Wide-field imaging at mm-wavelengths

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IRAM & Obs. de Paris

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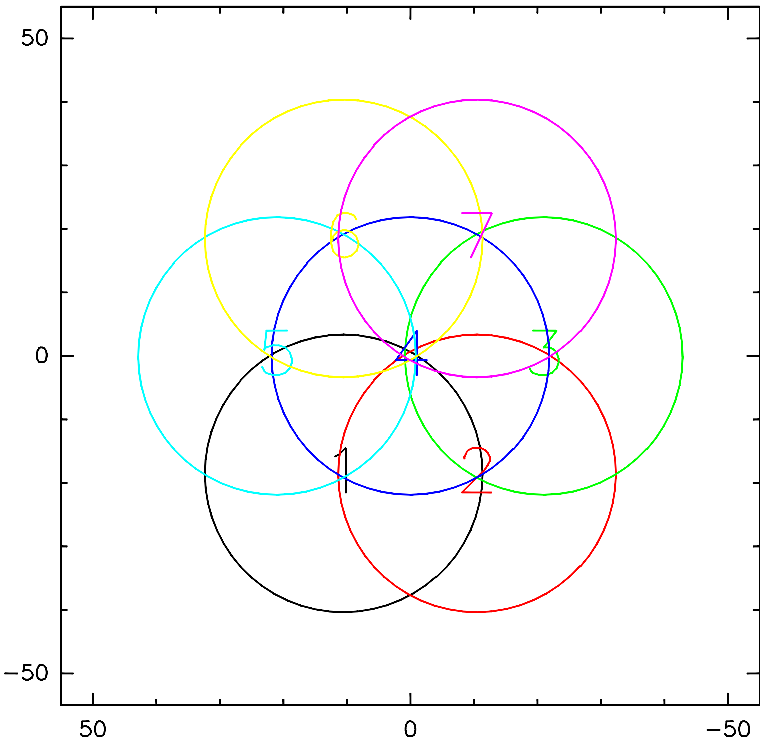
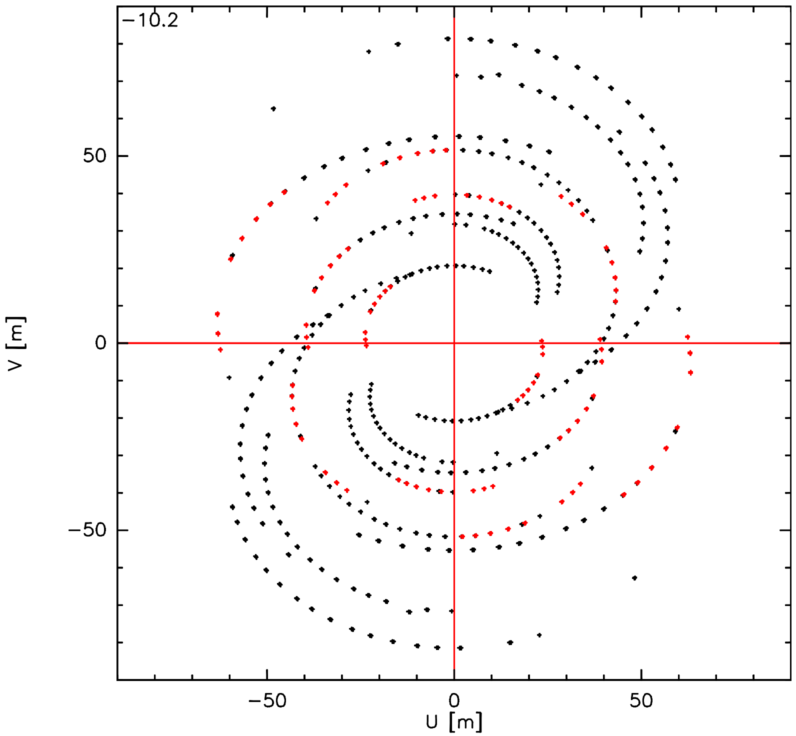
Observing setup: I. Interferometry

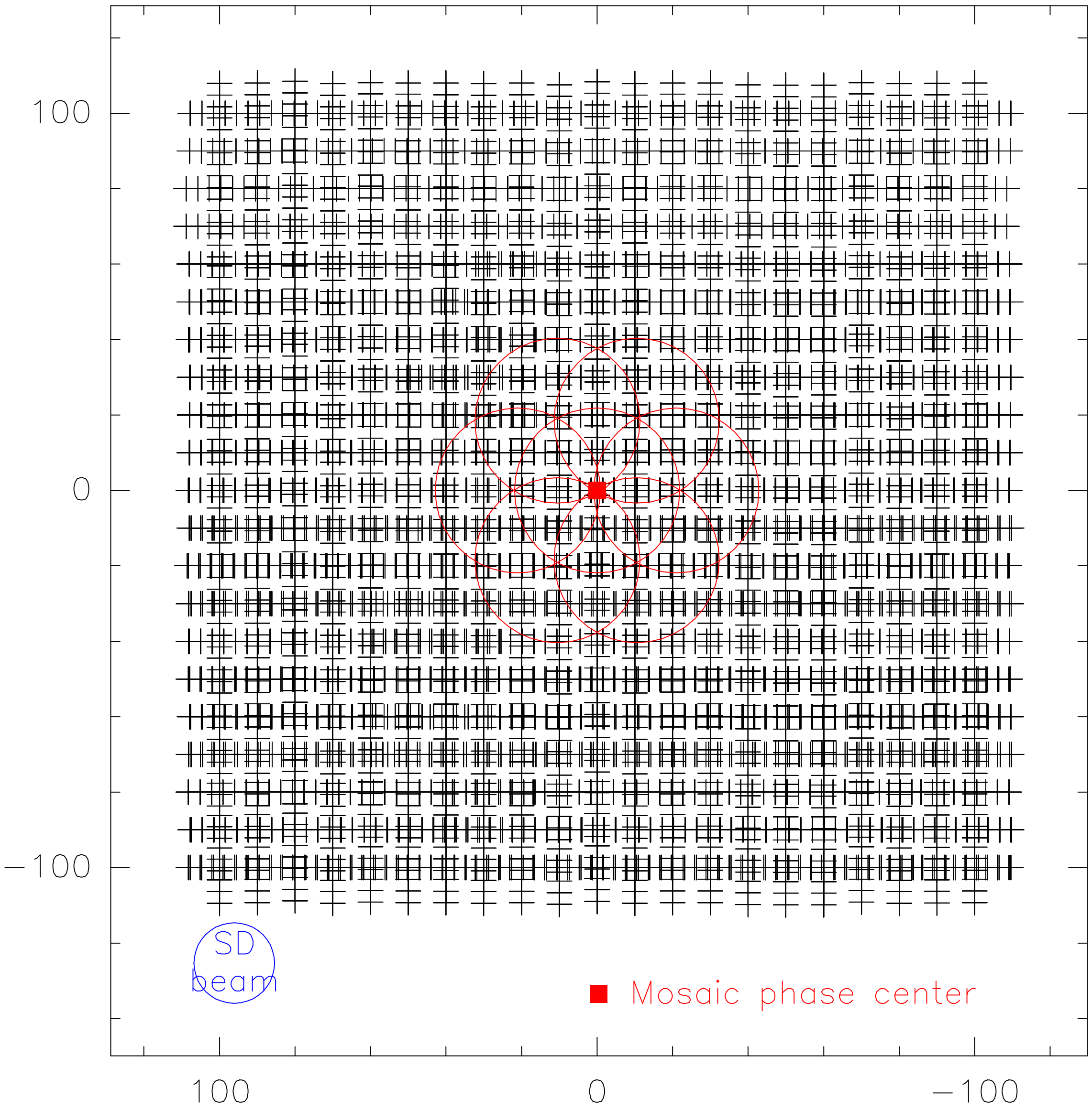




- Stop-and-go mosacing setup:
  - Loop around field positions $\Rightarrow$ similar uv coverage per field;
  - Contiguous time per field: Compromise between
    - Need of consistency between fields;
    - Minimization of dead times due to acceleration/deceleration.

- Example (setup during 8 hours)
  - 7 fields observed 3 minutes per fields in each loop;
  - Calibrator observed every 21 minutes;
  - Pointing and focus checked every hour.

