Reliably measuring the host galaxy mass of luminous AGN with GRAHSP

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http://astrost.at/istics/
eROSITA2024 conference

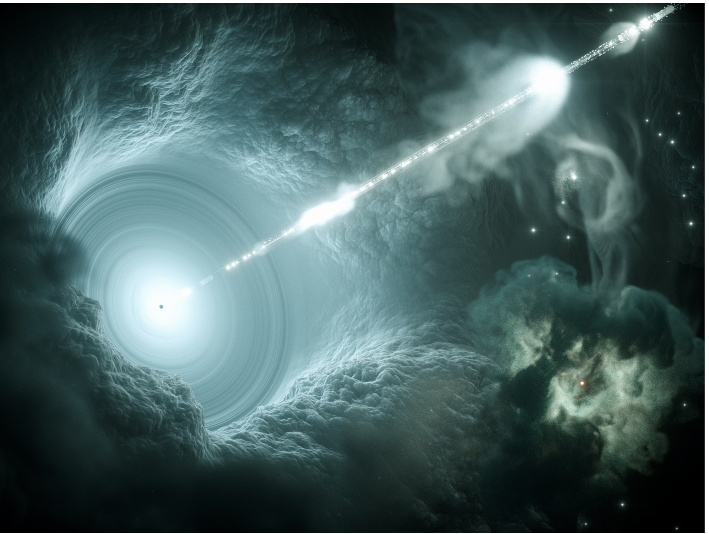
Why study host galaxies also of type 1 AGN

- Test coevolution link

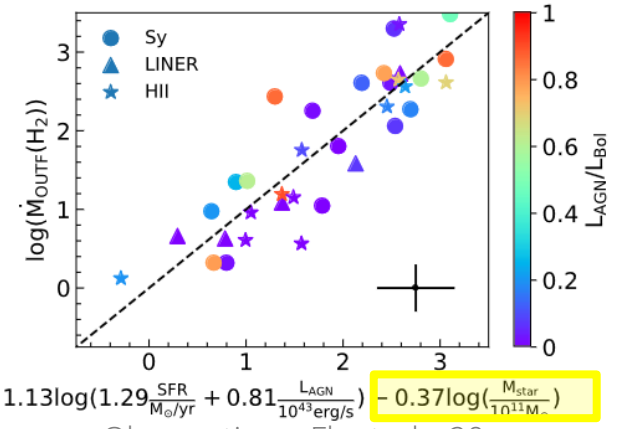
  M_* – M_{BH}

  SFR – L_{AGN}

- type-1/2 dichotomy: orientation or evolution?

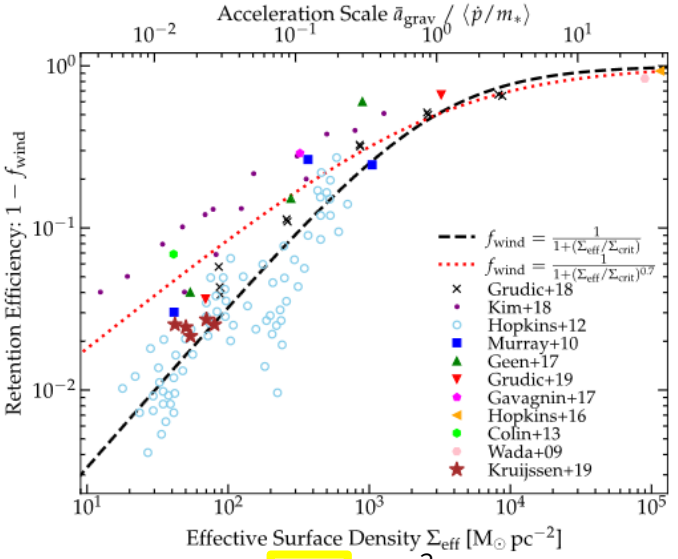


Outflows scale with gravitational potential (M*)



Observations: Fluetsch+20

see also Harrison & Ramos Almeida (2024)



M_* / pc^2

Simulation compilation: Hopkins+22

Host galaxy analysis group

Johannes Buchner

NWAY

Mara Salvato

modelling

stellar masses

eROSITA population

galaxy structure

SED fitter comparison

Hattie Starck (BSc)

Nico Lopez (MSc) → PhD

dwarfs

Zsofi Igo (PhD)

SBI & ML

obscuration

Nikolas Vasilas (Erasmus)

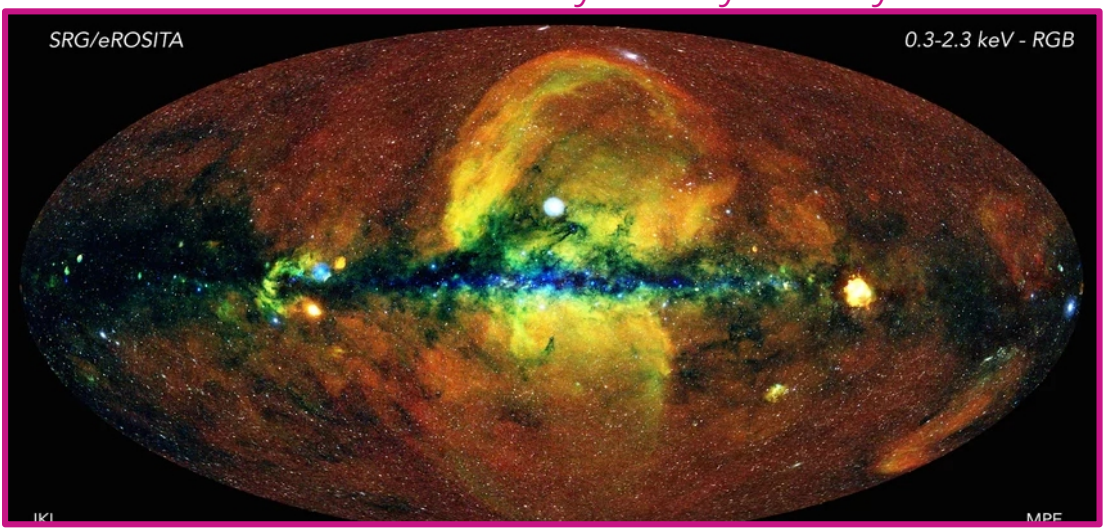
Ania Olchowska (MSc) → PhD

Black hole mass

Isabelle Gauger (PhD)

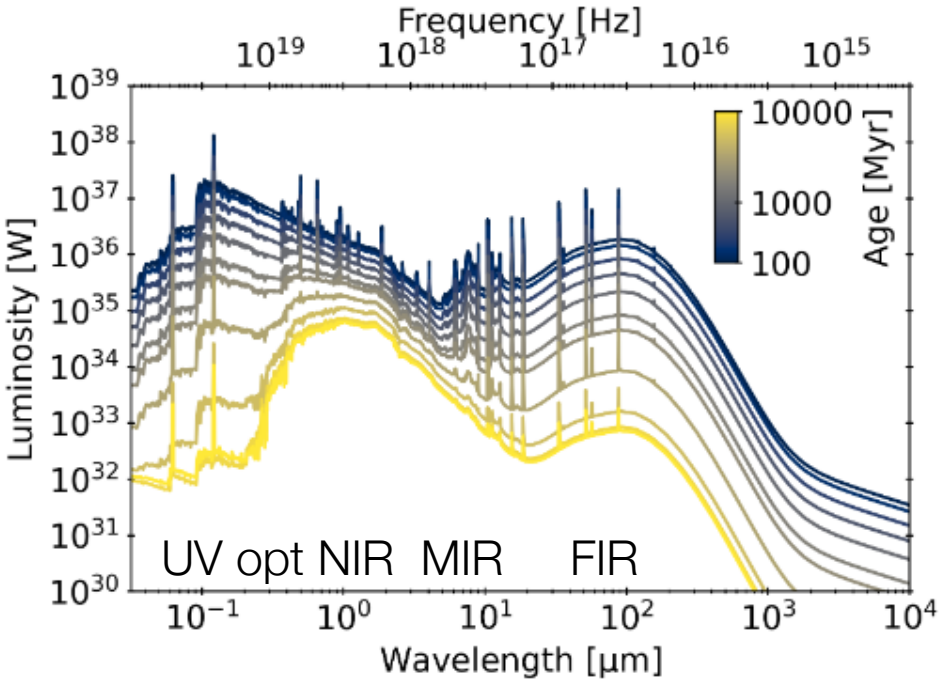
The eROSITA challenge: 1 million AGN

The eROSITA X-ray all-sky survey:



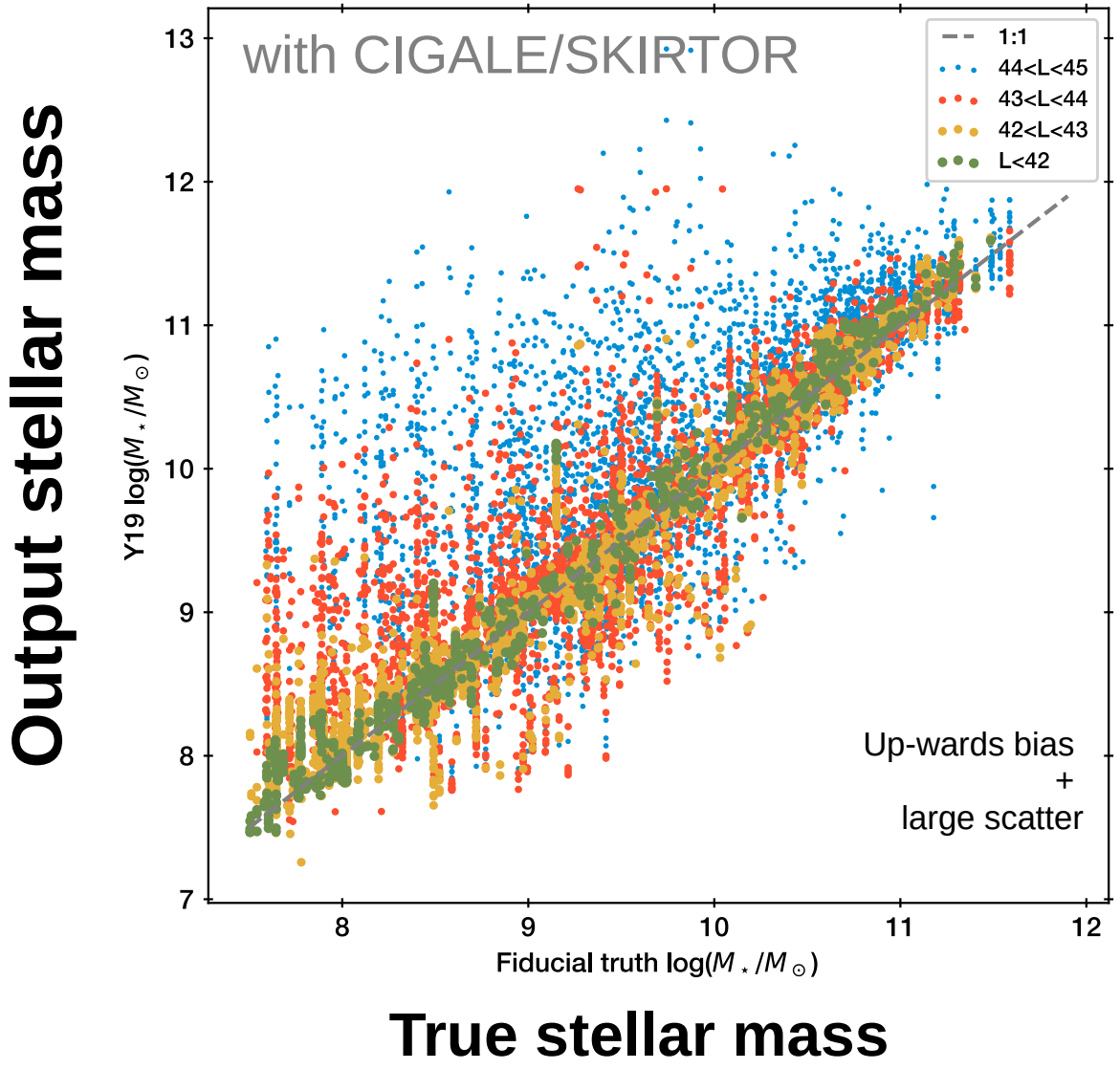
first clean large selection of AGN

Galaxy: UV to MIR



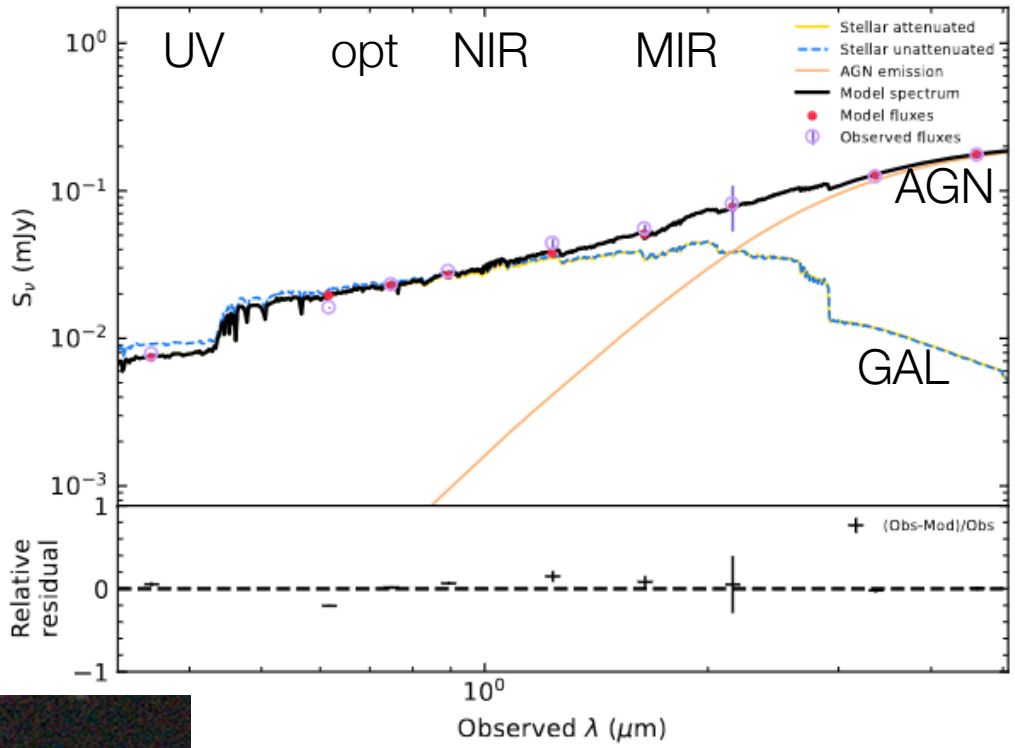
type 1 emit light in all wavelengths

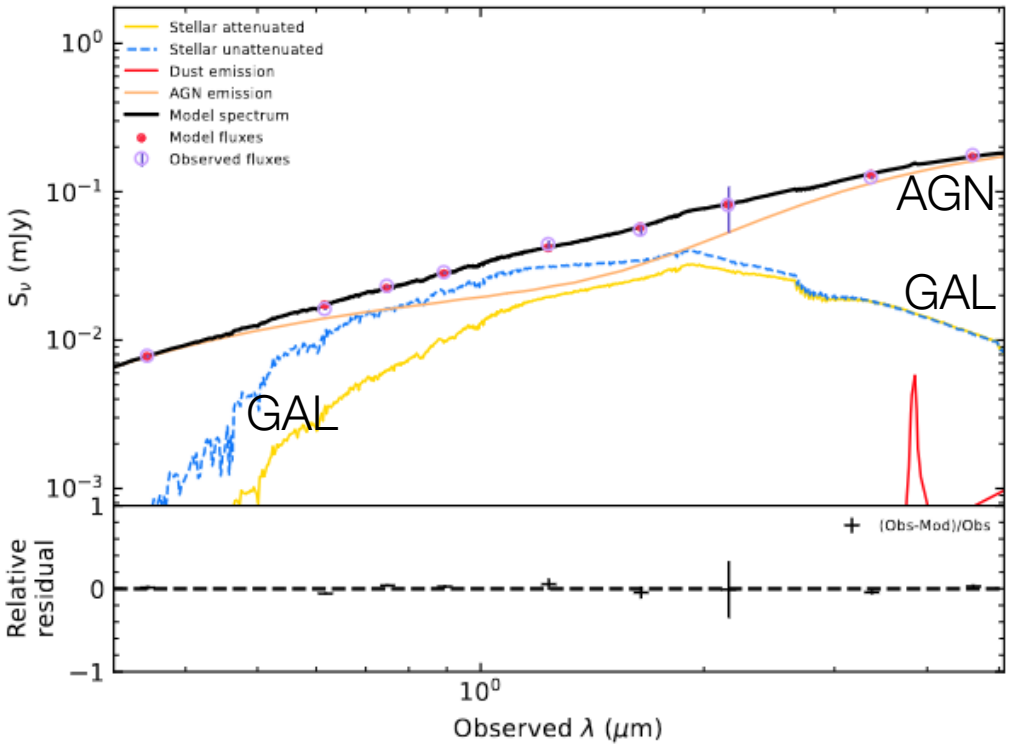
Problem: Host estimation is biased



- What causes the bias?
- How can we fix it?
- What about SFR?
- How do you know this?

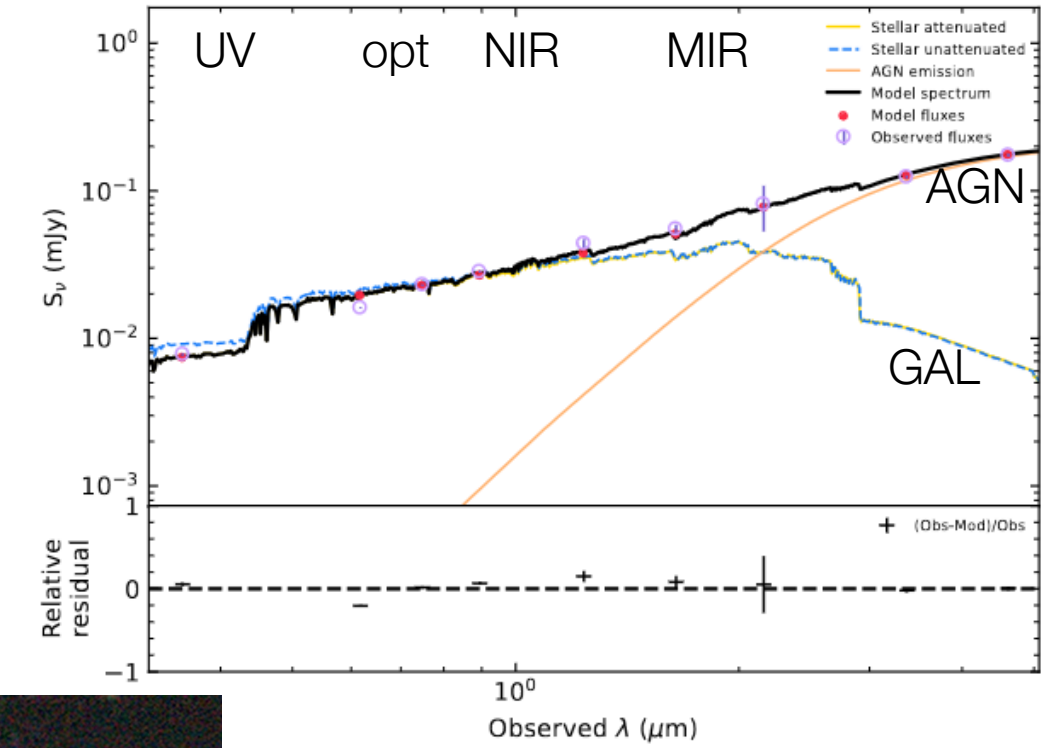
arxiv:2405.19297

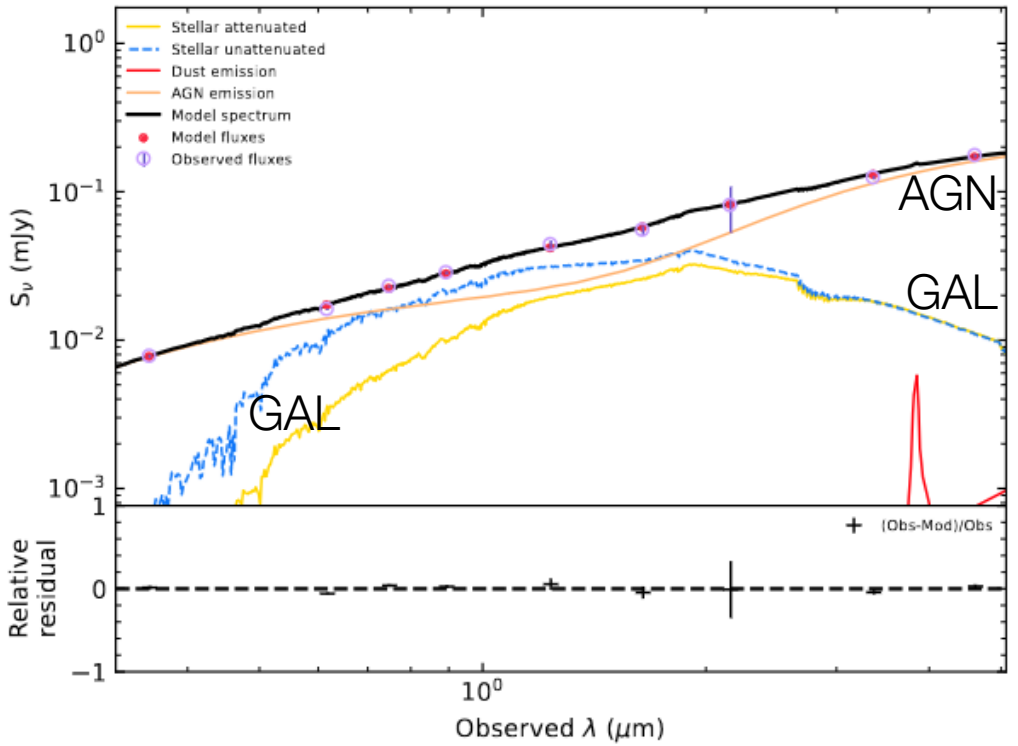




Galaxy + AGN model A ⟷ Galaxy + AGN model B

Which is the right decomposition?

