The Herschel Confusion Noise Estimator (HCNE) in HSPOT

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Confusion noise in the (far-) infrared

- Confusion noise: uncertainty in the point source flux determination due to background fluctuations
- May originate from an ensemble of discrete sources (e.g. the cosmic infrared background) or from a diffuse component (galactic cirrus)
- For discrete sources the actual limit can be set by the source density or by the photometric limit
- Cannot be improved by longer integration times - the “confusion noise” is a signal itself
- Especially important at infrared and submillimetre wavelengths
- Depends strongly on the spatial scale, previous FIR instruments (like ISO/ISOHPOT) were confusion noise limited

The Herschel Confusion Noise Estimator (HCNE)

- Part of HSPOT, currently at version v019
- Gives "per-pixel" noise and "point source uncertainty" for all PACS and SPIRE photometric bands at a specific sky position
- Considers the cosmic infrared background and the Galactic cirrus emission
- Cirrus confusion noise is calculated from the local surface brightness values
- Fluctuations due to zodiacal emission and source confusion due to asteroids can be neglected at the Herschel wavelengths (see Kiss et al., 2008)
- Previous releases were based on IRAS, ISO and DIRBE data

HCNE/v019
(the current release)

- Changes compared to the previous version (changes are summarized in the Release Note) :
  - Improved estimates of the ISM background temperature in the Herschel Background Estimator
  - New extragalactic background confusion limits based on the latest Herschel values (both PACS and SPIRE)
  - New cirrus confusion noise scaling based on Herschel-PACS 160 μm measurements, scaled to other Herschel bands, too, using conversion factors determined in simulated images

ISM background temperature correction in HCNE/v019

- Original issue: The Herschel Background Estimator uses a constant temperature for the ISM component → In some cases the ISM surface brightness values are under- or overestimated
- In HCNE/v019 a correction is applied, based on the *PredictDIRBE* tool (Kiss et al. 2006)
- Temperatures are based on DIRBE measurements, an independent temperature is fitted for the cold ISM component, zodiacal contribution is removed based on the short wavelength contribution
- Correction is sky-position specific and applied for all PACS and SPIRE bands

