Super-resolving Herschel imaging: a proof of concept using Deep Neural Networks

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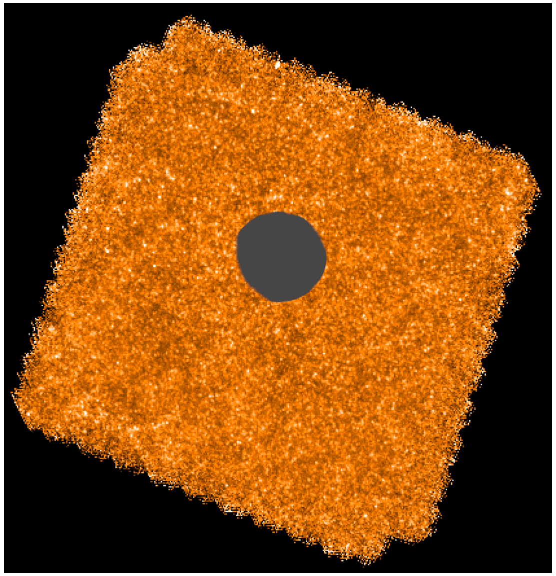
Why super-resolve Herschel SPIRE images?

- JCMT SCUBA-2 provides data with vastly improved PSF FWHM and confusion noise

- Herschel SPIRE covers a much larger area of the sky

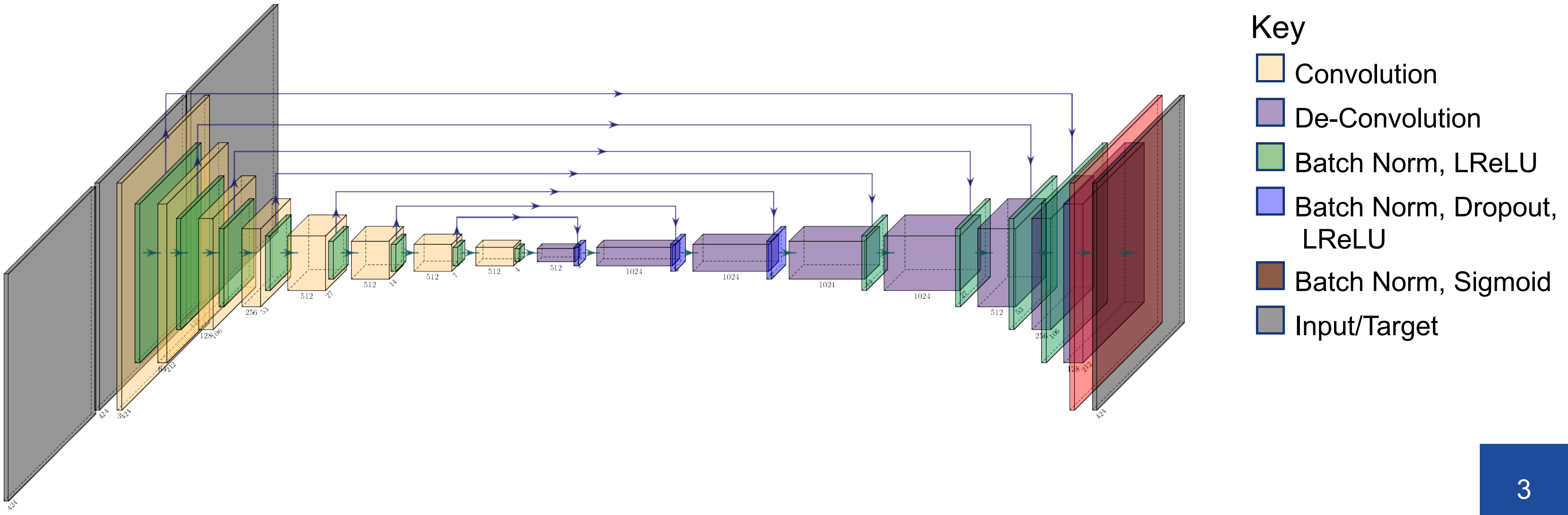
Lim et al. 2020, Oliver et al. 2012



Characteristic	Herschel SPIRE			JCMT SCUBA-2
Wavelength	250 µm	350 µm	500 µm	450 µm
PSF FWHM	18.1"	24.9"	36.6"	7.9"
Confusion noise (σ, mJy/beam)	5.8 ± 0.3	6.3 ± 0.4	6.8 ± 0.4	1
Pixel scale	6"	8.33"	12"	1"

How did we build the network?

