YOU'RE THINKING ABOUT STACKING ALL WRONG ALSO. HOT DUST AT HGH-Z

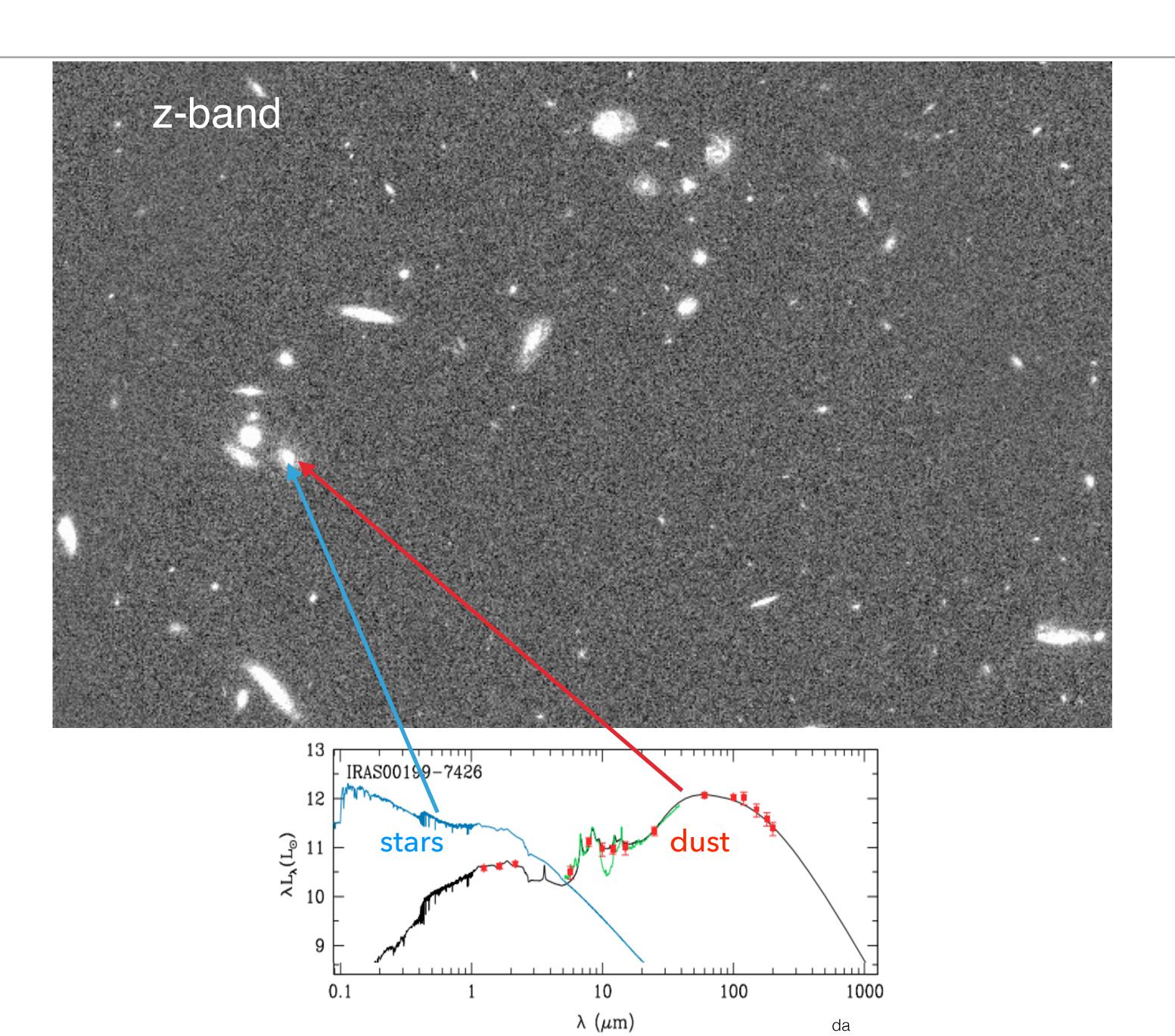
MARCO VIERO (CALTECH), GUOCHAO SUN, DONGWOO CHUNG, LORENZO MONCELSI, & SAM CONDON



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?

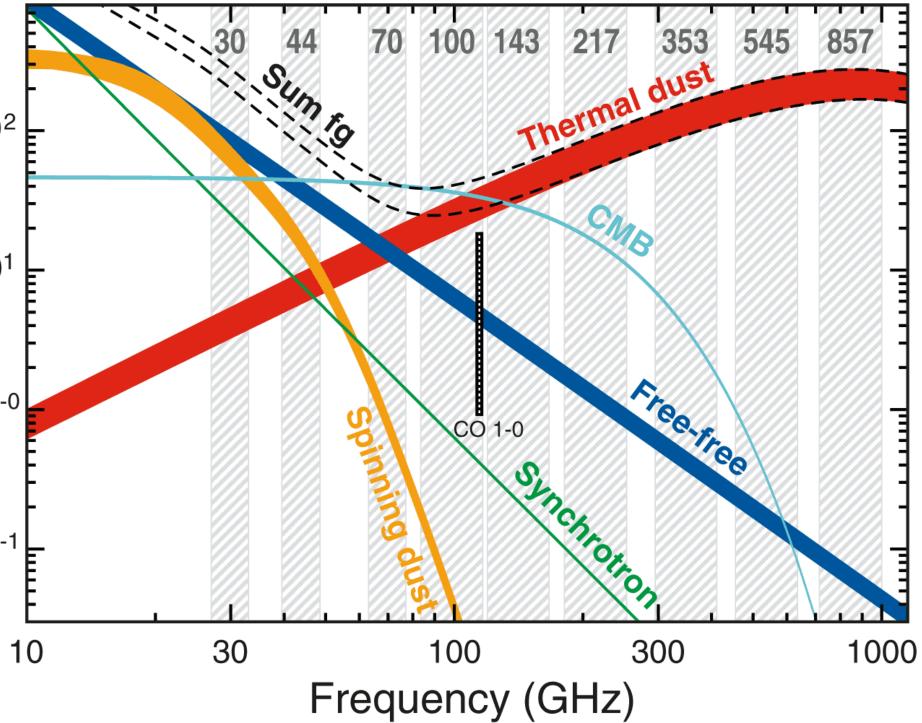


THINK OF STACKING AS:

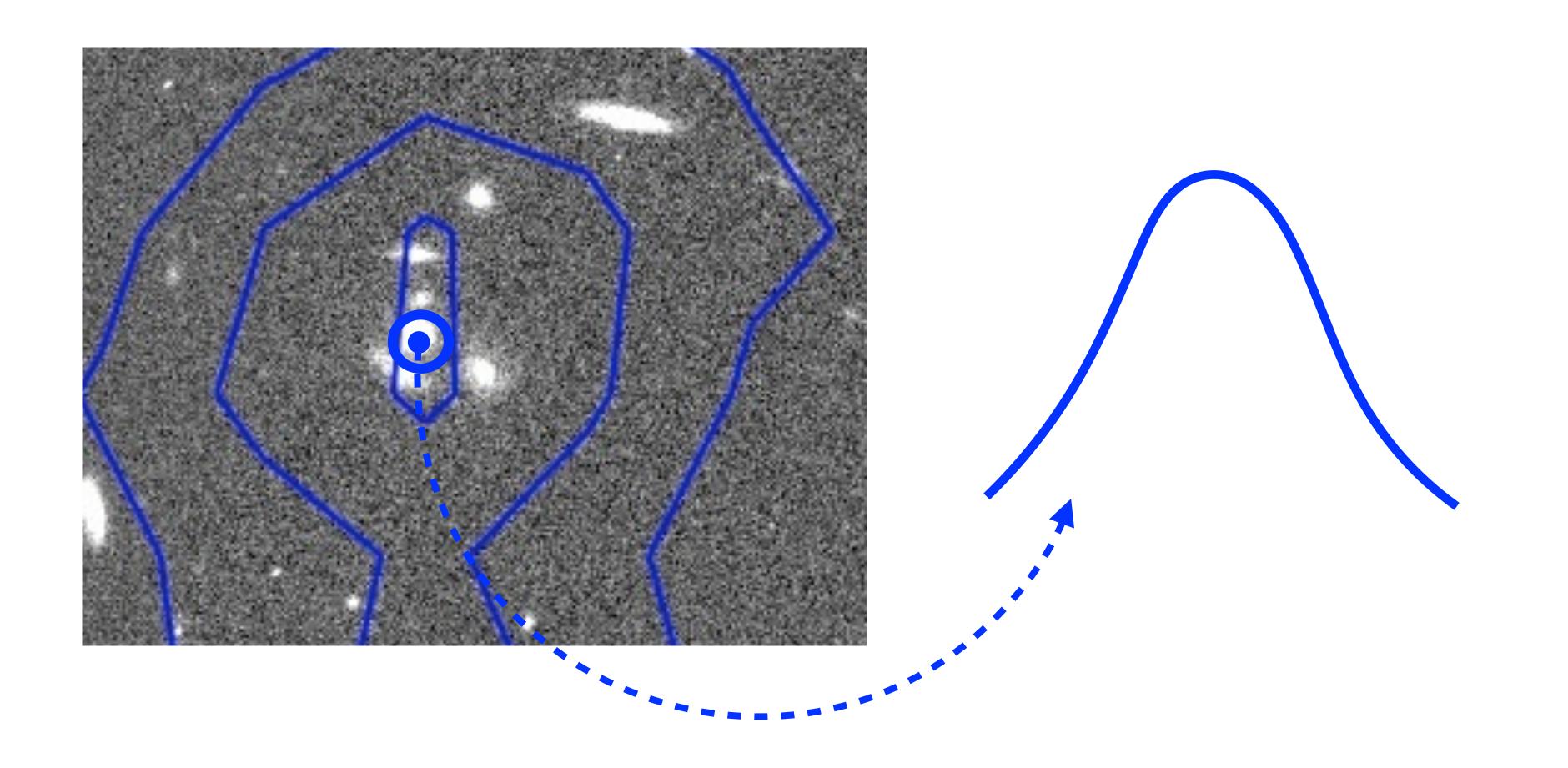
i) component separation(but in real-space)

