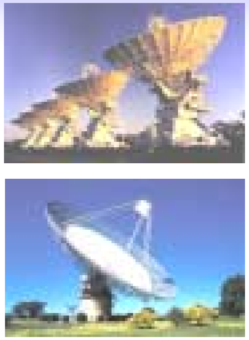
Merging Single-Dish Data

- Bibliography
- The short-spacing ‘problem’
- Examples
  - Images
  - Power spectrum
- Fourier (or UV) plane .*v*. sky (or image) plane combination
- Noise & calibration issues

Bibliography



- Stanimirovic (2002) ASP Conf. Series 278
- Sault & Killeen (2003) Miriad Users Manual
- Holdaway (1999) ASP Conf. Series 180
- Other work (partial list): Adler et al. (1992, ApJ, 392, 497); Bajaja & van Albada (1979, A&A, 75, 251); Cornwell, Holdaway & Uson (1993, A&A, 271, 697); Roger et al. (1984, PASA, 5, 560); Schwartz & Wakker (1991, ASP Conf. Ser. 19); Vogel et al. (1984, ApJ, 283, 655); Wilner & Welch (1994, 427, 898); Ye, Turtle & Kennicutt (1991, MNRAS, 249, 722).

The short(zero)-spacing problem

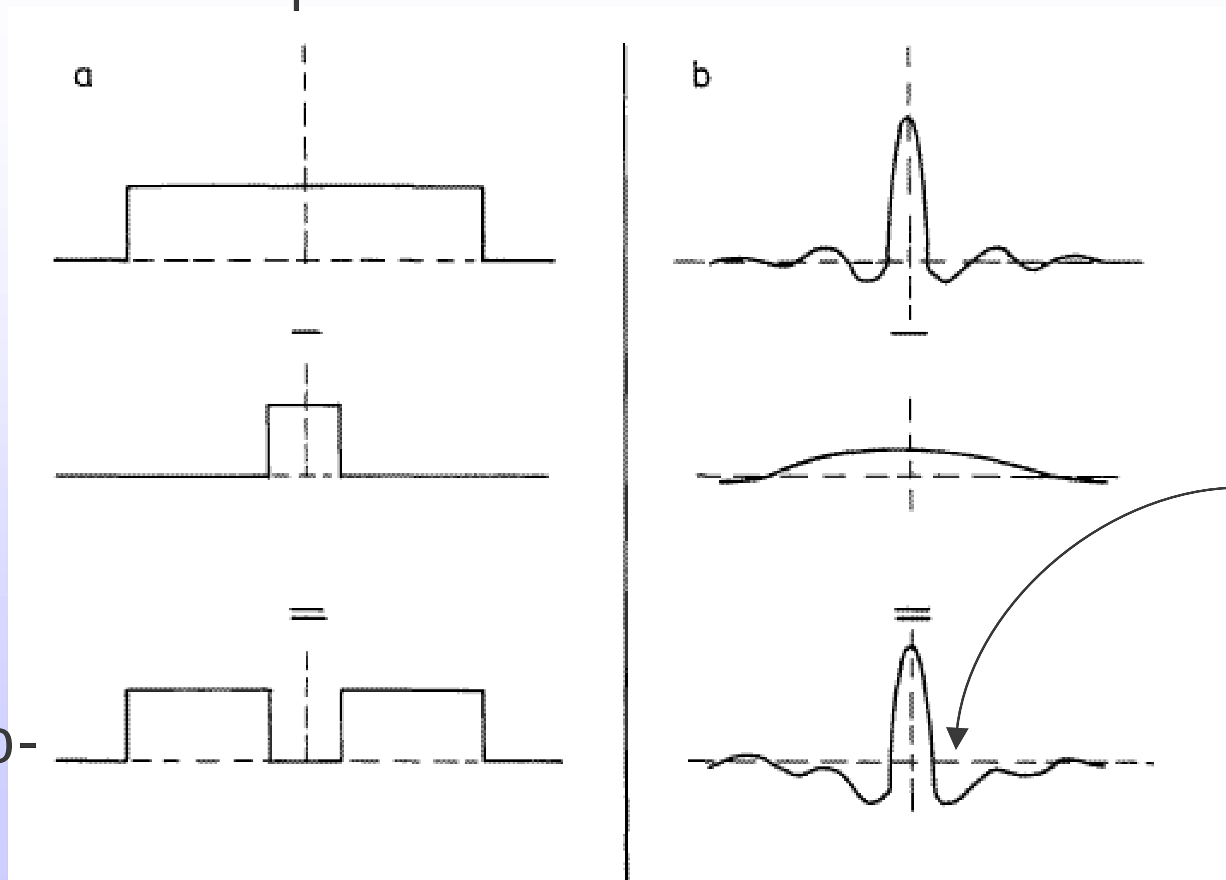
UV plane PSF

Braun & Walterbos (1985)

