The Variability Timescales and Brightness Temperatures of Radio Synchrotron/Cyclotron Flares

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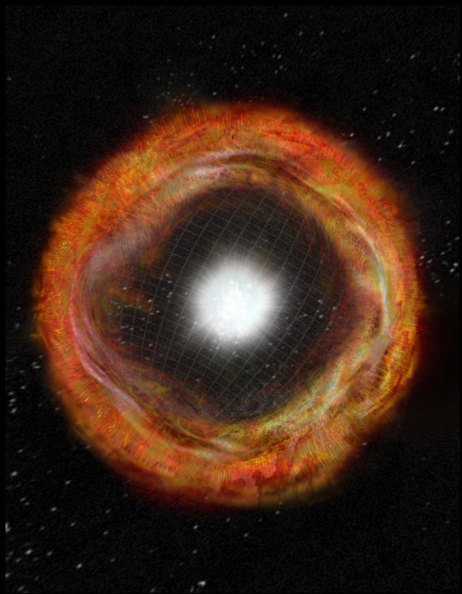
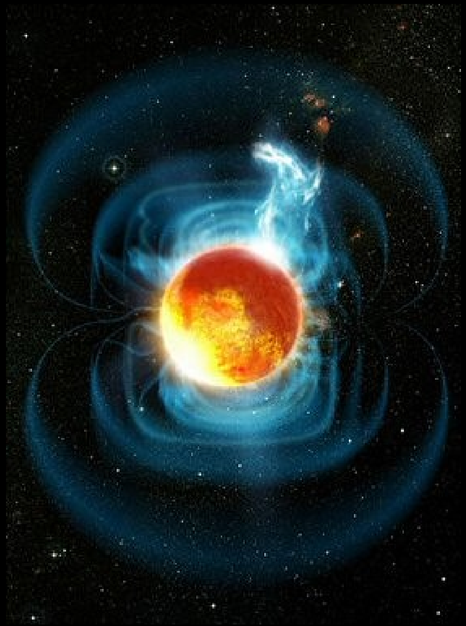
Examples of Synchrotron/Cyclotron Flares



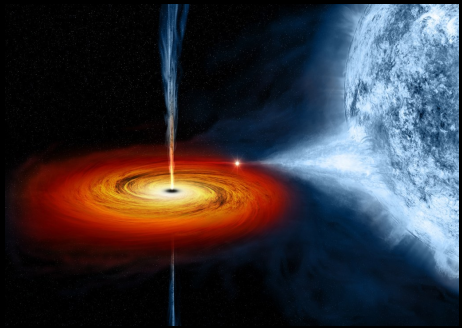
Isotropic expansion:

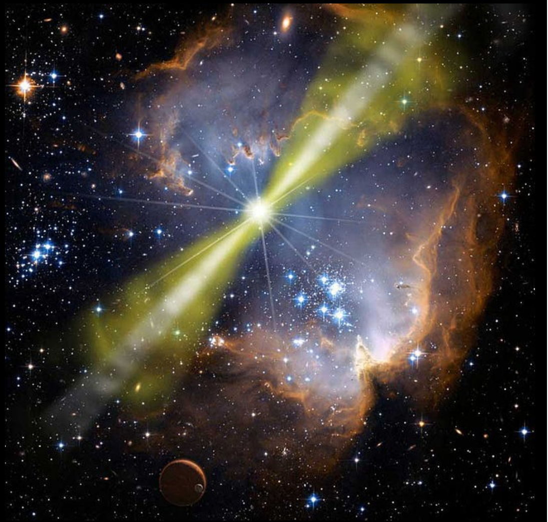
- Nova
- Supernova



Electrons trapped in the magnetic coronal loop

- Flare Star
- Magnetic CV



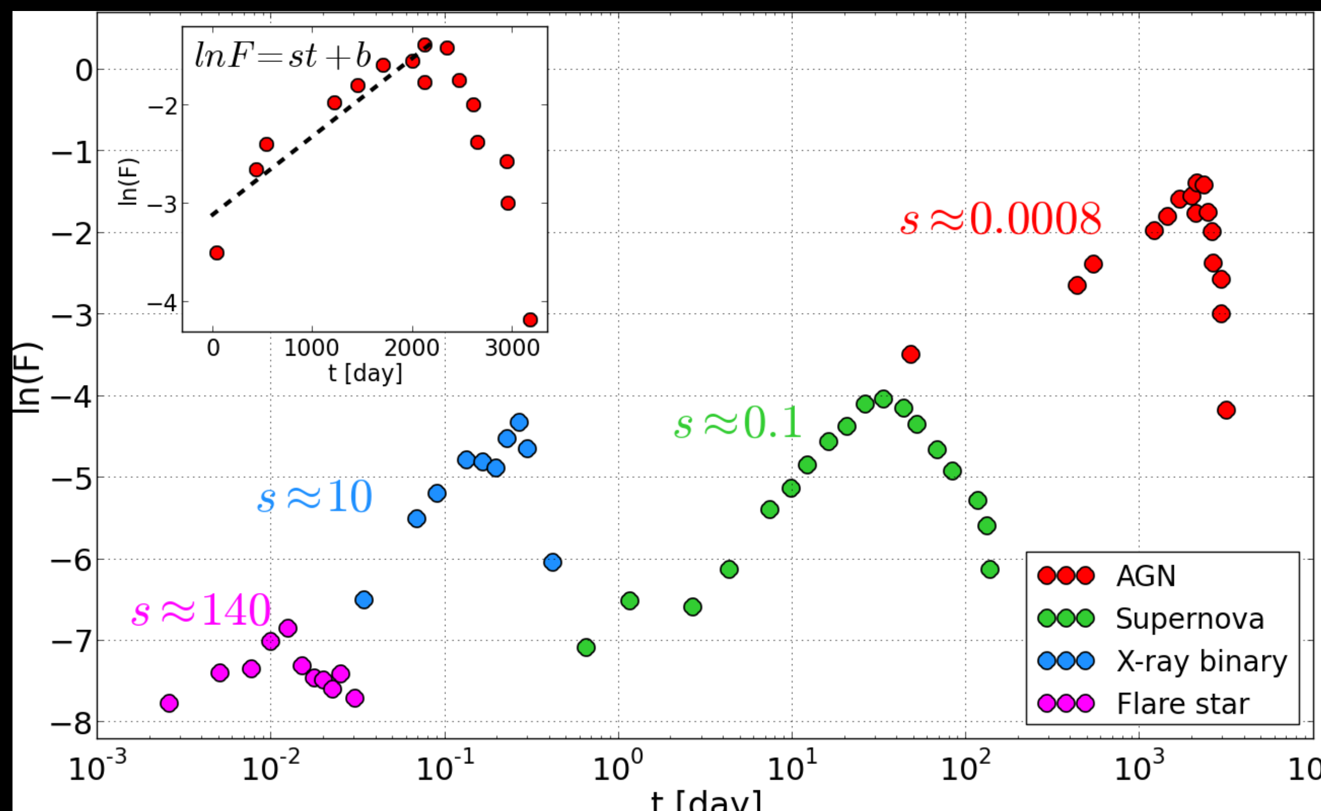


Collimated relativistic flows:

- X-ray binary
- GRB afterglow
- AGN

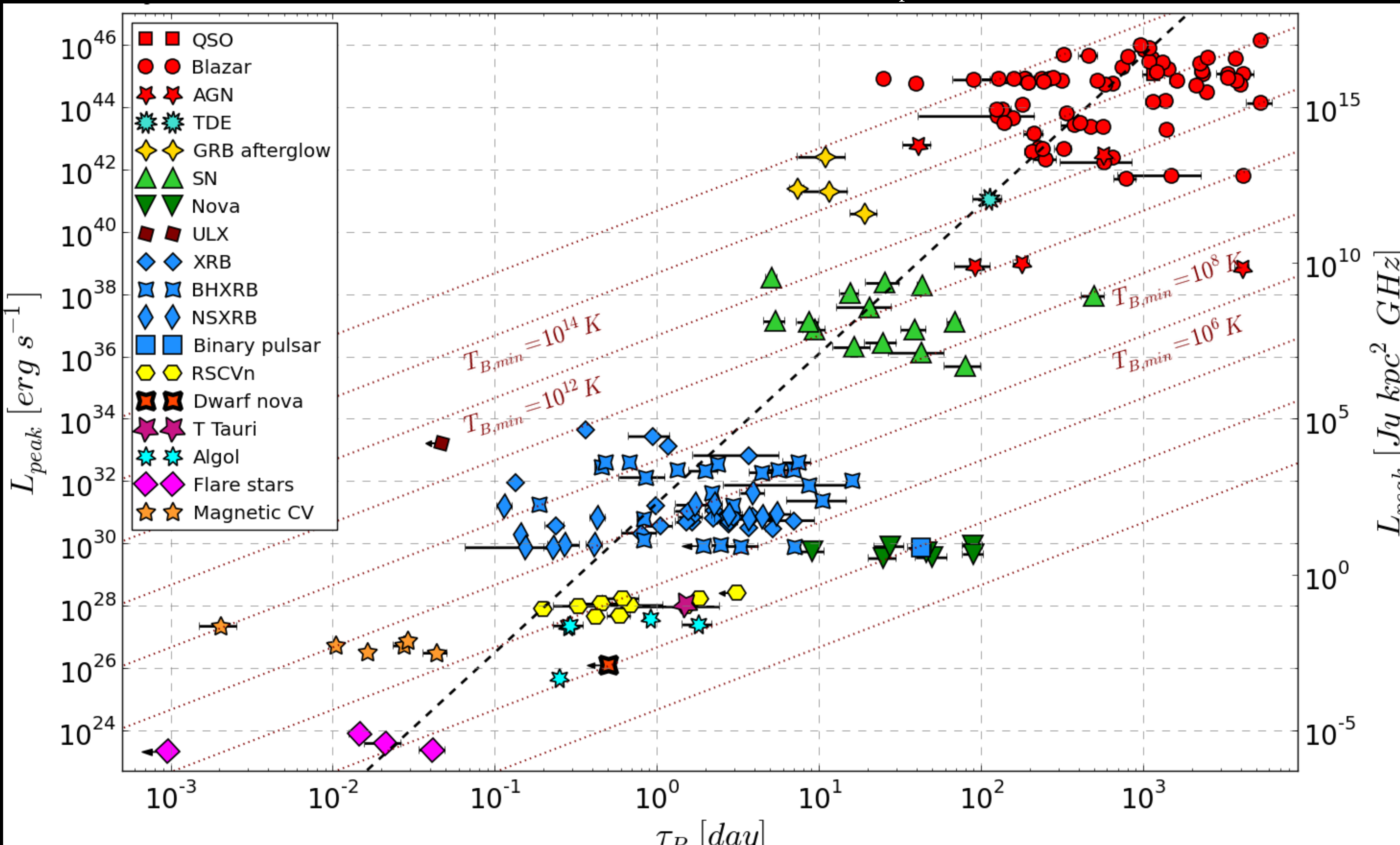
Synchrotron/Cyclotron Radio Flares

- Flares originating from stars to supermassive black holes
- Rise and decline phases fit by exponential functions
- Compared against peak radio luminosities
- Measured for a sample of ~ 200 light curves from ~90 objects
- 5 GHz – 8GHz
- Variability timescales ~min to ~yr