MadMaps at 160µm for HCNE/v019

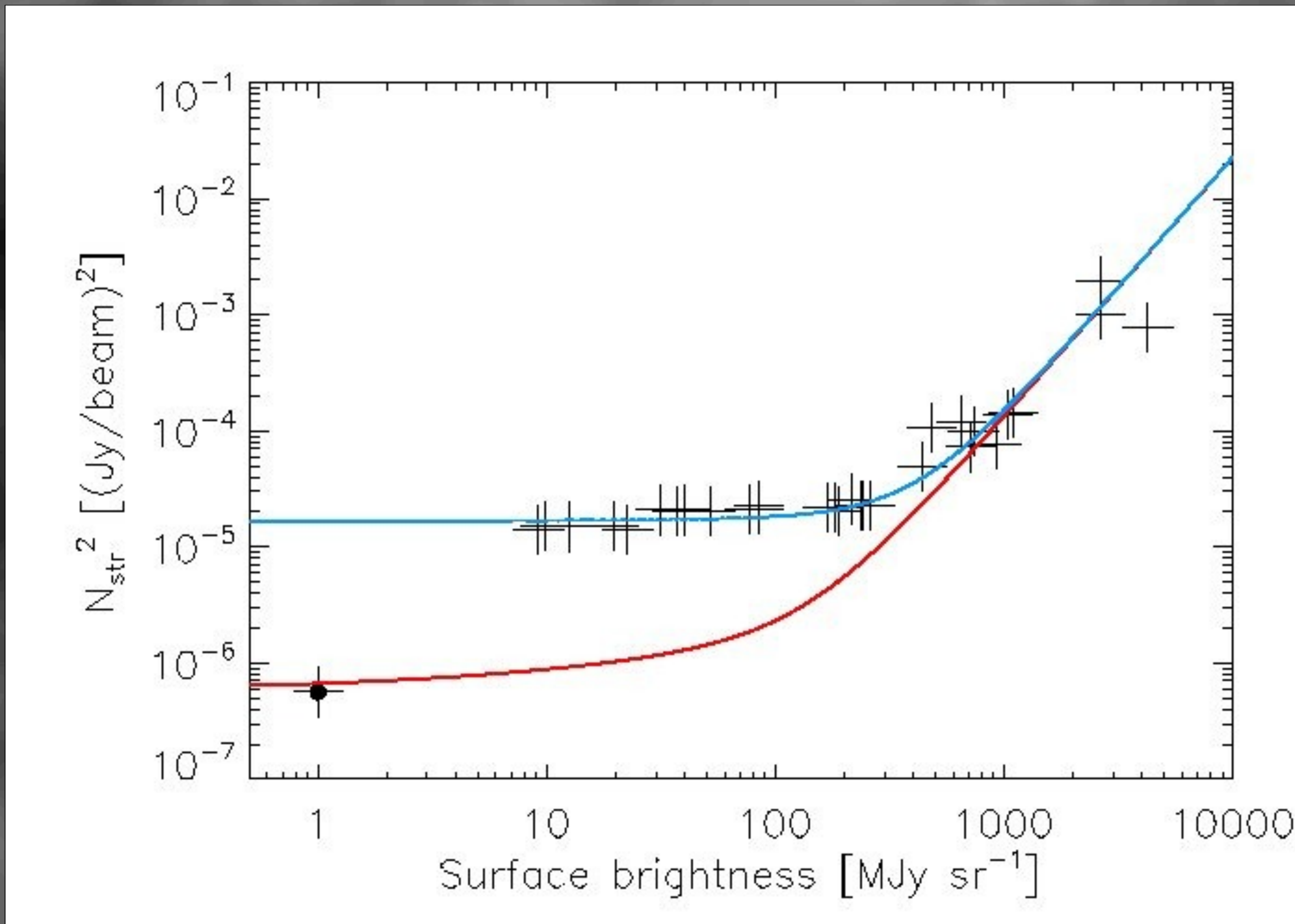
- Cirrus component of the confusion noise scales with the cirrus surface brightness - in HCNE this scaling is used to estimate the cirrus confusion noise
- In the previous releases the scaling was based on ISO/ISOPHOT measurements (100 and 200 µm), extrapolated to the spatial scale of Herschel detectors and to other wavelengths
- Now we have the possibility to use real Herschel maps at all photometric bands
- First step: cirrus in the PACS red band (cirrus is the strongest here)

MadMaps at 160µm for HCNE/v019

- Why MapMaps? - “Normal” Herschel maps does not preserve the true surface brightness scaling and structure
- Current sample: about 10 sky areas with various surface brightness, each divided into 4 subfields
- There is still an uncertainty in the sufrace brightness scaling - we use the PredictDIRBE tool to get the cirrus component (ZL and CIB removed) in the MadMap fields
- Structure noise (variation in the pixel-to-pixel surface brightness differences) is determined

MadMaps at 160μm for HCNE/v019

- Structure noise is fitted as a sum of instrument noise, CIB fluctuations and cirrus confusion noise