ideal

Central hole

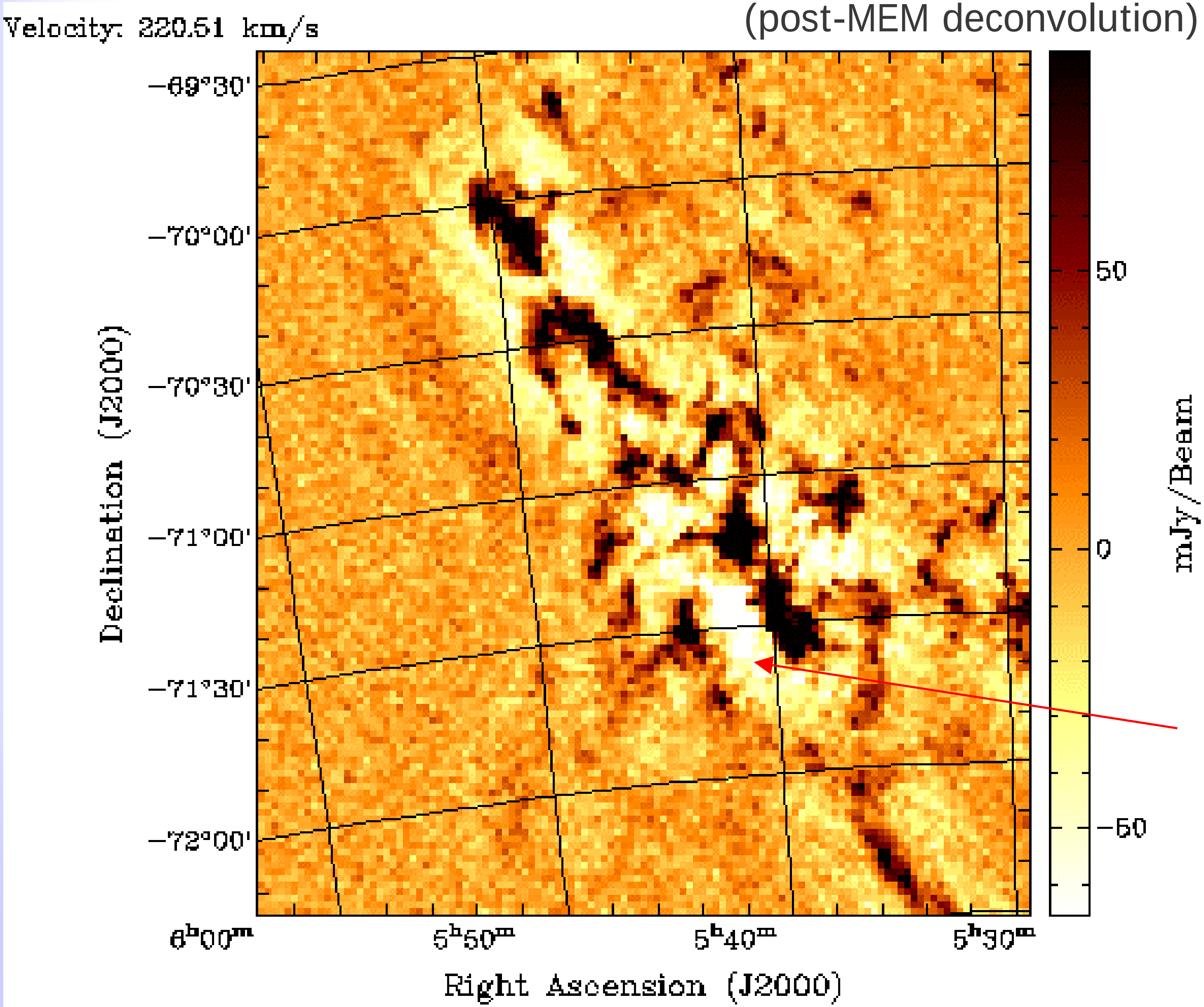
Typical interfero-meter

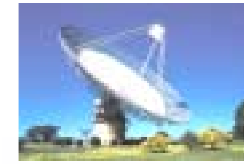


Negative 'bowl'

HI in the E-arm of the LMC (ATCA 4x750 m)

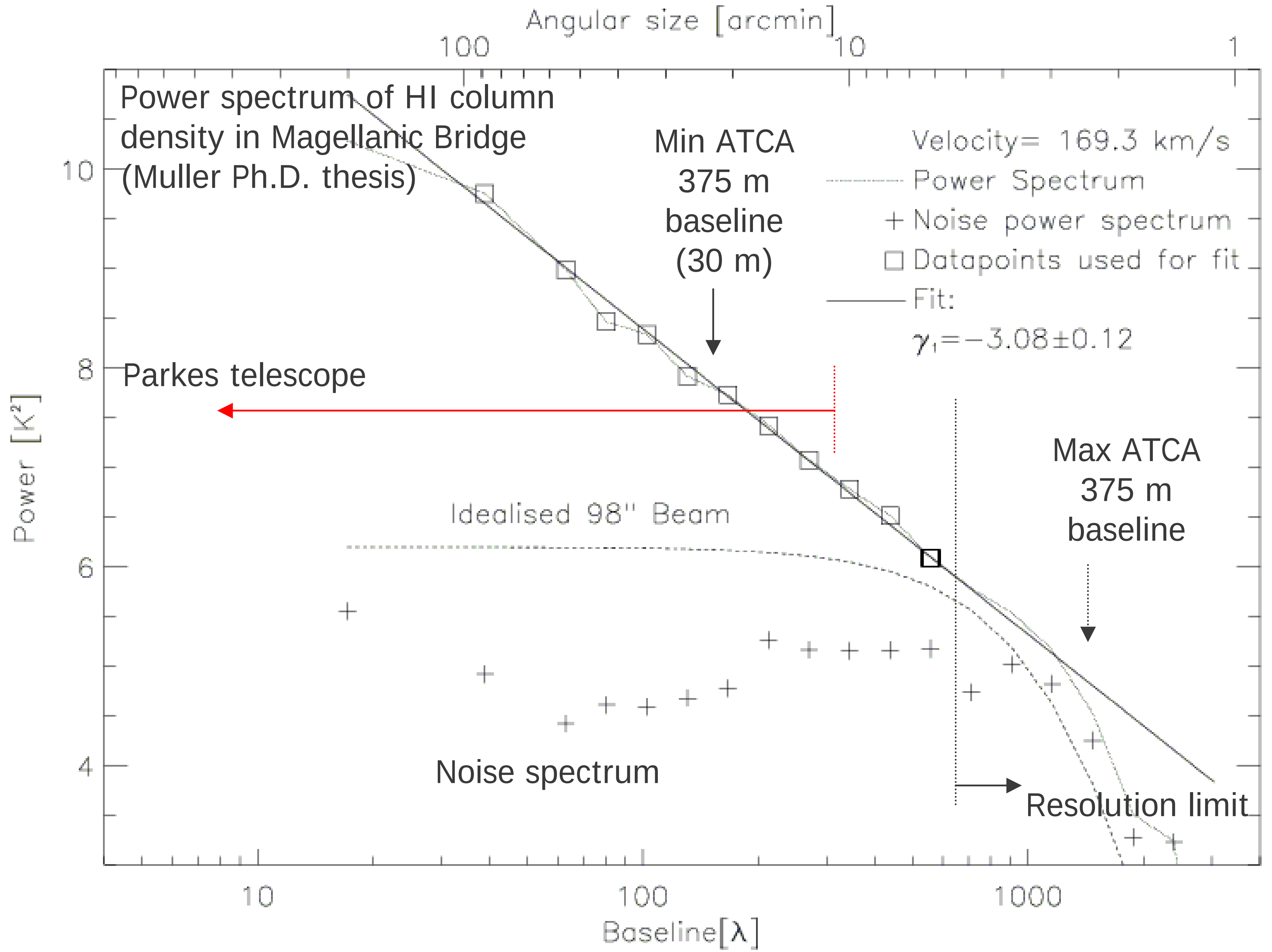
(post-MEM deconvolution)





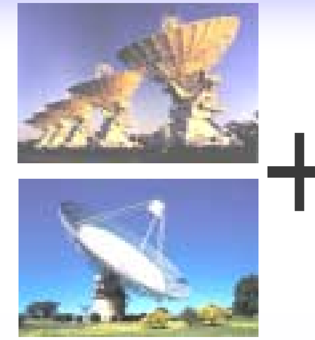
+

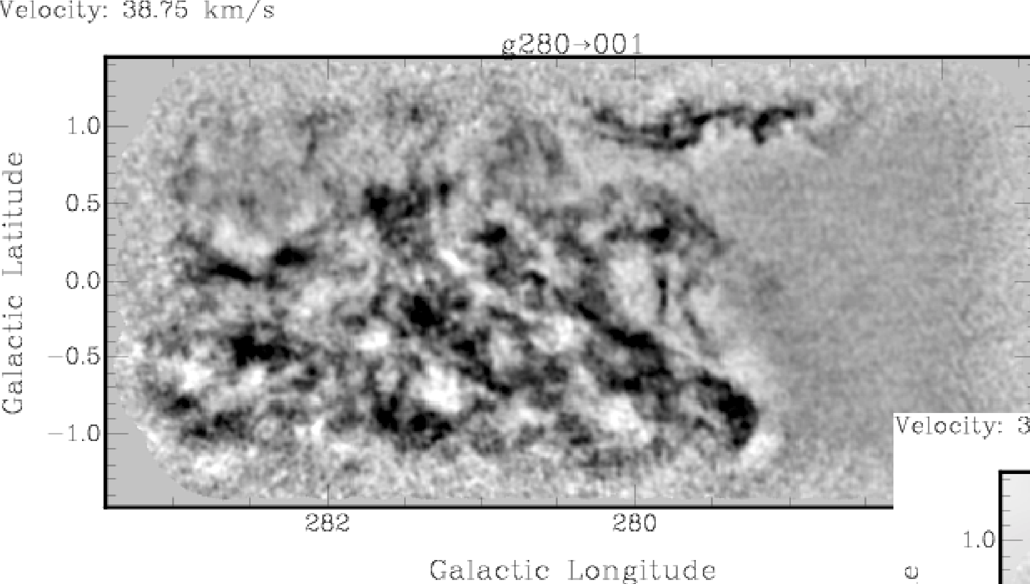
Negative 'bowl'



