INTRO TO RADIO TELESCOPES

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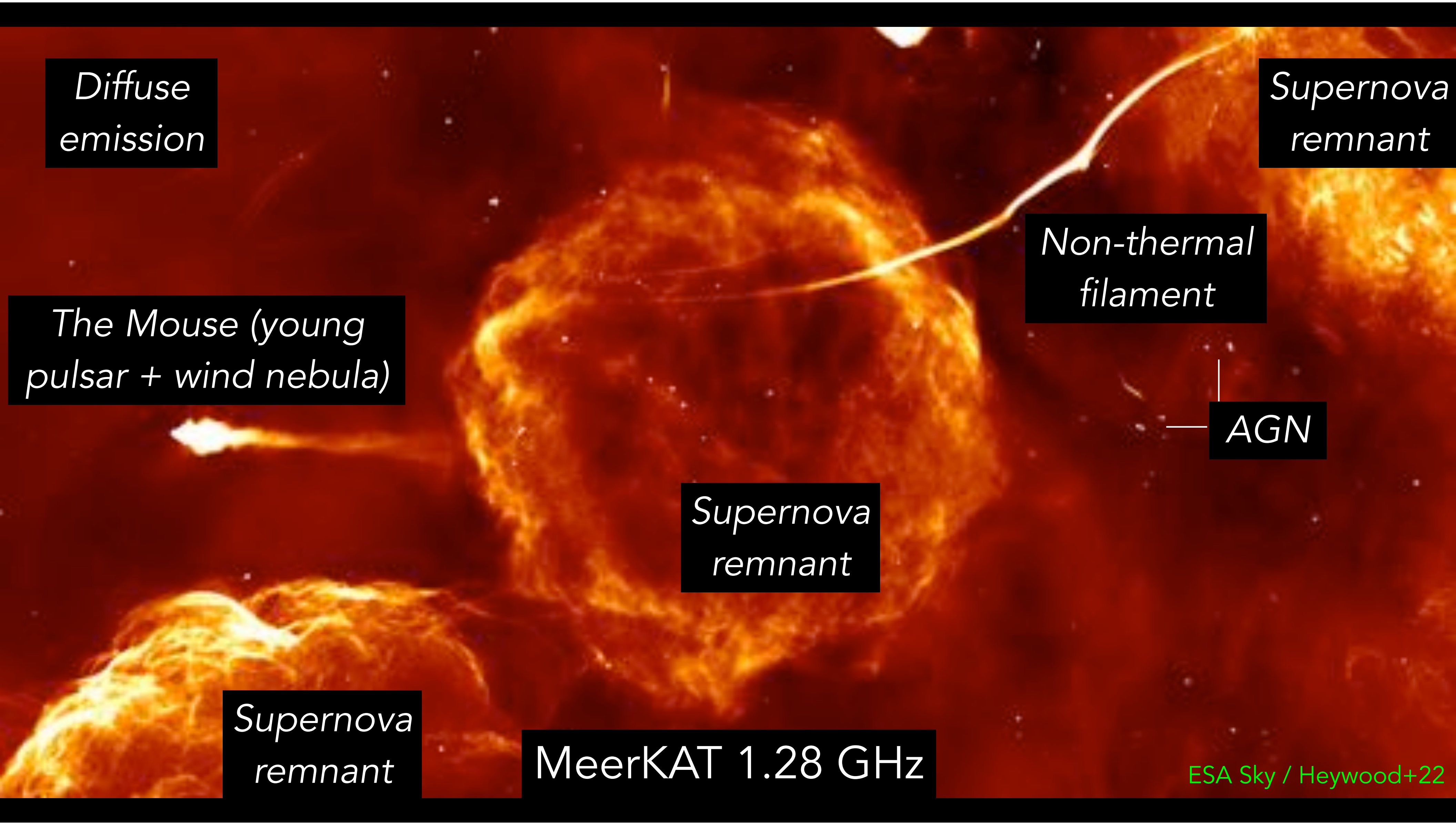
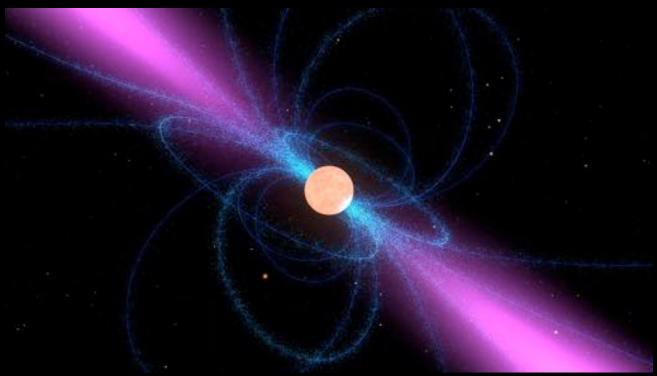
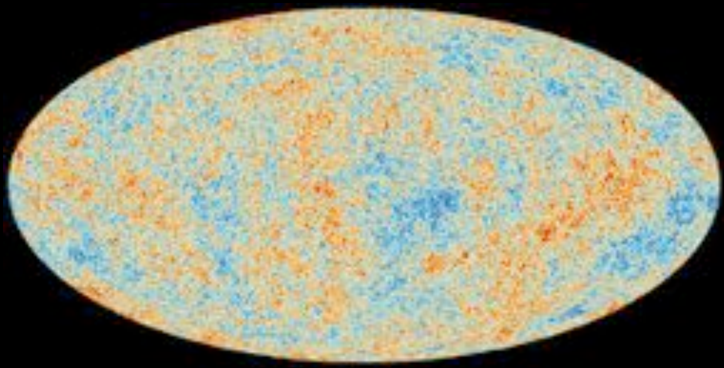

