

# Galactic studies: The need of combining data



Hacar+2018

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ORION-4D Project Leader

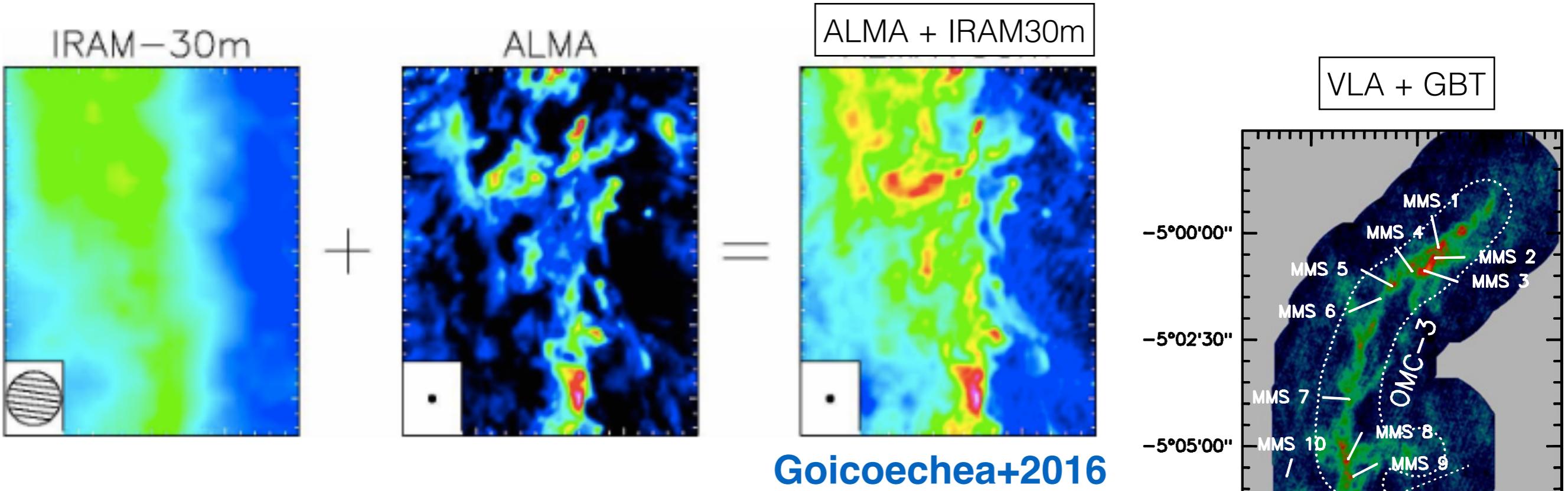
# Goals

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1. Why do we MUST combine data for Galactic studies?
2. Complex issues
3. Experience with real data  
(bonus track: hybrid method)

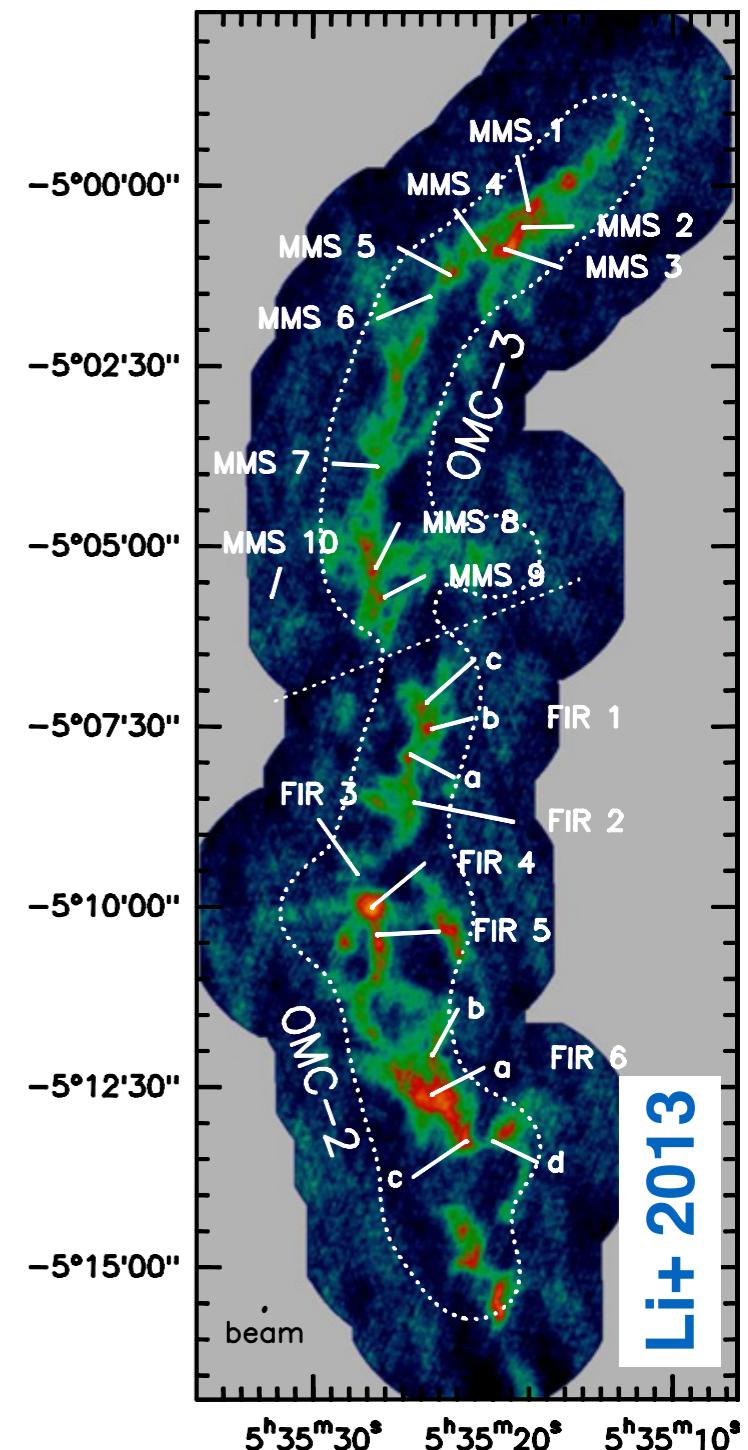


# Data combination in galactic studies

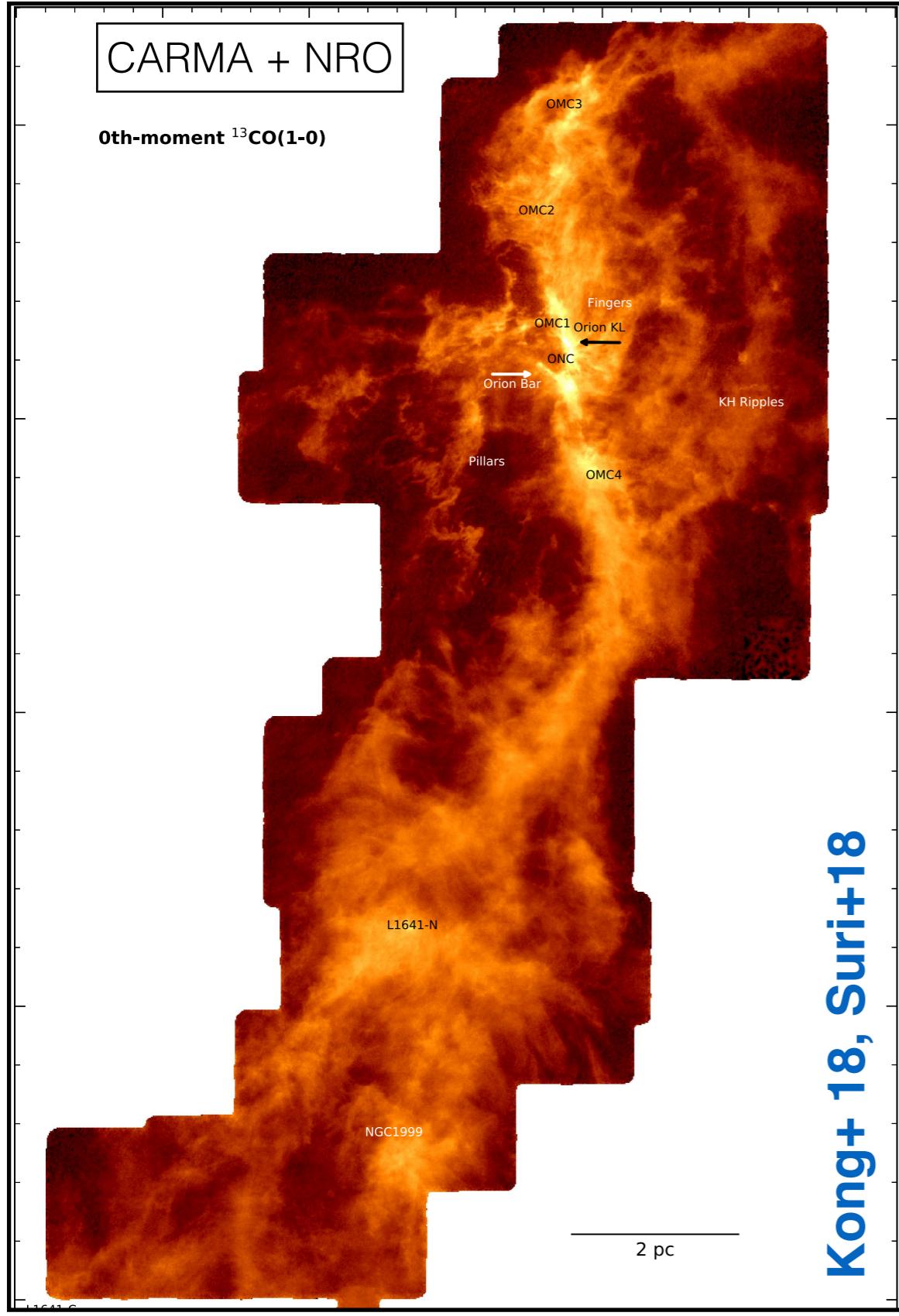


## Previous Galactic works:

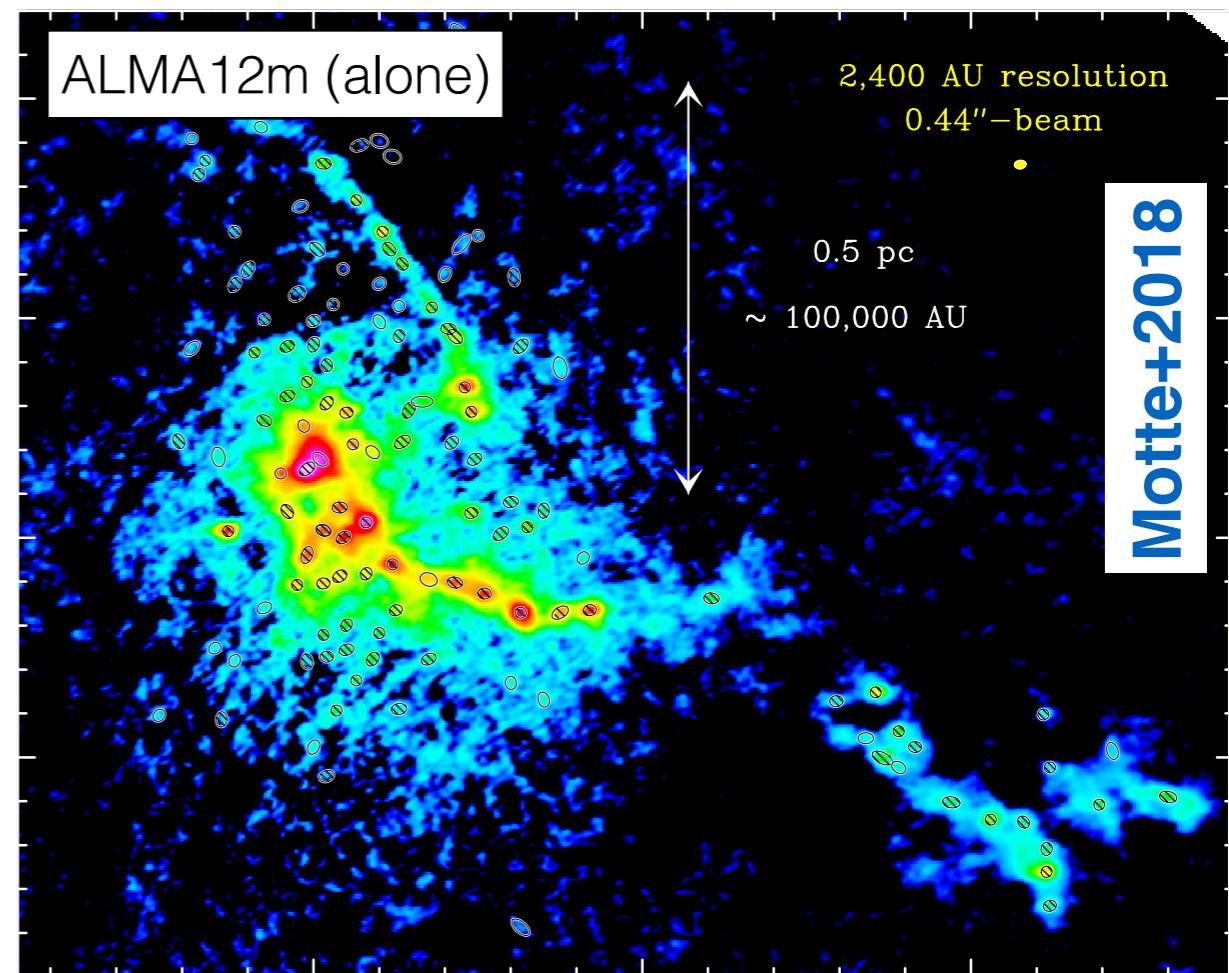
- Limited data combination
- Challenging reduction/imaging
- Low sensitivity
- Small mosaics (few pointings)