Luminosity vs Timescale

$$L_{peak} = 10^{31.35 \pm 2.13}\, \tau_R^{4.79 \pm 0.15}$$



Origin of the emission

Synchrotron:

- AGN
- GRB afterglow
- Supernova
- Nova
- X-ray Binary

Gyro-synchrotron:

- Algol
- RSCVn
- Magnetic CV
- Flare Star

$$\log(L_{peak}) = a\log(\tau) + b$$

	a ± δa	**b ± δb**
RISE	4.79 ± 0.15	31.35 ± 2.13
DECLINE	4.90 ± 0.20	29.45 ± 2.72

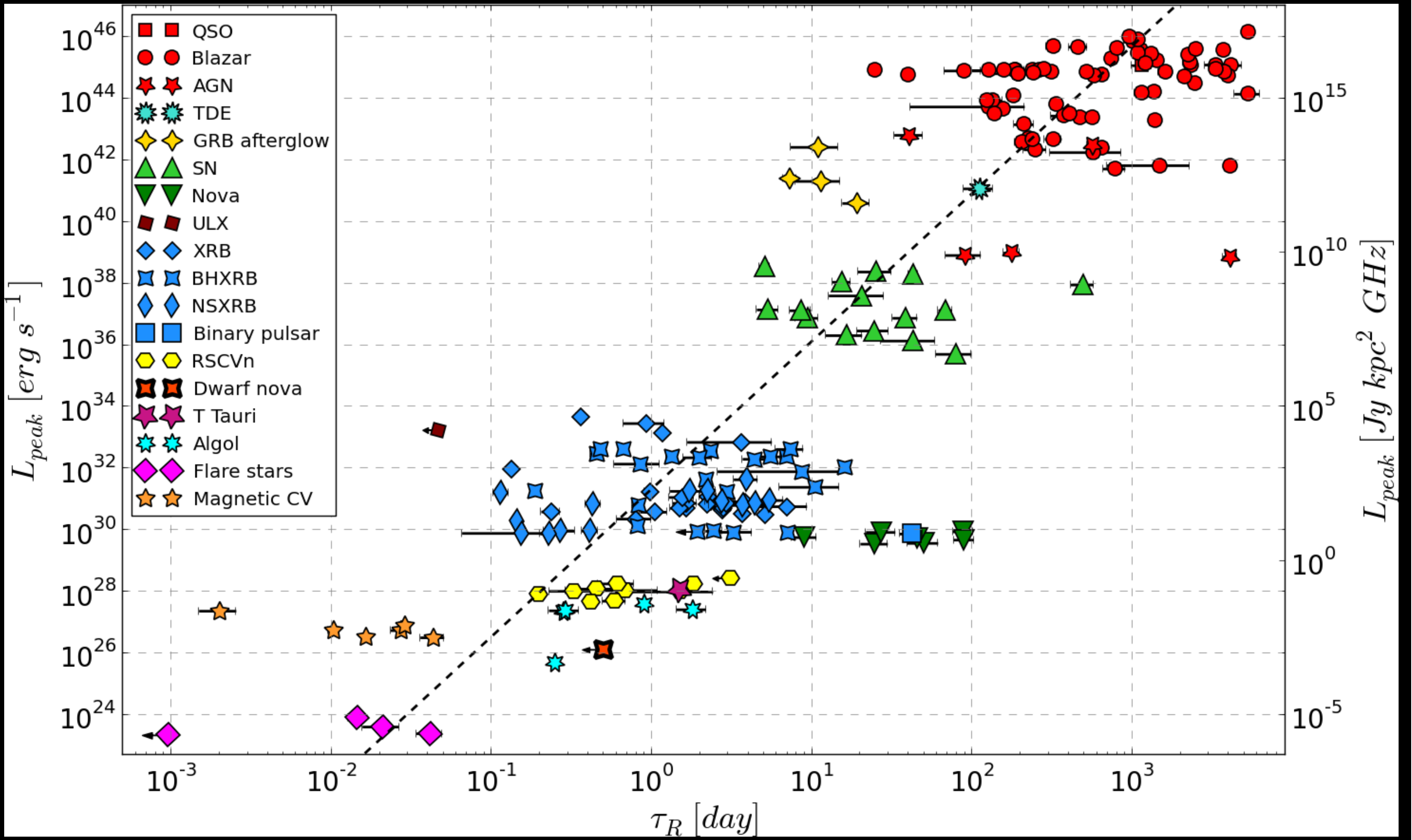
Linear fit done including all the sources

	a ± δa	**b ± δb**
RISE	4.86 ± 0.17	31.19 ± 2.45
DECLINE	5.47 ± 0.24	28.10 ± 2.99

Flares originating from gyro-synchrotron emission excluded from the fit

Luminosity vs Timescale

Fitted relation: $L_{peak} = 10^{31.35 \pm 2.13} \tau_R^{4.79 \pm 0.15}$



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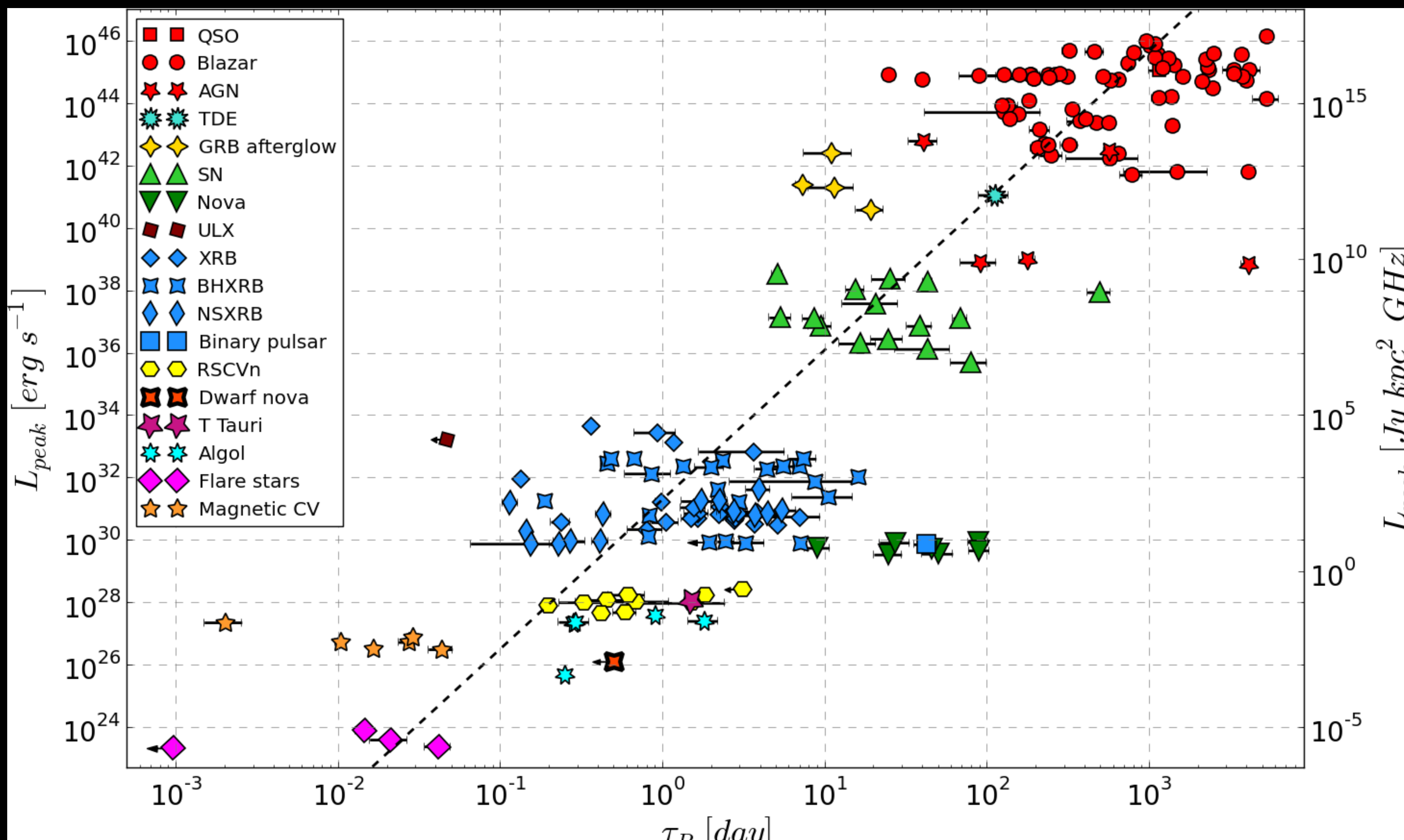
From Rayleigh-Jeans law: $L = \frac{2 k_B T_B \nu^3}{c^2} 4 \pi r^2$



