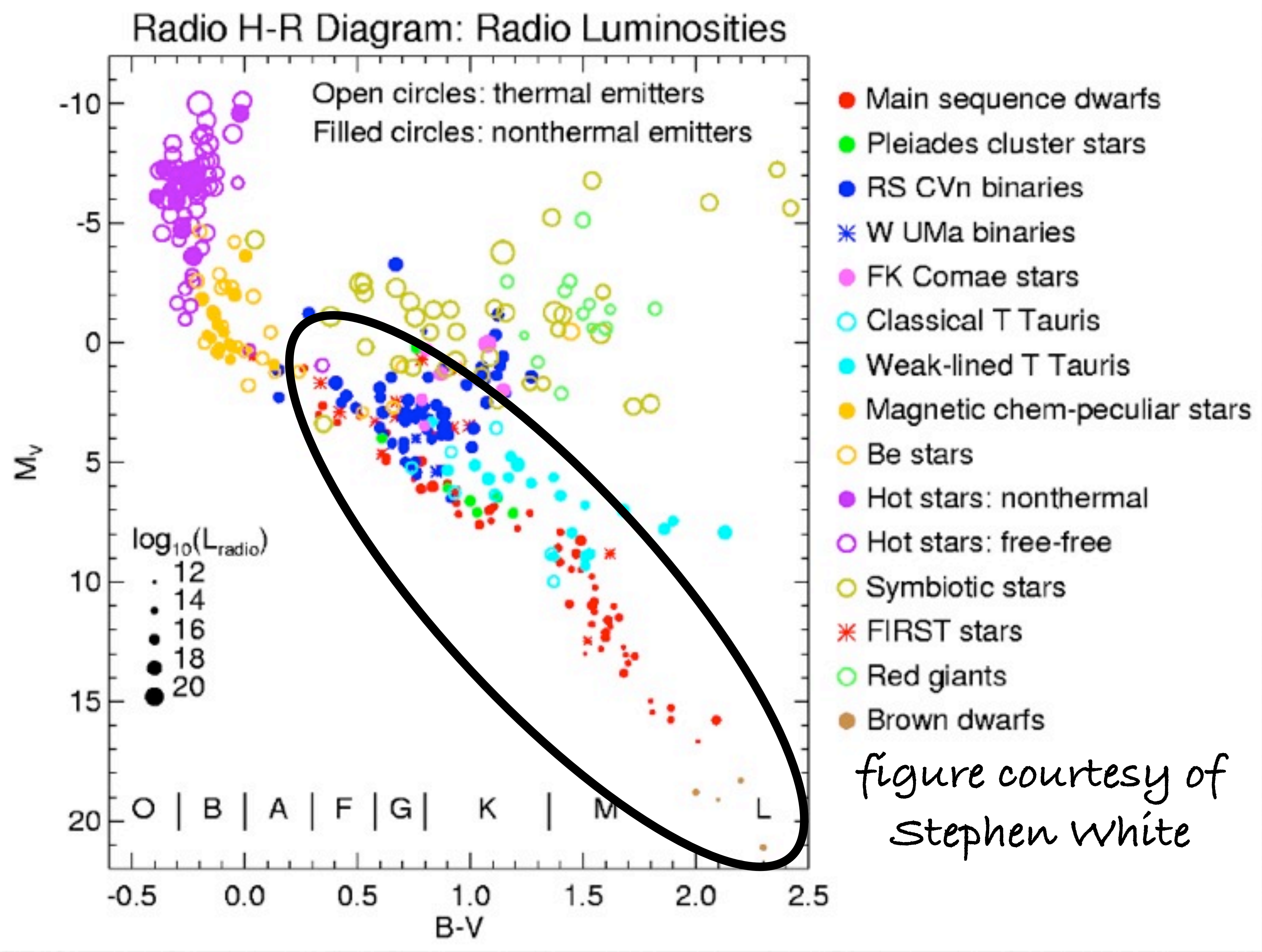
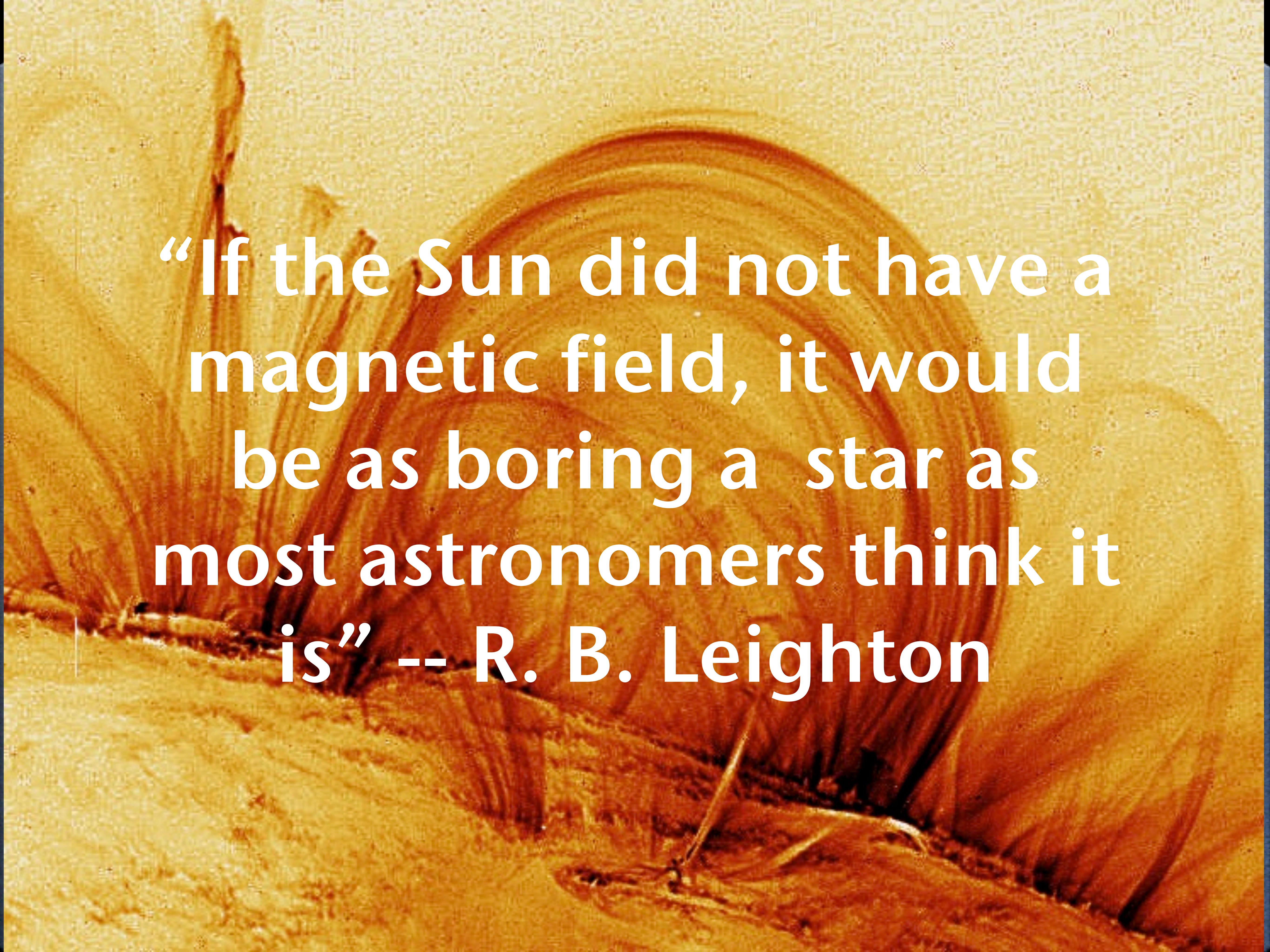