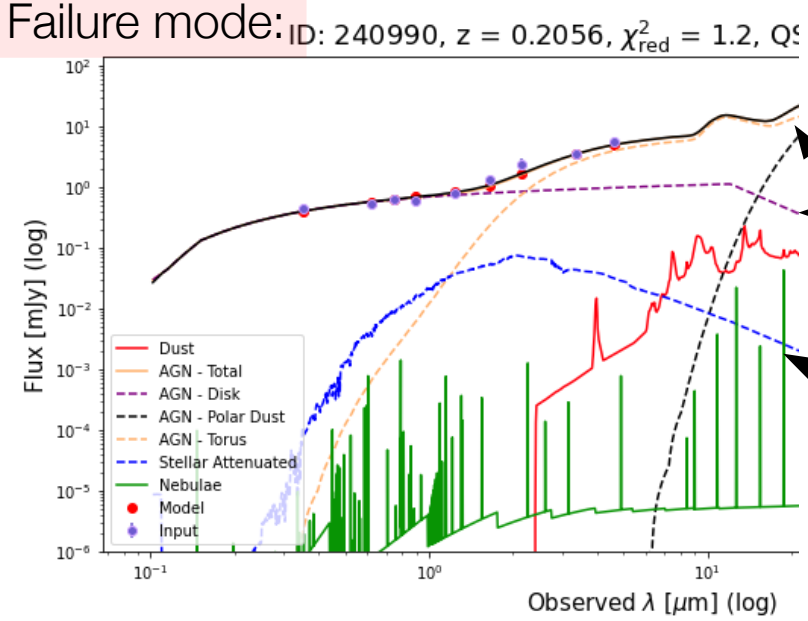




Galaxy + AGN model A ⟷ Galaxy + AGN model B

Which is the right decomposition?

Failure mode:



AGN components

Galaxy template jumps in to fix residuals

→ $\log M_* > 12$

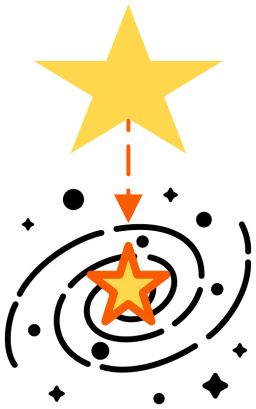
Different model → very different answers with small statistical error bars!

→ cannot be discovered from fit quality
→ cannot be addressed with simulations with the fitted model

→ systematic up-bias in M* & SFR

Can induce SFR – L(AGN) correlation
Can induce M* – L(AGN) correlation

The Chimeras benchmark



Pure galaxy sample

- COSMOS, isolated, clean photometry Laigle+15
- Remove X/IR/BL AGN
- spec-z

(M*, SFR estimated)

Random pair at same z

Pure QSO sample Shen+11

- SDSS (logL>45)
- Spec analysis

→ Lbol, mass

sum fluxes

QSO weight:
0.001% (logL~42) to 100%

hybrid object

Truth known:
M_*, SFR, L_{AGN}

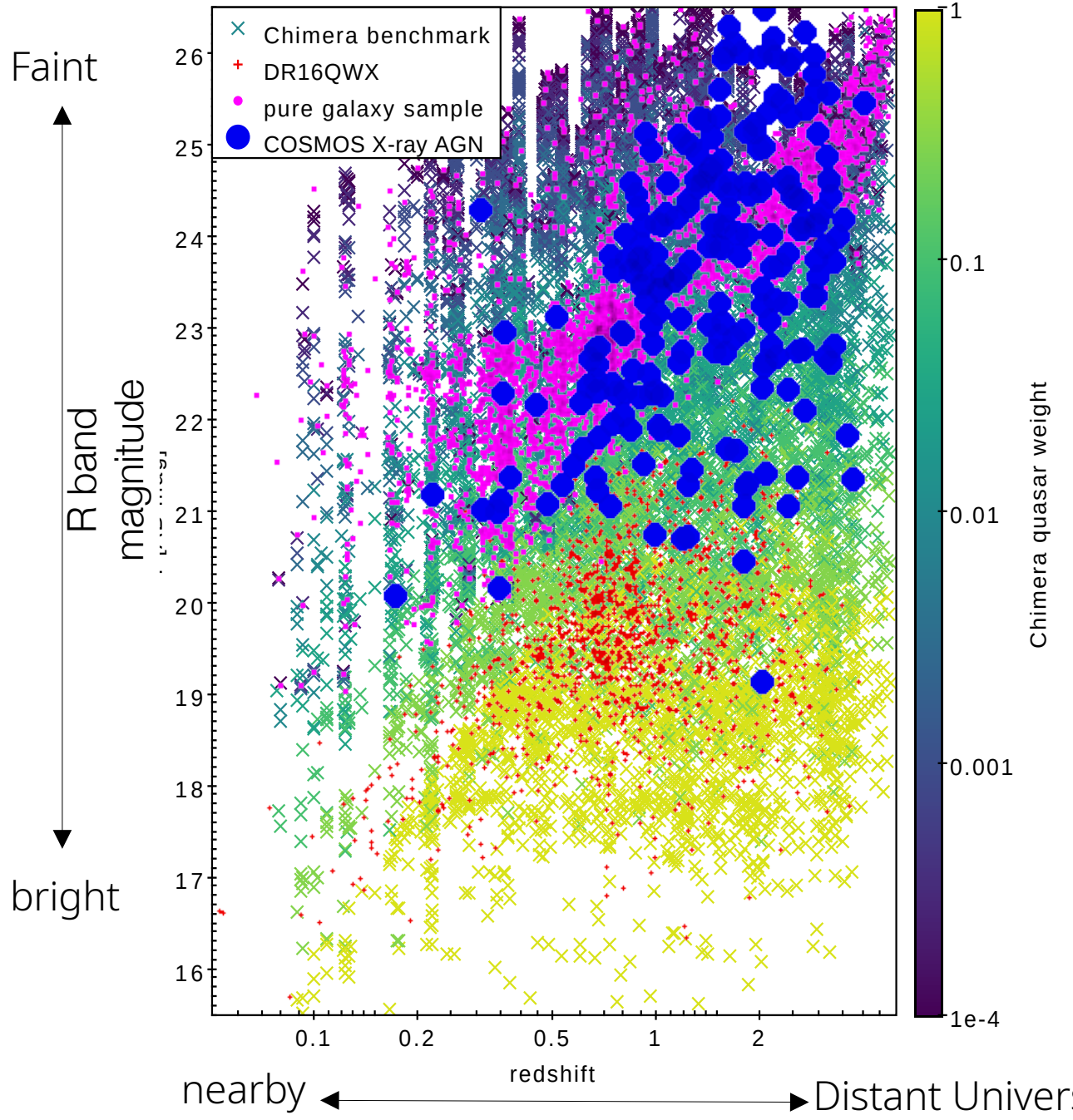
Validate SED fitting codes

Model-free!