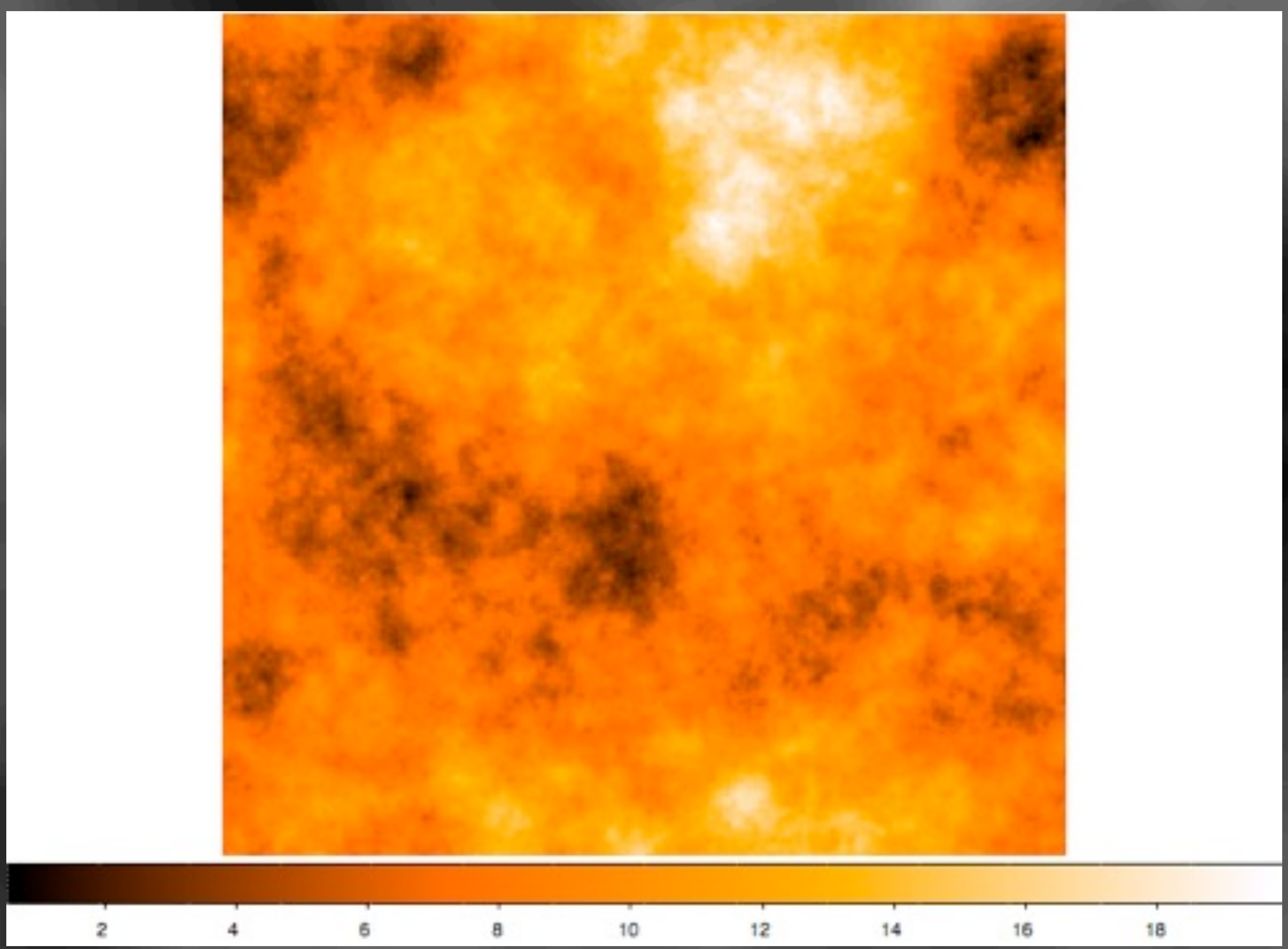


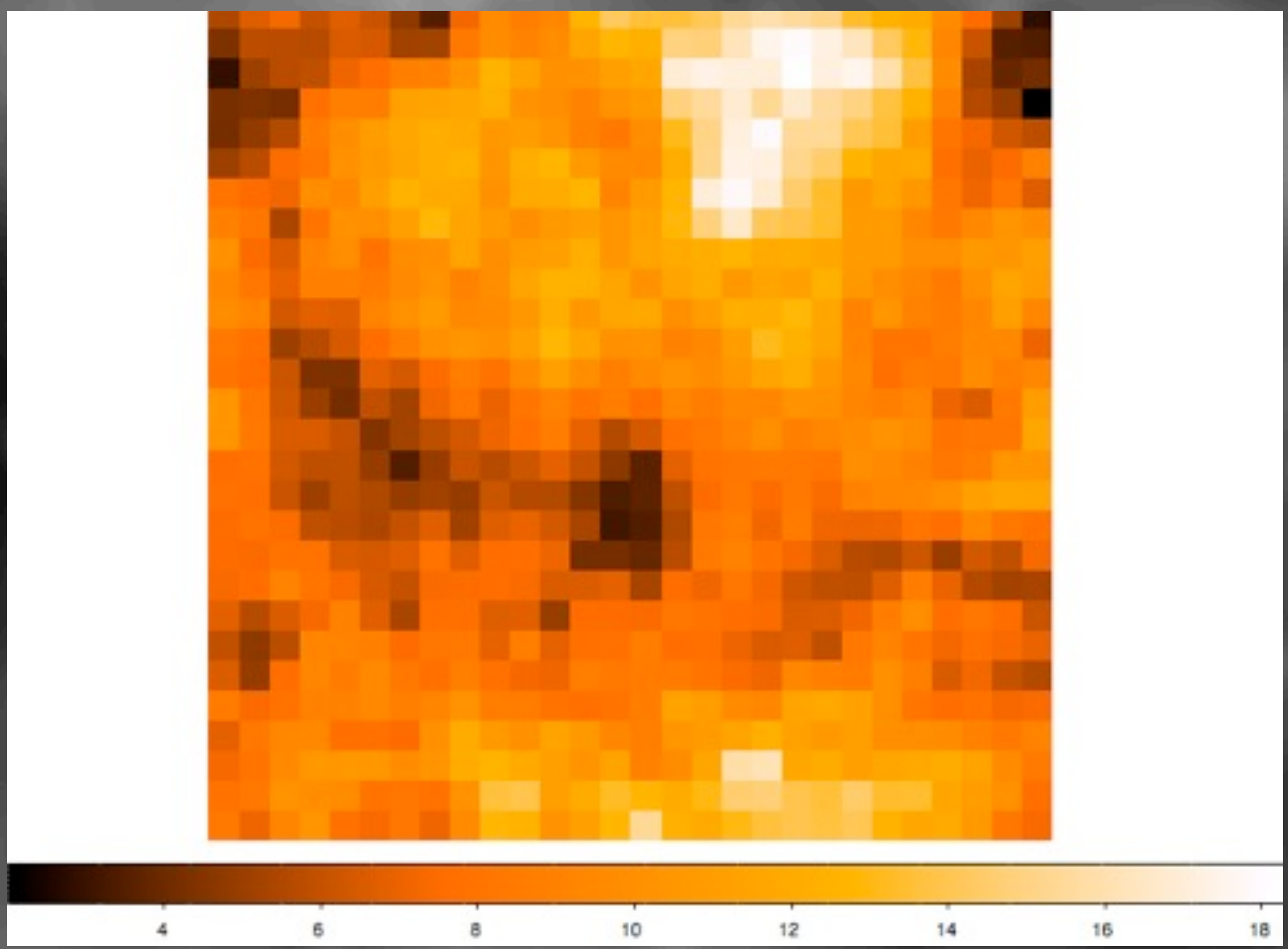
Conversion to other wavelengths

- Scaling to another wavelength should be $(\lambda/\lambda_0)^{1-\alpha/2}$, assuming a constant cirrus SED (constant average surface brightness values at all wavelengths)
- α: spectral index of the spatial power spectrum - was -3 for "classical" cirrus (IRAS), now rather considered as -2.5 for the cirrus at the Herschel spatial scale
- Seems easy, but this is only true for the resolution limit, and other effects may change the scaling (e.g. the same PACS detector at 70 and 100 µm)
- Checking of this scaling law by simulated maps of prescribed cirrus structure

Conversion to other wavelengths

- Structure noise is calculated in the simulated maps and compared with the original scaling law
- R_λ = 1.099, 0.856, 1.0, 1.334, 1.259, 1.210





Cosmic infrared background fluctuations

- The latest values are applied (point source uncertainty!):
  - 0.1 and 0.75 mJy at 100 and 160μm (Berta et al., 2010)
  - 5.8, 6.3, 6.8 mJy for the 250, 350 and 500μm SPIRE bands (Nguyen et al., 2010)
- The "point source uncertainty" values are transferred back to the "per pixel" values using the PSF and pixel information (as was in HCNE/v015)

