# Foreground subtraction

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# Foregrounds

- Galactic synchrotron
- Extragalactic Radio Sources (RS)
- Galactic Radio Recombination Lines occur at known frequencies and can be excised
- Free free electron emission (Bremsstrahlung)

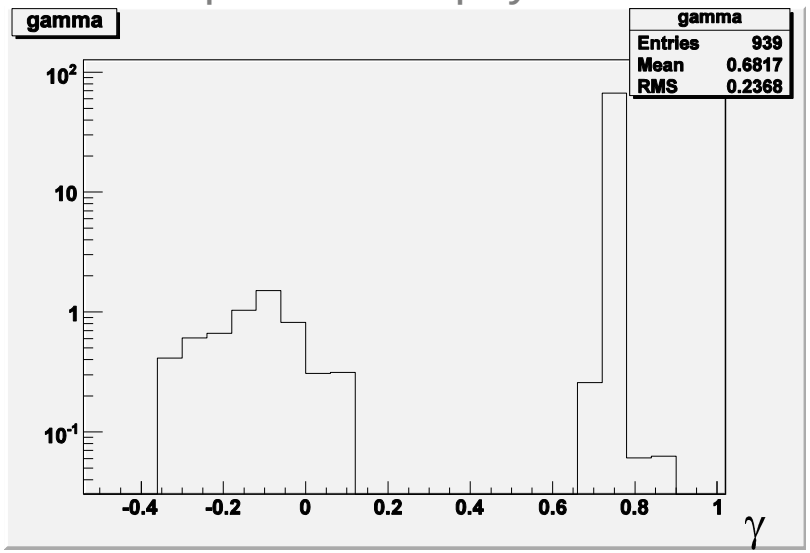
# RS subtraction: basic idea

- Radio sources >> HI
- But radio sources smooth in $\nu$ :

  RS flux $\propto \nu^{-\gamma}$

  $\gamma \approx 0.8$ (85%) or $\approx -0.1$ (15%) :

http://s-cubed.physics.ox.ac.uk




- Strategy

  1. Remove contribution from bright sources
  2. in each $(\theta_x, \theta_y)$ pixel fit and subtract a polynomial in $\nu$

works well for MWA (Murchinson Widefield Array, Australia)

(Bowman, Morales, Hewitt ArXiv:0807.3956)

# Bright sources

- Confusion limit $S_c$ : $\left\langle \frac{\#\,sources(S > S_c)}{pixel} \right\rangle = 1$

HSHS pixel size: (1+z)x0.21/100

$S_c$ = 8 mJy at $\nu$=570 MHz (z=1.5)

$\Rightarrow$ remove sources down to $S_{clean}$ = 40 mJy

- All sky catalog at $\nu$ =1420 MHz down to ≈ 4 mJy

J.J. Condon et al., Astronomical J. 115-1693 (1998)

Fit $\gamma$ to remove all sources from catalog

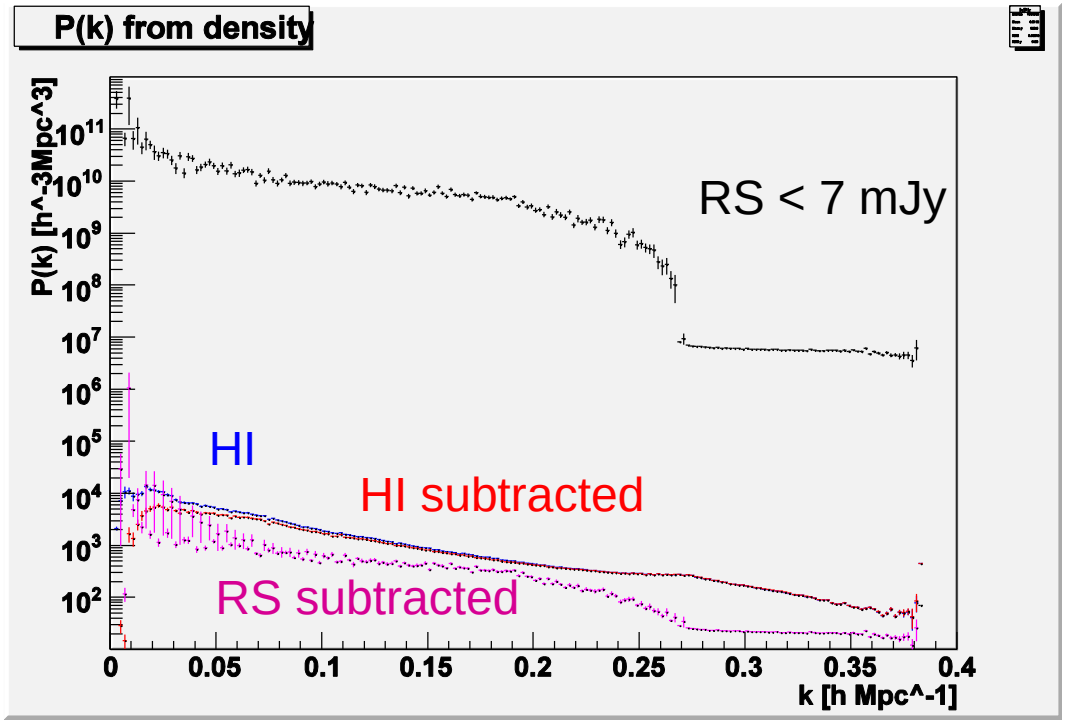
$\Rightarrow$ remove sources down to $S_{clean}$ ≈ 7 mJy at $\nu$ = 570 MHz