Hattie Starck

Data available: arxiv:2405.19297

An all-encompassing benchmark data set

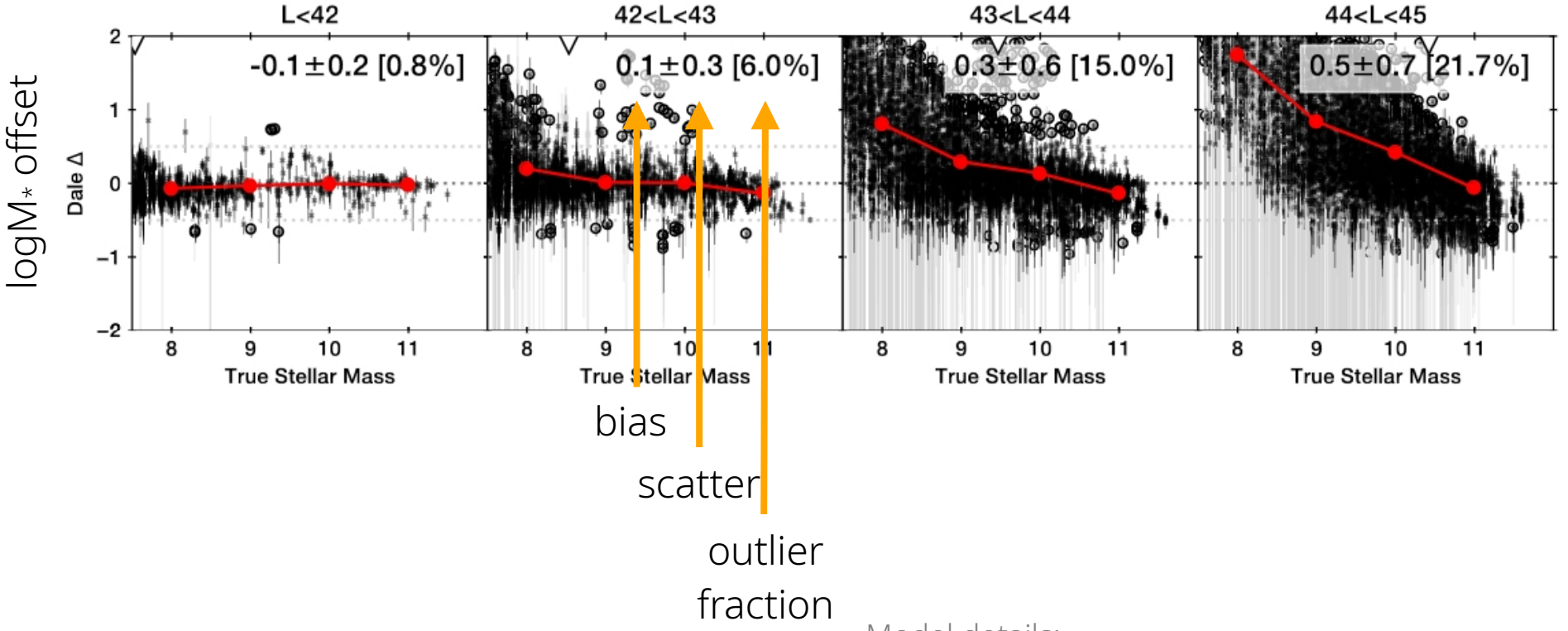


Now also used in the Euclid collaboration

Results: M* bias & scatter

bias to AGN light contamination

AGN luminosity →



Grey: Error bar >1dex

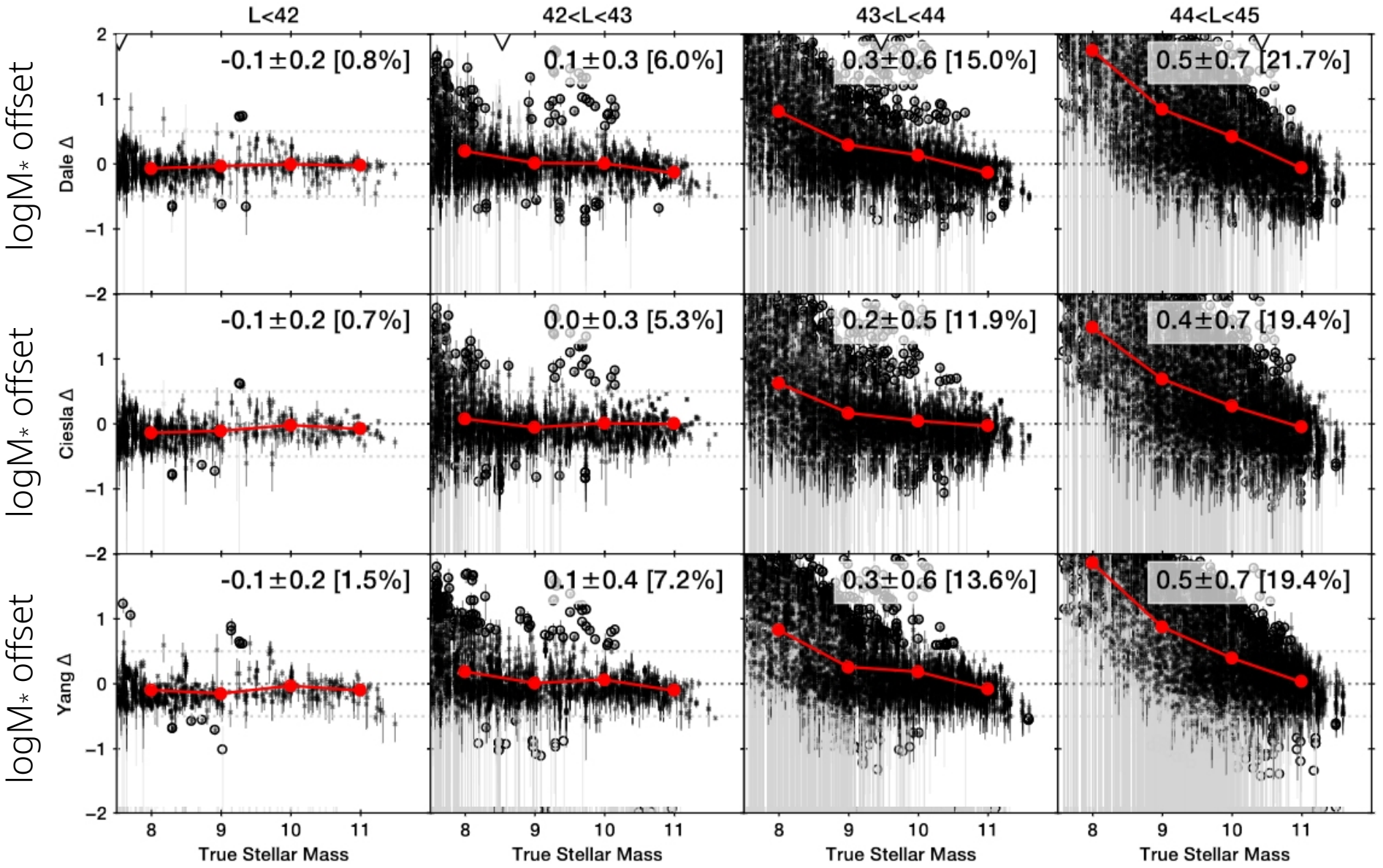
Model details:

- Delayed exponential - star formation episode BC03 SPS
- attenuation & energy-conserving re-emission in IR
- AGN: Dale+14, single parameter for AGN fraction

Buchner, Starck et al. (accepted)
arxiv:2405.19297

Current popular tool: CIGALE

3 different model setups



Buchner, Starck et al. (accepted)
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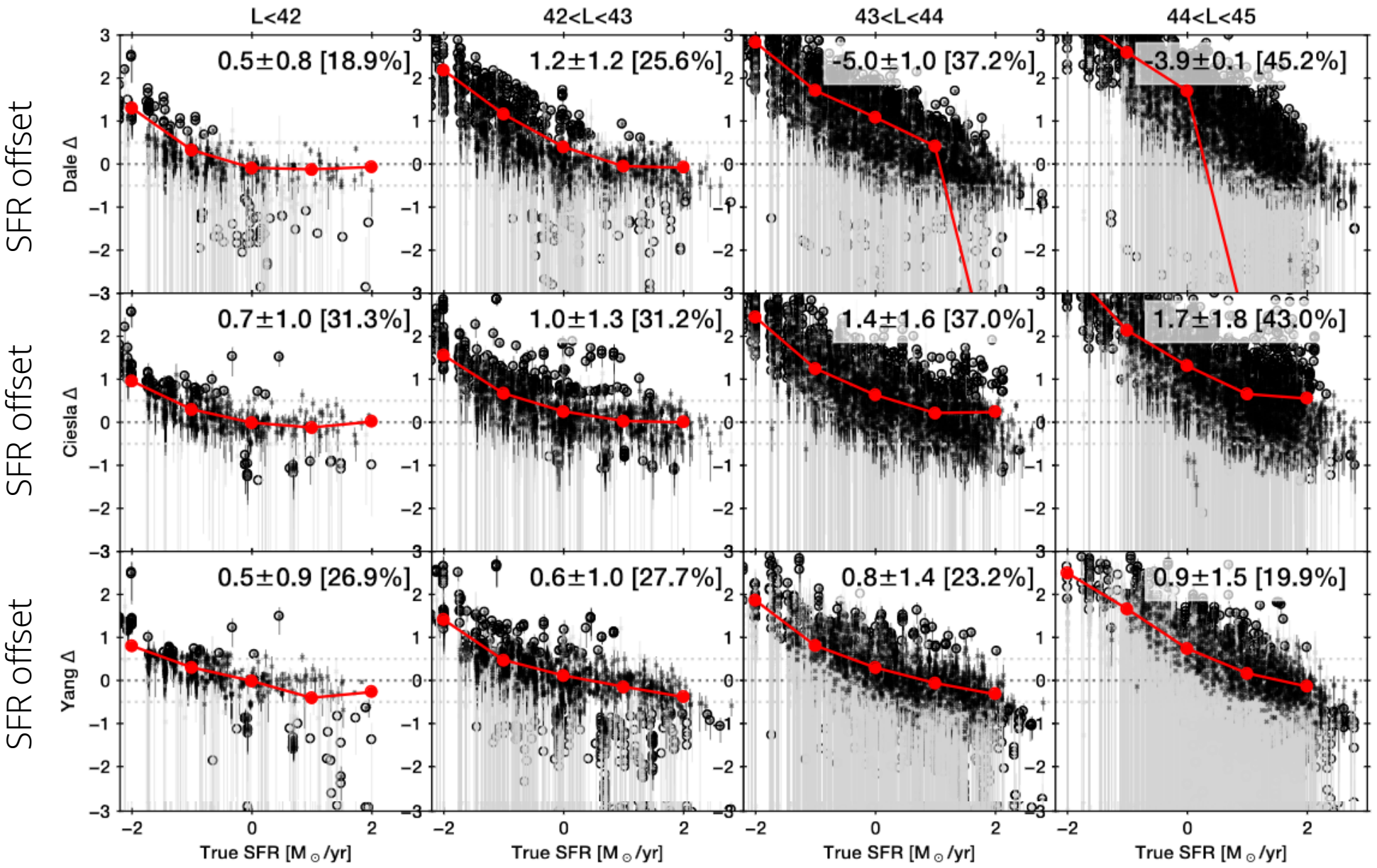
up-bias & large scatter also for SFR



Buchner, Starck et al. (accepted)
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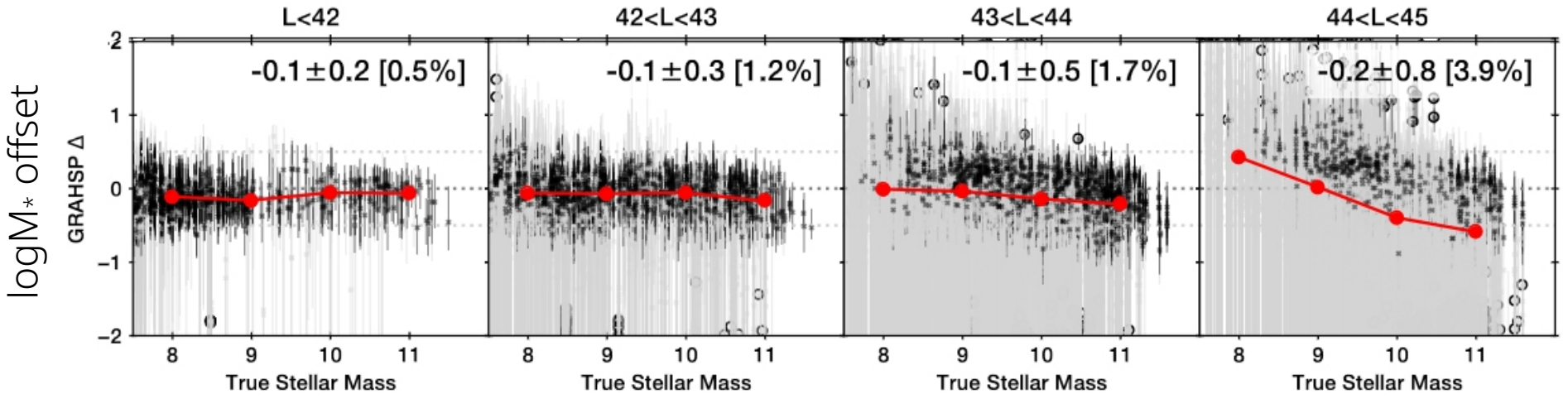
Our new tool: GRAHSP



Unbiased retrieval: AGN does not cause a systematic over-estimation

of stellar mass, SFR & AGN luminosity

Realistic error bars – no longer dominated by systematics

Full details: arxiv:2405.19297

The road to “unbiased” host estimates

GRAHSP approach:

Flexible, high-precision AGN model
→ many parameters
→ advanced fitting engine UltraNest

3min/source/CPU

Does it work? Reproduces:

1) Nearby AGN broad-band spectra

Brown et al AGN ATLAS

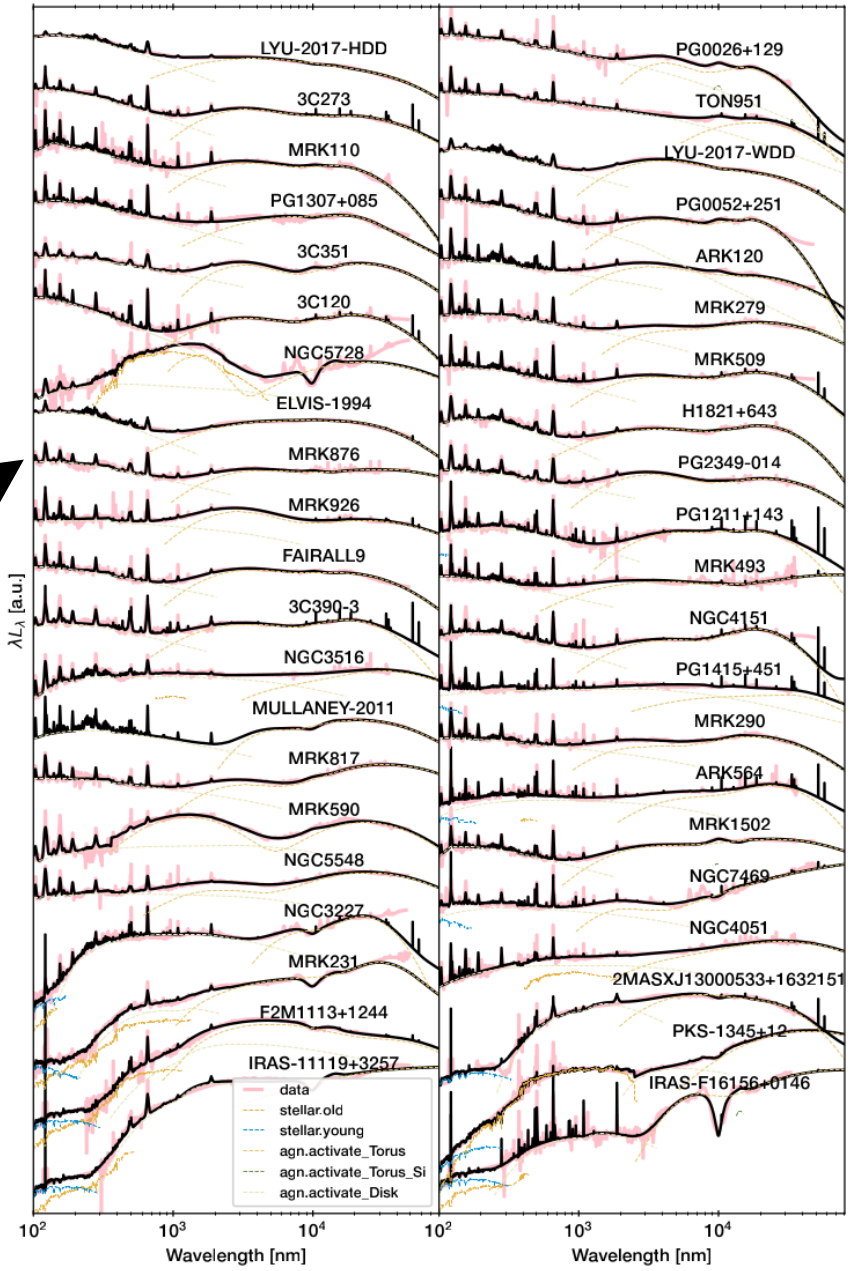
2) stacked optical quasar spectra

3) polarized-spectroscopy of the disk

4) emission lines

5) Color distributions vs z

and unbiased retrieval of SFR, M_*



What halts the growth of galaxies?