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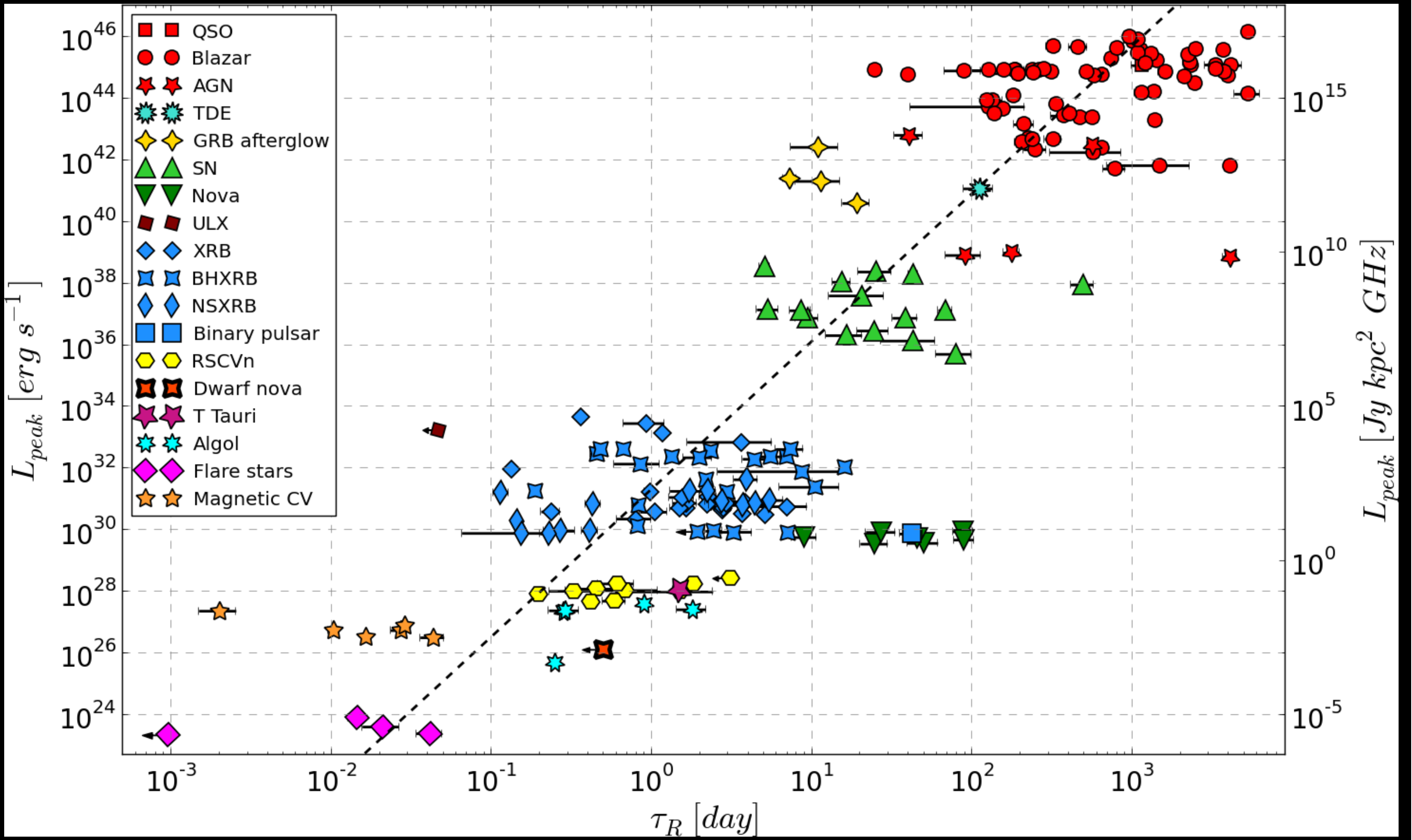
For the maximum size of the source:

$r = c \tau$



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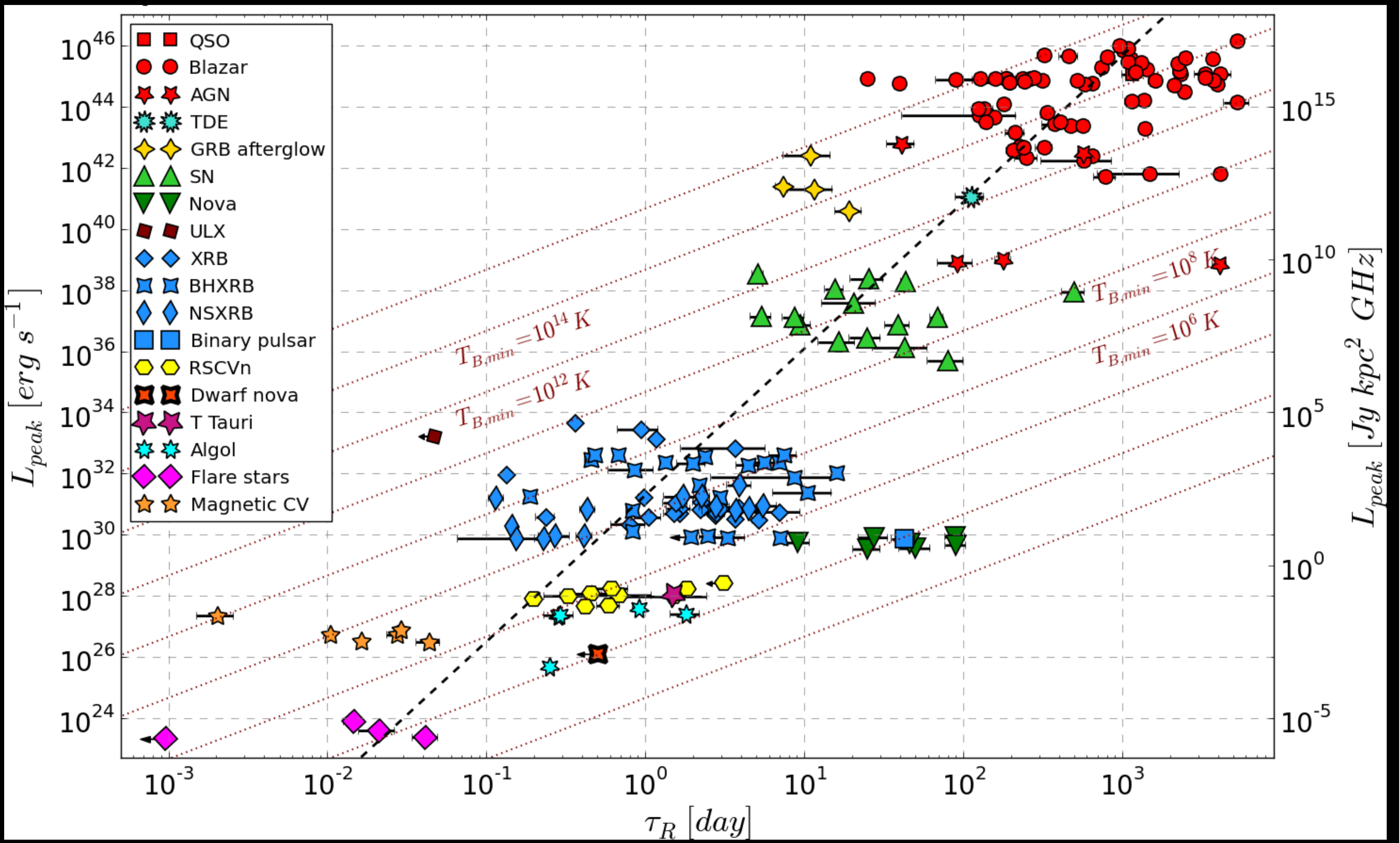
We expect:

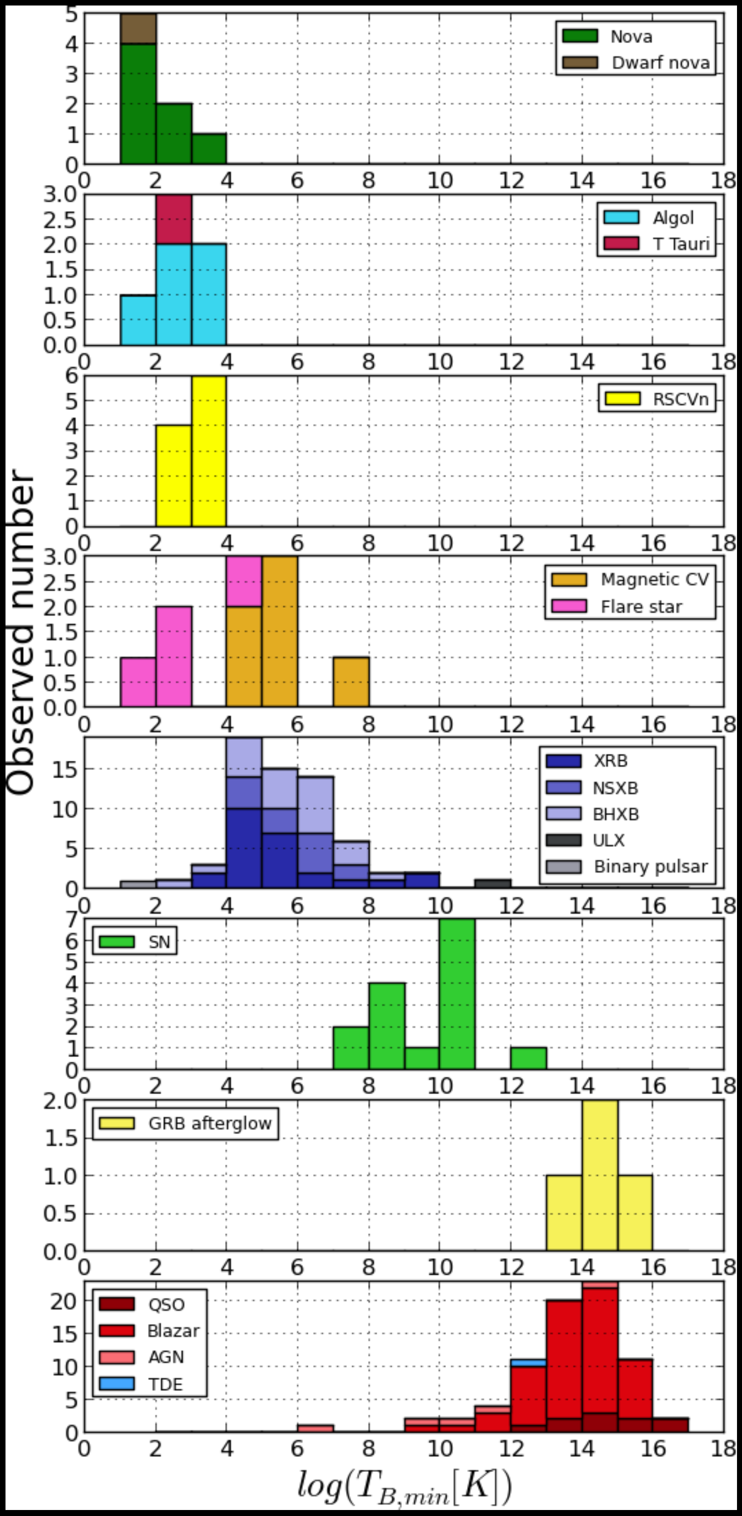
$L \propto T_{B,min} \tau^2$



Brightness Temperatures

- $T_{B,min}$ based on the variability time scale
is a rising function of source luminosity

- Why …?