Diffuse emission
Supernova remnant
Non-thermal filament
The Mouse (young pulsar + wind nebula)
AGN
Supernova remnant
Supernova remnant
MeerKAT 1.28 GHz
ESA Sky / Heywood+22

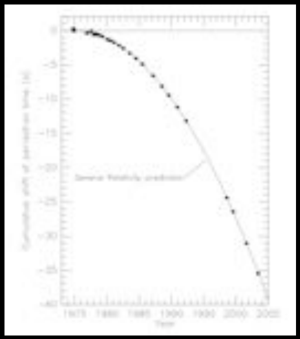
Discoveries made with radio telescopes



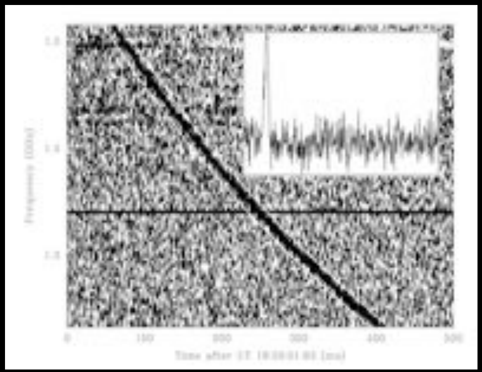
Pulsars



CMB

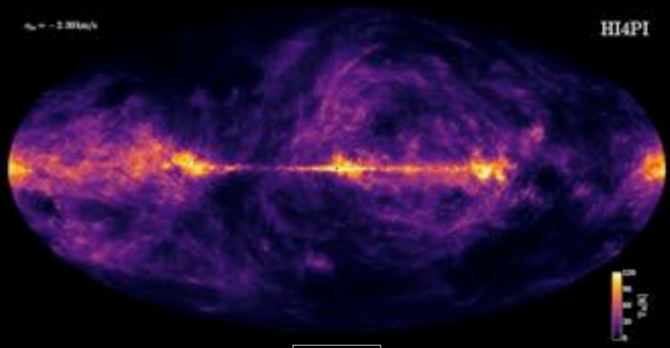


GW emission

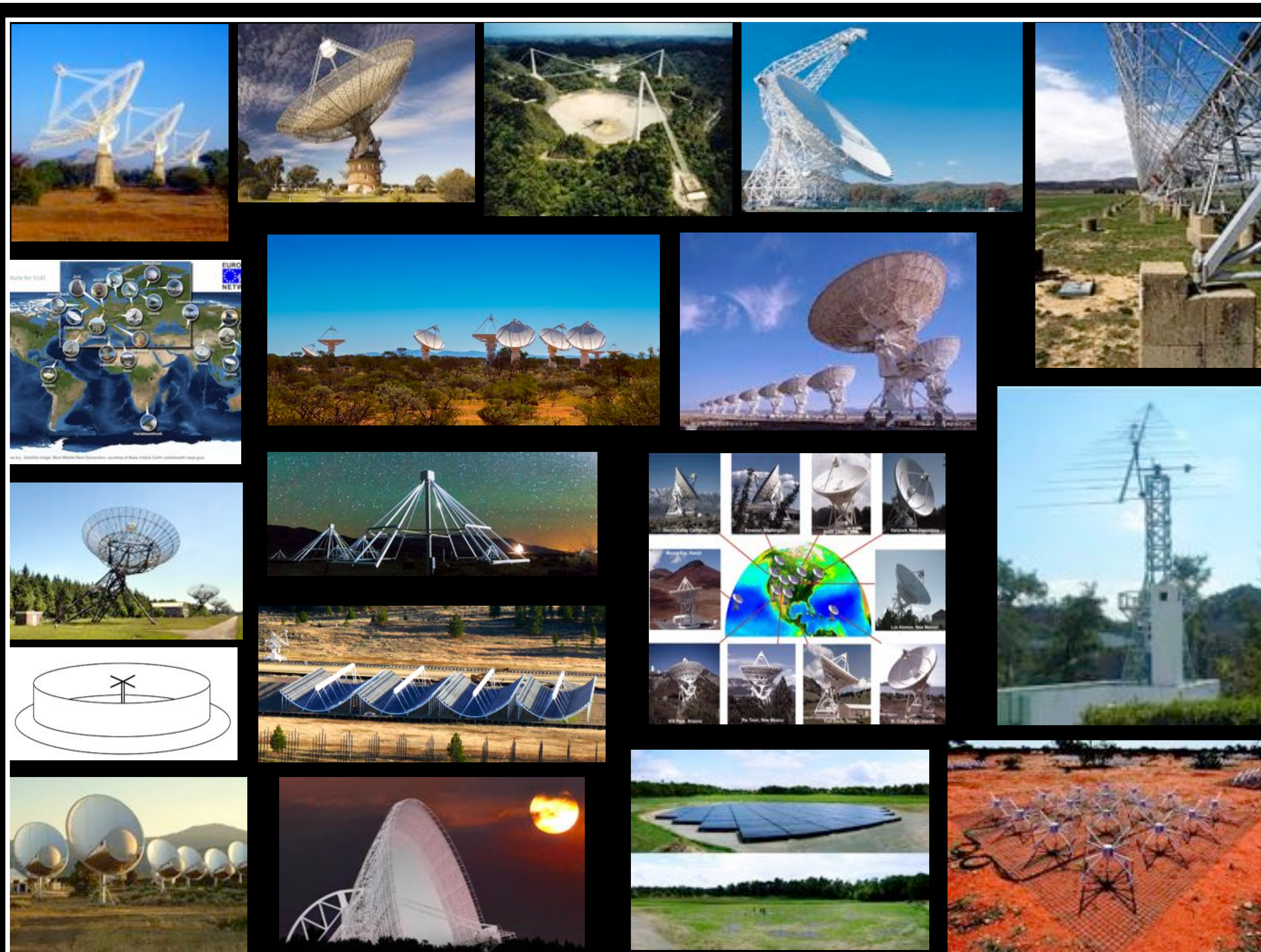


FRBs

Quasars



HI



Radio telescopes I: optics

How does the optical configuration of a radio telescope affect its performance?
Think about what a radio telescope "sees"

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Fourier relations between

- E-field in aperture/pupil plane ↔ image plane
- Spatial coherence function of incident radiation ↔ intensity pattern of radiators
- Aperture geometry and apodization ↔ point-spread function

Important to recognize the difference between Fraunhofer and Fresnel diffraction regimes.

Radio telescopes II: sensitivity

What do we measure with radio telescopes, and what determines its uncertainty?

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Received spectral power density from a source: $kT_\mathrm{A} \equiv P_\nu = \frac{A_e S_\nu}{2}$.

In total, $T_\mathrm{sys} = \frac{P_{\nu,\,\mathrm{tot}}}{k} = T_\mathrm{CMB} + T_\mathrm{radio\,bkg} + (1 - e^{-\tau_A})T_\mathrm{atm} + T_\mathrm{spill} + T_\mathrm{RX} + T_A$.