- The network is an autoencoder in a UNET configuration
- Architecture based on the GalaxyGAN generator (Schawinski et al. 2017)
- Sigmoid activation function is used to suppress noise in the output images.
- Training is done on an alternating set of simulated and real data



Training the Network – Simulated Data

- The simulated data is simulated using the Empirical Galaxy Generator
- Custom loss function combining
  - L1-loss
  - Mean flux difference
  - Median flux difference
  - Aperture flux differences based on sources identified in the simulated target data

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  - Mean flux difference
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  - Aperture flux differences based on sources identified in the simulated target data
- The aperture loss identifies source locations in the simulated data and compare aperture fluxes at these coordinates between the simulated and generated data.

$$L_{Aperture} = \frac{1}{N_S^{target}} \times \sum_{i=1}^{N_S^{target}} |f_i^{target} - f_i^{generated}|$$

Training the Network – Real Data

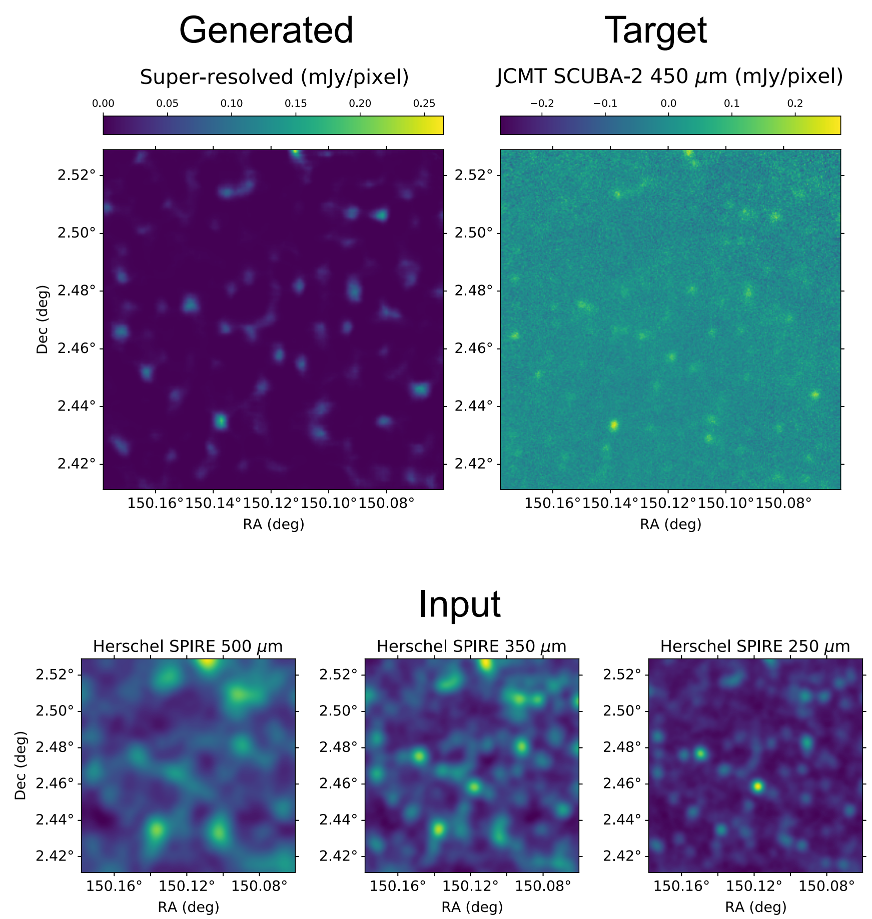
- The real data is from the Herschel SPIRE HerMES and the JCMT SCUBA-2 STUDIES surveys
- Custom loss function combining
  - L1-loss
  - Mean flux difference
  - Median flux difference
  - Aperture flux differences based on sources identified in the real target data
  - Aperture flux differences based on sources identified in the generated data
- The aperture loss identifies source locations in both the real generated data and cross-compare aperture fluxes at these coordinates between the real and generated data.

