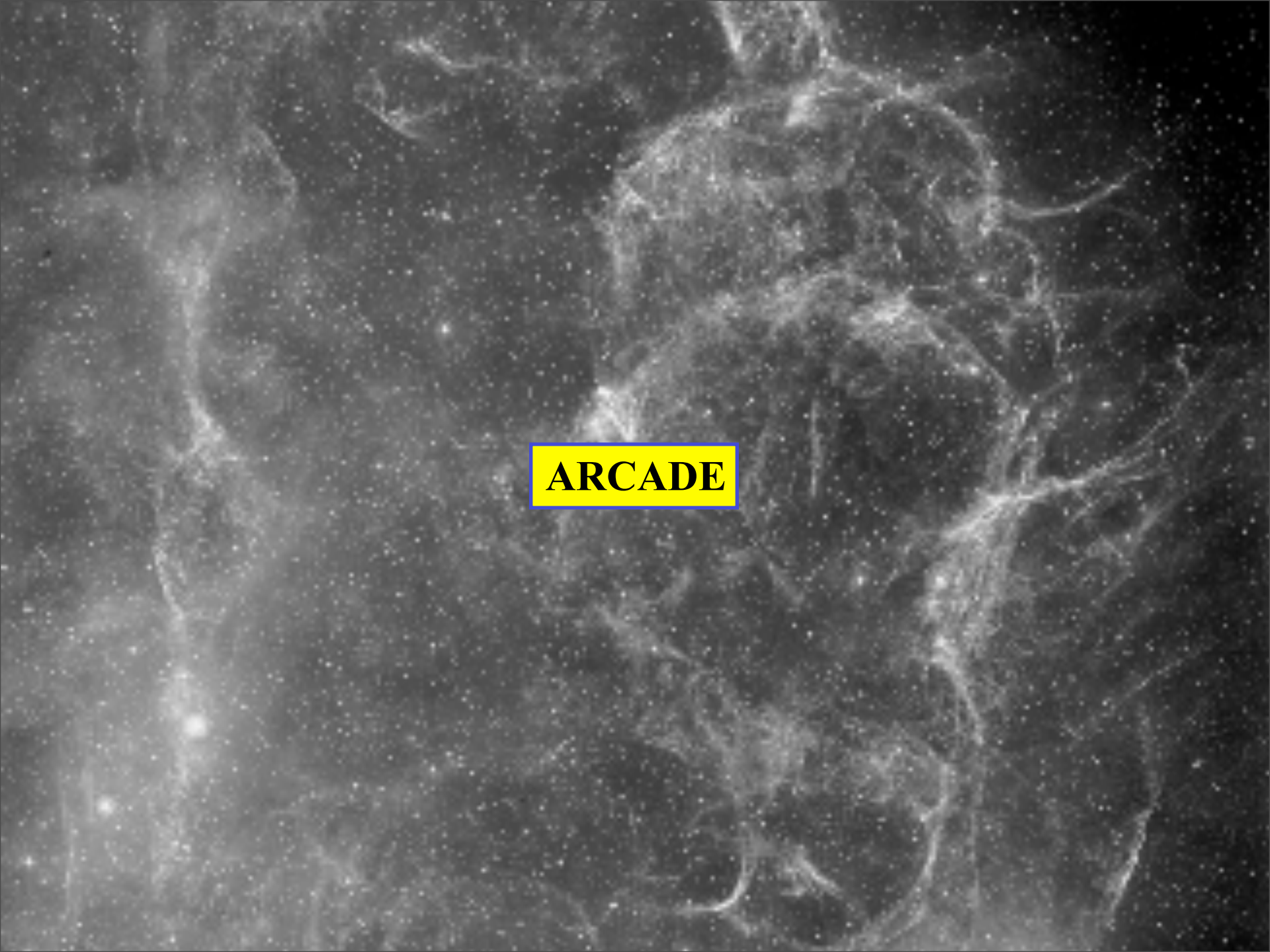
Part the First

Origin of the radio background

- ARCADE and the radio background
- General constraints
- Rejected hypotheses
- Very faint radio sources

Jack Singal
Lukasz Stawarsz
Vahe Petrosian
Andy Lawrence


ARCADE

ARCADE experiment

Instrument paper :
Singal et al 2009

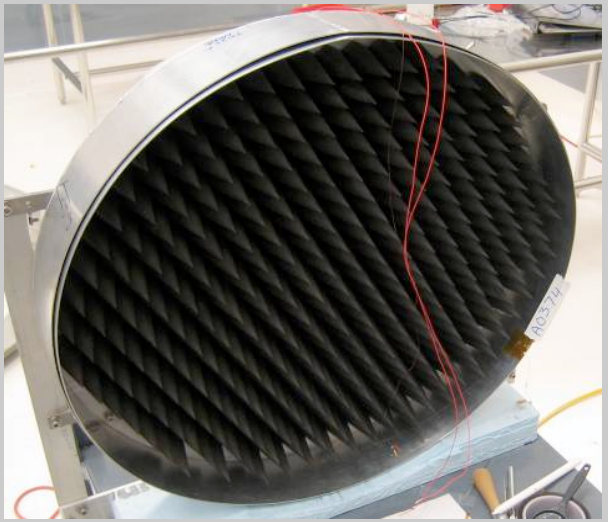
Absolute radiometry of sky 3-90 GHz

PI : A.Kogut

Balloon flight July 2006

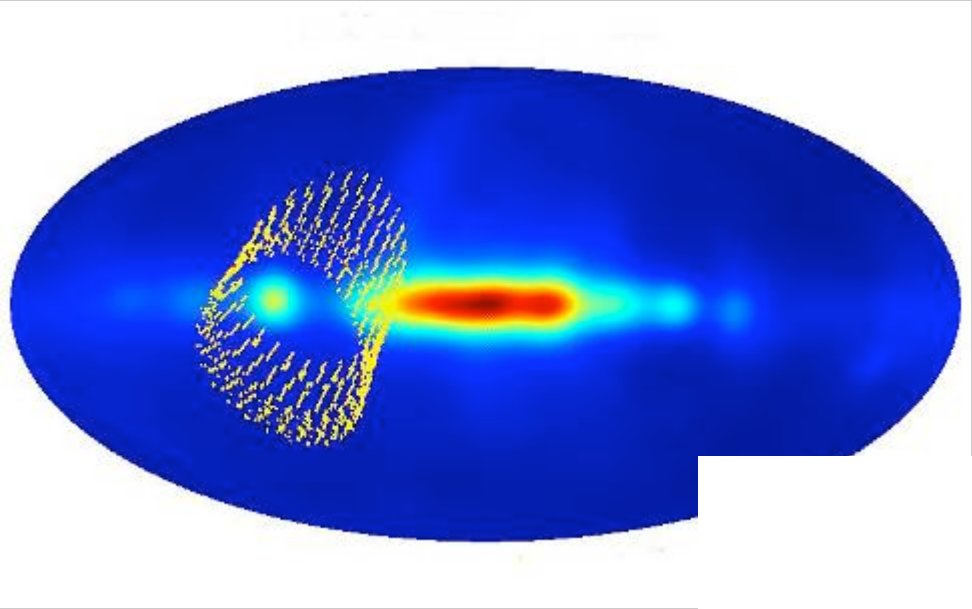
Feed Horns view either sky or calibrator

