# The Galactic distribution of SNRs

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## Outline

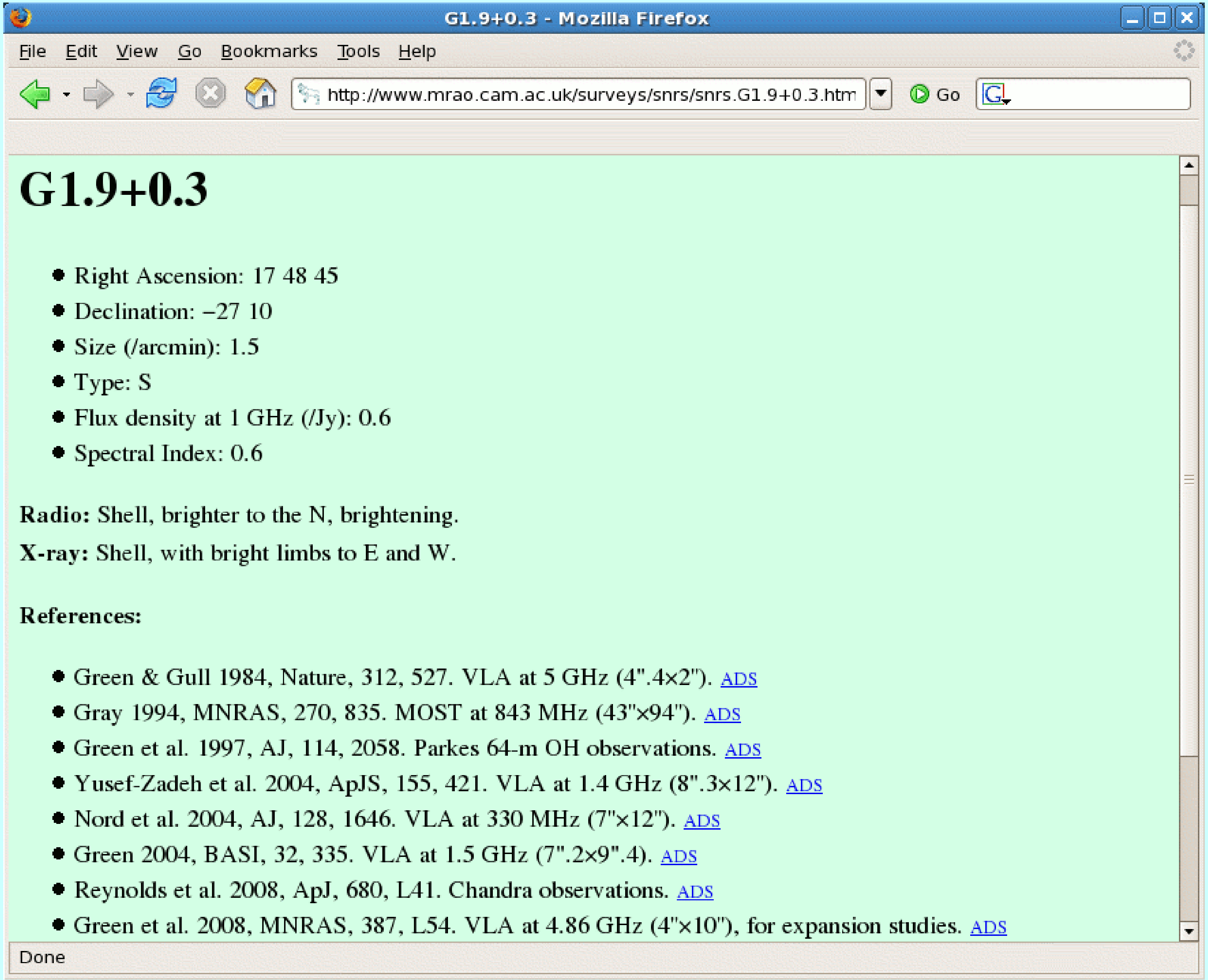
- a catalogue of 274 Galactic SNRs
- selection effects
- the $\Sigma$–$D$ relation
- the Galactic SNR distribution
- conclusions

## A Catalogue of Galactic SNRs

Since 1984 I have produced several catalogues of Galactic SNRs, see

`http://www.mrao.cam.ac.uk/surveys/snrs/`

- latest version – 2009 March – contains 274 remnants
  (the first version, 1984, contained 145 remnants)
  *Green 2009, Bulletin of the Astronomical Society of India, 37, 45*
- contains:
  - basic parameters
    (Galactic and equatorial coordinates, size, type, radio flux density at 1 GHz, radio spectral index, other names)
  - short descriptions of the observed structure in the radio, X-ray and optical
  - other notes (distances, pulsars or point sources nearby, etc)
  - references (with ADS links)
- it also includes lists of possible or probable SNRs reported in the literature




# G1.9+0.3

- Right Ascension: 17 48 45
- Declination: −27 10
- Size (/arcmin): 1.5
- Type: S
- Flux density at 1 GHz (/Jy): 0.6
- Spectral Index: 0.6

**Radio:** Shell, brighter to the N, brightening.

**X-ray:** Shell, with bright limbs to E and W.

**References:**


- Green & Gull 1984, Nature, 312, 527. VLA at 5 GHz (4".4×2"). ADS
- Gray 1994, MNRAS, 270, 835. MOST at 843 MHz (43"×94"). ADS
- Green et al. 1997, AJ, 114, 2058. Parkes 64-m OH observations. ADS
- Yusef-Zadeh et al. 2004, ApJS, 155, 421. VLA at 1.4 GHz (8".3×12"). ADS
- Nord et al. 2004, AJ, 128, 1646. VLA at 330 MHz (7"×12"). ADS
- Green 2004, BASI, 32, 335. VLA at 1.5 GHz (7".2×9".4). ADS
- Reynolds et al. 2008, ApJ, 680, L41. Chandra observations. ADS
- Green et al. 2008, MNRAS, 387, L54. VLA at 4.86 GHz (4"×10"), for expansion studies. ADS

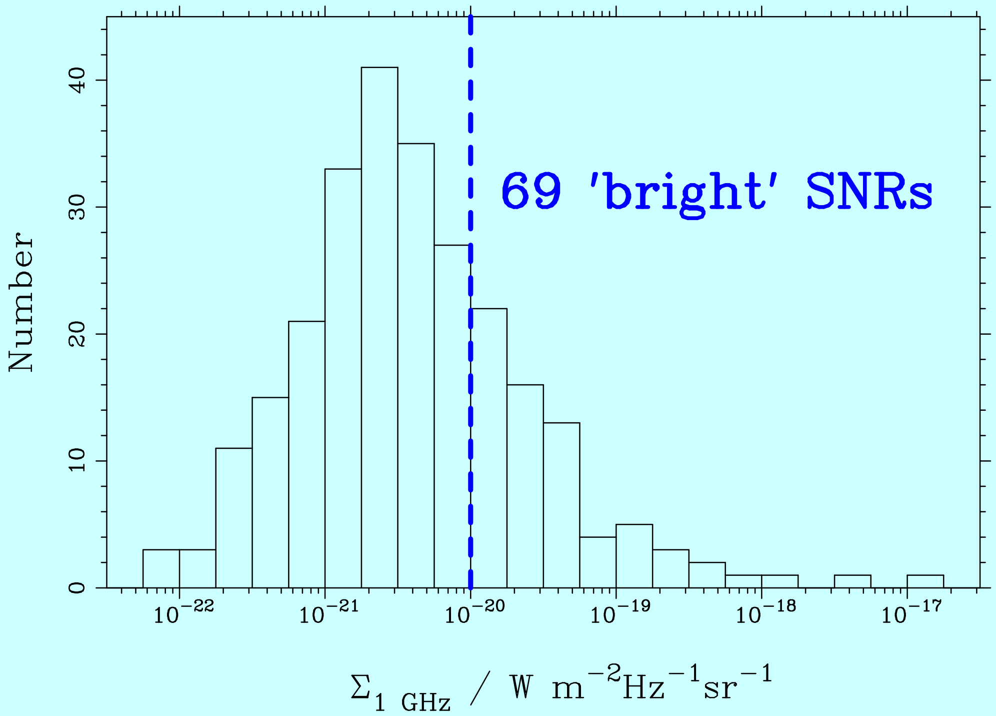

*An example webpage from the SNR catalogue*

## Selection effects

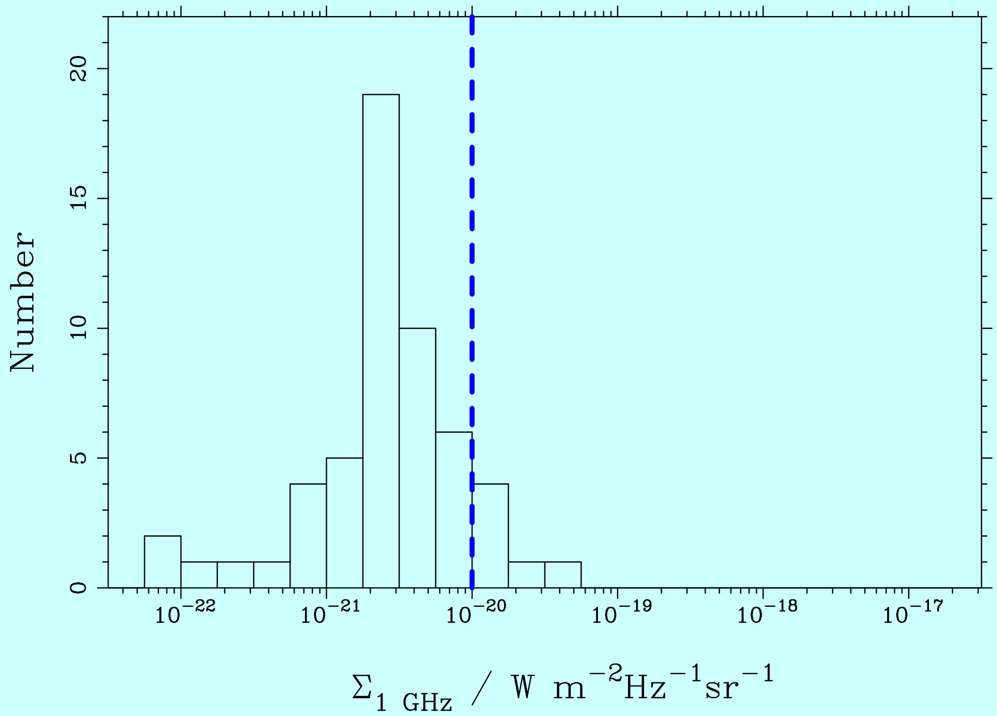
The dominant selection effects are those that are applicable at radio wavelengths:

1) faint remnants are difficult to recognise against the varying Galactic background
   - most fainter SNRs are in regions with low Galactic background i.e. in the 2nd and 3rd quadrants at large Galactocentric radii (or away from $b = 0°$)
2) small angular size remnants are not resolved in wide-field surveys, so are not recognised
   - so young but distant SNRs are missing from present catalogues
   - these missing SNRs are likely to be close to $b = 0°$ and to $l = 0°$, in complex regions of the Galactic plane, where confusion is a problem

Note: both selection effects apply more strongly nearer to $l = 0°$

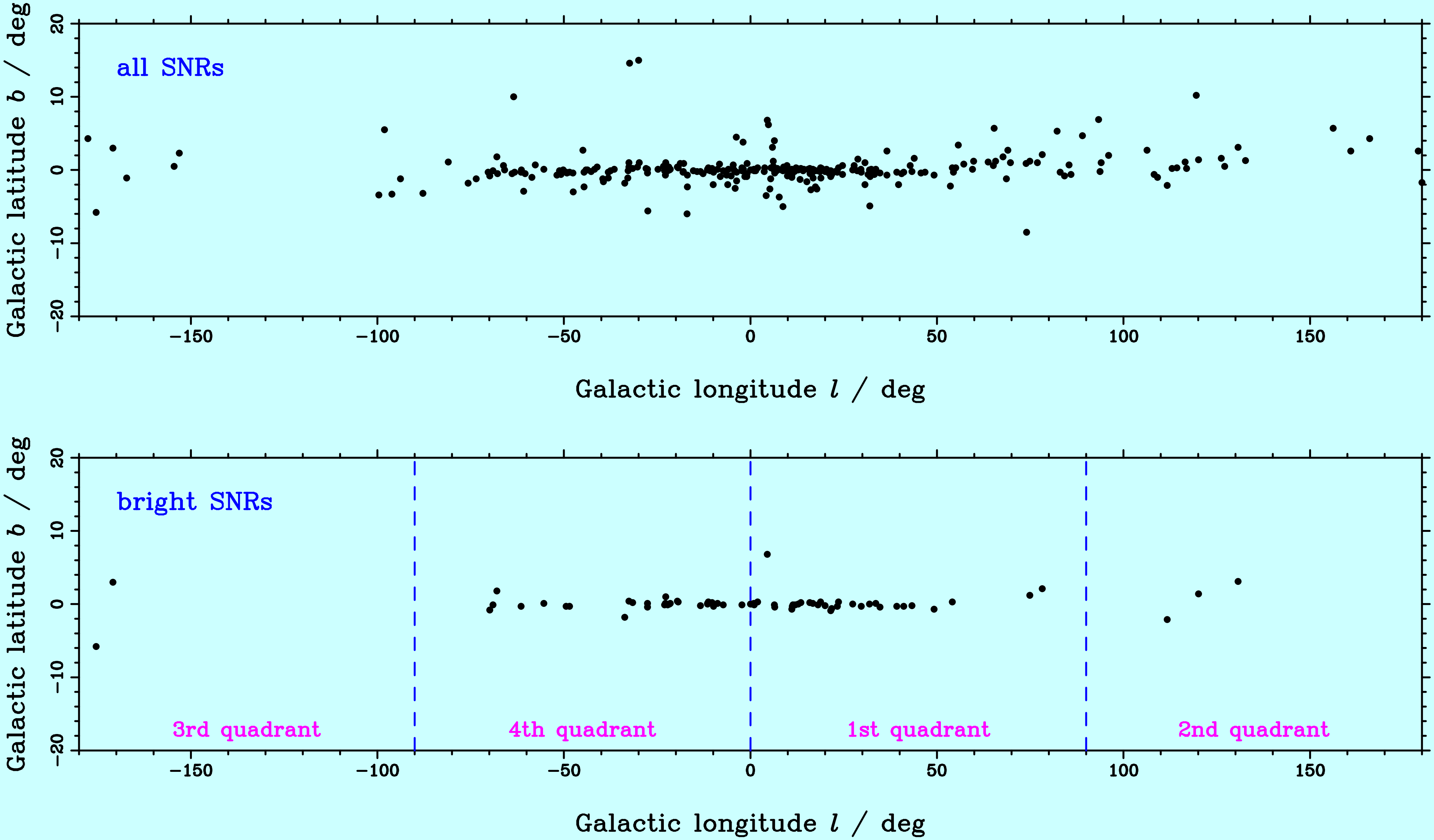



*Σ for all SNRs*



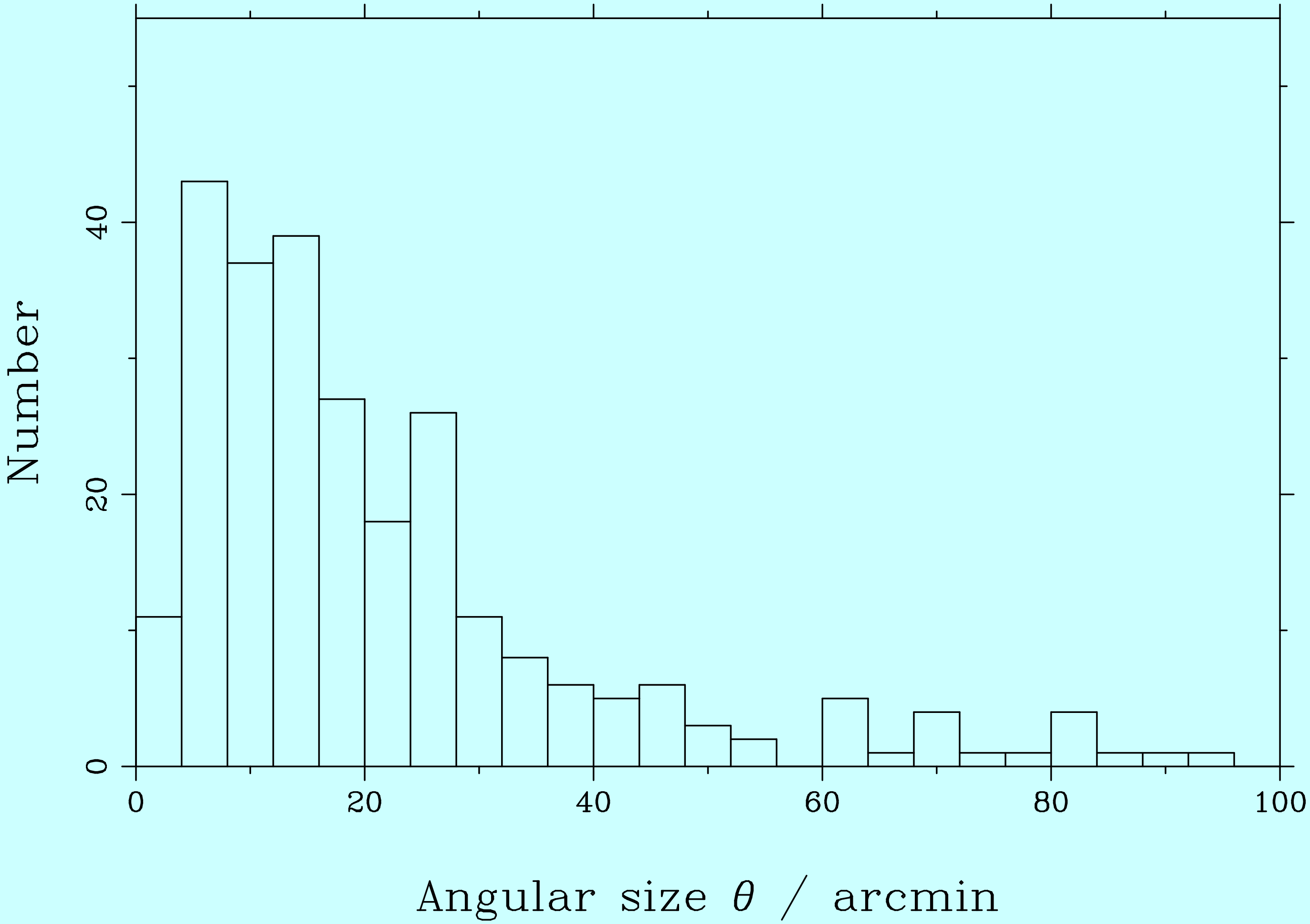

*Σ for recently identified SNRs*

- surface brightnesses completeness limit of $\approx 10^{-20}$ W $m^{-2}$ $Hz^{-1}$ $sr^{-1}$ (at 1 GHz) is suggested
- 69 SNRs brighter than this limit