$$L_{Aperture} = \frac{1}{N_S^{target}} \times \sum_{i=1}^{N_S^{target}} |f_i^{target} - f_i^{generated}| + \frac{1}{N_S^{generated}} \times \sum_{i=1}^{N_S^{generated}} |f_i^{target} - f_i^{generated}|$$

Network output I

- The network is designed to not recreate a realistic noise profile in the image

- Many recreated galaxies can be found in the Herschel SPIRE 250 μm image but their relative brightness is adjusted to reflect the 450 μm wavelength



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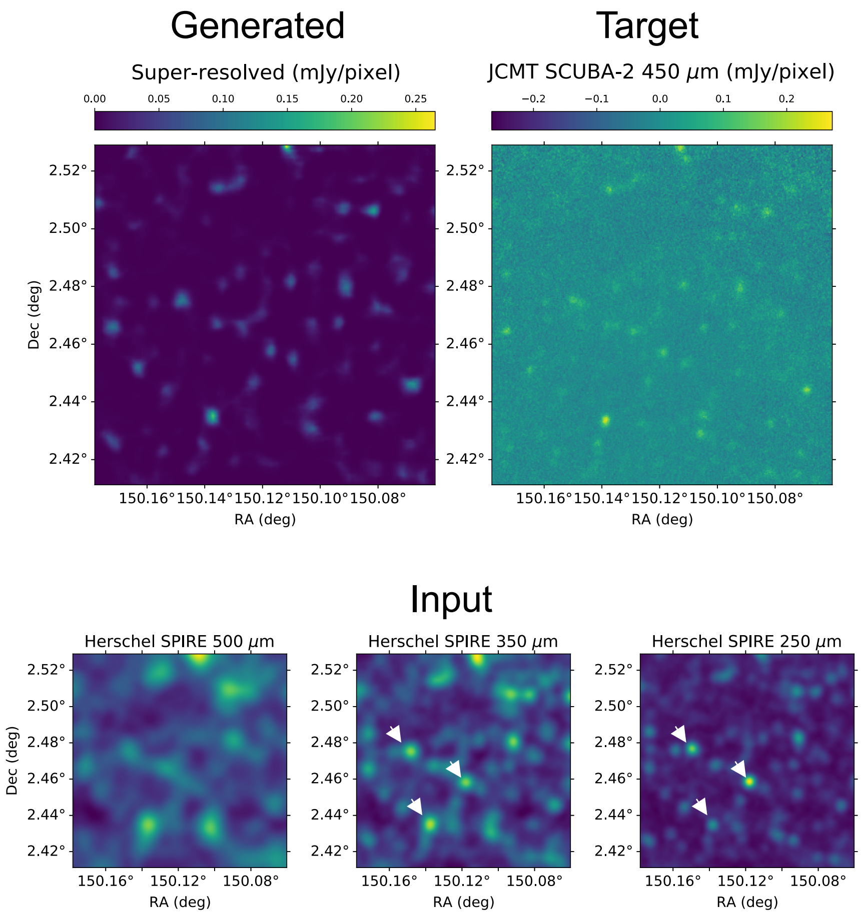

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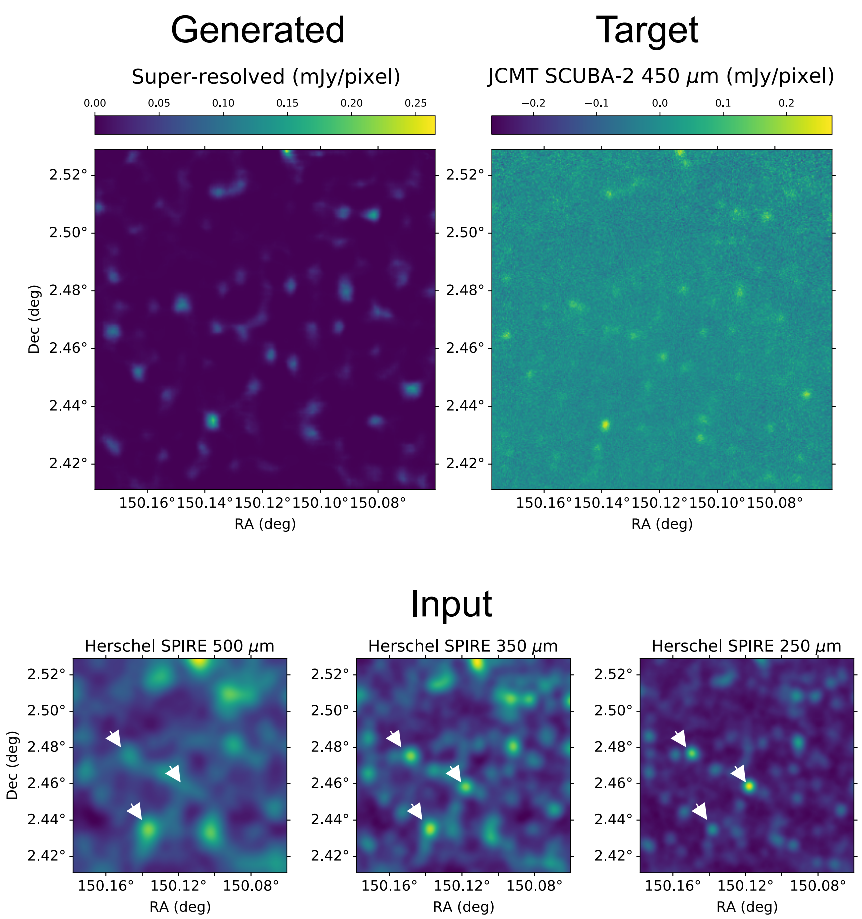