Calibrator one of blackest microwave objects ever made

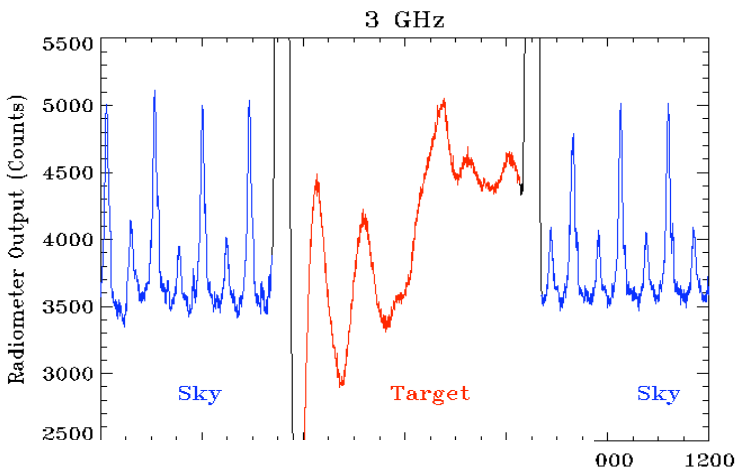


ARCADE measurements

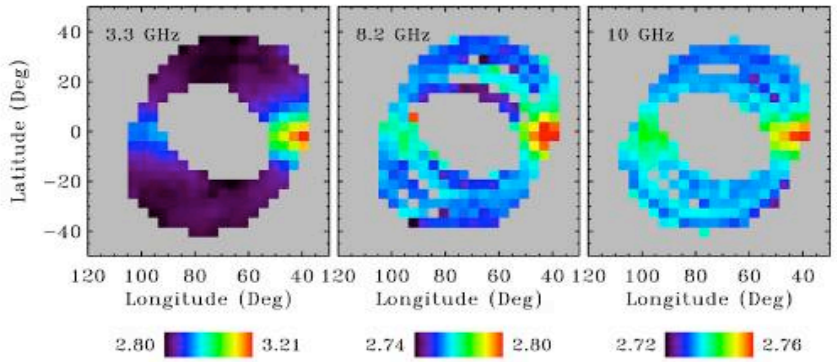
Raw measurements



Flight pattern on top of WMAP 22GHz map



Binned Skymap

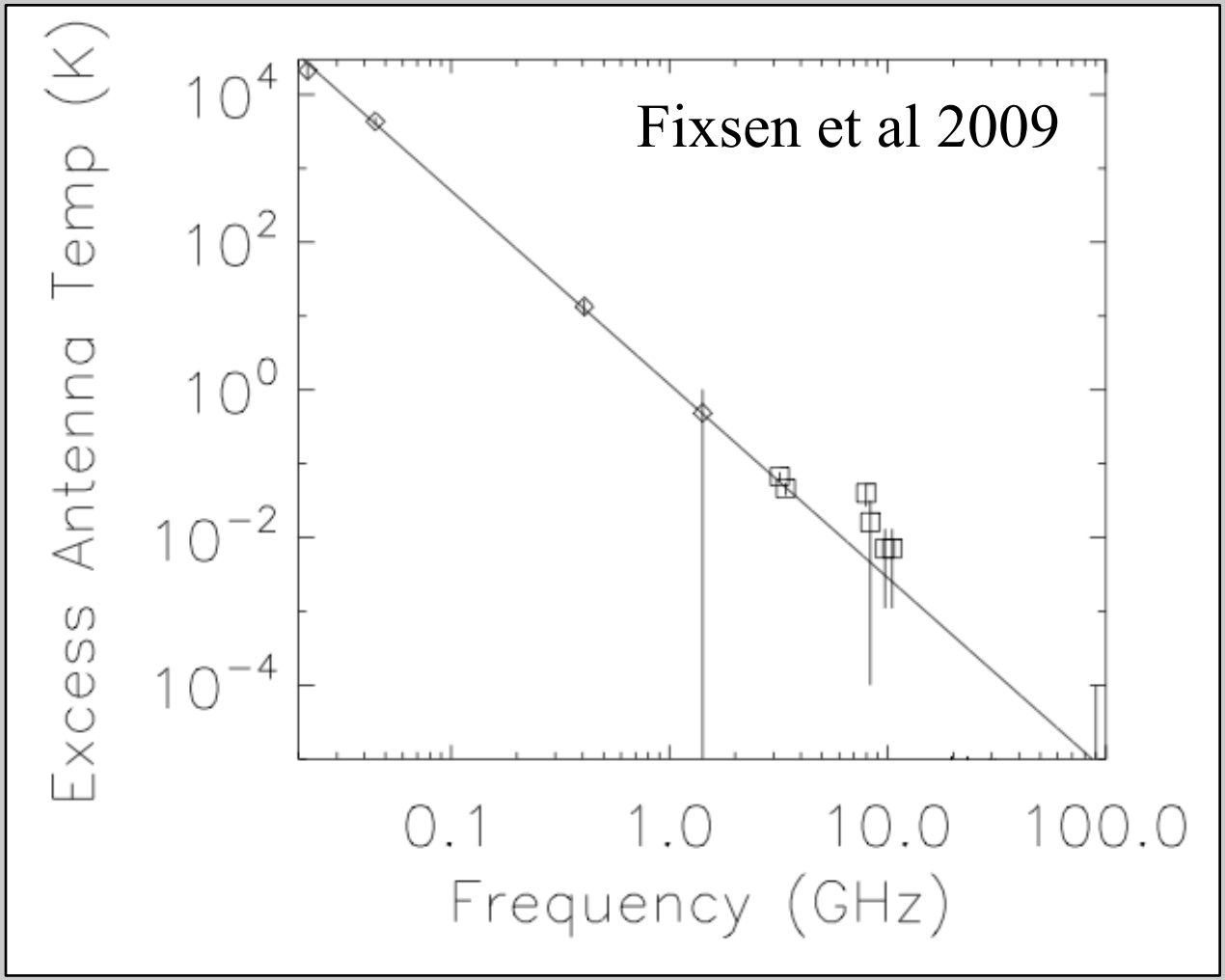


Result

Galactic foreground modelled with 158μm CII map

Results combine ARCADE, FIRAS, and low-frequency surveys

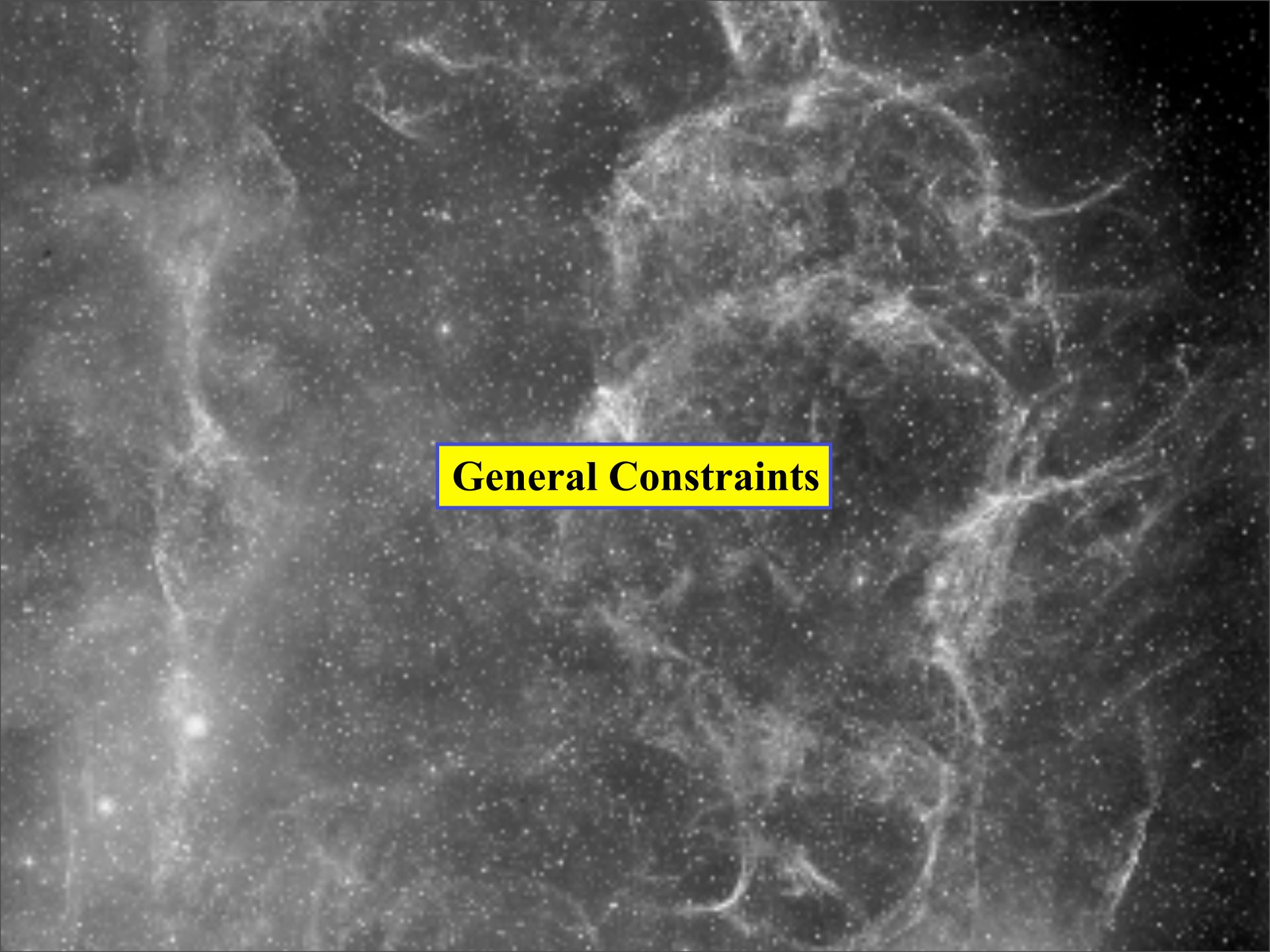
Looks like synchrotron



$$T_{BGND}(\nu) = T_R \left(\nu / 1\,GHz \right)^{\beta}$$

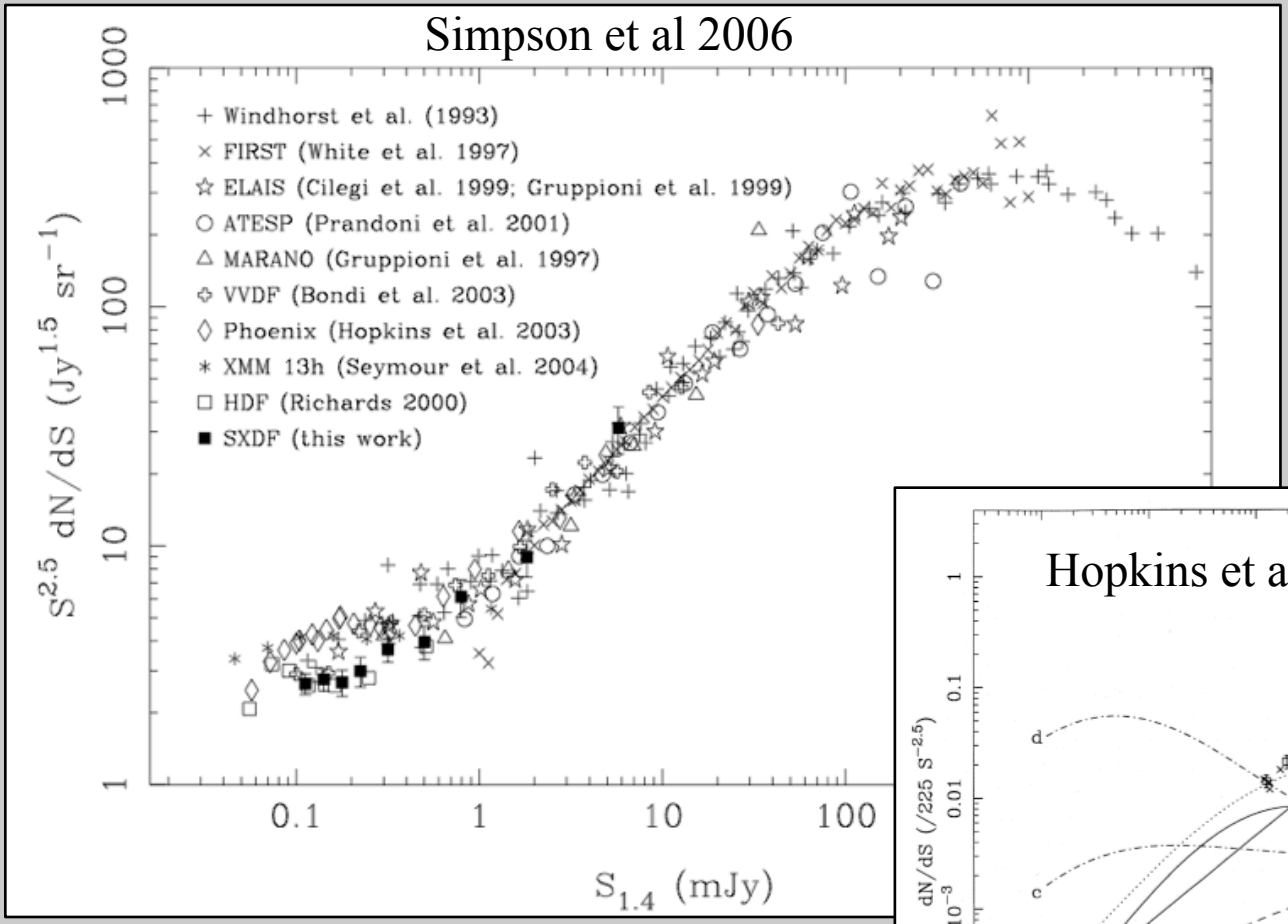
T_R = 1.17 ± 0.12K @ 1 GHz,

β = -2.60 ± 0.04


General Constraints

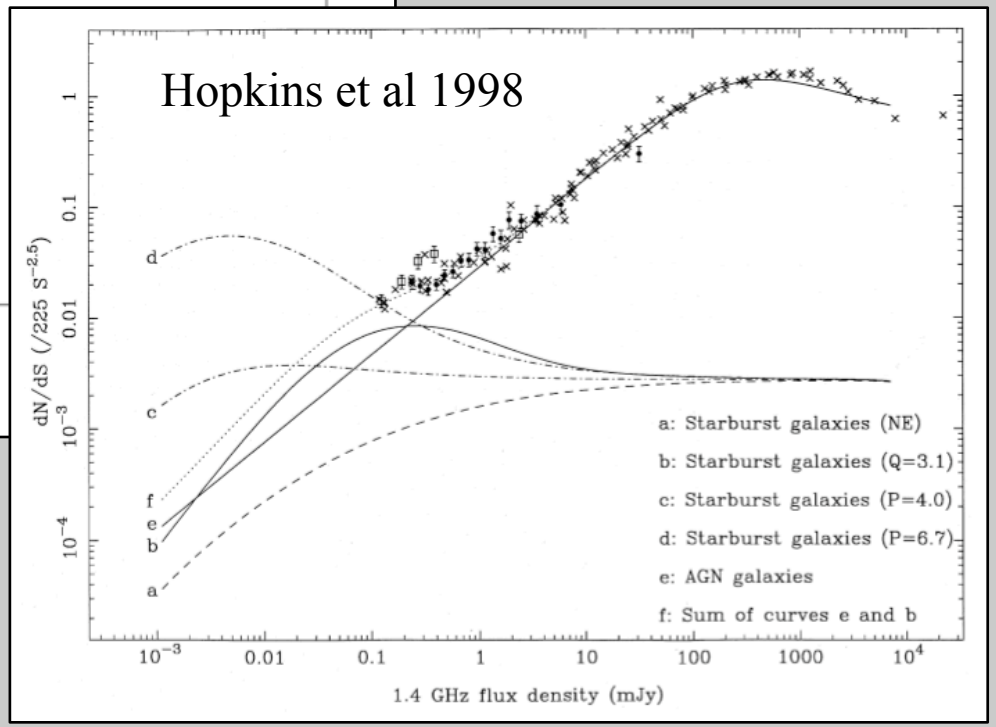
Not currently known radio sources

Simpson et al 2006



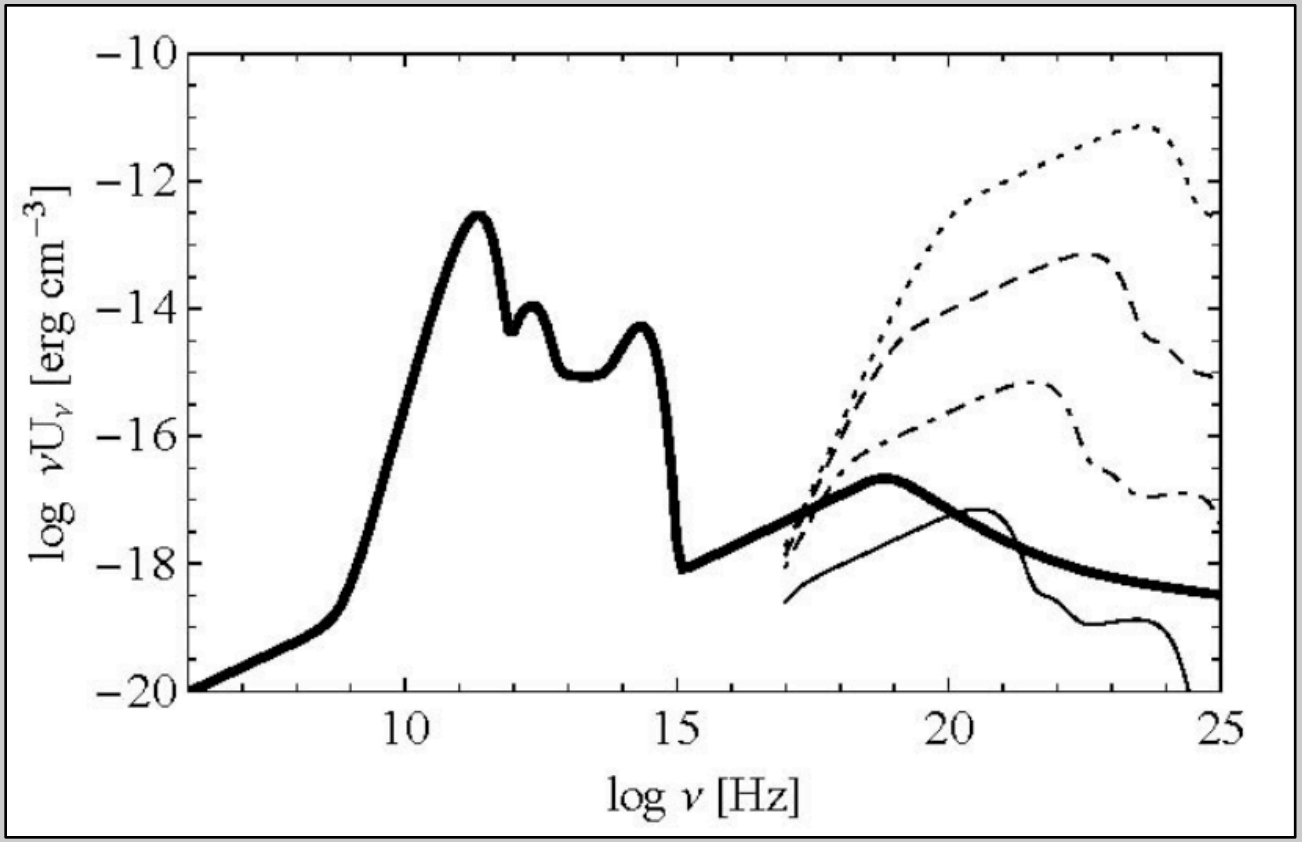
Popular models predict turn over just below current limits