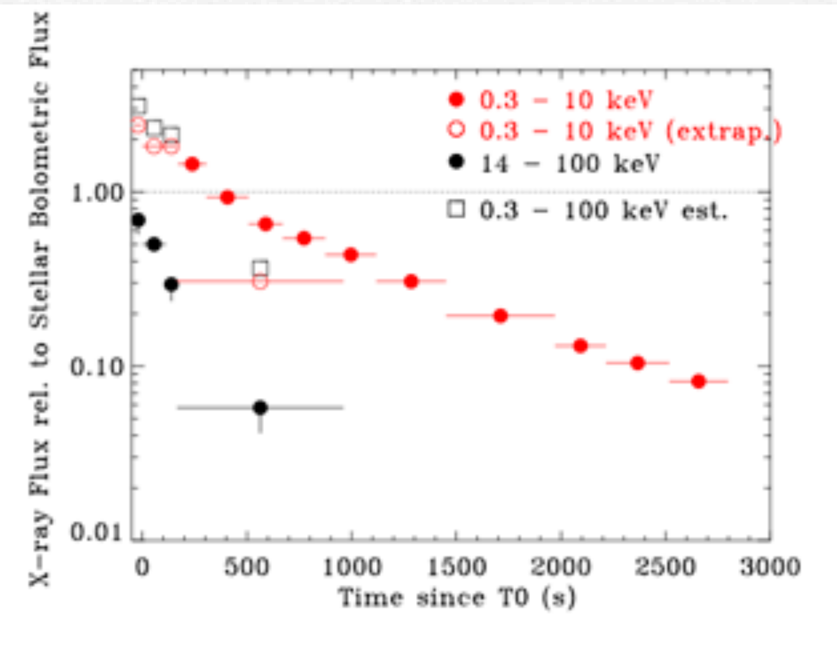
figure courtesy of Stephen White


"If the Sun did not have a magnetic field, it would be as boring a star as most astronomers think it is" -- R. B. Leighton

Observations of particle acceleration in stellar coronae constrain the importance of rotation and magnetic fields

- coherent and incoherent processes at work
  - plasma emission: $\nu_p \propto \sqrt{n_e}$
  - cyclotron maser emission: $\nu_B \propto B$
  - gyrosynchrotron emission: $s\nu_B$, s 10-100
  - synchrotron emission: s large