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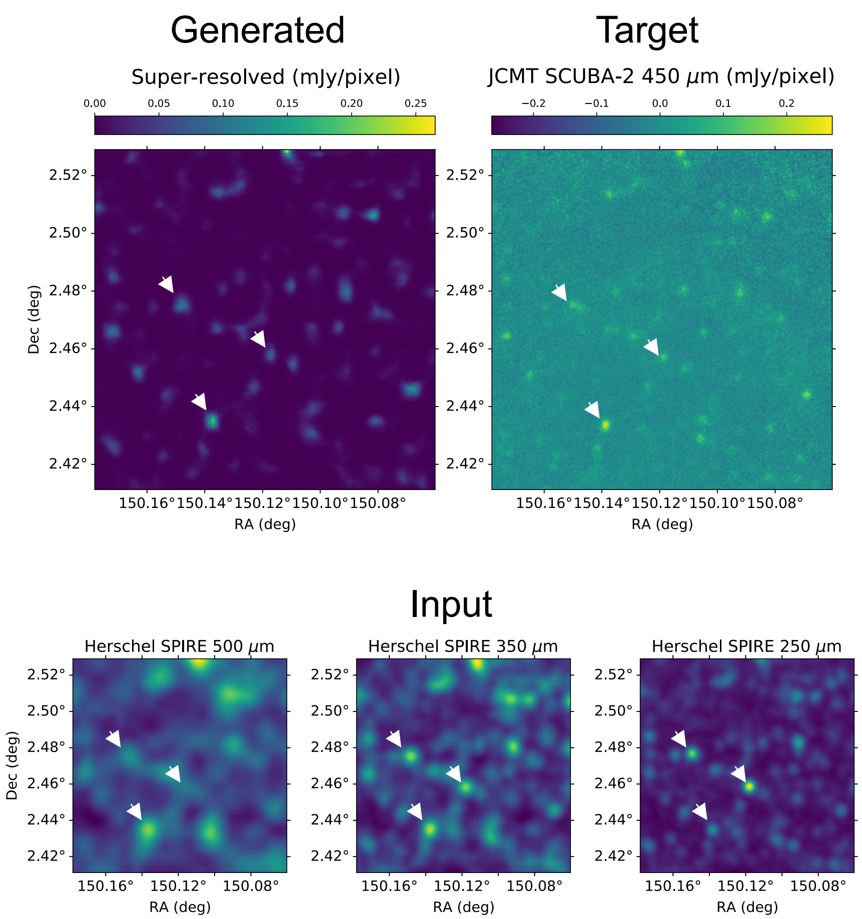
