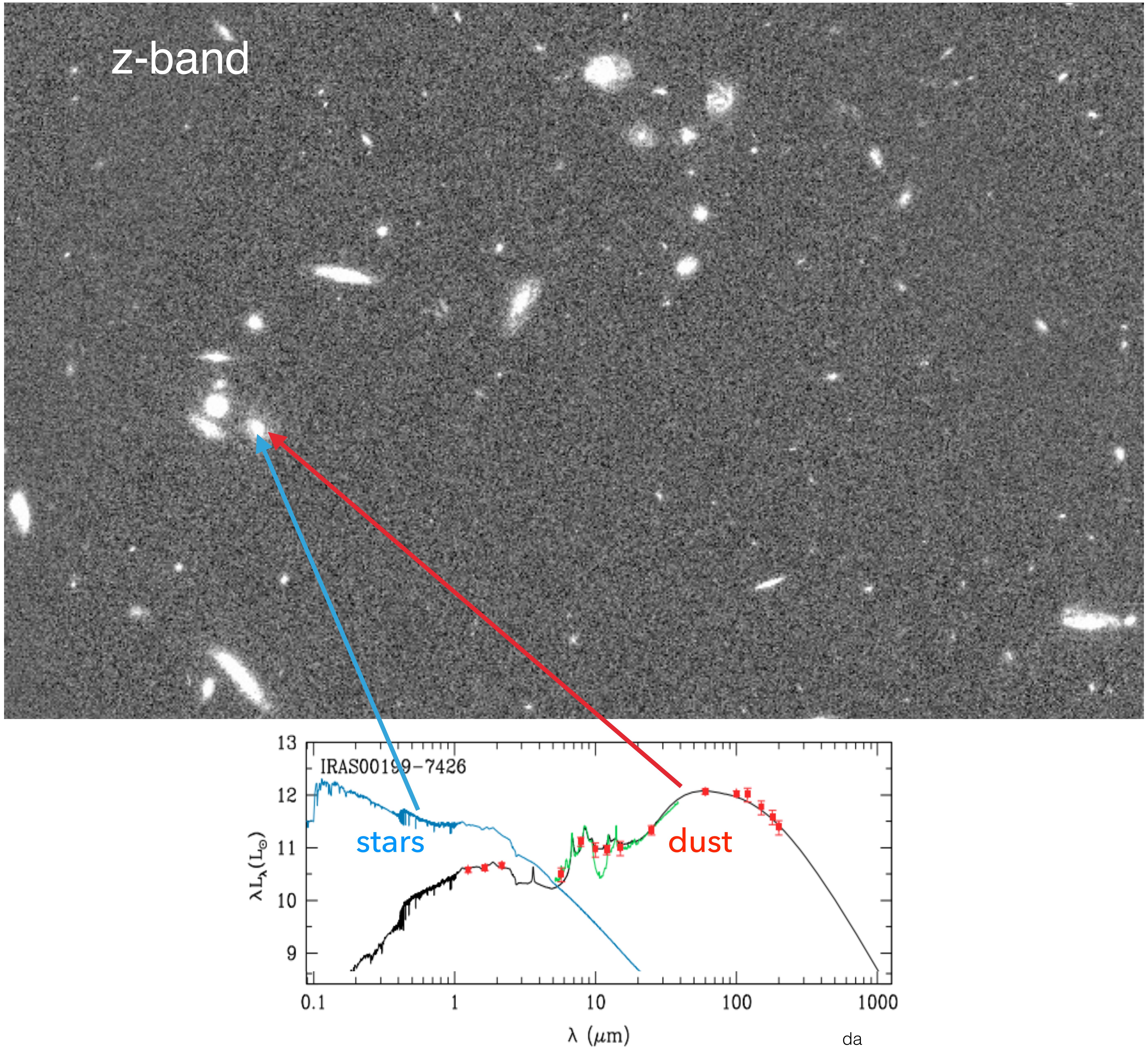
YOU'RE THINKING ABOUT STACKING ALL WRONG

ALSO, HOT DUST AT HIGH-Z

MARCO VIERO (CALTECH), GUOCHAO SUN, DONGWOO CHUNG, LORENZO MONCELSI, & SAM CONDON

DEALING WITH SOURCE CONFUSION

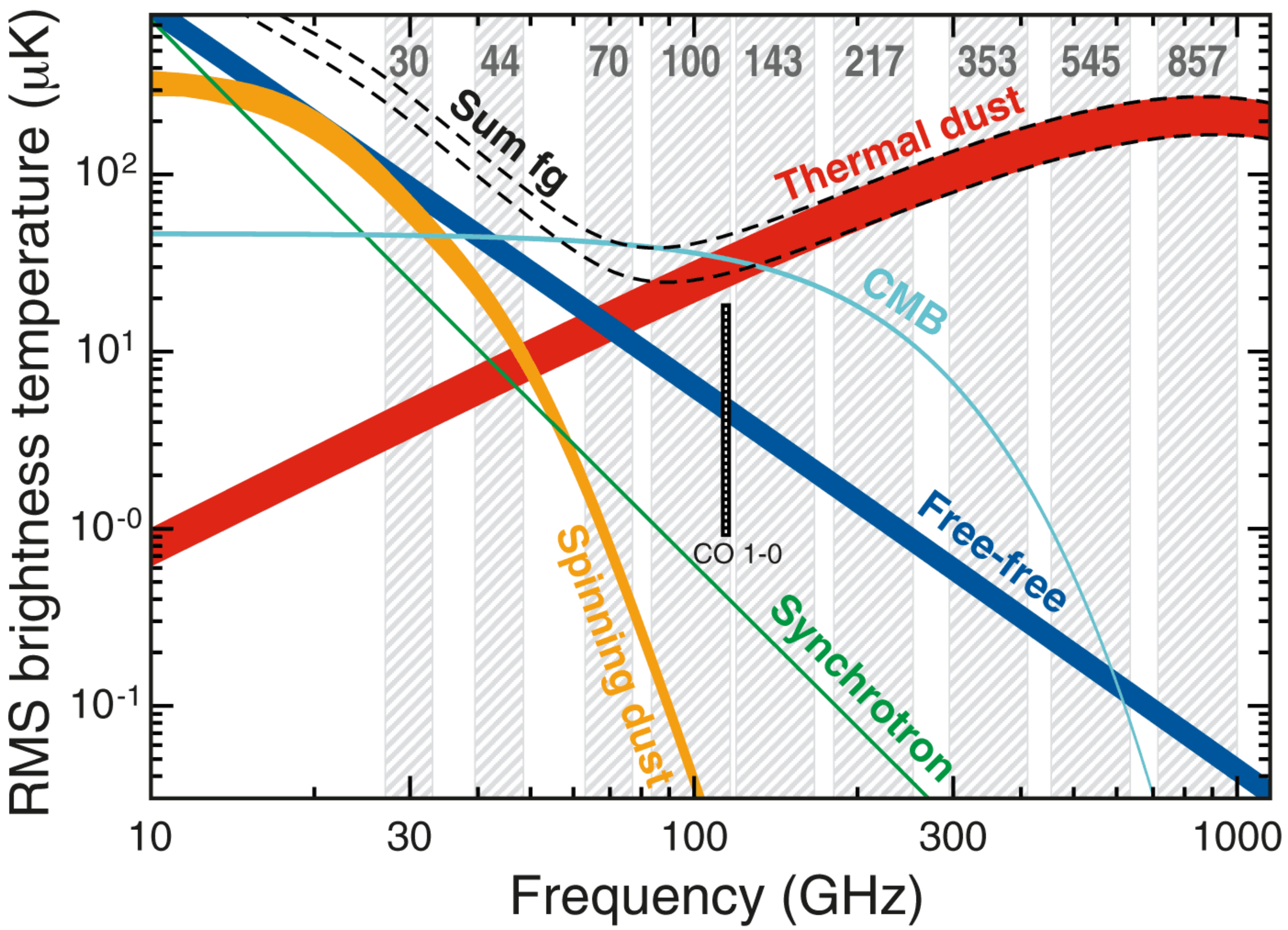
- In e.g. SPIRE 250um, only 15% of the flux is resolved into discrete sources, representing 1% of the objects.
- *How can you possibly tell which source is emitting FIR?*