Observing Setup: II. Single-Dish

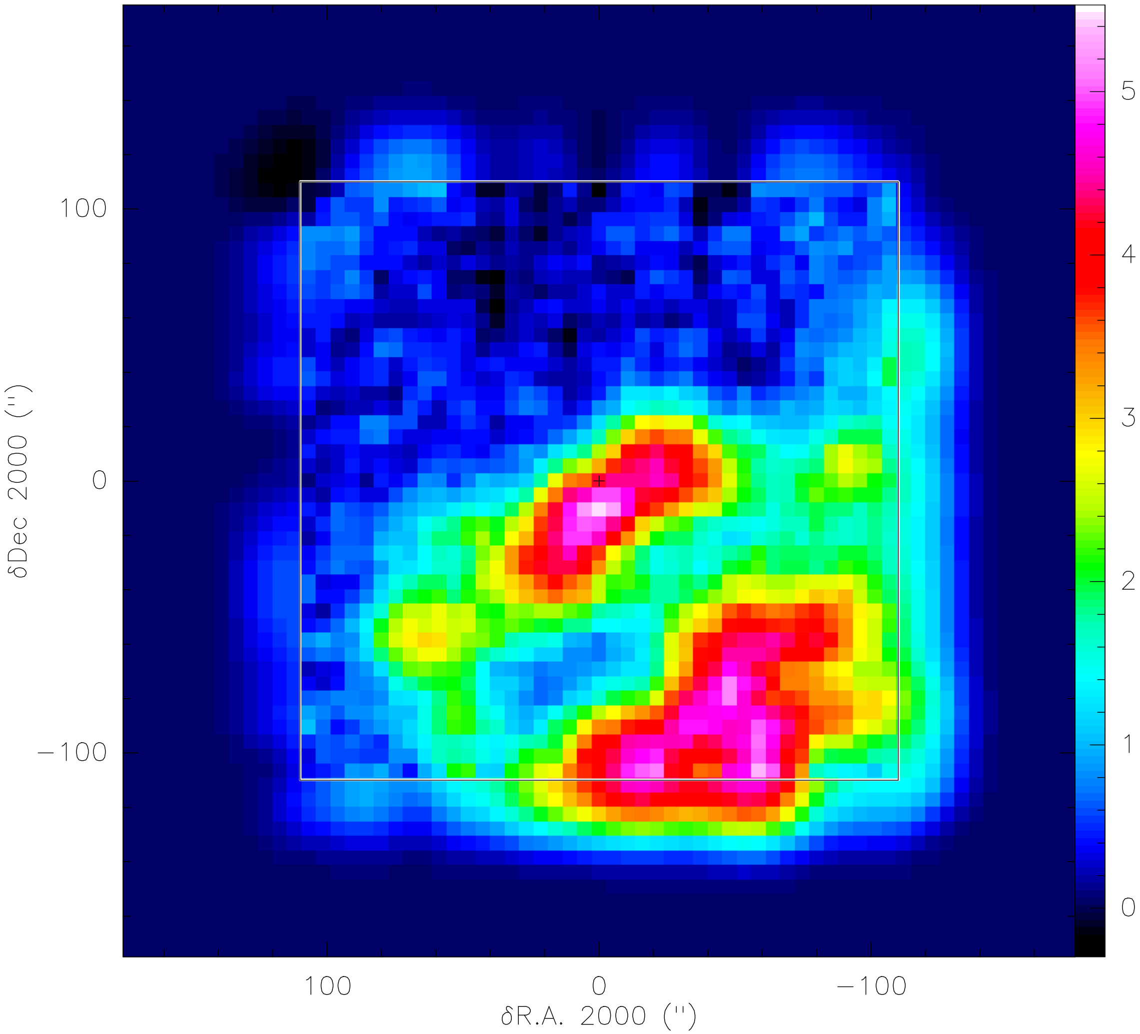


- On-The-Fly setup:
  - IRAM-30m resolution at 115 GHz: 22″.
  - Raster scanning in RA and then Dec
    - Speed: 3″/second;
    - Dump time: 1 second ⇒ 7 points/beam;
  - Separation between rasters: 10″ ⇒ Nyquist sampling.
- Calibration:
  - ON-OFF switching;
  - Hot/cold/atm measurement every 15 minutes;
  - Chopper wheel method;
  - Factor from T_A^* to T_{mb}: F_{eff}/B_{eff}

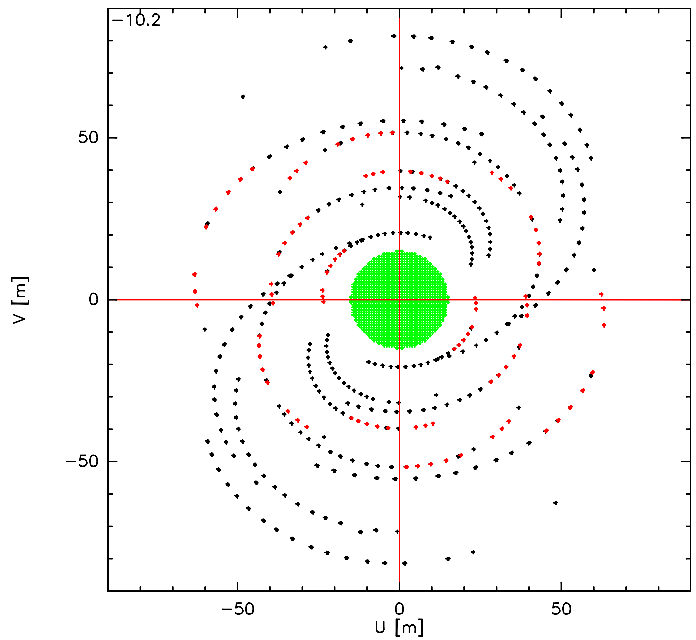
Short-Spacings Processing: I. Pseudo-visibilities

From $I_{\rm meas} = B_{\rm 30m} \star I_{\rm source} + N$

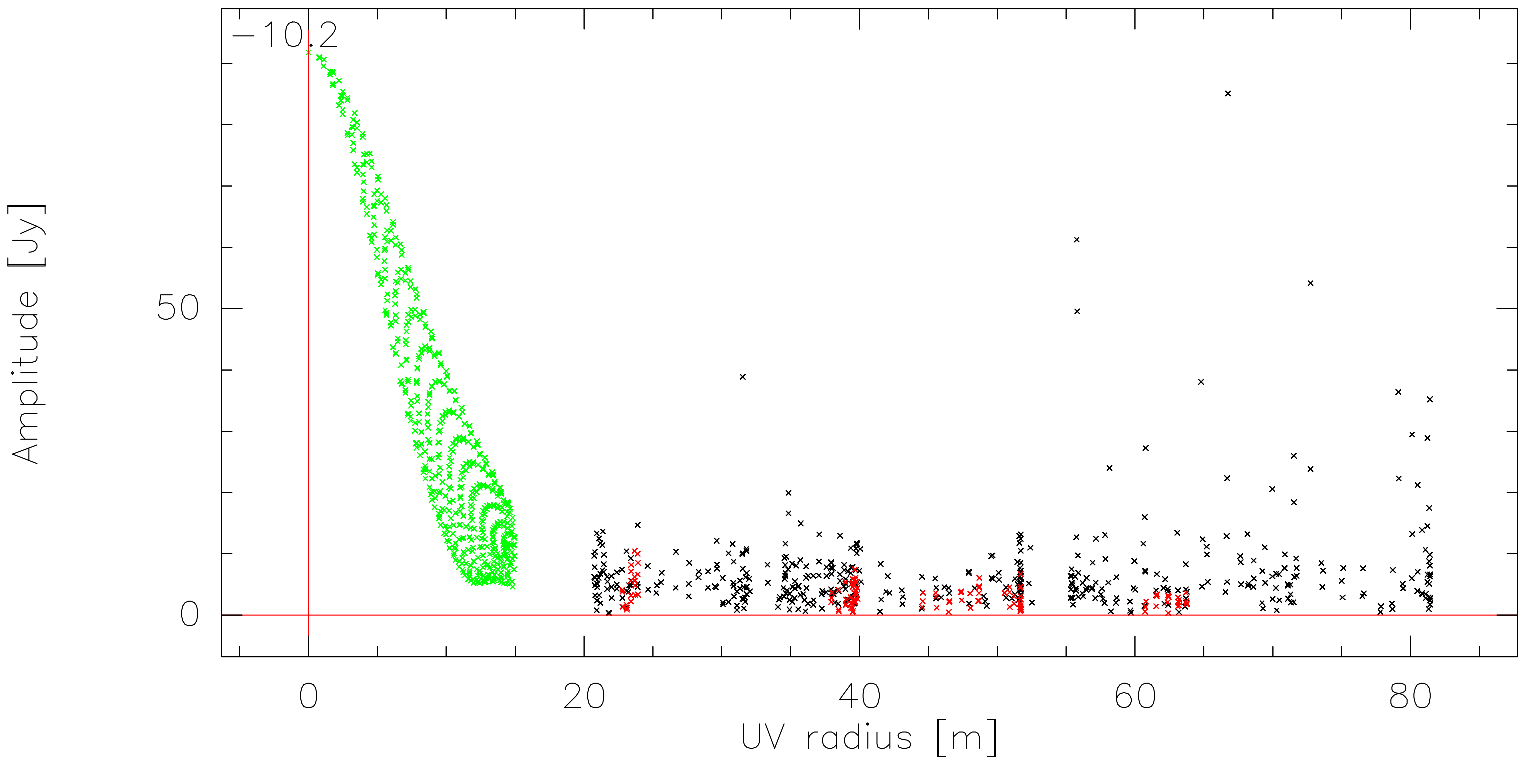
To $V_{\rm pseudo}(u,v) = \textbf{FT}\left\{B^{15m}_{\rm primary}.I_{\rm source}\right\}(u,v) + N$



1. Gridding + Apodization;
2. Deconvolution of $B_{\rm 30m}$ in uv plane;
3. Multiplication by $B^{15m}_{\rm primary}$ in image plane;
4. Sampling of pseudo-visibilities in uv plane.