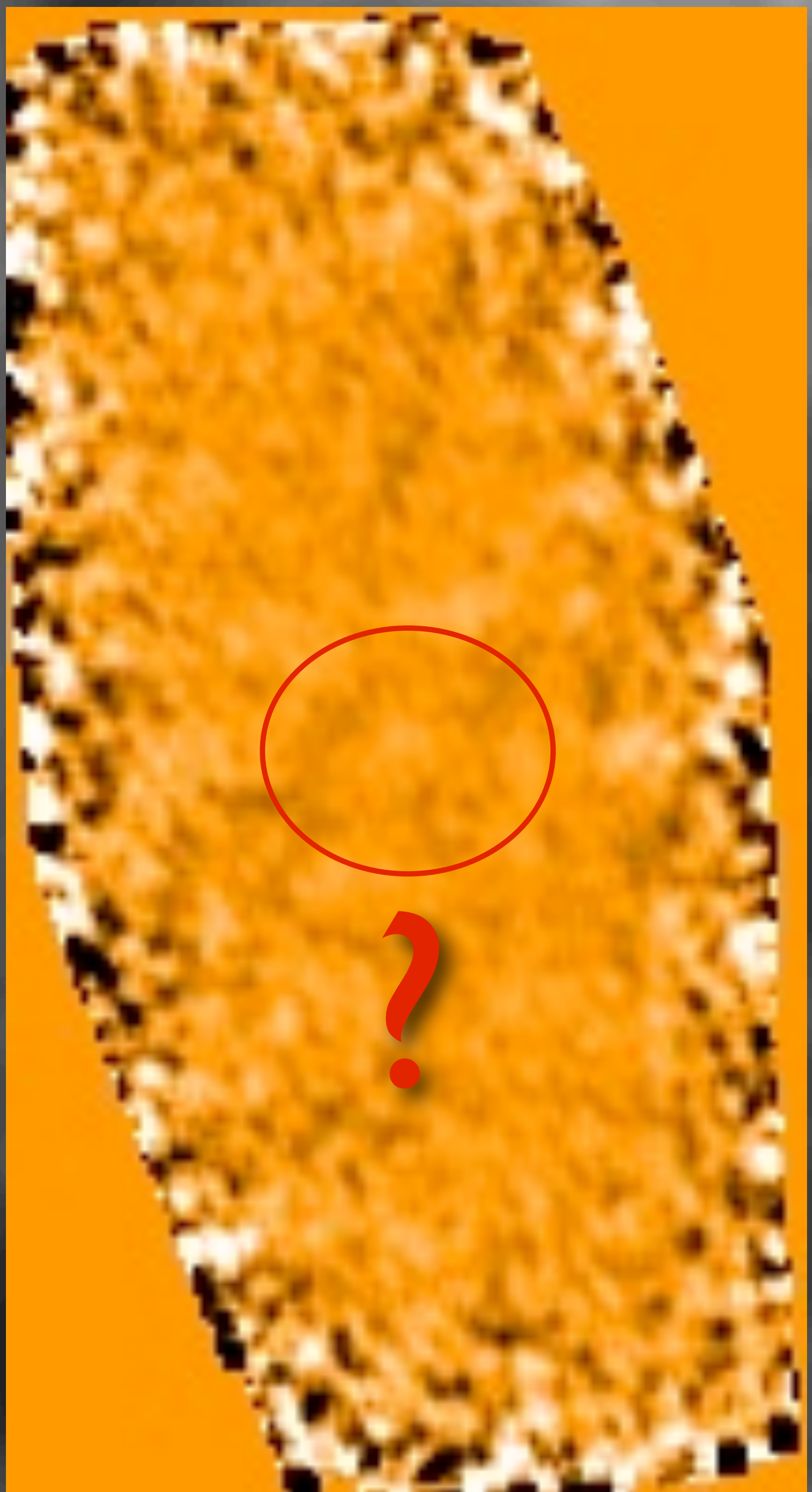
Main achievements in the latest version

- More accurate surface brightness for the cirrus calculations, especially in high surface brightness and "warm" regions - confusion noise is lower now for the longest wavelengths in these regions
- More realistic cirrus confusion noise for high surface brightness regions (above 200 MJy/sr), where the scaling was very inaccurate in the previous release (no reliable measurements were available in this regime)

Confusion noise for moving targets

- Data reduction point of view:
  - difficult to use tracking correction, correct handling of frames at different times, determination of signal-to-noise from the corrected images
- But: we may (with the right observing strategy) see the background at two different epochs, with the target at two different positions → an excellent opportunity to get rid of the confusion noise!