Angular size [arcmin]
100
10
1
Power spectrum of HI column density in Magellanic Bridge (Muller Ph.D. thesis)
Min ATCA 375 m baseline (30 m)
Velocity= 169.3 km/s
Power Spectrum
Noise power spectrum
Datapoints used for fit
Fit:
γ₁=−3.08±0.12
Parkes telescope
Max ATCA 375 m baseline
Idealised 98" Beam
Noise spectrum
Resolution limit
Power [K²]
10
8
6
4
10
100
1000
Baseline[λ]

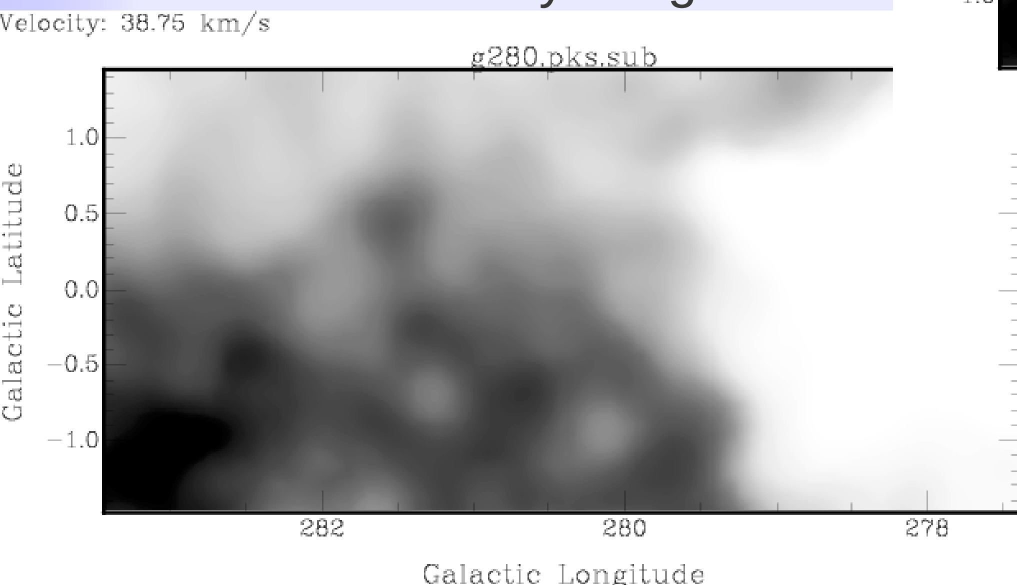
GSH 277+0+36 (McClure-Griffiths et al.)