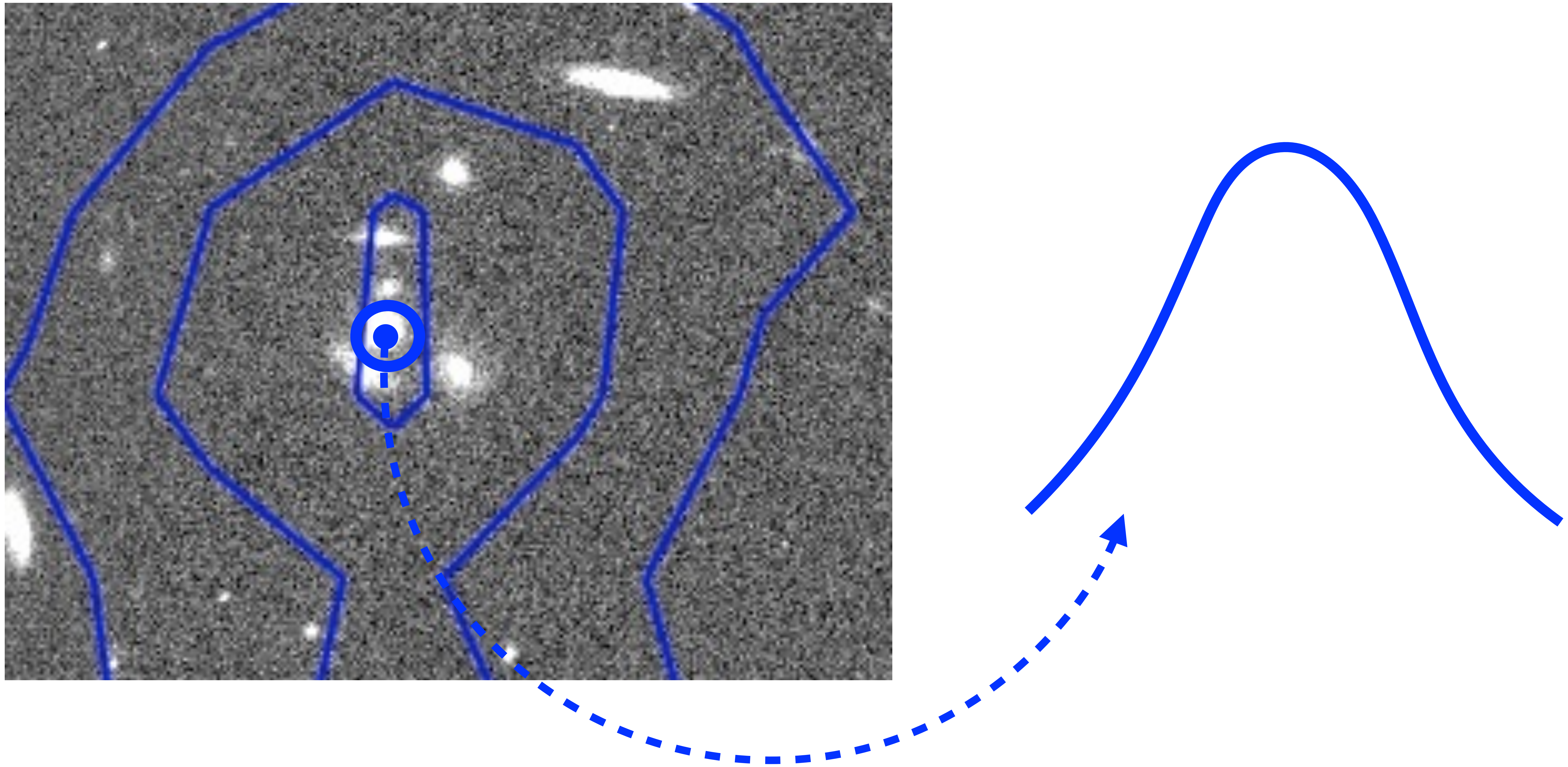
THINK OF STACKING AS:

i) component separation (but in real-space)