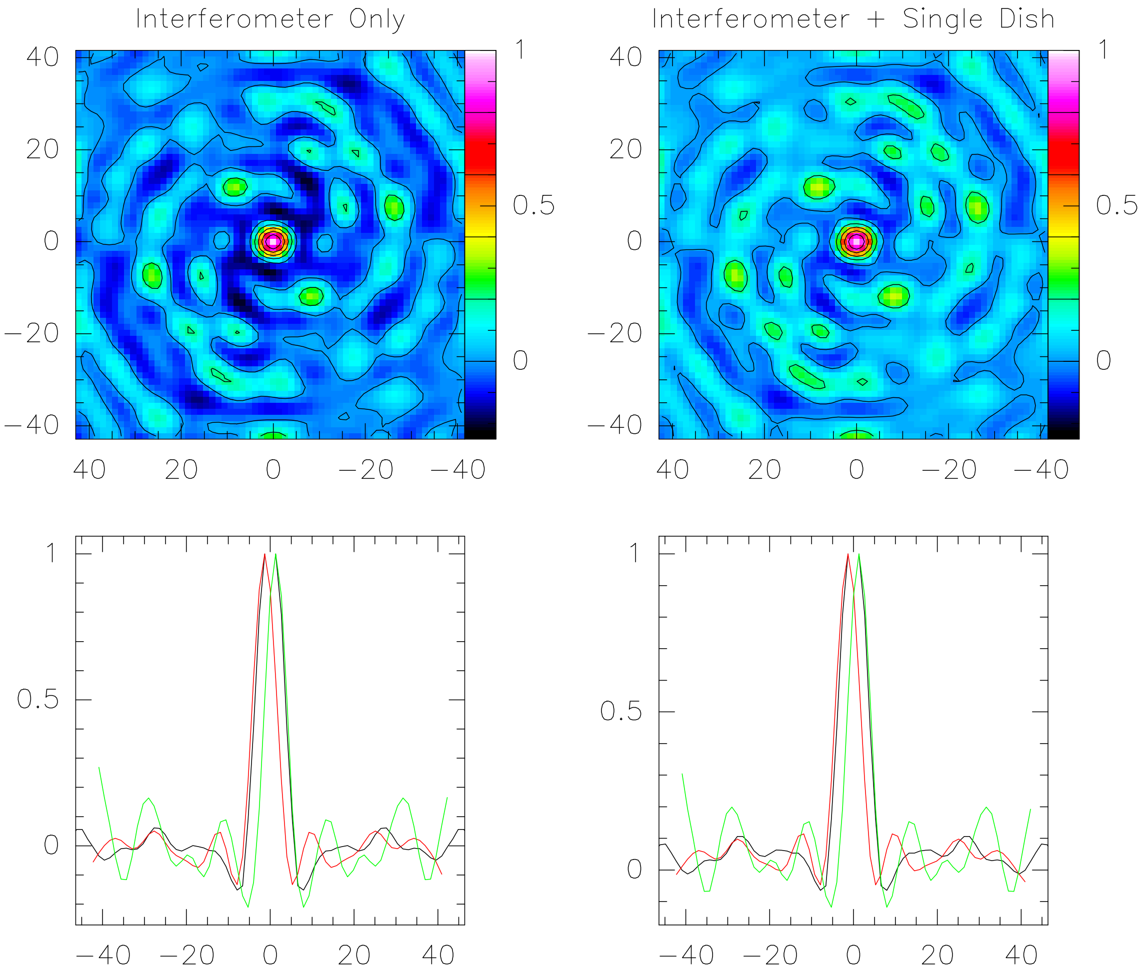
Short-Spacings:
II.1 Merging (Amplitude cross calibration)



- Amplitude cross calibration:
  - Extremely important (wrong ⇒ distortion);
  - Difficult to achieve (no overlap).

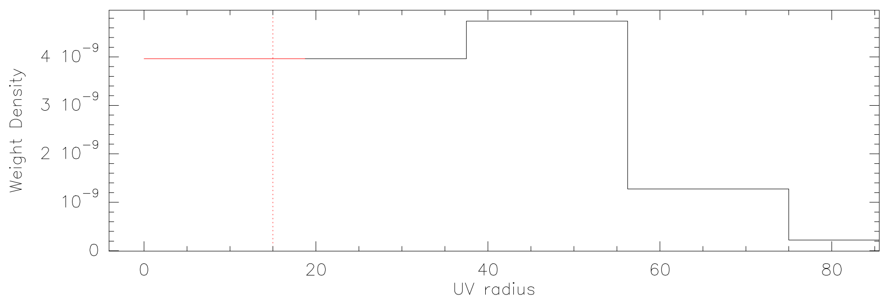
  ⇒ Careful independent work needed.
- Outlier points have extremely low weights ⇒ No need to clip them out.

Short-Spacings:
II.2 Merging (Weight density and dirty beam shape)



- Dirty beam = FFT of weight density;
- Single-dish total weight: A free parameter (as long as it is down-weighted...)

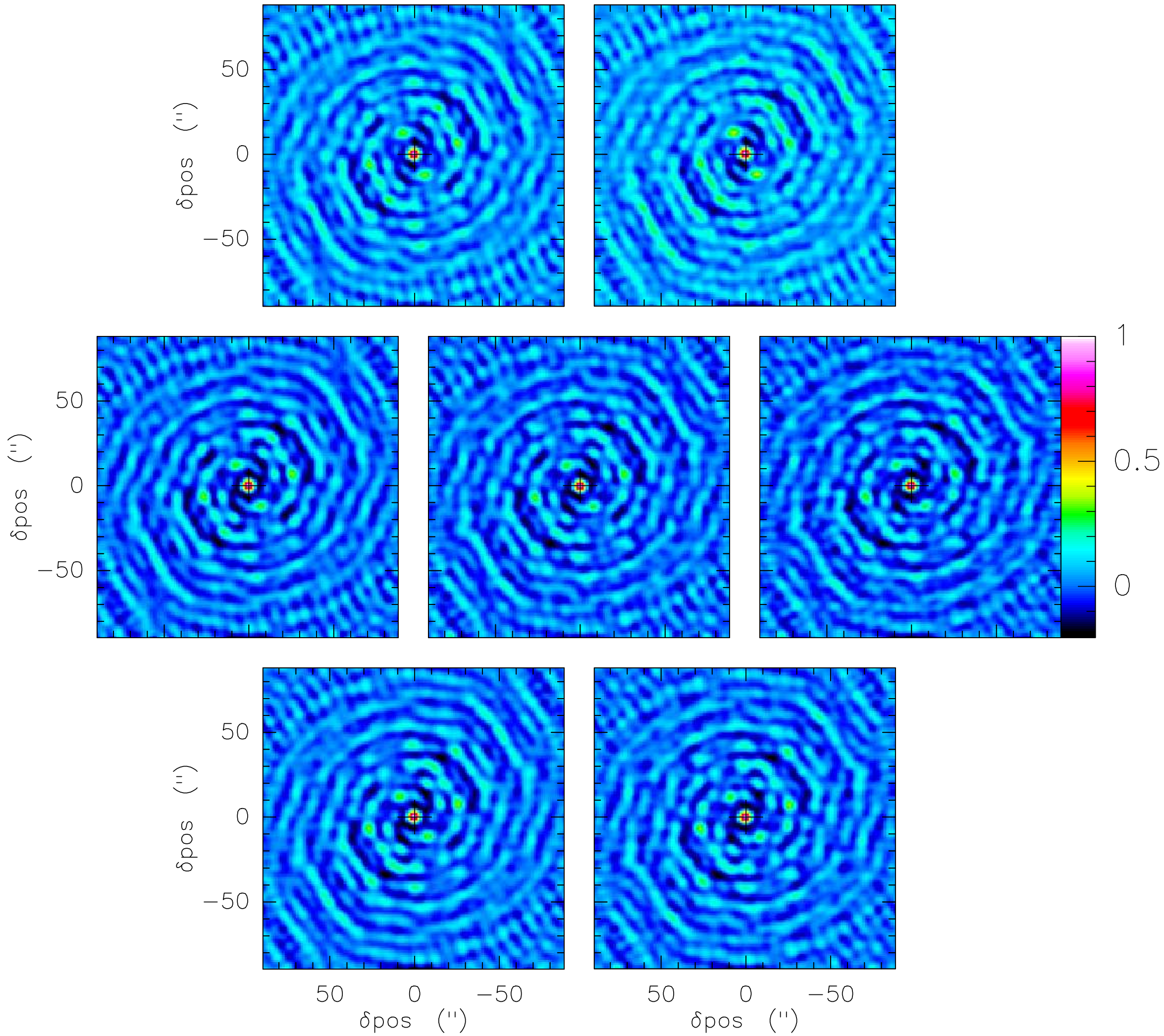
⇒ Single-dish total weight set to get a roughly Gaussian shape for the circularly averaged weight density.