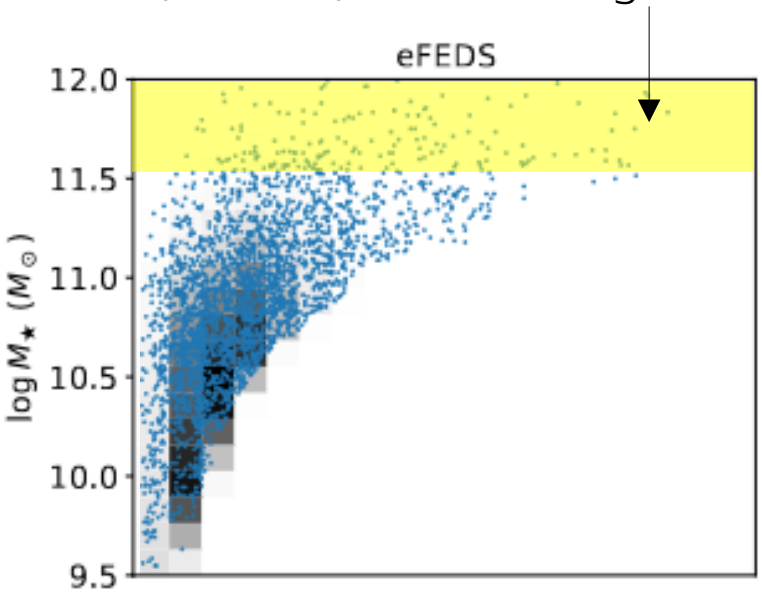
Johannes Buchner arxiv:2407.11127

The gas reservoir of galaxies can be altered by outflows driven by

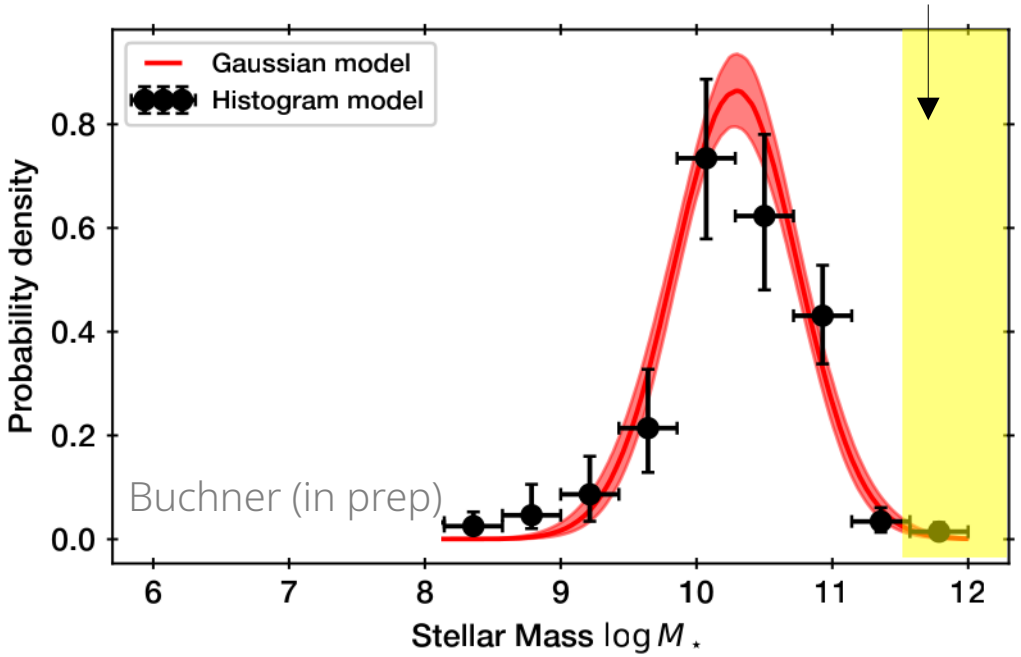
Consequences

M*-L_{AGN} relation (slope specific accretion rate)

Before (Zou+24): in massive galaxies



Now: no extremely massive galaxies



Future work

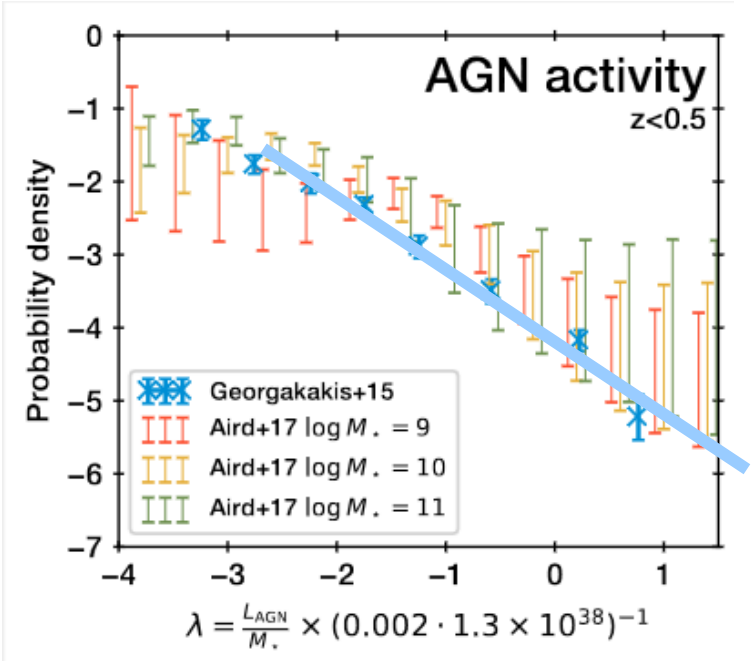
type 1/2 triggering differences

M_*-M_{BH} relation of AGN

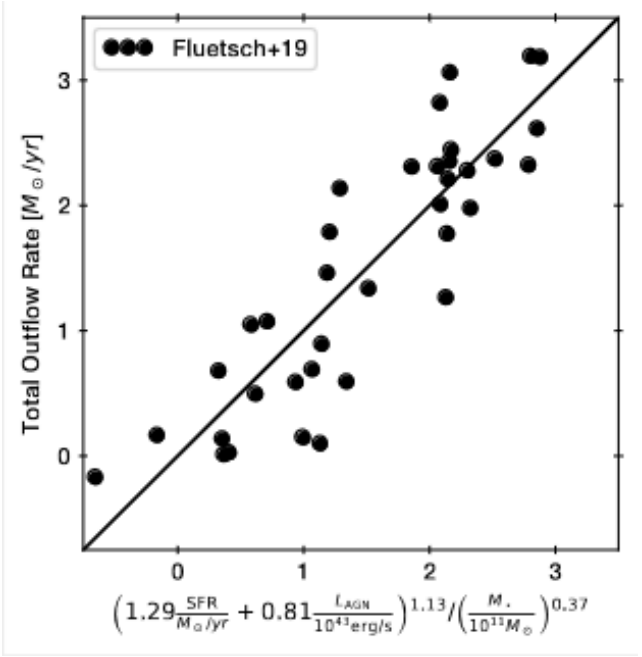
→ L_{AGN}/M* "Eddington ratio" change

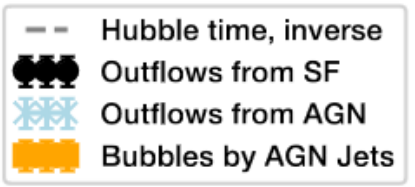
→ changes impact of outflows

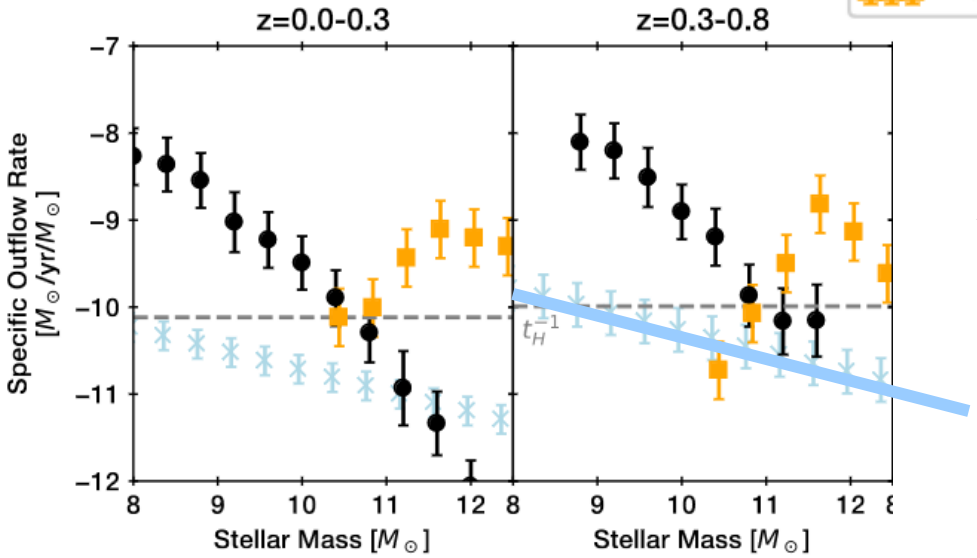
quasar-mode outflows vs. SF & jets



SAR = L_{AGN}/M_*







AGN-driven outflows not a dominant gas removal mechanism

→ arxiv:2407.11127

What halts the growth of galaxies?