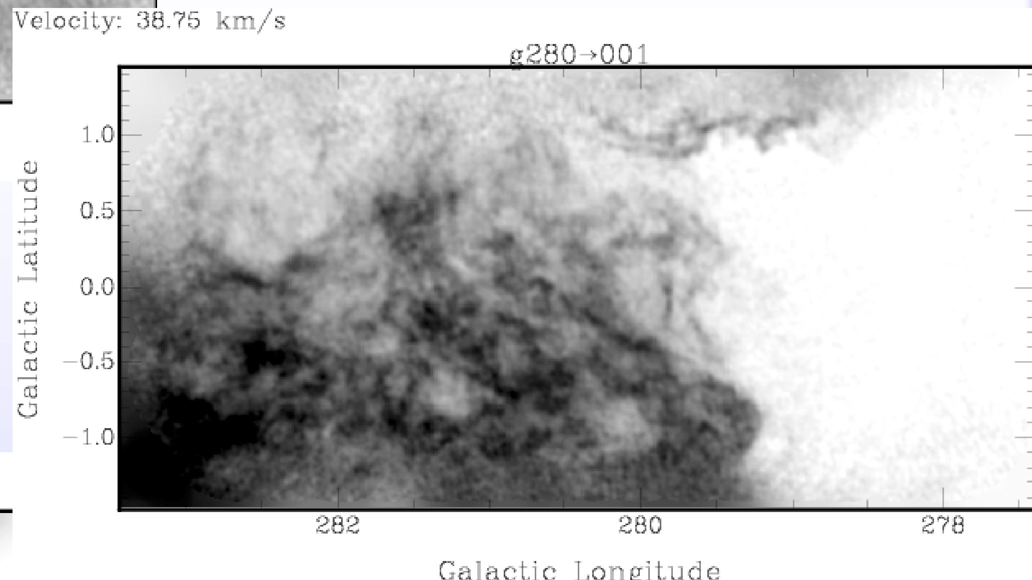




ATCA-only image

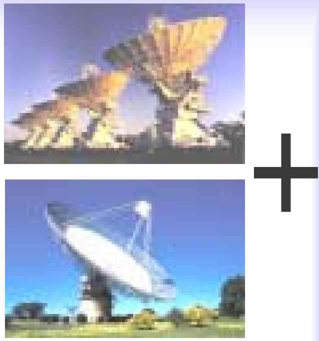
Parkes-only image



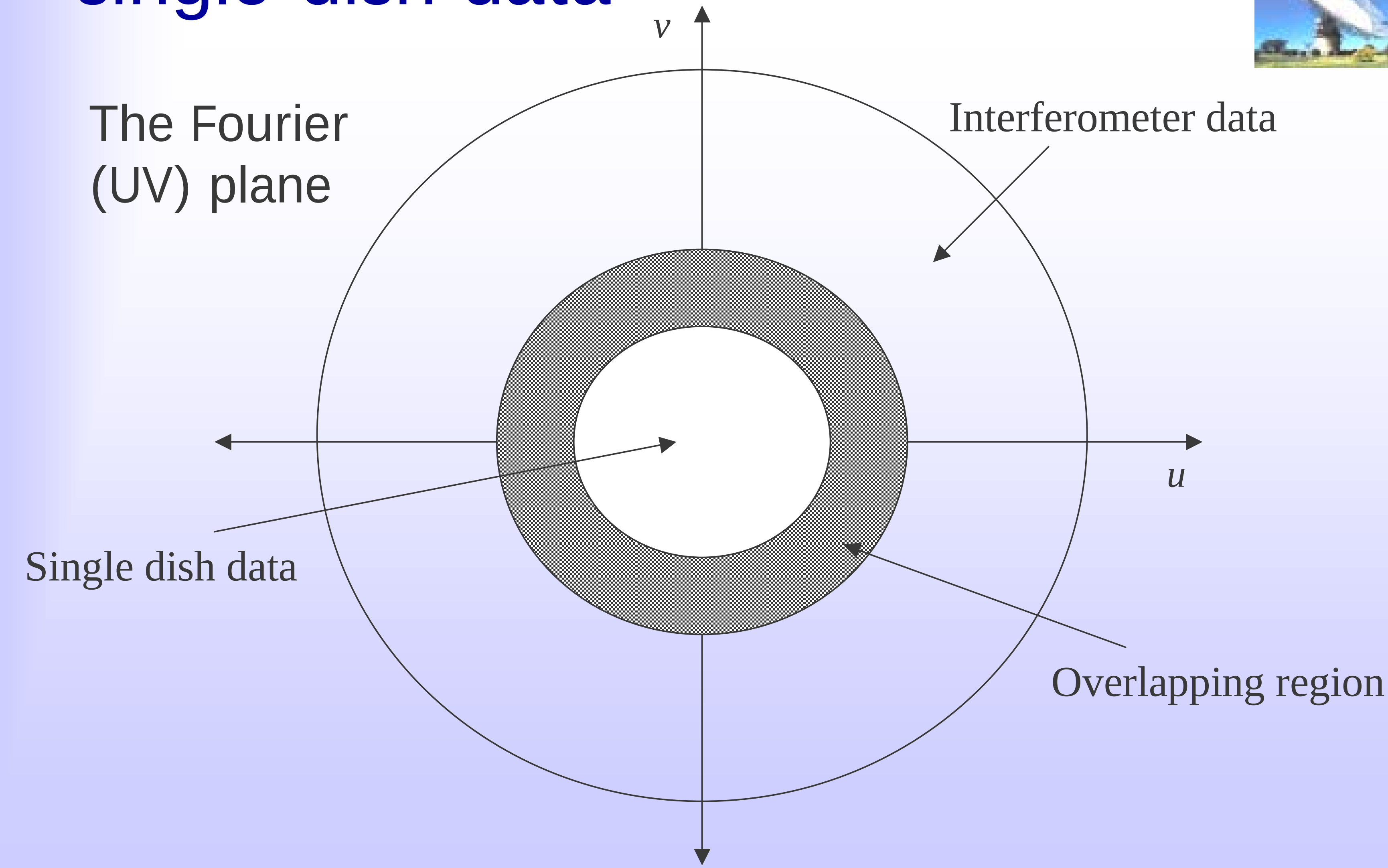


Combined image

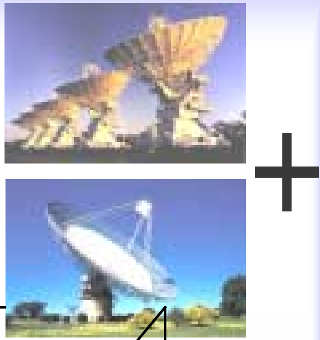
Merging interferometer and single-dish data



The Fourier (UV) plane

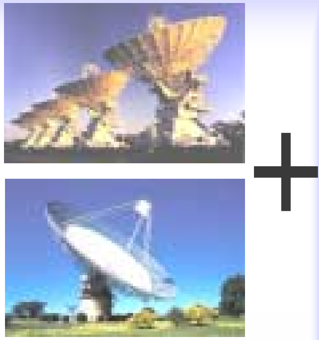


Data combination techniques

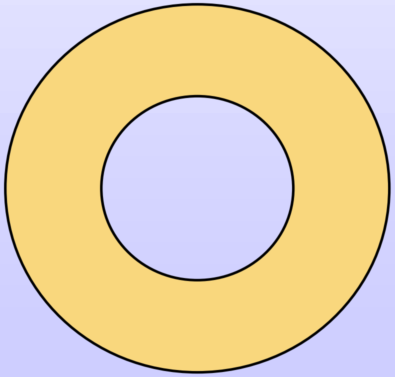


Dirty (non-linear) / *PSF-corrected (linear)*	Data combination in Fourier space	Data combination in image space
Not primary beam corrected	UV plane	Image plane
Primary beam corrected	Fourier plane	Sky plane

Image plane combination

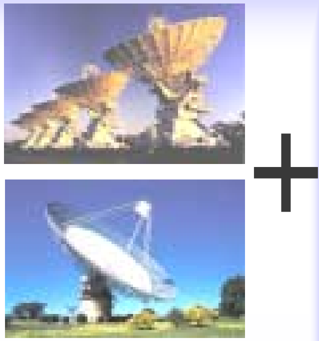


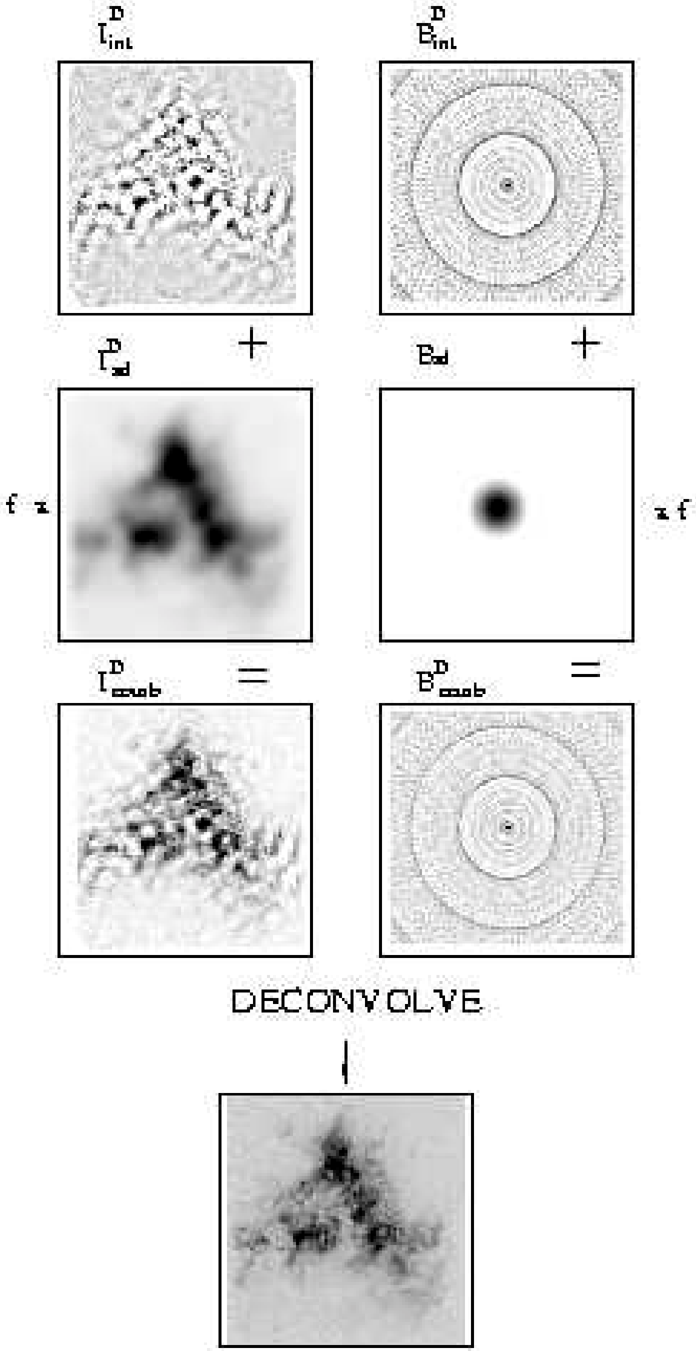
- Match resolution of data in overlap region
  - E.g. deconvolve SD image data with SD beam & convolve with interferometer beam
  - E.g. multiply interferometer image data with SD gain function
- Adjust flux density scales & weights (relative calibration)
- Add weighted, scaled images!
- If images are dirty, deconvolve.