# New era of interferometric surveys

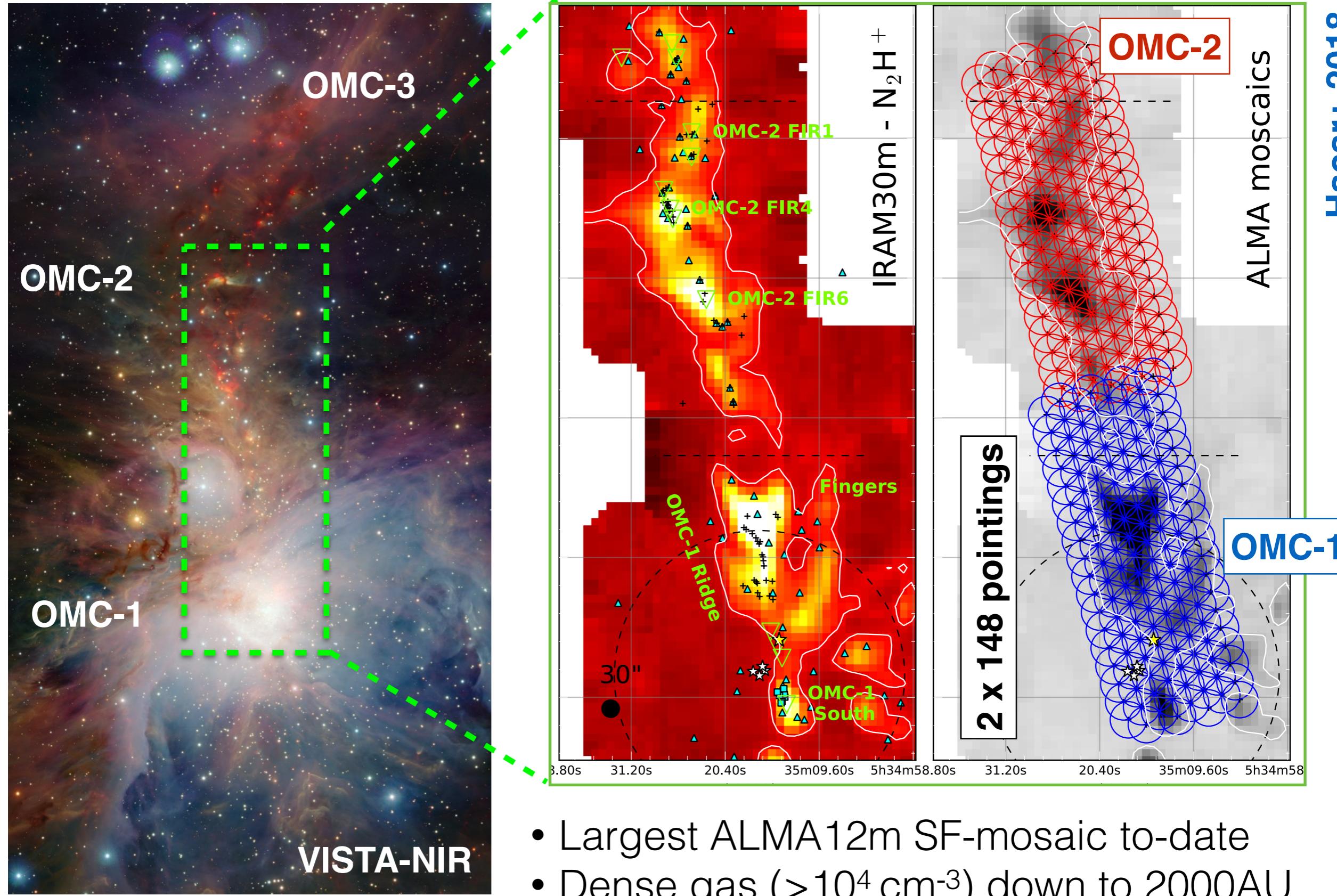


Kong+18, Suri+18

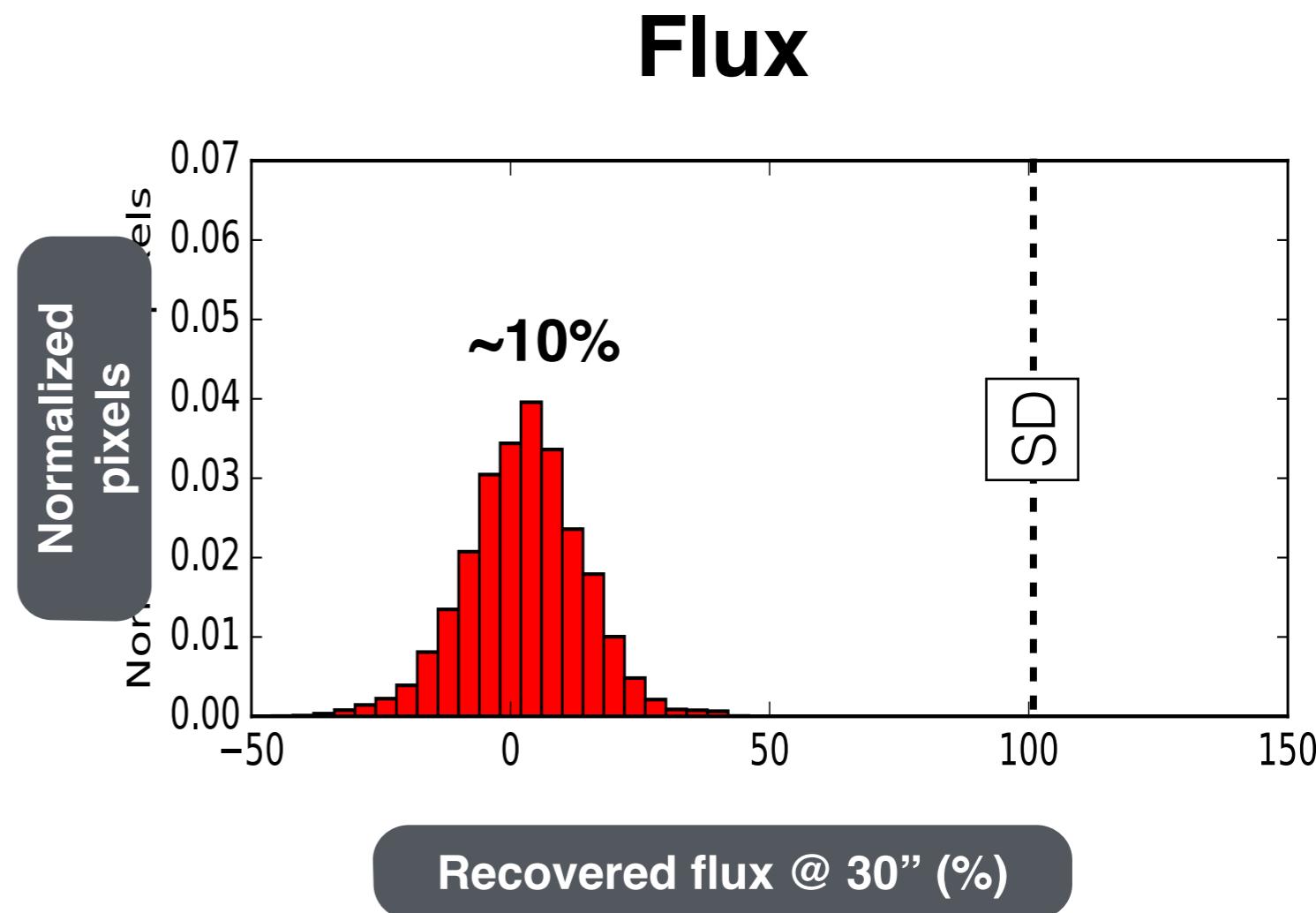
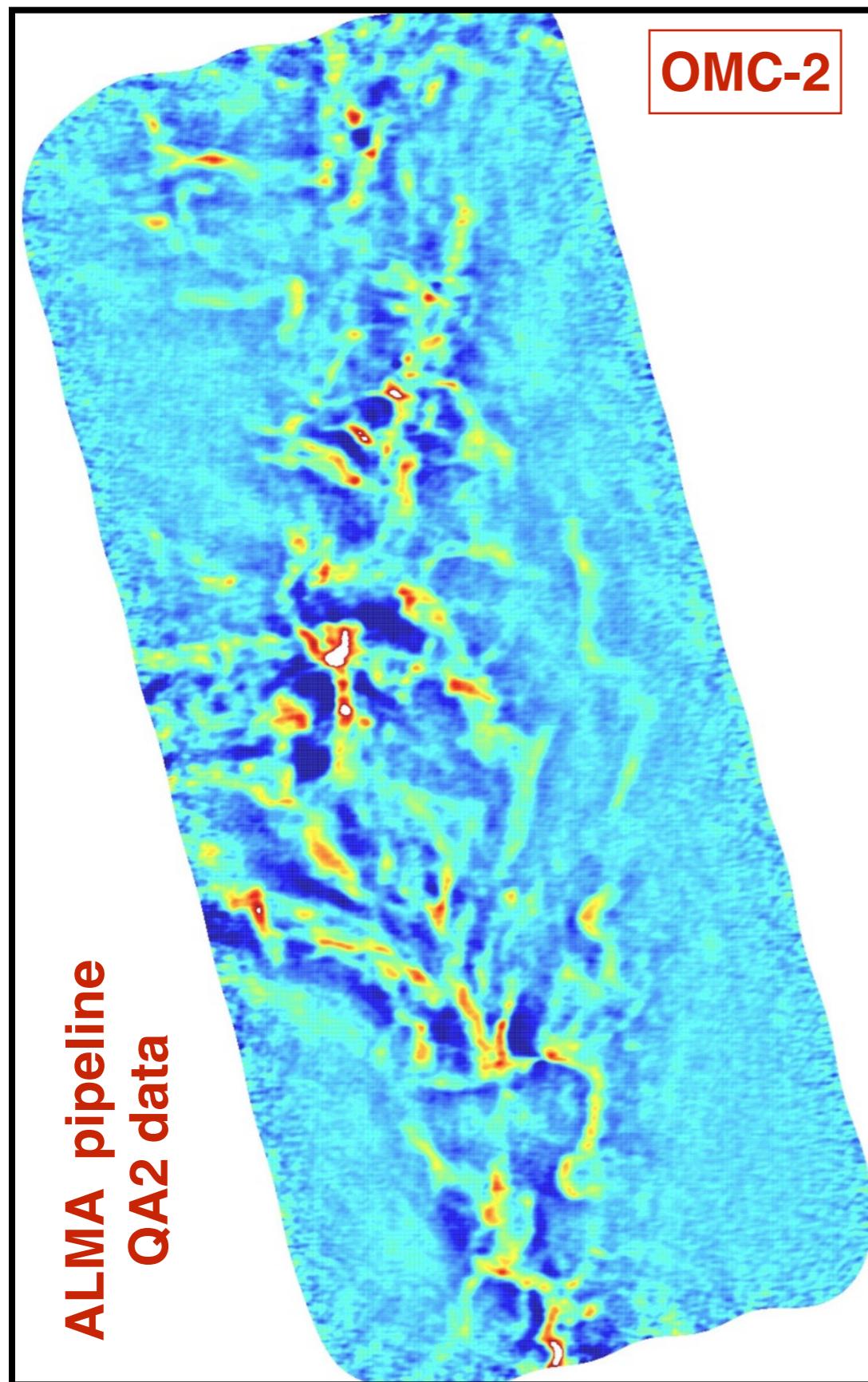


- New capabilities + sensitivity
- Powerful algorithms / machines
- Large-Programs (ALMA, SMA, VLA...)
- Large-scale interferometric maps:  
(e.g., Orion, SMC...)

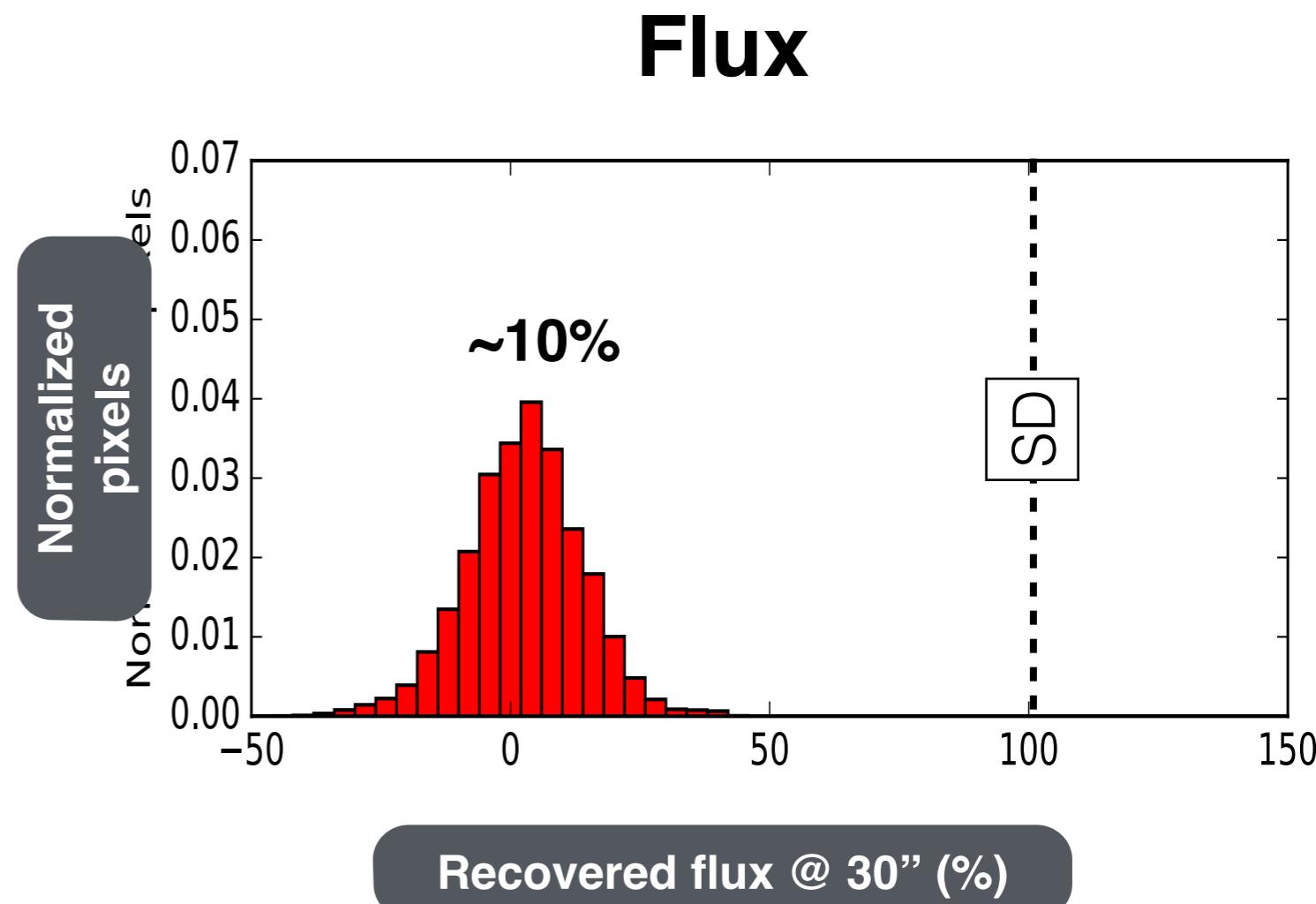
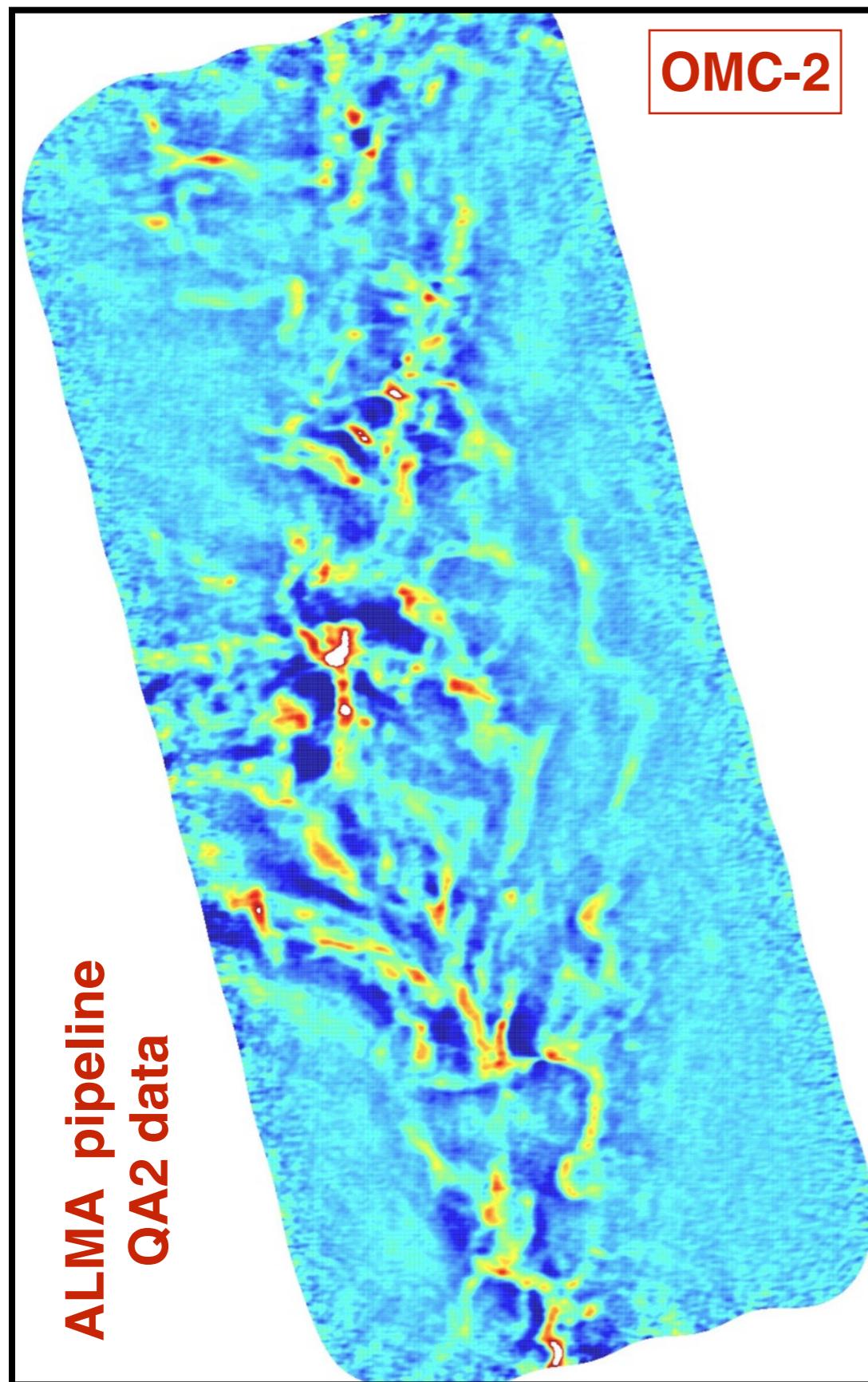
# ALMA + IRAM30m N<sub>2</sub>H<sup>+</sup>(1-0) observations



# ALMA (12m-only) data (I): flux losses



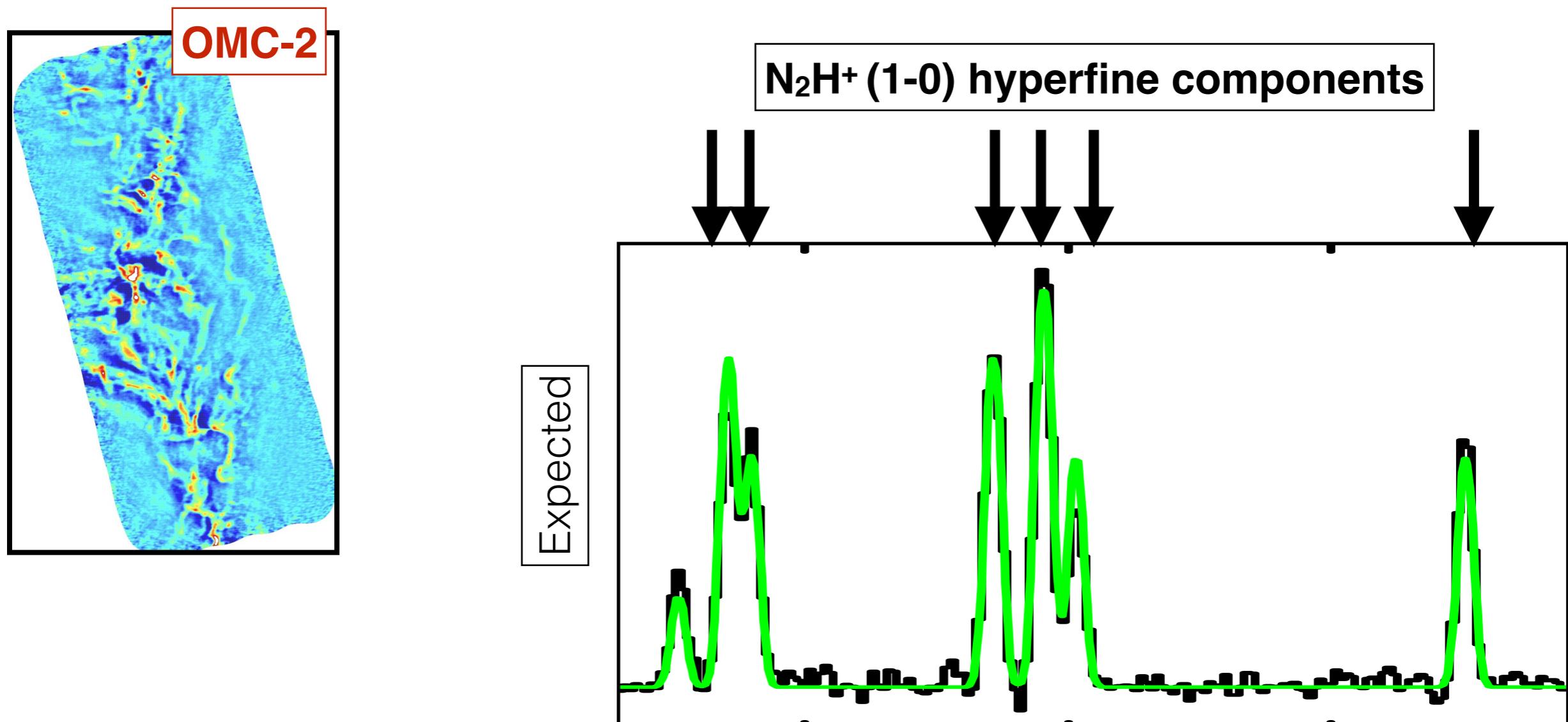
# ALMA (12m-only) data (I): flux looses



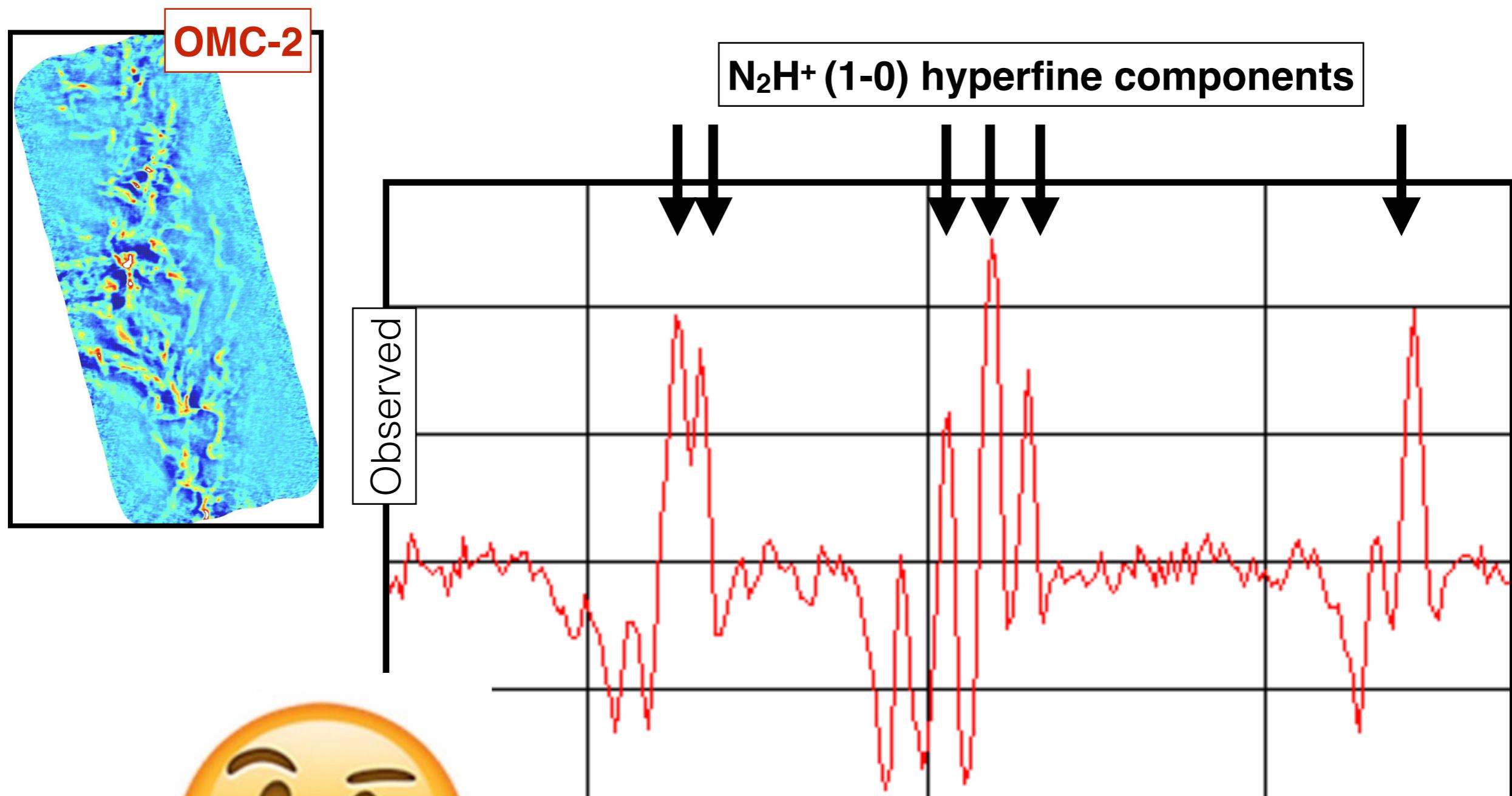
ALMA alone loses  
 $\sim 90\%$  of the total flux!