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The gas reservoir of galaxies can be altered by outflows driven by

Buchner, Starck et al. (accepted)
arxiv:2405.19297

Evolution of galaxies and black holes

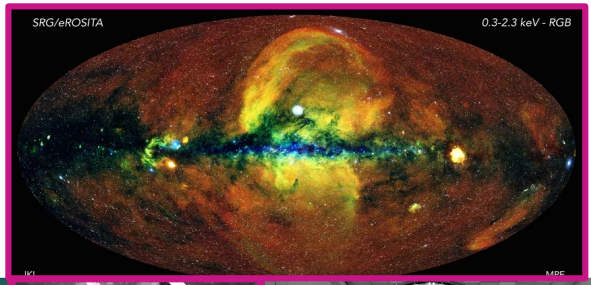
taking a data-science approach with mega-surveys

- New “unbiased” tool for quantifying AGN hosts
  GRAHSP
- Scales to large surveys bright future: eROSITA, Euclid, VRO, … Athena

  → see poster by Nikolas Vasilas
- Sample entire life cycle of AGN phase

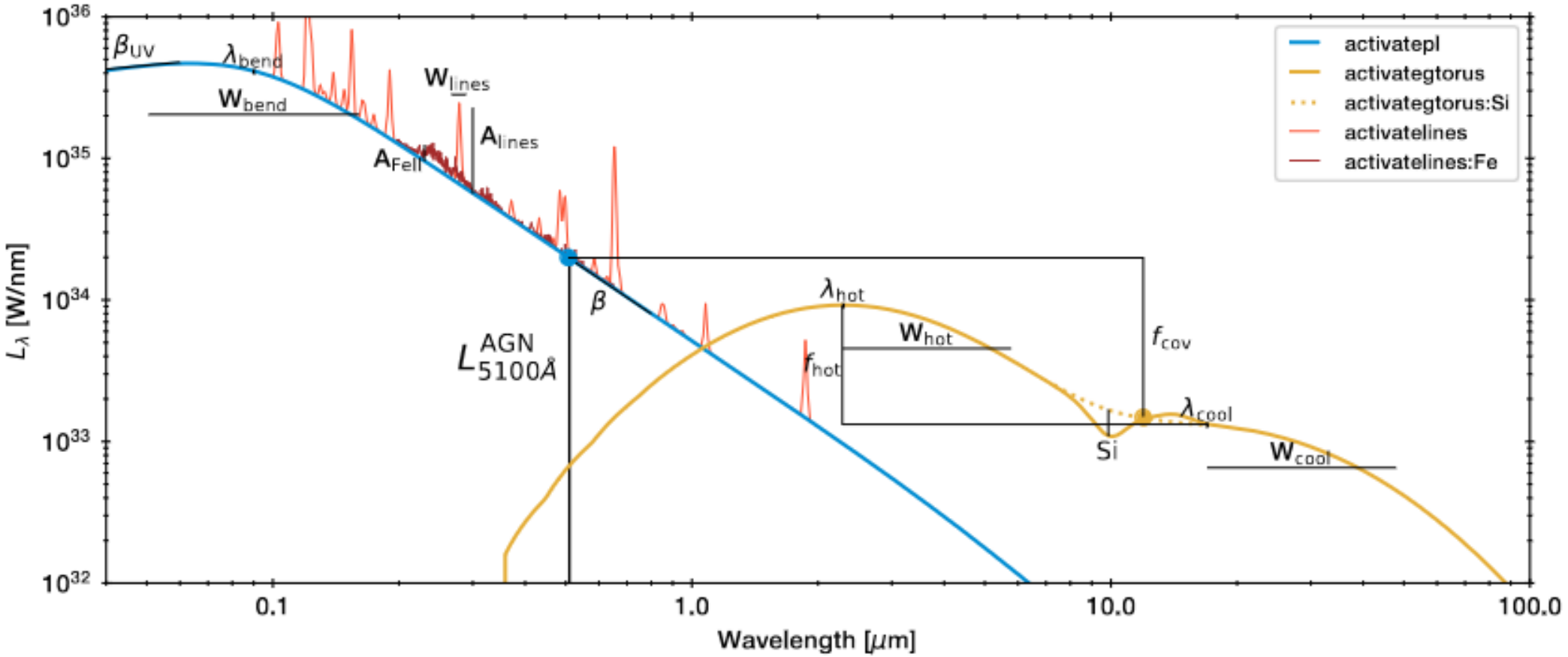
  trace the processes building stars and black holes

  address flickering with large sample:



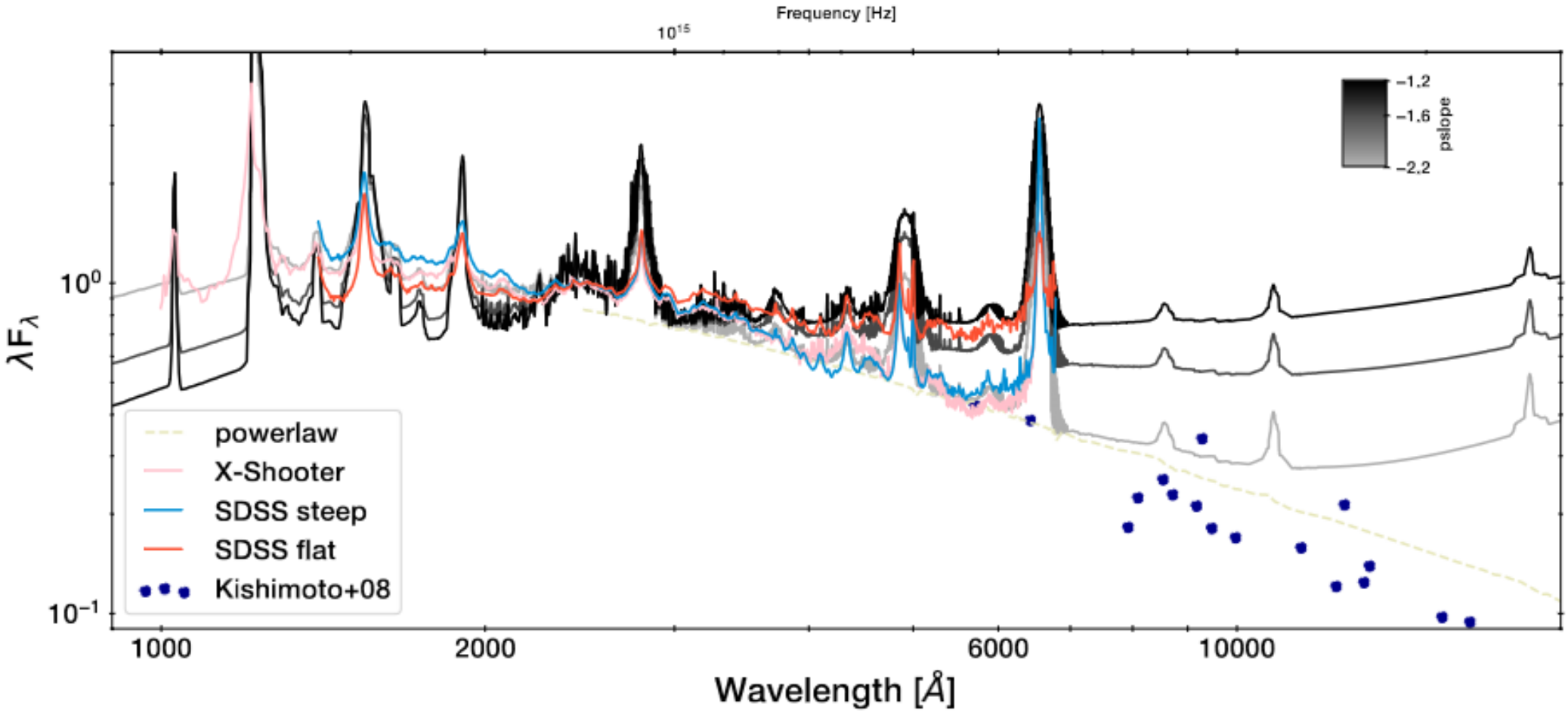
GRAHSP AGN model components

- flexible, empirical AGN model + model uncertainty
- state-of-the-art Bayesian inference engine UltraNest,
  scales to large samples and many parameters



+ SMC-like nuclear reddening

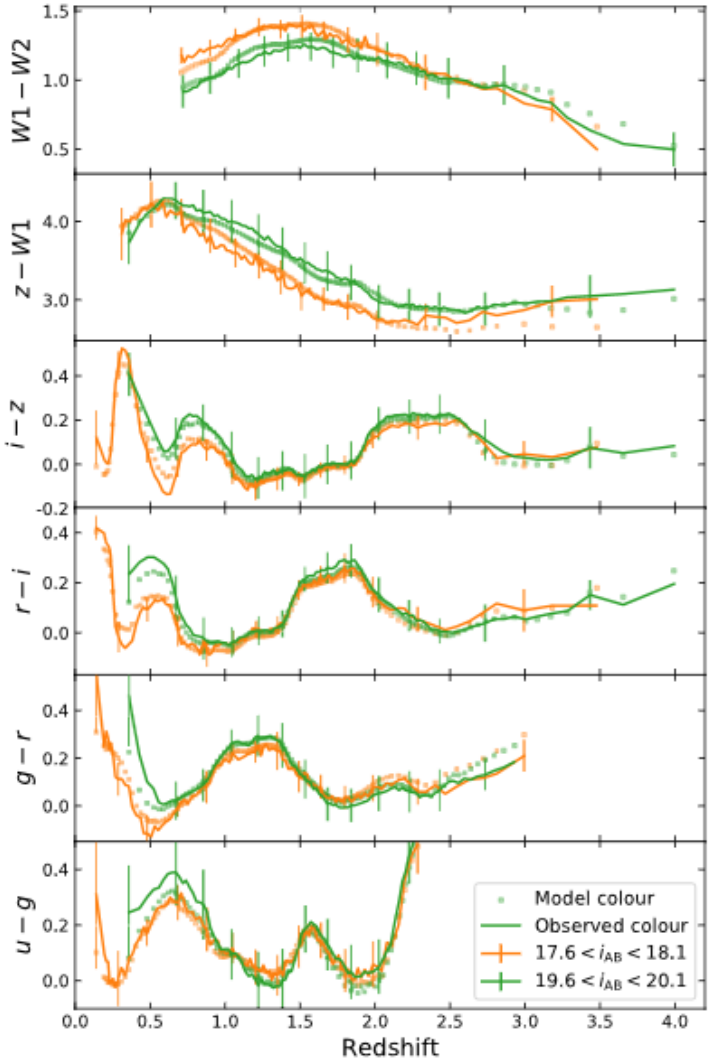
Test #1: quasar spectra



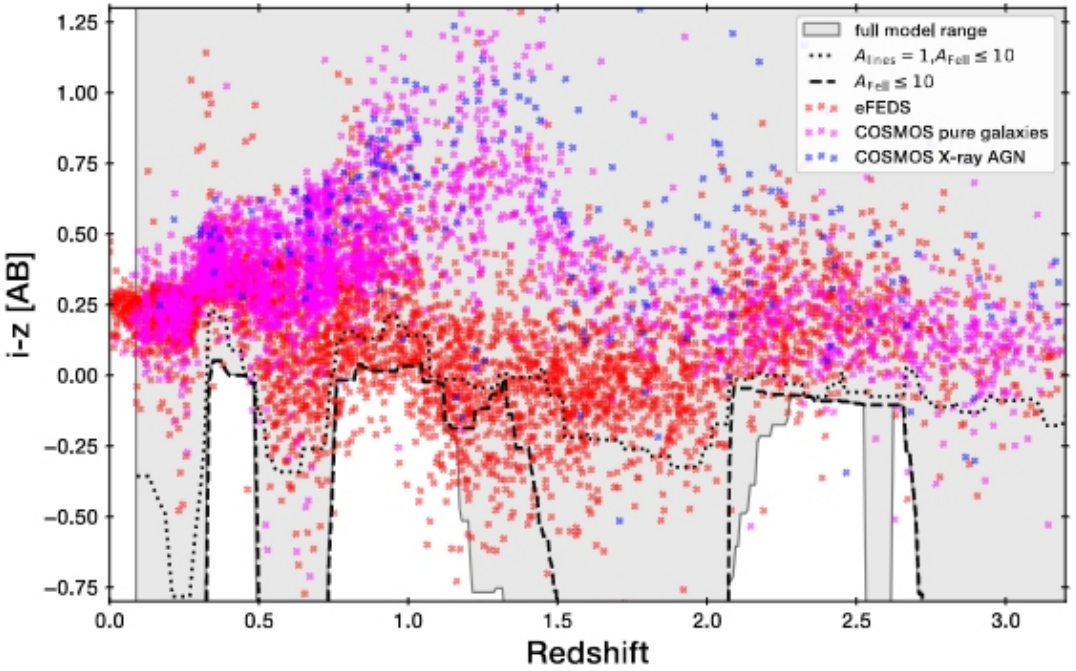
Test #2: colors

Average colors of quasars?