ii) using forced-photometry decomposition

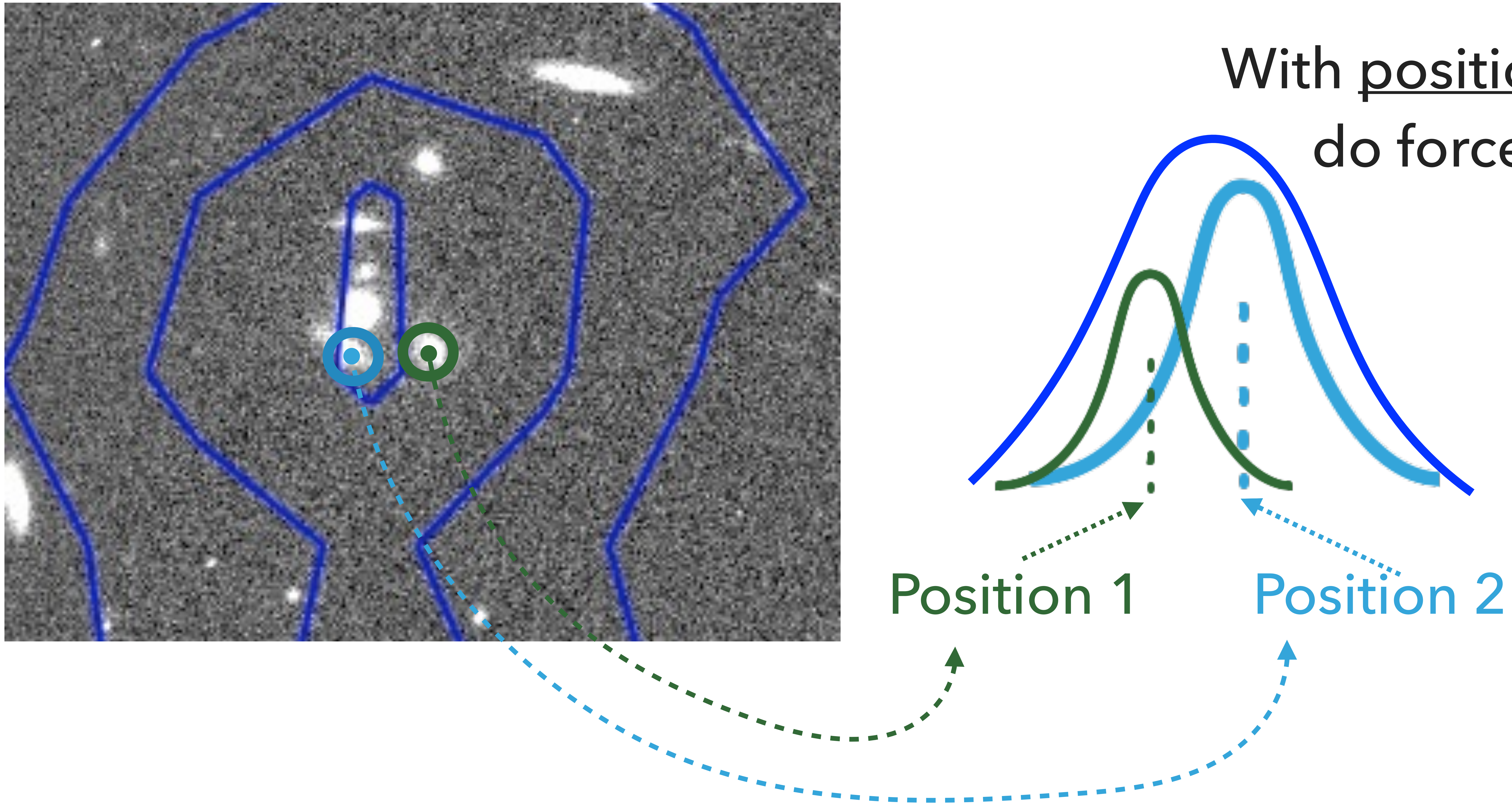


FORCED-PHOTOMETRY DECOMPOSITION

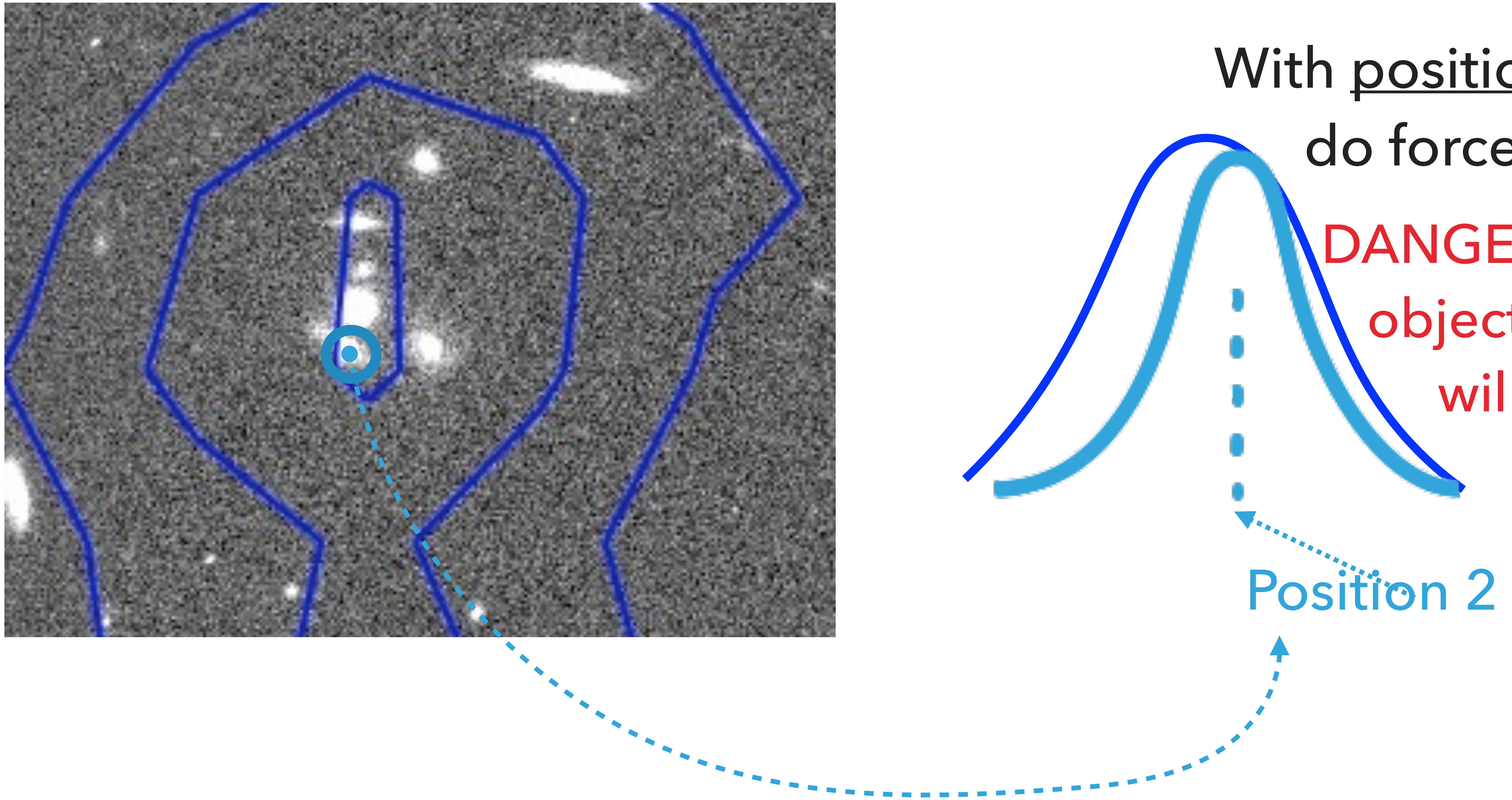


FORCED-PHOTOMETRY DECOMPOSITION

With positional priors can do forced photometry