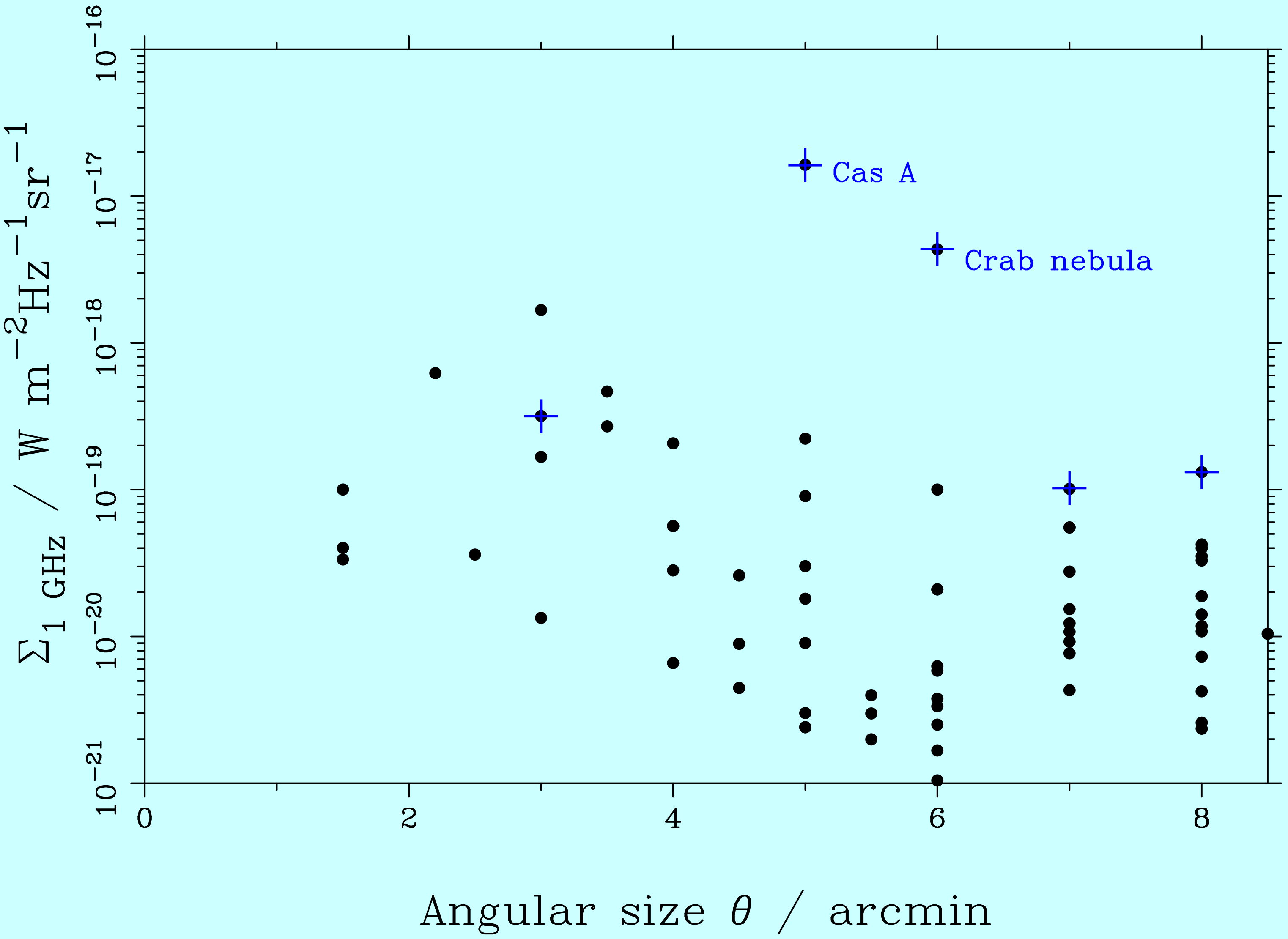



*Galactic distribution of (top) all Galactic SNR and (bottom) those SNRs with a surface brightness at 1 GHz greater than* $10^{-20}$ W m$^{-2}$ Hz$^{-1}$ sr$^{-1}$ *(the latitude and longitude axes are not to scale)*

# The angular size ($\theta$) selection effect




*Angular sizes of known Galactic SNRs (some larger remnants are omitted).*




*Surface brightness at 1 GHz against angular size for known Galactic SNRs of angular size ≤ 8 arcmin (the five historical remnants are indicated by additional crosses)*

## The $\Sigma - D$ relation: the ideal (1)

Since distance are not available for most Galactic SNRs, many statistical studies of have relied on the '$\Sigma - D$' relation

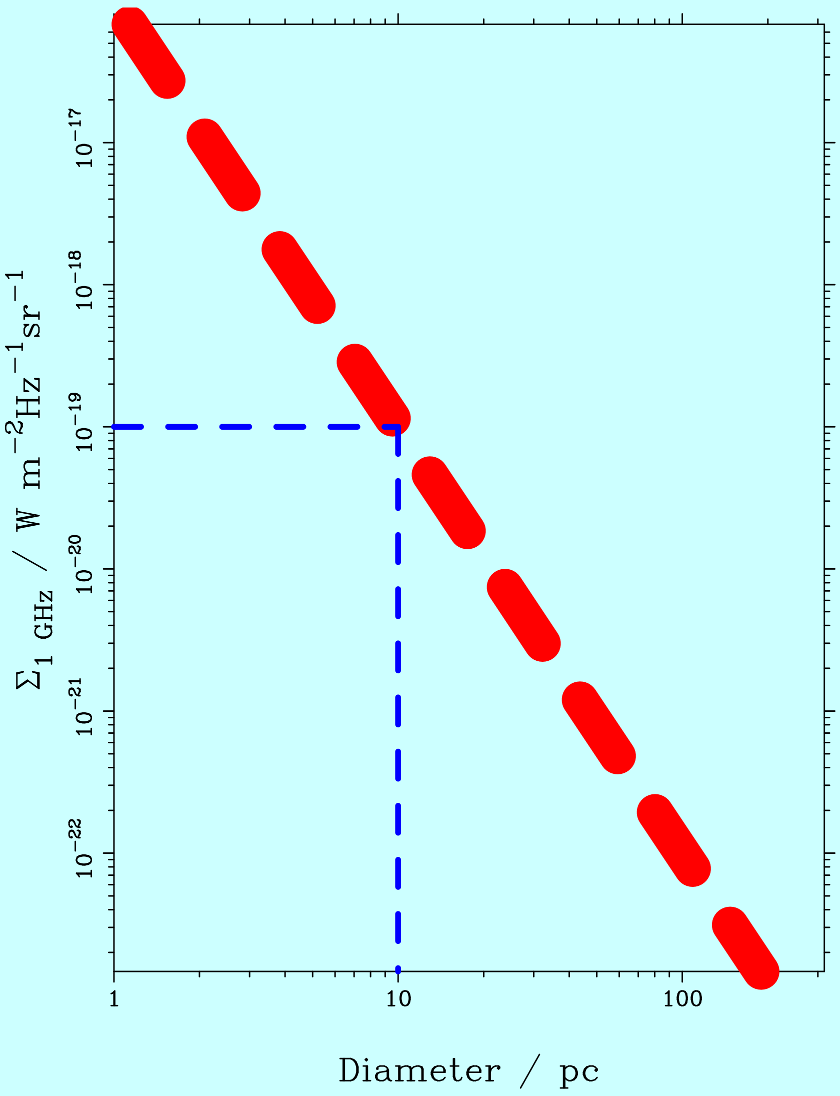
- for remnants with known distances, $d$, and hence known diameters ($D = \theta d$), physically large SNRs are seen to be lower surface brightnesses ($\Sigma$) than small remnants
- this correlation can be modelled as

$$\Sigma \propto D^{-n}$$

note that $\Sigma$ is *distant independent*

# The $\Sigma$–$D$ relation: the ideal (2)

- a physical diameter can be deduced from the *observed* surface brightness of any remnant using the $\Sigma$–$D$ correlation
- then a distance to the remnant can be deduced using its *observed* angular size

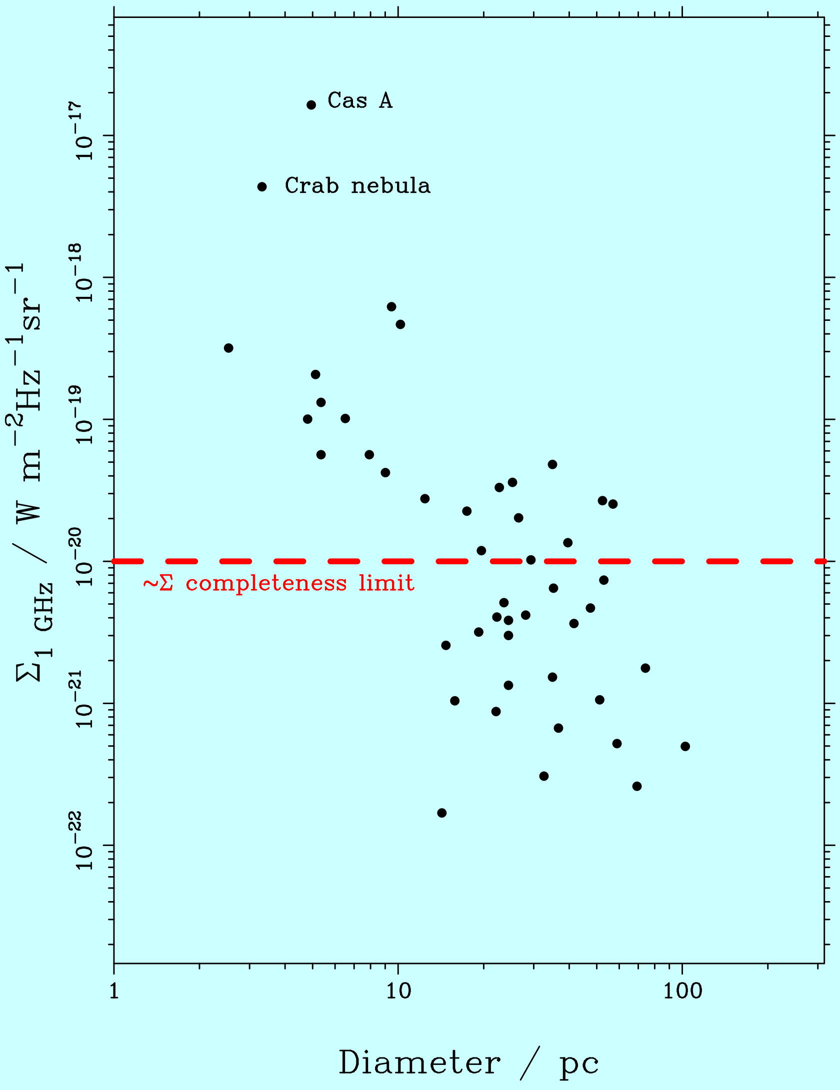



*An idealised $\Sigma$–$D$ relation for Galactic SNRs*

# Some reality (1): the observed $\Sigma$–$D$ relation

But, the observed '$\Sigma$–$D$' relation shows a wide range of diameters for a given surface brightness