ii) using forced-photometry decomposition

RMS brightness temperature (µK) 10-01 10-01

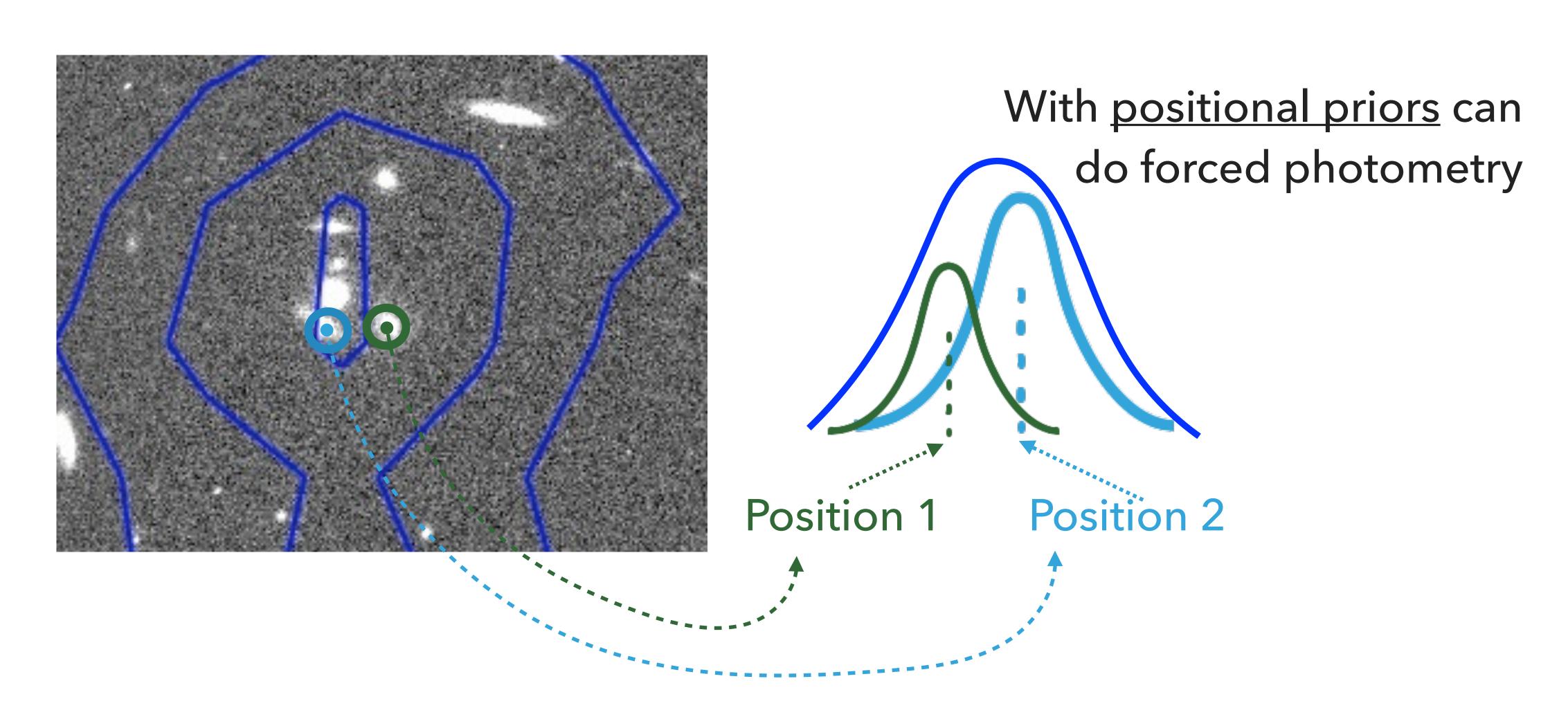


FORCED-PHOTOMETRY DECOMPOSITION



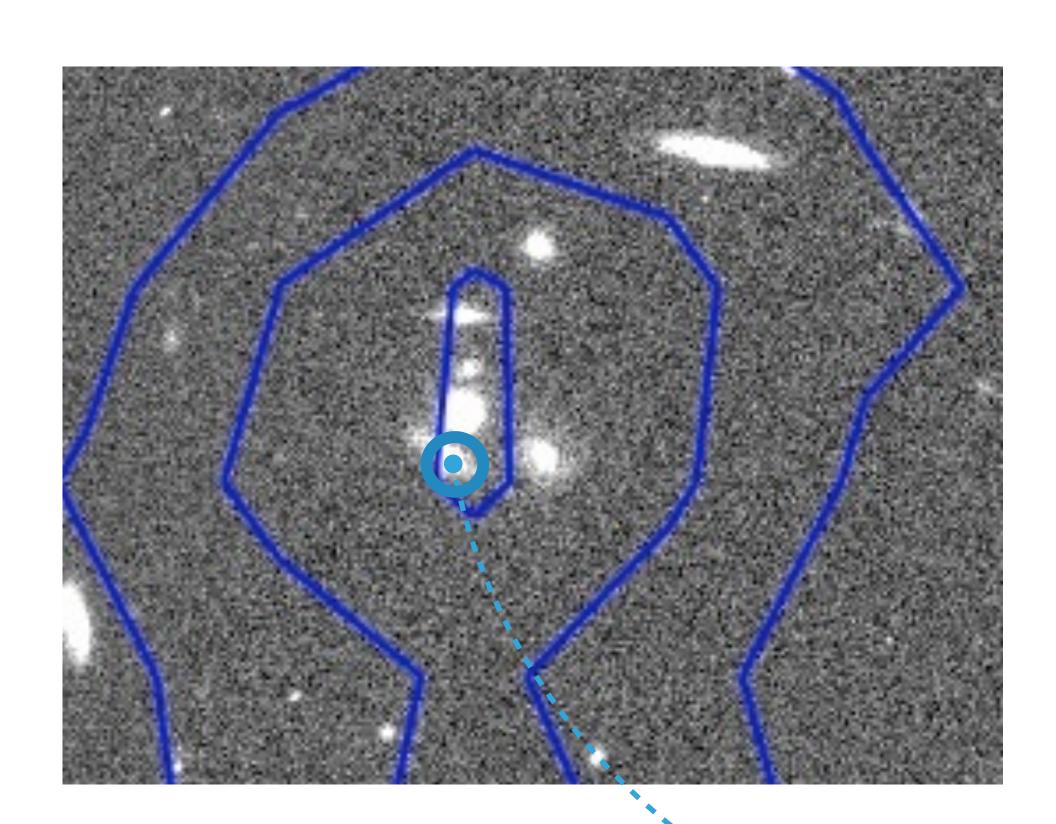


FORCED-PHOTOMETRY DECOMPOSITION





FORCED-PHOTOMETRY DECOMPOSITION



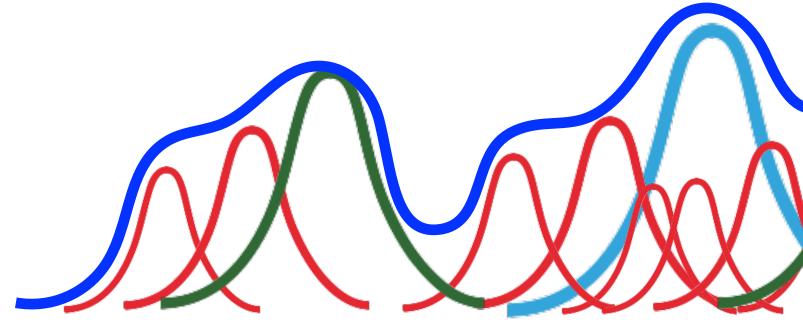