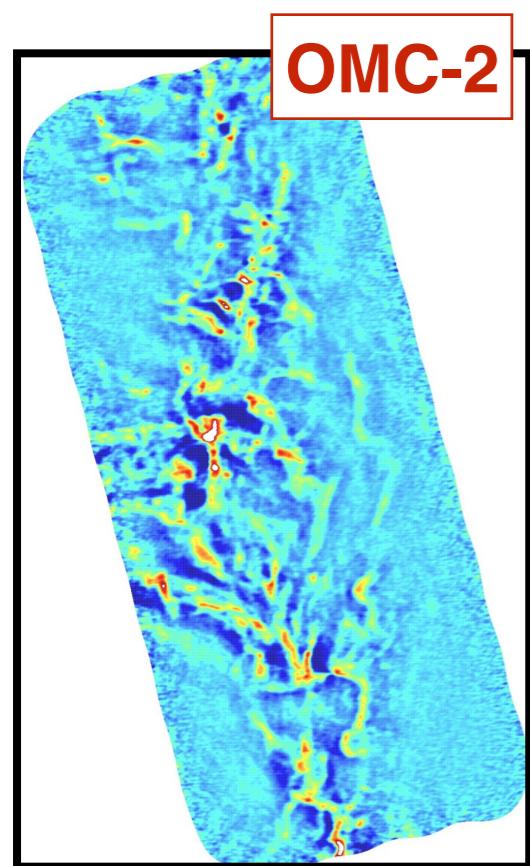
# ALMA (12m-only) data (II): velocity structure



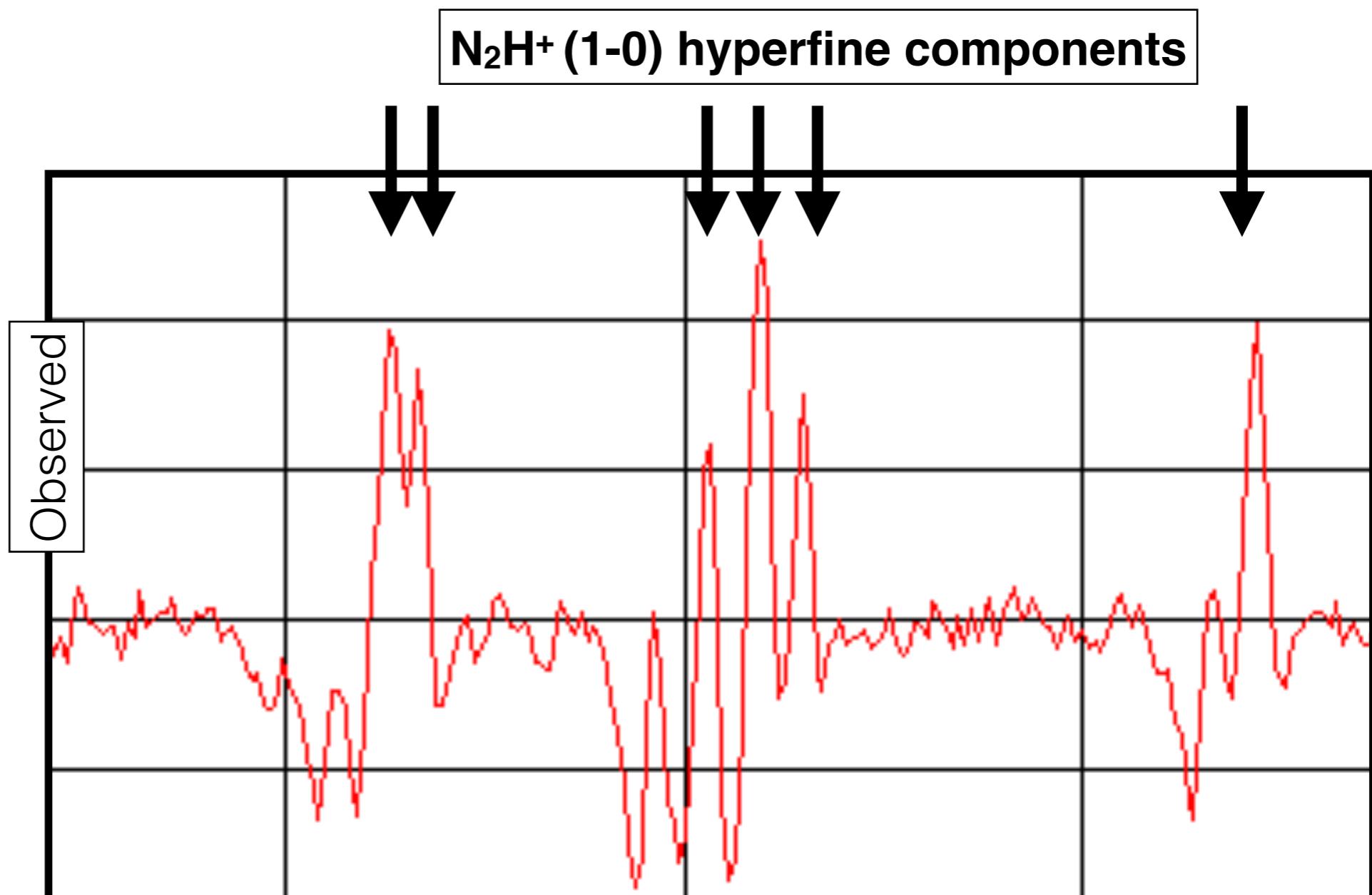
# ALMA (12m-only) data (II): velocity structure



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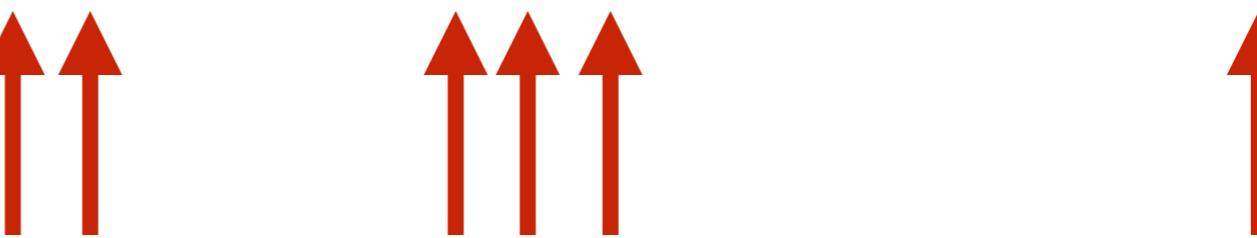
OMC-2



$\text{N}_2\text{H}^+$  (1-0) hyperfine components

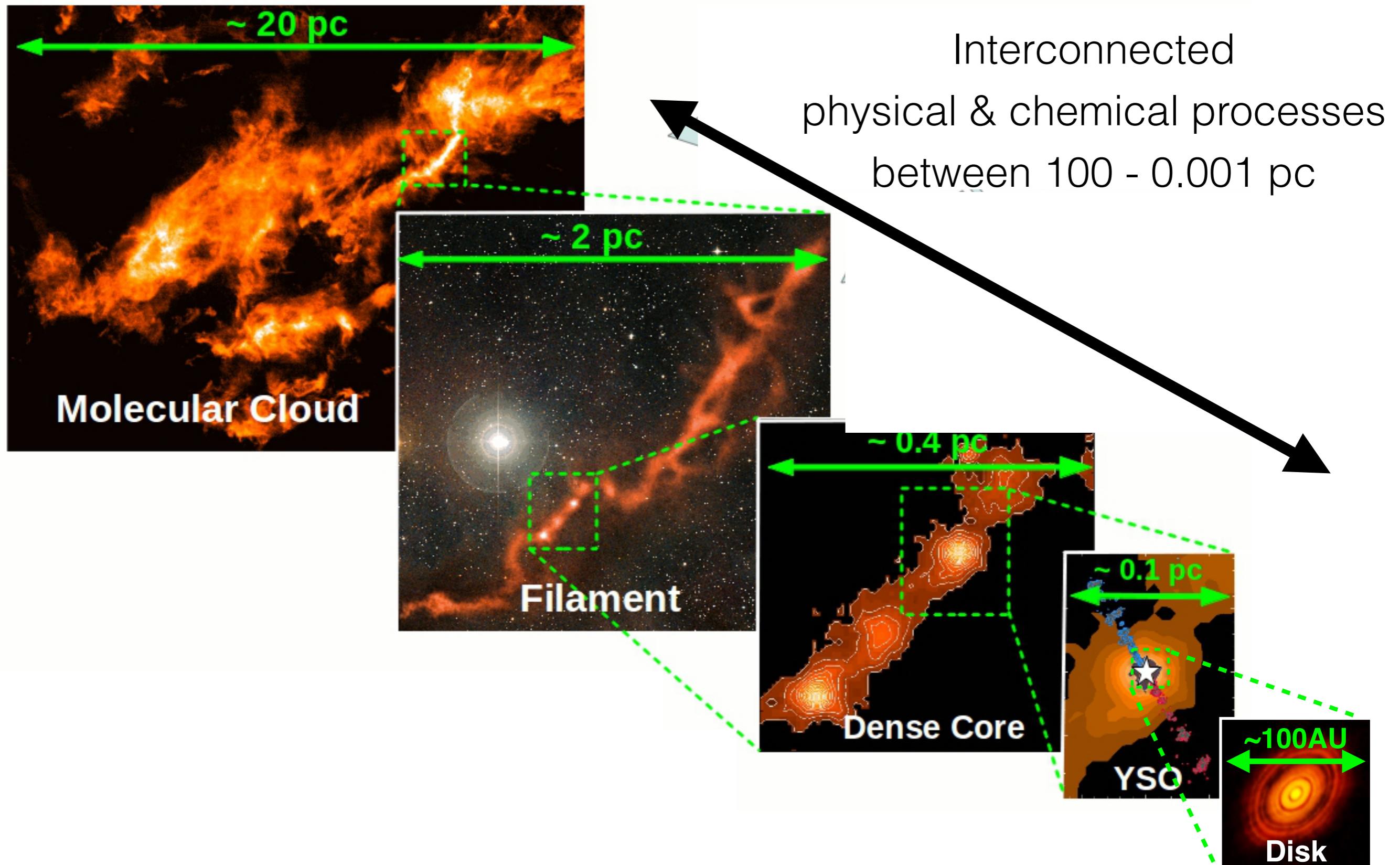


x100!

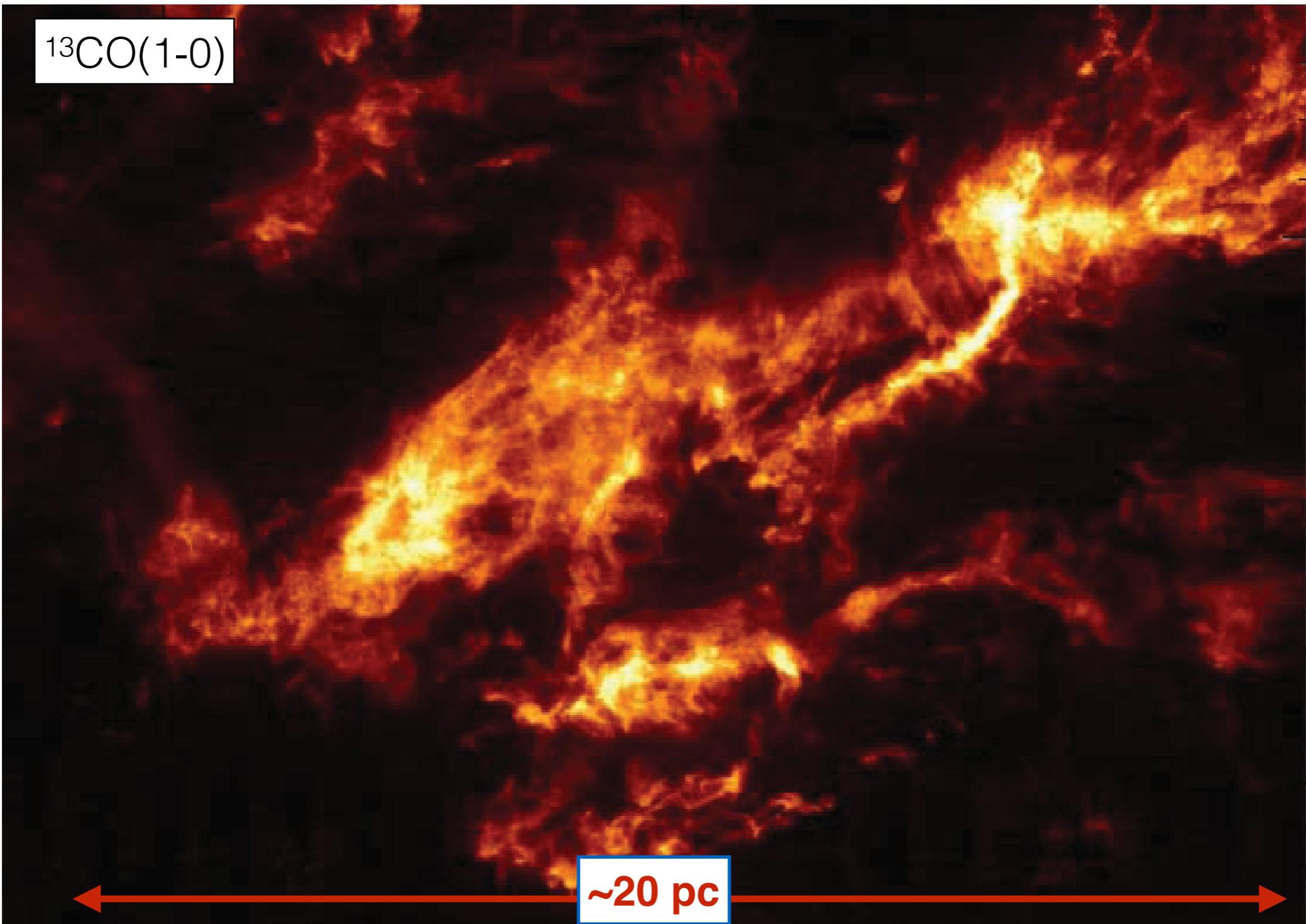


Filtering depends on space, velocity, environment...

# Galactic targets



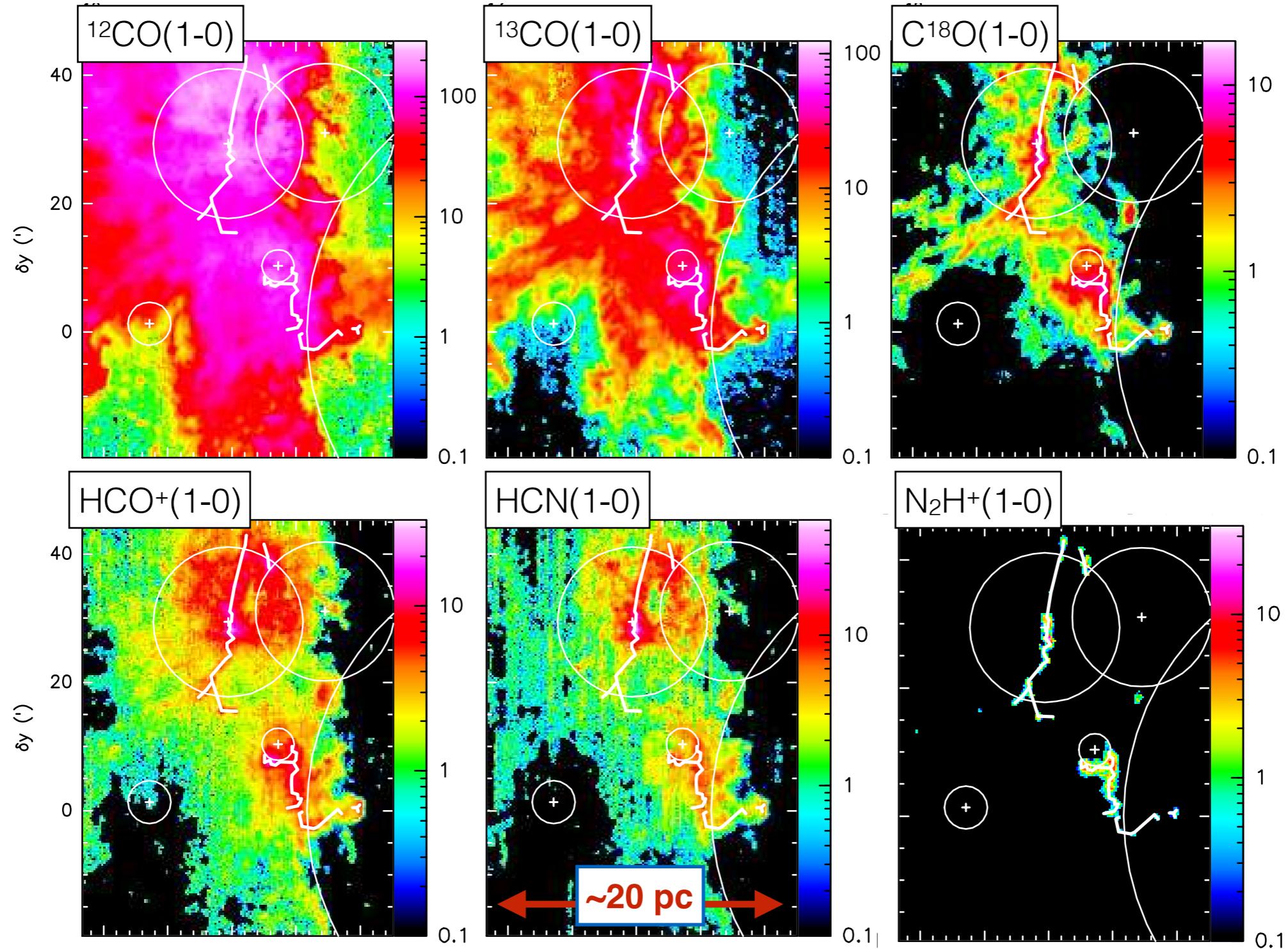
# ISM properties (I): extended emission



Goldsmith+ 2008

#1: shallow emission of common gas tracers (e.g., CO)