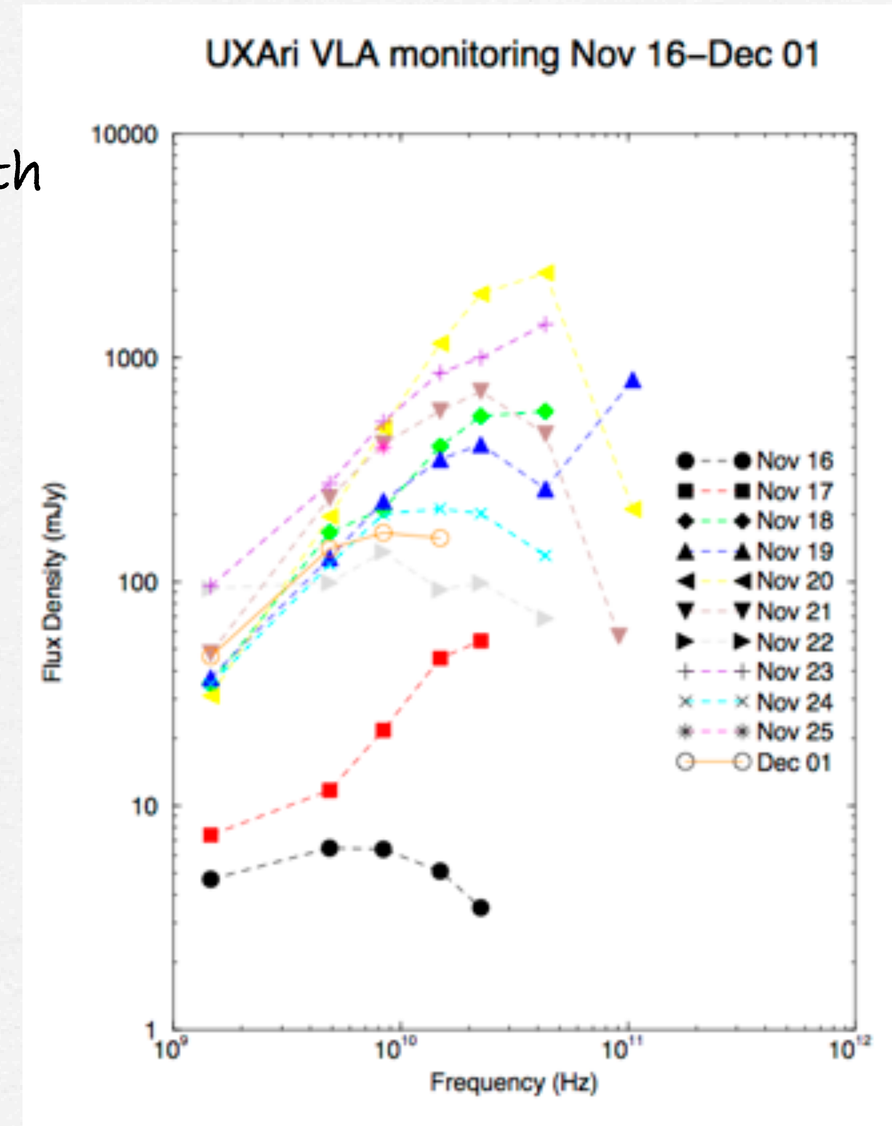
Stellar Radio Transients



Osten et al. 2010, "GRB" on a flare star at 5 pc

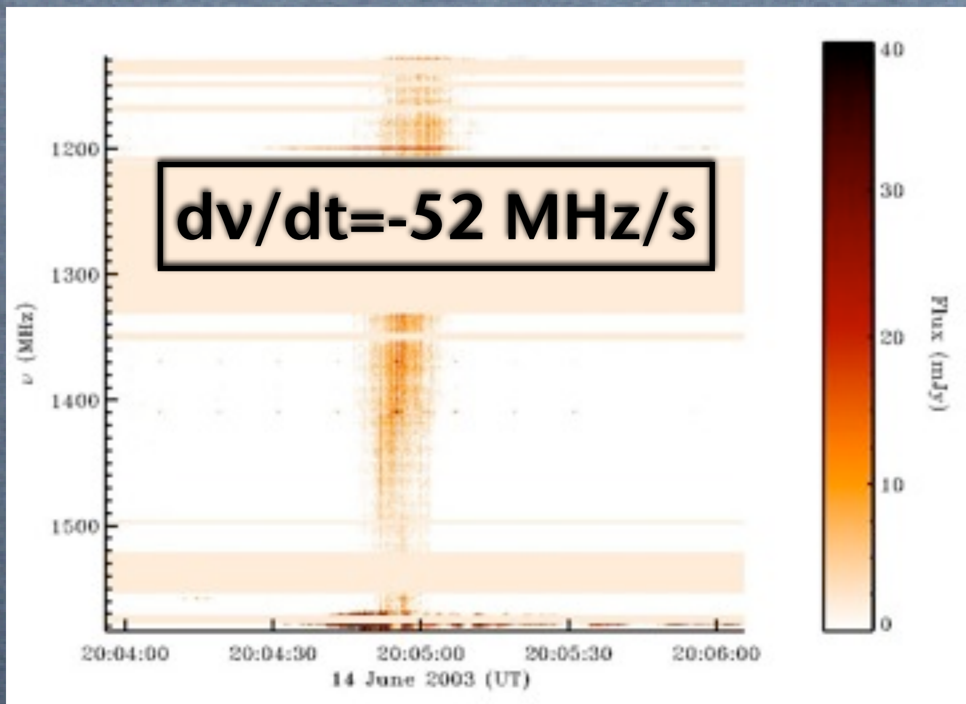
What is the radio equivalent of this?