Nyquist-Shannon sampling theorem implies $2BT$ independent samples in bandwidth *B* and time *T*.

But the estimator of T_sys is chi-squared with one d.o.f., implying a variance of $2T_\mathrm{sys}^2$.

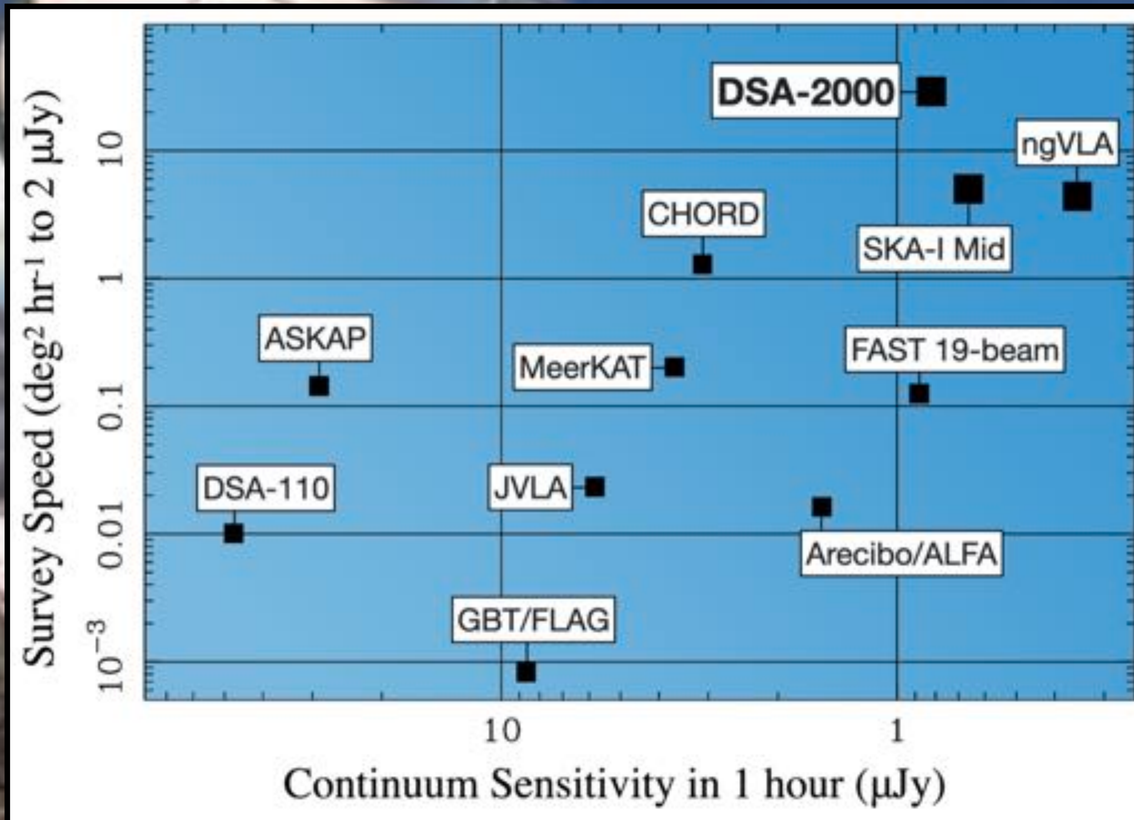
Thus, the uncertainty in a measurement of T_sys is

$$\sigma_T^2 = \frac{2T_\mathrm{sys}^2}{N} = \frac{T_\mathrm{sys}^2}{BT} \qquad \text{(radiometer equation)}$$

Radio telescopes III: signal processing

What can radio telescopes do that IR / optical / UV / X-ray / gamma-ray telescopes cannot?

The DSA-2000: the most powerful radio telescope ever built (2028+)



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What about a few decades from now?

A picture of the nHz gravitational-wave sky.

Mapping of the ionization of the IGM as the first stars and galaxies formed.

Small-scale baryon power spectrum with FRBs, leading to neutrino mass measurements.

Exotic pulsar systems: psr-bh, quark/strange star.

CMB B-mode polarization.

The composition of dark matter.