- Minimum visual change of the dirty beam;
- Dirty beam integral > 0 after addition of short-spacings.

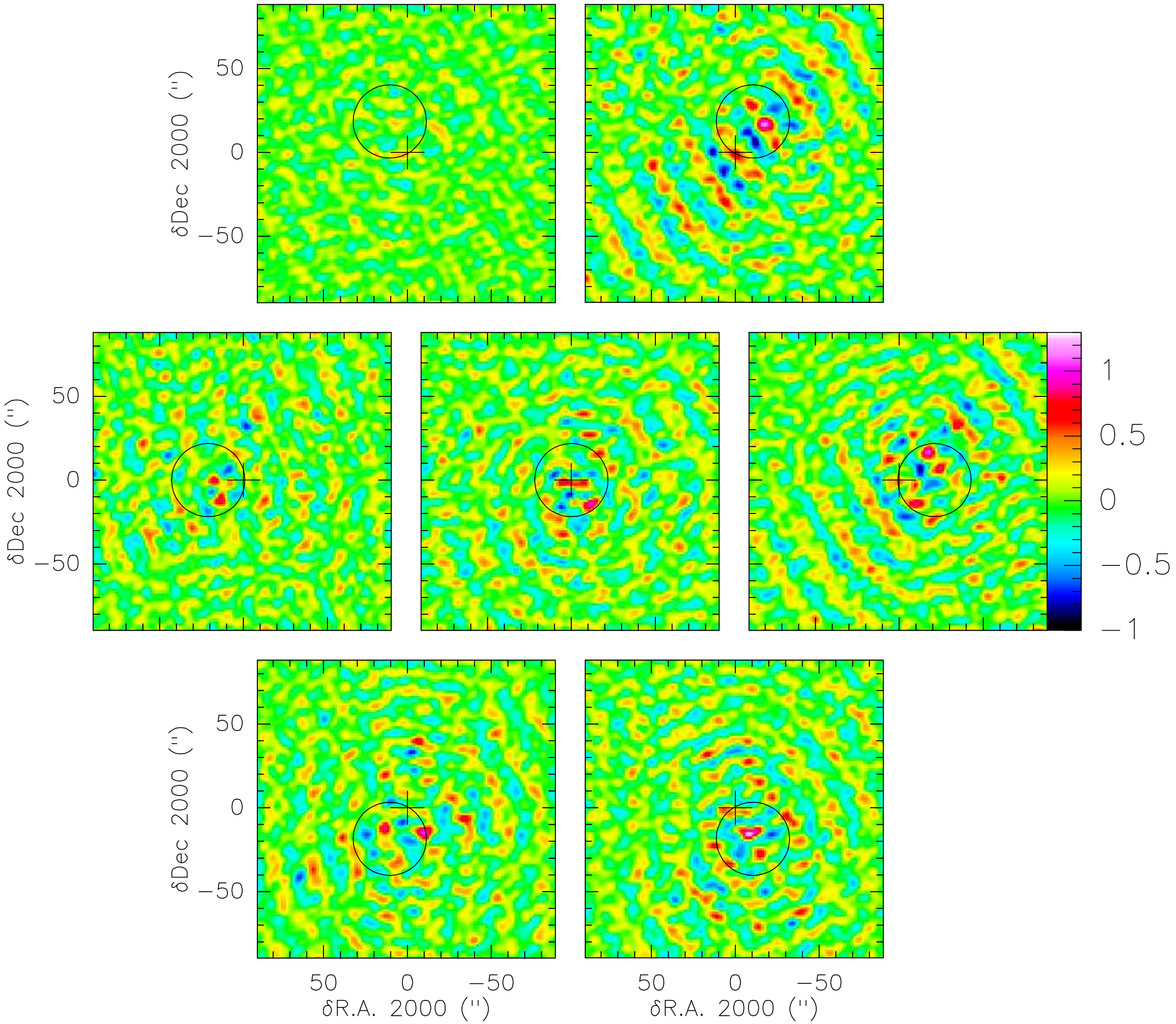
Imaging: Dirty beams

- One dirty beam per field (directly the final image size): $I_i = B_i \star (D_i.I_{\text{source}}) + N_i$.

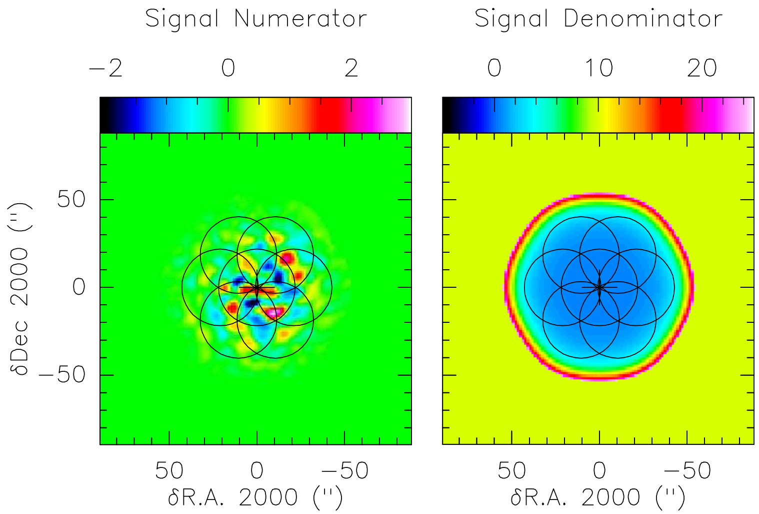


Imaging: Dirty image and noise (without short-spacings)

- One dirty image per field (directly the final image size): $I_i = B_i \star (D_i.I_{\text{source}}) + N_i$.

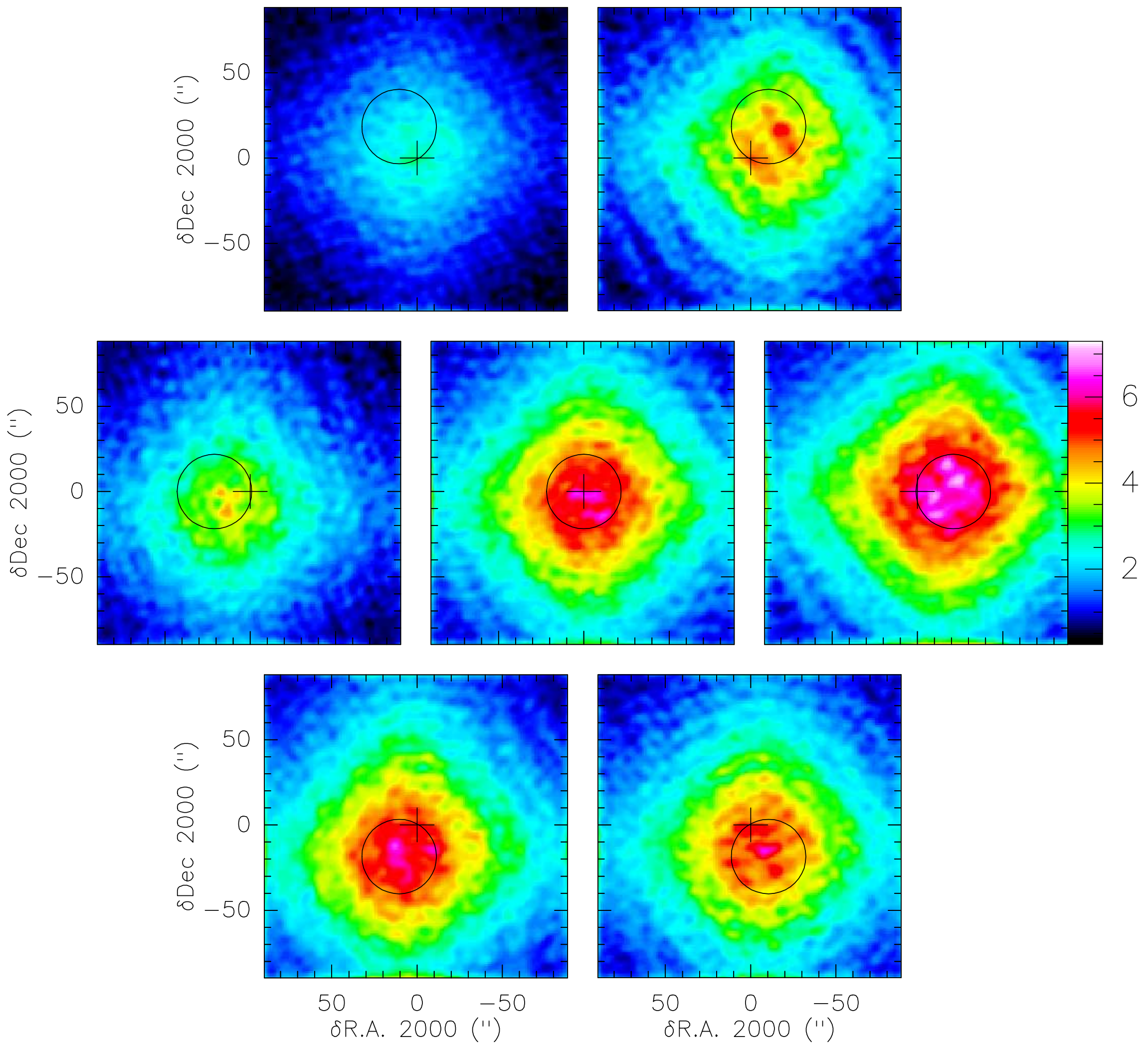


- Linear combination (optimal from signal-to-noise ratio point of view):
  - Signal:
    $$S(\alpha,\beta) = \frac{\sum_i \frac{B_i(\alpha,\beta)}{\sigma_i^2} I_i(\alpha,\beta)}{\sum_i \frac{B_i^2(\alpha,\beta)}{\sigma_i^2}};$$
  - Noise:
    $$N(\alpha,\beta) = 1 \Big/ \sqrt{\sum_i \frac{B_i^2(\alpha,\beta)}{\sigma_i^2}};$$
  - Signal-to-Noise Ratio: $\text{SNR}(\alpha,\beta) = \frac{S(\alpha,\beta)}{N(\alpha,\beta)}$.