- gyrosynchrotron emission associated with X-ray flares
- Swift triggers on hard X-ray emission from transient sources with quick reaction times
- need commensurate radio transient capability
- impact on habitability



Bastian & Beasley 1998

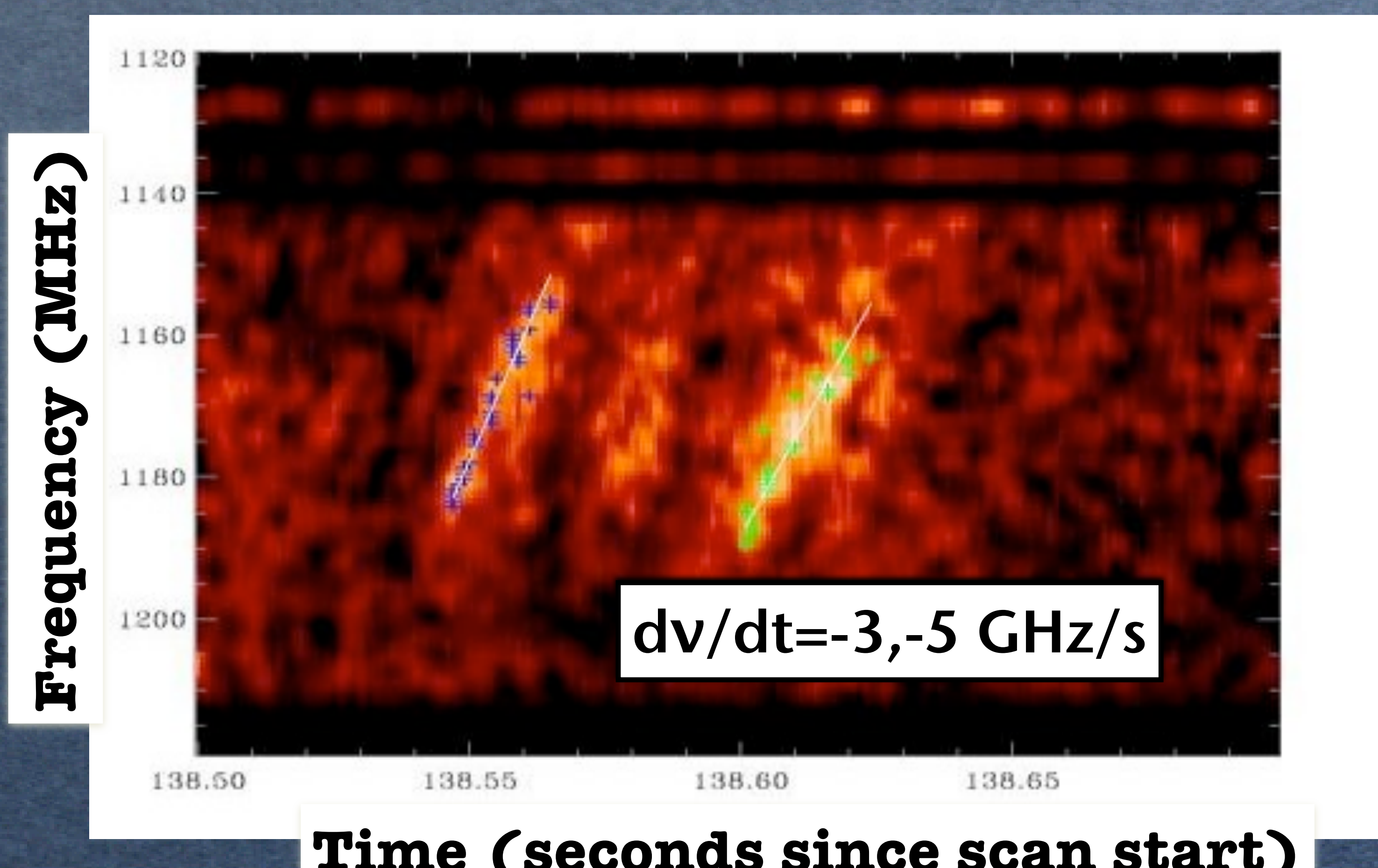
drifting radio bursts



Osten & Bastian 2006

key measurable quantities:

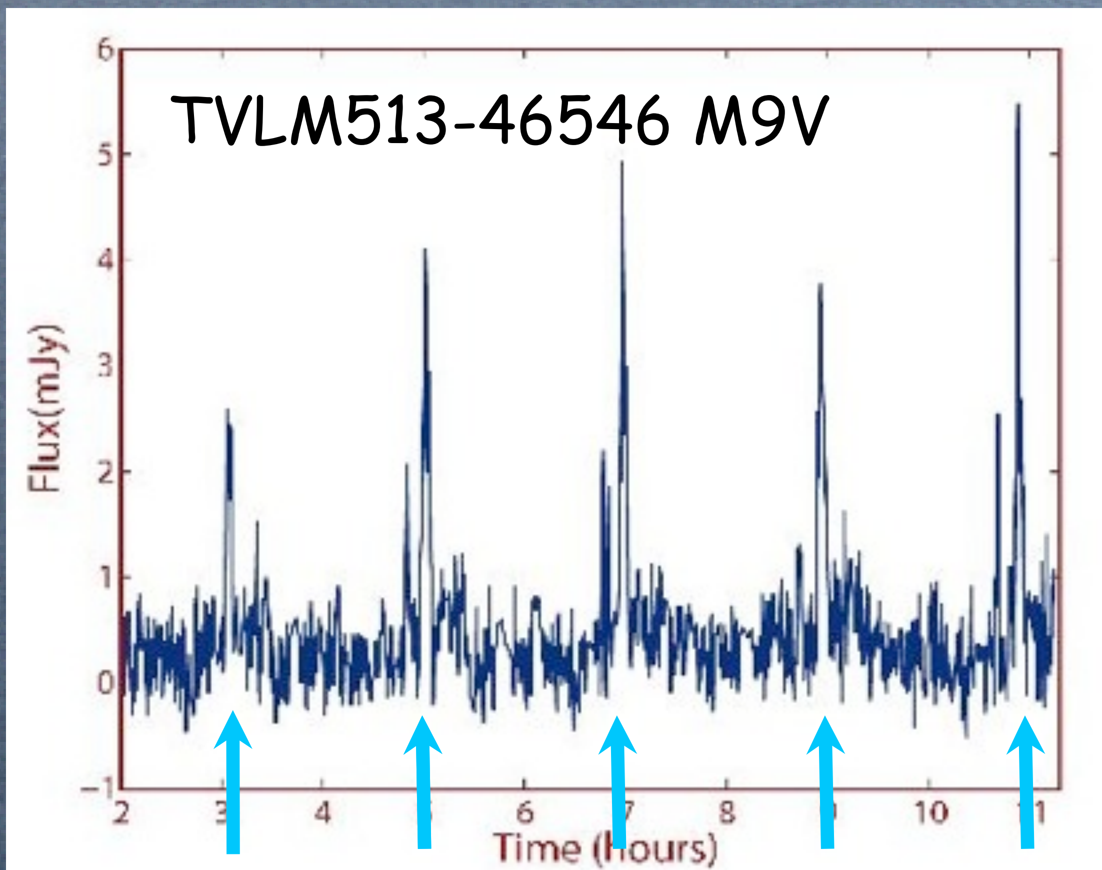
- durations
- bandwidths
- drift rates



use these quantities to infer physical conditions in source, emission mechanism (exciter speed, mag. field gradients)

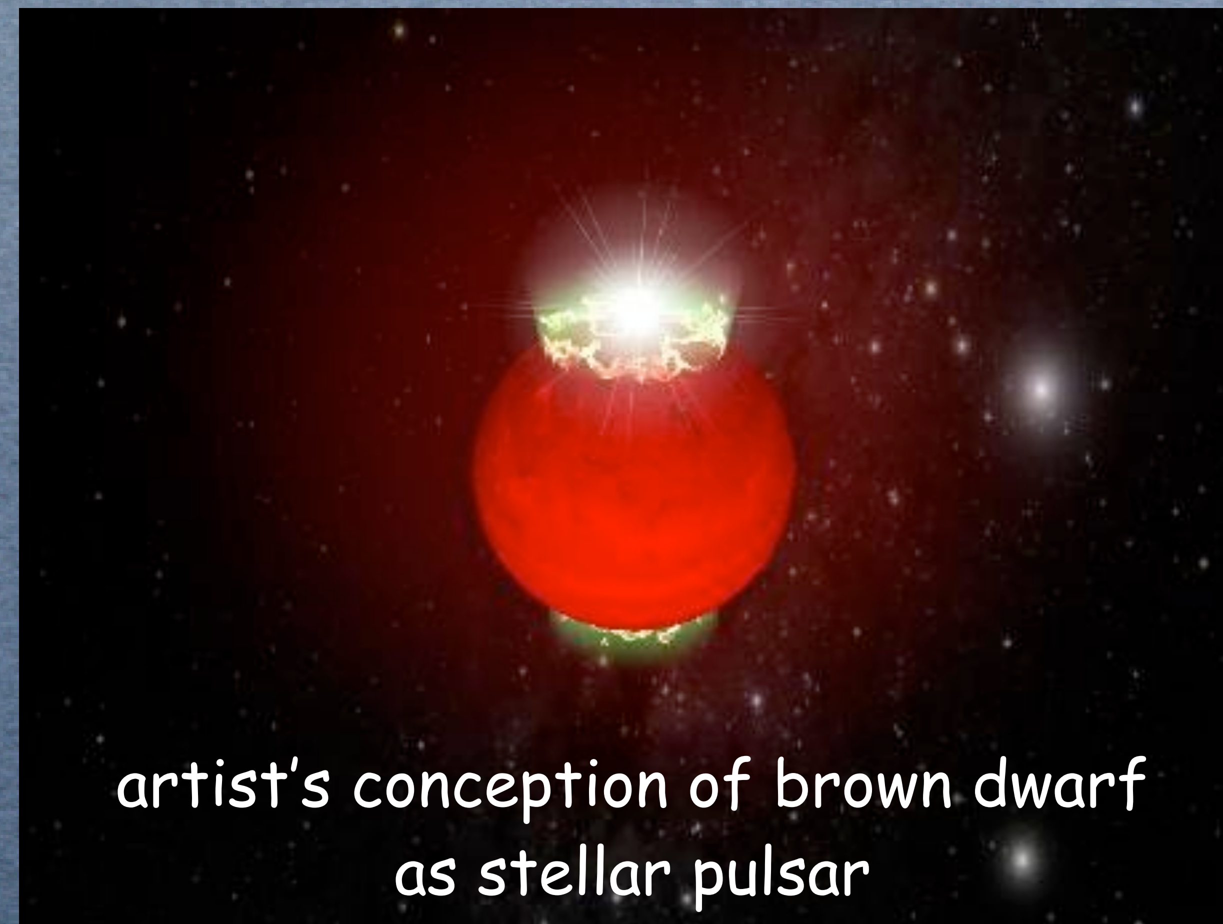
Osten & Bastian 2008

Magnetic structures are seen on substellar objects -- ultracool dwarfs (UCDs)