FORCED-PHOTOMETRY DECOMPOSITION

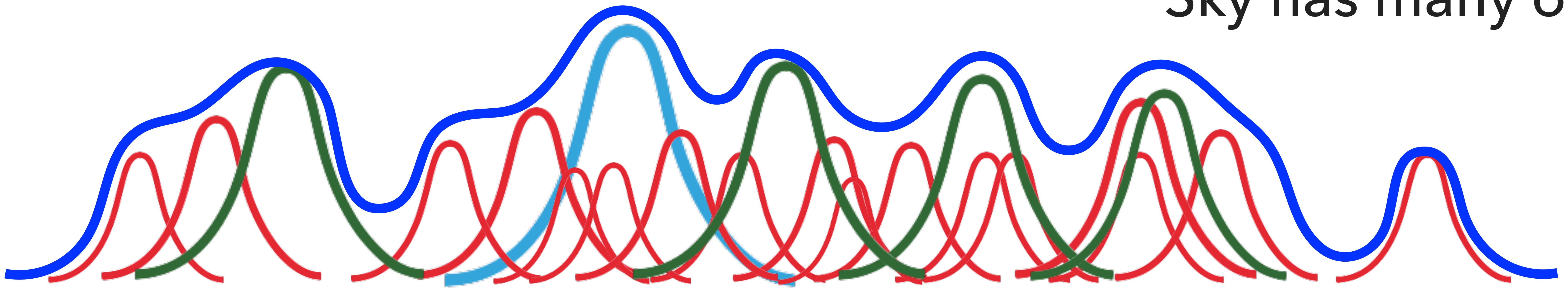


With positional priors can do forced photometry

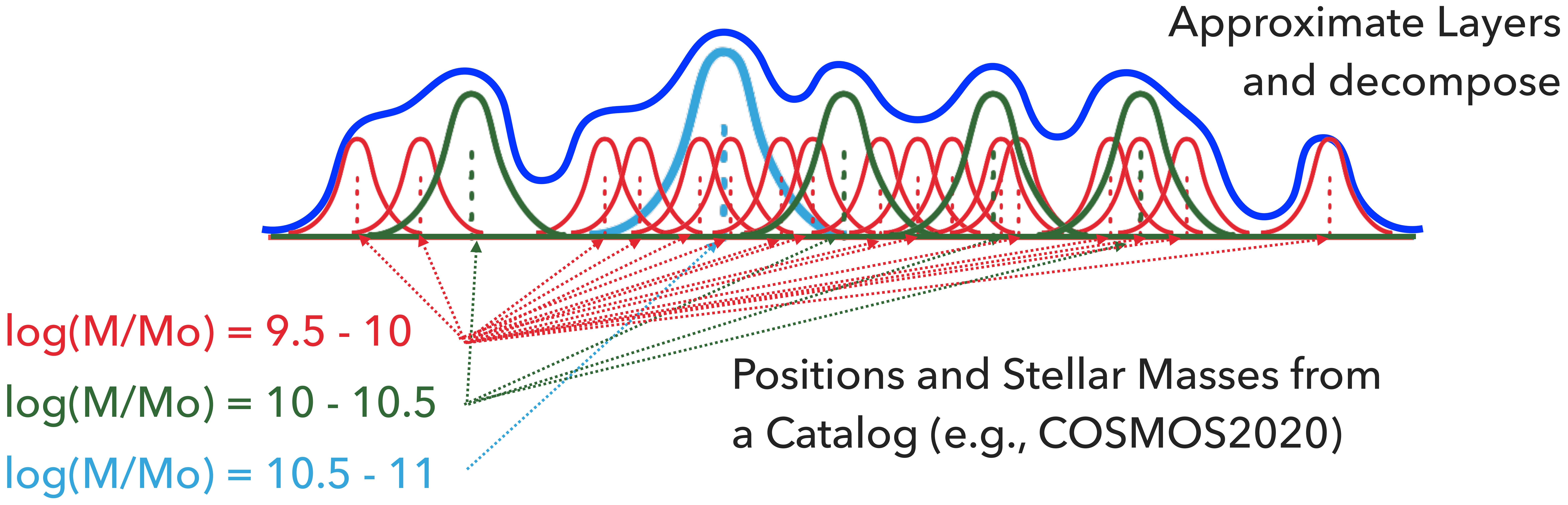
DANGER: Not fitting all objects simultanously will result in a bias.