# Subtraction on density map

- $S_{clean}$=7 mJy
- Subtract

  polynomial d=4

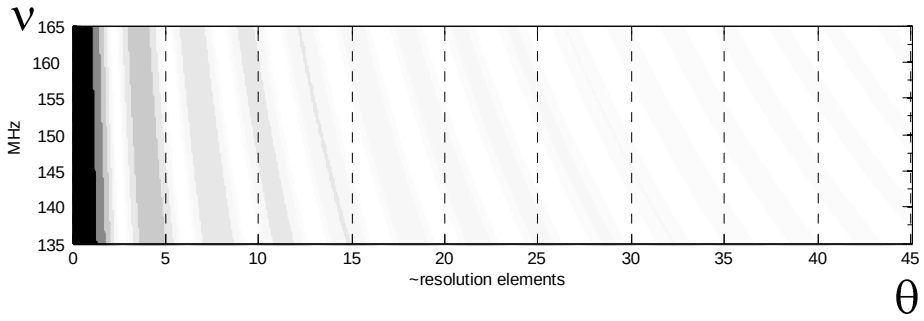
  over $\Delta\nu$=250 Mhz



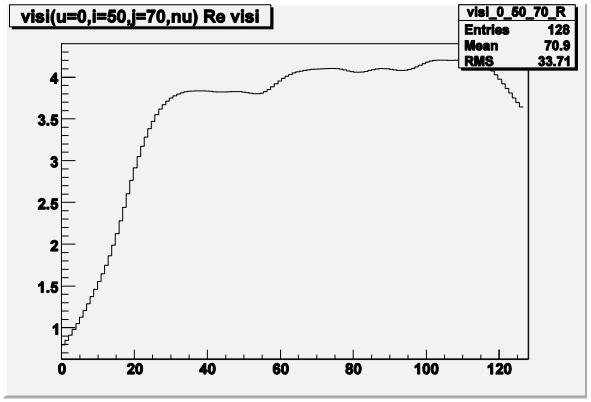

- Little HI removed
- HI > residual RS

# Beam telescope effect

- Synthesized beam scales with $\nu \rightarrow$ RS passing through secondary lobes




- visibility not a power law :




- FFT: also the bin center moves with $\nu$

$\rightarrow$multiply by a phase before FFT to have constant bin center

$\rightarrow$bins are correlated

# Galactic synchrotron

- Galactic synchrotron > point RS
- Conventional wisdom: smooth in $(\theta,\phi)$