Dirty ATCA image (mosaic)

Dirty ATCA beam (cube)





Parkes image

Parkes beam

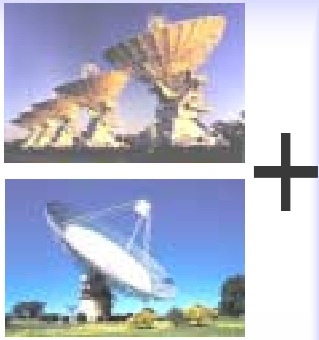
Linear combination

Linear combination

Stanimirovic et al. (1999)

Image combination equation

(Stanimirovic et al.; Sault et al)



Combined image: $$I_{\text{tot}} = w_{\text{int}} I_{\text{int}} + w_{\text{sd}} f_{\text{sd}} I_{\text{sd}}$$

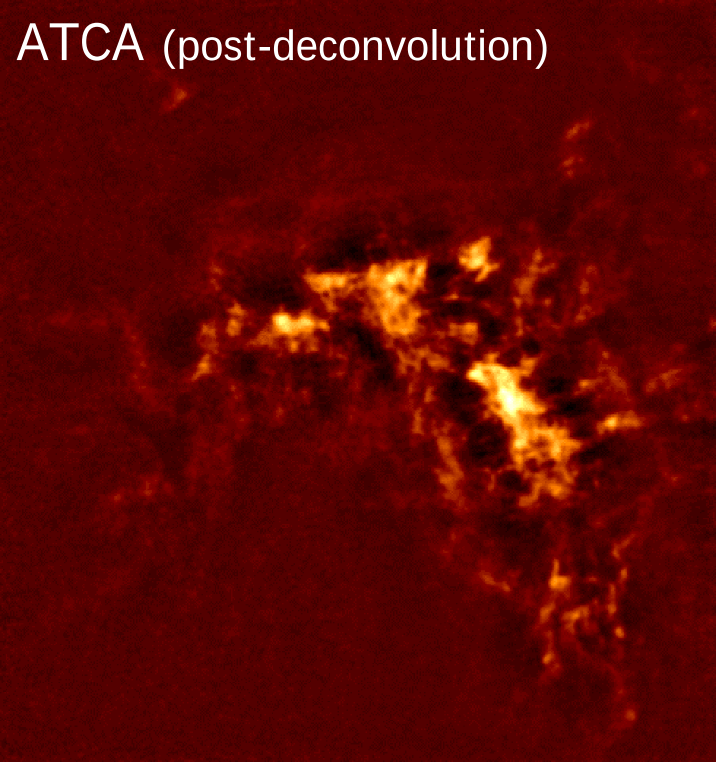
Weights

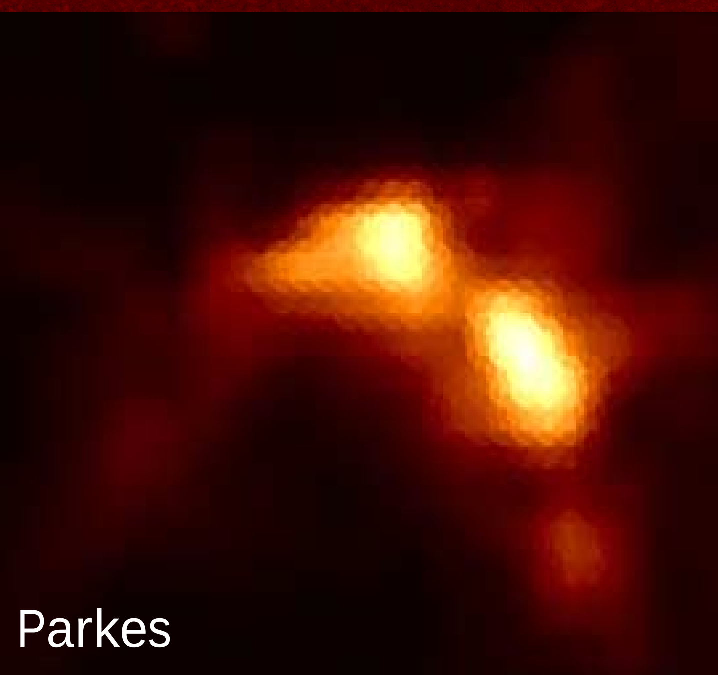
$$w_{\text{int}} = \frac{\Omega_{\text{sd}}}{\Omega_{\text{int}} + \Omega_{\text{sd}}}$$

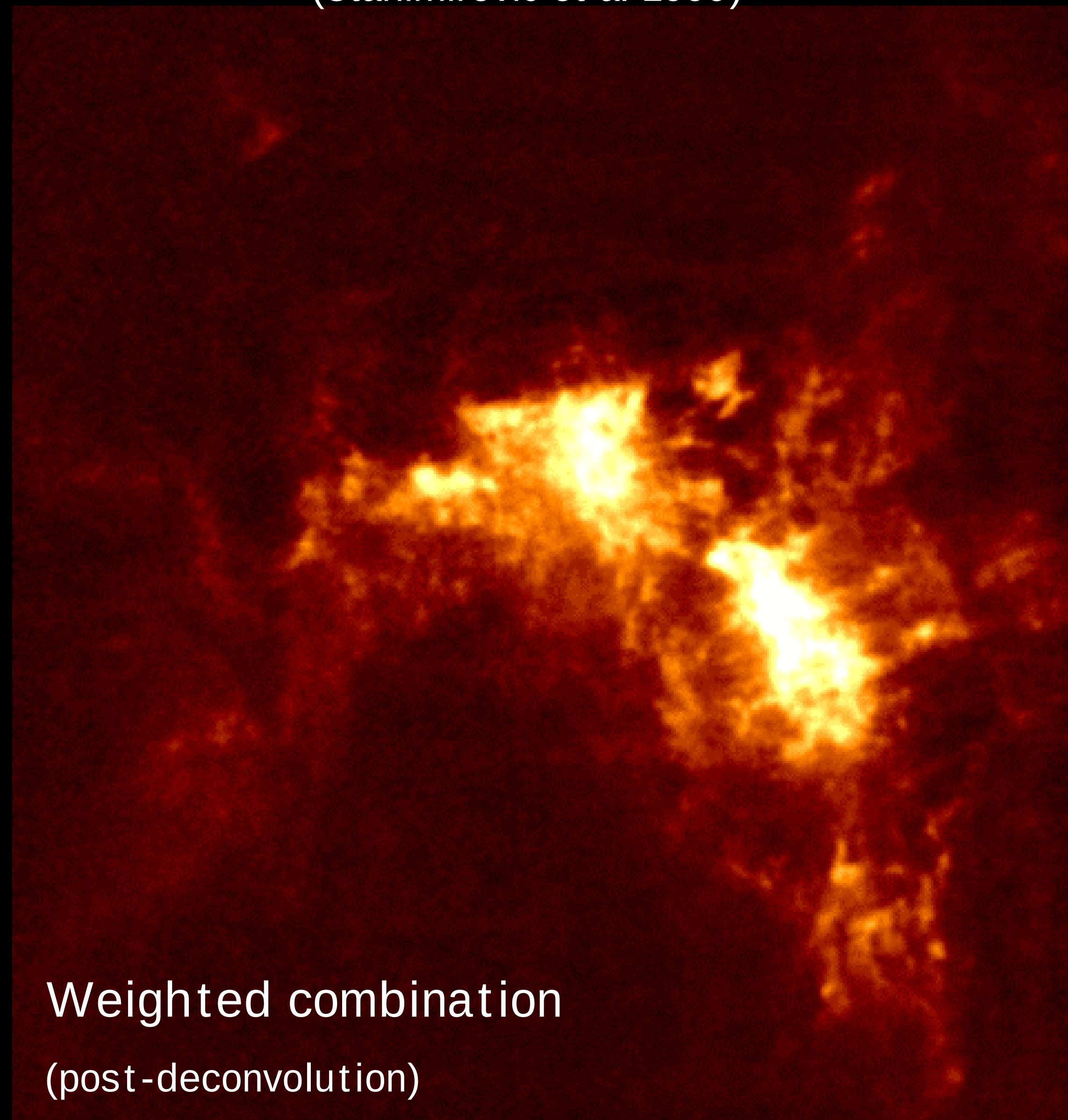
$$w_{\text{sd}} = \frac{\Omega_{\text{int}}}{\Omega_{\text{int}} + \Omega_{\text{sd}}}$$