With positional priors can do forced photometry DANGER: Not fitting all objects simultanously will result in a bias.

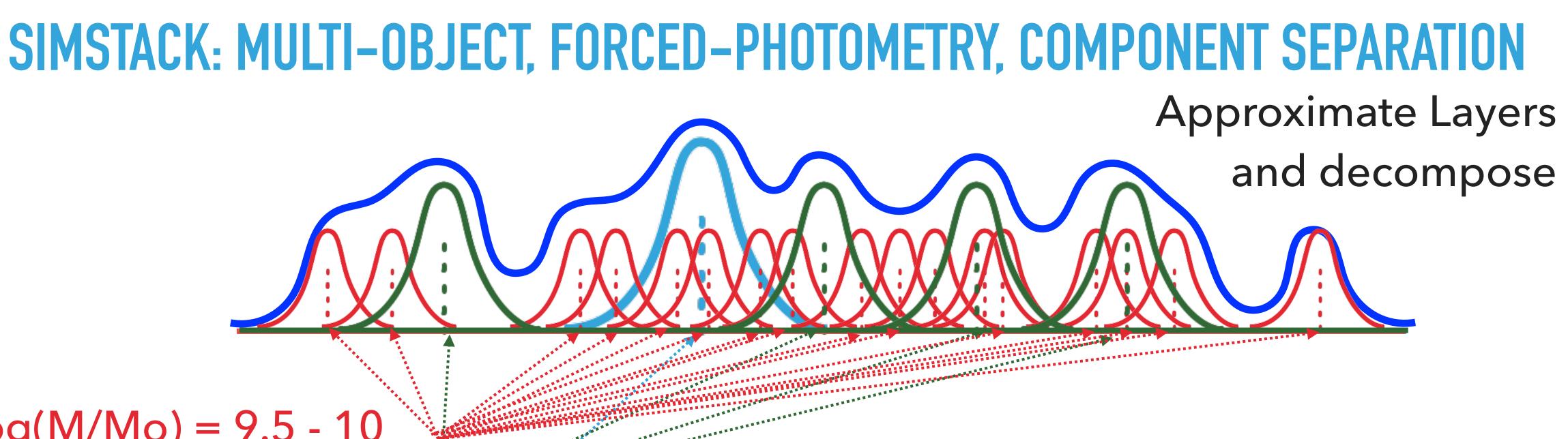
Position 2



SIMSTACK: MULTI-OBJECT, FORCED-PHOTOMETRY, COMPONENT SEPARATION Sky has many objects



log(M/Mo) = 9.5 - 10log(M/Mo) = 10 - 10.5log(M/Mo) = 10.5 - 11



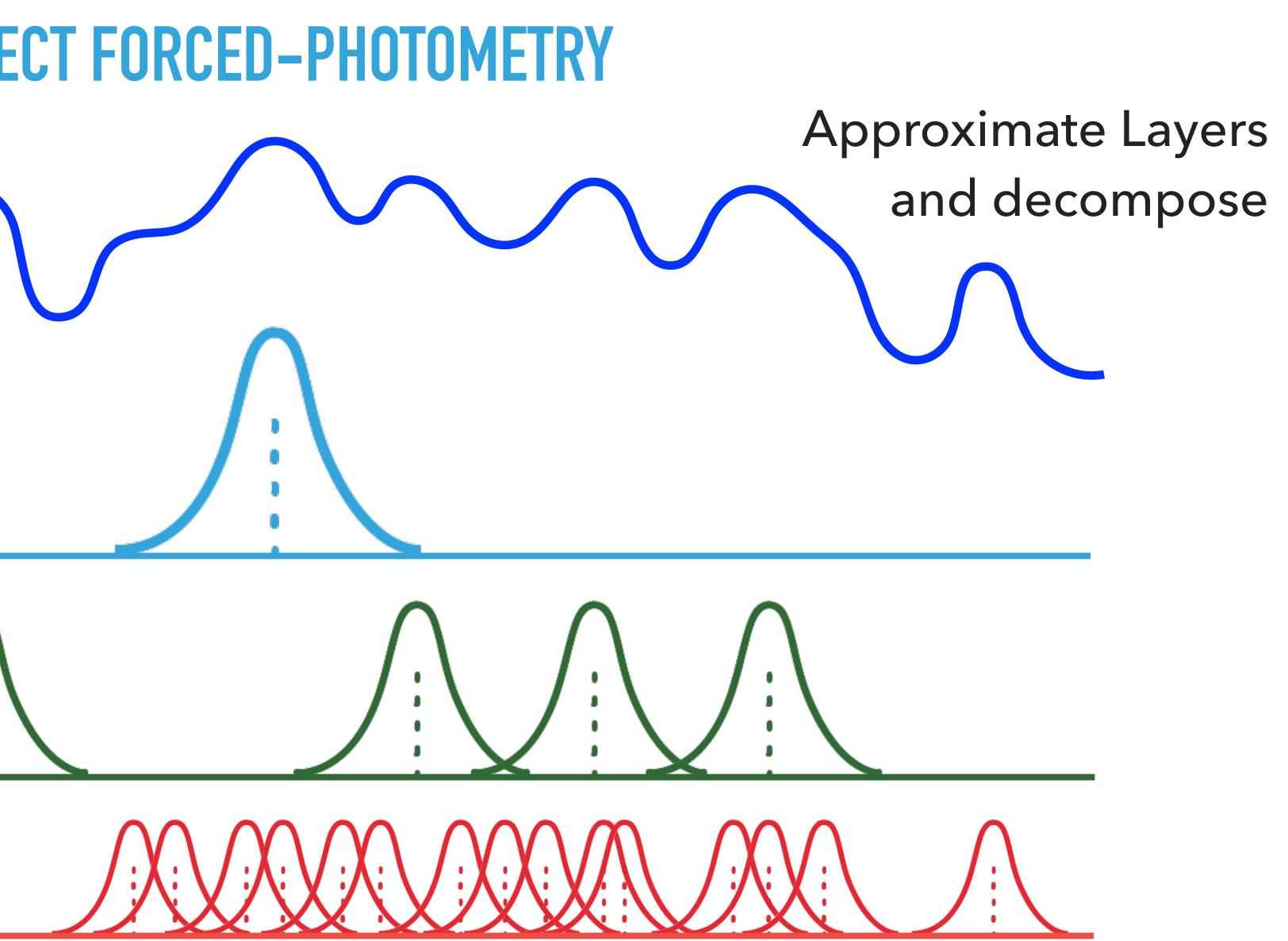
Positions and Stellar Masses from a Catalog (e.g., COSMOS2020)