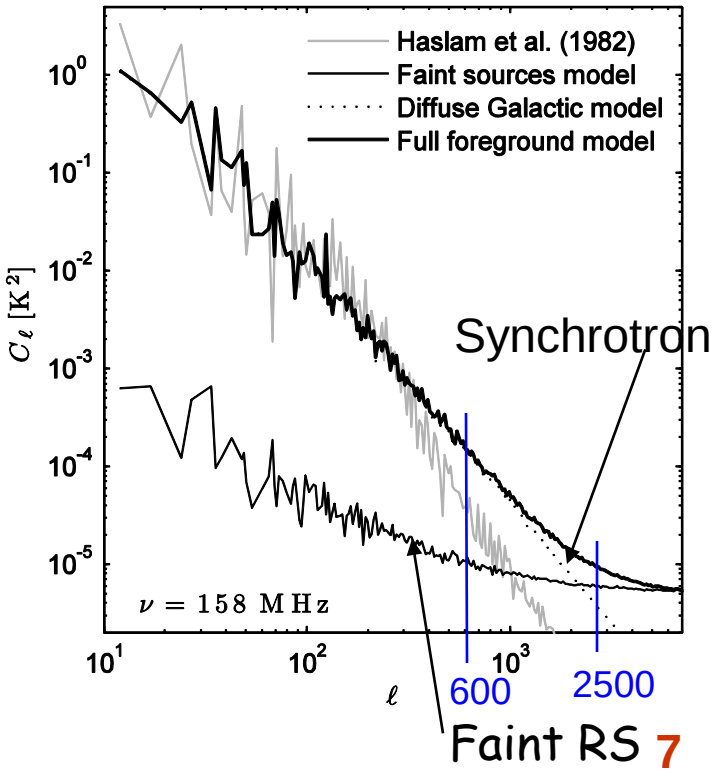
$\rightarrow$ no effect of RS passing in lobes

$\rightarrow$ less of a problem than point RS

- Ok for MWA ($\sigma$=0.07 deg, l=2500)
- True also for HSHS

($\sigma$=0.3 deg, l=600) ?

- To be checked with simulations



# Reconstruction

Ansari et al., arXiv:0807.3641

- FFT in time
- FFT along cylinder
- visibility between cylinder pairs distant by $\lambda u$

$$\tilde{V} = FFT\,3D[V]$$

$$\Gamma(\vec{k}) \propto \frac{\sum_u \tilde{V}(\vec{k},u)}{\sum_u F(\vec{k},u)}$$

$$P(\vec{k}) = \left\langle \Gamma(\vec{k}) \right\rangle$$

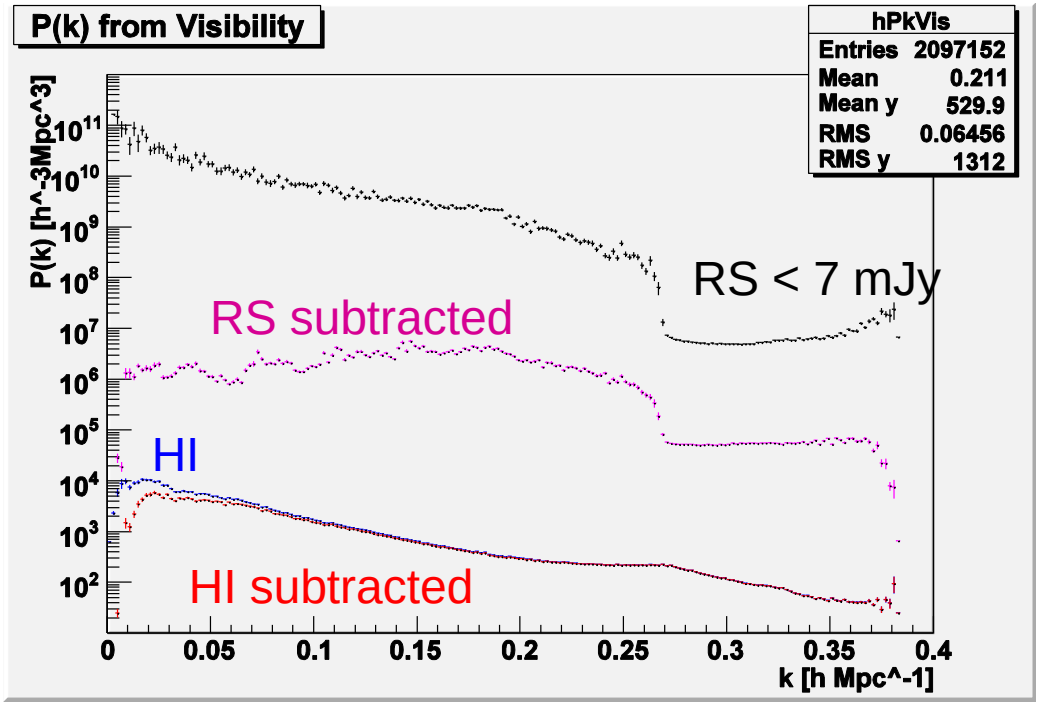
- for the moment using only u which has largest F( k,u) for given k $\Rightarrow$ wiggles in RS residuals