Confusion noise for moving targets (example)



- Measurements: Cold moving target in the PACS red band, observations separated by ~1 day
- Left: Single PACS red band image -- the source is invisible (lost in the background)

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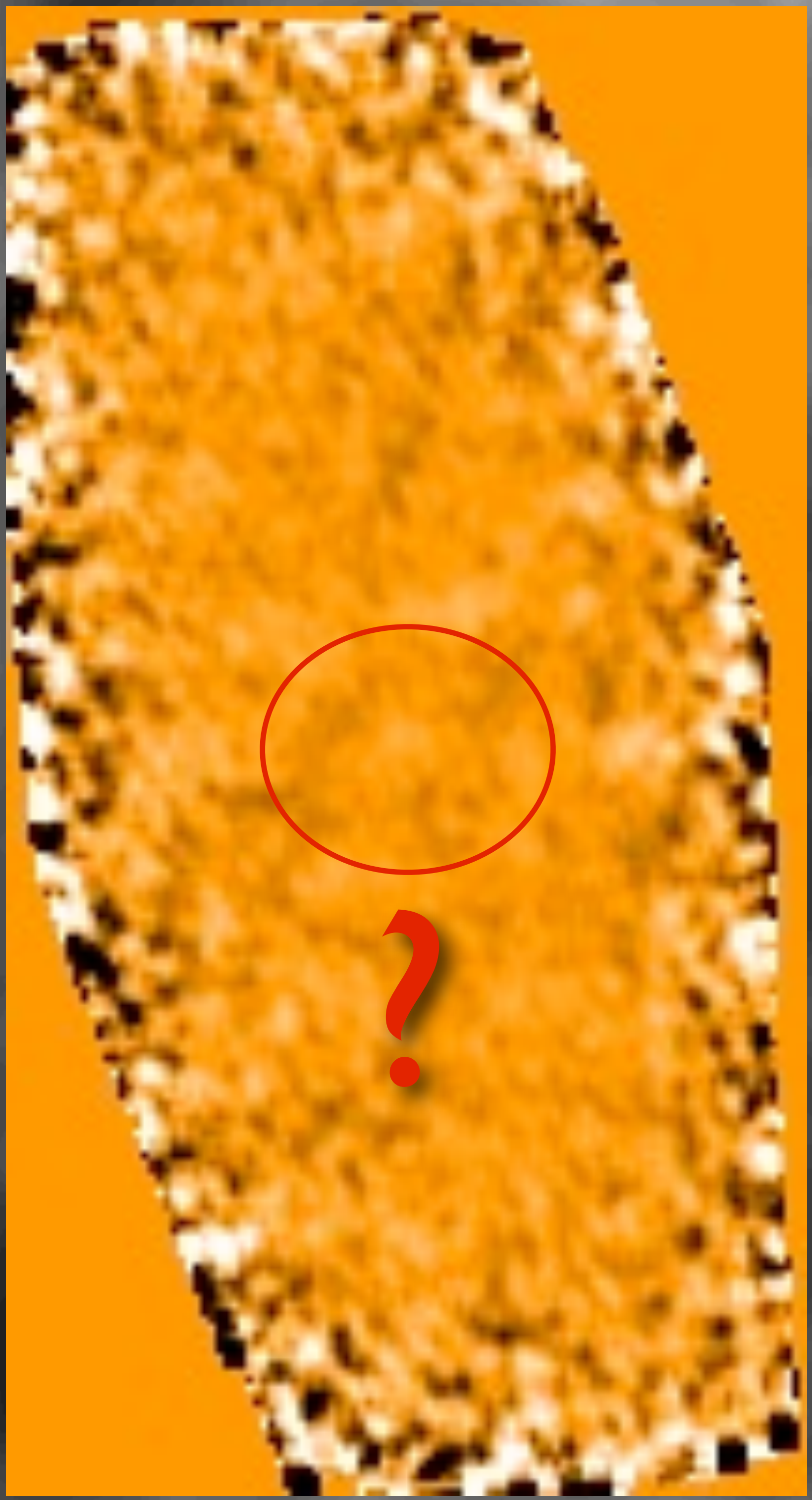