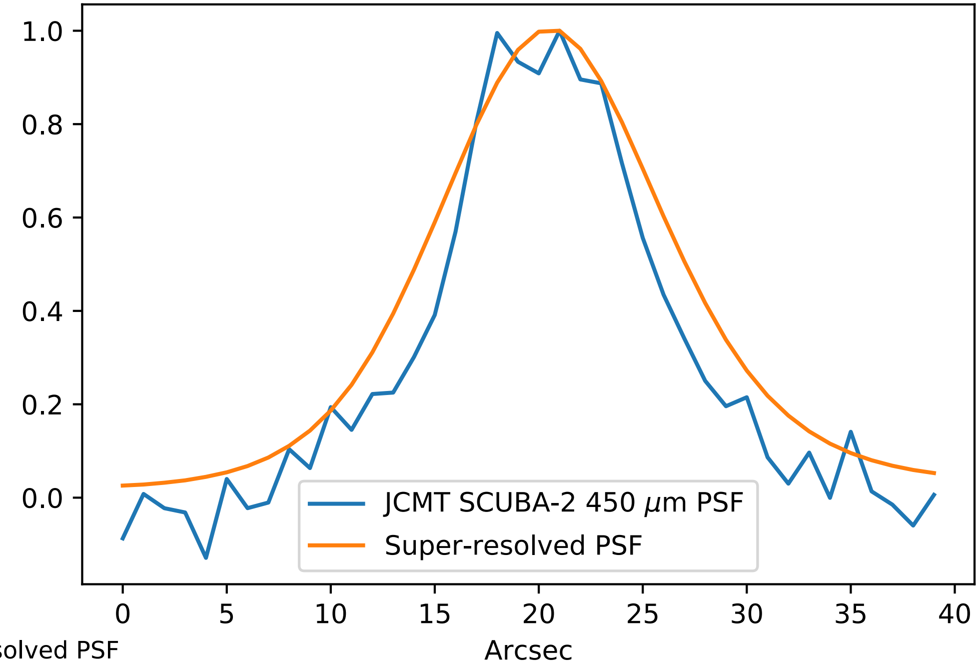
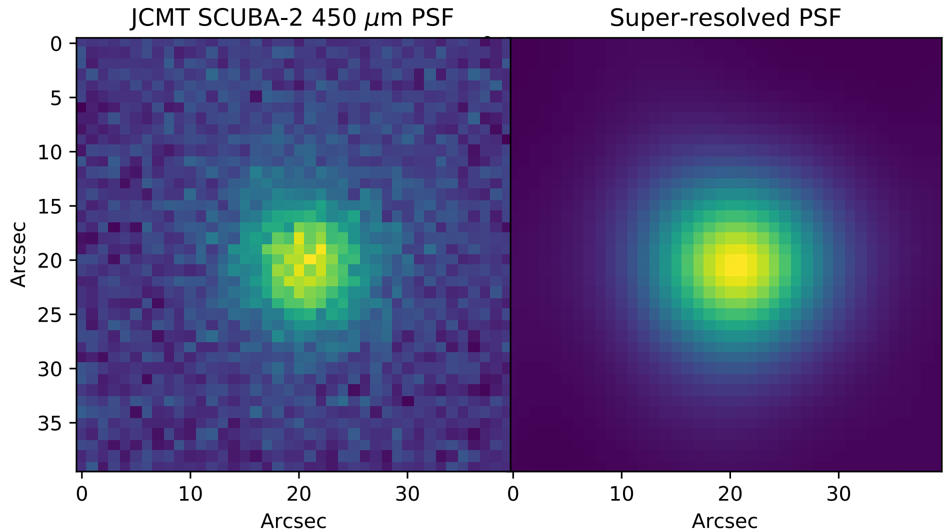