Hopkins et al 1998



Background 6 x larger than integrated source counts

Mag field limit



Same electrons make IC x-γ background : ratio depends on B

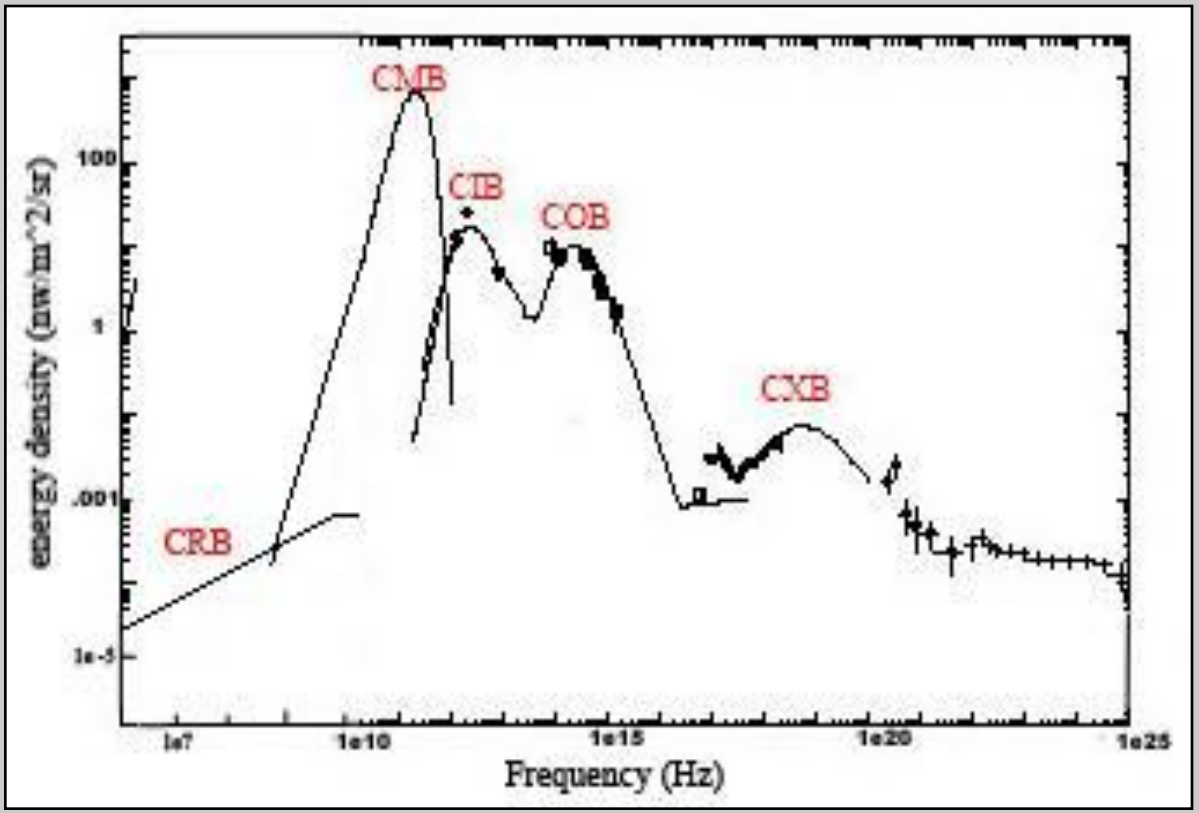
B>1μG

Not in IGM (nano-Gauss)

Similar to known radio galaxies and SNRs

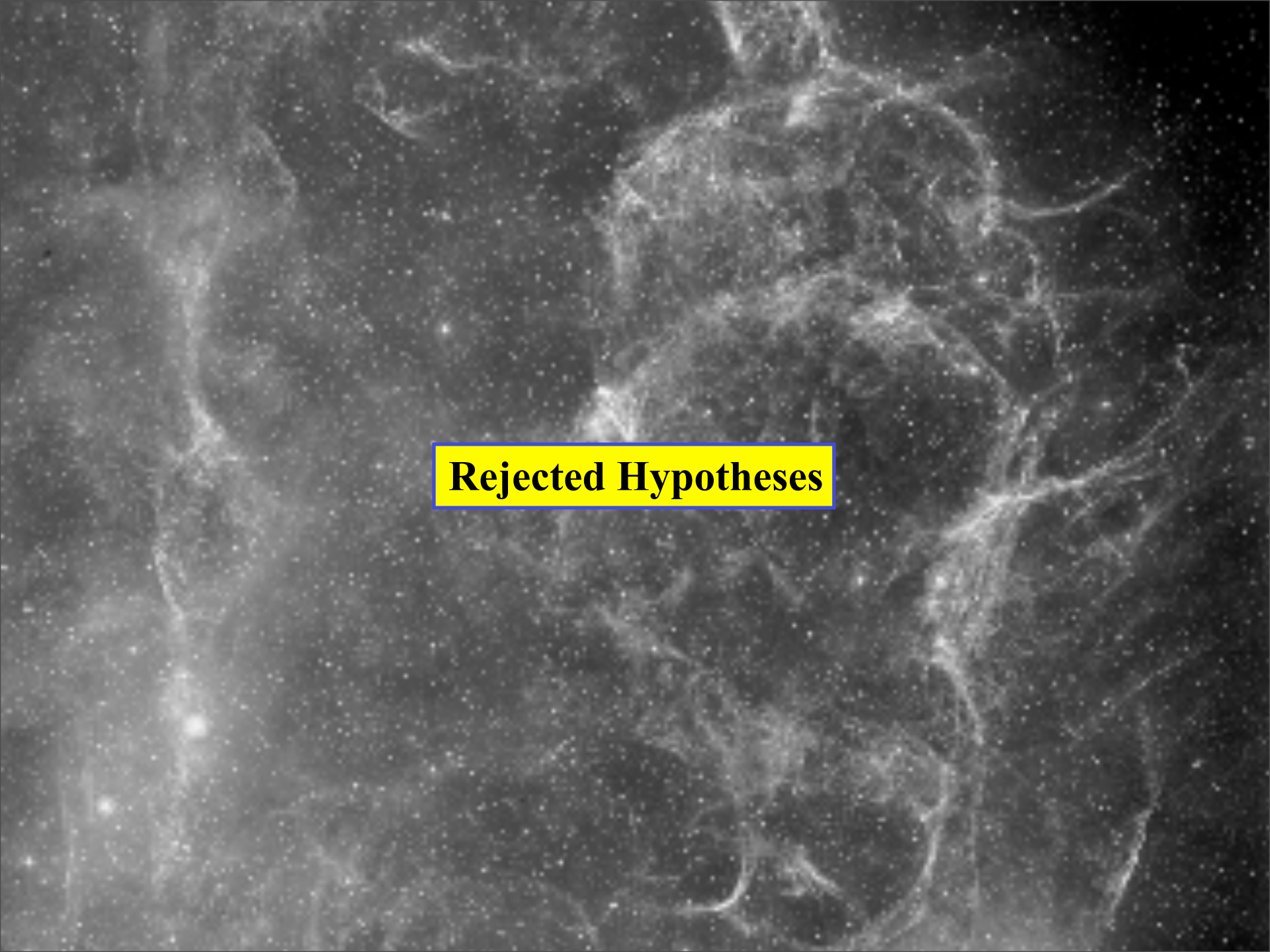
Note also α=0.6

IR background



Sources obeying standard radio/IR correlation also make FIR background

==> 5-25% of the CRB from such sources

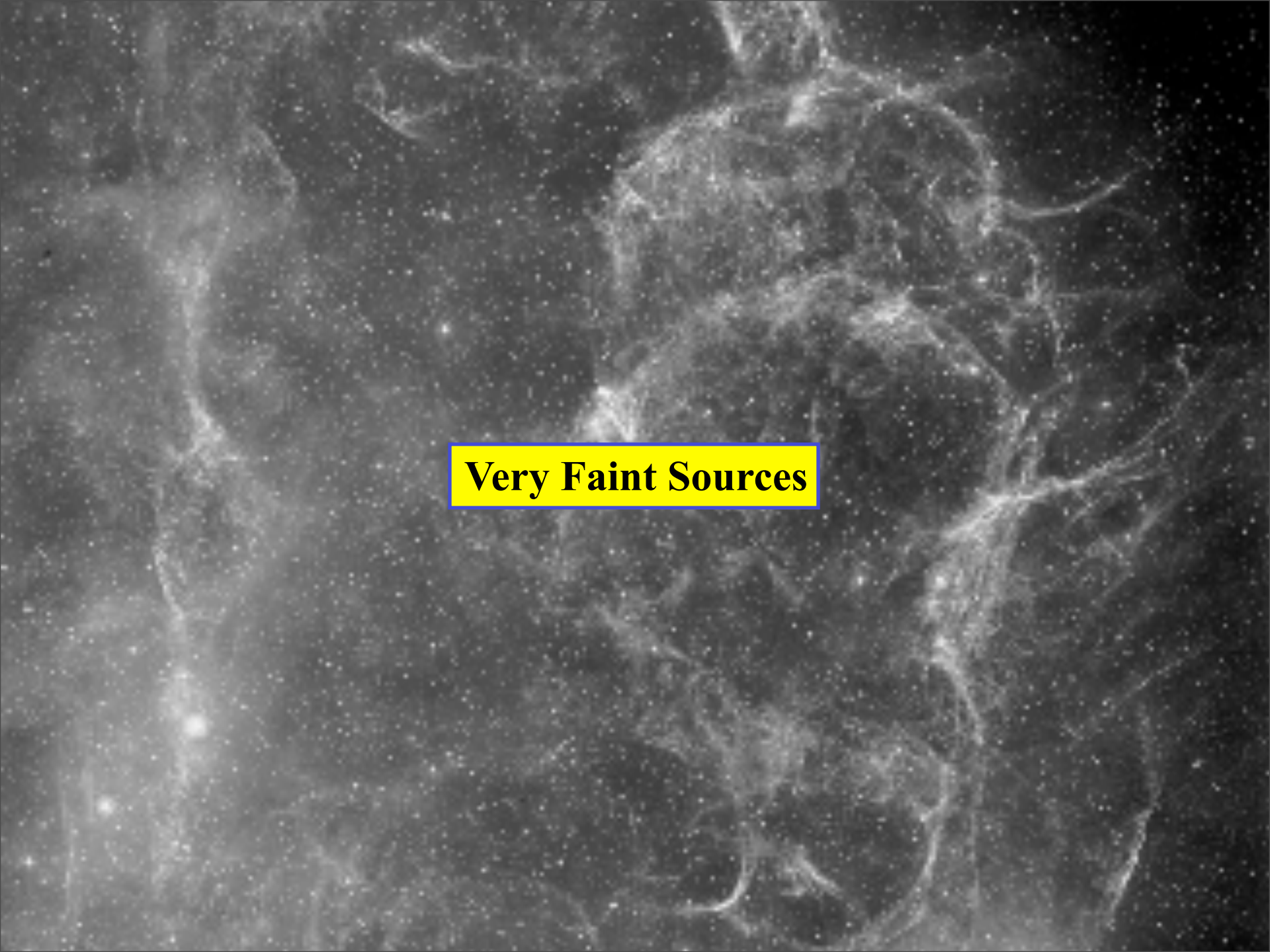

Rejected Hypotheses

Missing Low Surface Brightness emission

- FRI tails ? No - too steep
- Cluster relic sources ? No - too steep
- Missing LSB population ?
  - No - new ATLB survey suggests maybe +50%
- Bad beam correction in faint surveys ?
  - No - repeats at different resolutions agree