- for a particular surface brightness the diameters of SNRs vary by up to about an order of magnitude
- given the observational selection effects, this range may be even larger

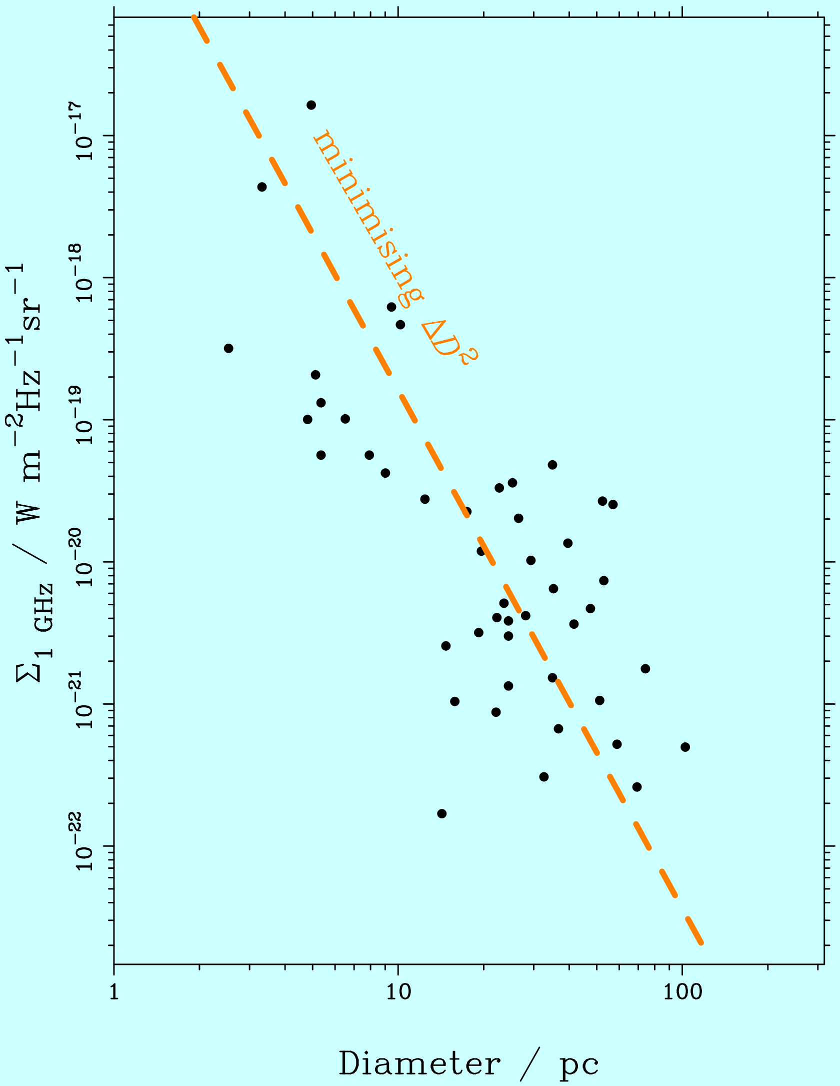



*The $\Sigma$–$D$ relation for 47 Galactic SNRs with known distances*

# Some reality (2): which regression?

- least-squares regression by minimising the $\Sigma$ differences, and by minimising the $D$ differences, are *not* the same
- to *predict* $D$ from $\Sigma$, then a least squares fit minimising deviations in $D$ *not* in $\Sigma$ should be used

e.g. Case & Bhattacharya (1998, ApJ, 504, 761) derived a relationship with $n = 2.65 \pm 0.30$ for Galactic SNRs by minimising deviations in $\Sigma$, which *overestimates* the diameters (and distances) of fainter remnants)




*The $\Sigma$−$D$ relation for 47 Galactic SNRs with known distances*

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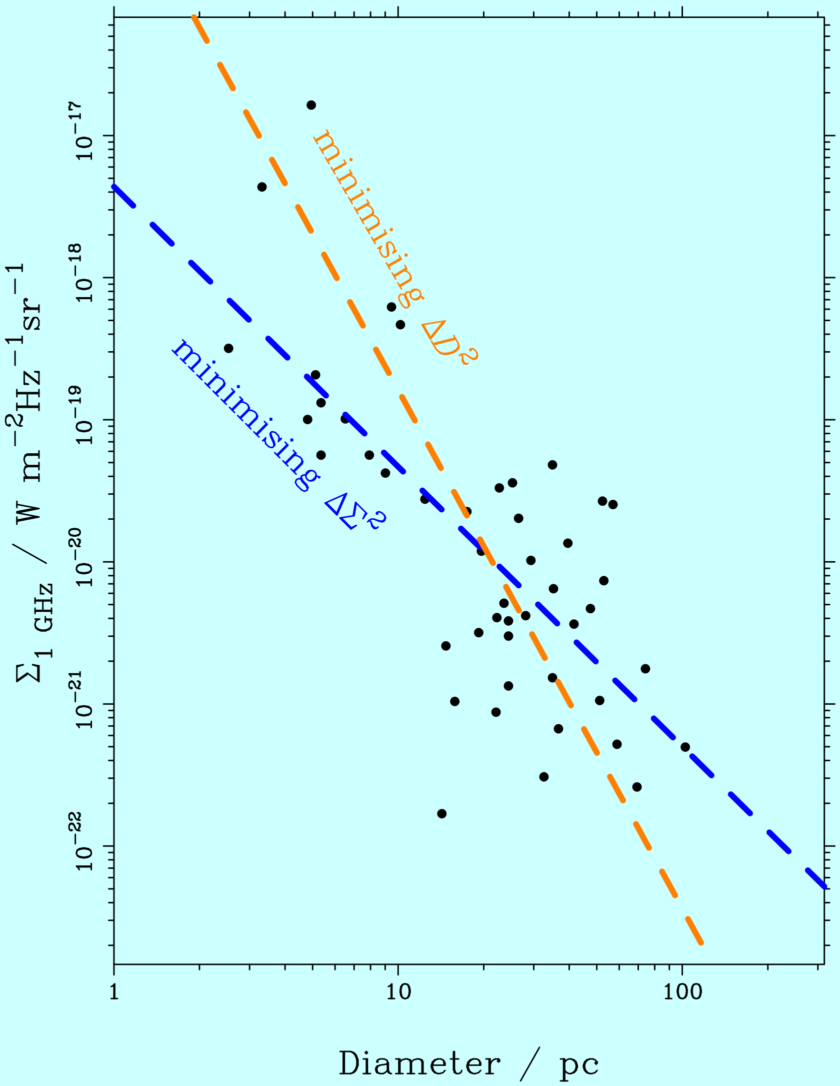
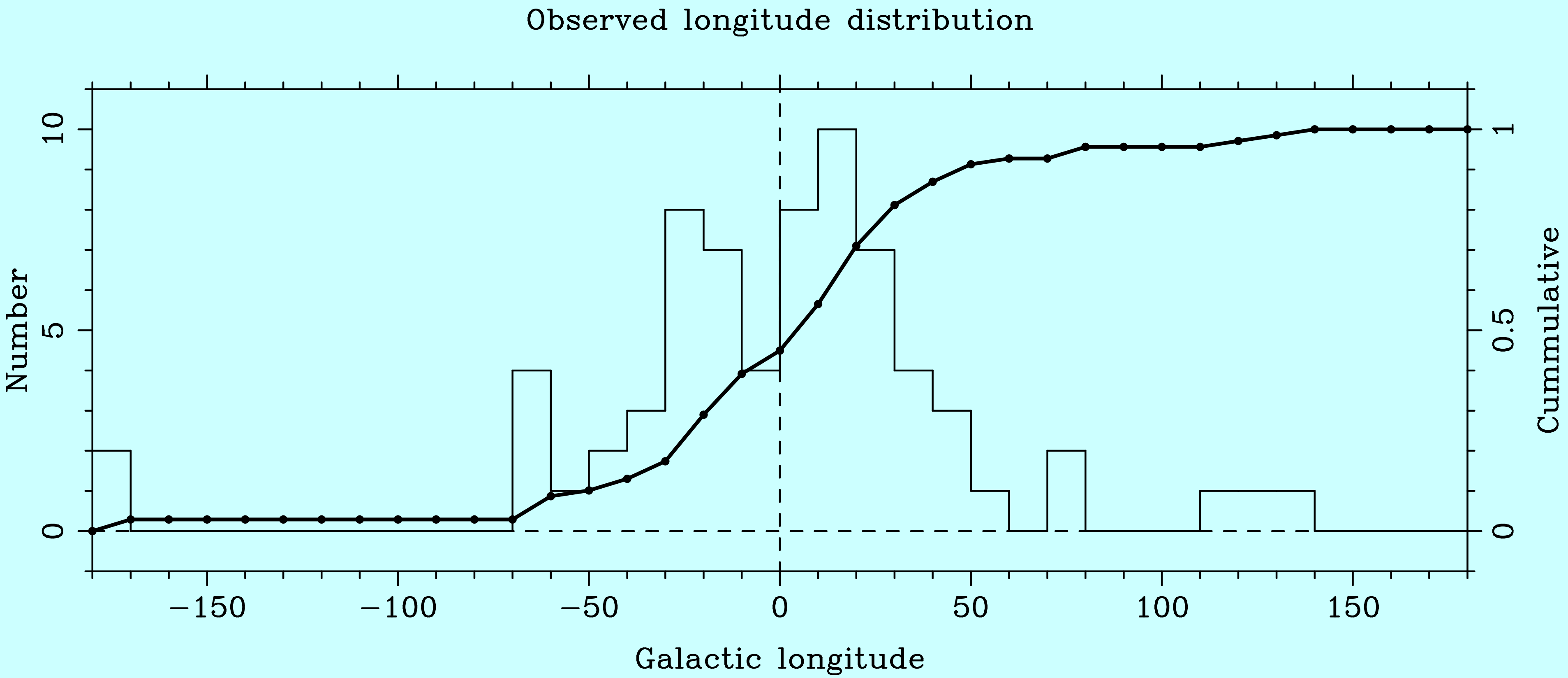