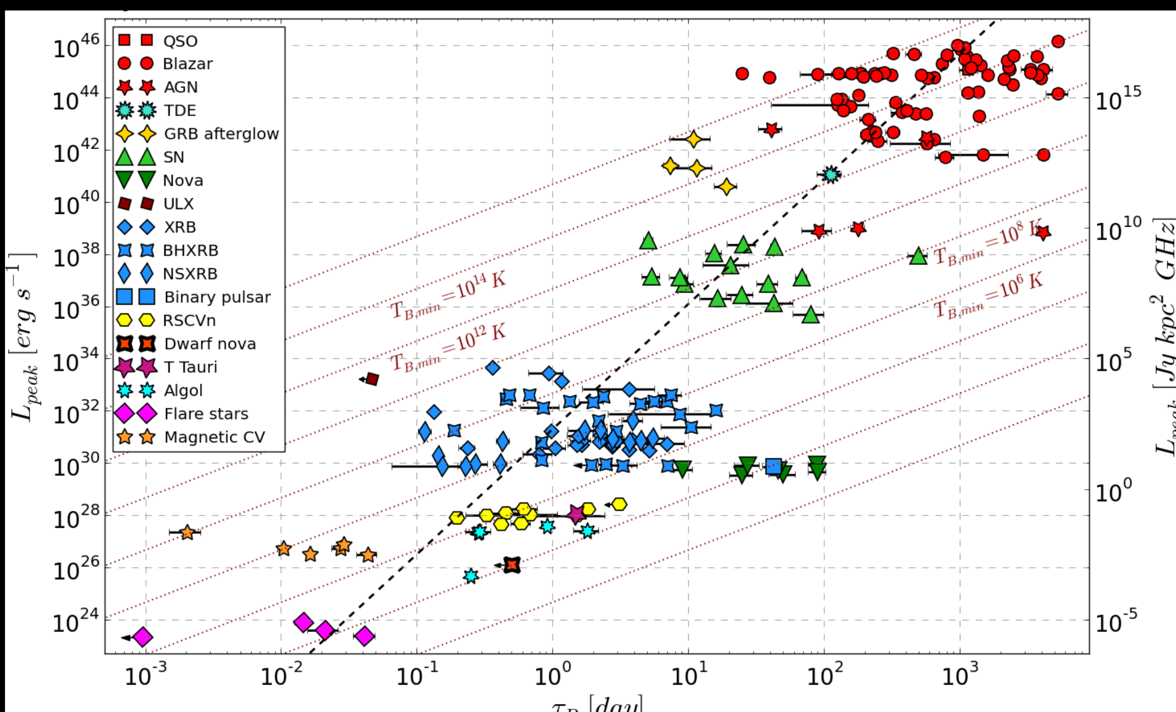


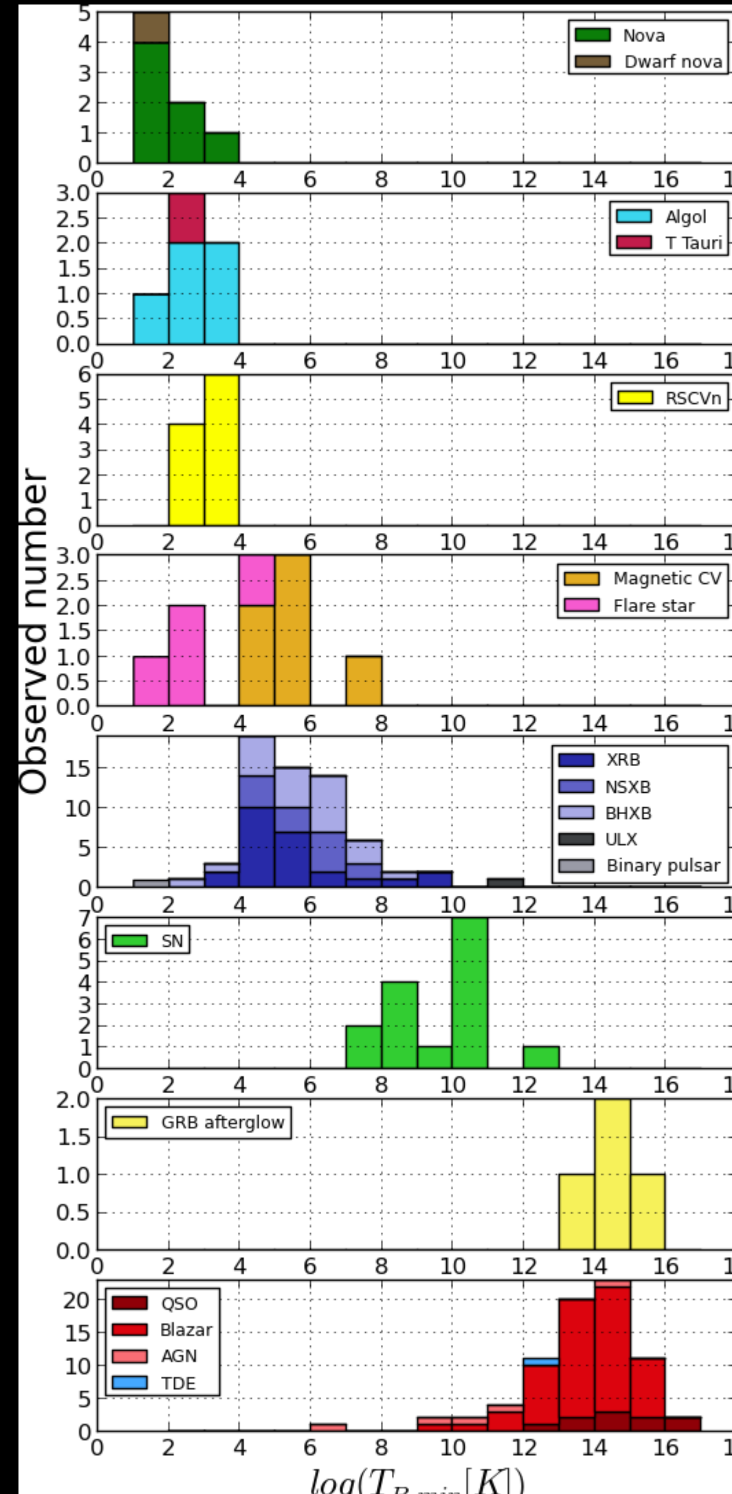
Brightness Temperatures

$$T_{B,min} \propto \frac{L}{r^2}$$

Relativistic beaming?

$$L_{obs} \gg L_{intr} \qquad \tau_{obs} \ll \tau_{intr}$$





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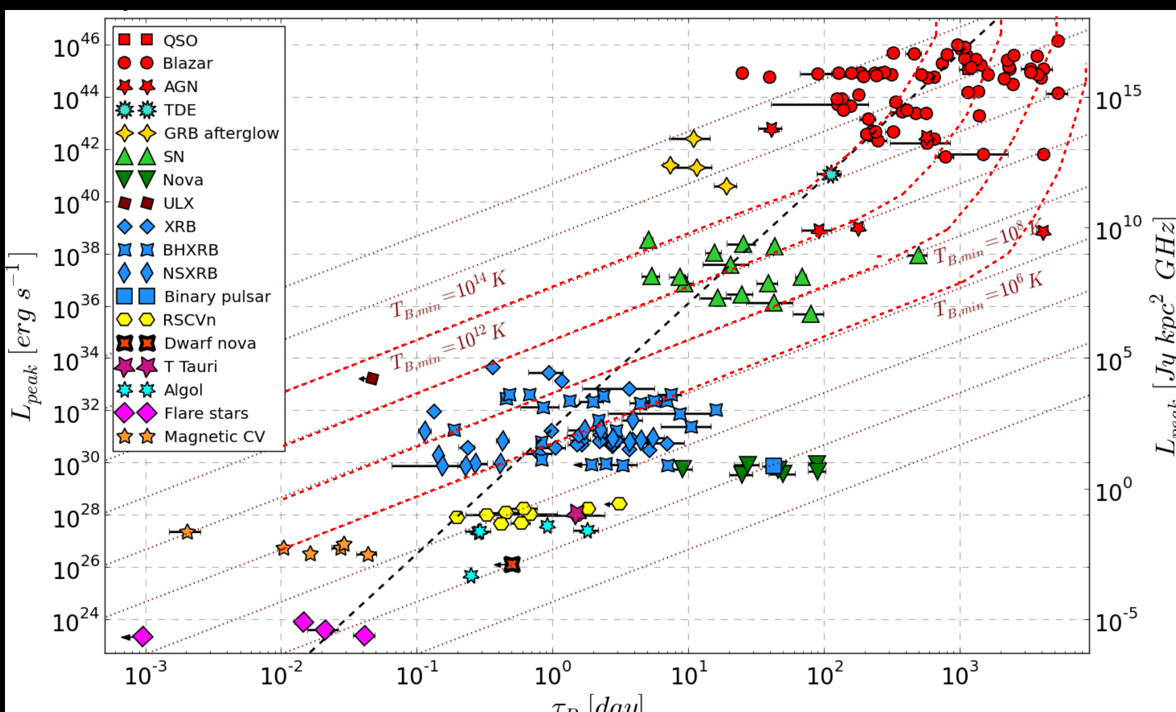
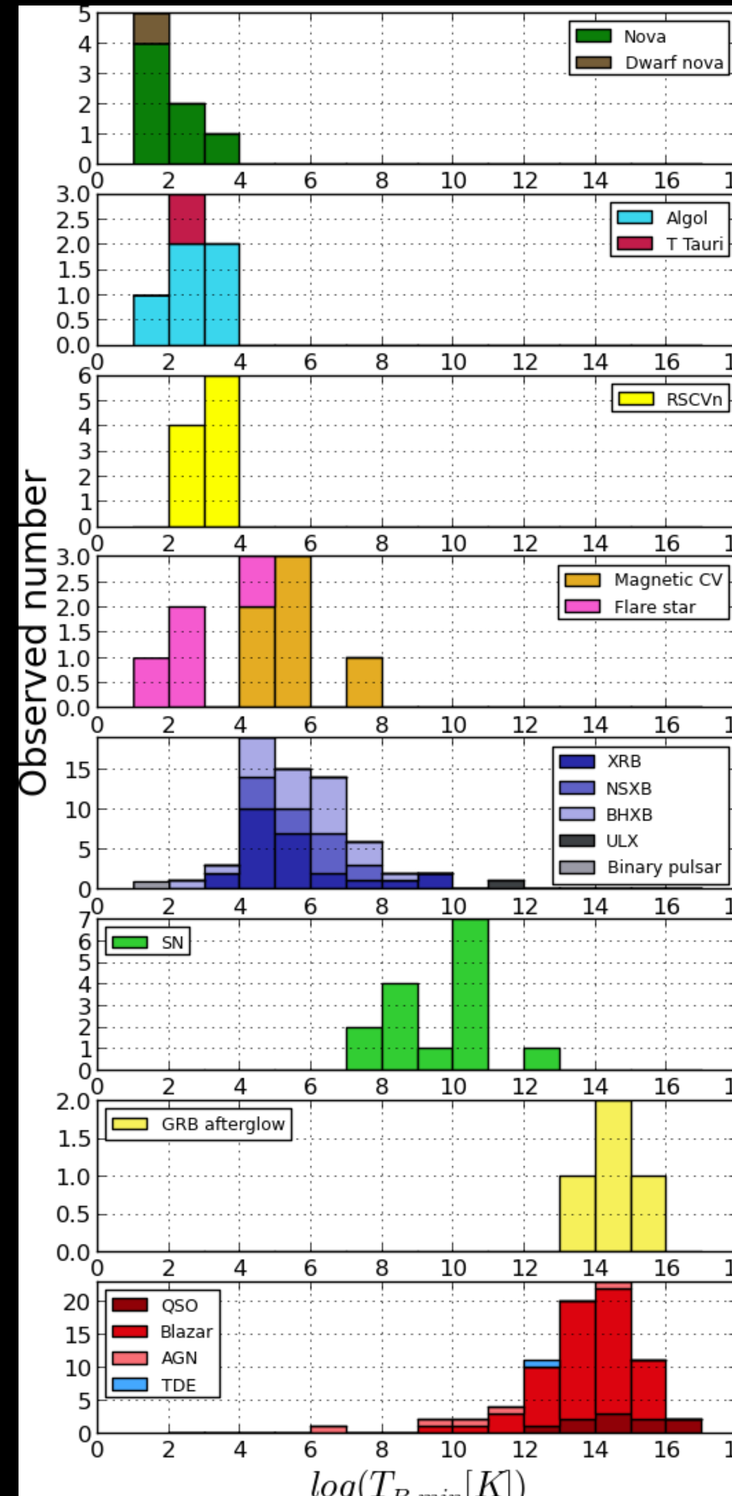