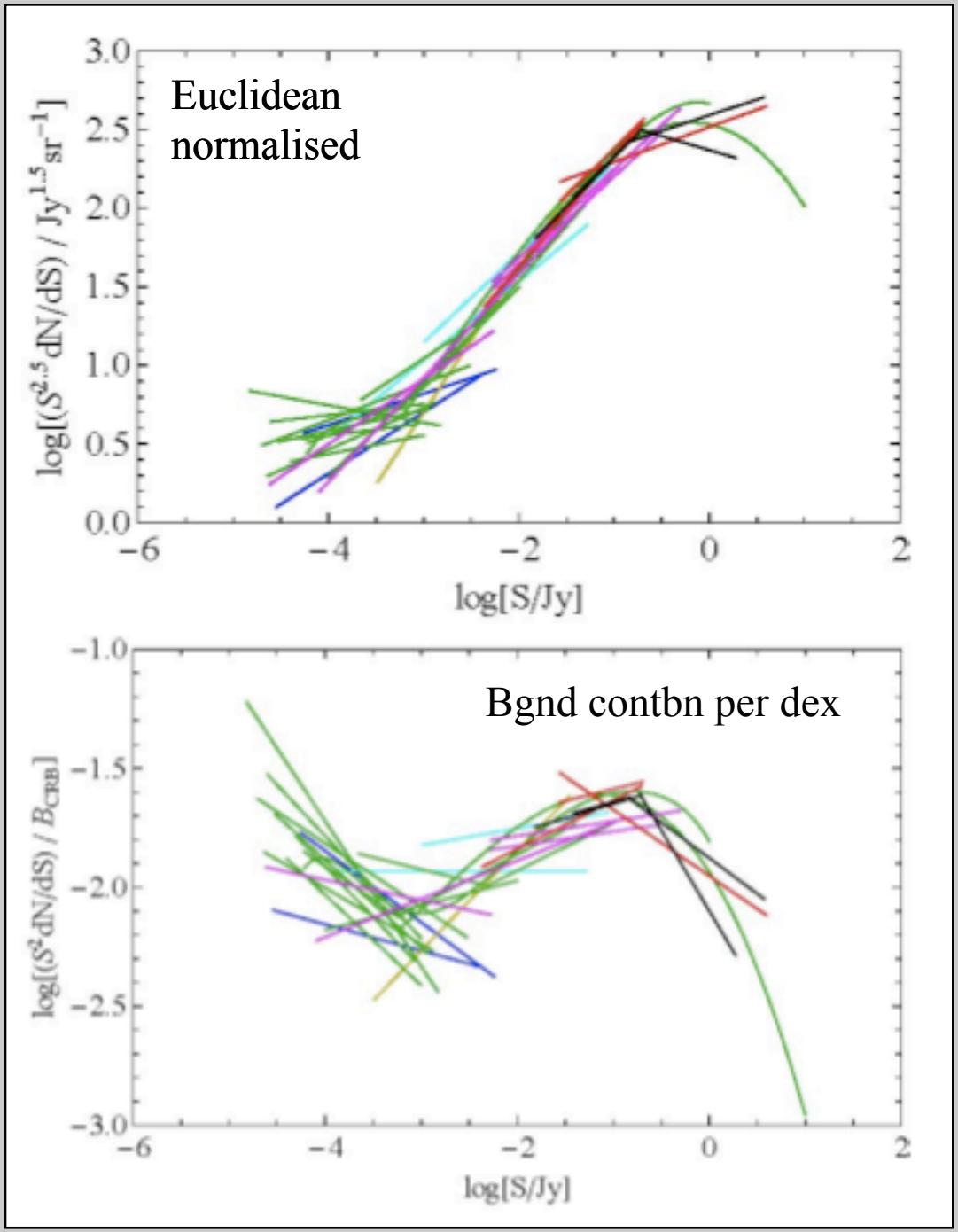
Known Types of Source

- Radio Loud AGN : 16%
- Radio Quiet Quasars : <4%
  - otherwise exceed optical counts
- Radio Supernovae : 0.1%
- Star forming Galaxies
  - known sources : 10%
  - max contbn if obey IR/radio : <26%


Very Faint Sources

Counts compilation

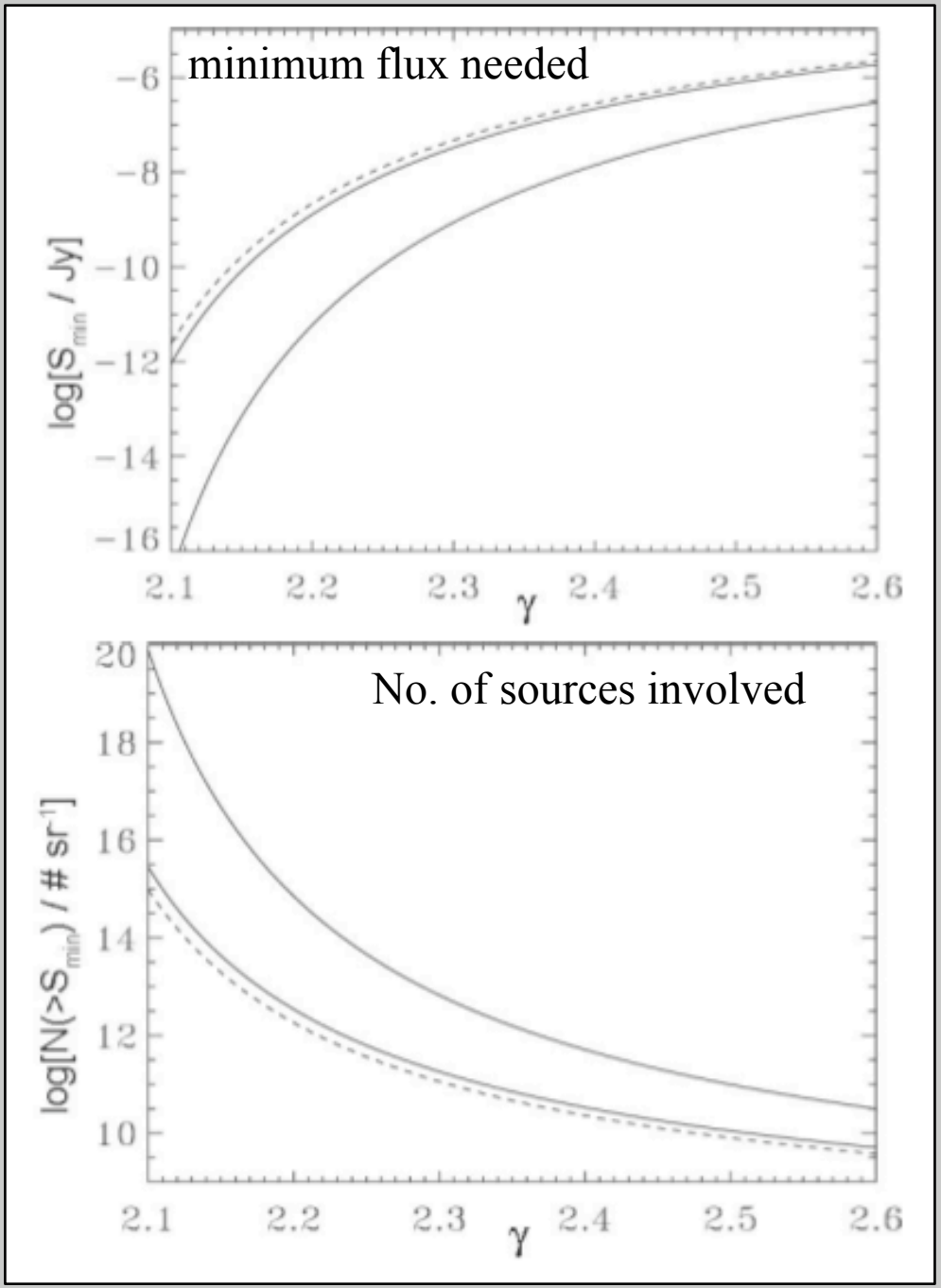
Can extrapolated counts explain background ?



Bgnd from very faint sources

If close to Euclidean :

S(min) ~ 0.1 μJy
N(sky) ~ 10^{11} sources



Ordinary galaxies

- 10^{11} ~ galaxies in observable universe
  - HDF : 3000 gals in 2 arcmin : N=1.1x10^{11}
  - local lum fn : 0.02 gals/Mpc^3 (>0.1 L_*)
  - in volume to z=6 : N=5.7x10^{10}
- S=0.1μJy ~ 10^{22} W/Hz at z=3
  - ==> 10^9 L_{sun} FIR equivalent
  - boring normal spirals, not LIRGs

CRB = SF from distant spirals ?

- Requires radio/IR higher at high z
  - yes : Vlahakis et al 2007; Beswick et al 2007; Seymour et al 2009
  - no : Ibar et al 2008, Ivison et al 2009
  - maybe : Ivison et al 2010
- Physical reason : at high-z
  - More efficient CR formation ?
  - Higher B ?

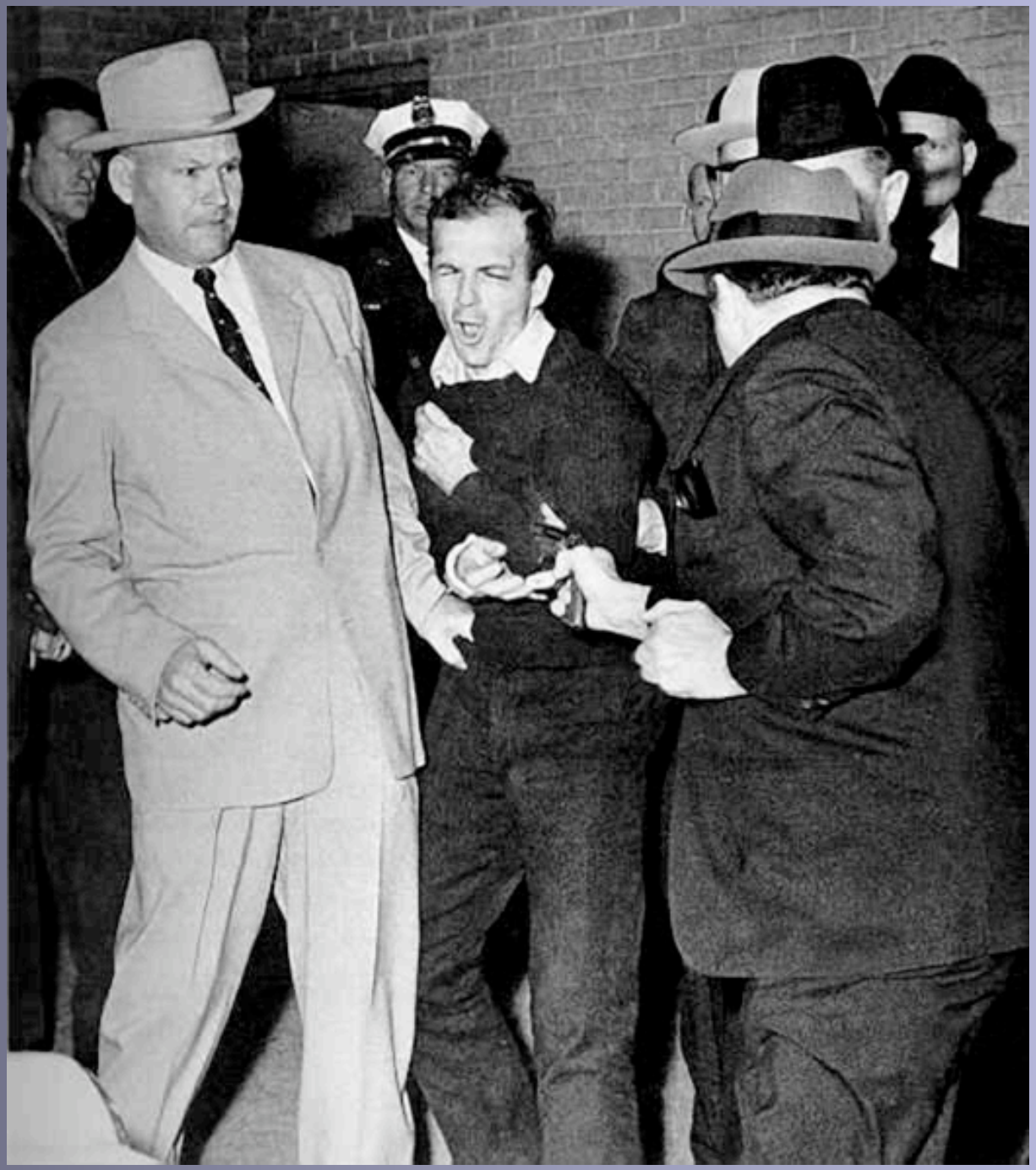
CRB = distant AGN ?