# ISM properties (II): chemistry & tracers



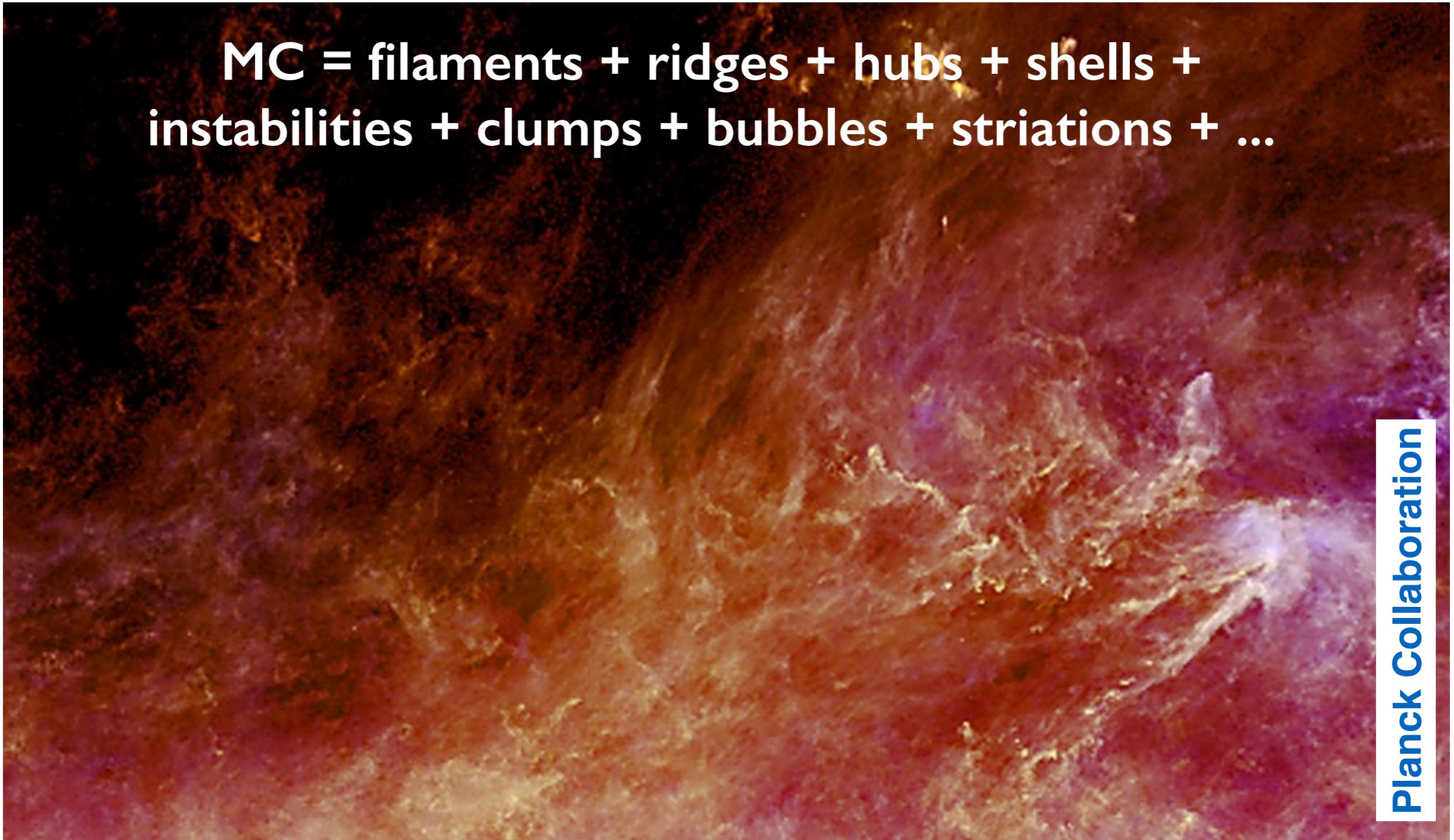
Pety+ 2017

#2: distinct tracers emit at different scales

# ISM properties (III): dust continuum

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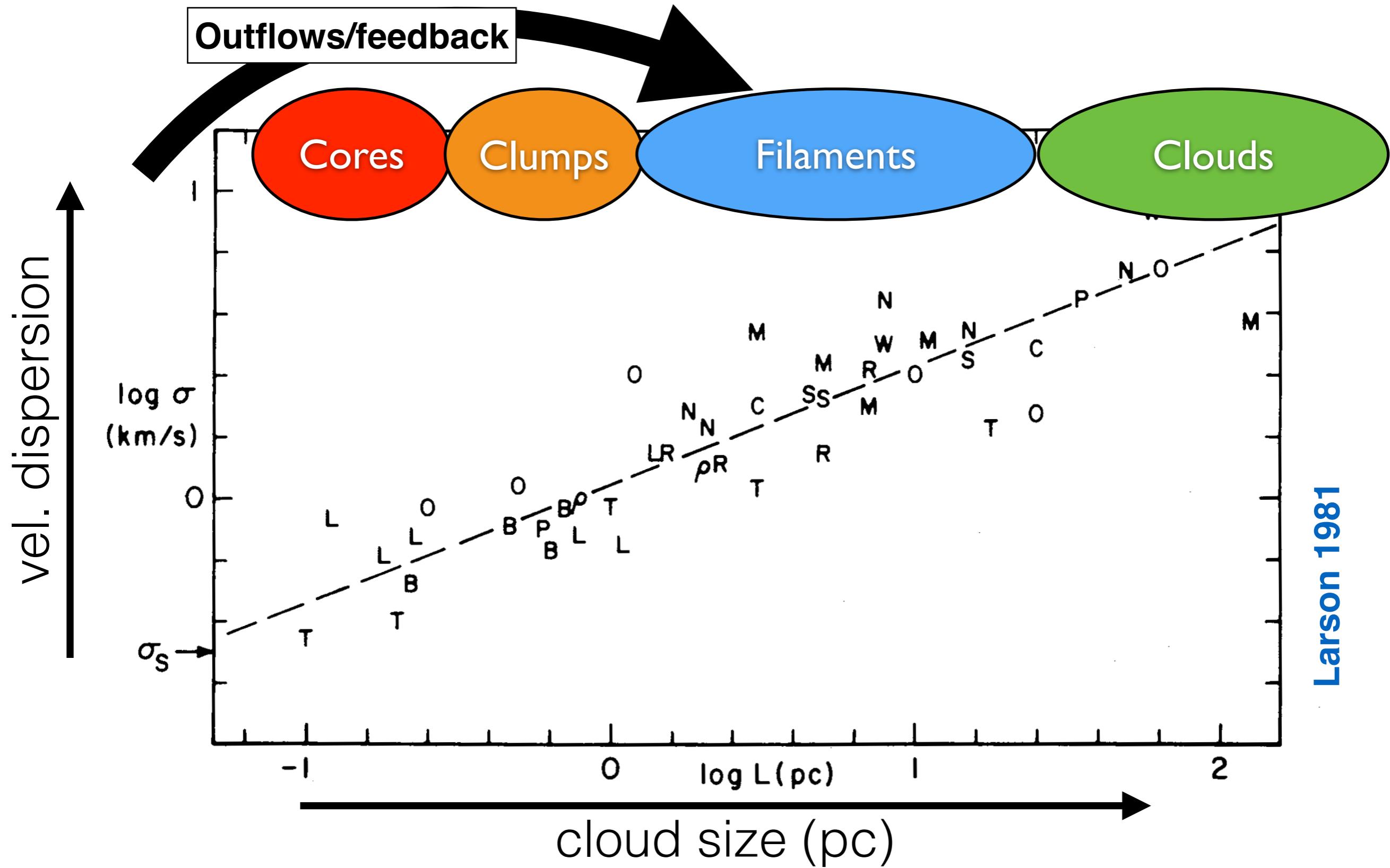
**MC = filaments + ridges + hubs + shells +  
instabilities + clumps + bubbles + striations + ...**



Planck Collaboration

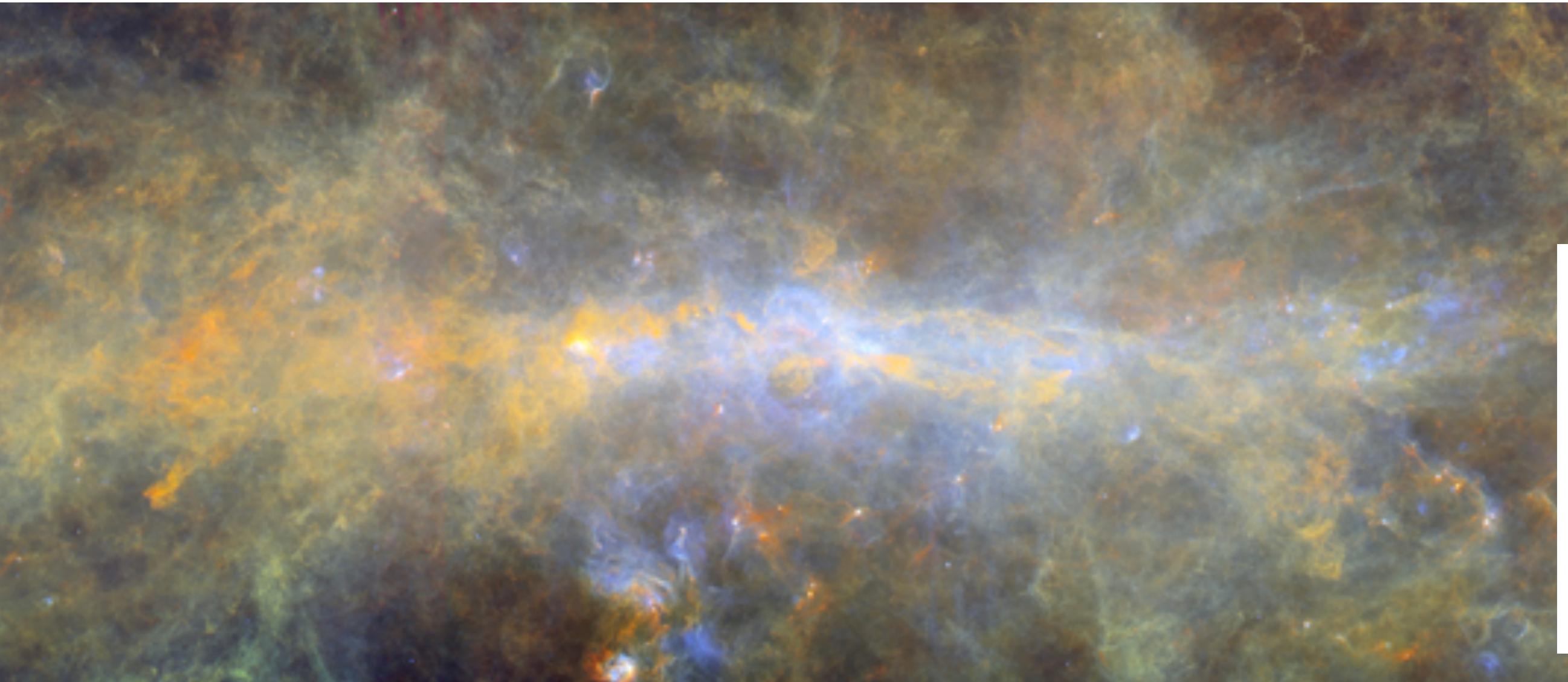
#3: dust continuum is even worse!

# ISM properties (IV): turbulence



# ISM properties (V): complexity

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Herschel Continuum

#5: extremely crowded regions & high contrast

# Maximum Recoverable Scale (MRS) (I)

$$\theta_{MRS} \approx 0.6\lambda/L_{min}$$

	Band	3	4	5	6
	Frequency (GHz)	100	150	185	230
Configuration					
7-m	$\theta_{res}$ (arcsec)	12.5	8.35	6.77	5.45
	$\theta_{MRS}$ (arcsec)	66.7	44.5	36.1	29.0
<u>C43-1</u>	$\theta_{res}$ (arcsec)	3.38	2.25	1.83	1.47
	$\theta_{MRS}$ (arcsec)	28.5	19.0	15.4	12.4
C43-2	$\theta_{res}$ (arcsec)	2.3	1.53	1.24	0.999
	$\theta_{MRS}$ (arcsec)	22.6	15.0	12.2	9.81
C43-3	$\theta_{res}$ (arcsec)	1.42	0.943	0.765	0.615
	$\theta_{MRS}$ (arcsec)	16.2	10.8	8.73	7.02
C43-4	$\theta_{res}$ (arcsec)	0.918	0.612	0.496	0.399
	$\theta_{MRS}$ (arcsec)	11.2	7.5	6.08	4.89

**MRS** ~30" @ 1kpc < 0.15 pc

**MRS** ~30" @ 140pc < 0.02 pc

**Most of the ISM emission filtered out by ALMA!!**

# Maximum Recoverable Scale (MRS) (II)

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- Uniform estimate (e.g., ALMA OT)
- Sometimes used as **blind** filter of larger scales
- No effect at smaller scales

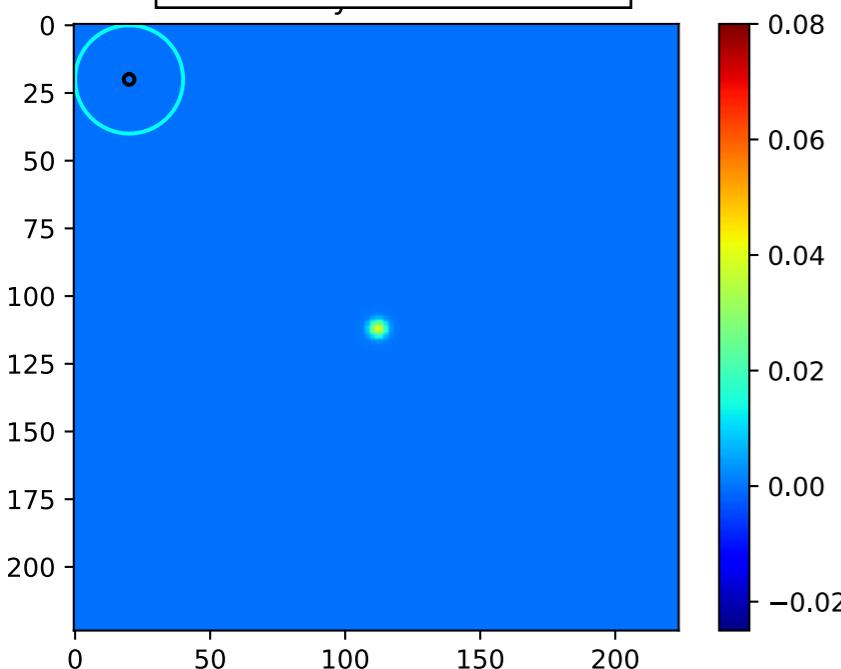


# Exercise (I): definition

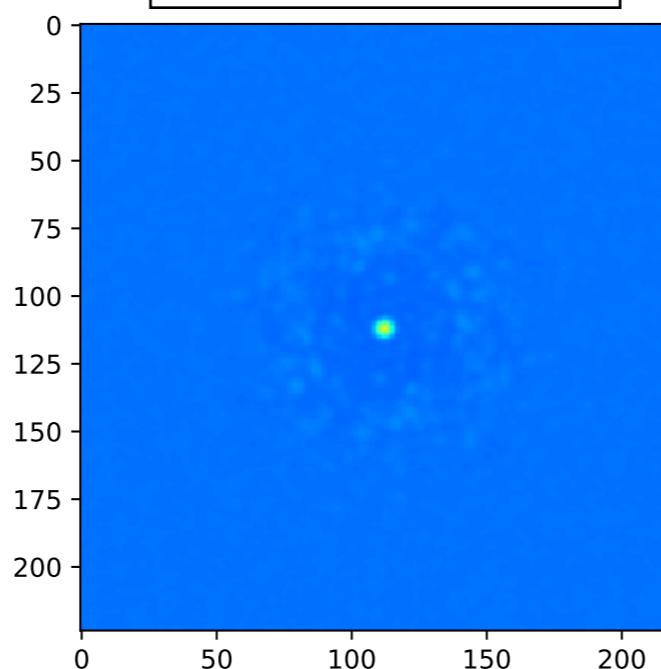
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- ALMA simulator (input + vis. + CLEAN)
- Compact 12-m (only) config. = without zero spacing
- Noiseless input + large integration time
- Mosaic  $\gg$  MRS
- Different source shapes & config.  $\sim$  ISM