# RS subtraction with beam effect

- $S_{clean}$=7 mJy
- Subtract

  polynomial d=4

  over $\Delta\nu$=250 Mhz



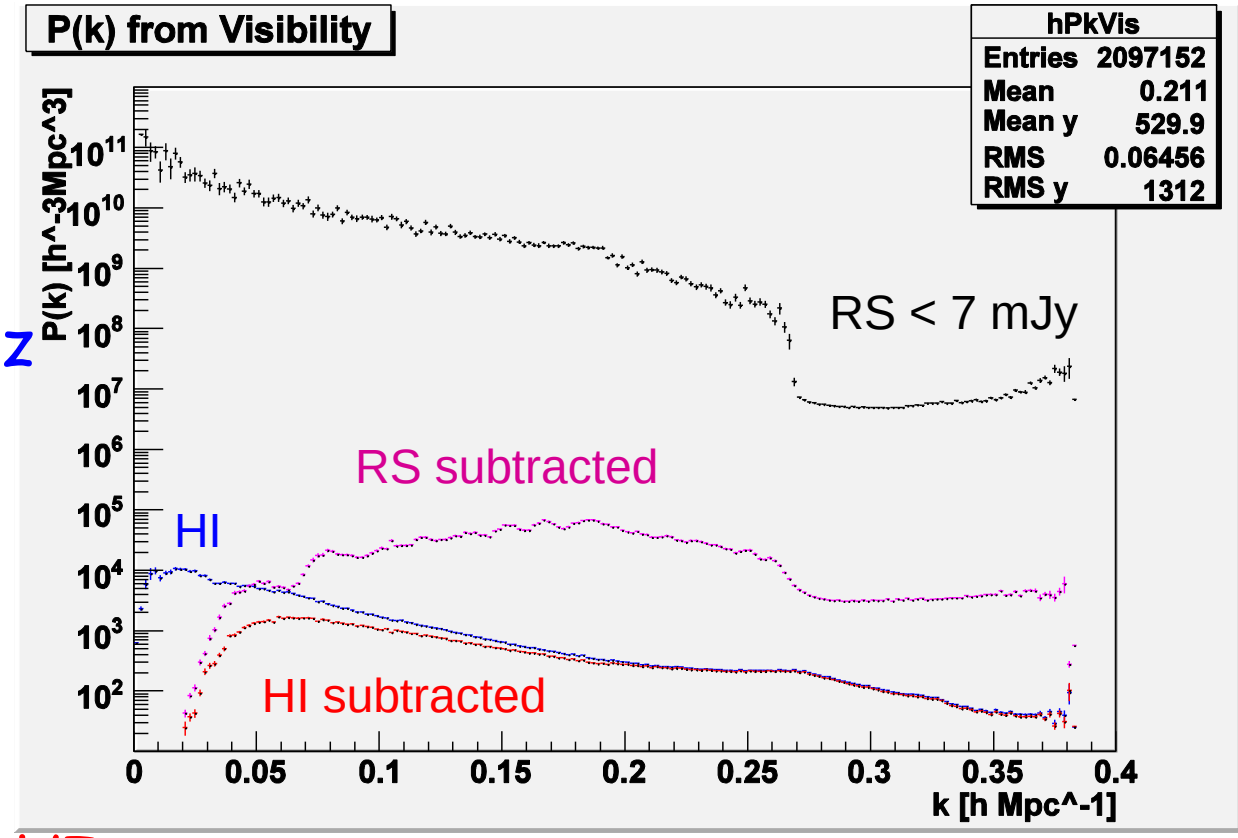

- residual RS >> HI

# RS subtraction with beam effect

- $S_{clean}$=7 mJy
- Subtract

  polynomial d=4

  over $\Delta\nu$=250/4 Mhz

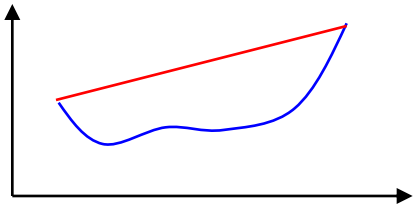



- we start to remove HI
- still RS> HI

# Subtraction of a sky model

- Polynomial is a bad model for $V(\nu) \Rightarrow$ new strategy

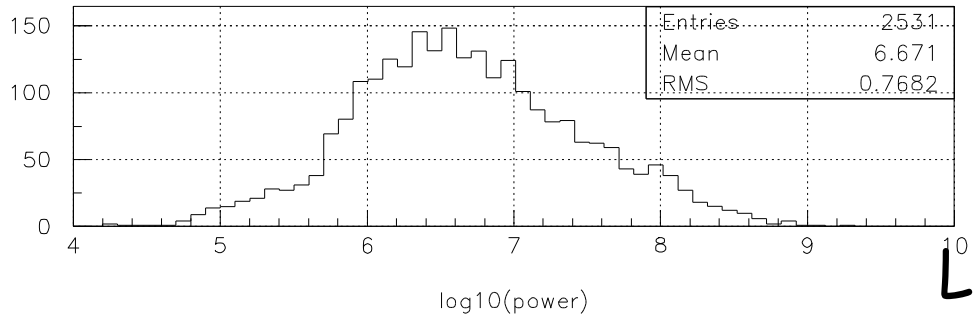
1. Remove bright sources
2. Subtract a sky model:
   effective sources on a grid (67 nodes / HSHS pixel)
   with fixed $\gamma$, only parameter : source flux
3. In each $(\theta_x,\theta_y)$ bin, remove $a\nu+b$
   such that $\phi=0$ at $\nu_{min}$ and $\nu_{max}$



- To test the idea : no fit,
  compute source flux from known RS flux and positions

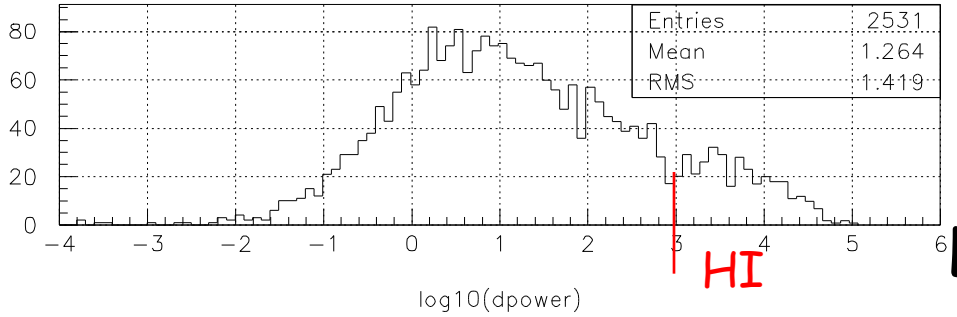
# First test of sky model subtraction

Log $P_{RS}$
in individual modes
(RS < 7 mJy)