*The $\Sigma$−$D$ relation for 47 Galactic SNRs with known distances*

# The Galactic SNR distribution




*Observed l-distribution of 69 ‘bright’ Galactic SNRs.*

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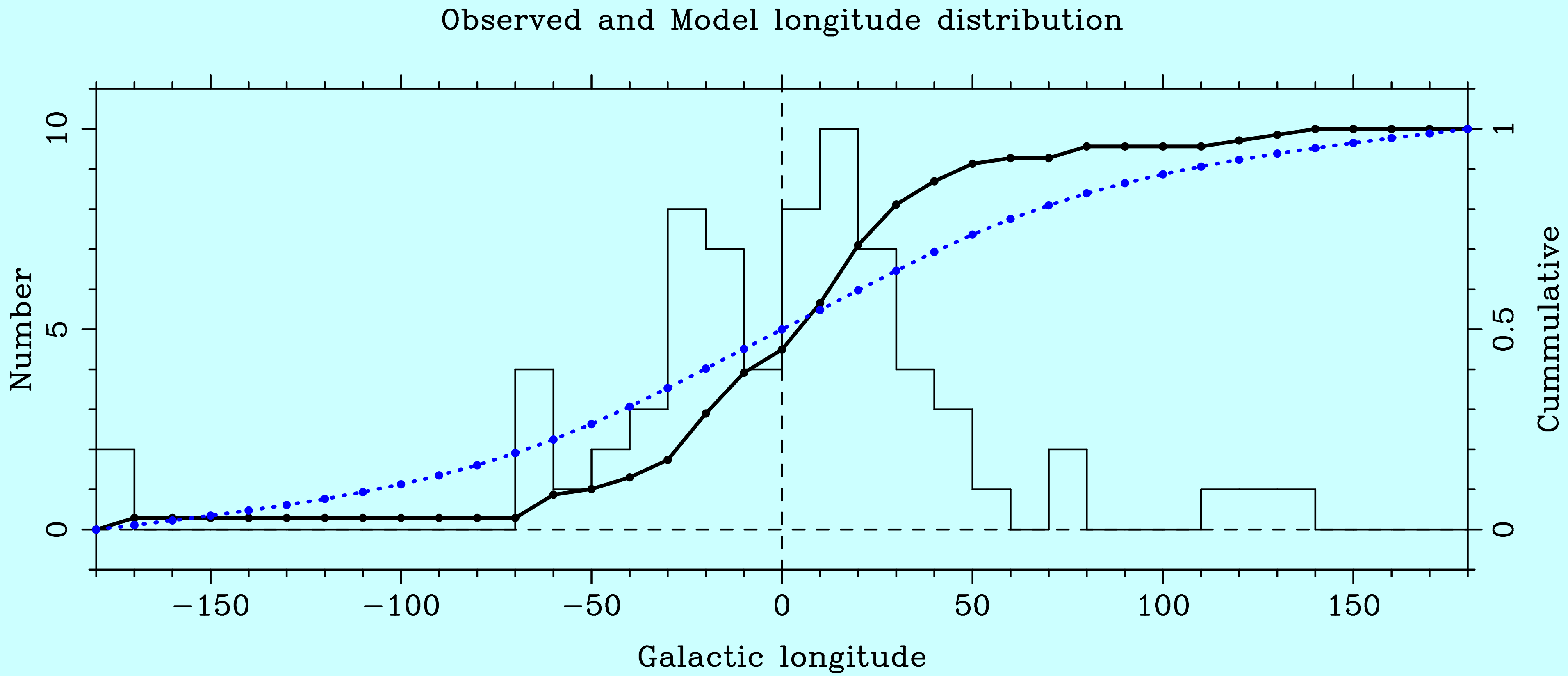


*Observed l-distribution of 69 'bright' Galactic SNRs, and model.*

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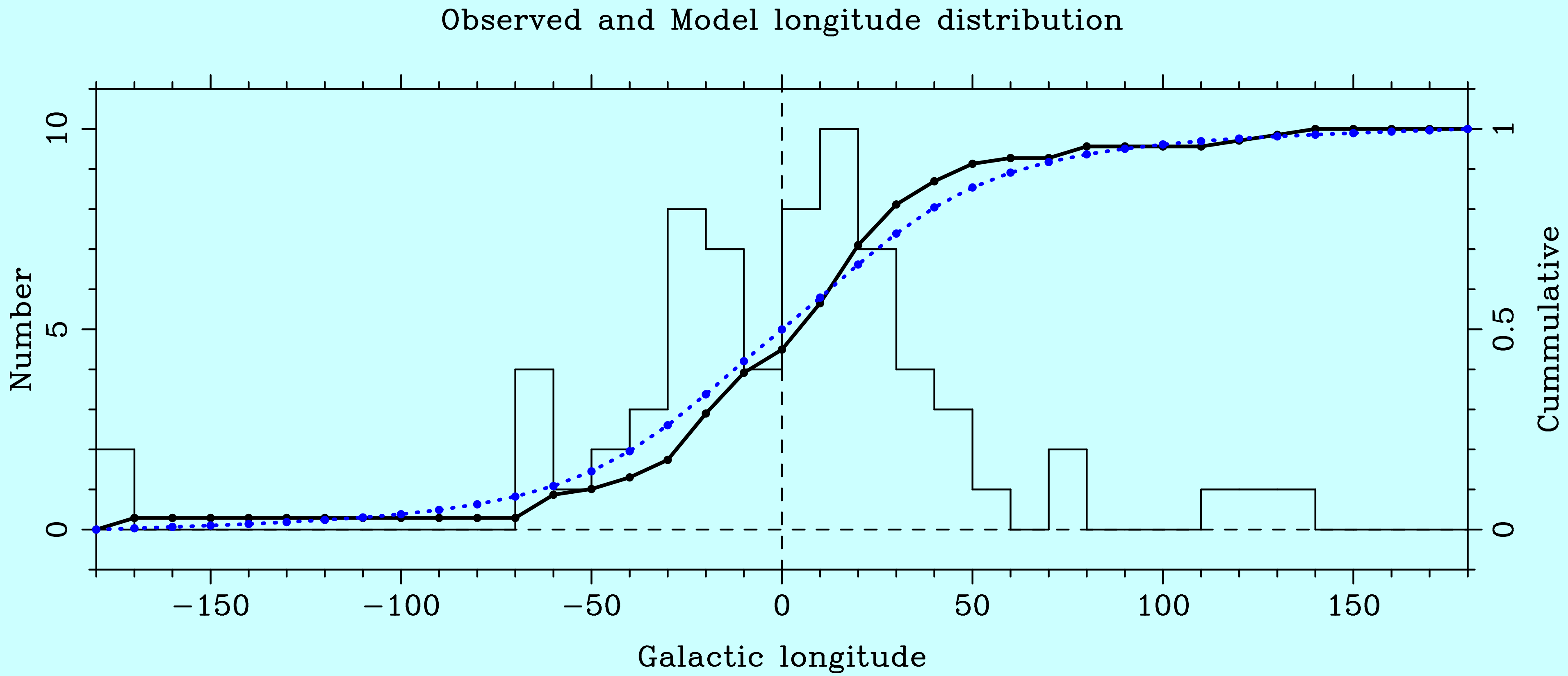