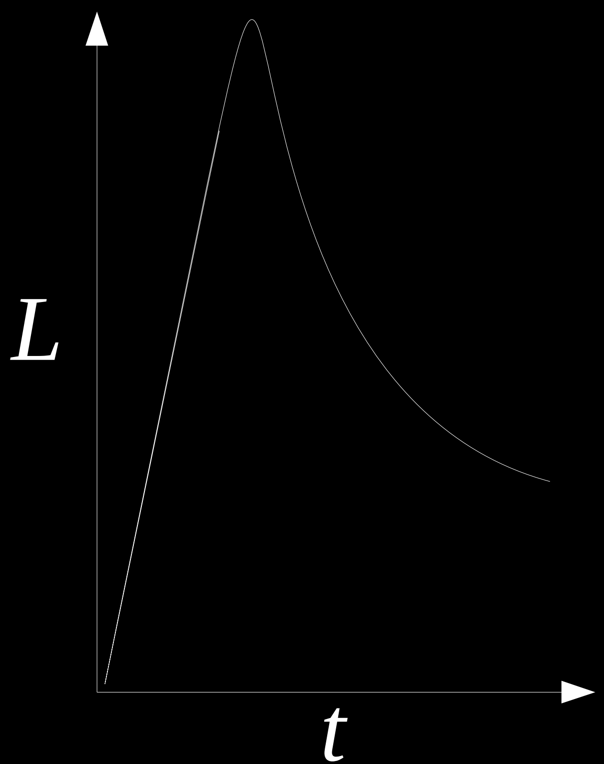


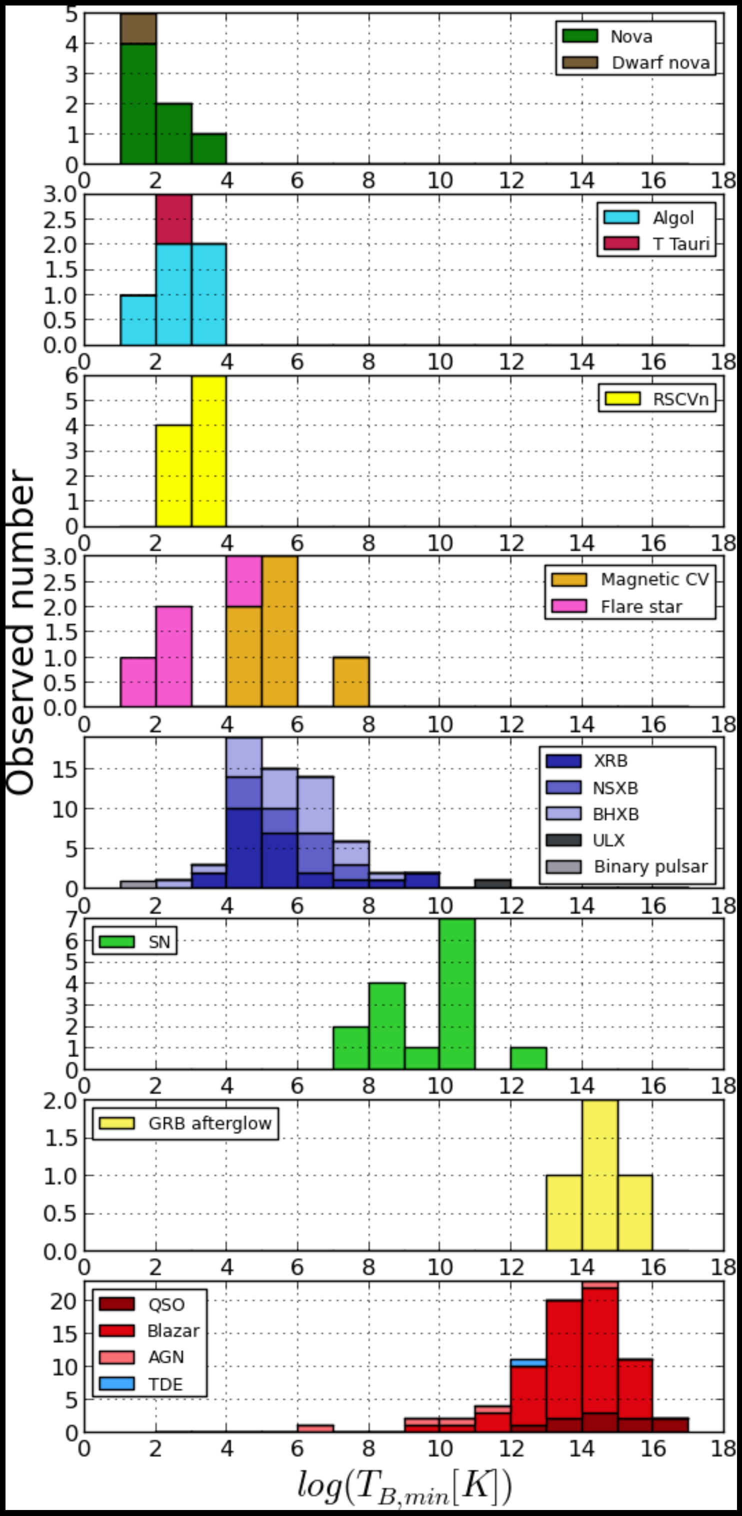
Would apply to AGN, GRB

Brightness Temperatures

$$T_{B,min} \propto \frac{L}{r^2}$$

Different size? $r = v\tau$



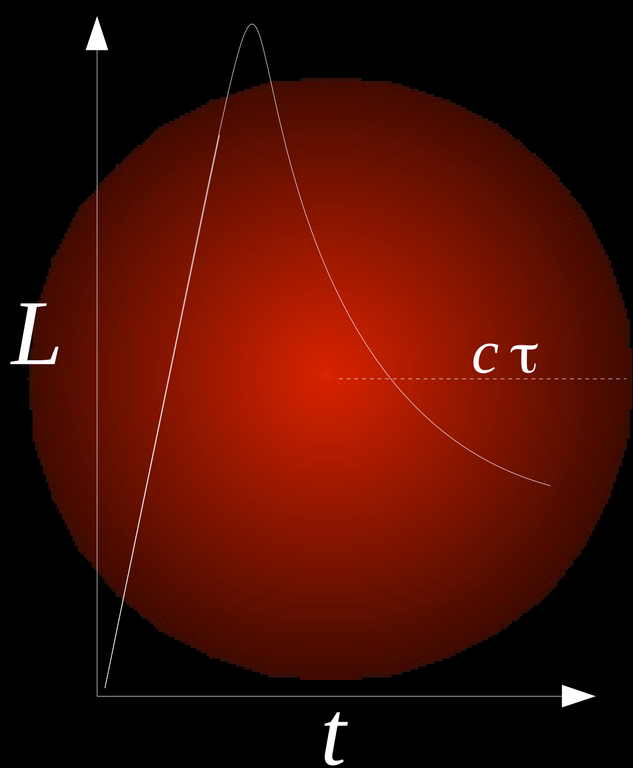