SIMSTACK: MULTI-OBJECT FORCED-PHOTOMETRY

Layer 1

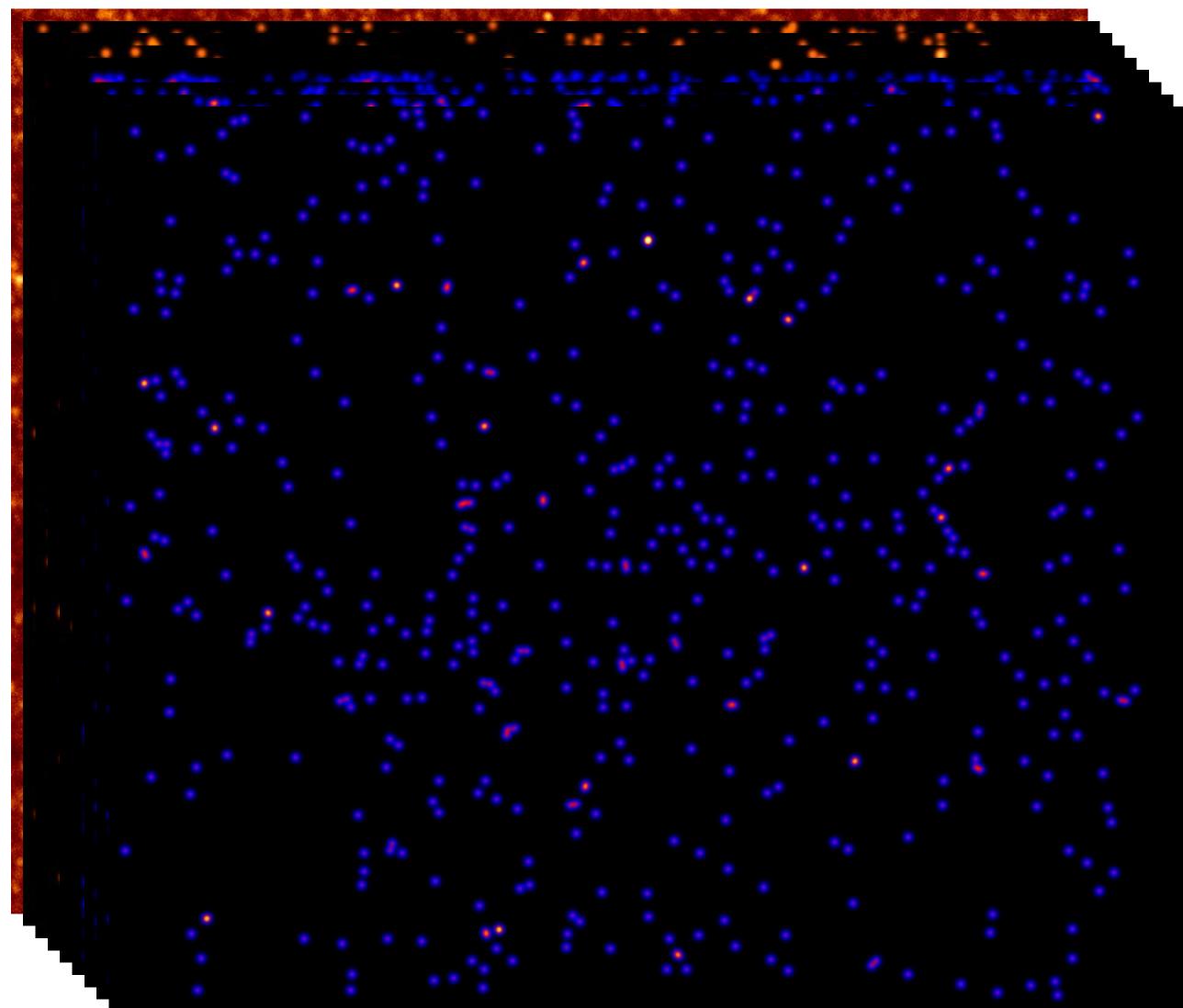
Layer 2

Layer 3



SIMSTACK IN PRACTICE — CREATE CUBE OF LAYERS

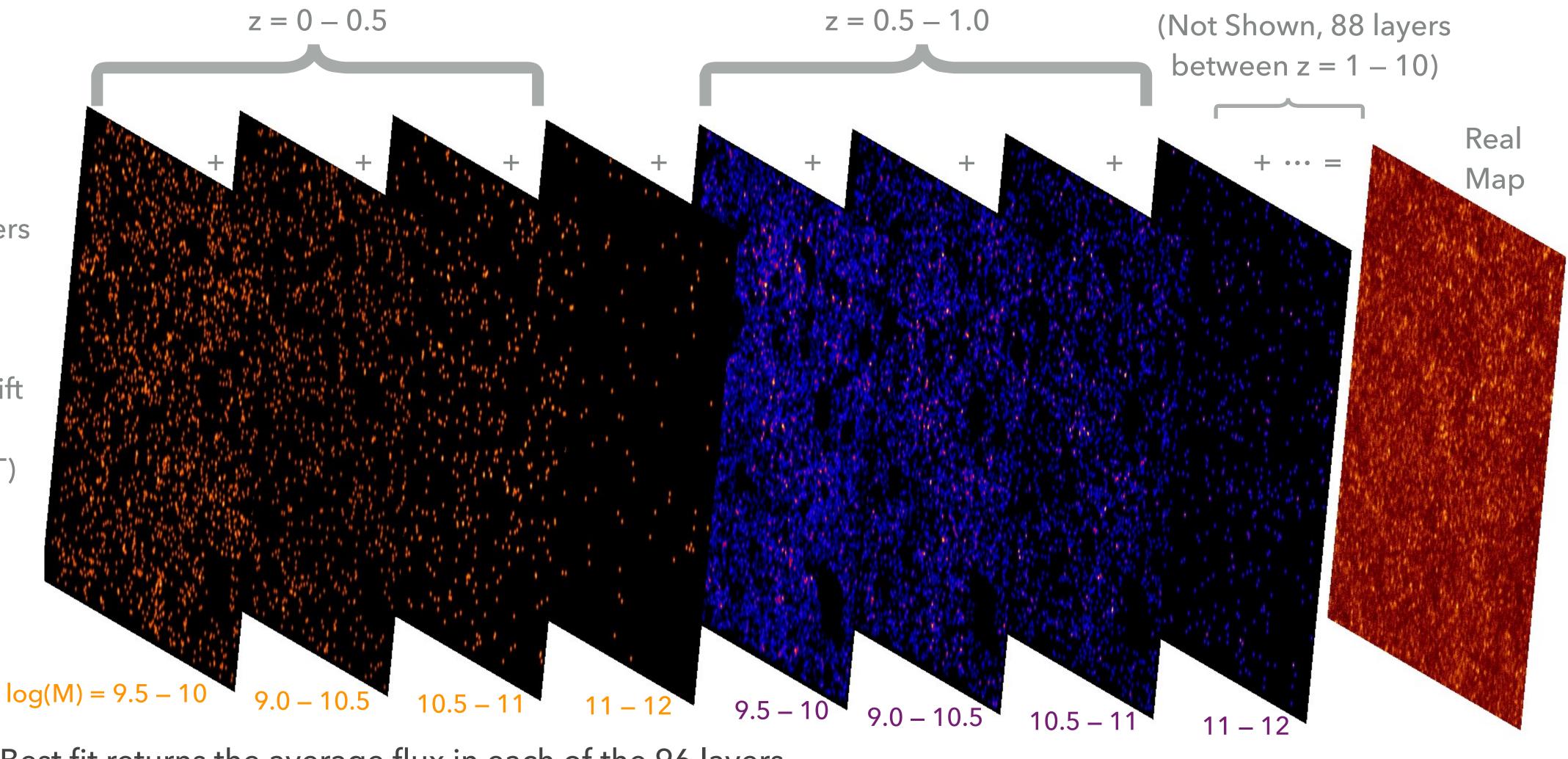
- SPIRE 500 micron
- ► z=0-0.5, log(M)=9.5-10
- ▶ z=0-0.5, log(M)=10-10.5
- z=0-0.5, log(M)=10.5-11
- ► z=0-0.5, log(M)=11-12
- ► z=0.5-1.0, log(M)=9.5-10
- z=0.5-1.0, log(M)=10-10.5
- ► z=0.5-1.0, log(M)=10.5-11
- ► z=0.5-1.0, log(M)=11-12
- plus 88 more layers z=1-10



SIMSTACK

SIMSTACK IN PRACTICE — STACK ENTIRE CUBE SIMULTANEOUSLY

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



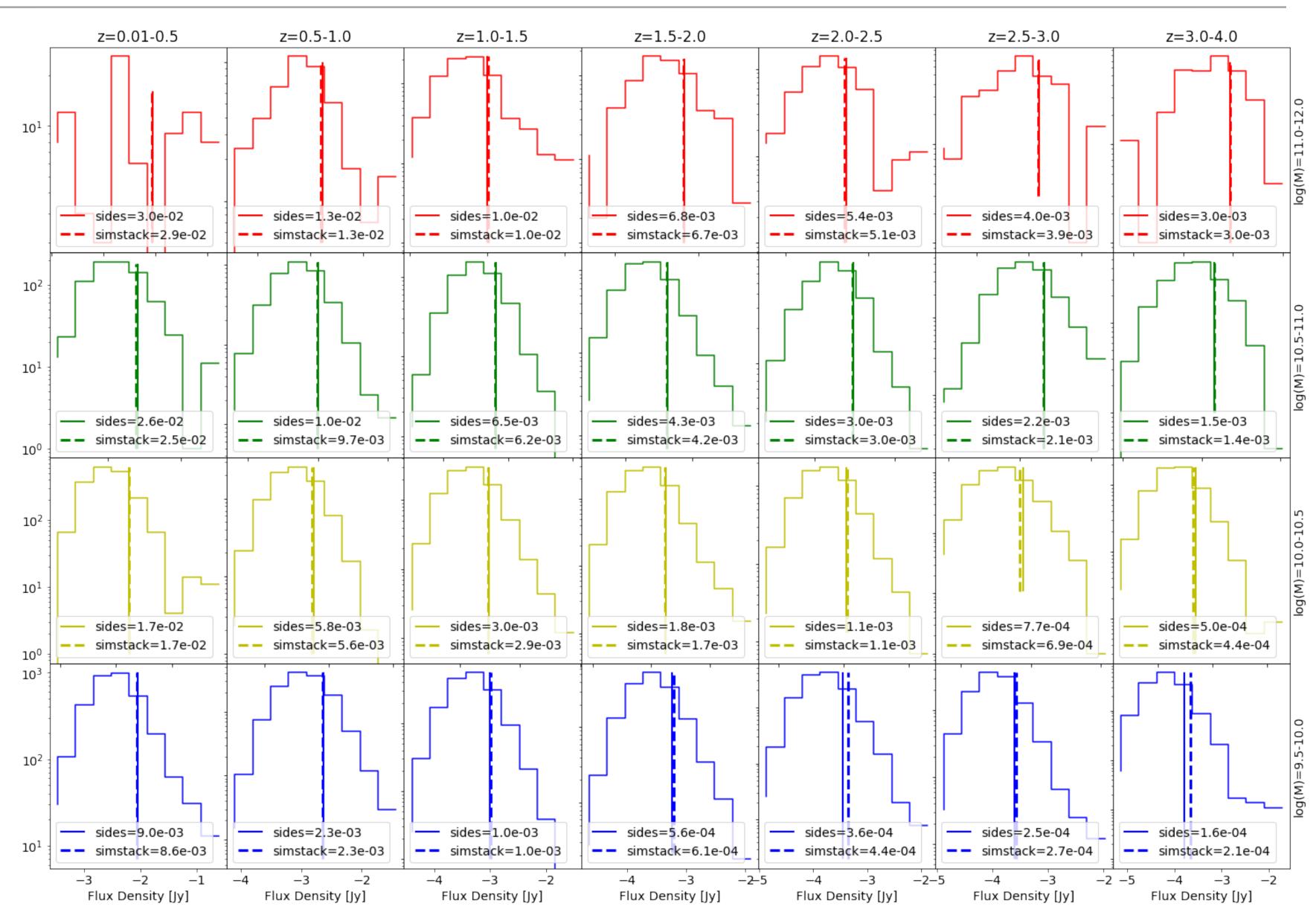
Best fit returns the average flux in each of the 96 layers.