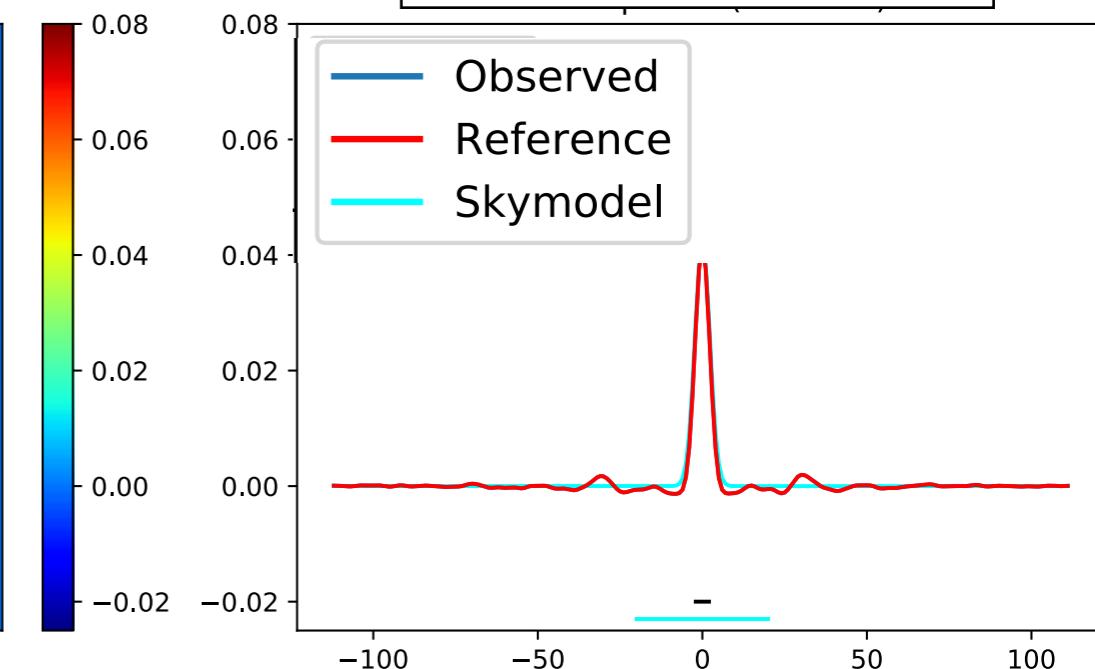
Sky model



Simulation

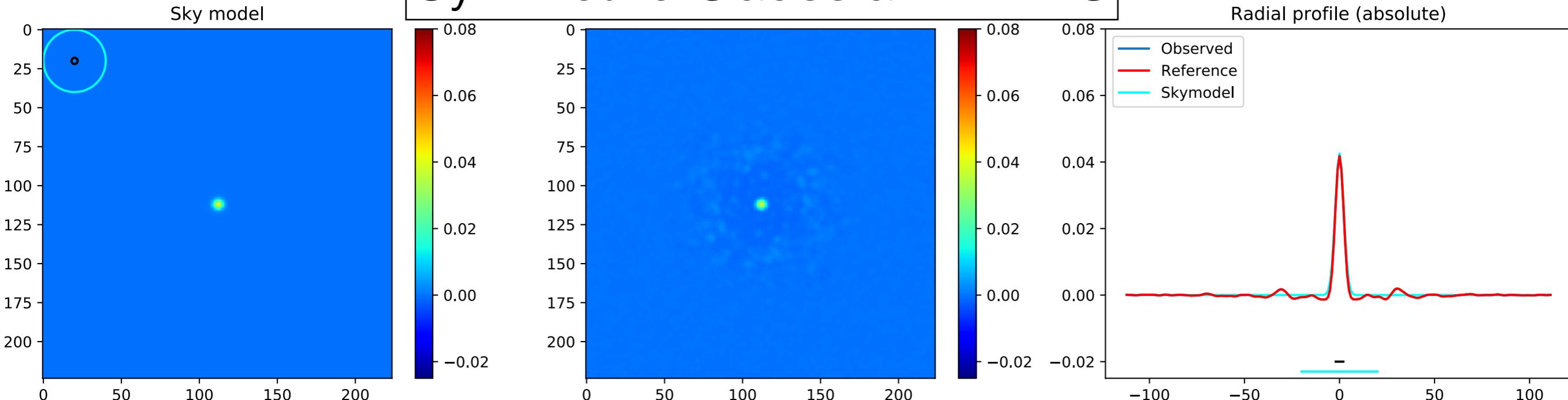


Radial profile

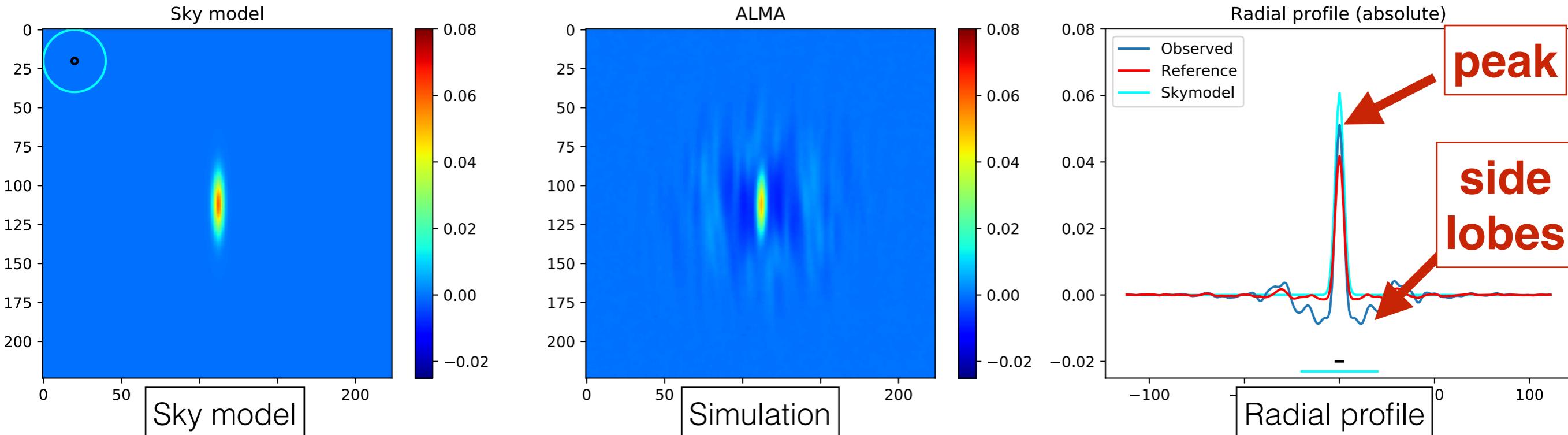


# Exercise (II): simple gaussians

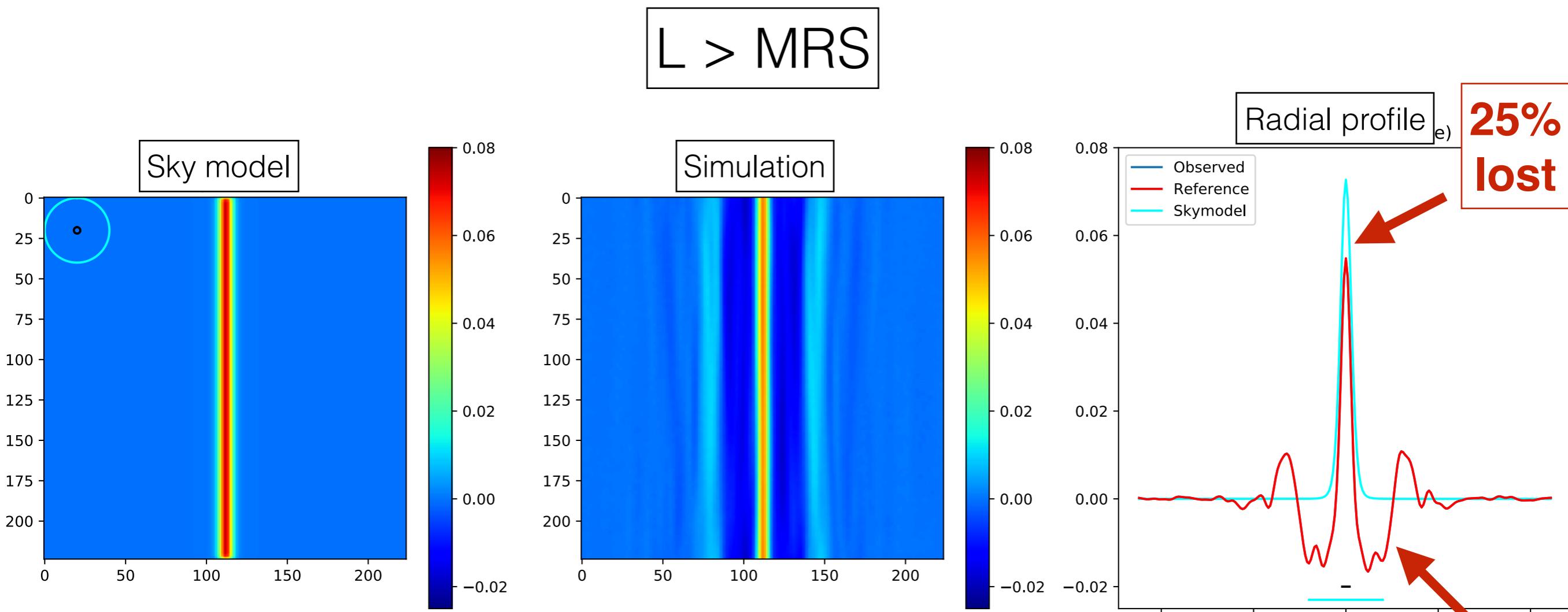
Symmetric Gaussian < MRS



Elongated Gaussian ~ MRS



# Exercise (III): filamentary structure

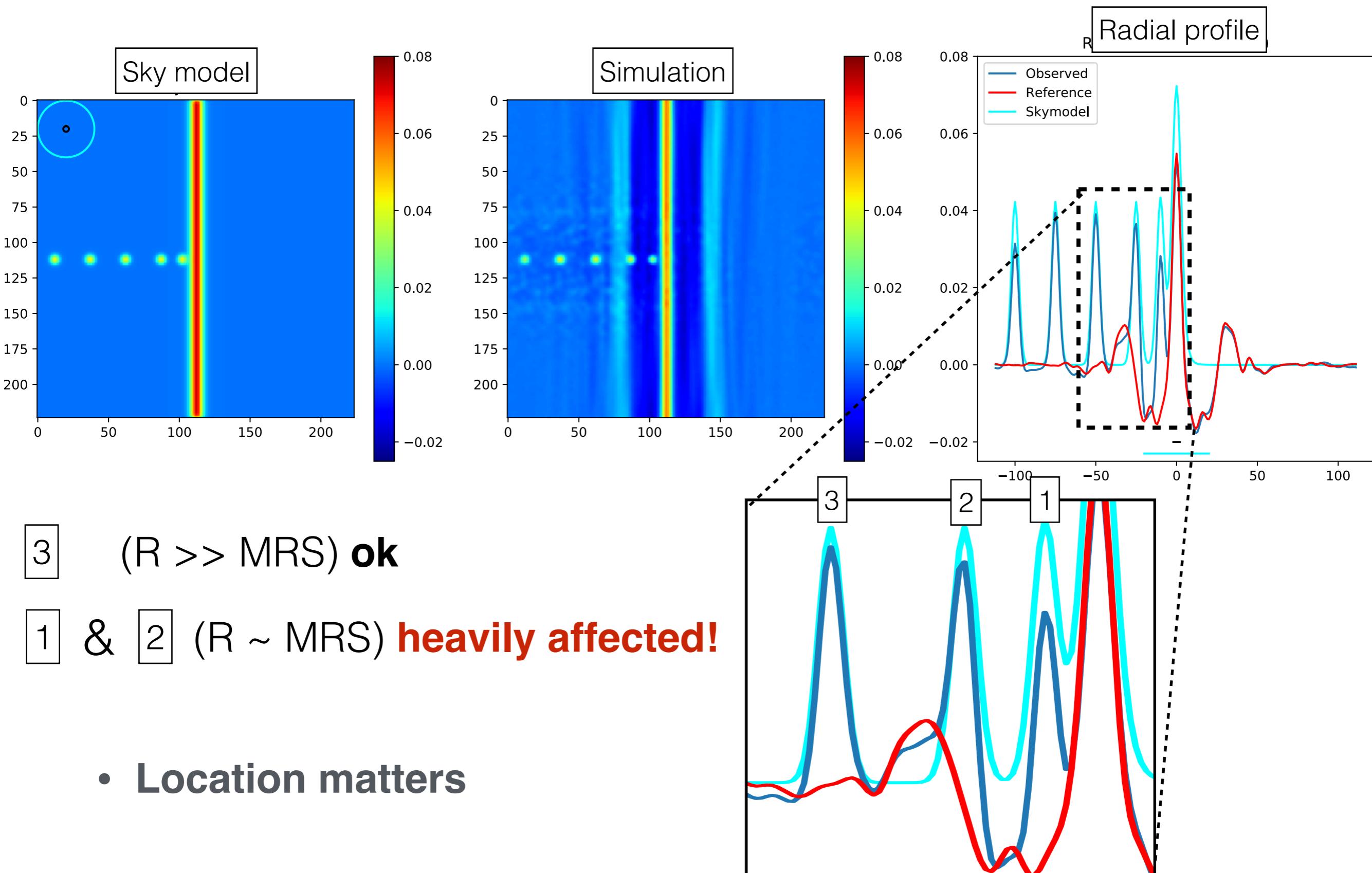


- Strong side-lobes even when  $R \ll MRS$
- Losses also affect central emission ( $R < MRS$ )!

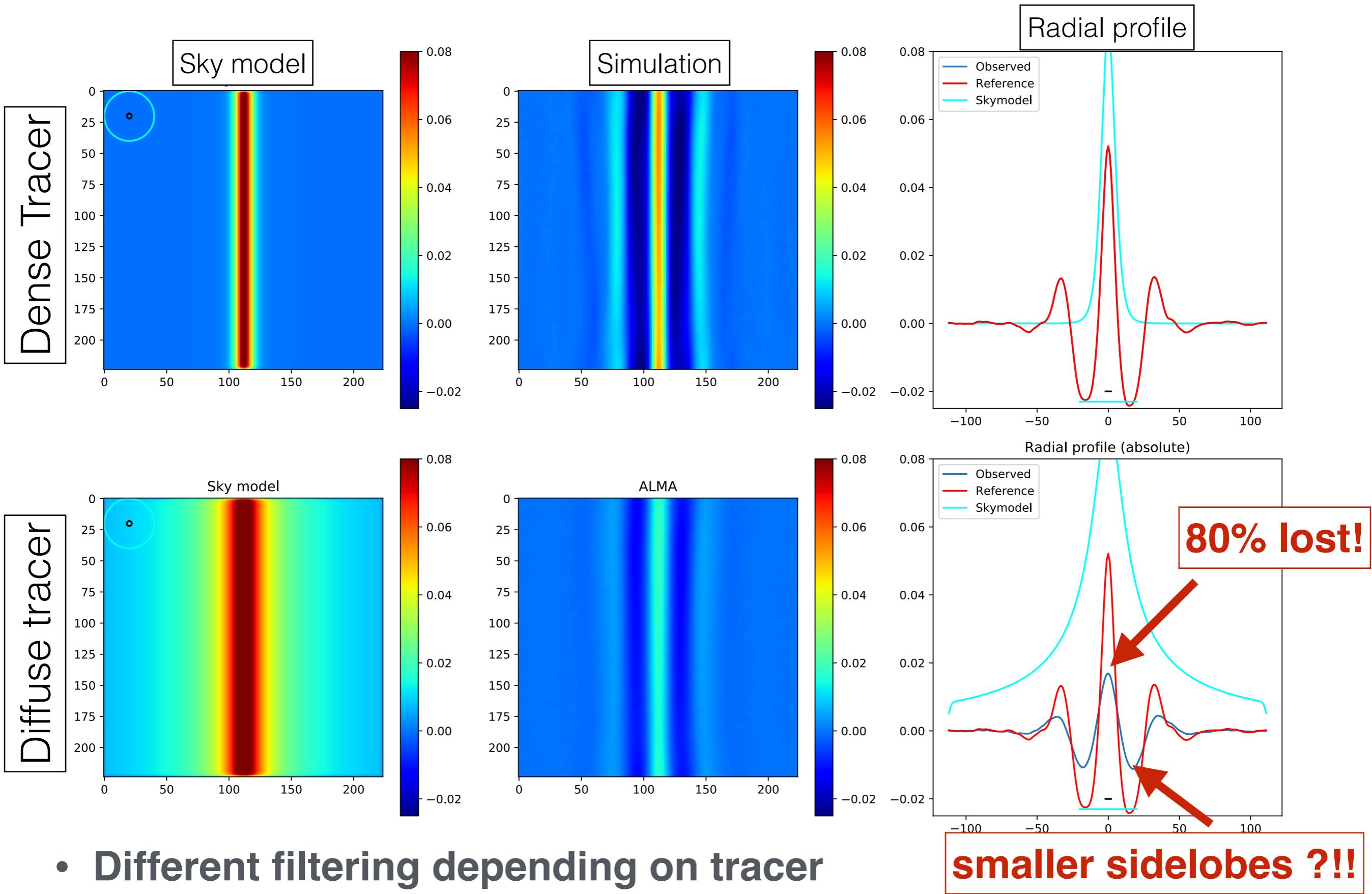
**side lobes**

**25% lost**

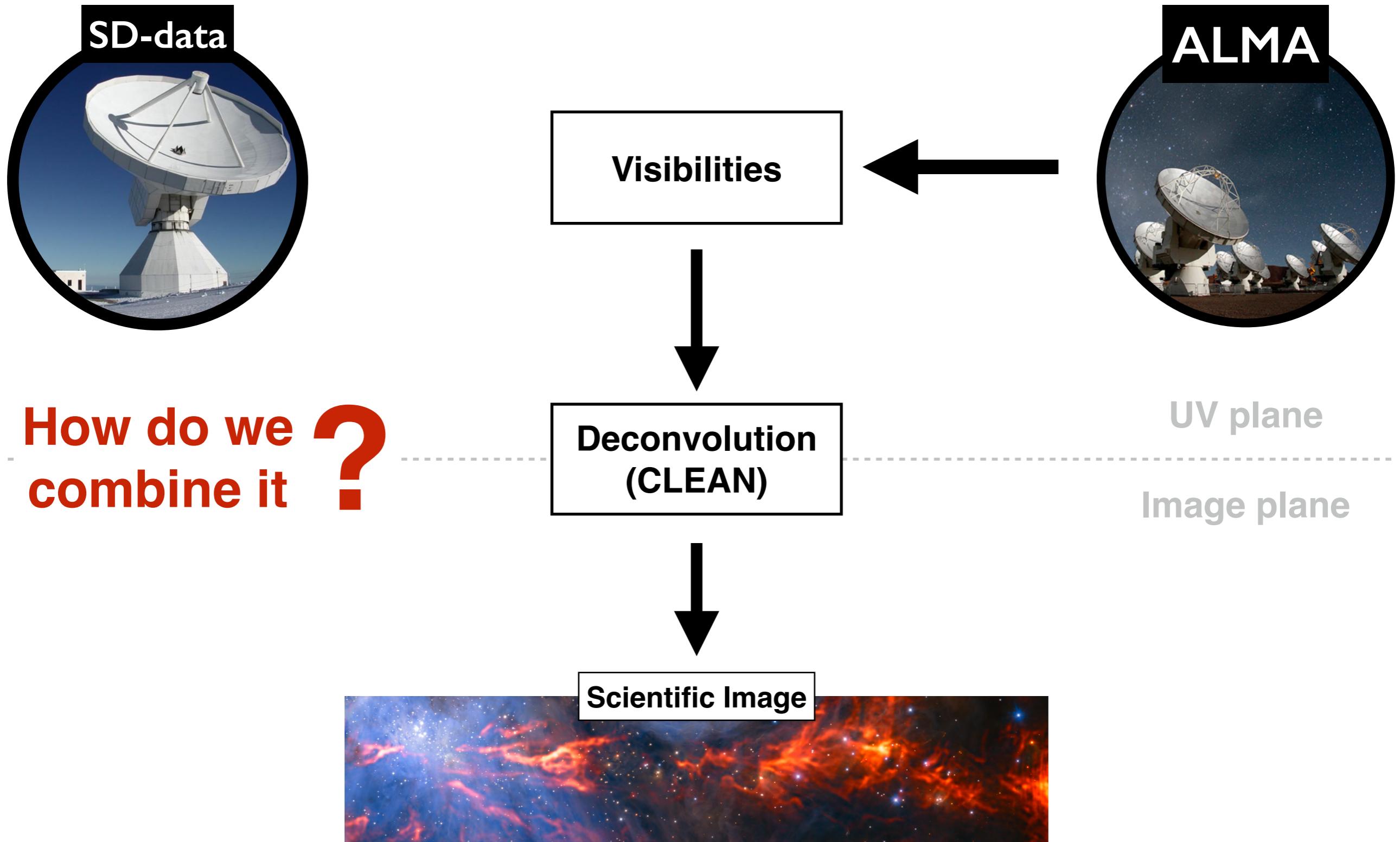
# Exercise (III): complex environment



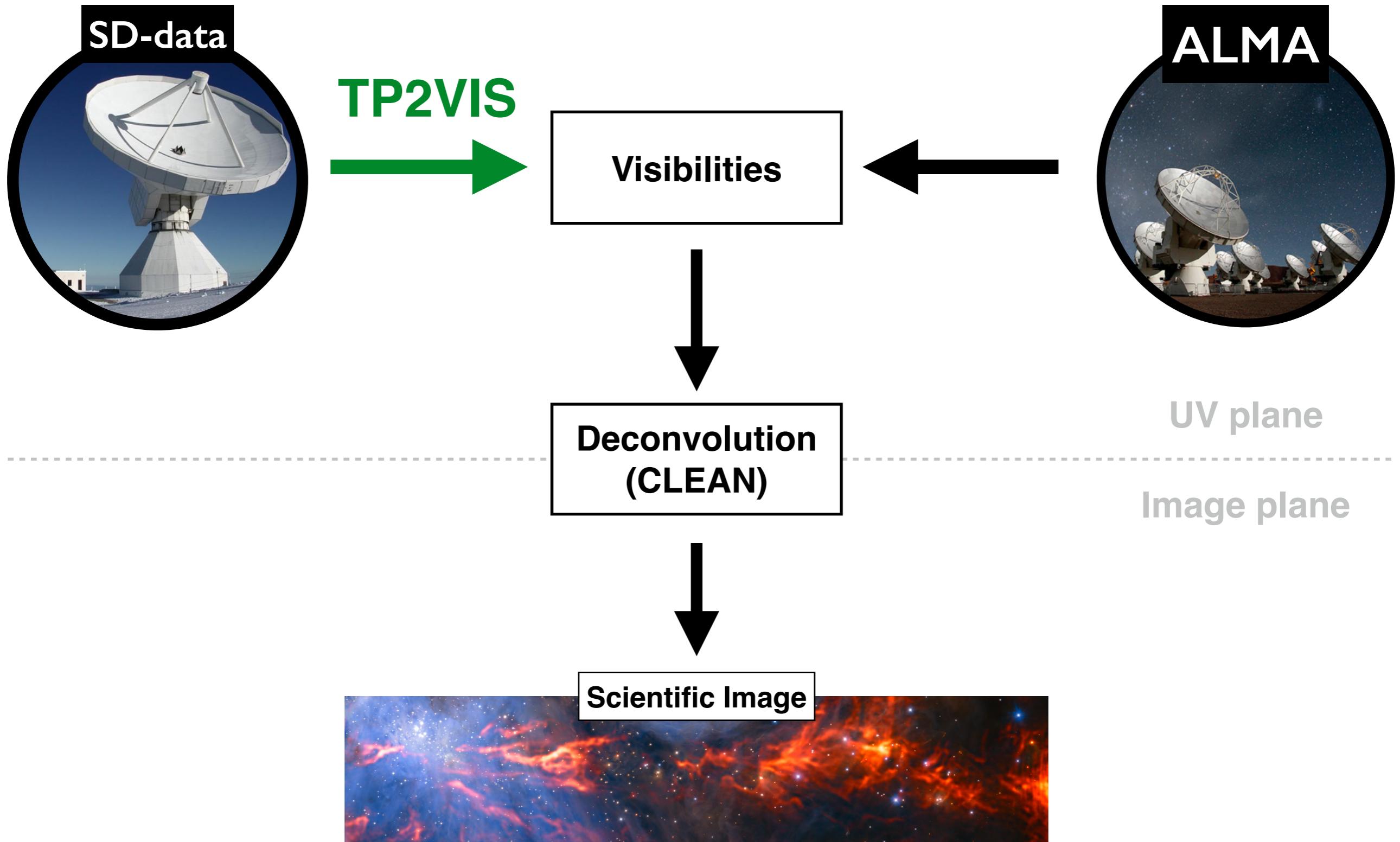
# Exercise (IV): shallow emission & tracers