- Requires ~all early gals to be active
  - but at very low level
  - and radio loud : R~100
  - jets but no (or weak) quasar-like emission
- Physical reason : at high-z
  - growing black holes spinning faster ==> jets ?
  - Subsequent chaotic accretion ==> no net spin ?
  - cf Sikora et al 2007, Volonteri et al 2007, Fanadakis et al 2010

Consequences for SKA

- Huge numbers of faint sources
- If star-forming spirals
  - source size ~1" ≈ effective beam
  - 5 beams / source : "natural" confusion
- If weak nuclear jets
  - source size prob ≤0.1"
  - confusion depends on array resolution
  - 150km at 1.4GHz = 0.3" just ok

Interlude



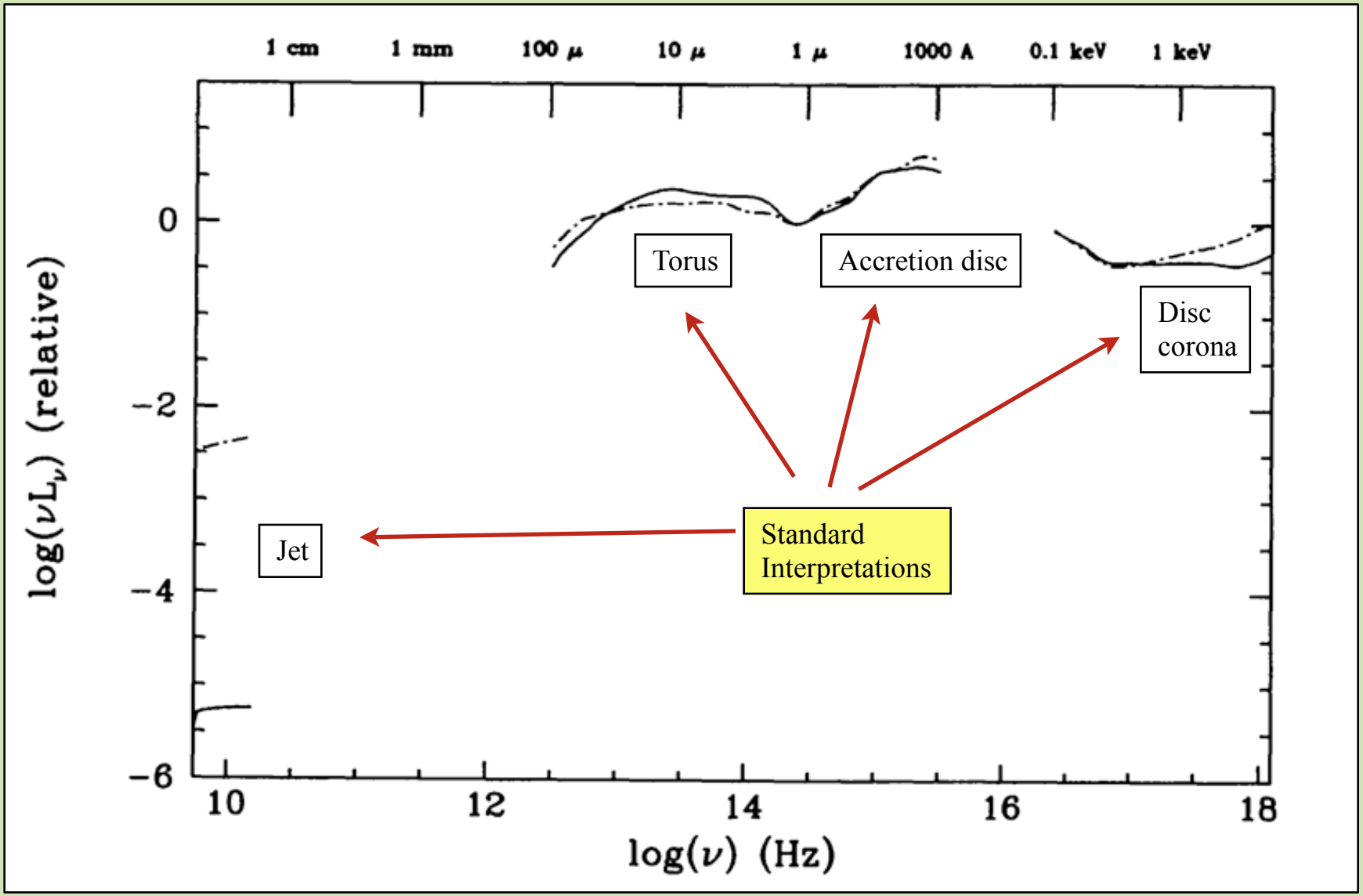
Oswald being shot by Jack Ruby ?

The uncovered truth: Oswald and Ruby in a jam

Part the Second

The quasar SED

Mean quasar SED Elvis et al 1994



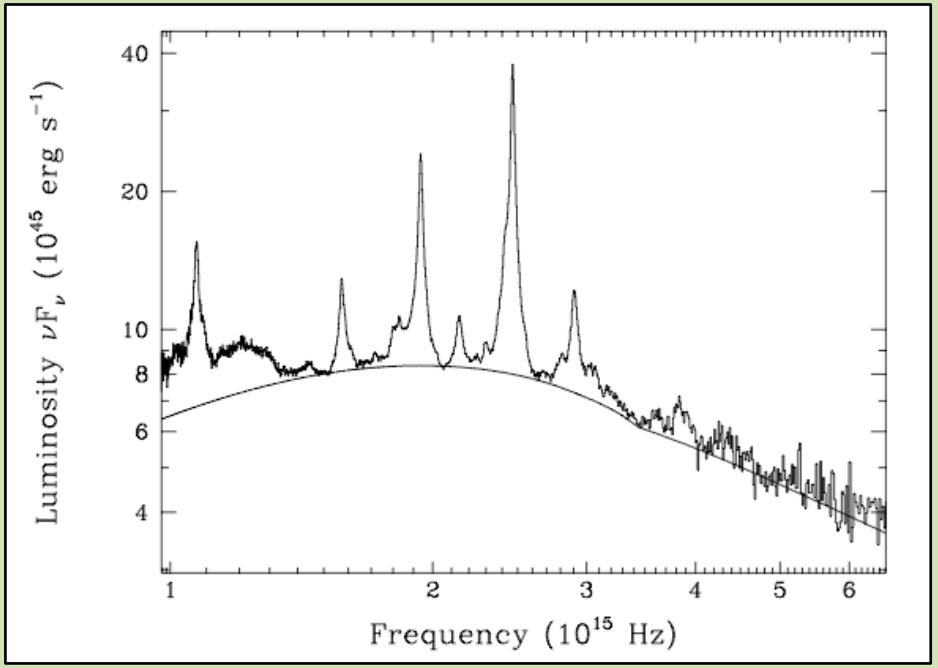
Accretion disc problems

- Ionisation problem
- Temperature problem
- Timescale problem
- Co-ordination problem

ROYAL OBSERVATORY EDINBURGH

Ionisation problem

- Ly α / Total requires $\alpha_{FUV} \sim 0$ to 0.5
  - Netzer 1985, Collin-Souffrin 1986, Dumont et al 1998
- but observed $\alpha_{FUV} \sim 1.8$
  - Zheng et al 1997, Telfer et al 1998
- FUSE obsns find range of slopes
  - Scott et al 2004
  - some do have $\alpha_{FUV} \sim 0$?



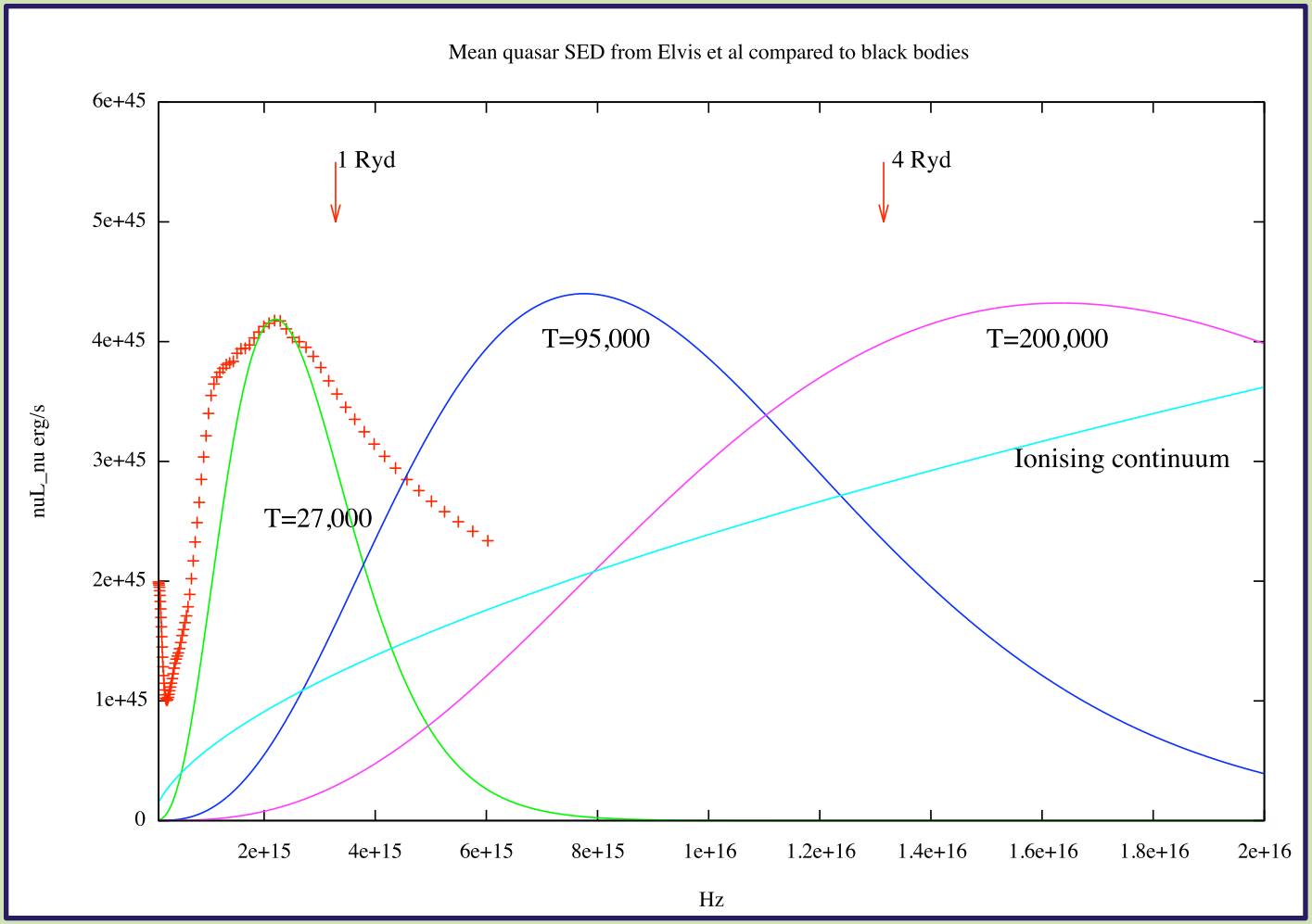
Zheng et al 1997
high-z quasar composite

Temperature problem

The SED is not much different from a blackbody.. and is **too cool**

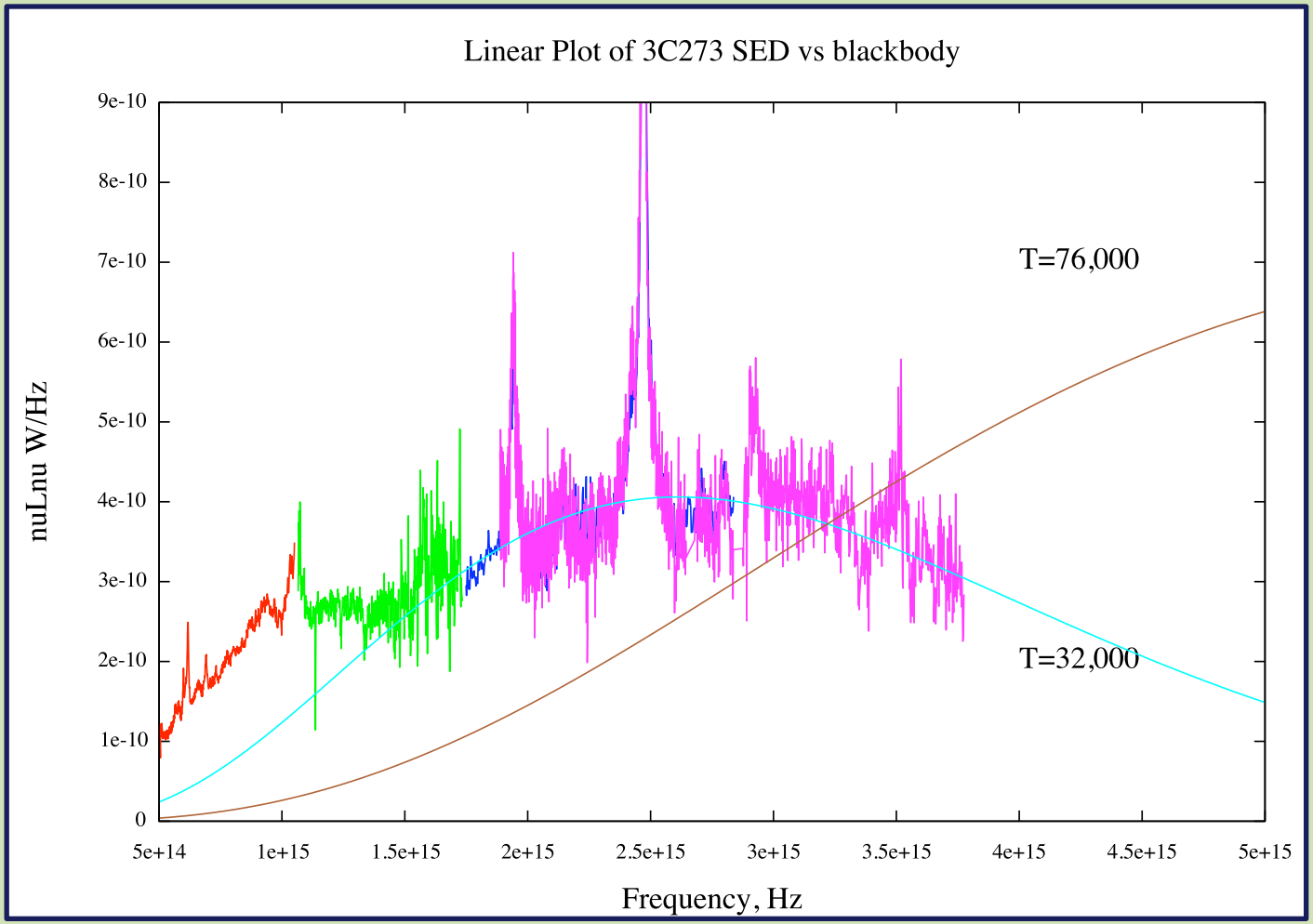
Observation: ~ 30,000

Expectation : ~ 100,000



$$T_{ch} = 95,000 \left(\frac{L}{L_{Edd}}\right)^{1/4} \left(\frac{M}{10^9 M_\odot}\right)^{-1/4} \left(\frac{R}{5R_{Sch}}\right)^{-1/2}$$