SIMSTACK: MULTI-OBJECT, FORCED-PHOTOMETRY, COMPONENT SEPARATION

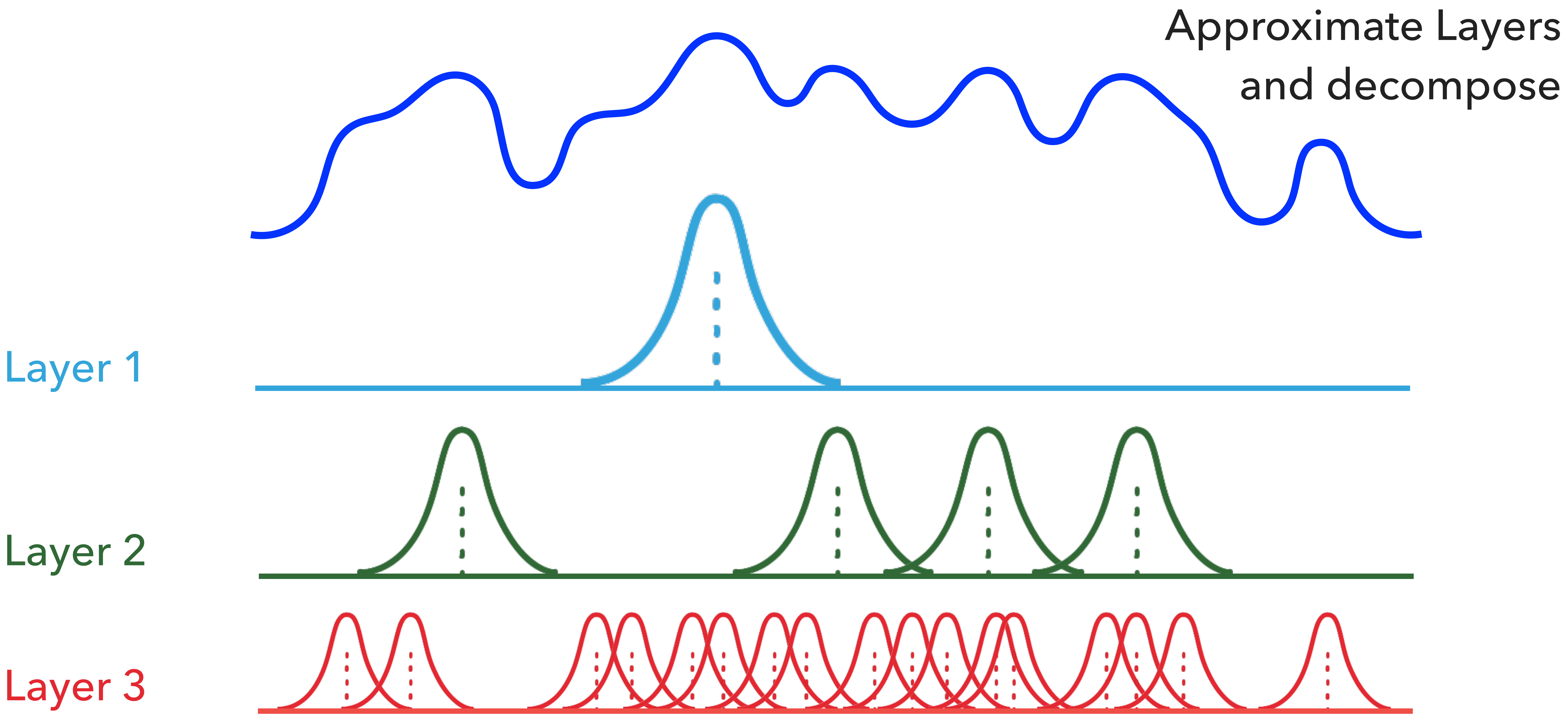
Sky has many objects



SIMSTACK: MULTI-OBJECT, FORCED-PHOTOMETRY, COMPONENT SEPARATION

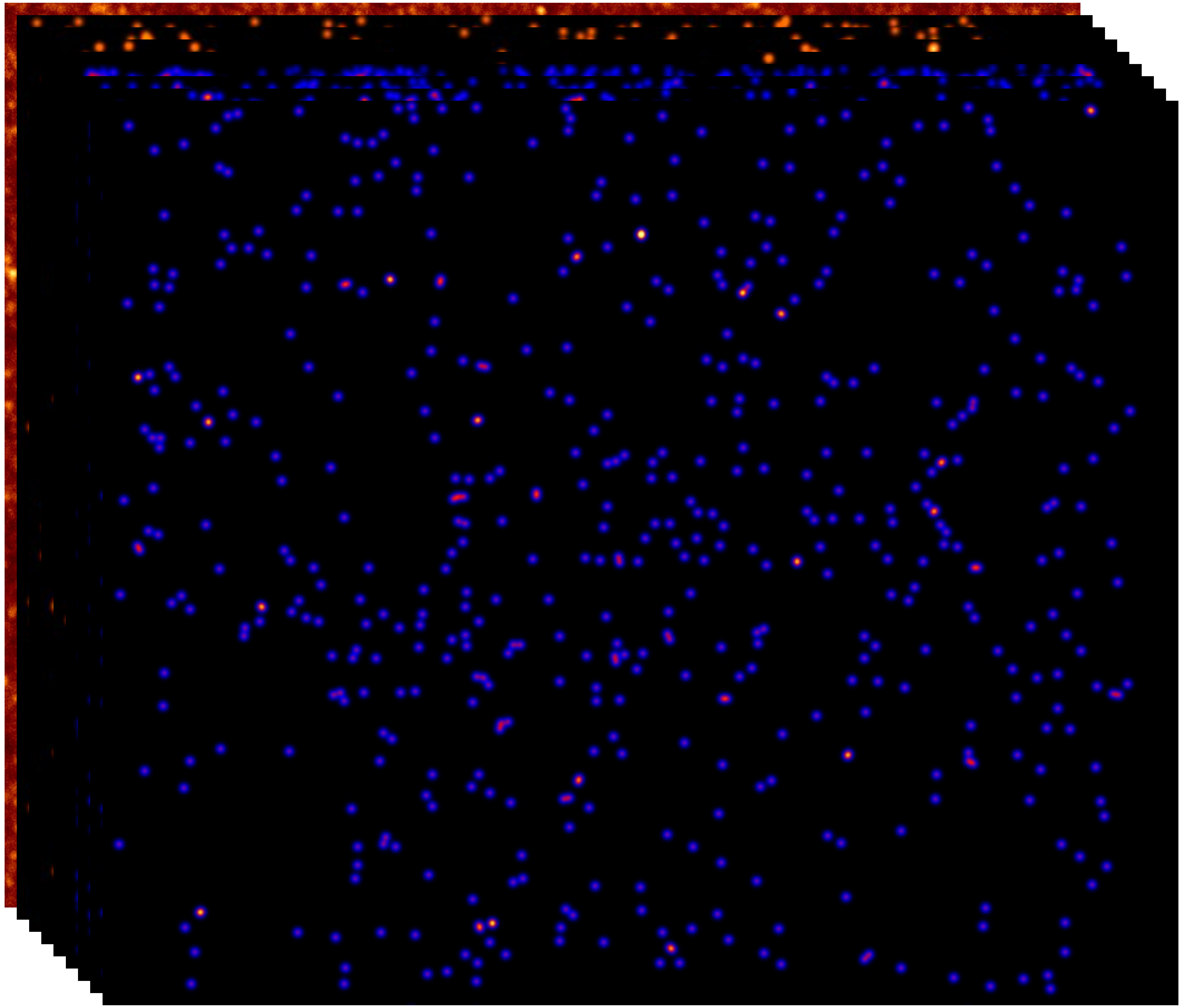


SIMSTACK: MULTI-OBJECT FORCED-PHOTOMETRY



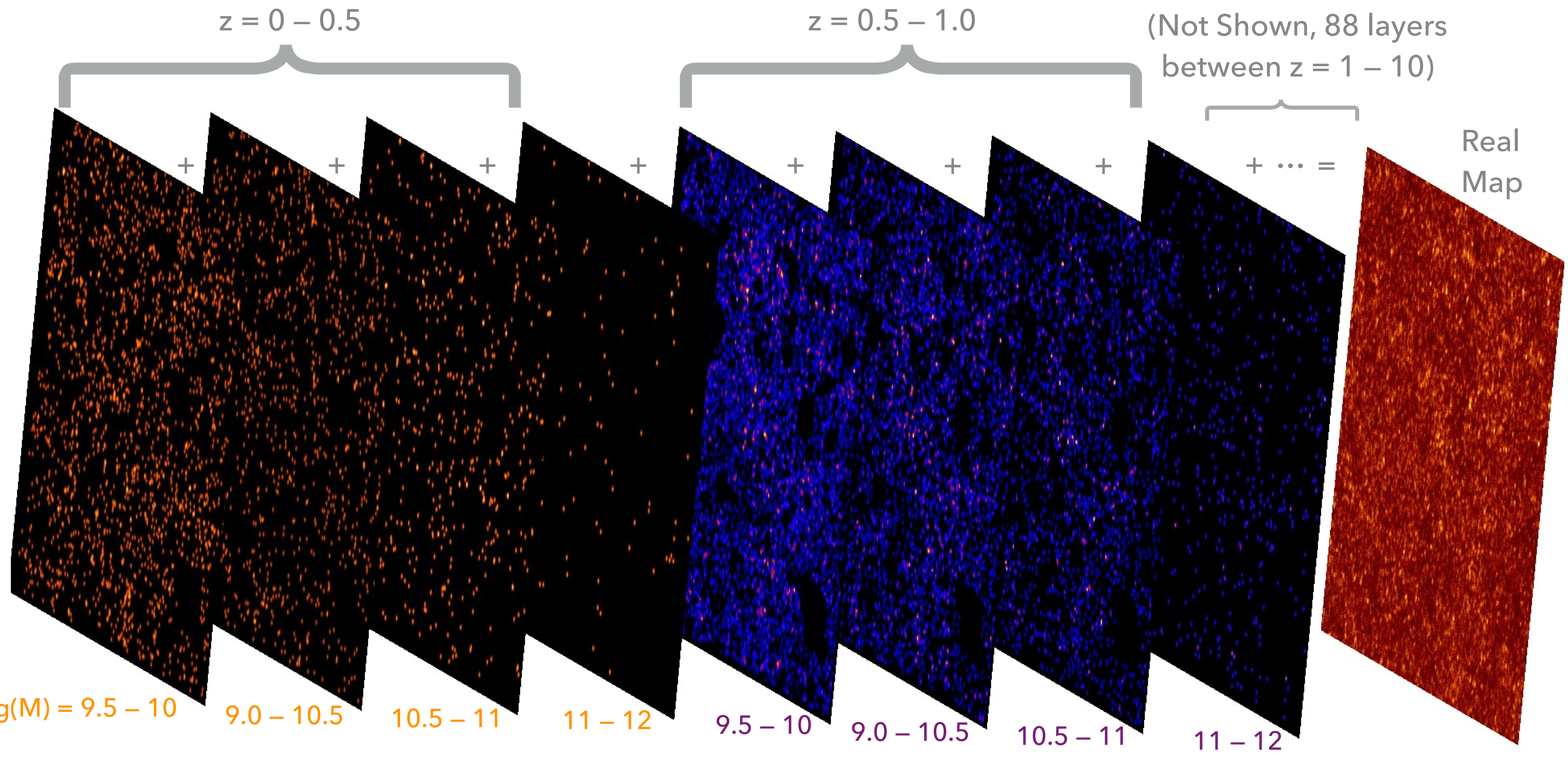
SIMSTACK IN PRACTICE —– CREATE CUBE OF LAYERS

- SPIRE 500 micron
- z=0–0.5, log(M)=9.5-10
- z=0–0.5, log(M)=10-10.5
- z=0–0.5, log(M)=10.5-11
- z=0–0.5, log(M)=11-12
- z=0.5–1.0, log(M)=9.5-10
- z=0.5–1.0, log(M)=10-10.5
- z=0.5–1.0, log(M)=10.5-11
- z=0.5–1.0, log(M)=11-12
- plus 88 *more* layers z=1-10