Example of image-plane combination: SMC in HI at V_h=130 km/s

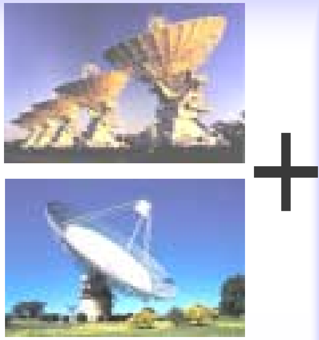
(Stanimirovic et al 1999)





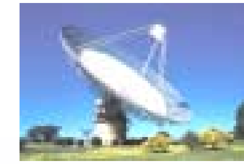


Fourier plane combination

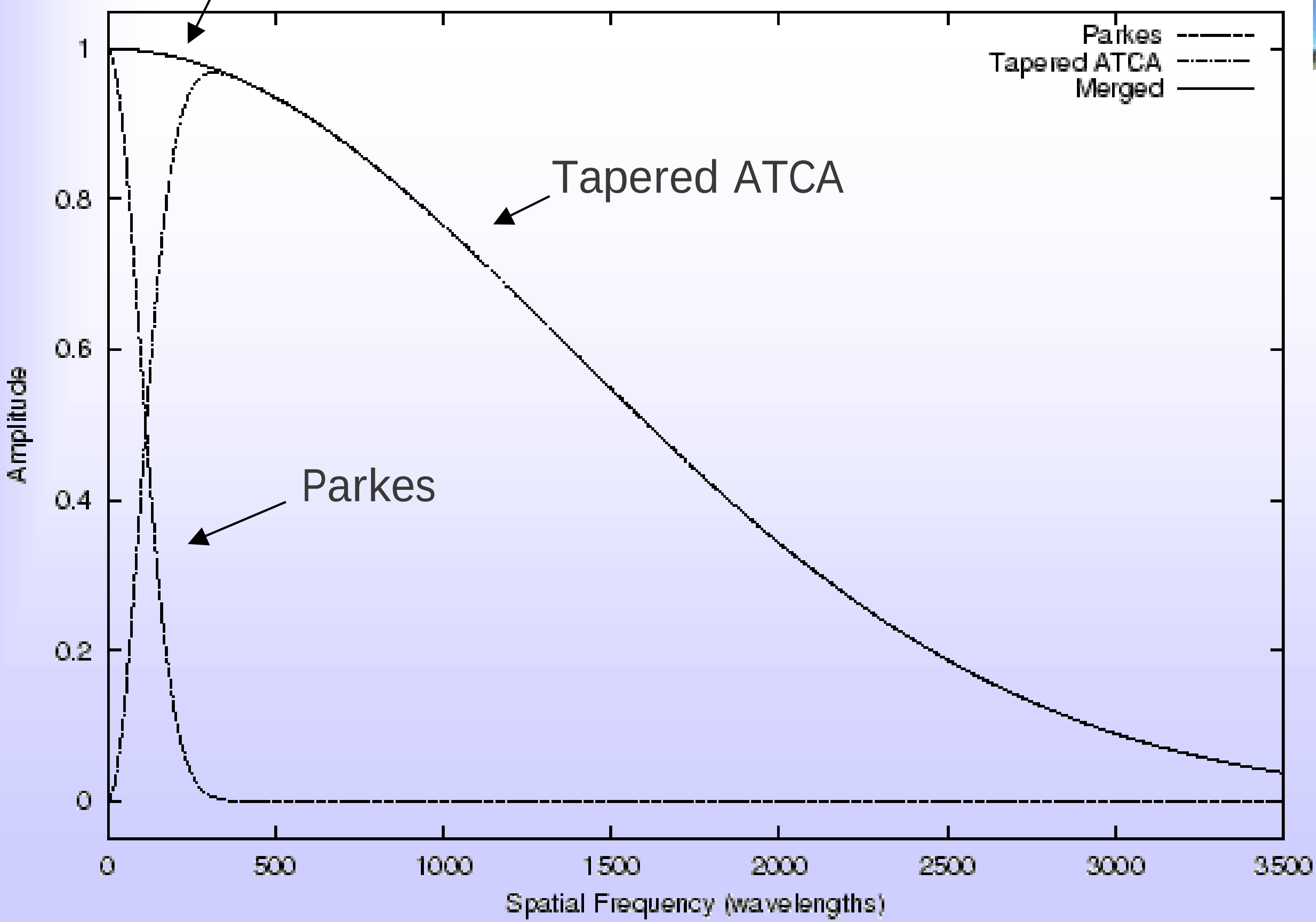


- Appropriately weight data in overlap region
  - E.g. taper interferometer Fourier-plane data with transform of SD beam
  - Multiply SD Fourier-plane data with transform of interferometer beam
- Adjust flux density scales (relative calibration)
- Add in Fourier plane!

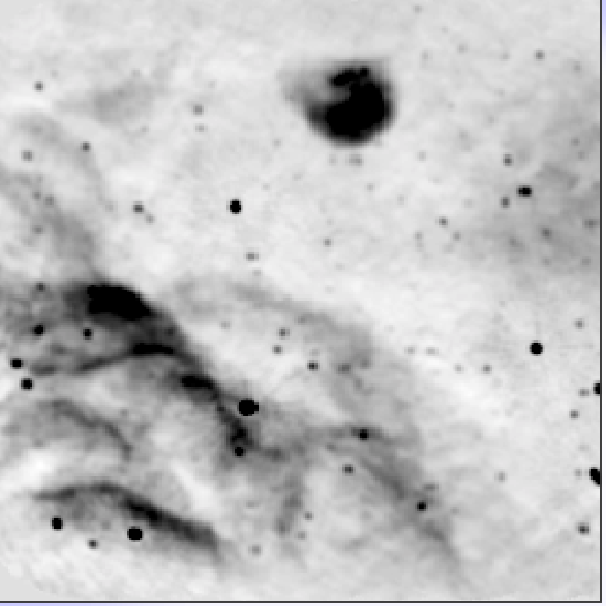
Weighting function in Fourier plane



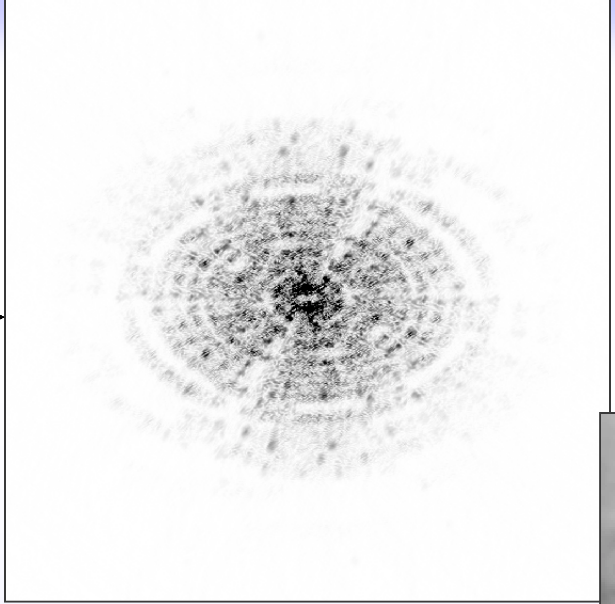
+



Example of Fourier plane combination: McClure-Griffiths et al.