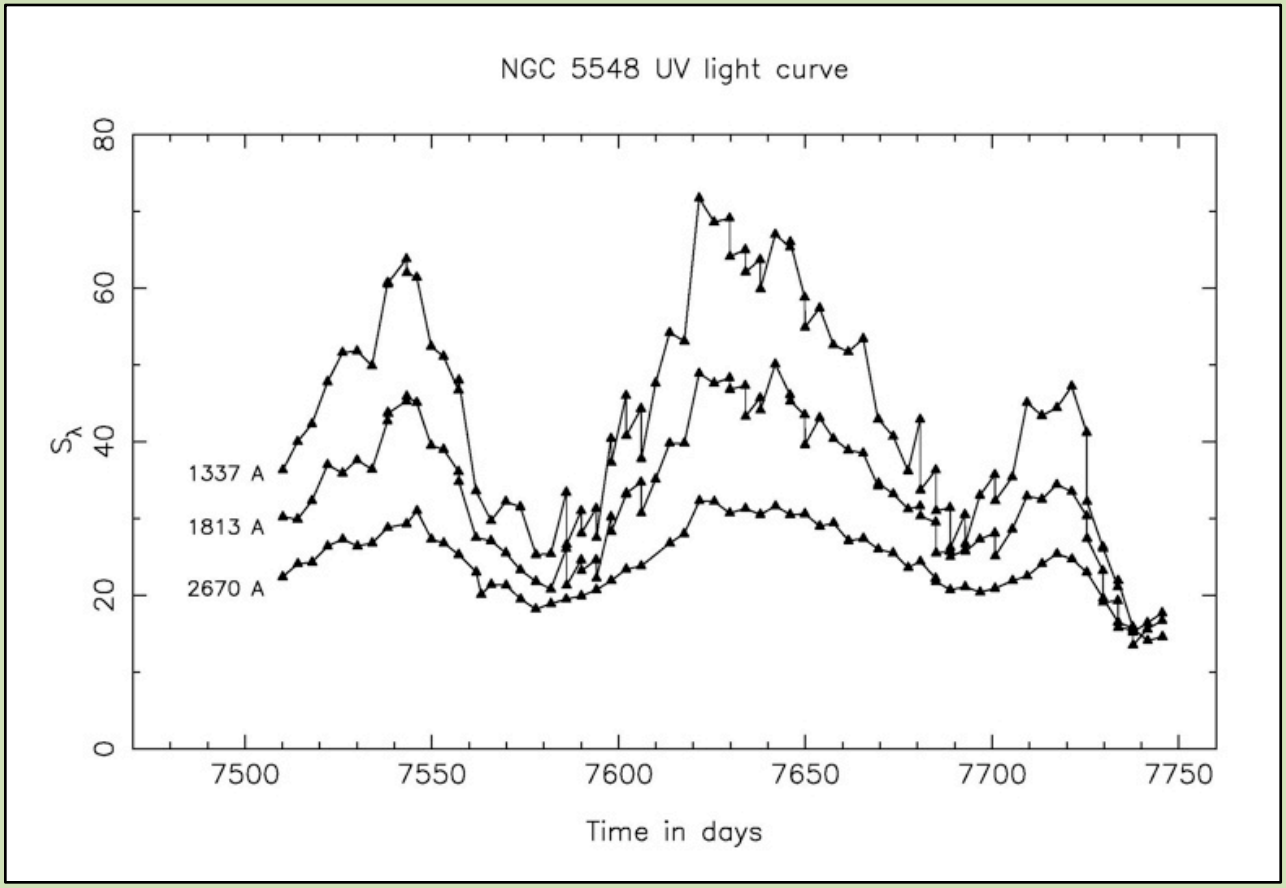
3c273



M_9=0.89 L/L_E=0.36 ==> T=76,000

T=32,000 ==> R/R_S = 28 ?

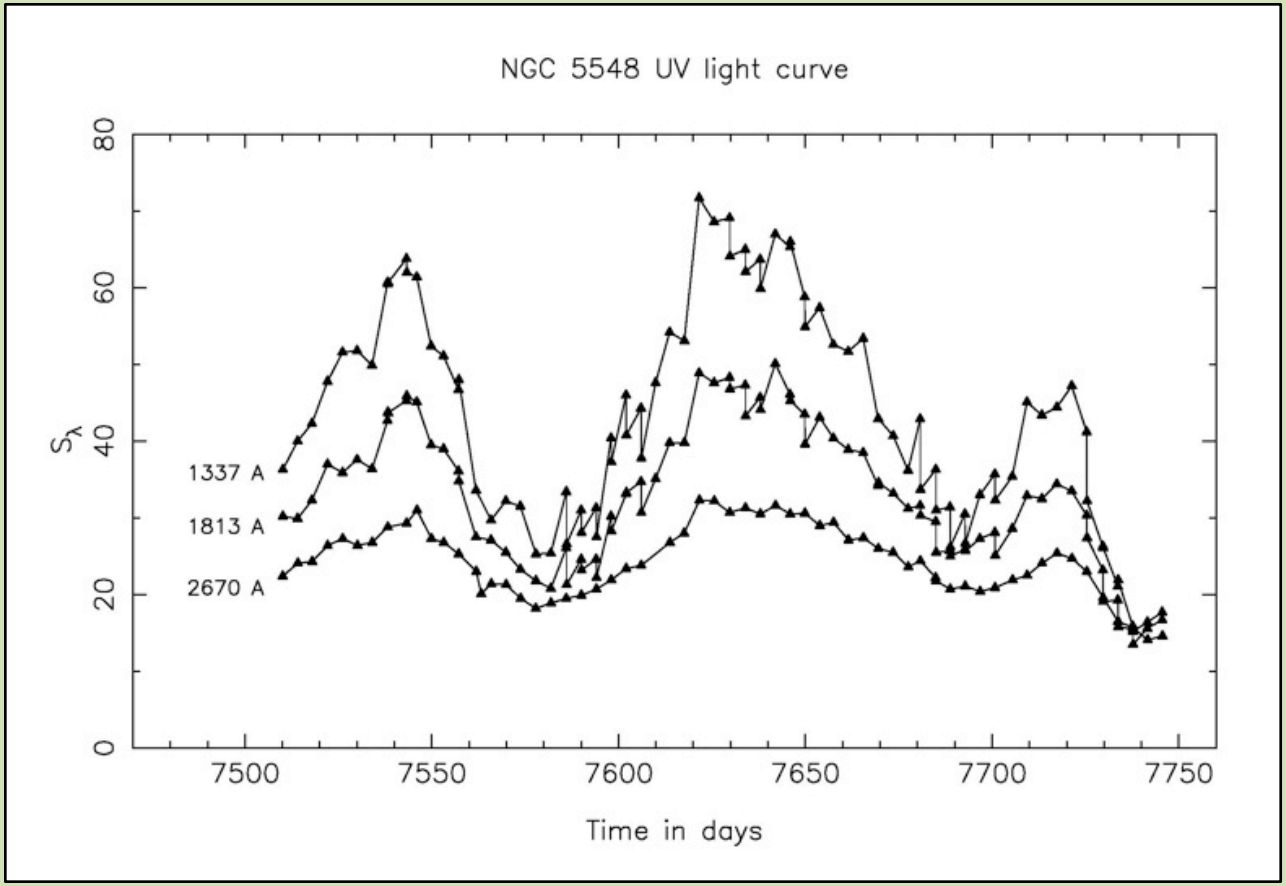
timescale problem



Timescale ~40 days

- too fast for viscosity or sound
- too slow for light
- roughly the dynamical timescale : why ?

co-ordination problem

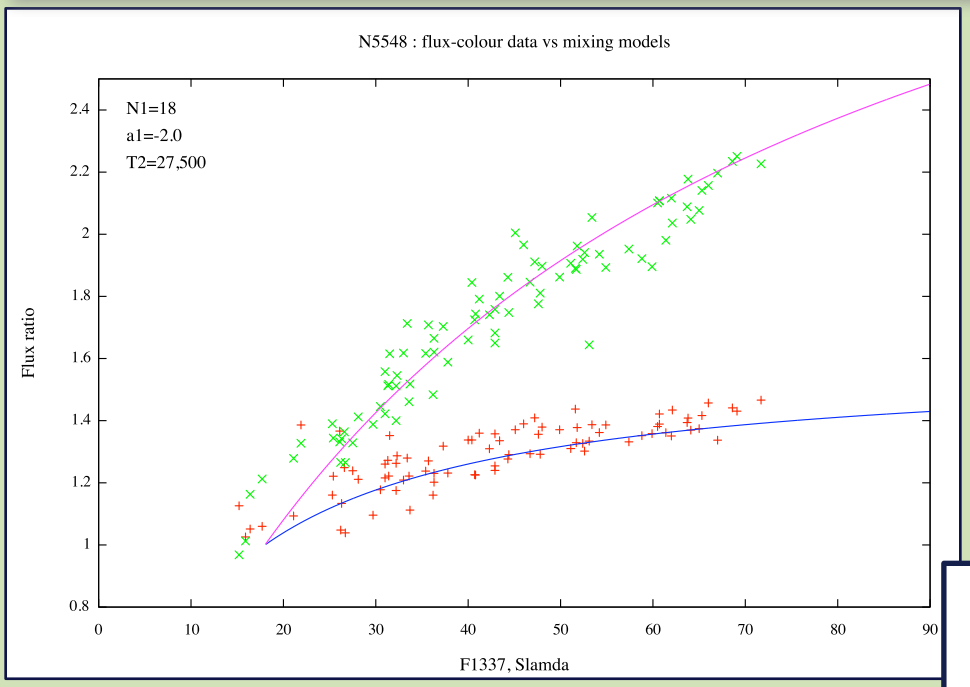


Different wavelengths should come from different radii, with different timescales

Shorter wavelengths vary with larger amplitude, but same timescale and same phase : bluer when brighter

what fits variability data ?