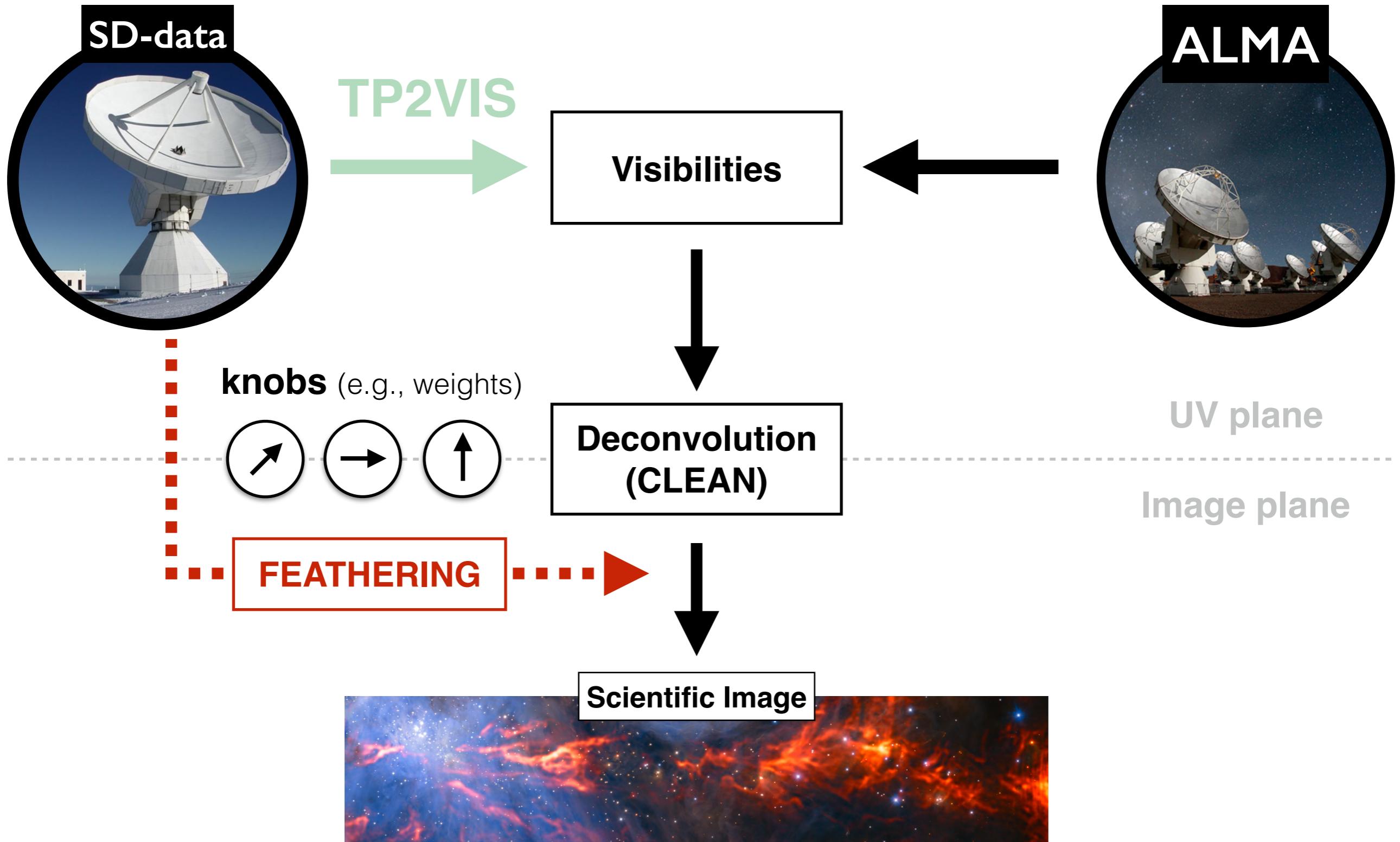
# Combining zero-spacing



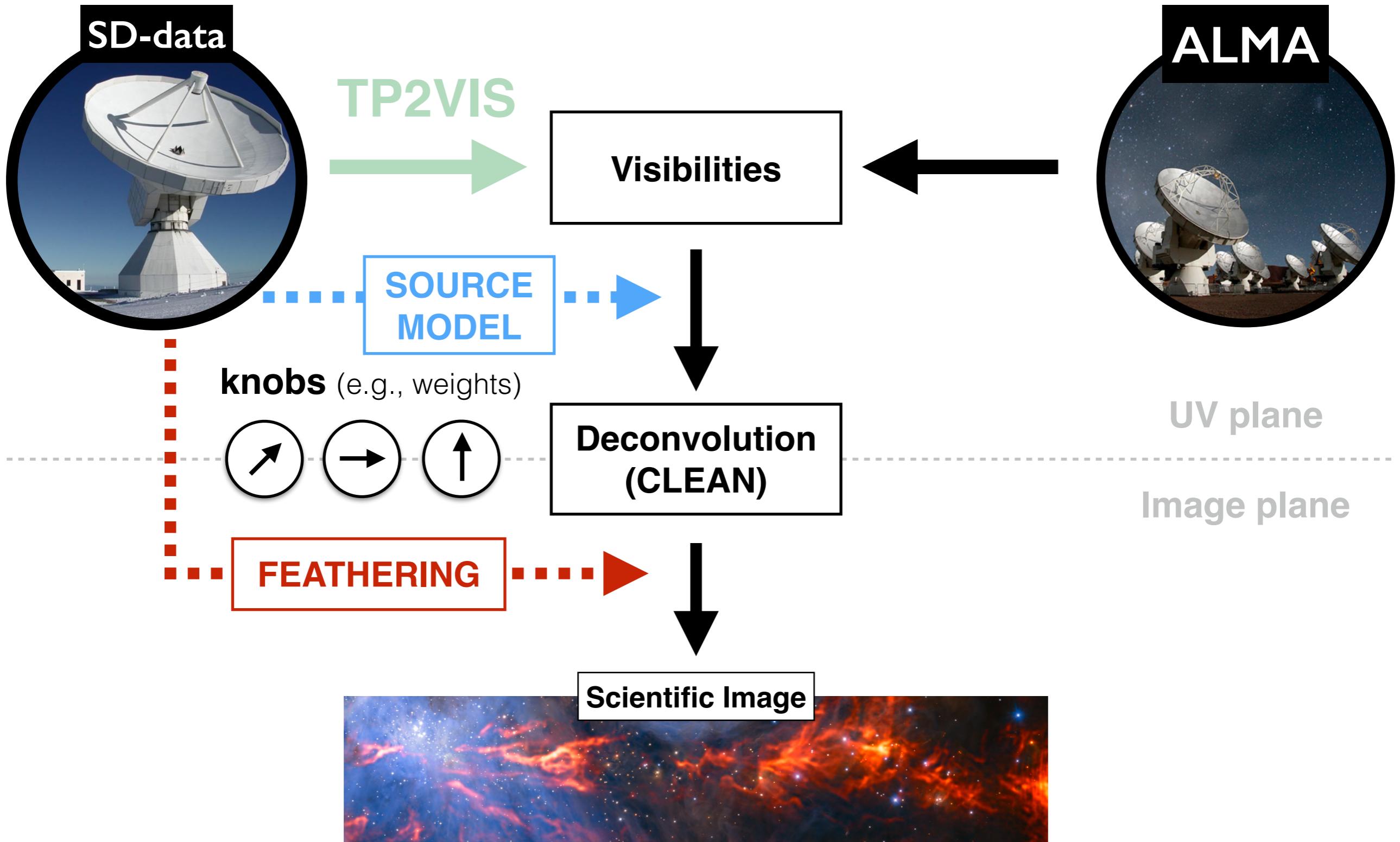
# Combining zero-spacing



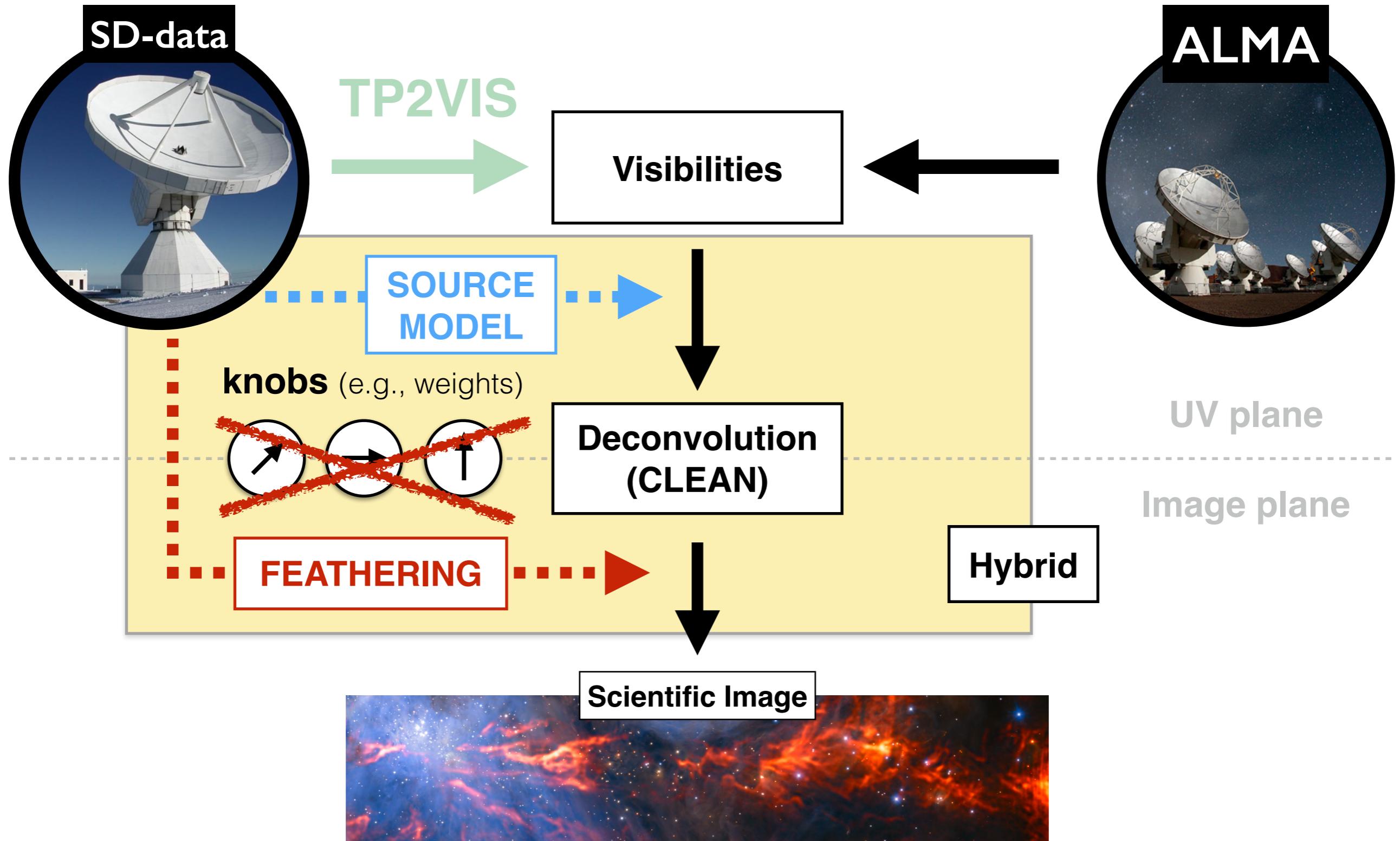
# Combining zero-spacing



# Combining zero-spacing



# Combining zero-spacing



# Empirical tests

1. ALMA12m alone (no zero-spacing)
2. ALMA12m + IRAM30m @ feathering only
3. ALMA12m + IRAM30m @ model + feathering (hybrid)
4. ALMA12m + IRAM30m @ model + feathering + mscale

$$Q = \frac{\text{SD-data} - \text{ALMA} @ \text{SD res.}}{\text{SD-data}}$$

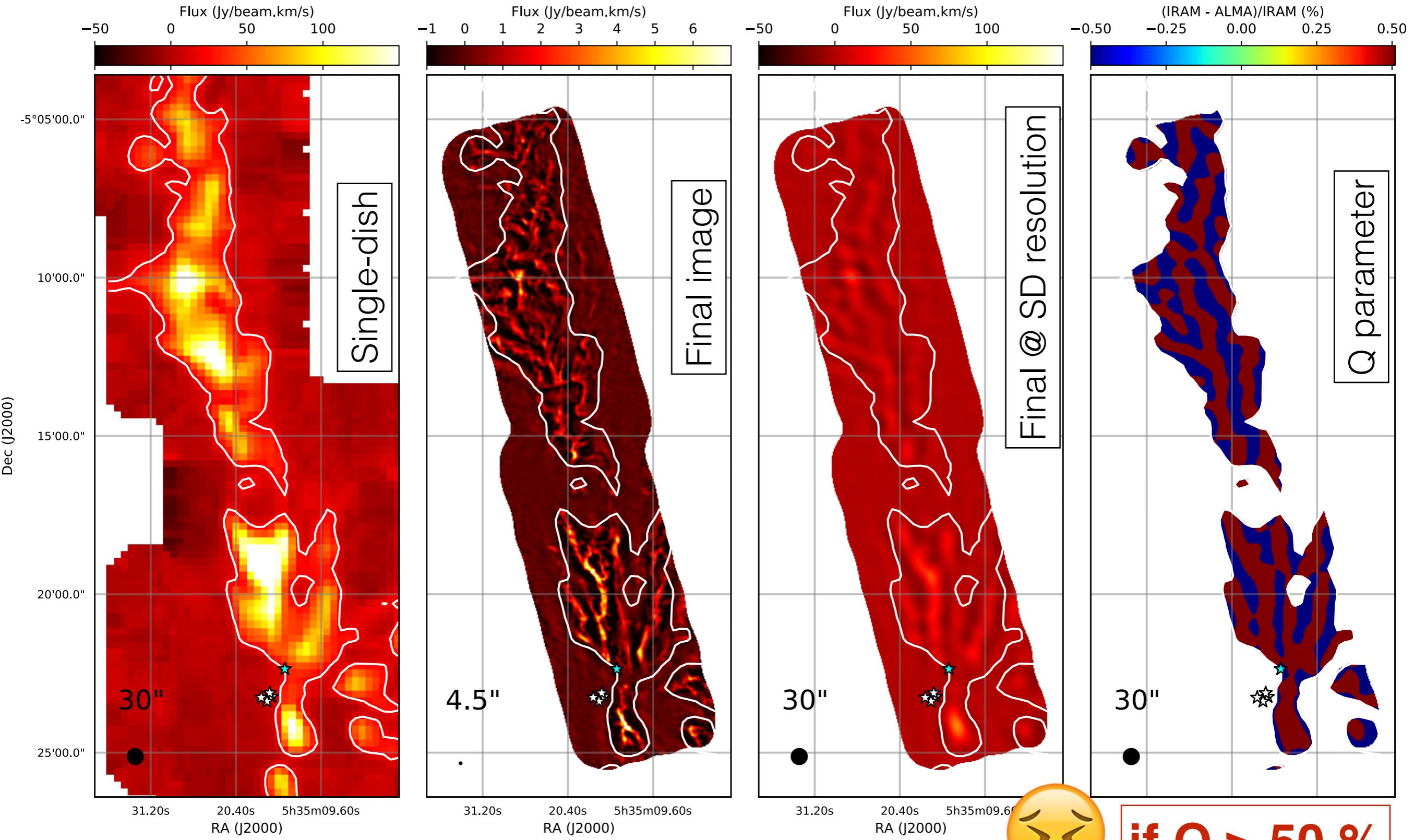
Goodness parameter

SD-data  -  @ SD res.