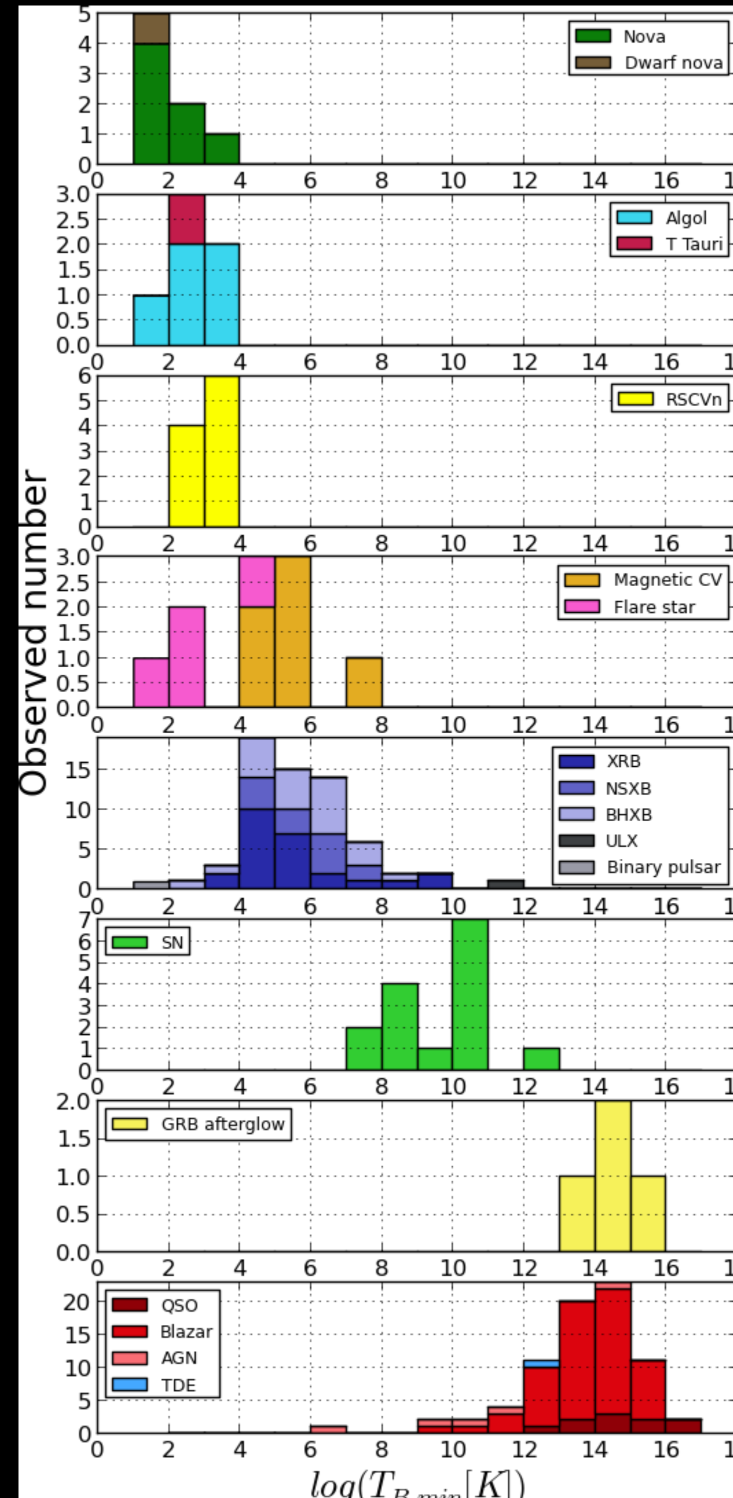
Brightness Temperatures

$$T_{B,min} \propto \frac{L}{r^2}$$

Different size? $r = v\tau$

$v \sim c$





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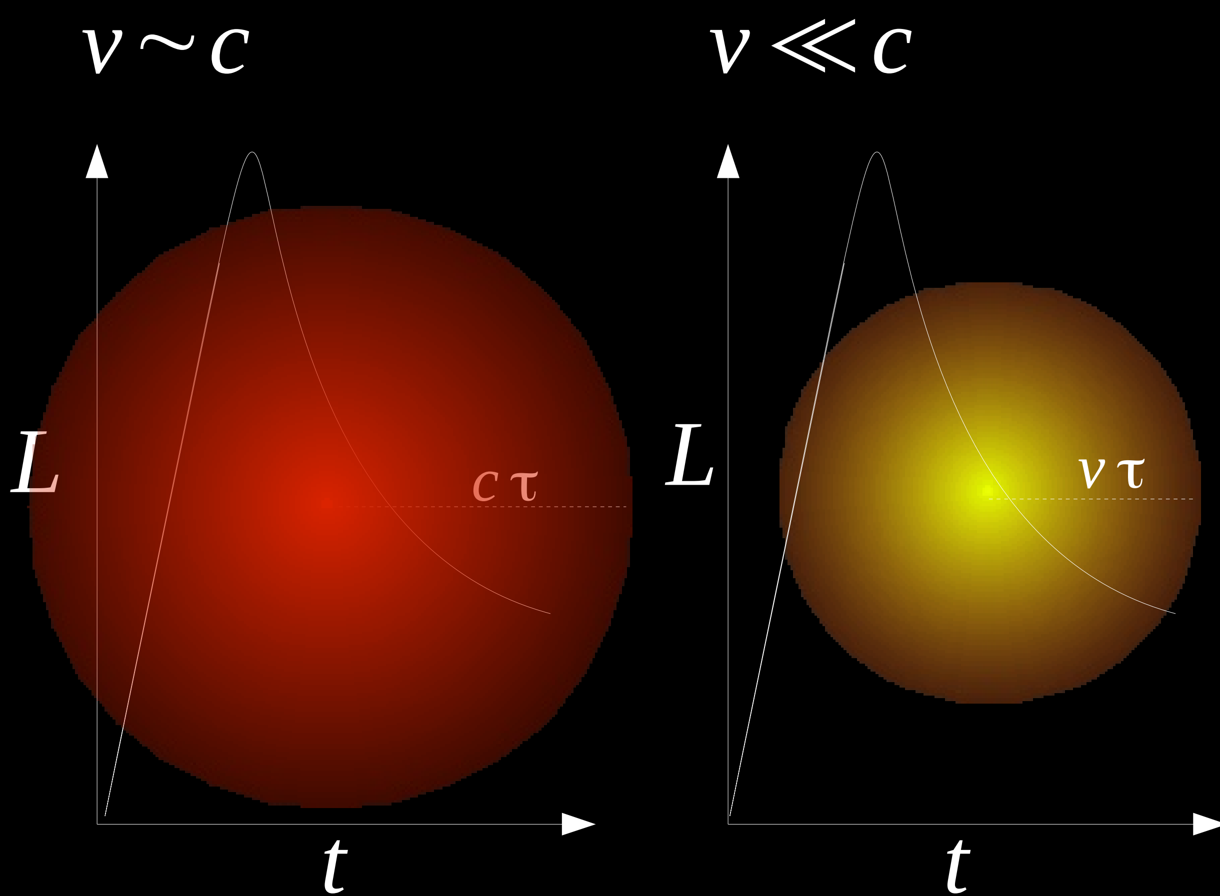
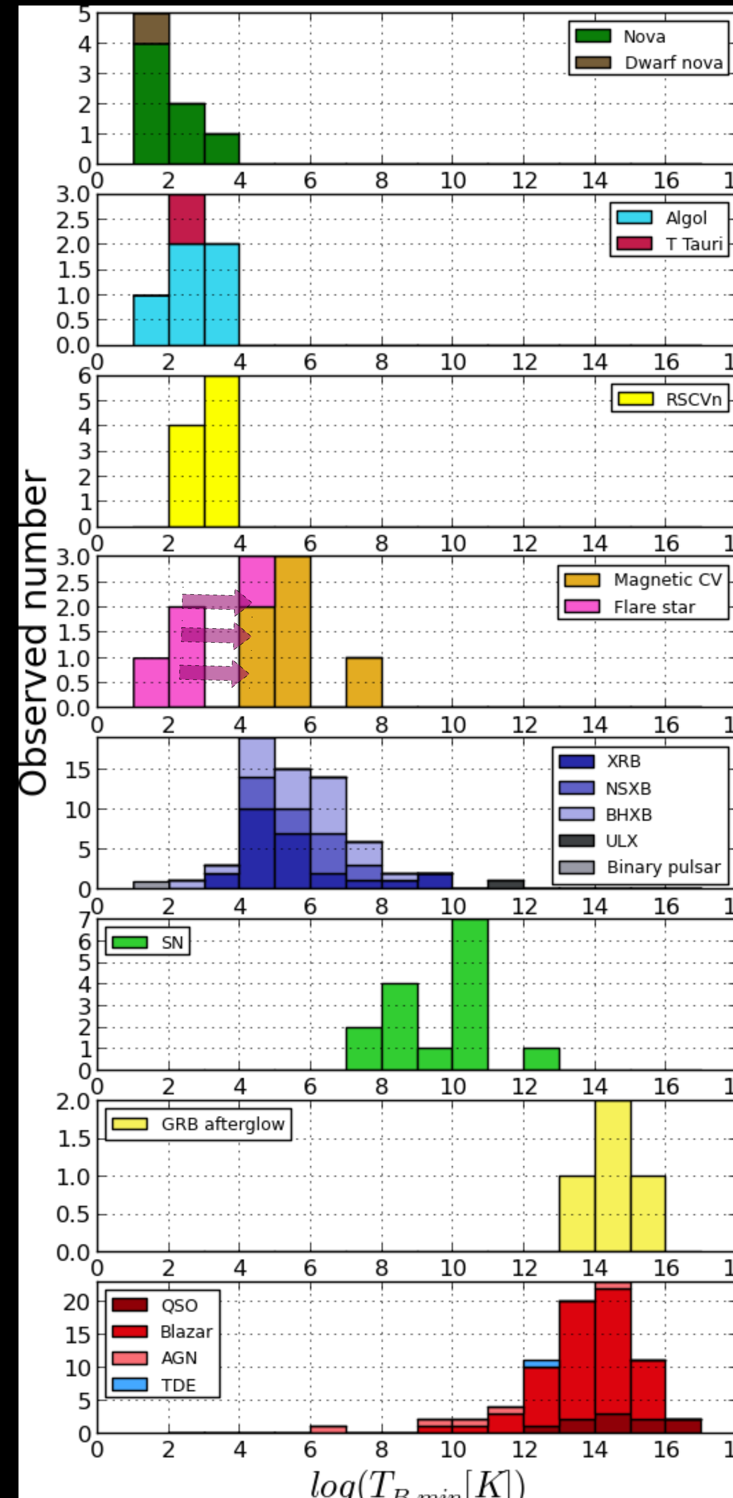