SIMSTACK — THIS SIMULATION ON GITHUB: VIERO2022/NOTEBOOKS/APPENDIX/SIDES_SIMULATION

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)



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:

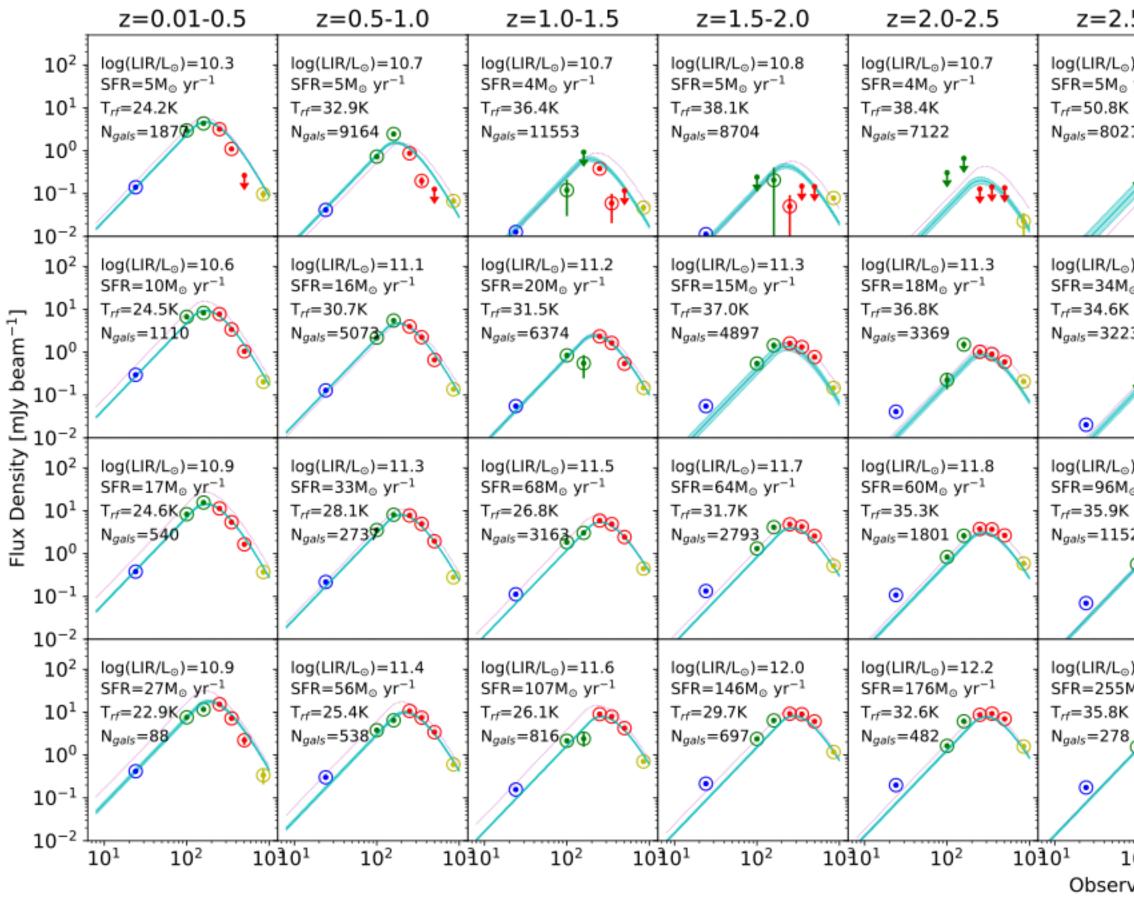
HTTPS://GITHUB.COM/MARCOVIERO/SIMSTACK3/TREE/MAIN/VIERO2022

AND:

HTTPS://ZENODO.ORG/RECORD/6792395



SIMULTANEOUS STACK TO Z = 10



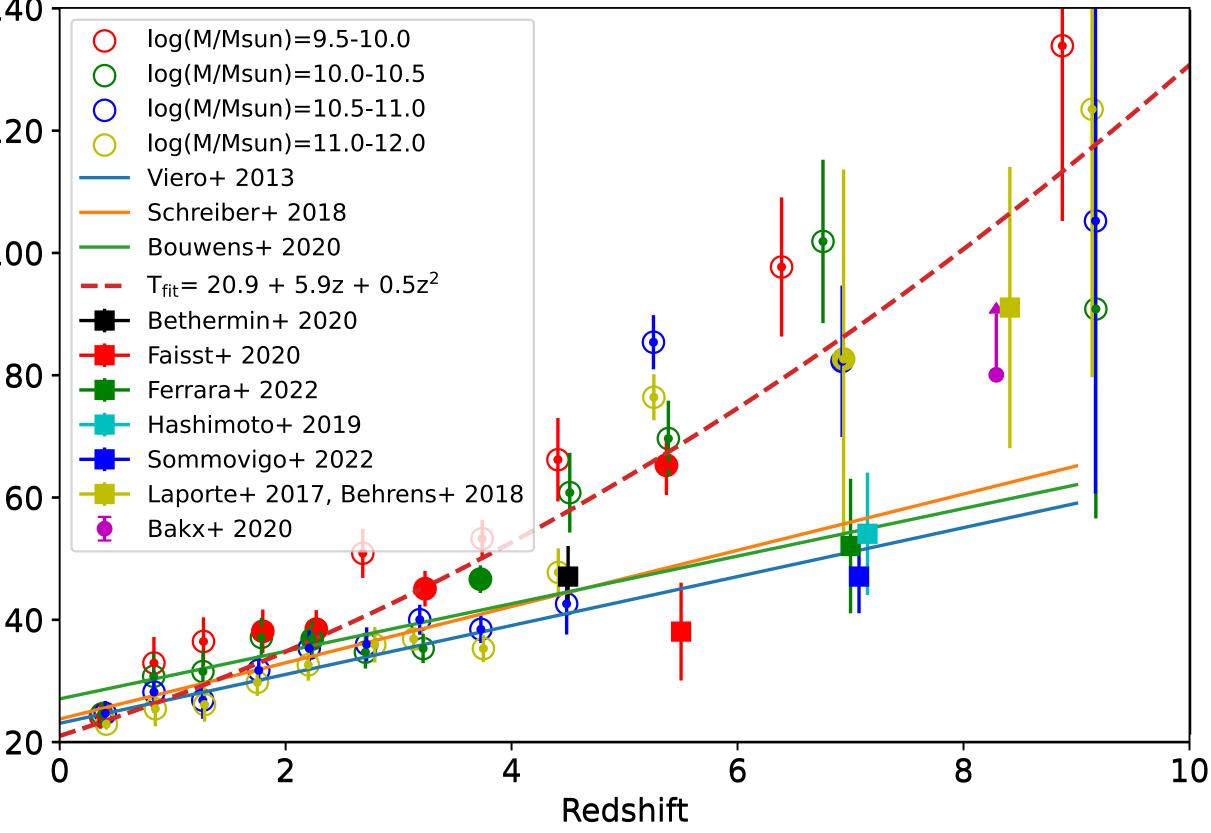
.5-3.0	z=3.0-3.5	z=3.5-4.0	z=4.0-5.0	z=5.0-6.0	z=6.0-8.0	z=8.0-10.0
	$log(LIR/L_{\odot})=10.8$ SFR=4M _{\odot} yr ⁻¹ T _{rf} =45.0K N _{gals} =6103	$log(LIR/L_{\odot})=11.4$ $SFR=8M_{\odot} yr^{-1}$ $T_{rf}=53.2K$ $N_{gals}=3797$	$log(LIR/L_{\odot})=11.7$ SFR=7M _{\odot} yr ⁻¹ T _{rf} =66.1K N _{gals} =4730	$log(LIR/L_{\odot})=11.3$ $SFR=4M_{\odot} yr^{-1}$ $T_{rf}=65.2K$ $N_{gals}=1432$	$log(LIR/L_{\odot})=12.0$ SFR=3M _{\odot} yr ⁻¹ T _{rf} =97.6K N _{gals} =581 •	$log(LIR/L_{\odot})=12.7$ SFR=4M _{\odot} yr ⁻¹ T _{rf} =133.8K N _{gals} =225
₀)=11.4 M _☉ yr ⁻¹ K 23 ↓ ♥ ♥ ♥ ♥ ♥	log(LIR/L _☉)=11.5 SFR=42M _☉ yr ⁻¹ T _{rf} =35.2K N _{gals} =2279	$log(LIR/L_{\odot})=11.8$ $SFR=27M_{\odot} yr^{-1}$ $T_{rf}=46.6K$ $N_{gals}=1210$	log(LIR/L ₀)=12.1 SFR=22M ₀ yr ⁻¹ T _{rf} =60.7K N _{gals} =1528	$log(LIR/L_{\odot})=12.3$ SFR=21M _{\odot} yr ⁻¹ T _{rf} =69.6K N _{gals} =623	$log(LIR/L_{\odot})=12.3$ SFR=5M $_{\odot}$ yr ⁻¹ T _{rf} =101.8K N _{gals} =355	log(LIR/L _o)=12.7 SFR=22M _o yr ⁻¹ T _{rf} =90.8K N _{gals} =214
 ∞)=12.0 M_☉ yr⁻¹ K 52 9 9 	log(LIR/L ₀)=12.2 SFR=106M ₀ yr ⁻¹ T _{rf} =39.9K N _{gals} =750	log(LIR/L _☉)=12.0 SFR=104M _☉ yr ⁻¹ T _{rf} =38.4K N _{ga/s} =297	$log(LIR/L_{\odot})=12.3$ SFR=124M _{\odot} yr ⁻¹ T _{rf} =42.5K N _{gais} =419	$log(LIR/L_{\odot})=12.7$ SFR=18M _{\odot} yr ⁻¹ T _{rf} =85.3K N _{gals} =205	log(LIR/L _o)=12.4 SFR=15M _o yr ⁻¹ T _{rf} =82.2K N _{gals} =127	$log(LIR/L_{\odot})=12.8$ SFR=16M _o yr ⁻¹ T _{rf} =105.2K N _{gals} =117
©)=12.4 5M _☉ yr ⁻¹ K	log(LIR/L _o)=12.4 SFR=242M _o yr ⁻¹ T _{rf} =36.8K N _{gals} =263	$log(LIR/L_{\odot})=12.5$ SFR=354M _{\odot} yr ⁻¹ T _{rf} =35.2K N _{gals} =62	$log(LIR/L_{\odot})=12.8$ SFR=215M _{\odot} yr ⁻¹ T _{rf} =47.7K N _{gals} =182	$log(LIR/L_{\odot})=12.7$ $SFR=29M_{\odot} yr^{-1}$ $T_{rf}=76.3K$ $N_{gals}=88$	$log(LIR/L_{\odot})=13.0$ $SFR=54M_{\odot} yr^{-1}$ $T_{rf}=82.6K$ () $N_{gals}=50$ () ()	$log(LIR/L_{\odot})=13.1$ $SFR=16M_{\odot} yr^{-1}$ $T_{rf}=123.4K$ $N_{gals}=68$
10^2 $10\overline{10^1}$ 10^2 $10\overline{10^1}$ 10^2 $10\overline{10^1}$ 10^2 $10\overline{10^1}$ 10^2 $10\overline{10^1}$ 10^2 $10\overline{10^1}$ 10^2 rved Wavelength [μm]						