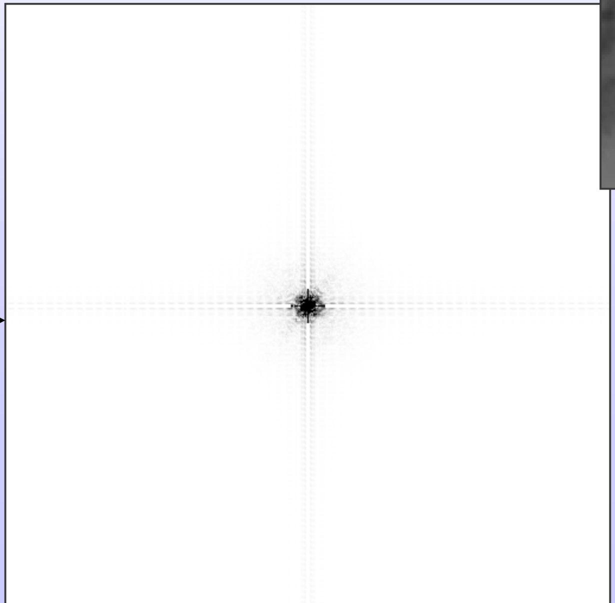


FT →

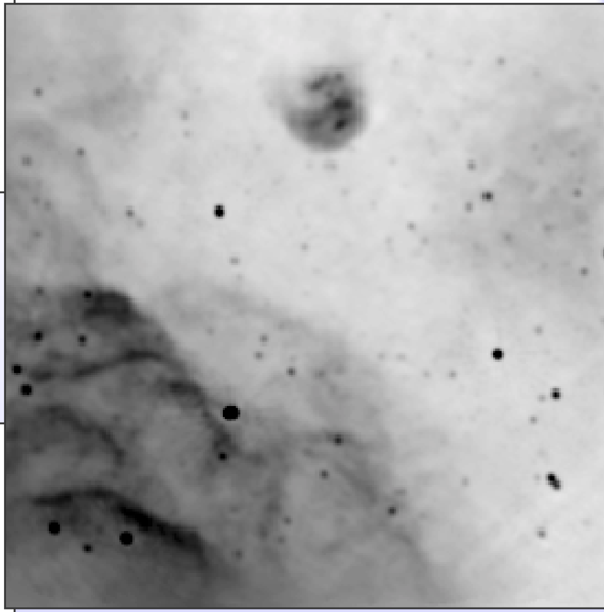


\+ f_{cal} x

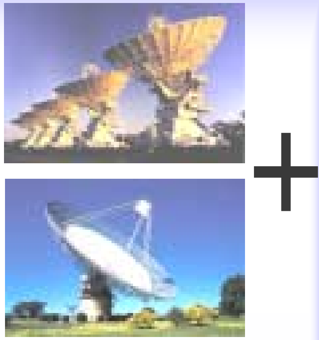
FT →



FT^{-1} =



Practical Implementation



- AIPS, miriad & aips++ all have possibilities
- Miriad is well-tested for ATCA+Parkes data:
  - Immerge allows feathering in Fourier plane [Fourier plane]
  - Mosmem allows SD data to be introduced as a ‘default’ image [image plane]
  - Mosmem allows image data to be combined at deconvolution step (joint deconvolution, non-linear combination) [image-plane] **

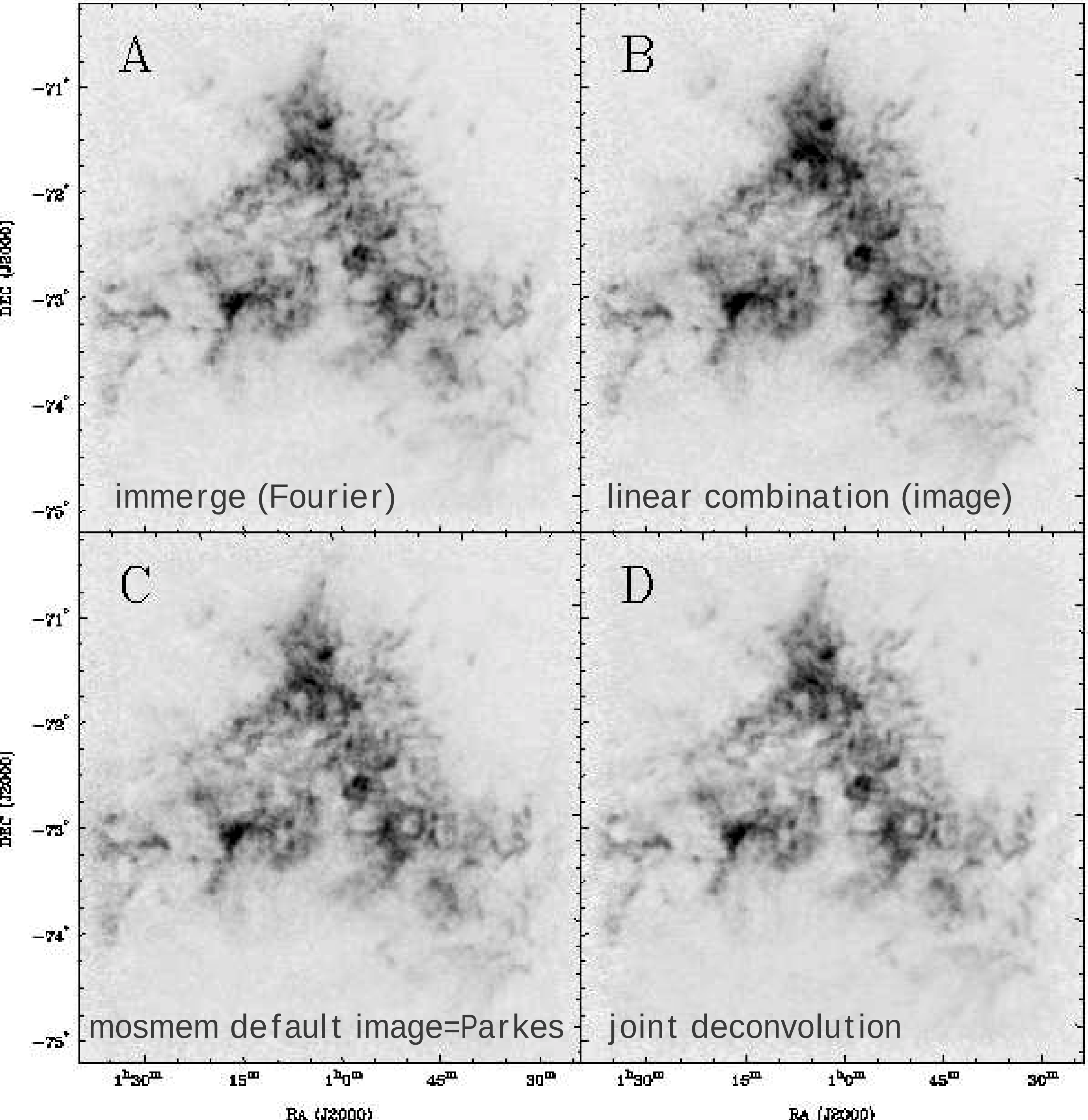
Joint deconvolution

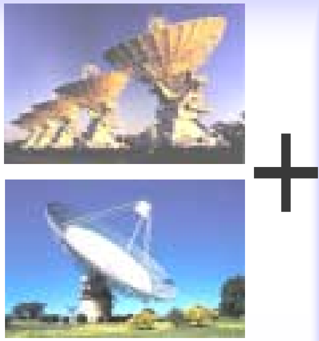
Maximize "entropy": $$\aleph = -\sum_i I_i \ln\left(\frac{I_i}{M_i e}\right)$$