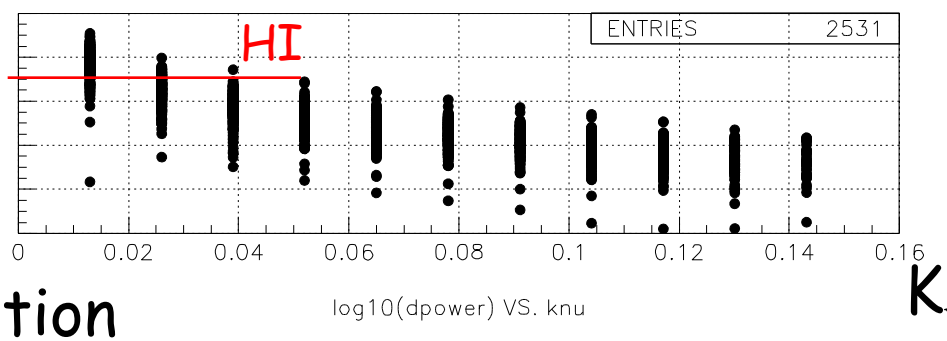

Log $P_{RS}$

Idem after
subtraction




Log $P_{RS}$

Log $P_{RS}$




$K_\nu$ ($hMpc^{-1}$)

Could be combined
with polynomial subtraction
→ promising

# An additional subtraction step

Morales, Bowman, Hewitt Astroph. J. 648:767-773

- "Residual error subtraction"

  - statistical error due to noise

  - model error (polynomial is not a perfect model)
- subtraction on p(**k**), not on image/visibilities
- make templates for the residual $p_{RS}(\mathbf{k})$

  which are different from $p_{HI}(\mathbf{k})$ (≈ isotropic)

# Conclusions and prospects

- Foreground subtraction is a hard and important task
- do not have a valid strategy yet
- further study sky model (+ polynomial) subtraction

  if this works fit procedure for sky model
- Study removal of galaxy synchrotron
- Test removal of known bright sources with unknown $\gamma$
- try "residual error subtraction"
- use simulations to study systematic effects

  e.g. pixel jitter should be smaller than $10^{-3}\ \delta\theta$