EXCESS HEATING AT Z > 4

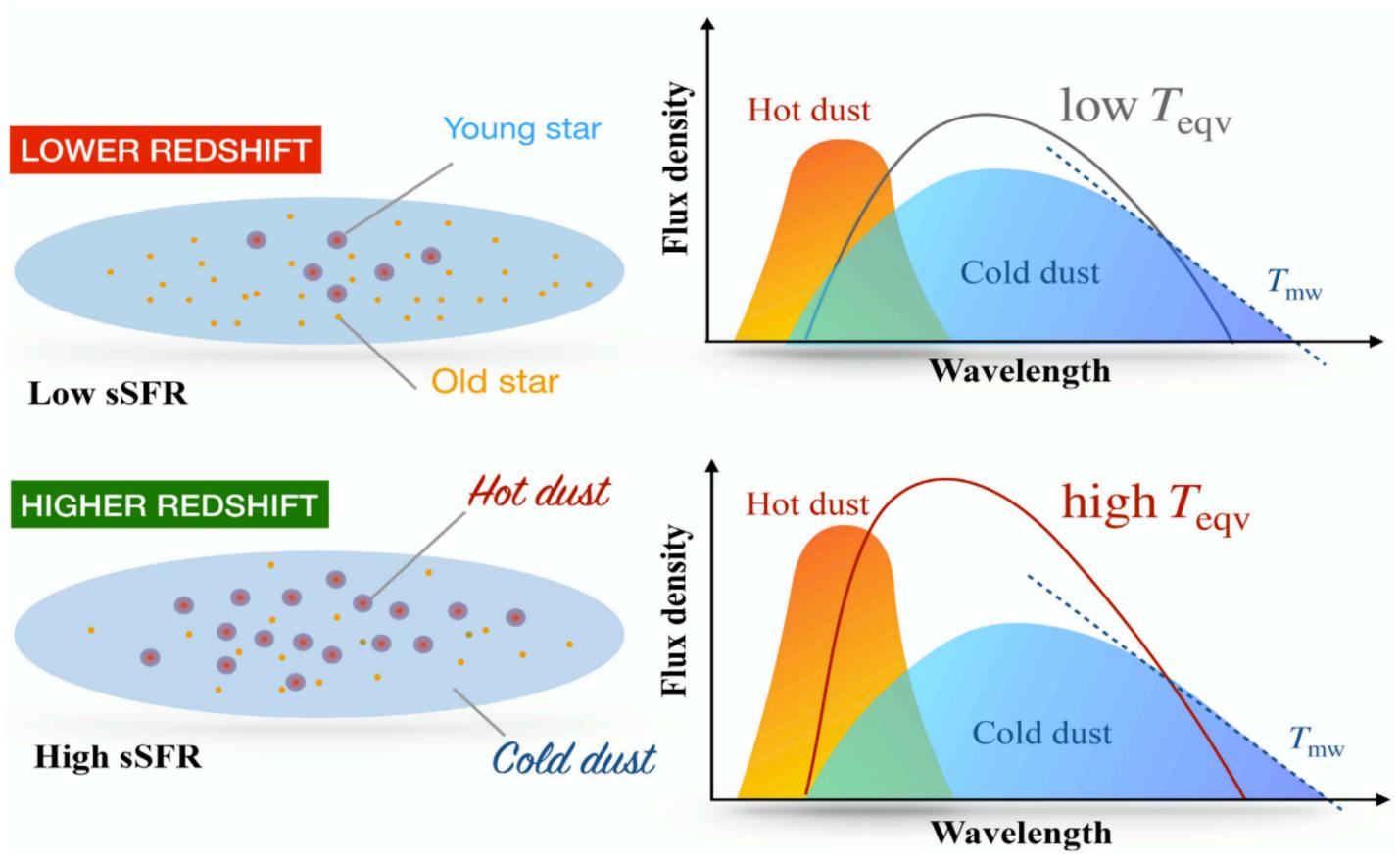
- ALPINE/ALMA objects mostly 140 line up with existing trends $(T=50 \text{ at } z \sim 7).$
- Two objects much hotter (T=80K at z=8.3).
- Full sample agrees at z < 4,</p> and rises rapidly at higher z.
- CMB is subdominant.