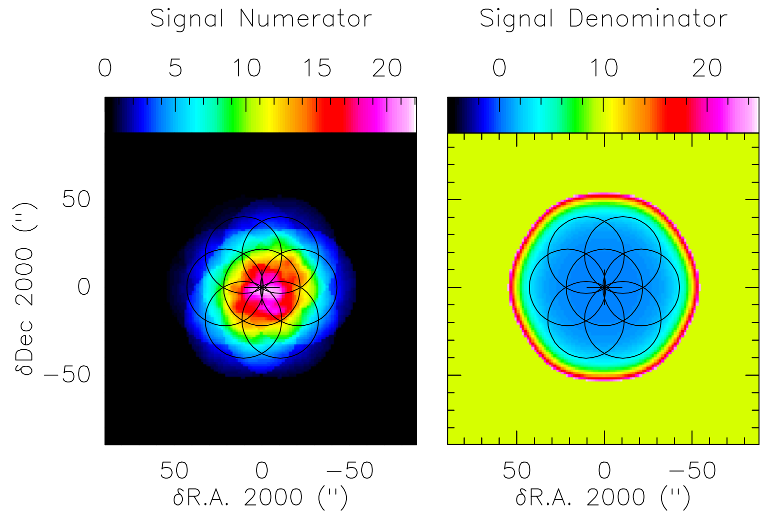


Imaging: Dirty image and noise (with short-spacings)

- One dirty image per field (directly the final image size): $I_i = B_i \star (D_i . I_{\text{source}}) + N_i$.



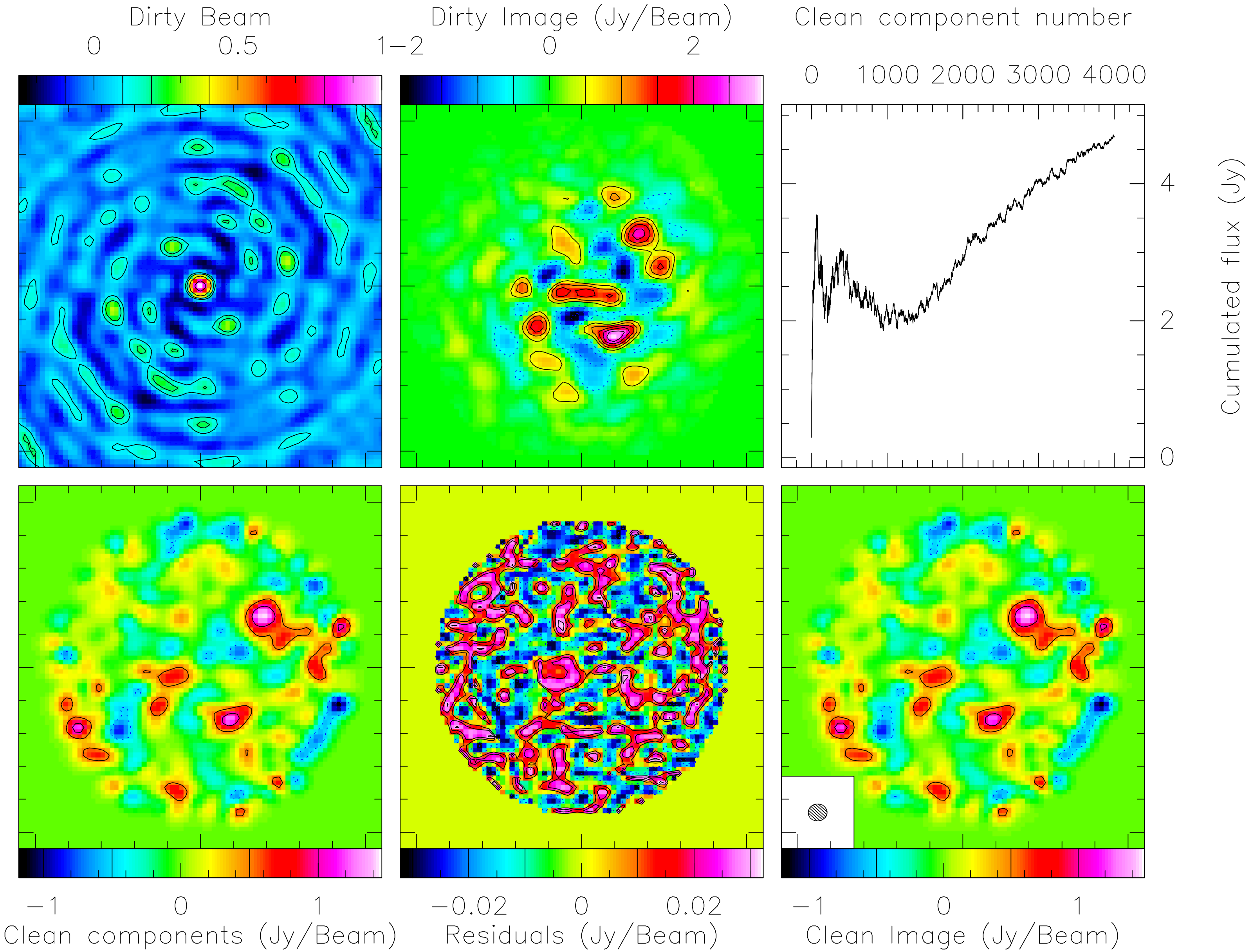
- Linear combination (optimal from signal-to-noise ratio point of view):
  - Signal:
  $$S(\alpha,\beta) = \frac{\sum_i \frac{B_i(\alpha,\beta)}{\sigma_i^2} I_i(\alpha,\beta)}{\sum_i \frac{B_i^2(\alpha,\beta)}{\sigma_i^2}};$$
  - Noise:
  $$N(\alpha,\beta) = 1 \Bigg/ \sqrt{\sum_i \frac{B_i^2(\alpha,\beta)}{\sigma_i^2}};$$
  - Signal-to-Noise Ratio: $\text{SNR}(\alpha,\beta) = \frac{S(\alpha,\beta)}{N(\alpha,\beta)}$.