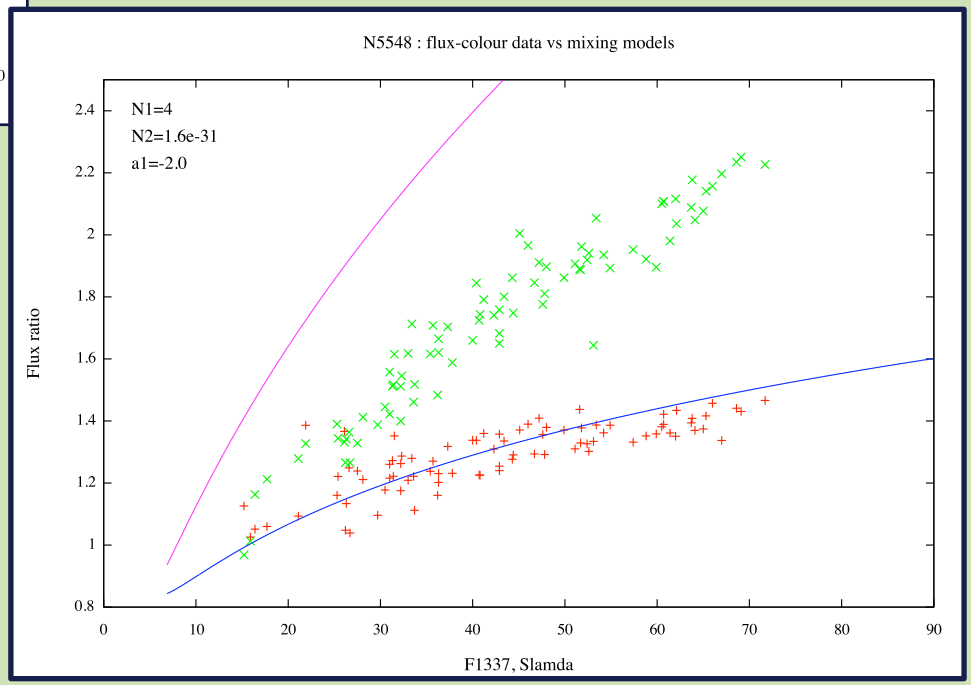
Constant red thing
Variable blue thing



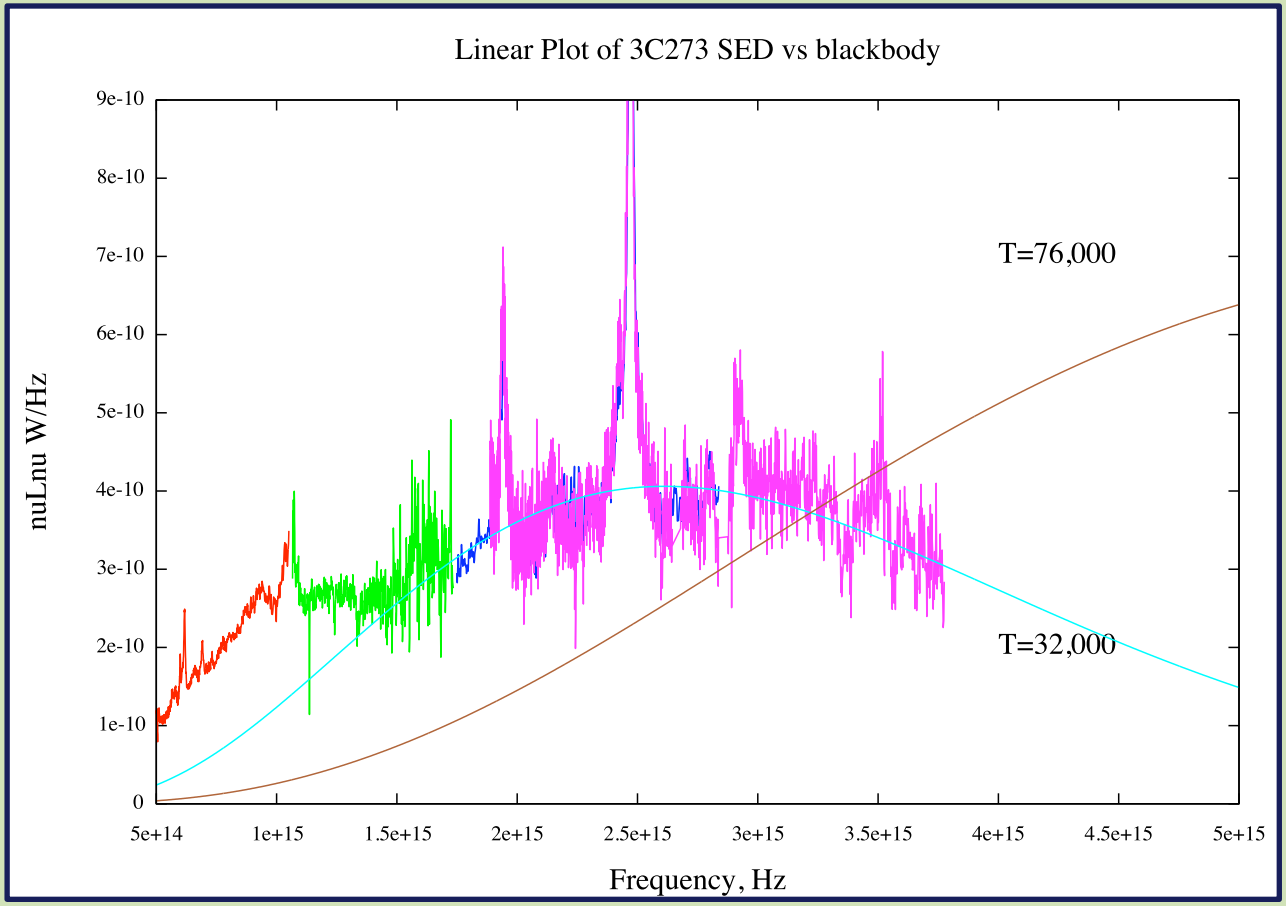
* Temp fixed at 27,500
* Area varies
* YES

The variable blue component has to be a fixed shape ????

* Temp varies
* Area fixed
* NO



My guess ...



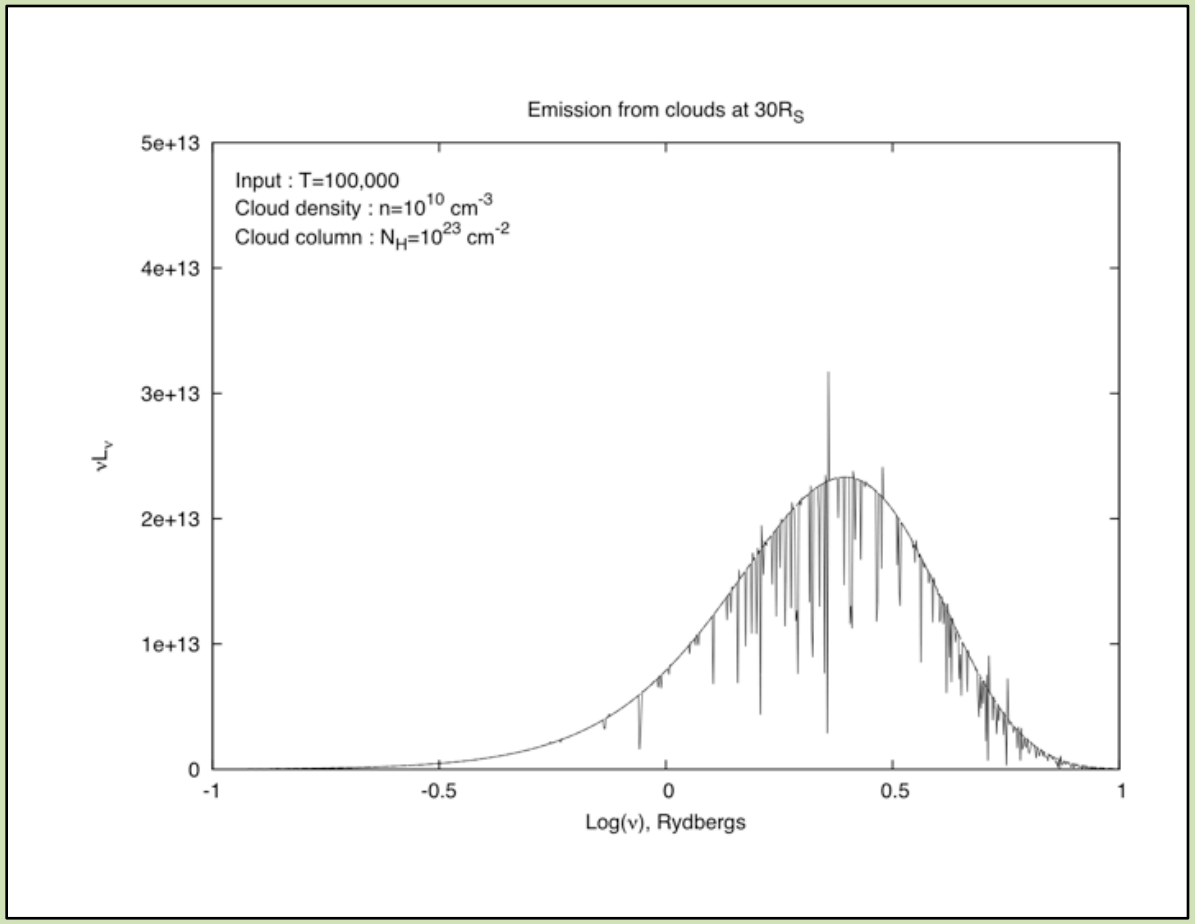
Broad Lines:
ionised clouds at
R~1000 R_S

v~10,000 km/s

What about ionised clouds at R~30 R_S ?

v~75,000 km/s

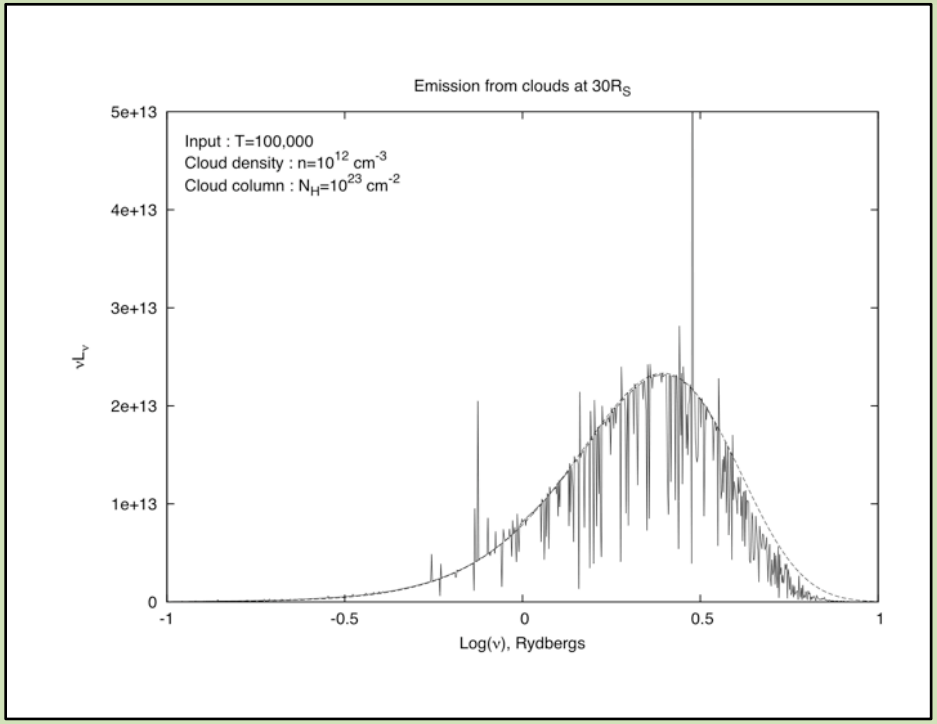
BLR-like clouds

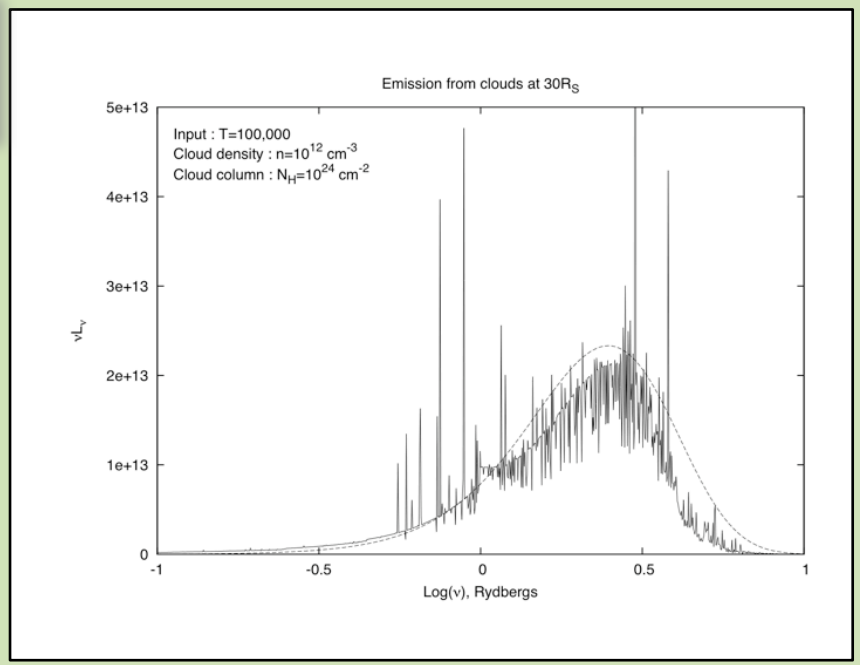


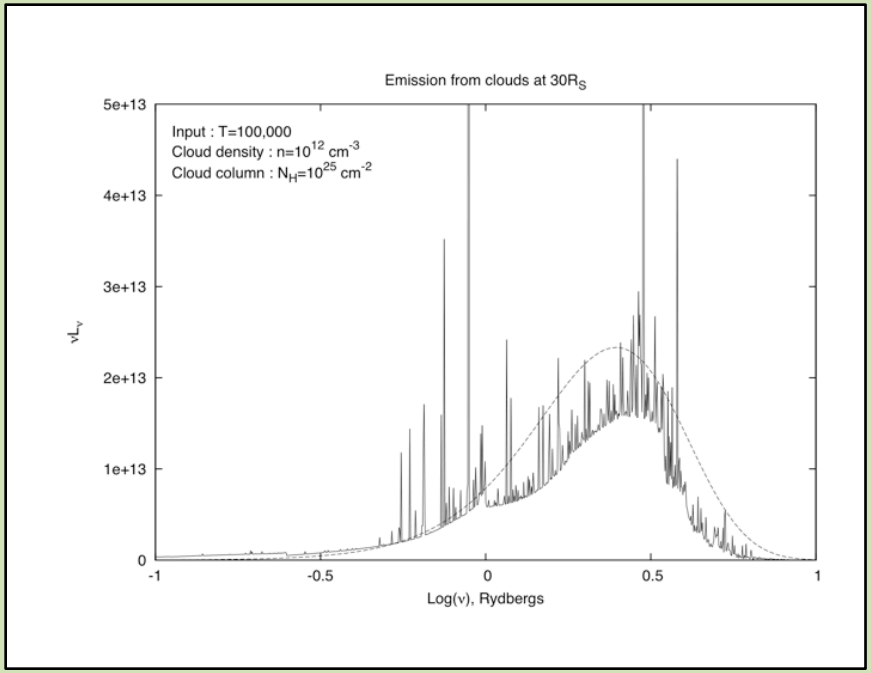
For n~10^{10} clouds are completely ionised at all plausible column densities