$0.1\ M_{sun}$, $0.1\ R_{sun}$ star with $P_{rot} \sim 2$ hours, showing pulsating radio bursts

Hallinan et al. 2007

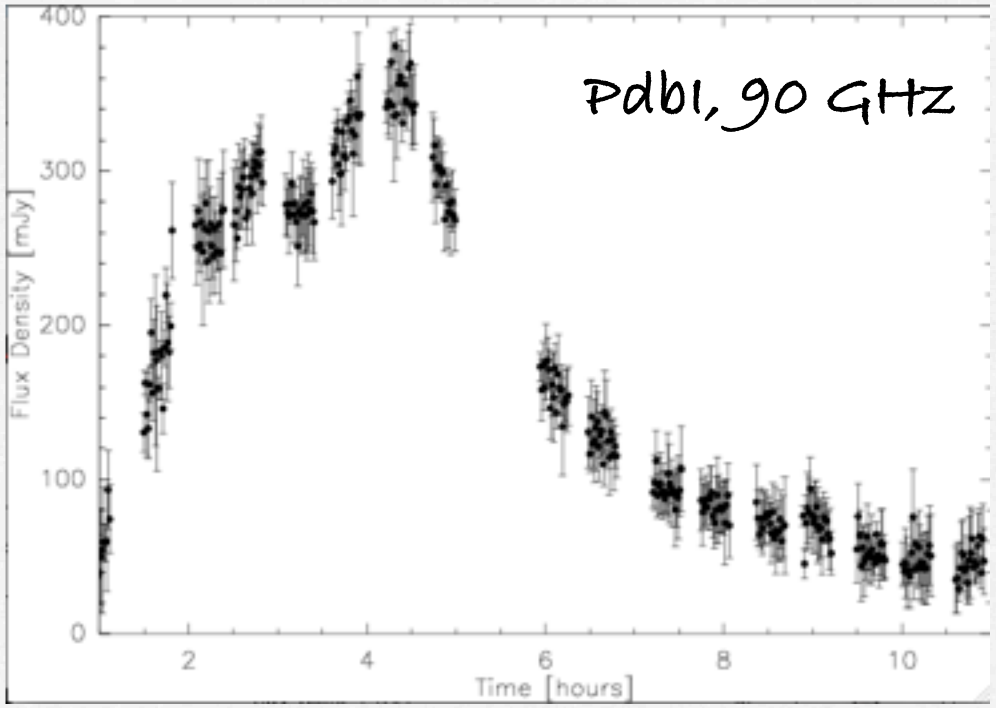


magnetic field of strength 3 kG produces maser emission at 8.4 GHz = 3.6 cm

brown dwarf is behaving more like a planet than a star

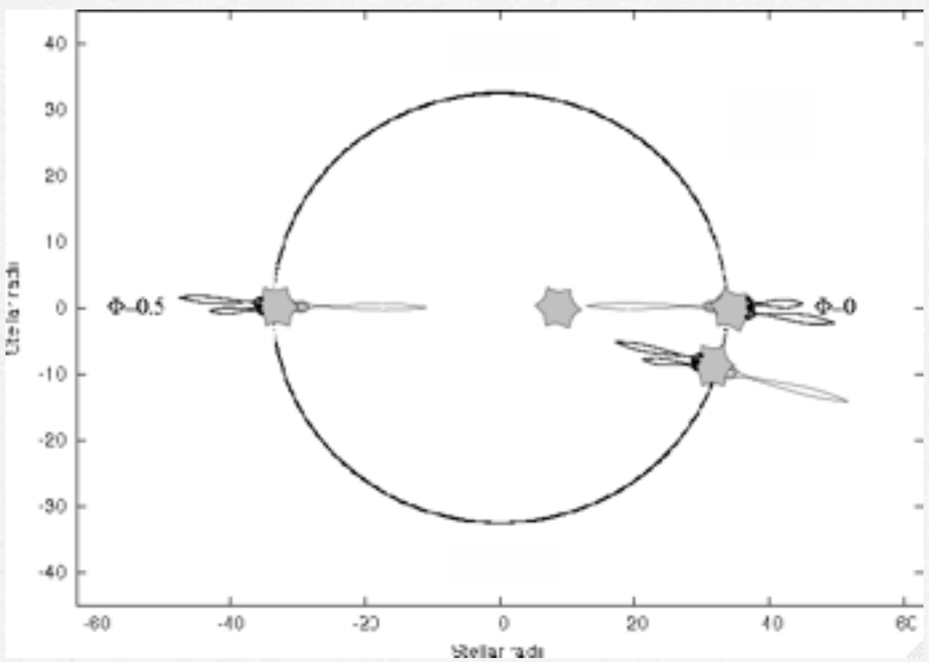
importance of mm variability

- mm emission generally ascribed to dust emission from disks
- to date, a few YSOs have illustrated spectacular mm flares
- appears to be periodic, interacting magnetospheres
- attributed to synchrotron emission based on spectrum and timescales
- does this only affect binaries? what is the impact on SED modelling, particle environment for forming planets?