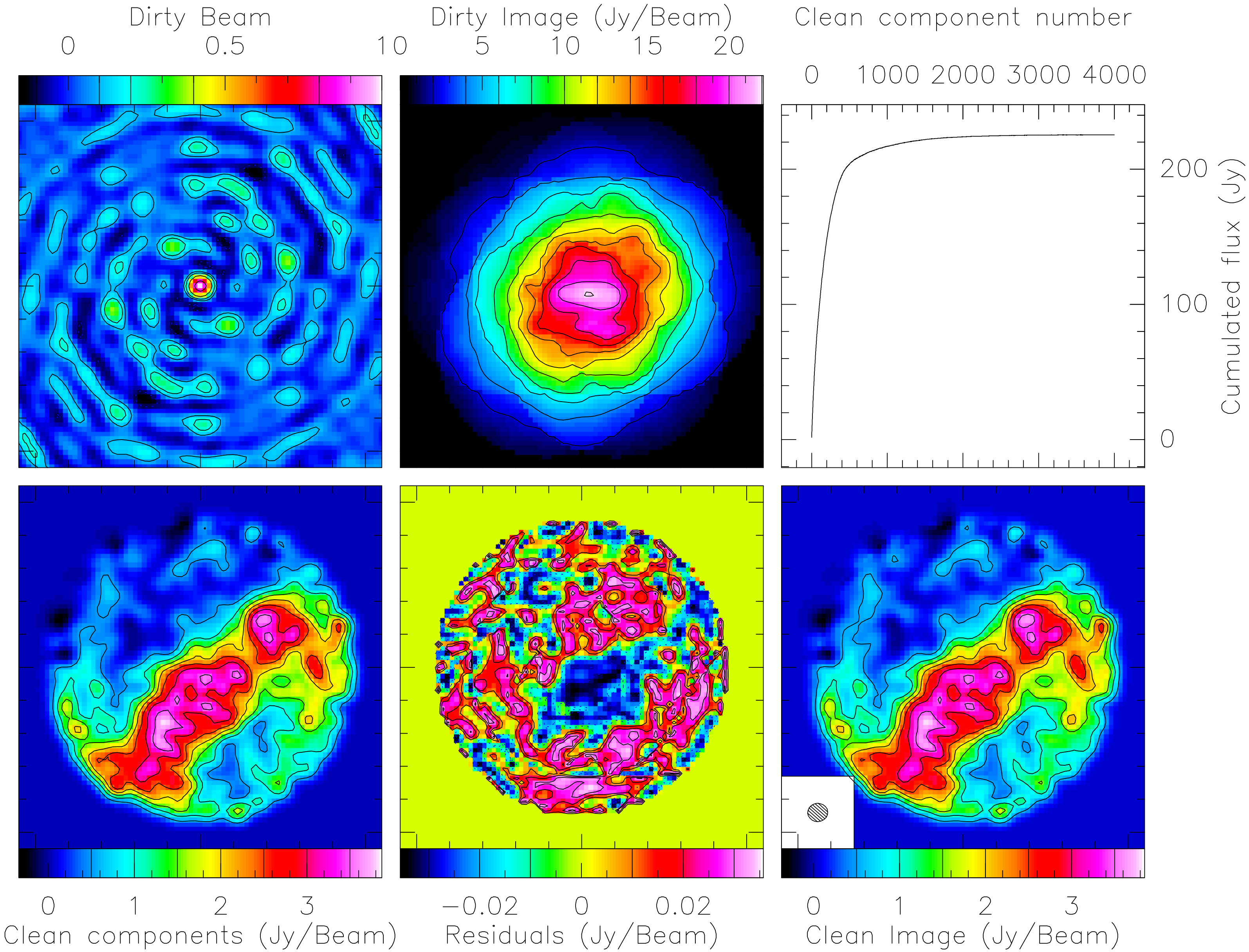
- Same as single field except:
  - The CLEAN components are searched on the SNR map;
  - The residual and SNR maps are iterated as:
    - $S_k(\alpha,\beta) = S_{k-1}(\alpha,\beta) - \frac{\sum_i \frac{B_i(\alpha,\beta)}{\sigma_i^2} \gamma\, I_k}{\sum_i \frac{B_i^2(\alpha,\beta)}{\sigma_i^2}}$

      with $I_k = B_i \star \{D_i(\alpha_k,\beta_k).I_k.\delta(\alpha_k,\beta_k)\}$ and $\gamma \sim 0.2$;
    - $\mathrm{SNR}(\alpha,\beta) = \frac{S_k(\alpha,\beta)}{N(\alpha,\beta)}$.

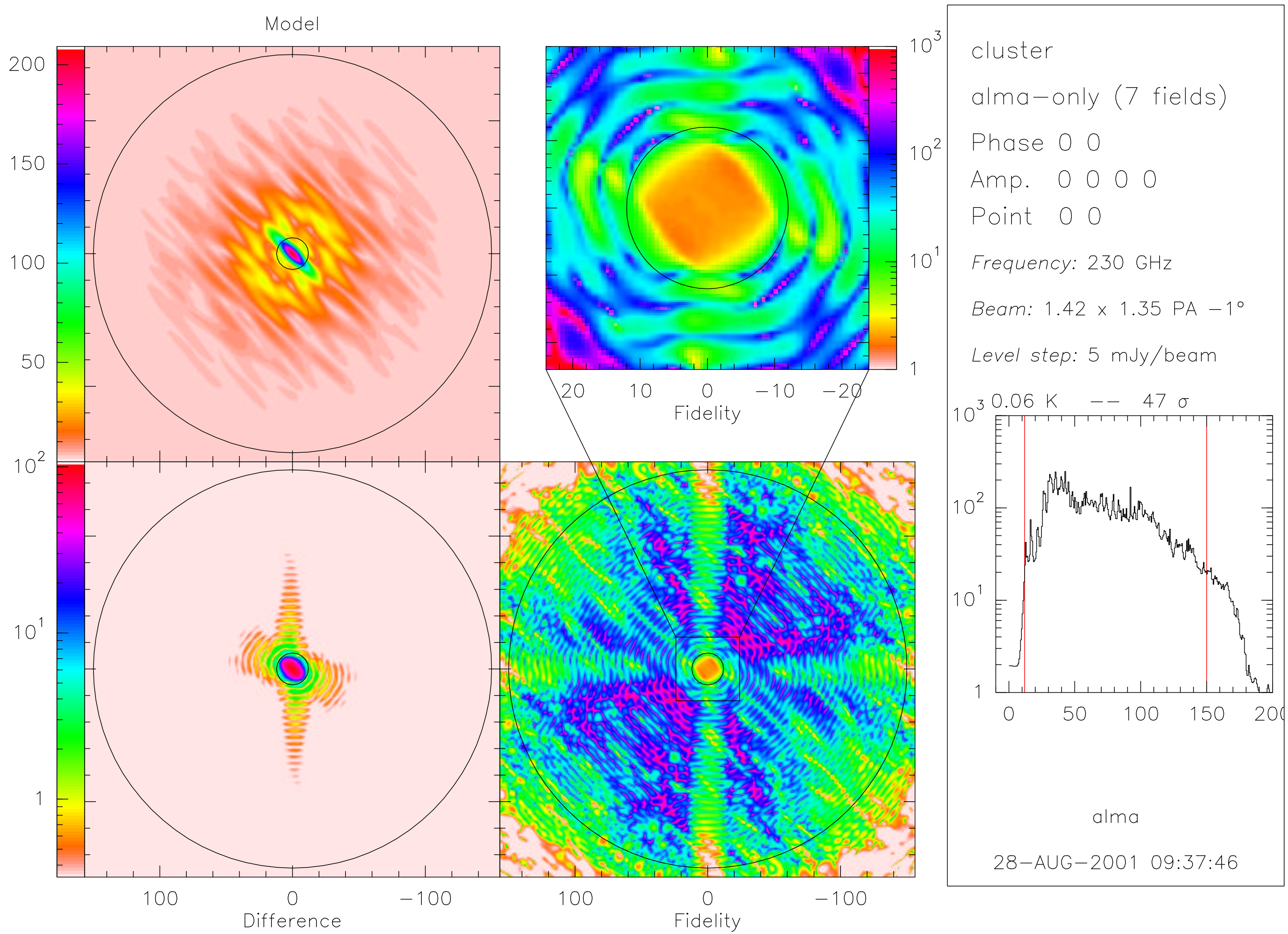
Deconvolution: II.1 Practice (Without short-spacings)



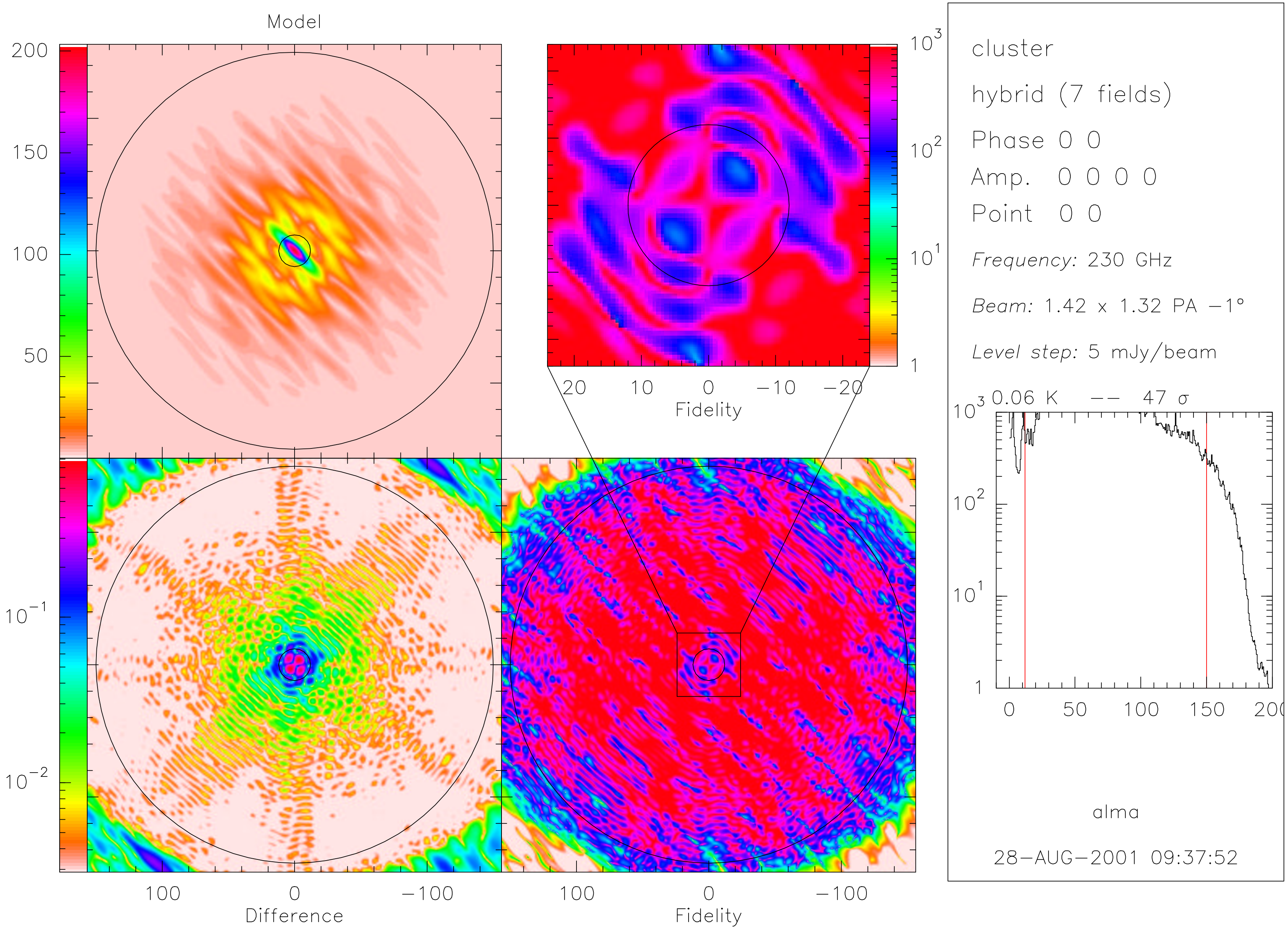
Deconvolution: II.2 Practice (With short-spacings)