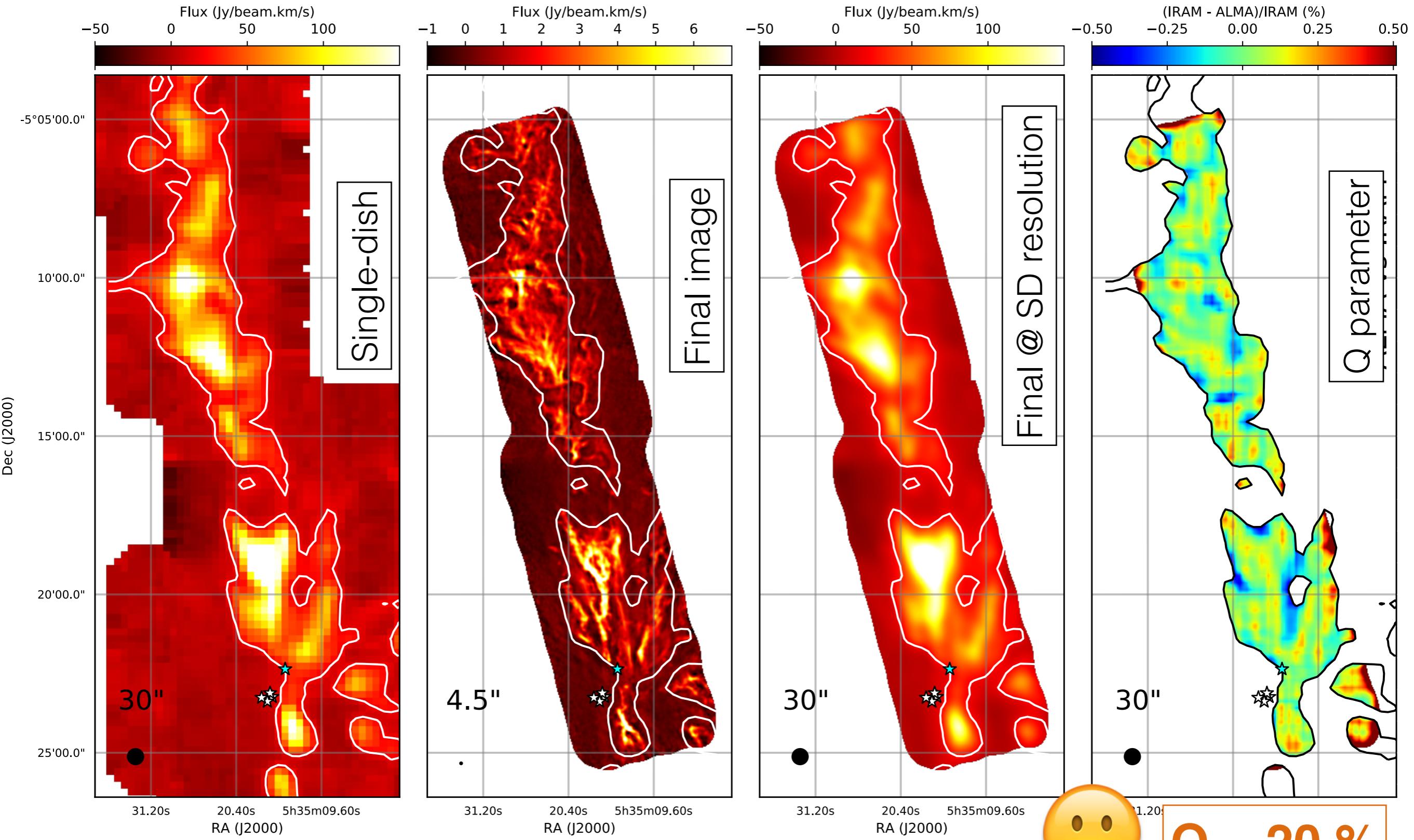
if  $Q \sim 0$  

if  $Q \neq 0$  

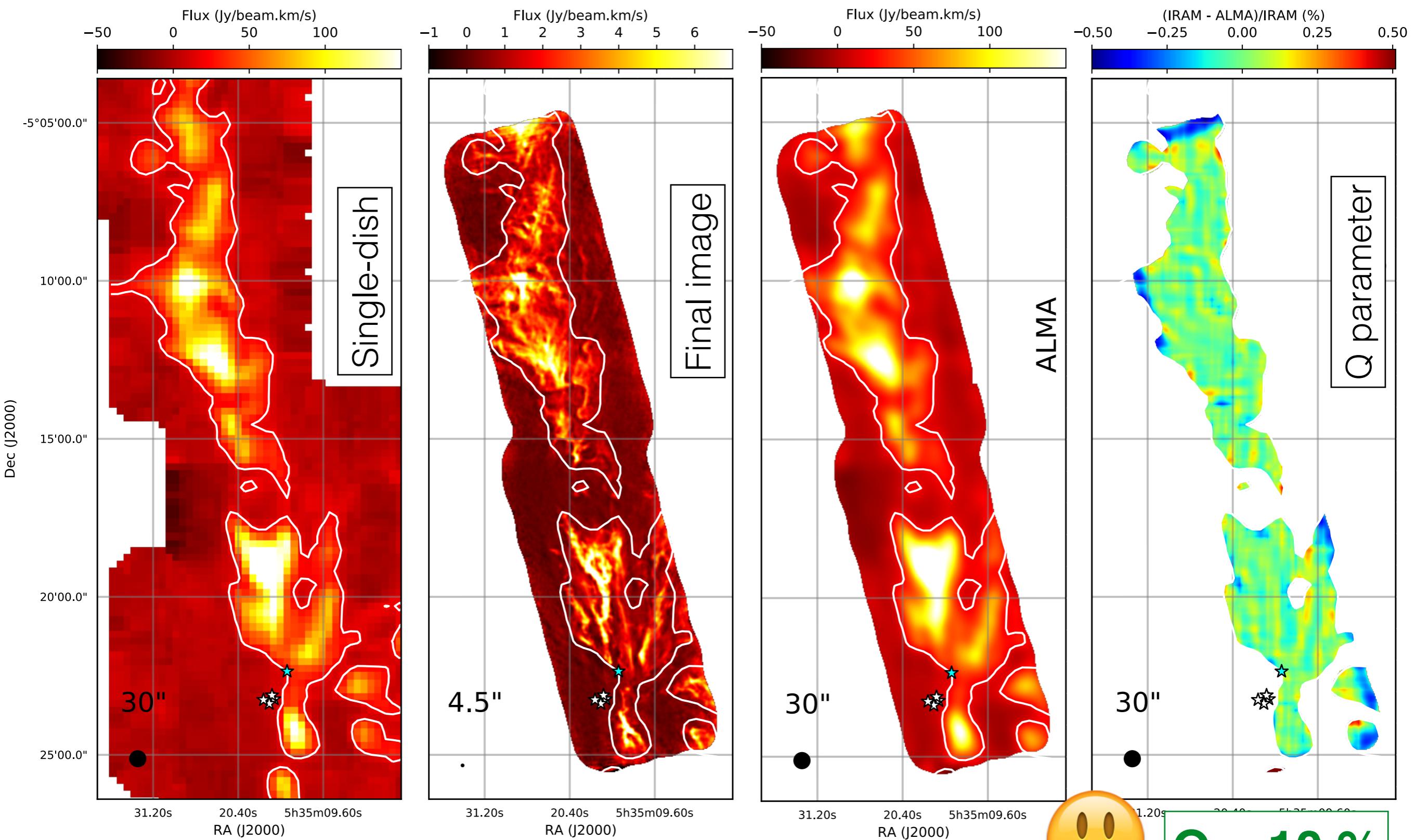
# Case #1: ALMA alone



# Case #2: ALMA + feathering (only)

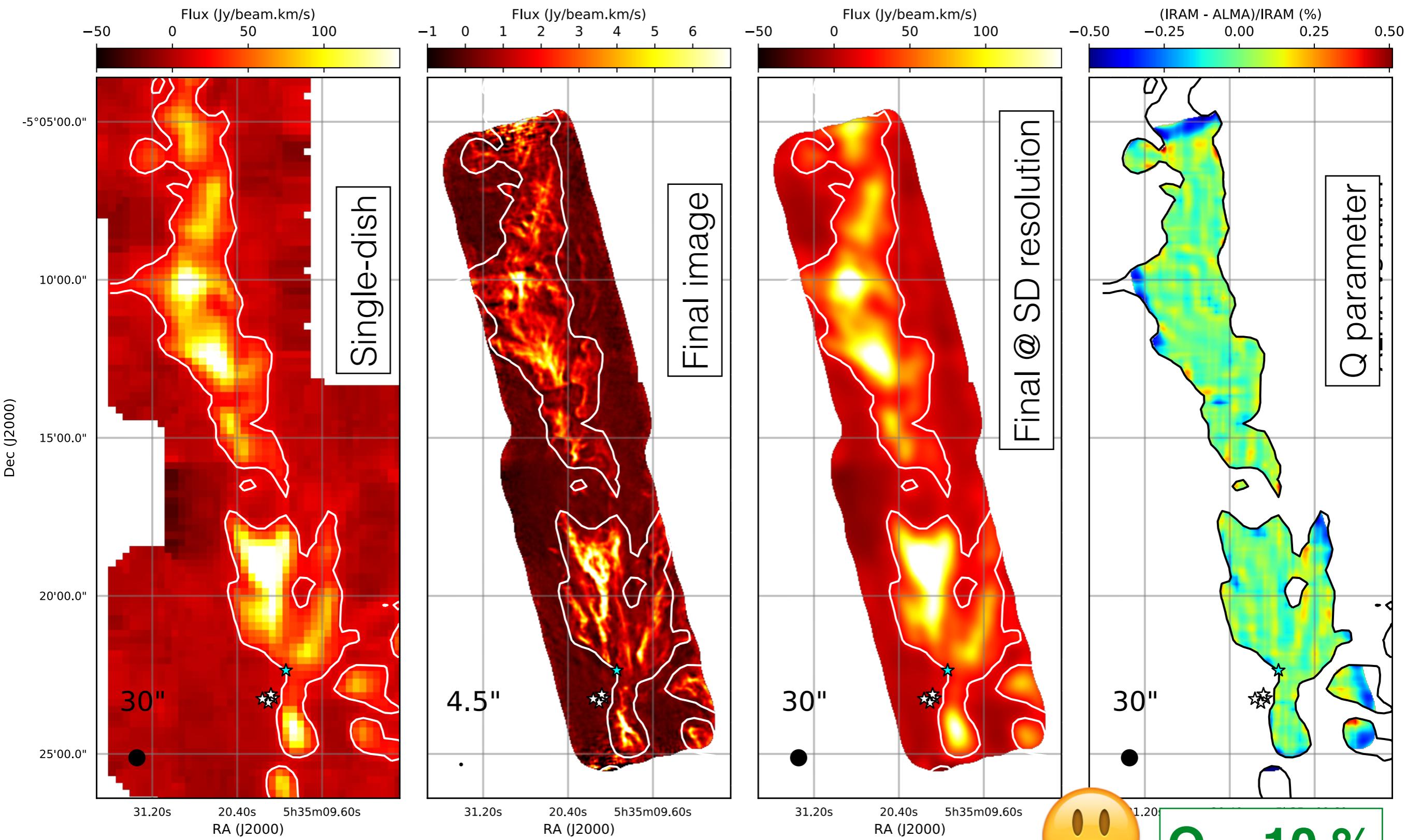


# Case #4: ALMA + model + feathering

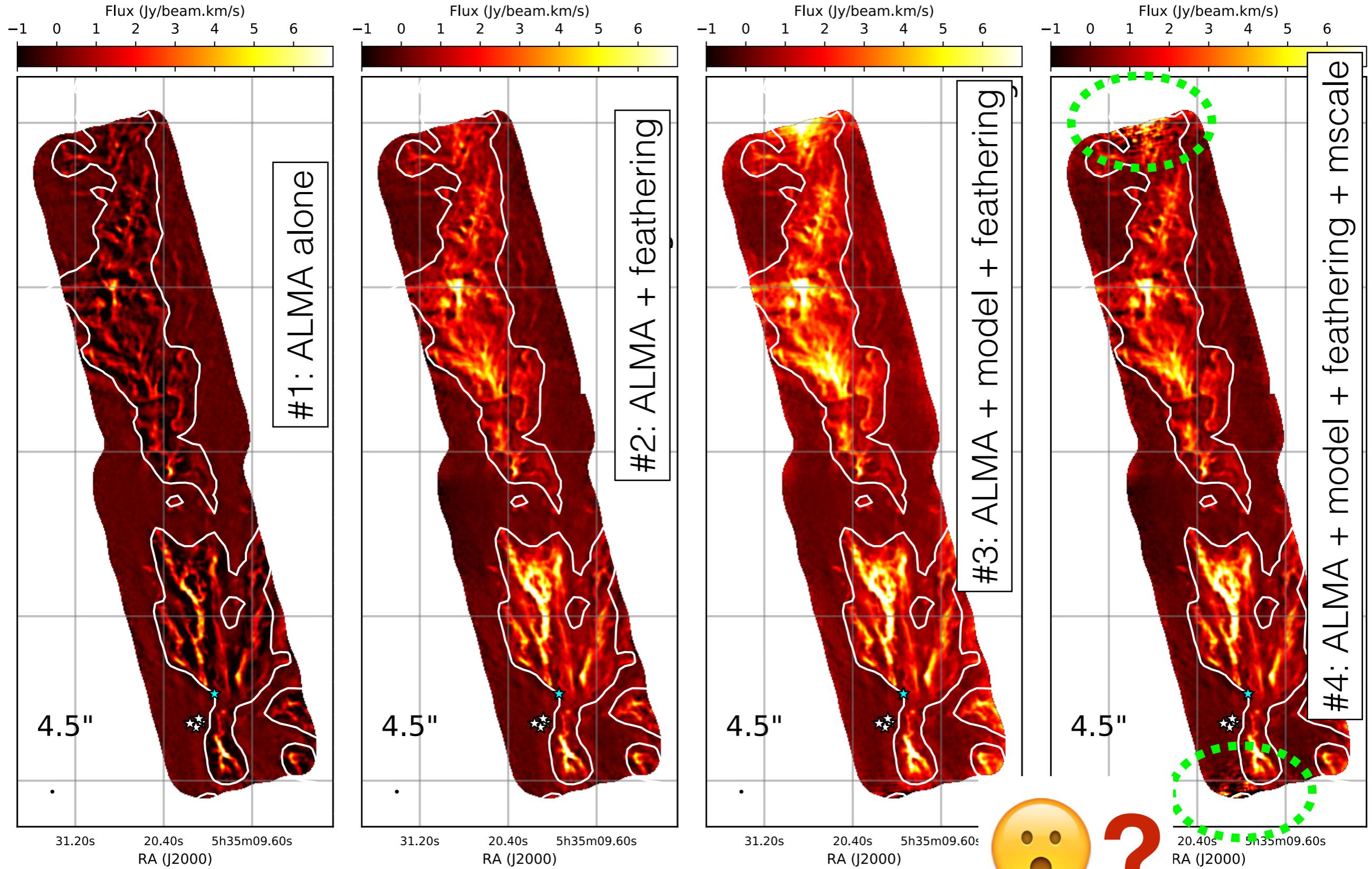


**Q ~ 10 %**

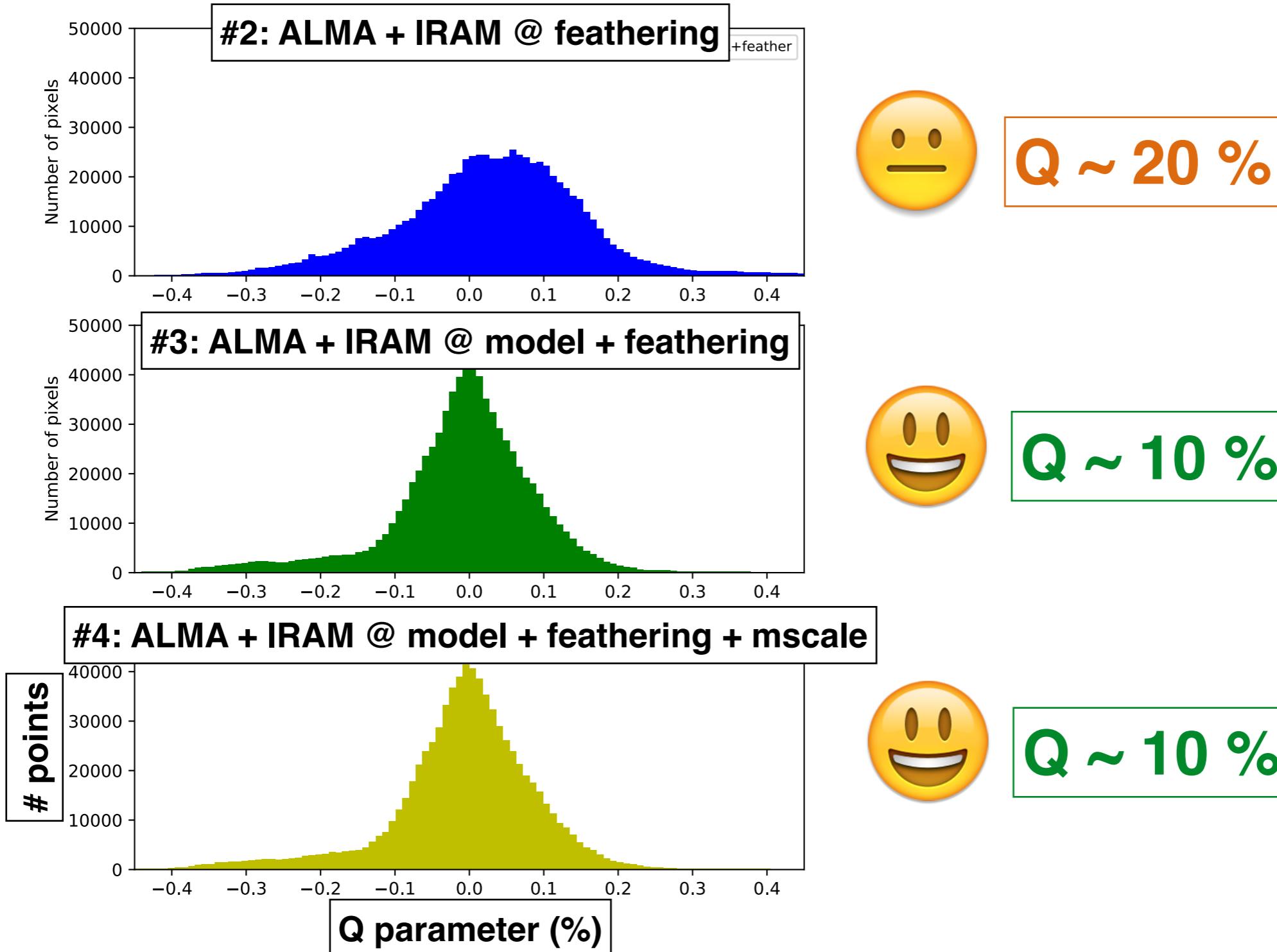
# Case #4: ALMA + model + feathering + mscale