SIMSTACK IN PRACTICE — STACK ENTIRE CUBE SIMULTANEOUSLY

96
Total Layers
i.e.,
4 mass
x
12 redshift
x
2 (SF/QT)

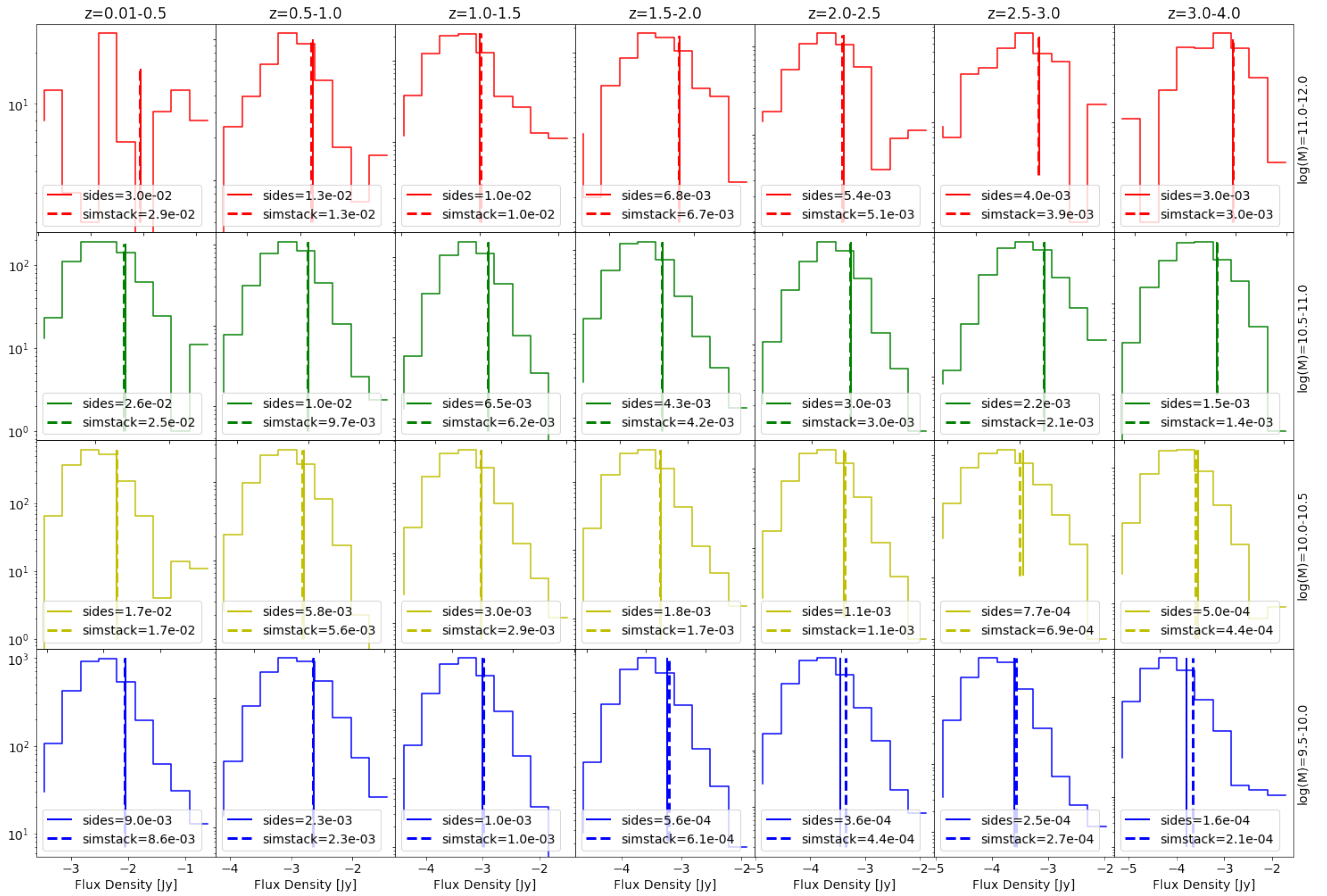


Best fit returns the average flux in each of the 96 layers.

SIMSTACK + SIDES

- Histograms of fluxes of input catalog objects:
  - Solid lines the catalog object *mean* fluxes.
  - Dashed lines the SIMSTACK fluxes.

OMG it works!



Made using pySIDES: Bethermin et al. 2017 – [arXiv:1703.08795]

HOT DUST AT HIGH REDSHIFT

- COSMOS – 1.6 deg2
- Catalog
  (Weaver+2022 arXiv:2110.13923)
  - 111,227 galaxies
  - FARMER/LePhare photometry/photo-z's
  - redshifts 0 - 10
  - Split into star forming/quiescent (NUVrj)
- Maps
  - Spitzer/MIPS (24μm)
  - Herschel/PACS (100 & 160μm)
  - Herschel/SPIRE (250, 350, 500μm)
  - S2CLS (850μm)

PAPER

THE EARLY UNIVERSE WAS DUST-RICH AND EXTREMELY HOT
VIERO, SUN, CHUNG, MONCELSI & CONDON
ACCEPTED BY MNRAS LETTERS TODAY!
ARXIV: 2203.14312

CODE

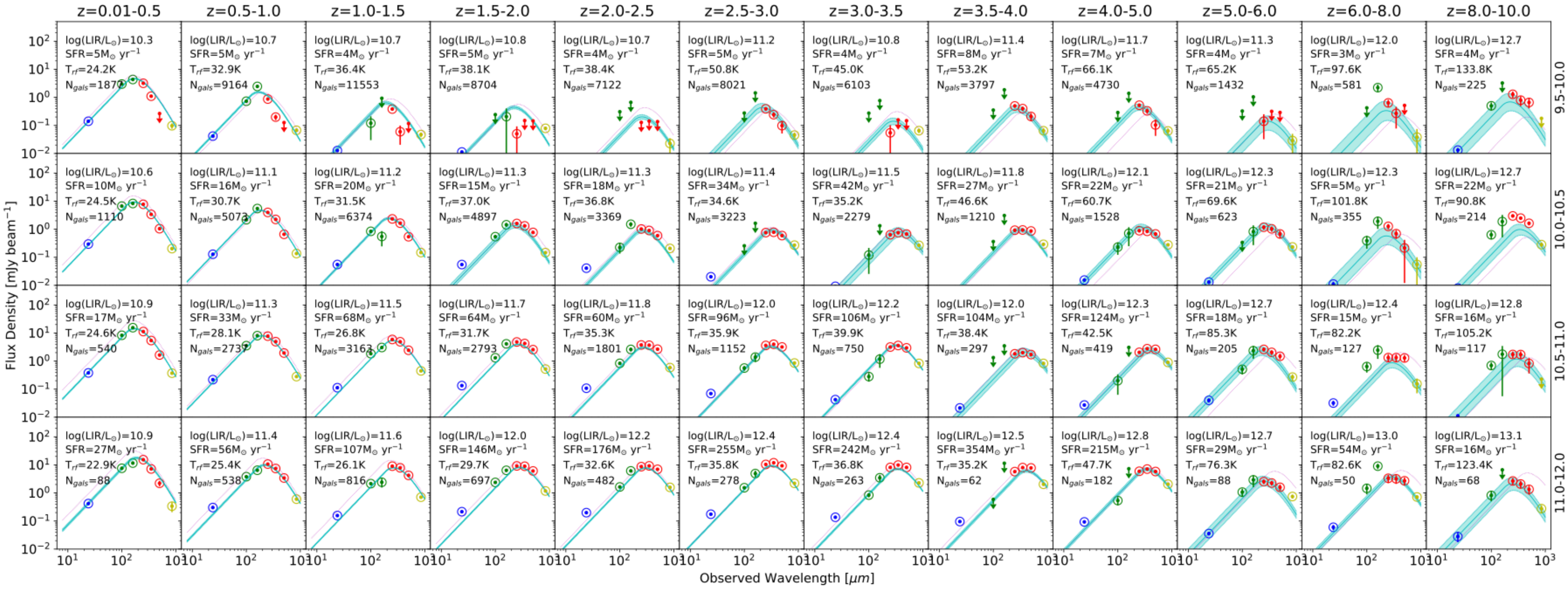
ALL PYTHON CODE, DATA, SIMULATIONS, AND INSTRUCTIONS TO REPRODUCE THE RESULT CAN BE FOUND AT:

HTTPS://GITHUB.COM/MARCOVIERO/SIMSTACK3/TREE/MAIN/VIERO2022

AND:

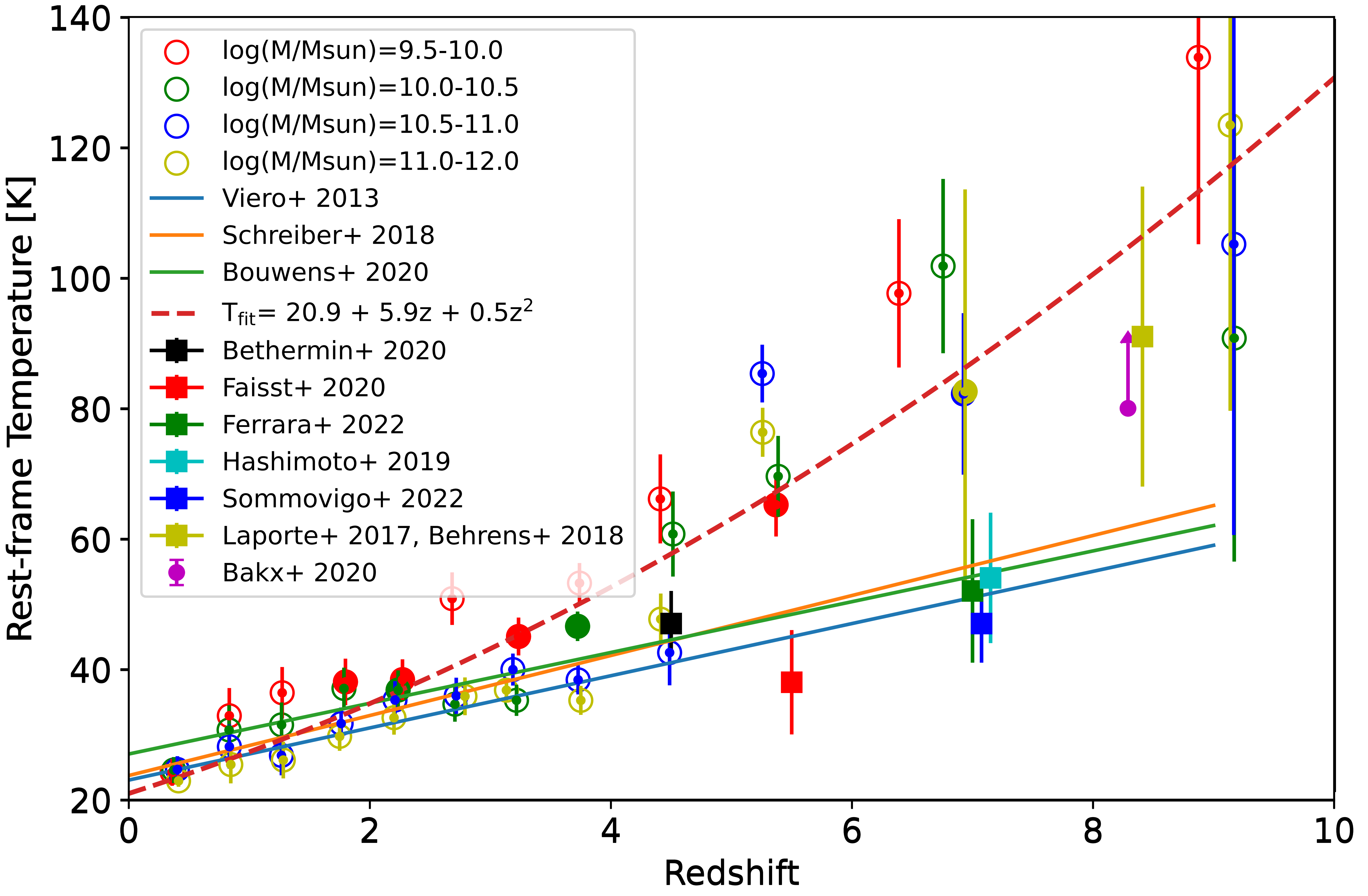
HTTPS://ZENODO.ORG/RECORD/6792395

SIMULTANEOUS STACK TO Z = 10



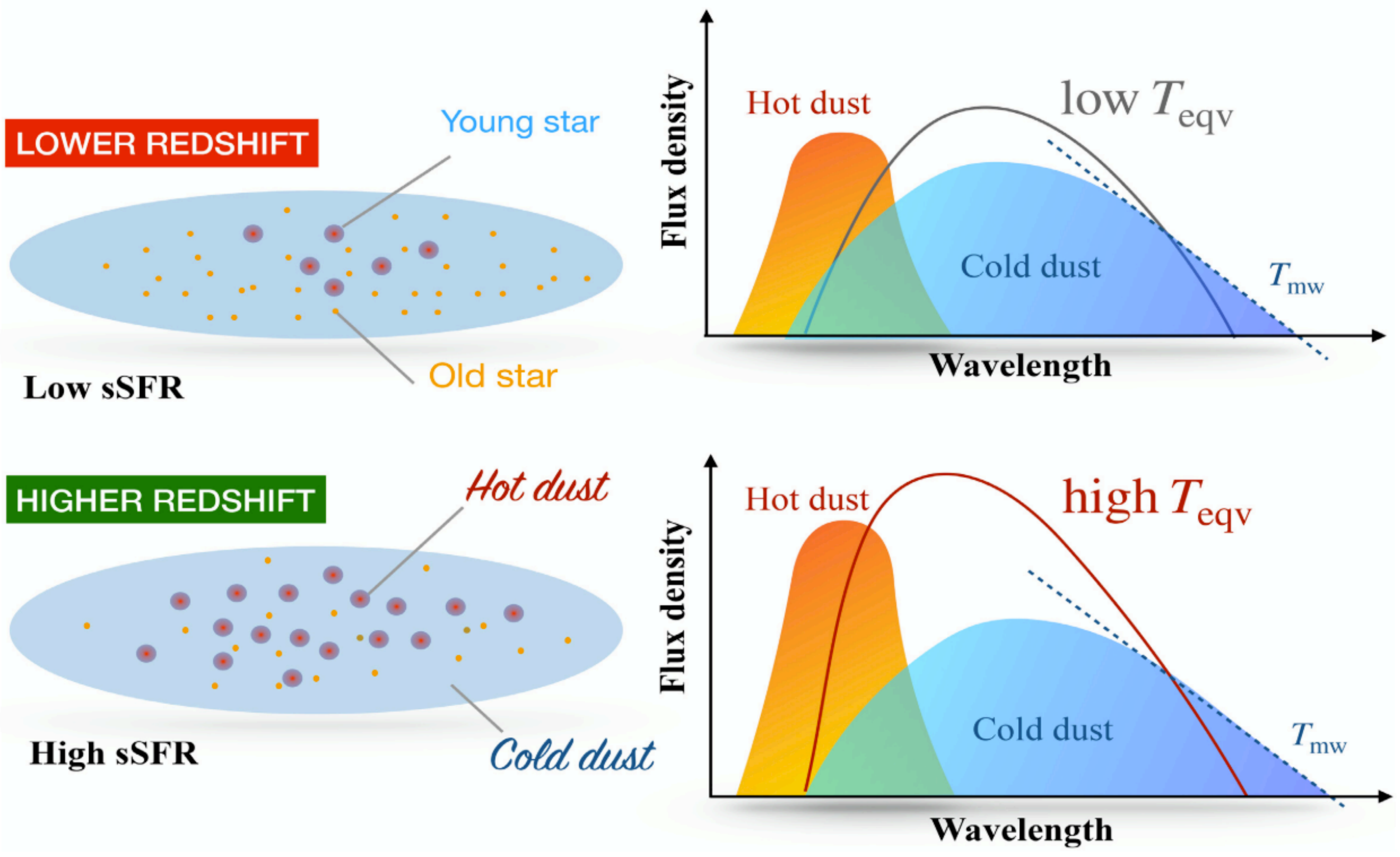
EXCESS HEATING AT Z > 4

- ALPINE/ALMA objects mostly line up with existing trends (T=50 at z~7).
- Two objects much hotter (T=80K at z=8.3).
- Full sample agrees at z < 4, and rises rapidly at higher z.
- CMB is subdominant.



HOT DUST? REALLY??