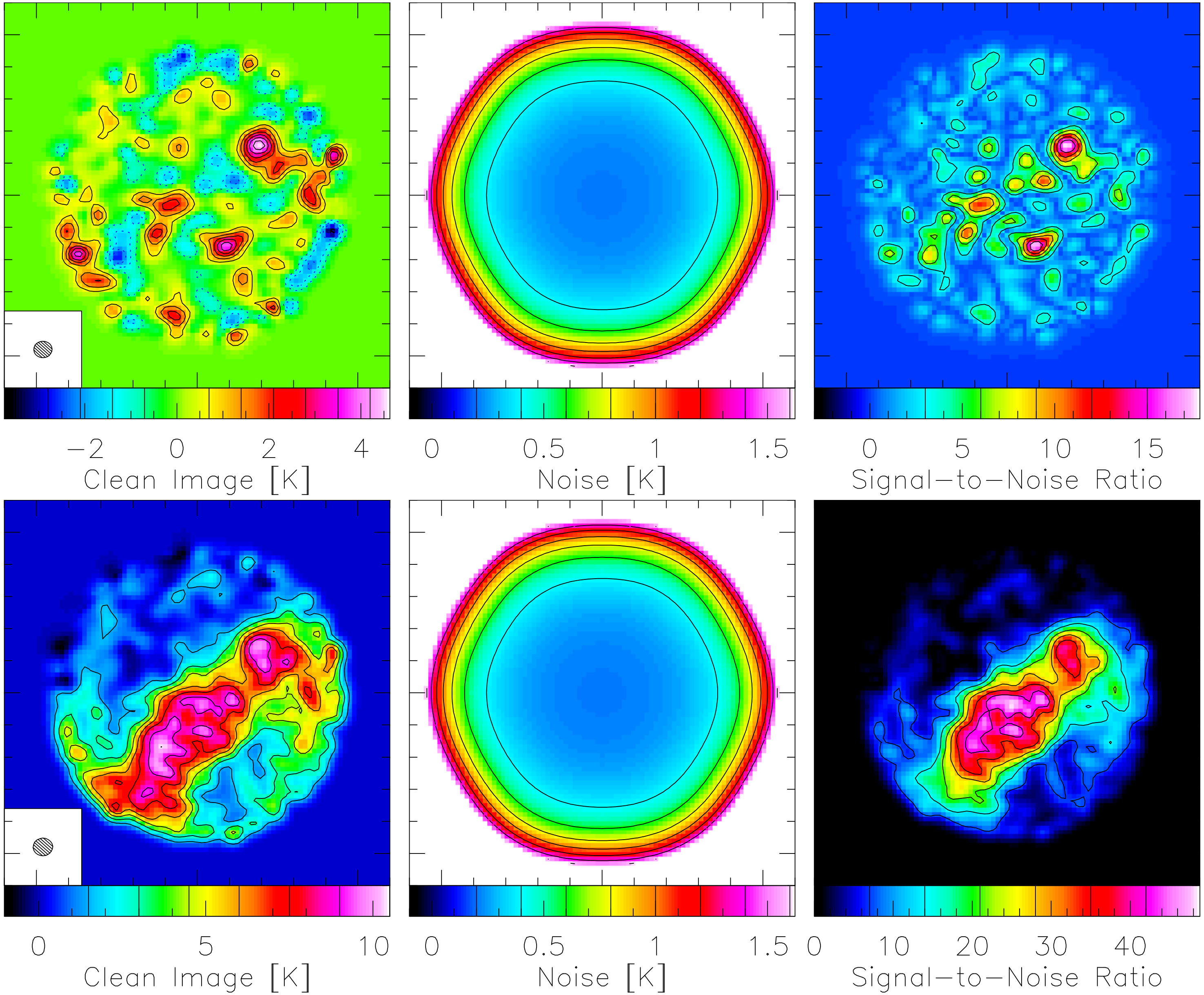
Deconvolution: III.1 ALMA alone



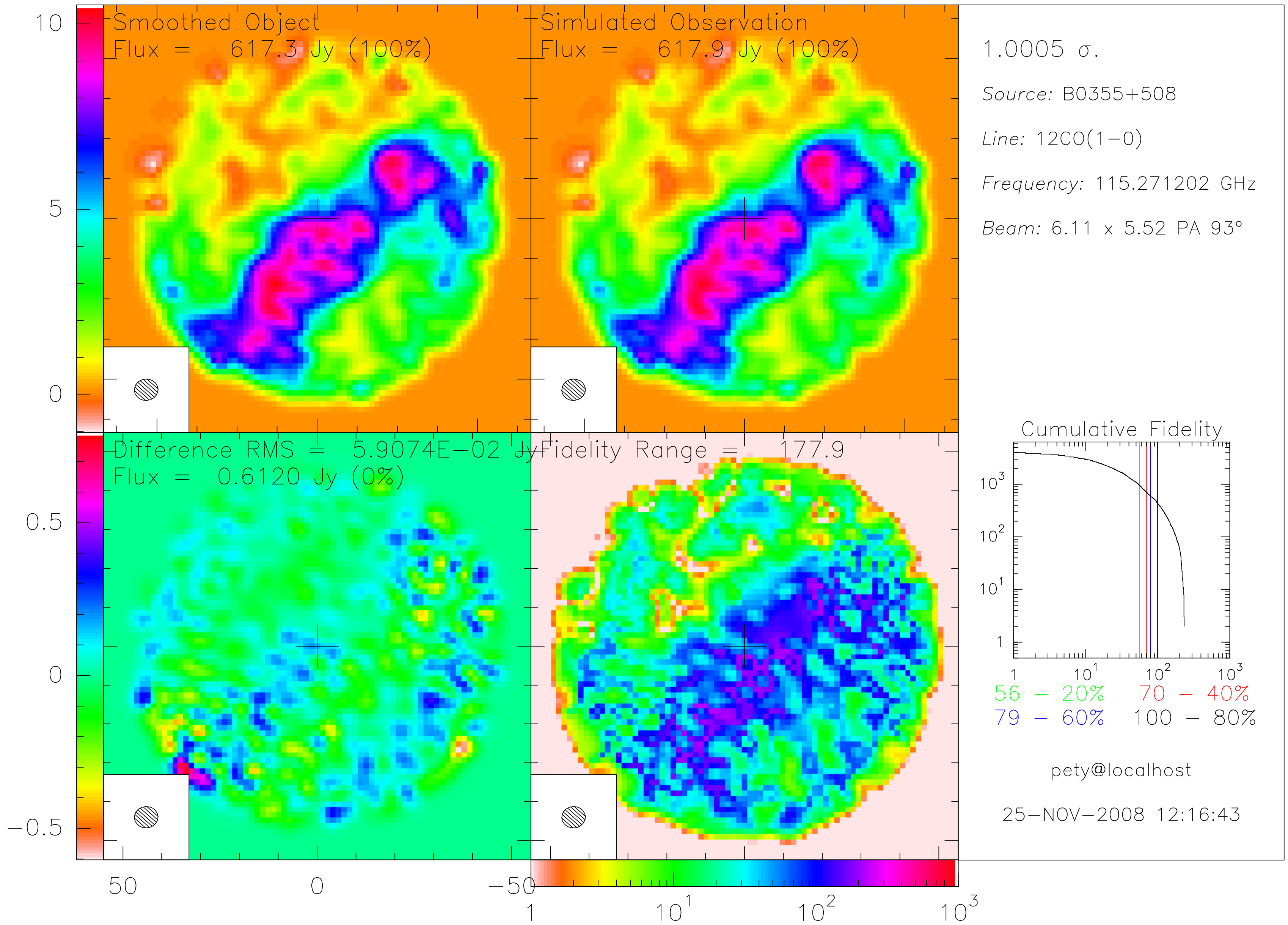
Deconvolution: III.2 ALMA + ACA
Short-Spacings also help at large uv radius