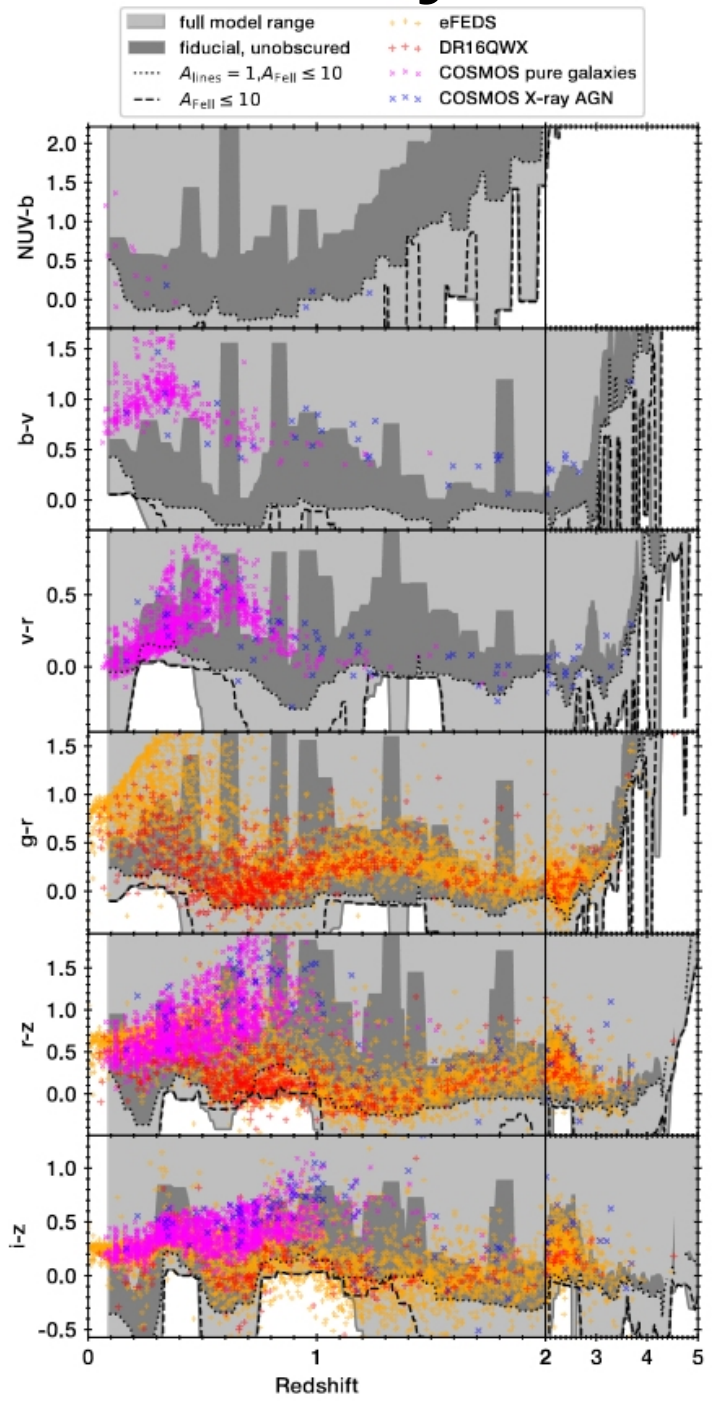
Temple, Hewett & Banerji 2023

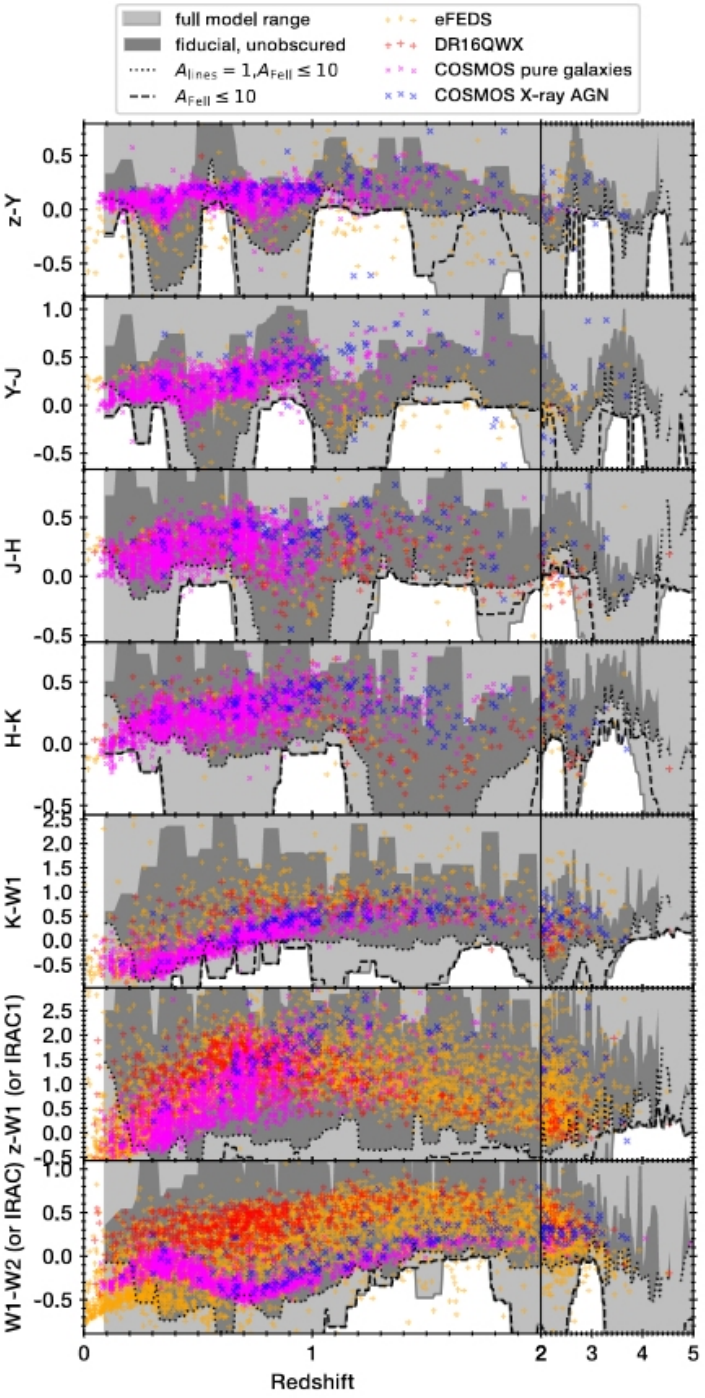


Diversity of colors of AGN & galaxies



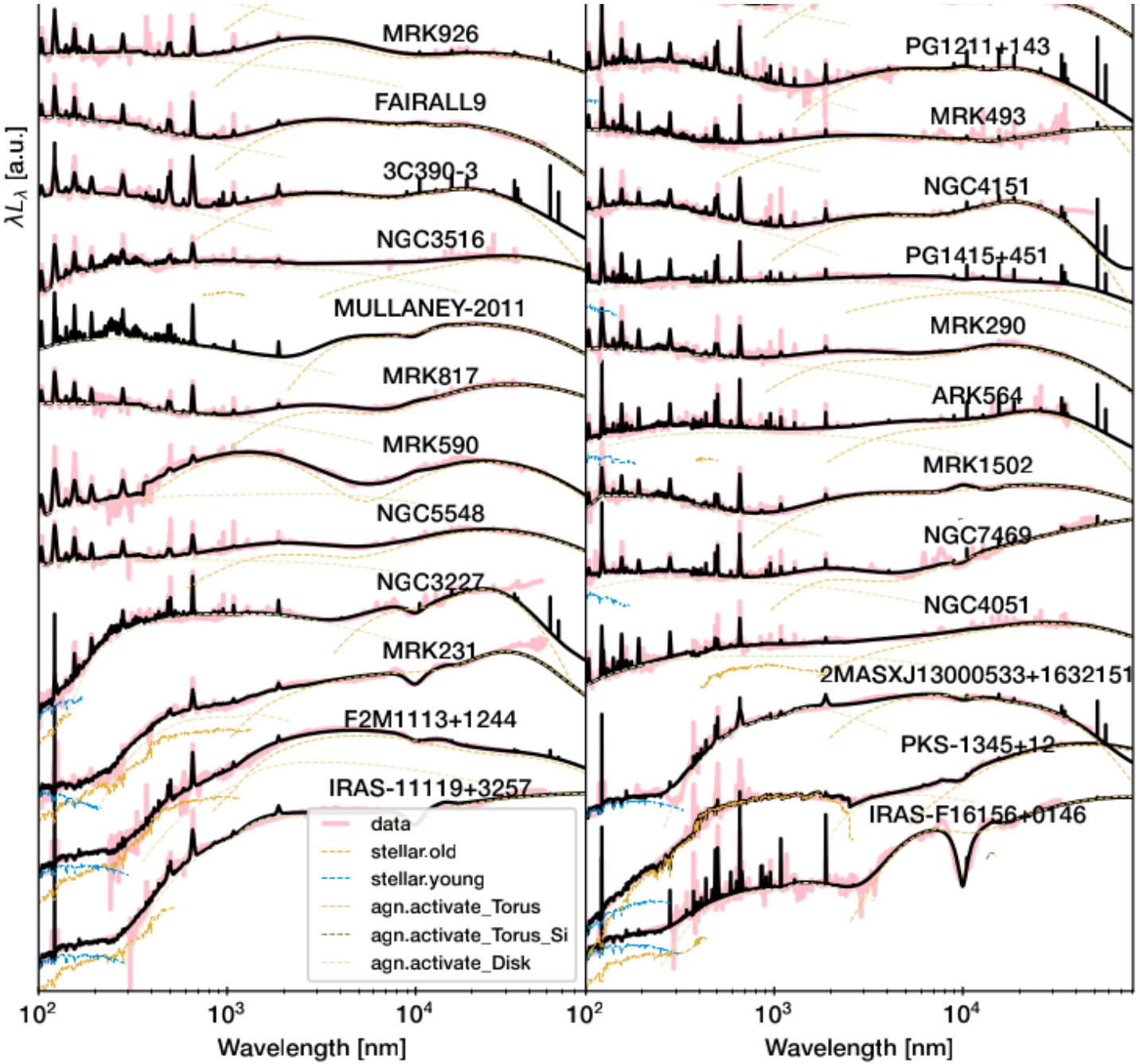
Test #2: full diversity of colors

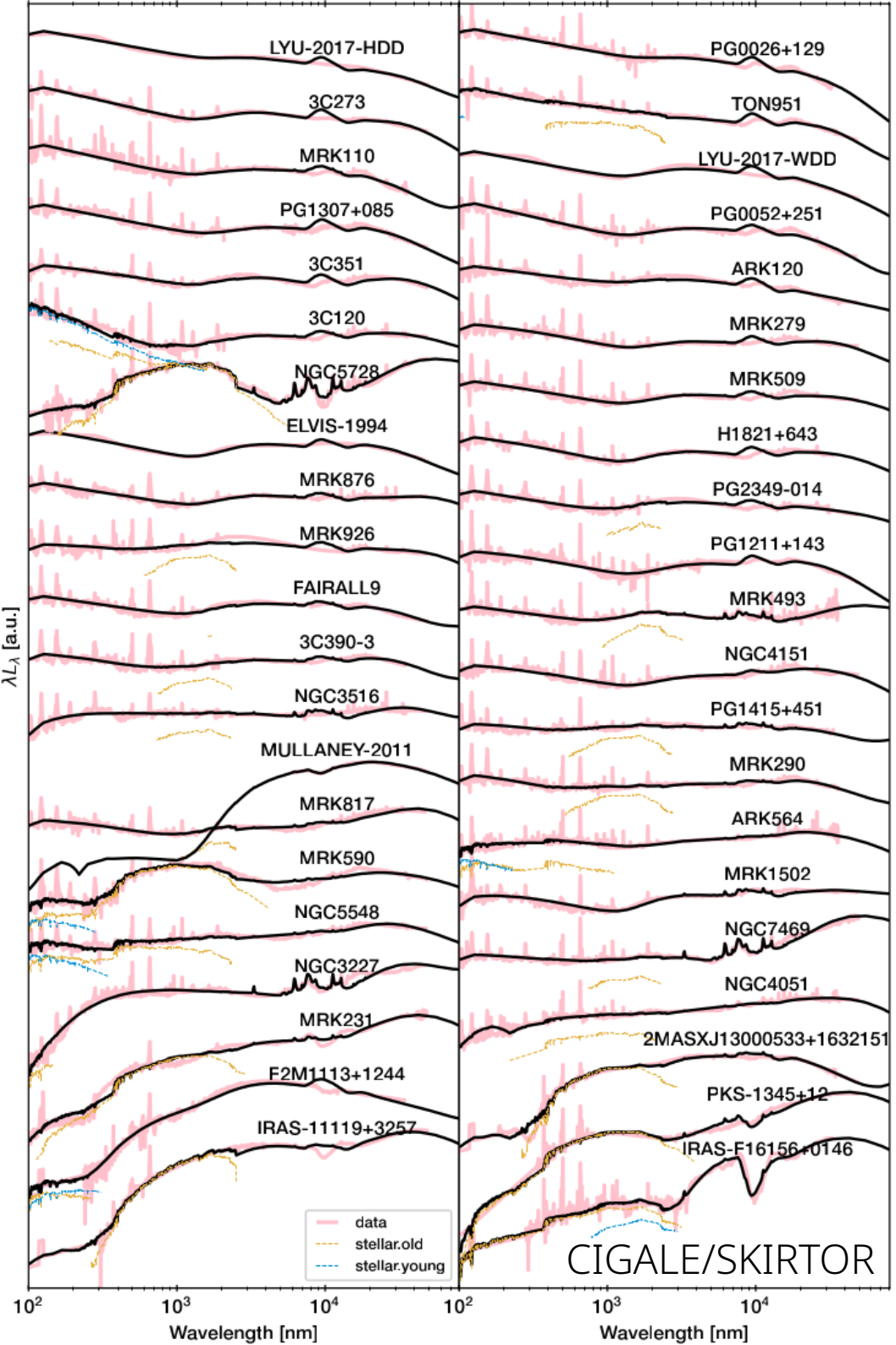




Test #3: Brown AGN SED Atlas

- Compilation of spectra and photometry
- Extinction-corrected, aperture-corrected

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3C351
3C120
NGC5728
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MRK876
MRK926
FAIRALL9
3C390-3
NGC3516
MULLANEY-2011
MRK817
MRK590
NGC5548
NGC3227
MRK231
F2M1113+1244
IRAS-11119+3257