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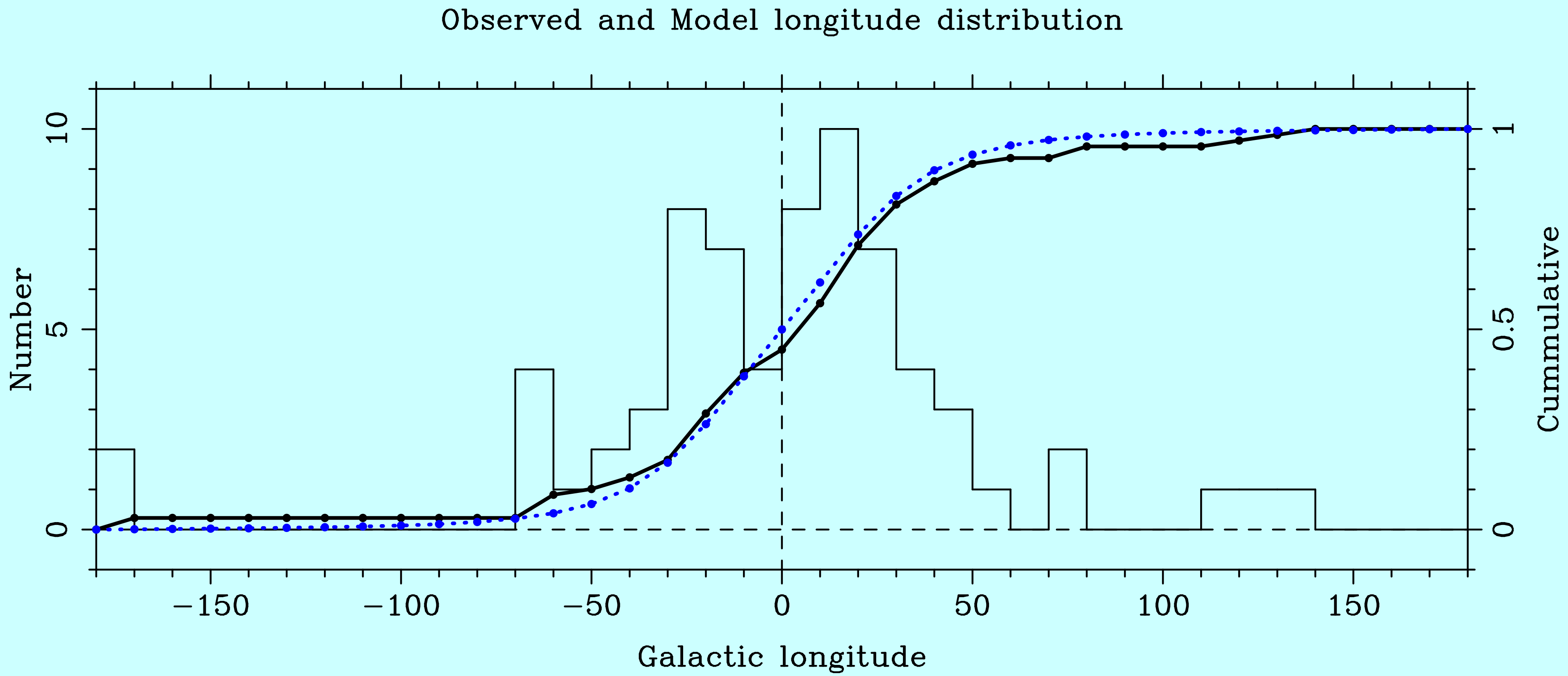


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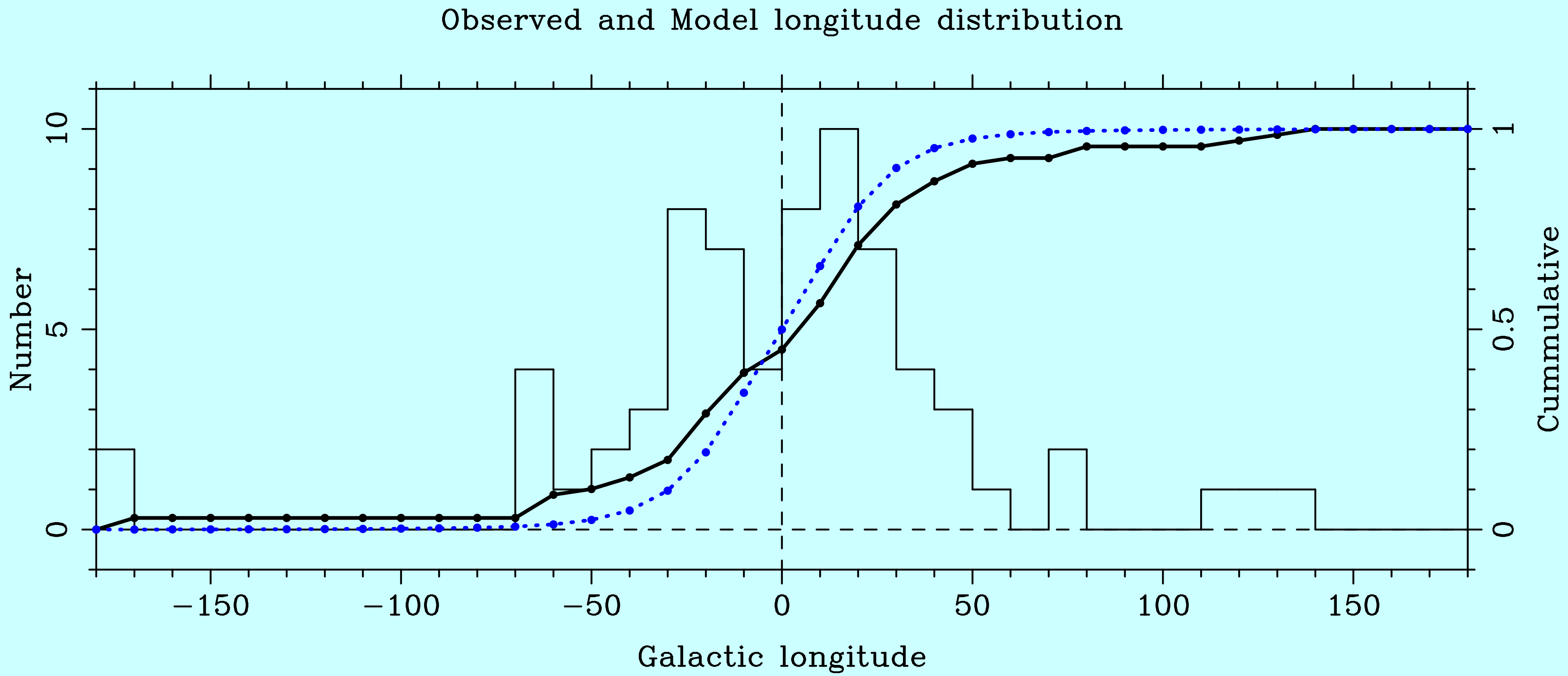


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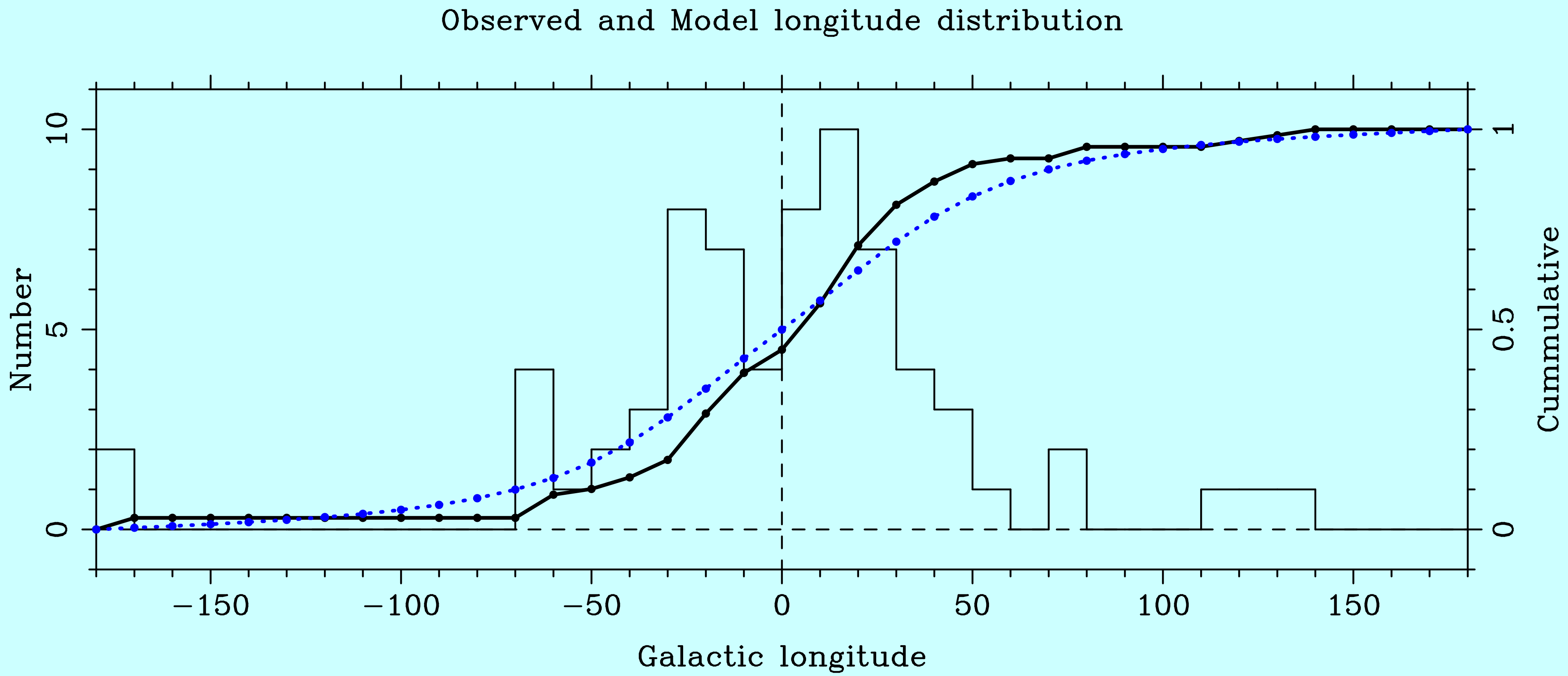
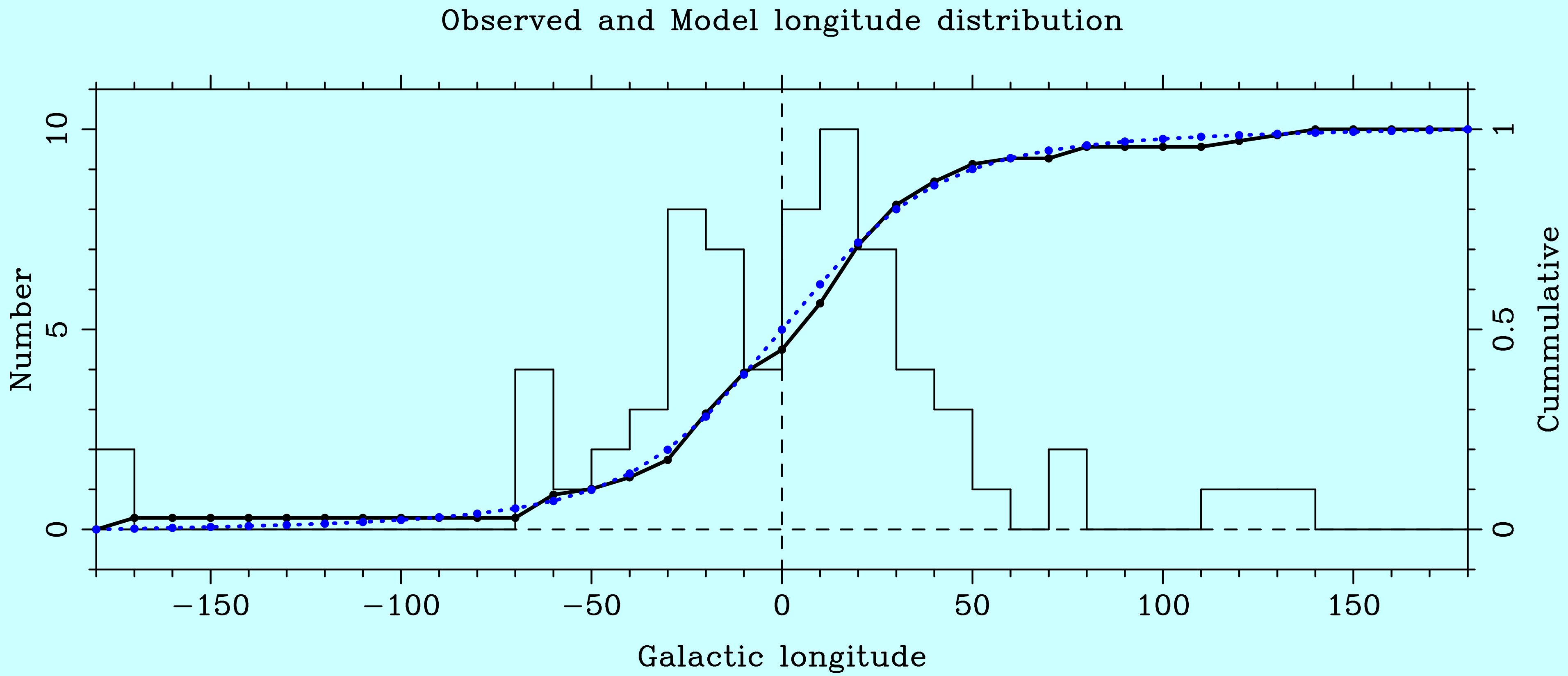