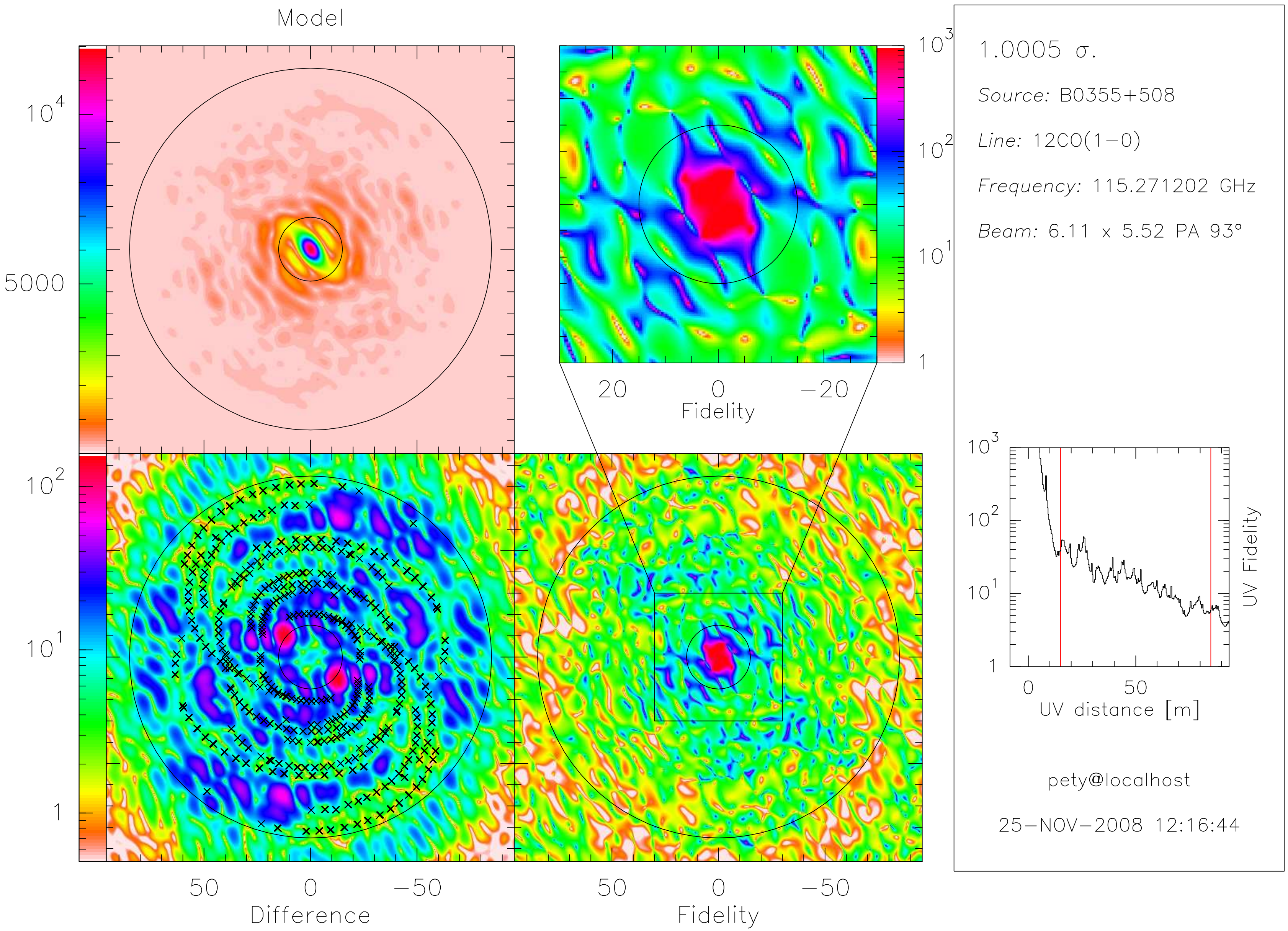
Signal-to-Noise Ratios



Fidelities: I. Image plane

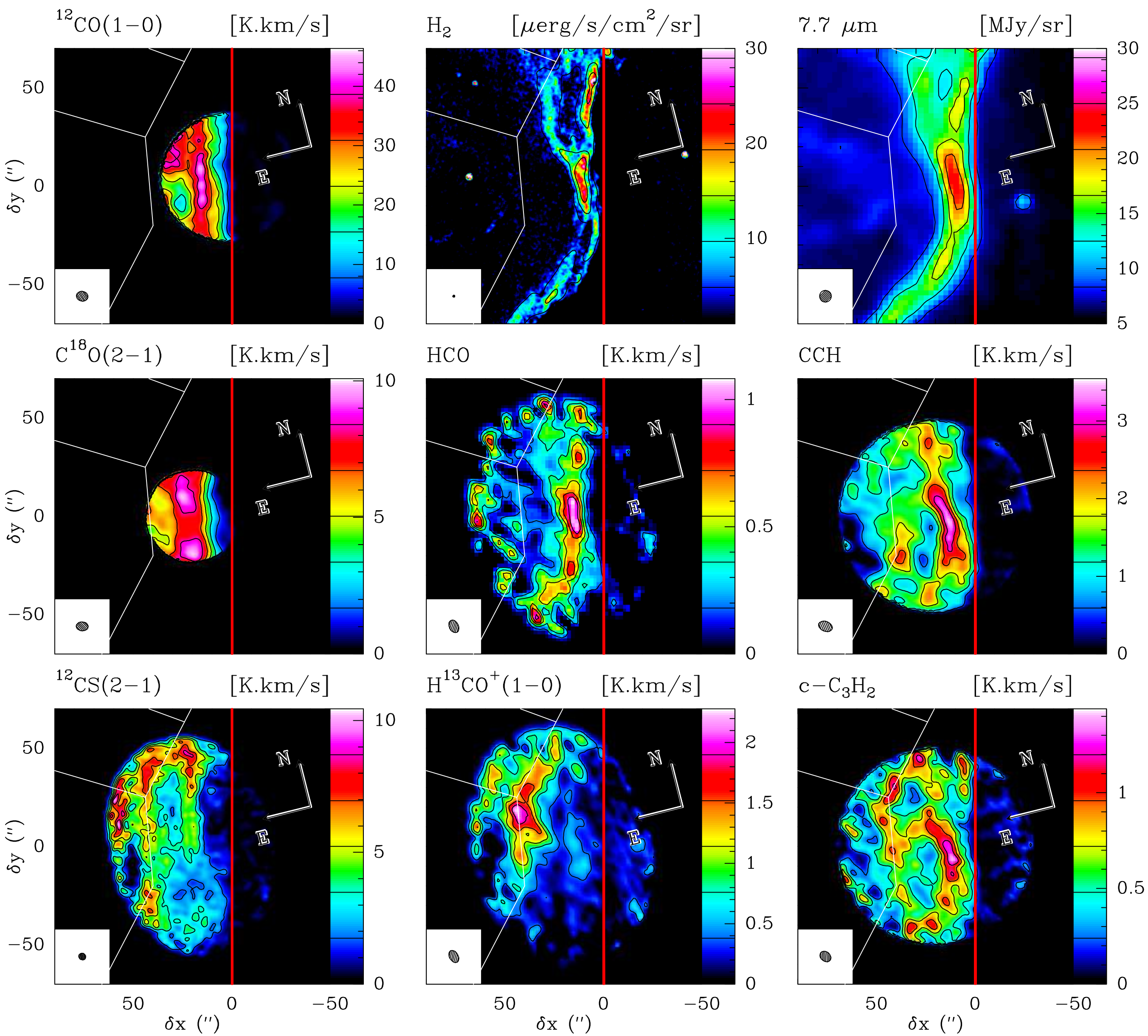


Fidelities: II. uv plane



Mosaicing: A standard observing mode

An example among many: The Horsehead PDR



Next step: Interferometric On-The-Fly

- N.Rodriguez-Fernandez in the framework of the European FP6 "ALMA Enhancement" grant.

Bibliography

- ALMA memos:

#386 Pety, Gueth & Guilloteau, 2001, "ALMA+ACA Simulation Tools"

#387 Pety, Gueth & Guilloteau, 2001, "ALMA+ACA Simulation Results"

#398 Pety, Gueth & Guilloteau, 2001, "Impact of ACA on Wide-Field Imaging Capabilities of ALMA"

- Data sets used in this presentation:
  - Pety, Lucas & Liszt, 2008, A&A, 489, 219, "Imaging galactic diffuse gas: Bright, turbulent CO surrounding the line-of-sight to NRAO150"
  - Pety et al., 2007, Molecules in Space and Laboratory, 13, "The Horsehead mane: Towards an observational benchmark for chemical models" and references therein.