PG0026+129
TON951
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MRK493
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MRK1502
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IRAS-F16156+0146
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stellar.young
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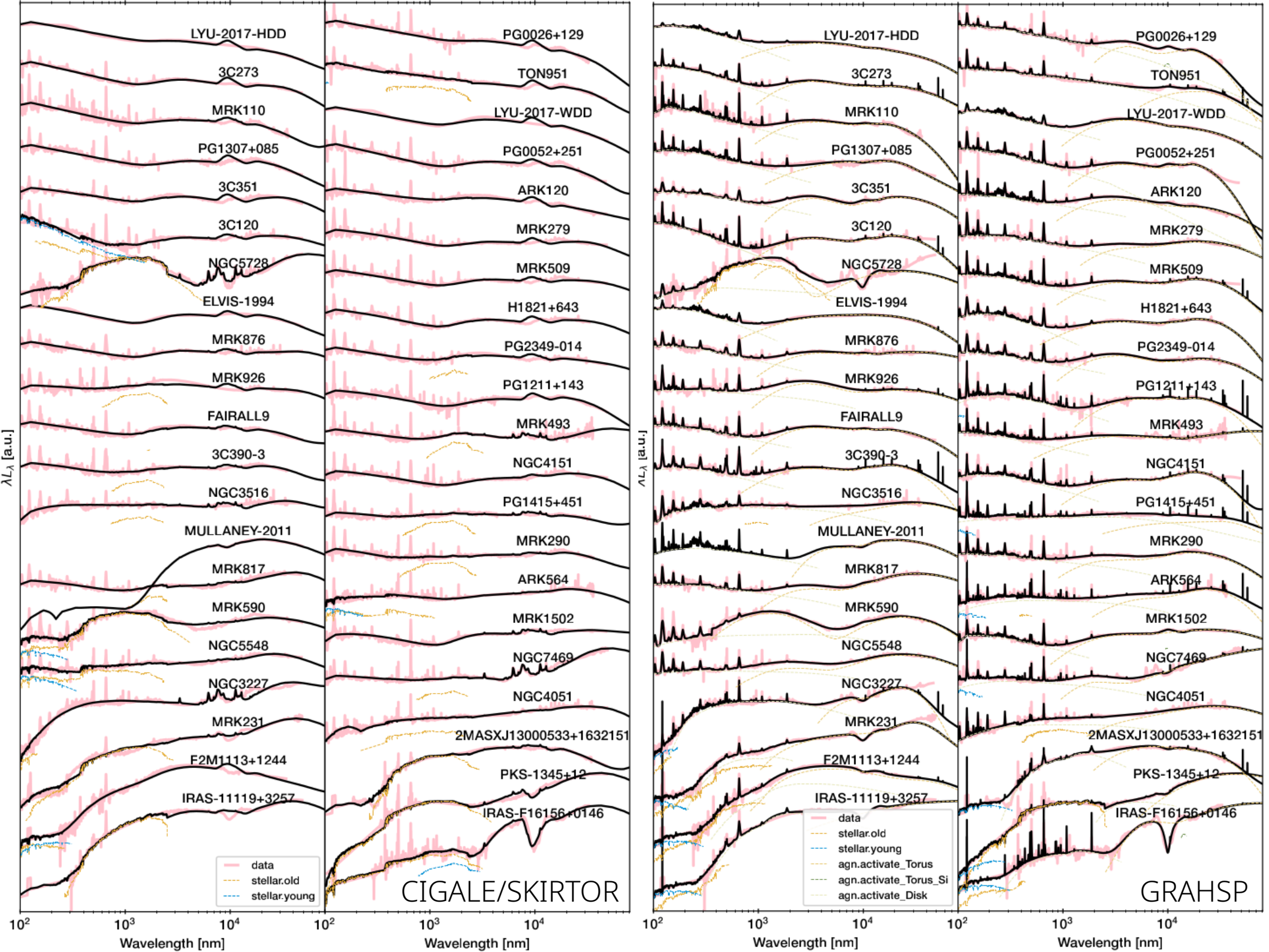
Wavelength [nm]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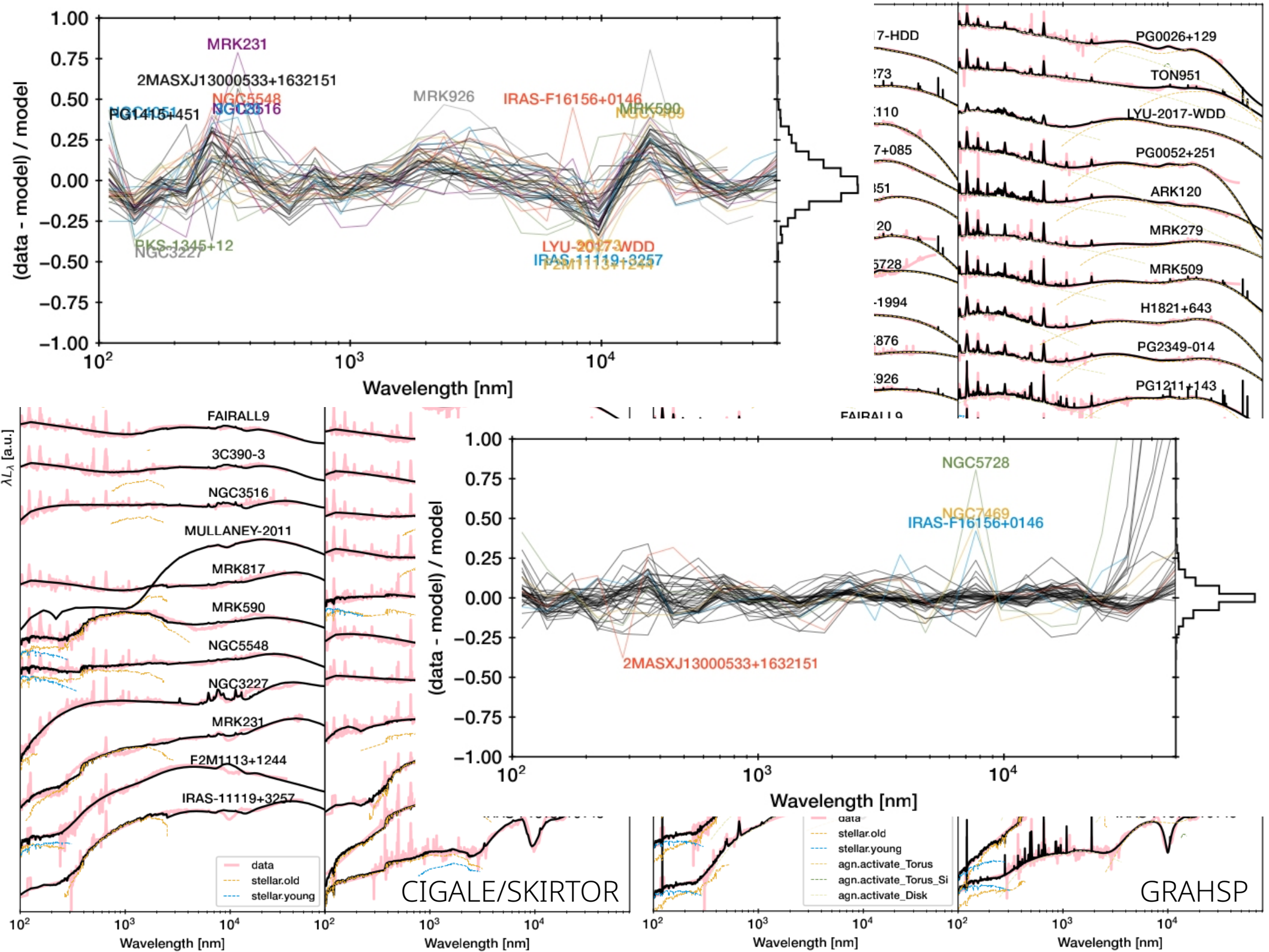
Wavelength [nm]
10^2
10^3
10^4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Wavelength [nm]
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