*Observed l-distribution of 69 'bright' Galactic SNRs, plus projection of Case & Bhattacharya distribution with surface density*

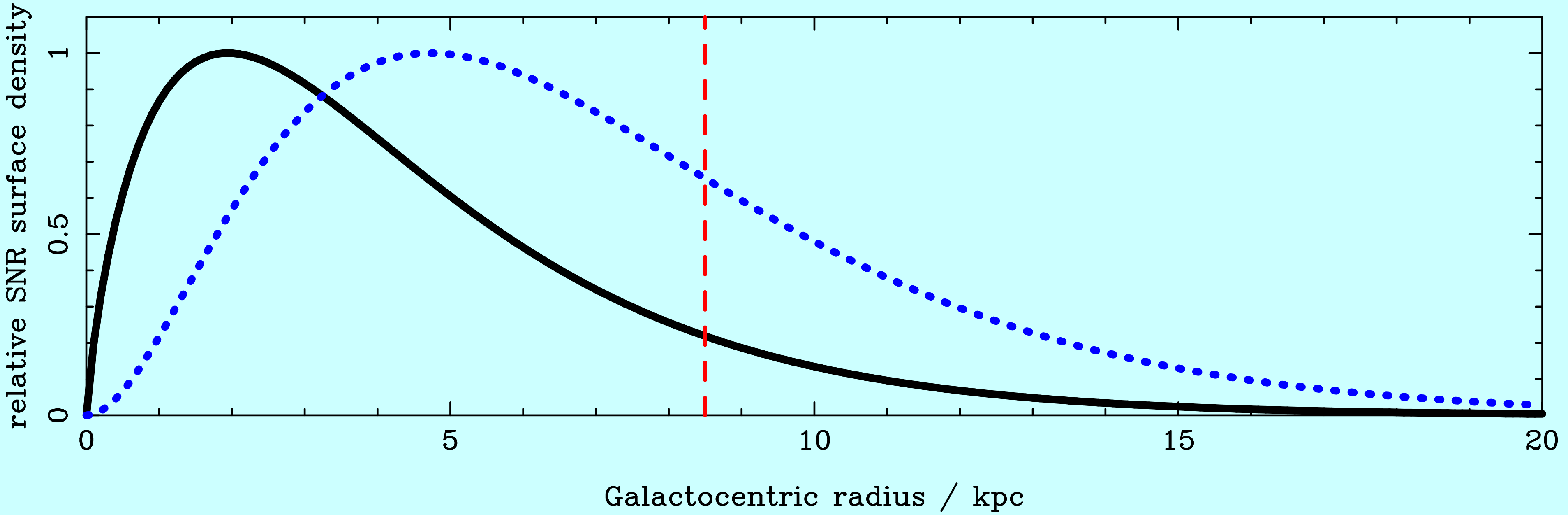
$$\propto \left(\frac{R}{R_\odot}\right)^{2.0} \exp\left[-3.6\frac{(R-R_\odot)}{R_\odot}\right].$$




*Observed l-distribution of 69 'bright' Galactic SNRs, plus projection of a distribution with surface density*

$$\propto \left(\frac{R}{R_\odot}\right)^{0.8} \exp\left[-3.5\frac{(R-R_\odot)}{R_\odot}\right].$$

# Galactocentric radial distribution




*Galactocentric radial distribution for:*

*solid black line: best-fit power-law/exponential*

*dotted blue line: Case & Bhattacharya power-law/exponential.*

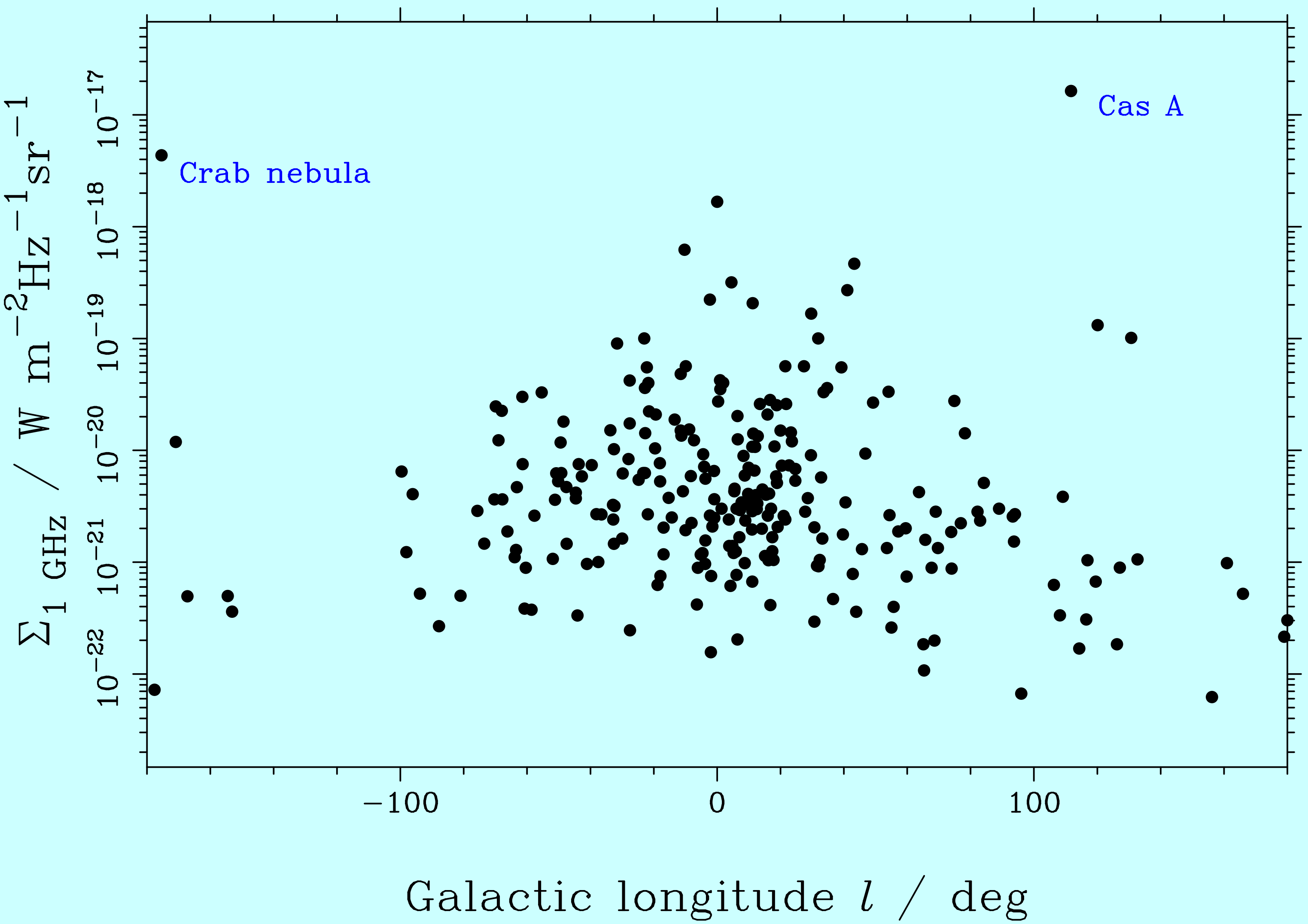
## Conclusions

- selection effects are important for statistical studies of SNRs;
- SNRs show a large range of properties, so the $\Sigma{-}D$ relation is unreliable for individual remnants;
- power-law/exponential distribution of bright remnants implies a more compact distribution than found by Case & Bhattacharya (1998),
  - but not a unique inversion to a radial distribution.