Network output II

- The output achieves a PSF FWHM comparable to that of the JCMT SCUBA-2 450 μm images

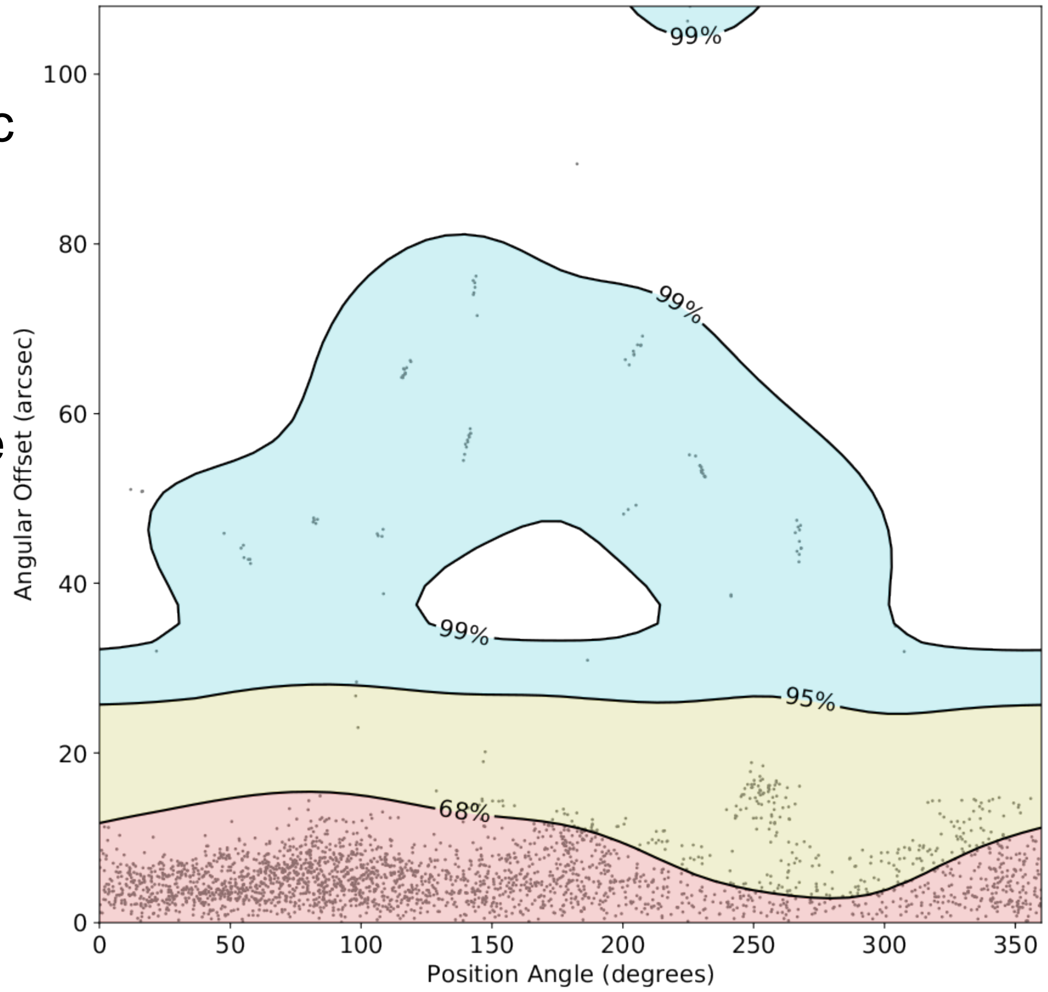
- The generated PSF is more regular due to reduced noise