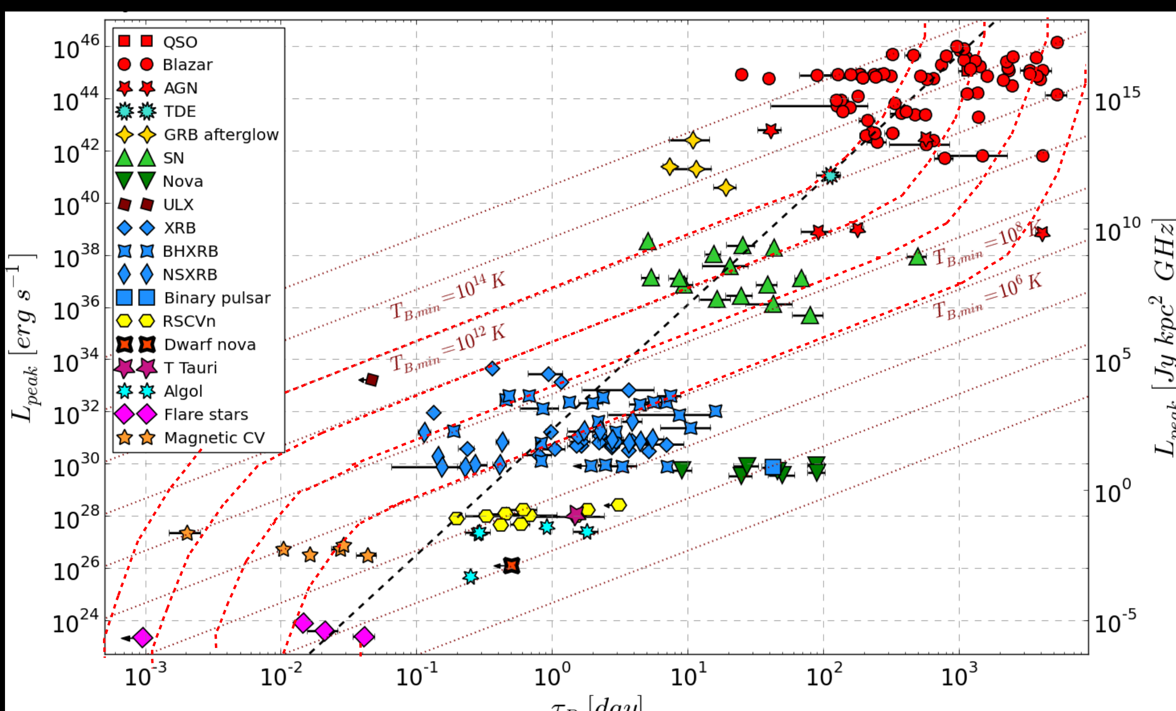


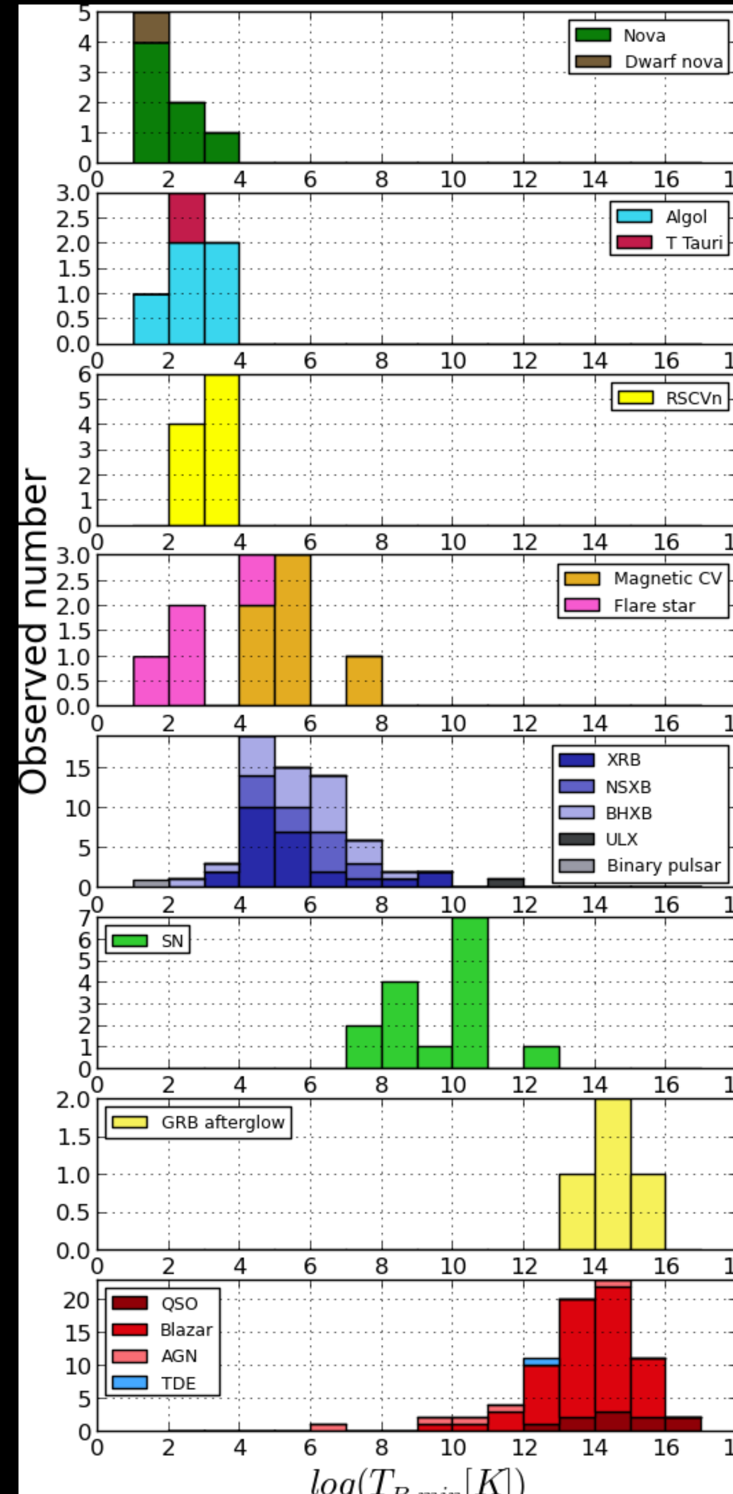
$T_{B,min}$ will be higher if the size of the source is smaller

Brightness Temperatures

For flare stars: $v \sim 10^{-2} c$

$$T_{B,min}[flare\ star] \propto \frac{L}{(c\tau)^2} 10^4 \gg \frac{L}{(c\tau)^2}$$





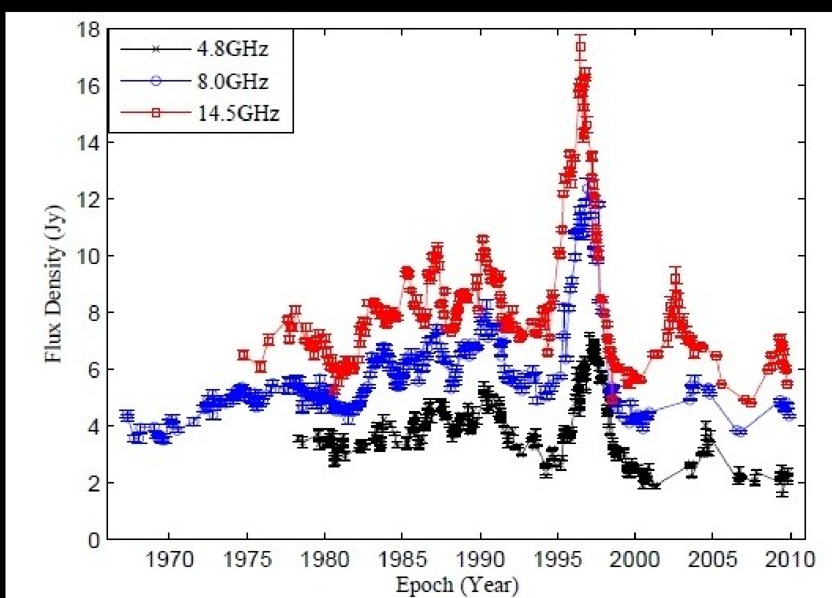
Two Types of Radio Transients

Incoherent synchrotron:

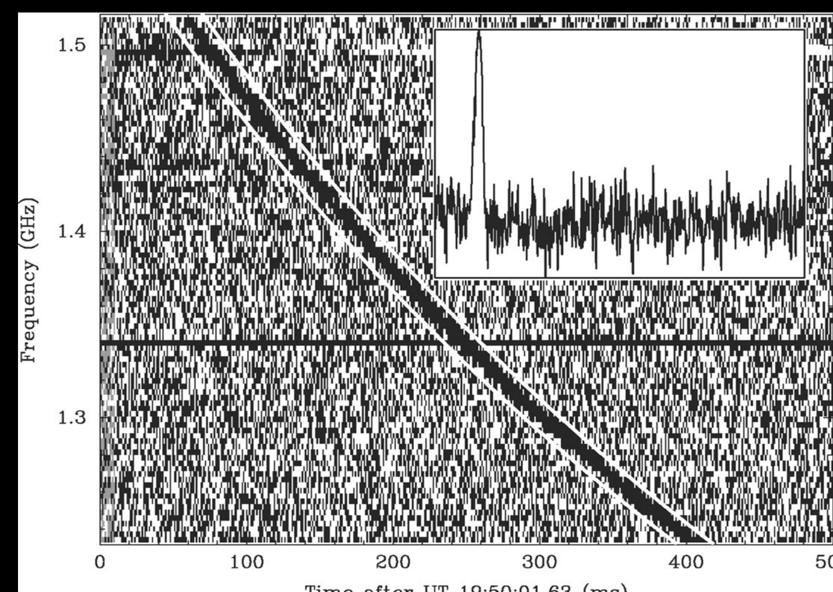
- Slow variability
- Limited brightness temperature
- Detected in image plane

Coherent:

- Fast variability
- High brightness temperature
- Detected in time series

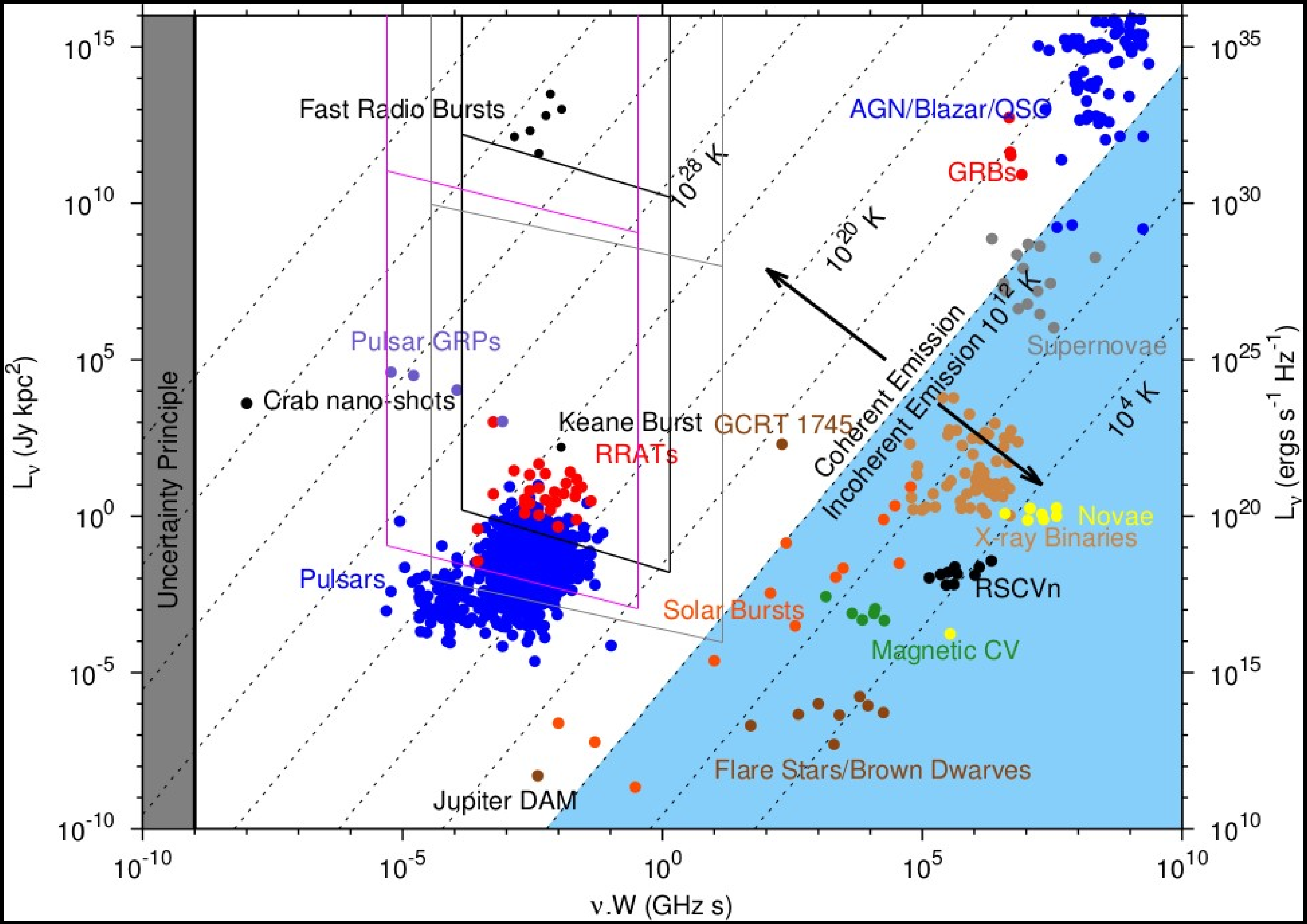


Blazar NRAO 530



FRB, Lorimer et al. (2007)