Subject to (1) $$\sum_i \left\{I^D_{\text{int}} - B_{\text{int}} * I\right\}_i^2 < N\sigma^2_{\text{int}}$$

(2) $$\sum_i \left\{I^D_{sd} - \frac{B_{sd} * I}{f_{sd}}\right\}_i^2 < M\sigma^2_{sd}$$

- This may be the best approach for Mopra+ATCA data

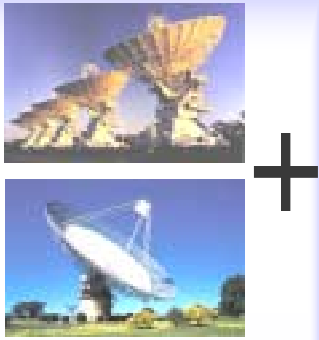




Comparing different methods using the SMC in HI at 169 km/s

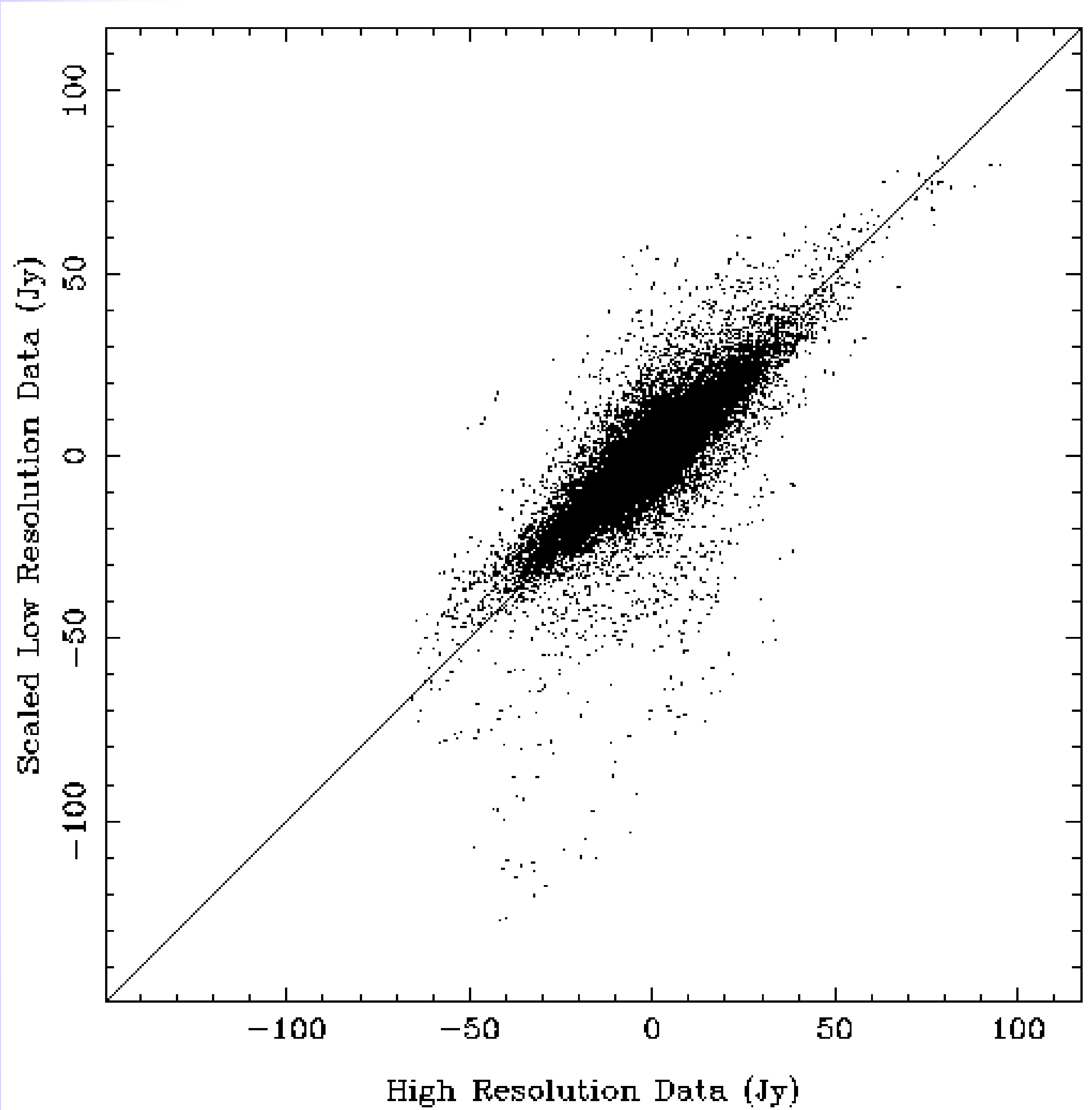
(Stanimirovic 2002)

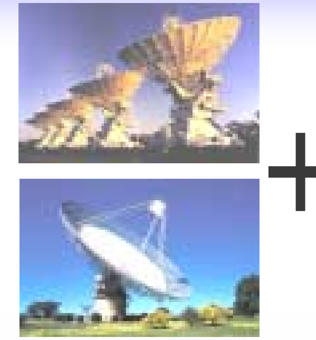
Comparison of methods



- Not much difference between available techniques for Parkes & ATCA combination
  - Which is 'best' depends on scientific use
  - Minimum ATCA baseline with useful S/N is 20 m (post-mosaic), cf. 30 m physical
  - Parkes maximum baseline with useful S/N & reliability is 40 m, cf. 64 m physical
- Linear Fourier plane approach (immerge) is very fast. No reason not to use this.
- Mopra+ATCA is harder and will need non-linear image-plane technique. Also:
  - need to handle change of beam shape, calibration, pointing & opacity with time.

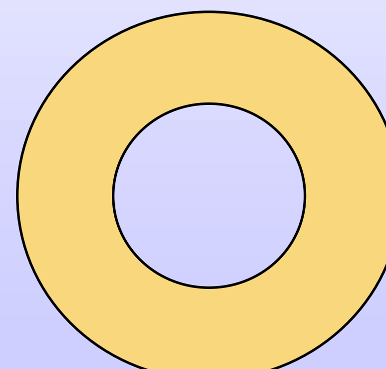
Check you understand your calibration



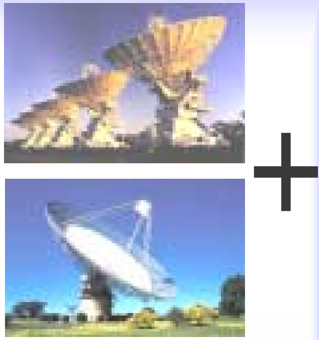


Relative scaling of data in overlap region from immerge

(120-170λ 130-200 km/s HI in SMC)



Summary



- If your objects are extended and you need to mosaic, you will need to add single-dish data.
- Parkes+ATCA: excellent combination 1-20 GHz.
- Mopra+ATCA at 80-115 GHz: possible, but challenging.
- For the AT Compact Array, so relatively little single-dish data needed

$$\frac{\tau_{sd}}{\tau_{sd}} \approx \left(\frac{\Omega_{pb,\mathrm{int}}}{\Omega_{sd}} \right)^{-2} n_{beams}^{-1}$$

- Linear Fourier plane combination works well