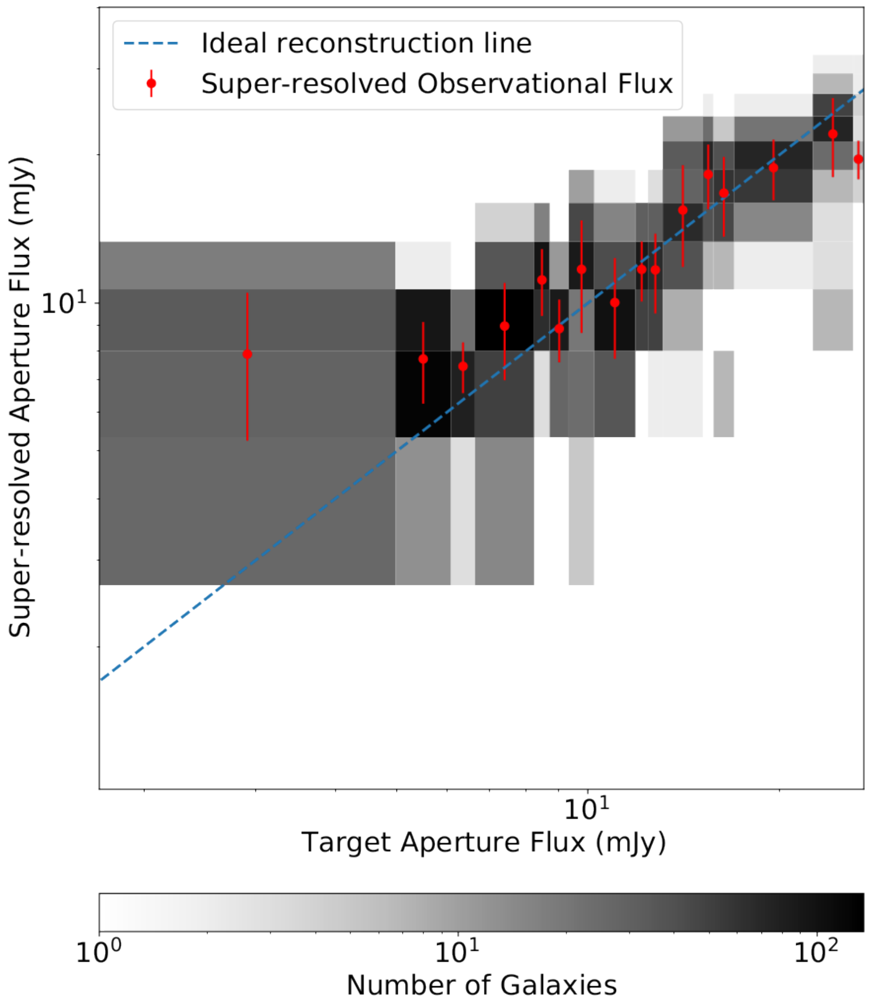
Network output III

- Positional reconstruction is generally inside ~12 arcsec
- A few generated sources are more than 20 arcsec from a real source, these are likely artefacts from the generator



Network output IV

- The network achieves a good flux reconstruction in galaxies brighter than 9 mJy
- The network overestimates the flux of the faintest galaxies



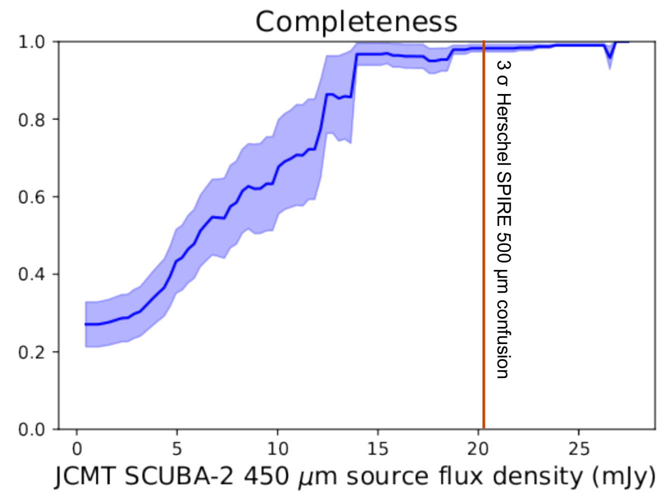
Network output V

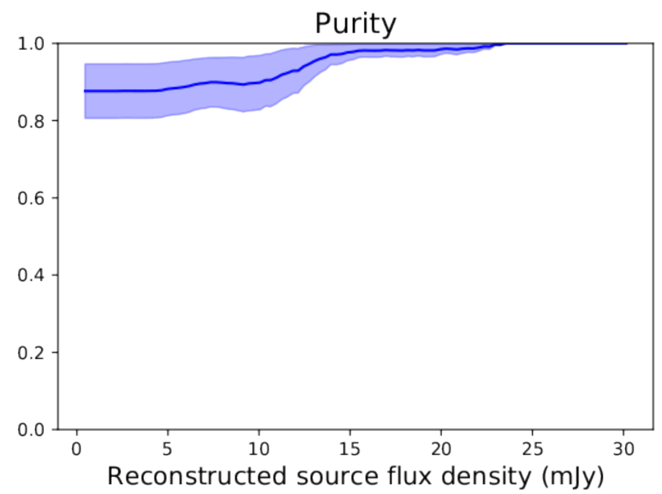
- Completeness (Recall) = $$\frac{TP}{TP + FN}$$

- Purity (Precision) = $$\frac{TP}{TP + FP}$$

- Network Completeness plateaus about 95% for sources brighter than 15 mJy

- High Purity of the Network as the Purity never drops below 87%





Future work

- Super-resolve all the Herschel SPIRE imaging from the COSMOS field and make a source catalogue
- Super-resolve the fields used in the JCMT SCUBA-2 RAGERS project
- Cross-correlate super-resolved sources with existing catalogues

Thank you for listening

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