# Comparisons



# Data combination: quantitative comparison

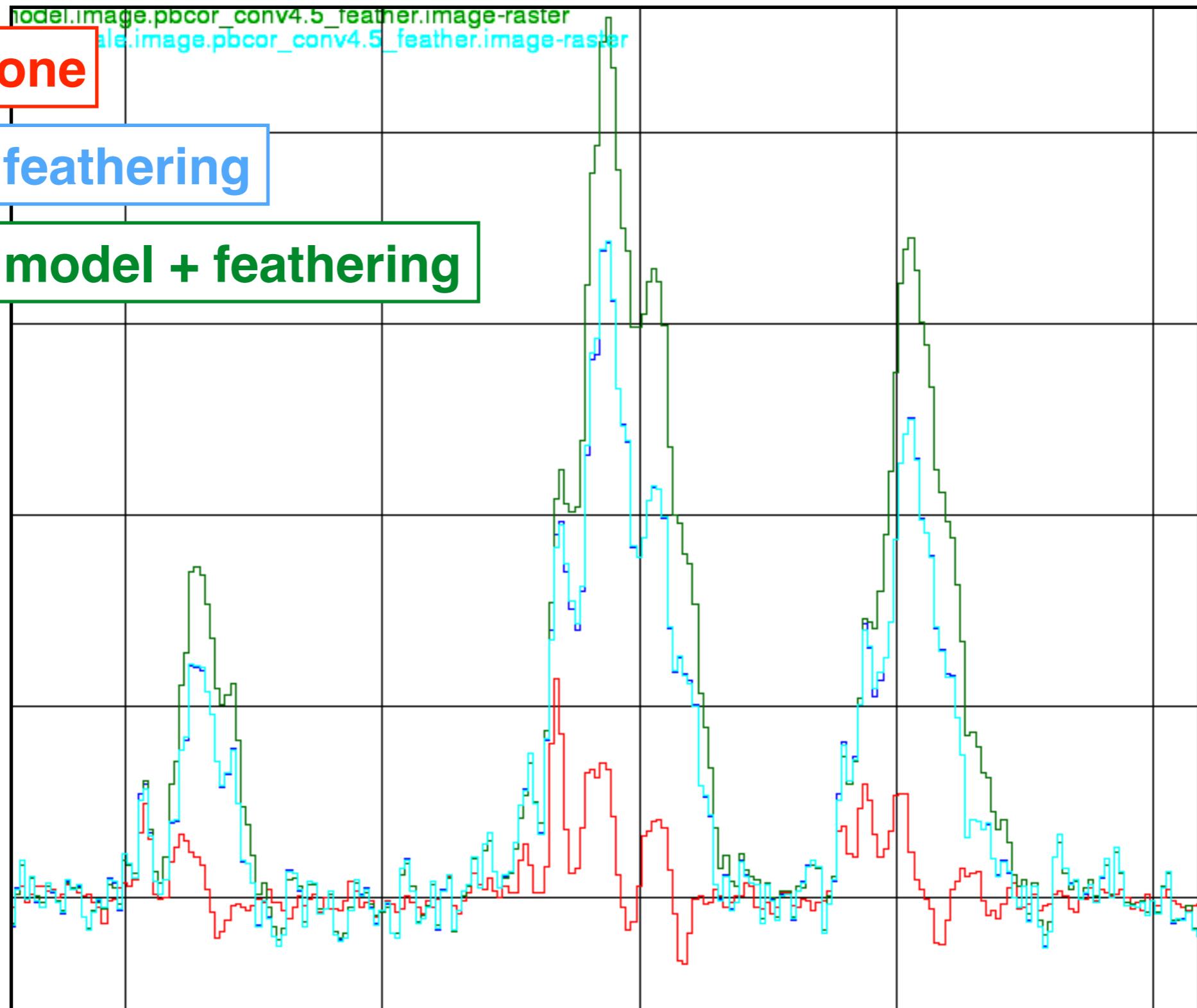


# Filtering effects on lines profiles

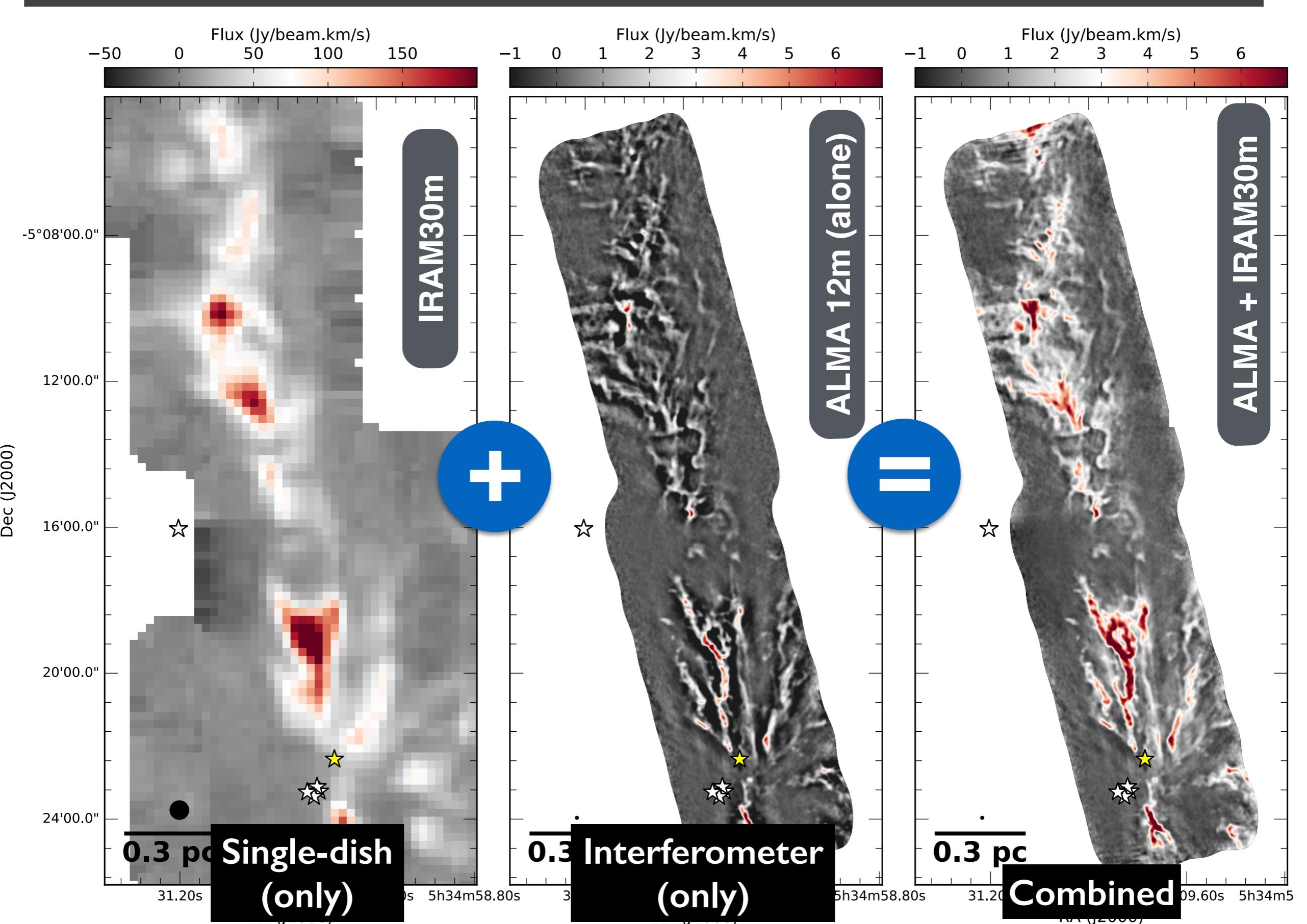
#1: ALMA alone

#2: ALMA + feathering

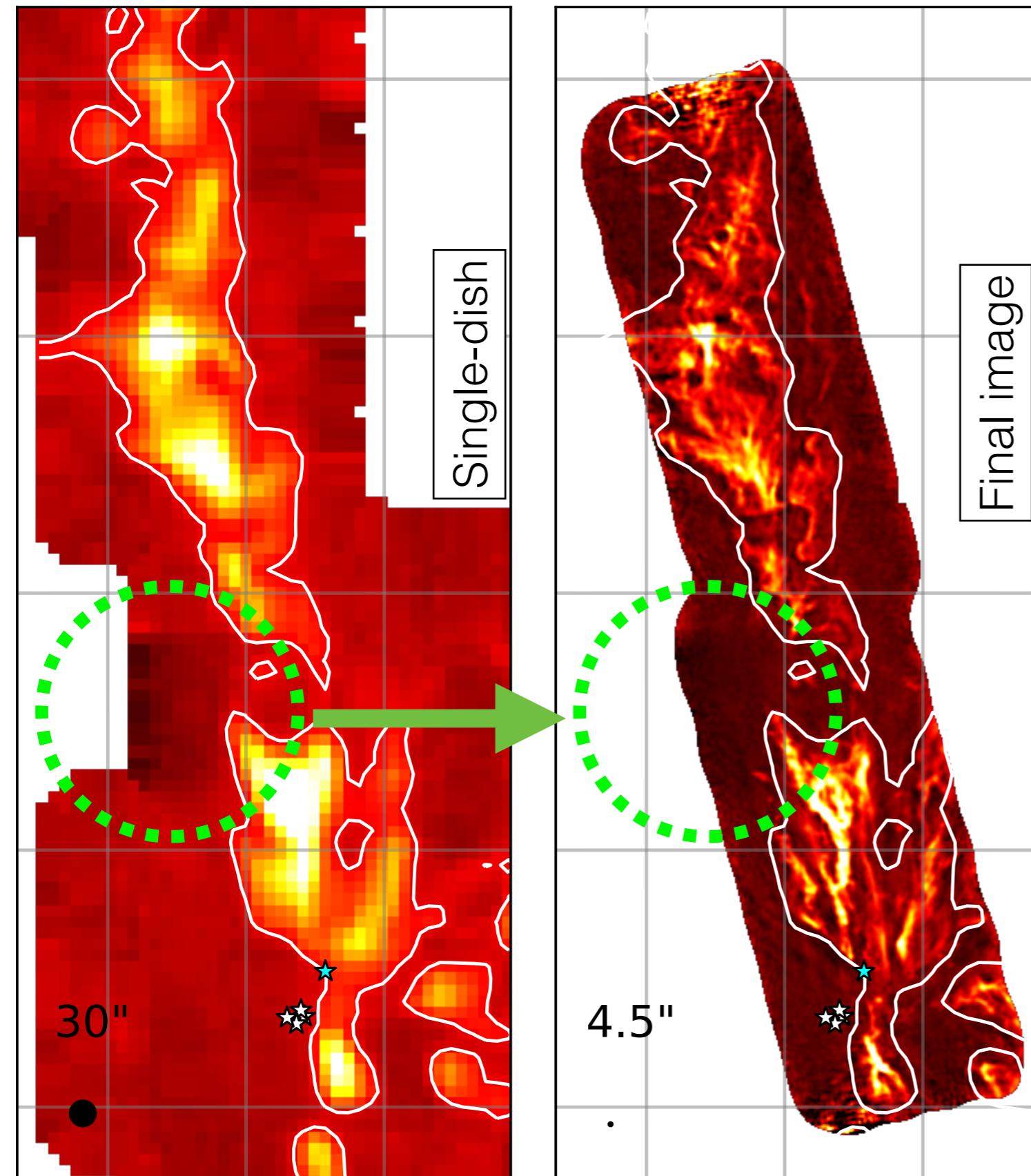
#3: ALMA + model + feathering



# Final image

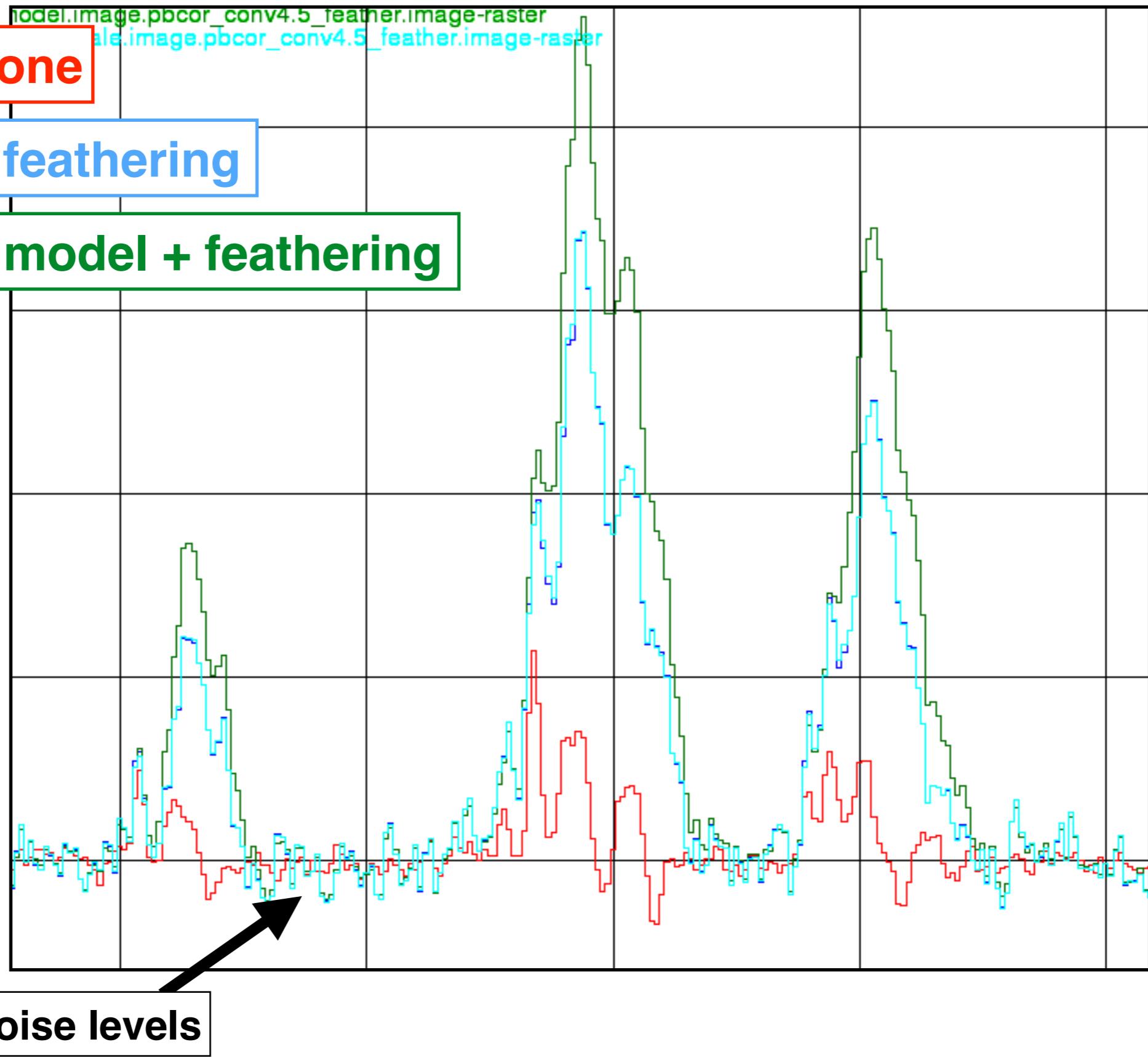


# SD-data quality & combination (I)

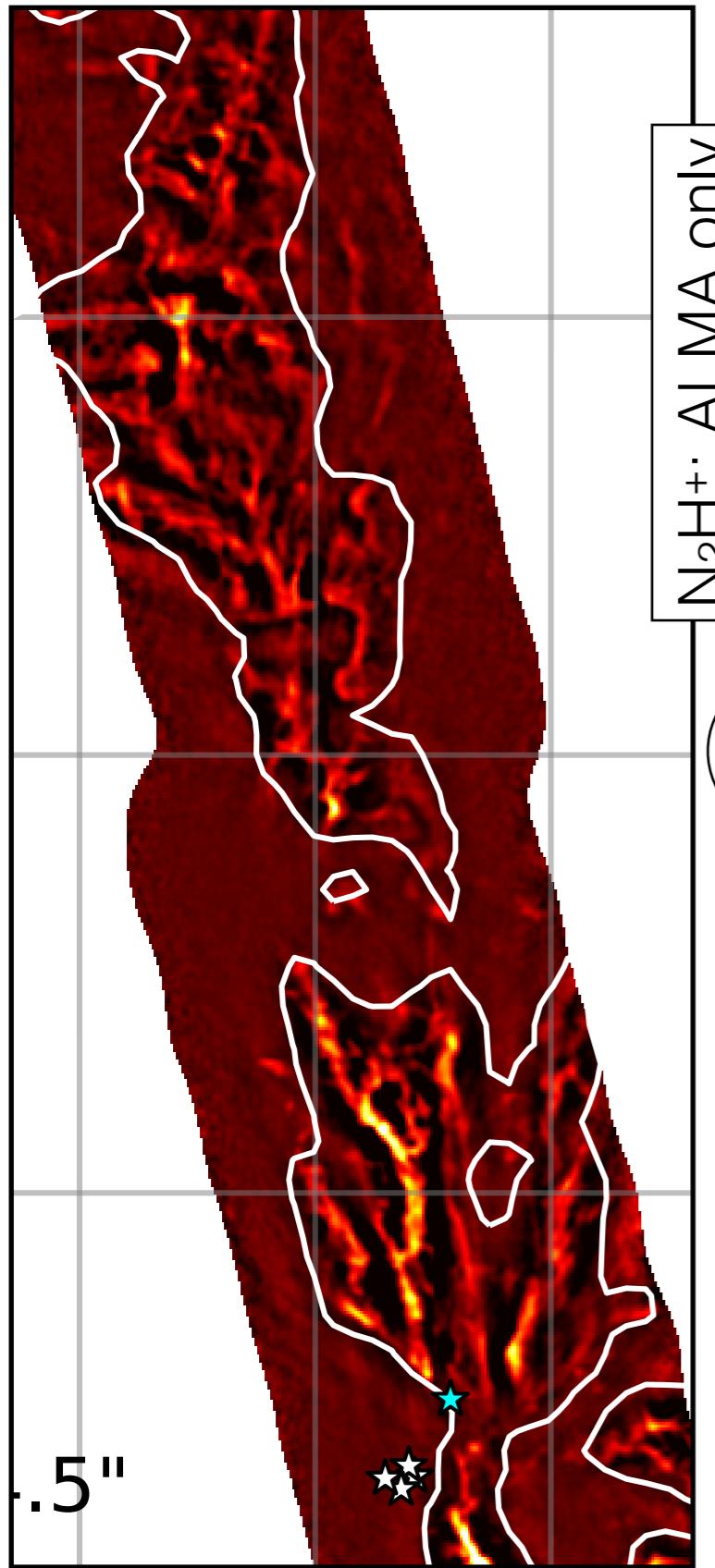


- SD features “translated” into the final image (baselines, instabilities, noise...)
- High-quality SD-data needed!

# SD-data quality & combination (I)

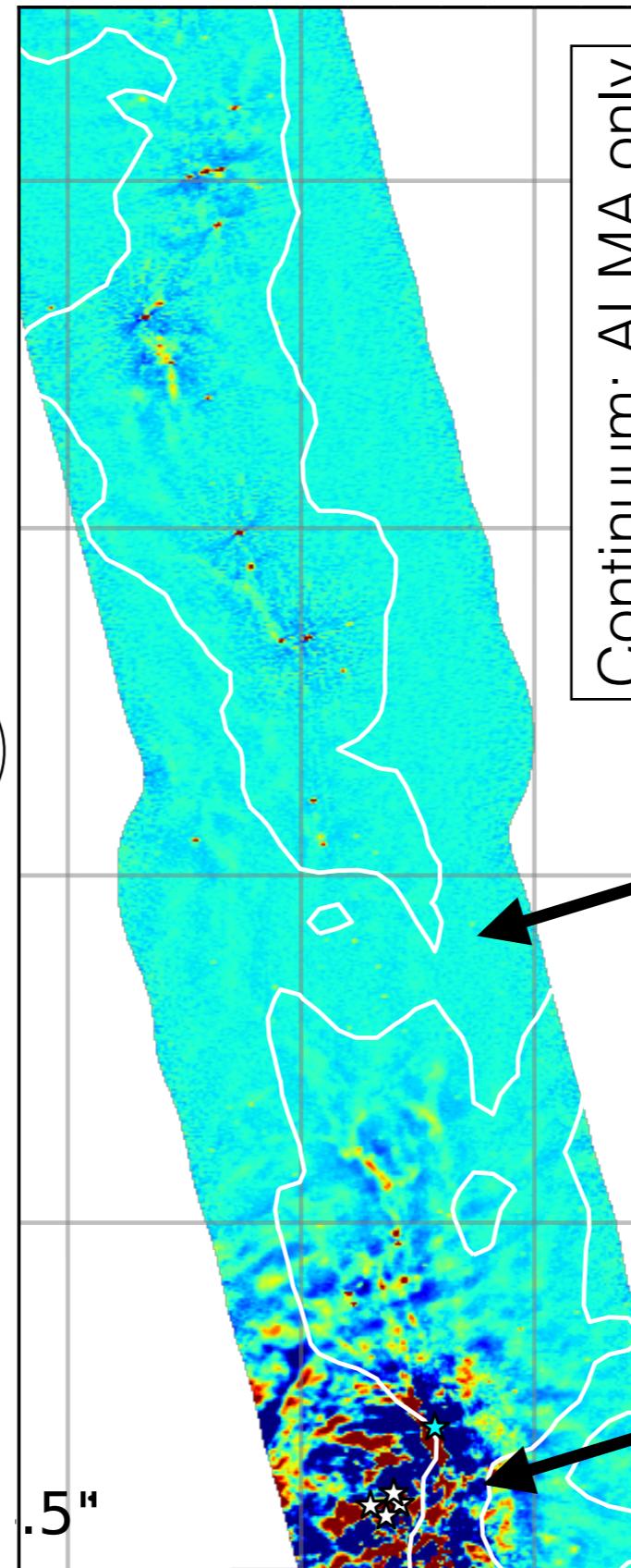


# The perils of interferometry-only continuum data



$\text{N}_2\text{H}^+$ : ALMA only

vs



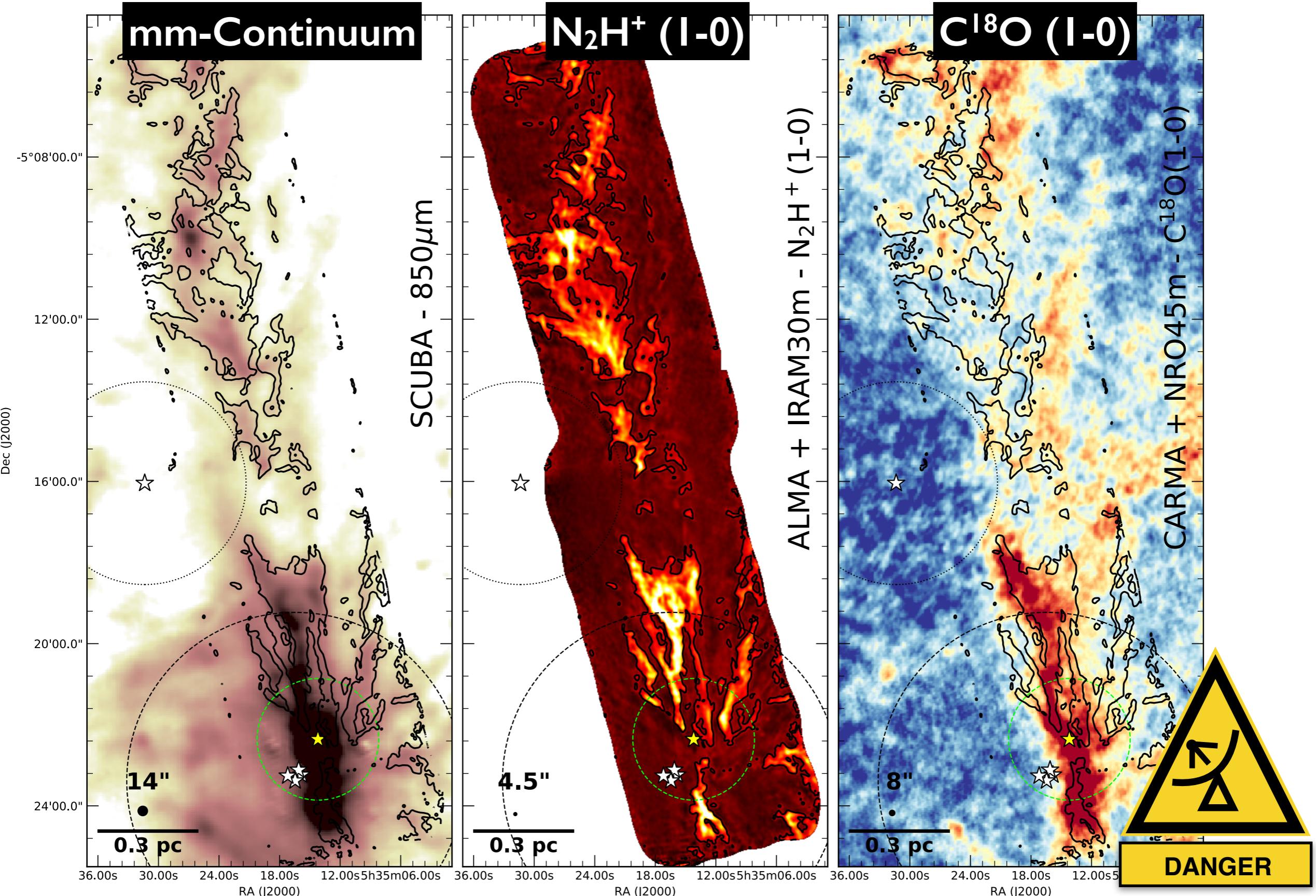
Continuum: ALMA only



Flat (low-noise)  
continuum

Nebula  
free-free contamination

# Different tracers = different issues



# Conclusions for Galactic Studies

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- Galactic sources = challenge for interferometers
- **\*ALWAYS\*** combine your data
- We need a fidelity/quality parameter (e.g., Q)
- Reduce the number of knobs
- Can we find a universal recipe?

**Our suggestion:  
Interferometer + SD @ model + feathering**

**similar to  
Tokashi's results**