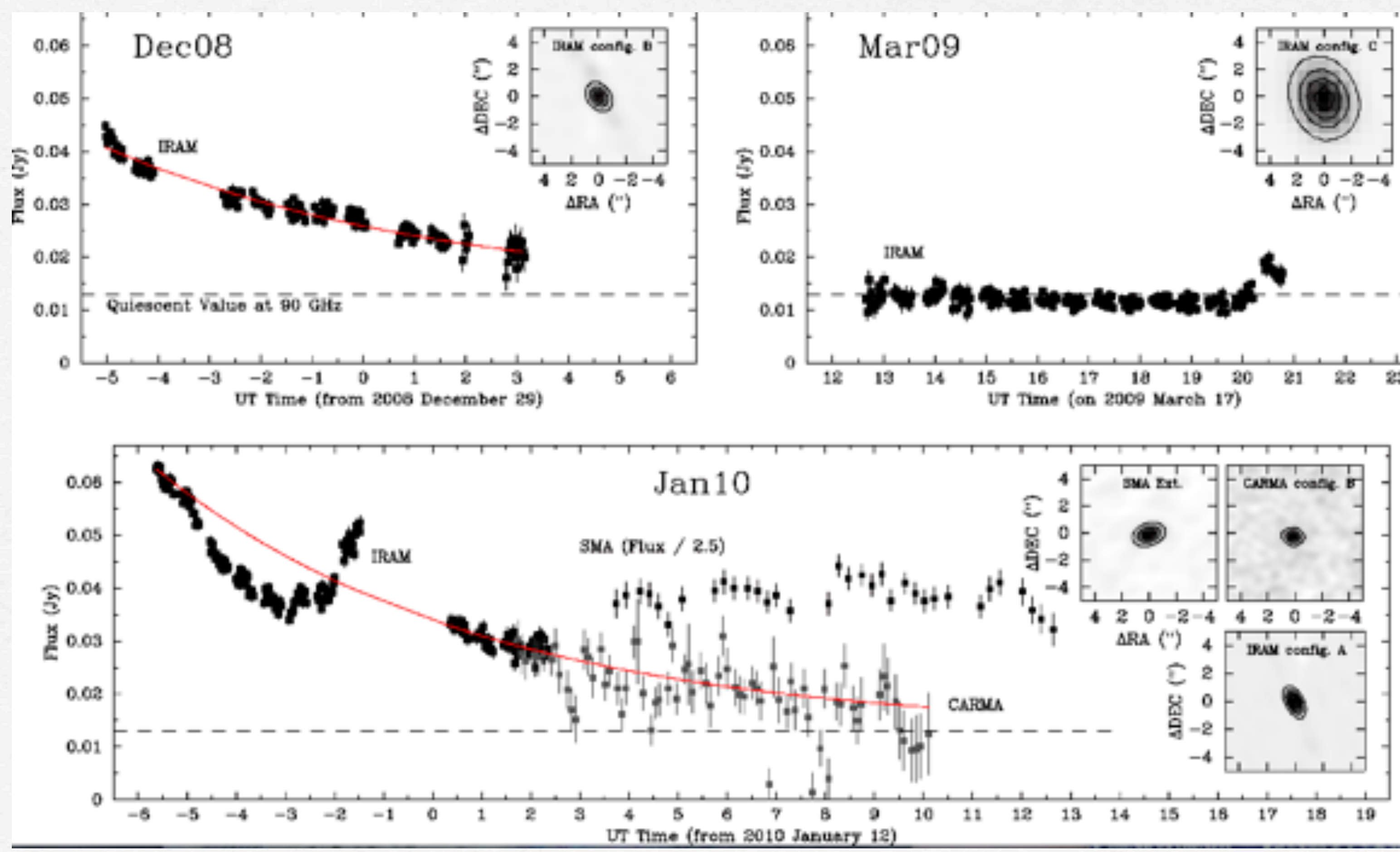
V773 Tau; Massi et al. 2006
mm flares with a periodicity on the order of the orbital period, ~52 days

importance of mm variability



Interacting magnetosphere scenario

also seen in DQ Tau; Salter et al. 2010



with ALMA's sensitivity, can detect stellar chromospheres at mm wavelengths

- magnetically heated regions above the stellar surface, corresponding to temperatures in excess of Teff
- expect to see optically thick thermal bremsstrahlung emission in the mm wavelength range
- τ=1 @7000 K at 3mm (with density enhancements the τ=1 layer shifts to larger heights, hence higher T)
- integrated brightness reveals information about stellar surface coverage with dense (active) chromospheric regions