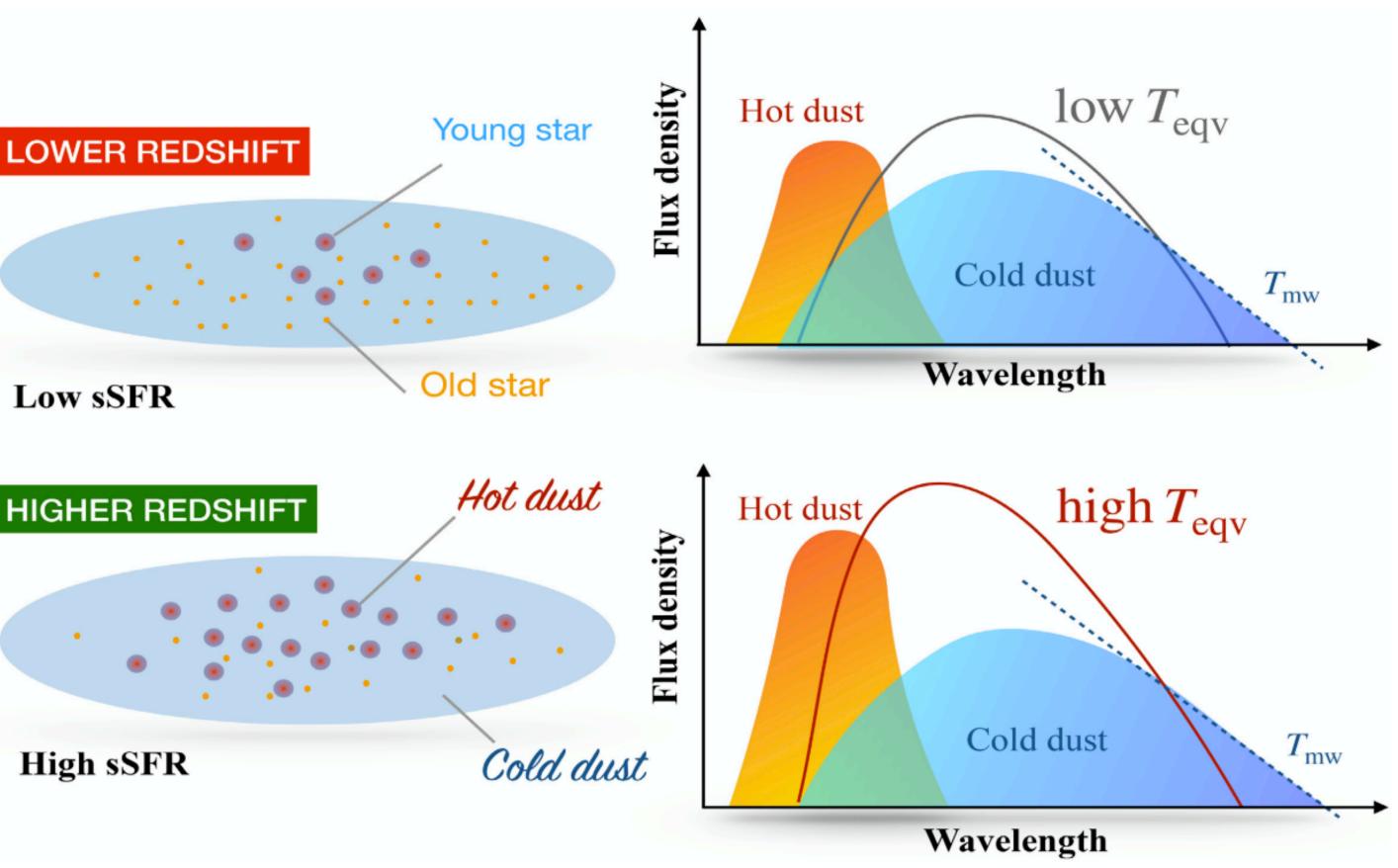
120 Rest-frame Temperature [K] 40



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)

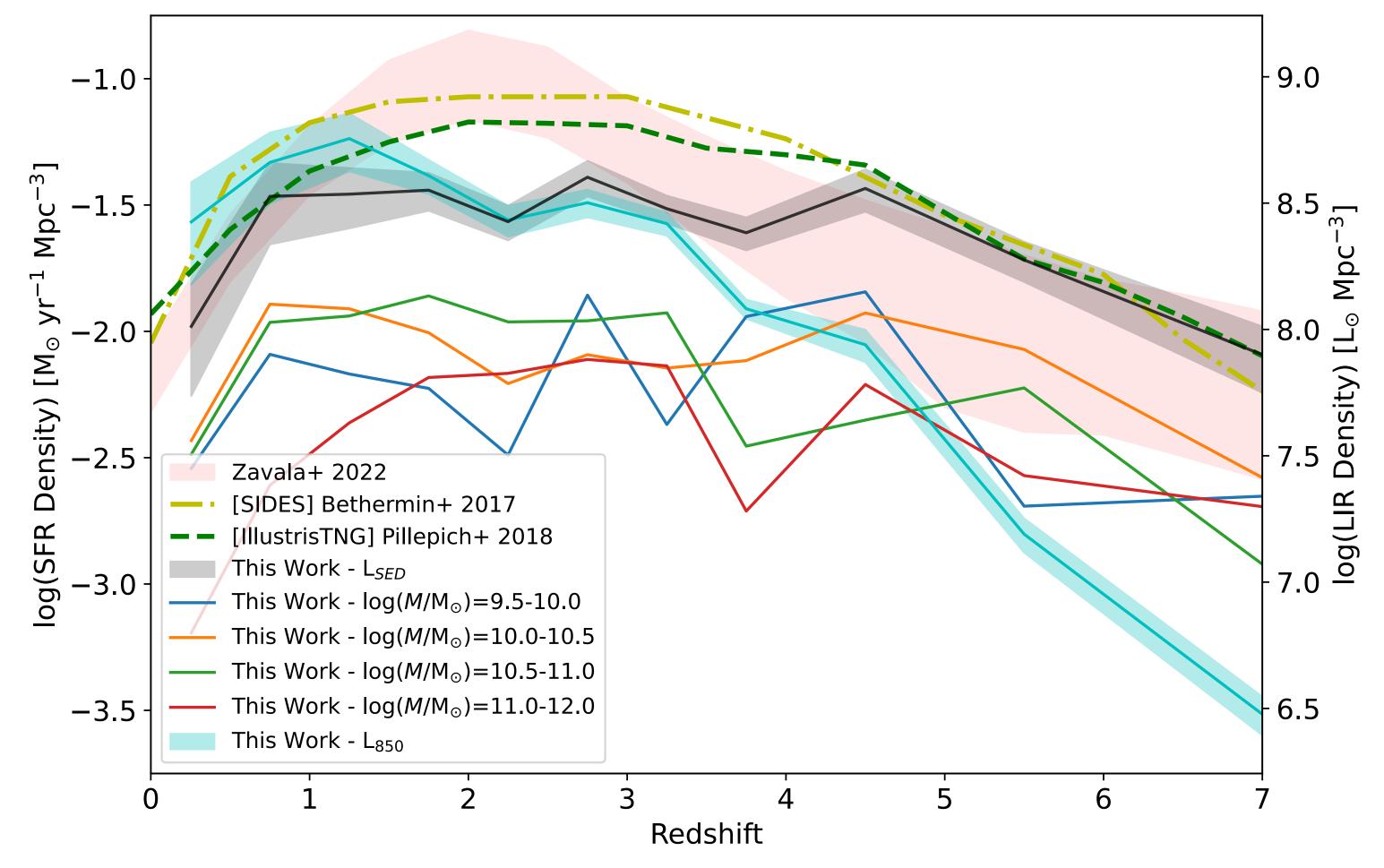




Liang+ 2019 arXiv:1902.10727

SFRD

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



VIERO, SUN, CHUNG, MONCELSI, & CONDON 2022 — ARXIV:2203.14312

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!

```
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"}
[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_G03_sci_10.cutout.fits", "path_noise":"MAPSPATH mips_24_G03_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.fits", "path_noise":"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.fits", "path_noise": "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"}
```

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

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

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"}