Model runs using Ferland's *Cloudy*

High density clouds

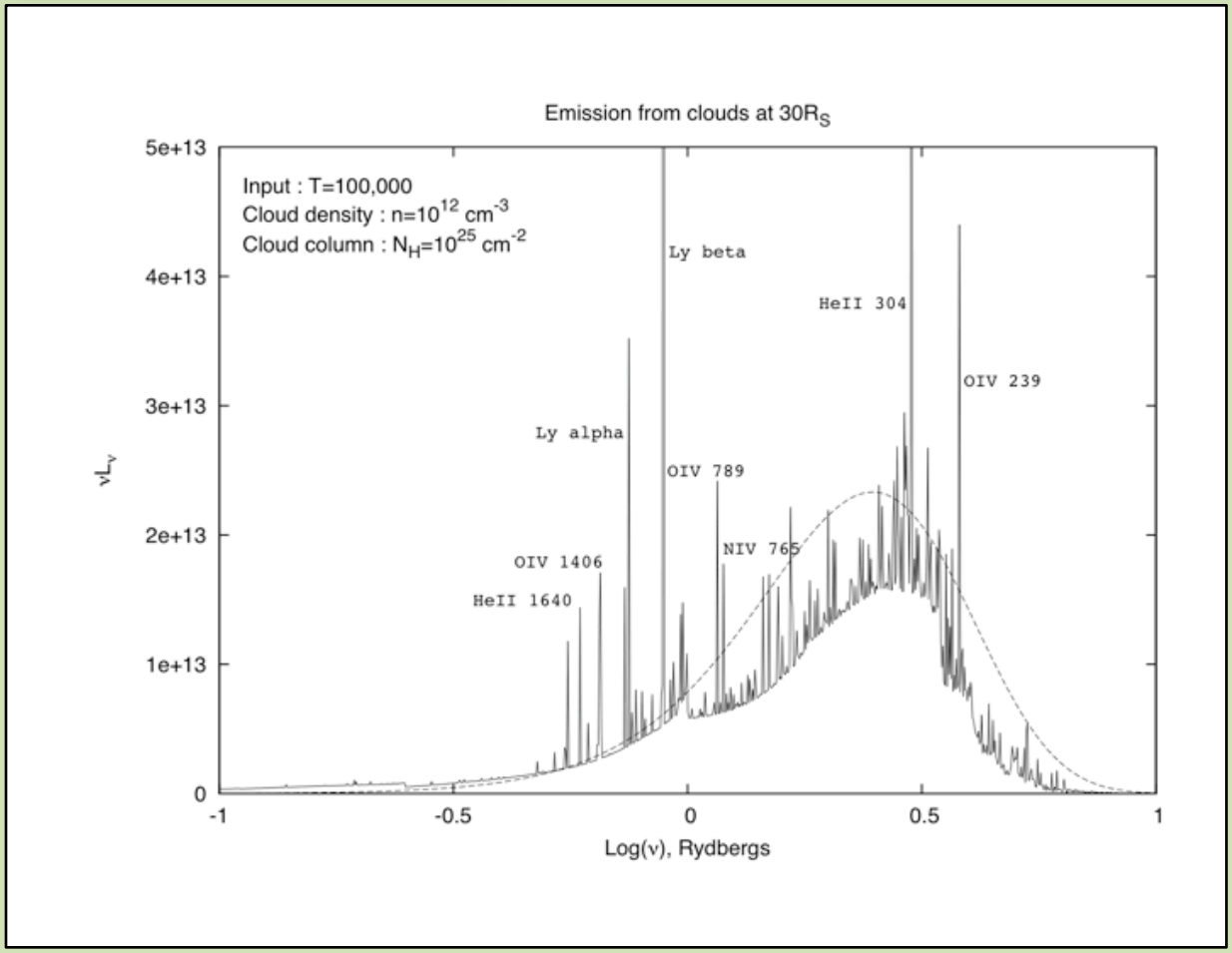






For n~10^{12} clouds with N_H>10^{23} have a neutral zone and have strong line reflection

Line IDs



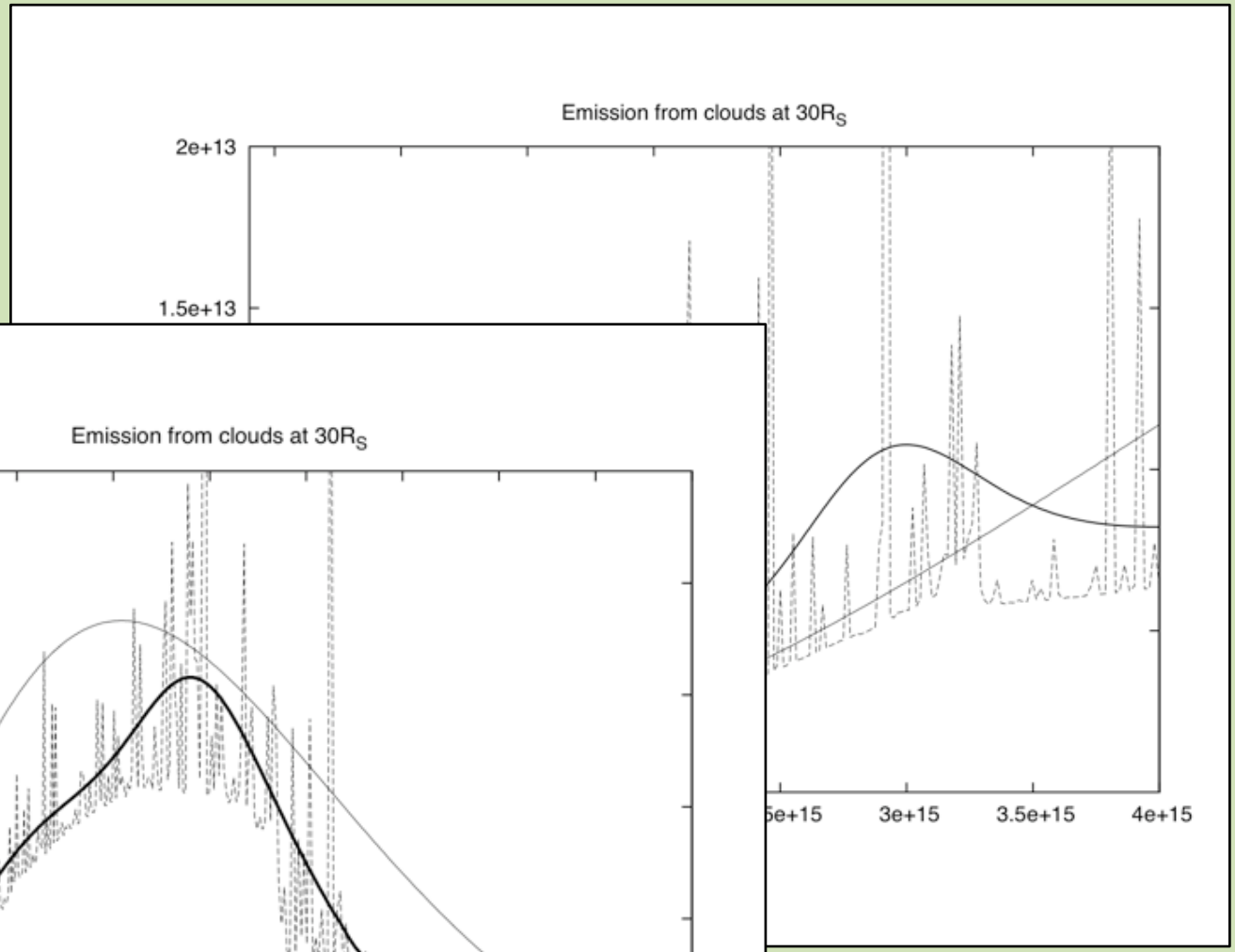
Dominated by HeII Ly-α and HI Ly-β

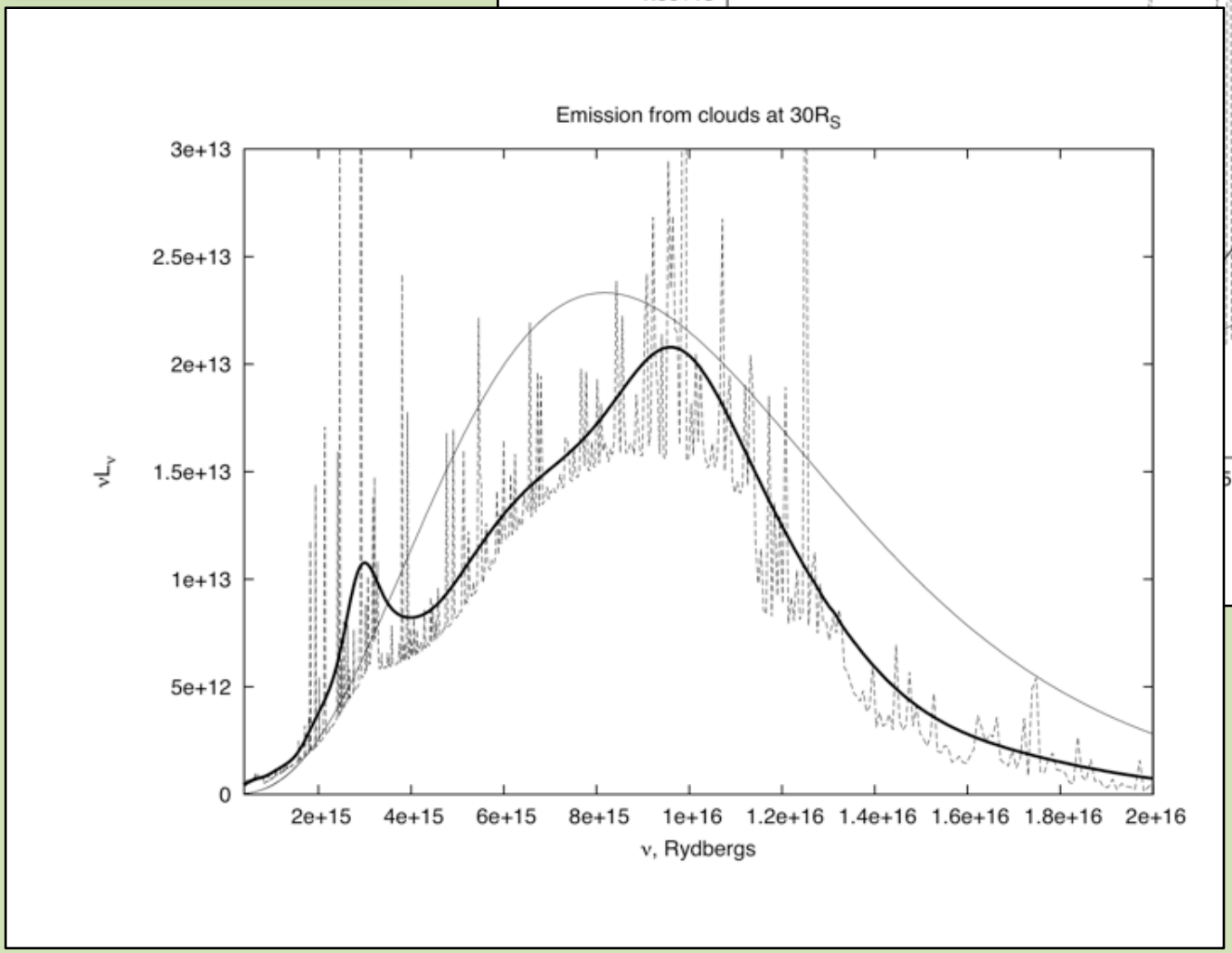
When smeared, will naturally make double peaked SED

Potentially solves temperature, co-ordination, and ionisation problems

Variability : likely form-expel-form cycle

smeared output





FIN