Mass Loss in Cool Stars

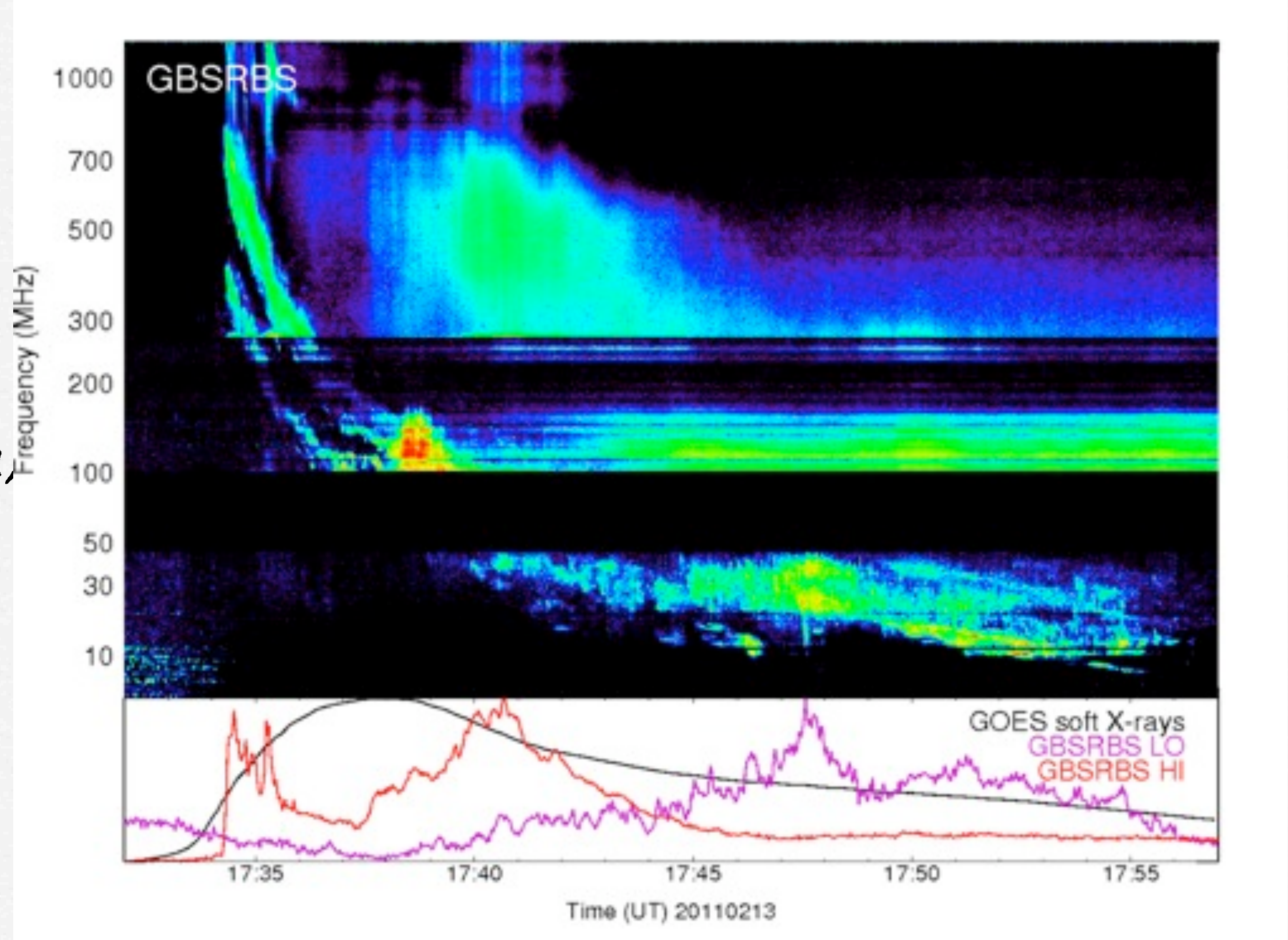
- Detecting mass loss in cool stars on the main sequence has proved to be a thorny issue -- MS cool stellar winds are feeble ($(dM/dt)_{\odot}$ is ~1e-14 $M_{\odot}$/yr)
- expect both steady and variable mass loss, in analogy with Sun.
    - scattered measurements of X-ray absorption enhancements during stellar flares have been interpreted as CMEs. few and far between (esp. given number of stellar X-ray flares)
    - charge exchange X-ray emission provides upper limits on mass loss within astrospheres
    - enhanced astrospheric absorption in stellar Lyman α profiles
- affects circumstellar environment, can alter the character of planetary atmospheres (viz. Mars)

Low Frequency emission from Stellar CMEs

- solar type II radio bursts: drifting radio bursts with slow frequency drift, produced by MHD shock propagating through the solar corona; radiation at ν_p and $2\nu_p$

- strong association between solar CMEs and type II radio bursts, although still the flare/CME/type II relationship is not fully understood

- expect that coronally active stars, with high flaring rate, should produce type II bursts -> detectable with e.g. LOFAR, MWA, LWA



GBSRBS example (Feb. 13, 2011) of a type II burst

“you learn a lot by looking”

- stars capable of unpredictable behavior; expect the unexpected
- stellar radio community is small
  - make use of advances in primarily large telescope projects
  - unique resources for information not available at other wavelengths
  - importance of multi-wavelength approach

> There are more things in heaven and earth, Horatio,
> Than are dreamt of in your philosophy.
>
> *Hamlet Act 1, scene 5, 159–167*