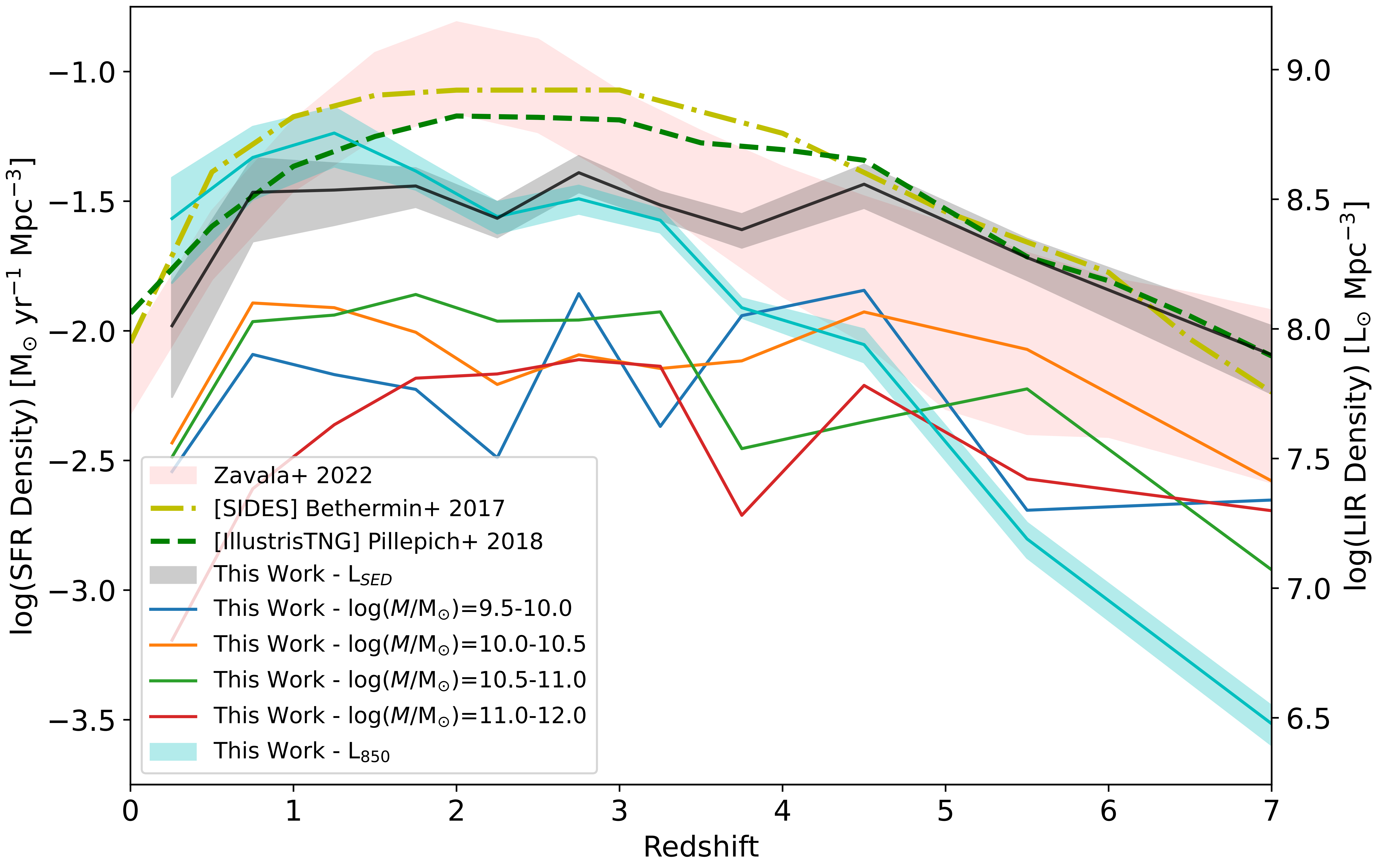
- Simulations show compact, hot dust regions (e.g., Behrens+ 2018)
- Evolving sSFR (Liang+ 2019)
- Solves tension in low IRX/beta values at high-z (Capak 2015)
- Solves unrealistic dust masses at high-z (Leśniewska & Michałowski 2019)



Liang+ 2019 arXiv:1902.10727

SFRD

- Grey converted from the LIR density
- Blue converted from 850um rest-frame
- Good agreement with models. Missing faint objects at z=1-5?



JUPYTER NOTEBOOKS TO REPRODUCE THE MEASUREMENT ARE ON GITHUB

- Instructions and code at https://github.com/marcoviero/simstack3
  - Install, Download Data, Setup configuration file, and GO. Easy!

vim

```
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
; Example parameter file for simstack code
;
; Contact: Marco Viero (marco.viero@caltech.edu)
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
[general]
binning = {"stack_all_z_at_once": 1, "add_background": 1, "crop_circles": 1}
error_estimator = {"bootstrap": {"initial_bootstrap": 1, "iterations": 150}, "write_simmaps": 0, "randomize": 0}
cosmology = Planck18

[io]
output_folder = PICKLESPATH simstack stacked_flux_densities
shortname = cosmos2020_farmer

drop_maps = 1
drop_catalogs = 0

[catalog]
path = CATSPATH cosmos
file = cosmos2020_FARMER.csv
;Catalog specific names for redshift, stellar mass, RA, and DEC
astrometry = {"ra":"ALPHA_J2000", "dec":"DELTA_J2000"}
classification = {"split_type":"nuvrj", "redshift":{"id":"lp_zBEST", "bins":"[0.01, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 5.0, 6.0, 8.0, 10]"}, "stellar_mass":{"id":"lp_mass_med", "bins":"[9.5, 10.0, 10.5, 11.0, 12.0]"}, "split_params":{"id":"sfg", "bins":{"UV-R":"res
tNUV-R", "R-J":"restR-J"}}  }

[maps]
; If noisemap is the second extension of the fits file, then noise and map are the same.
; Maps need to be in Jy/beam.  If they are not, add solid angle of beam to "area" to convert them.
mips_24    = {"wavelength": 24.0, "beam":{"fwhm":5.51,"area":1.328e-09}, "color_correction":1.24, "path_map": "MAPSPATH mips_24_GO3_sci_10.cutout.fits", "path_noise":"MAPSPATH mips_24_GO3_unc_10.cutout.fits"}
pacs_green = {"wavelength":100.0, "beam":{"fwhm":7.49,"area":2.033e-09}, "color_correction":1.0, "path_map": "MAPSPATH COSMOS_PACS100_20160805_img_avg.fits", "path_noise":"MAPSPATH COSMOS_PACS100_20160805_img_avg_noise.fits"}
pacs_red   = {"wavelength":160.0, "beam":{"fwhm":11.33,"area":4.658e-09}, "color_correction":1.0, "path_map": "MAPSPATH COSMOS_PACS160_20160728_img_avg.fits", "path_noise":"MAPSPATH COSMOS_PACS160_20160728_img_avg_noise.fits"}
spire_PSW  = {"wavelength":250.0, "beam":{"fwhm":17.62,"area":1.0}, "color_correction":1.018, "path_map": "MAPSPATH cosmos-uvista_PSW.signal.cutout.fits", "path_noise":"MAPSPATH cosmos-uvista_PSW.noise.cutout.fits"}
spire_PMW  = {"wavelength":350.0, "beam":{"fwhm":24.42,"area":1.0},  "color_correction":0.9914, "path_map": "MAPSPATH cosmos-uvista_PMW.signal.cutout.fits", "path_noise":"MAPSPATH cosmos-uvista_PMW.noise.cutout.fits"}
spire_PLW  = {"wavelength":500.0, "beam":{"fwhm":35.69,"area":1.0}, "color_correction":0.95615, "path_map": "MAPSPATH cosmos-uvista_PLW.signal.cutout.fits", "path_noise":"MAPSPATH cosmos-uvista_PLW.noise.cutout.fits"}
scuba_850  = {"wavelength": 850.0, "beam":{"fwhm":12.1,"area":1.0}, "color_correction":1e-3, "path_map": "MAPSPATH S2CLS_COSMOS_NMF_DR1_new_header.cutout.signal.fits", "path_noise":"MAPSPATH S2CLS_COSMOS_NMF_DR1_new_header.cutout.noise.fits"}
~
```

CMB-S4

HERSCHEL MAPS >100 DEG2
MM-MAPS SENSITIVE TO HIGH-Z
OPTICAL COUNTERPARTS RUBIN/ROMAN
SOPHISTICATED SYNCHROTRON FOREGROUND MODELING?
BIN BY TRACERS OF LENSING FOREGROUNDS?
EXTEND SIMSTACK FROM BINNING TO PARAMATERIZATION