Radio Transients Parameter Space



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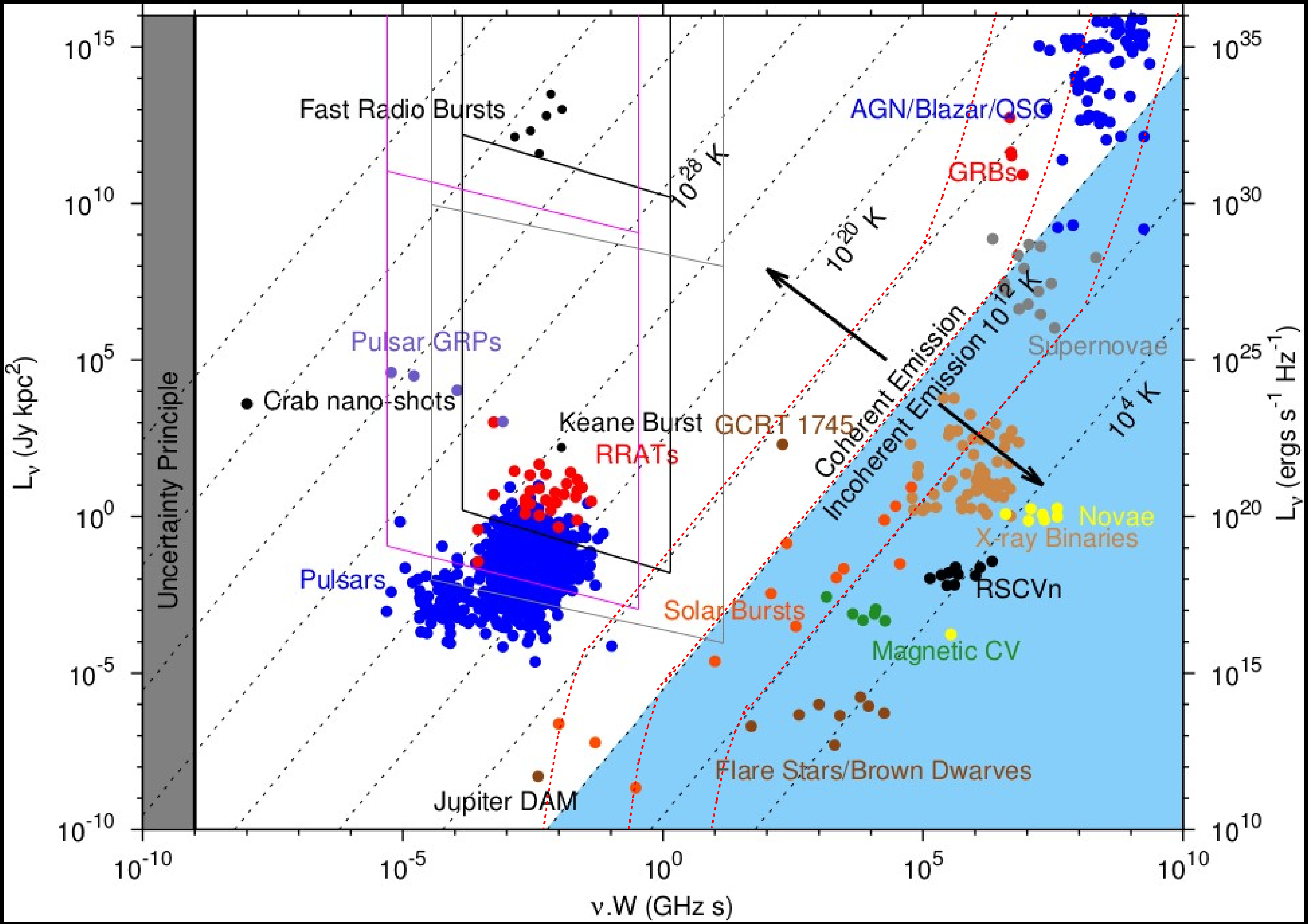
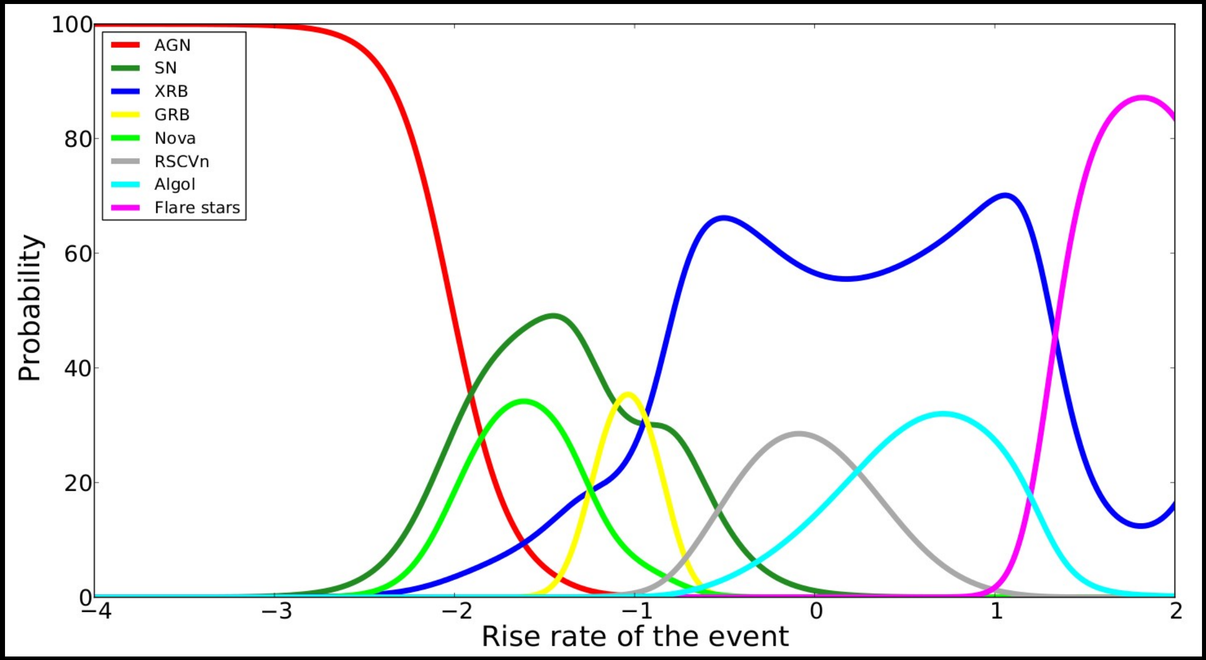
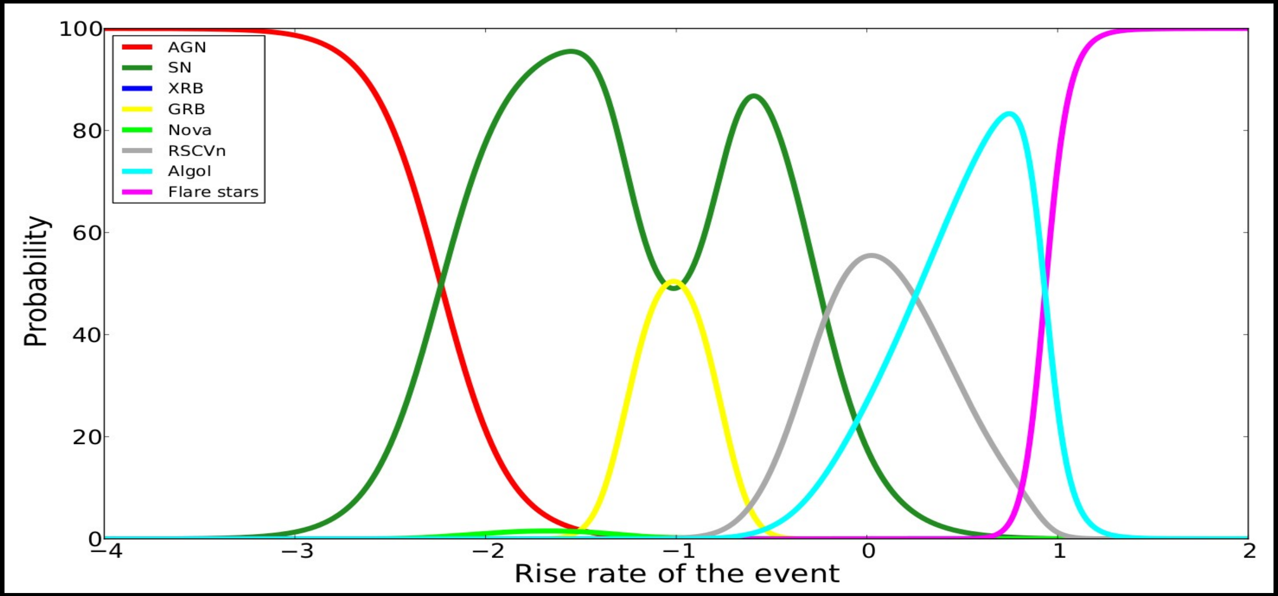


Pietka, Fender, Keane 2014; to be re-submitted after the first referee report

Next: Transients Classification Tool





Estimated sky rates of different classes of objects at the flux limit of 0.1 mJy

Class	Rate (deg^{-2}) single epoch
Flare stars	1.2398
Algol	0.00896
RSCVns	0.0106
Novae	0.0021
Dwarf Novae	0.0013
XRBs	2.4e-05
SGRs	4e-07
Supernovae	0.2078
GRBs	0.052
TDEs	0.5196
AGNs	2.2768

Conclusions

- Broad correlation between radio luminosity and variability timescales $L \propto \tau^5$

- NOT what we would expect for events with the same brightness temperature

  relativistic beaming ?
  varying relation between the radius and the variability timescale ?

- Variability timescales as a method of classification radio transients originating from synchrotron events