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- Right: Differential image in the PACS red band (primary minus follow-on)

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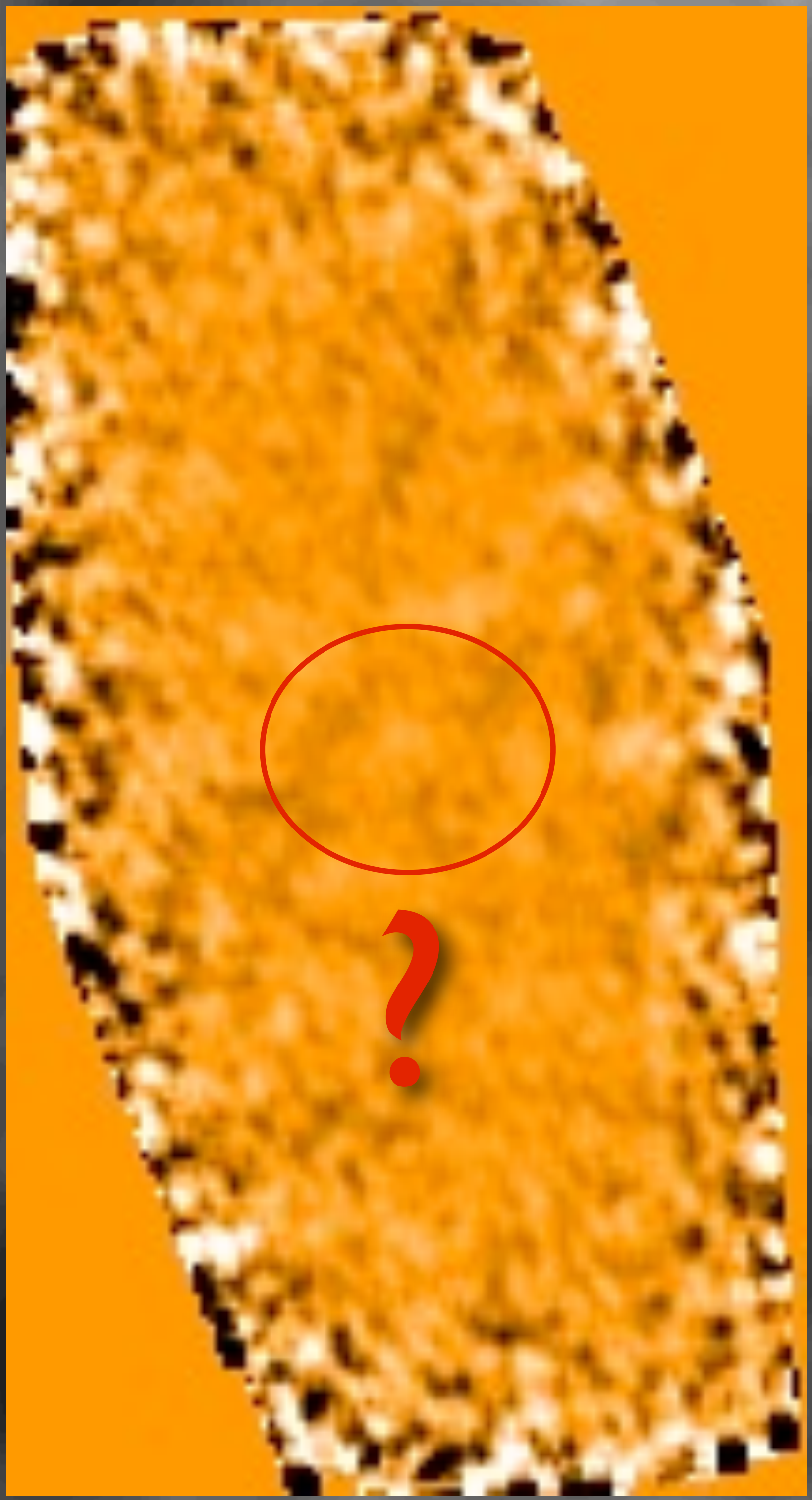

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