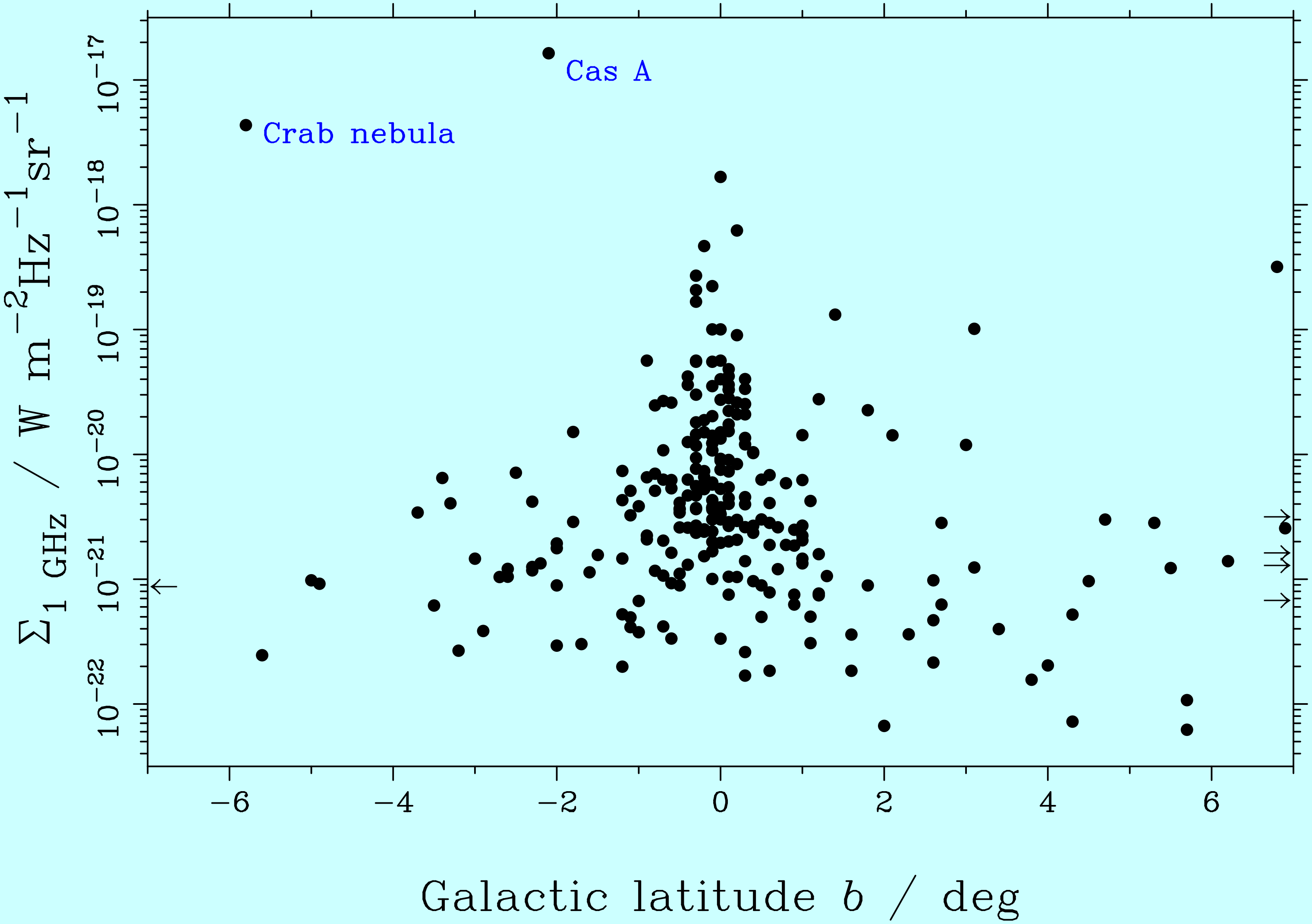
But:

- remaining selection effects mean this apparent distribution is likely to be too broad
- may not be the true distribution, depending on the observability of SNRs (e.g. brightness/visible lifetime changing with ISM density etc.)

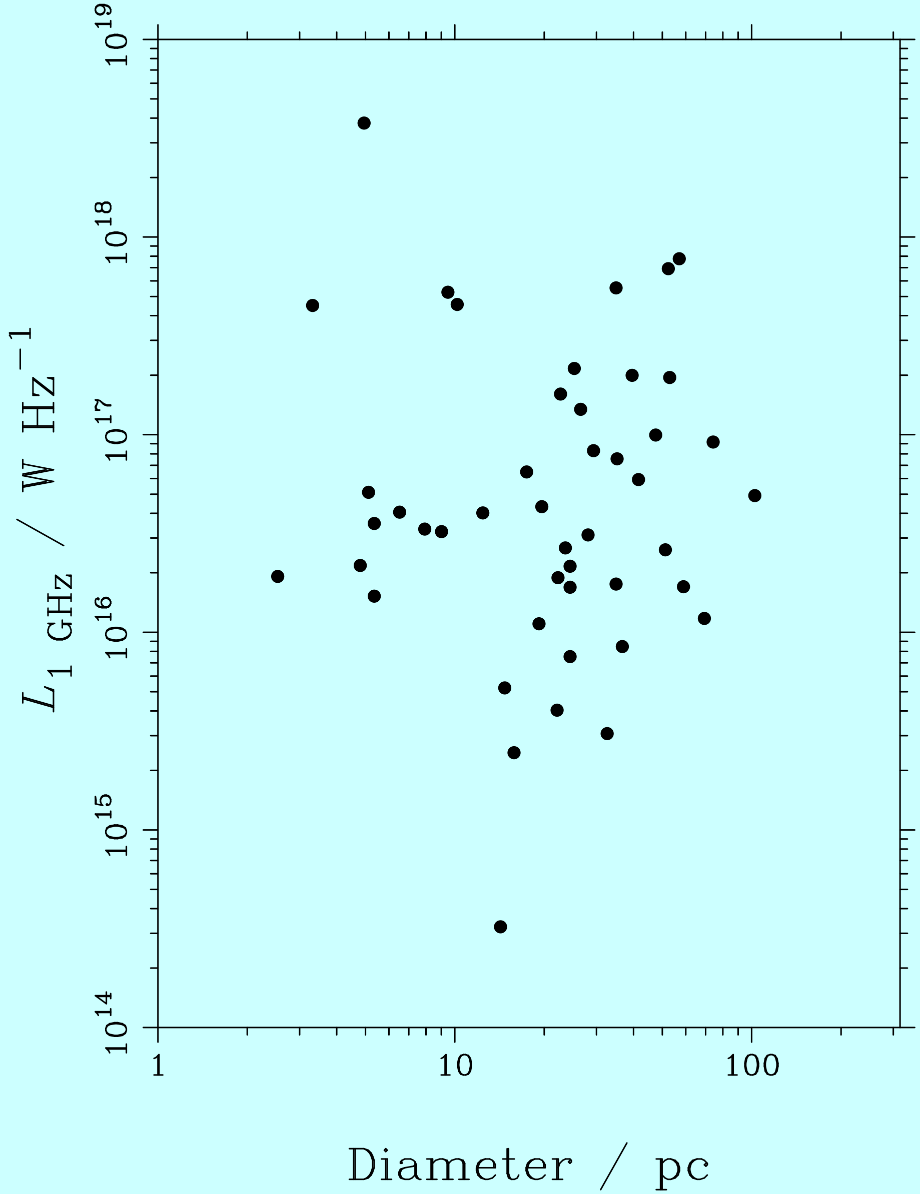
*The End!*




*The distribution of surface brightness against longitude for 258 Galactic SNRs*




*The distribution of surface brightness against latitude for 253 Galactic SNRs (the surface brightnesses of the other 5 remnants with |b| > 7° are indicated by arrows at the left and right edges of the plot)*




*The distribution of luminosity against diameter for SNRs with known distances.*

- surface-brightness is plotted, as it is a distance-independent *observable* for all SNRs
- instead consider the radio luminosity of the remnants ($L$). Since

$$\Sigma \propto \frac{S}{\theta^2} \quad \text{and} \quad L \propto S d^2$$

then

$$\Sigma \propto \frac{L}{(\theta d)^2} \quad \text{or} \quad \Sigma \propto \frac{L}{D^2}.$$

i.e. much of the correlation in the $\Sigma$–$D$ is inevitable, given this $D^{-2}$ bias.