A pan-chromatic study of cosmic evolution of AGN using JWST

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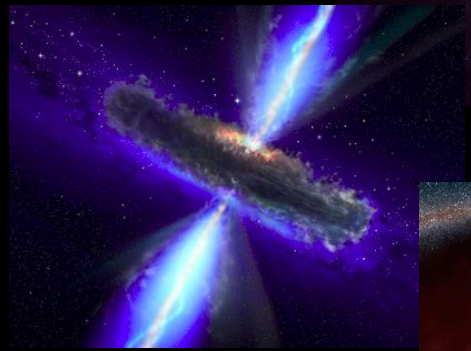
Background Image: NASA/JPL-Caltech

Talk outline

- Aim of the project
- Observations
  - Overview of JWST
  - Sample selection
  - Ancillary data
- Modelling
  - Model definitions
  - Fitting framework
- Results
- Conclusions and future work

R. Thompson (University of Arizona)

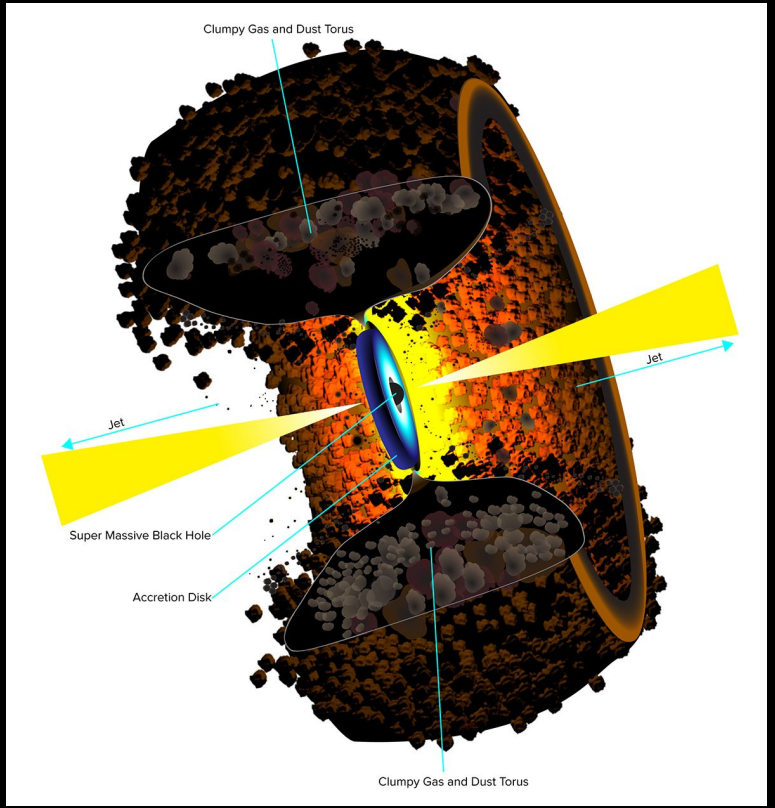


AVO project and Paolo Padovani

NASA/JPL-Caltech

What is an AGN?

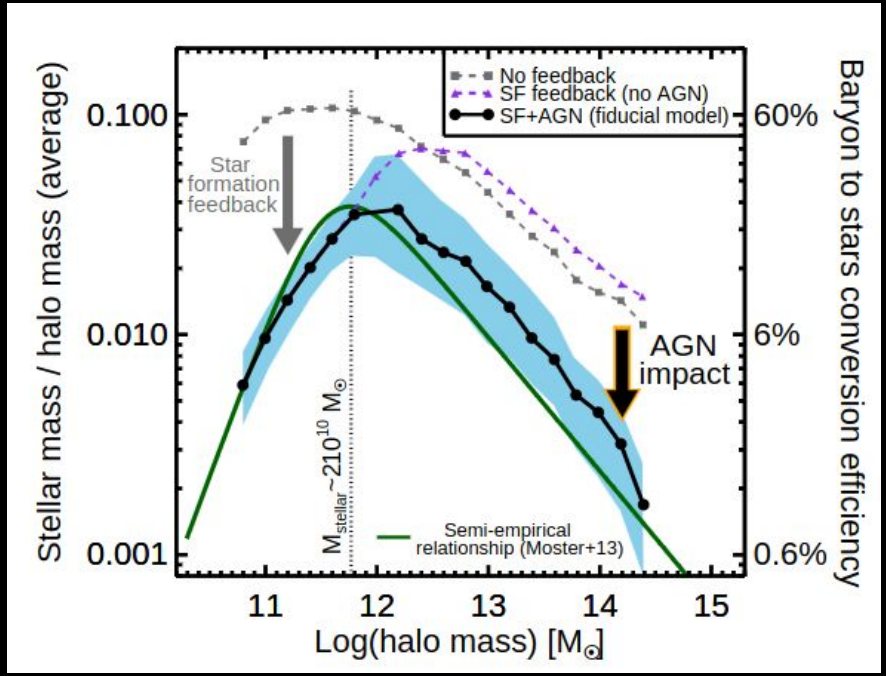
- Accreting supermassive black hole at the centre of most galaxies.
- Discovered nearly 100 years ago.
- Simple models had only a few parameters like luminosity.
- Unified model: Various observed types of AGN are result of the viewing angle of the observer.
- Accretion disk and dusty torus.



B. Saxton NRAO/AUI/NSF

Why do we care about AGN?

- Inject energy into surroundings.
- AGN feedback necessary to reproduce the observed properties of galaxy populations.
- Affect star formation rate.
- Main component of Cosmic X-ray Background (CXB)

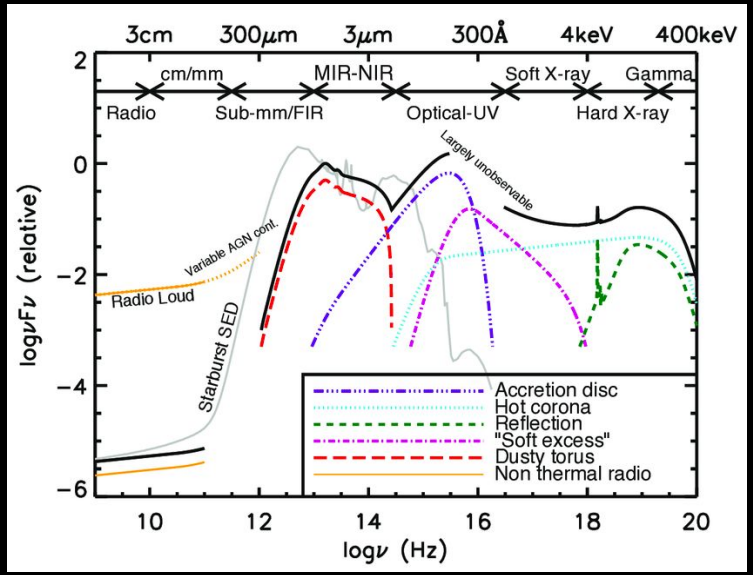


Harrison, 17

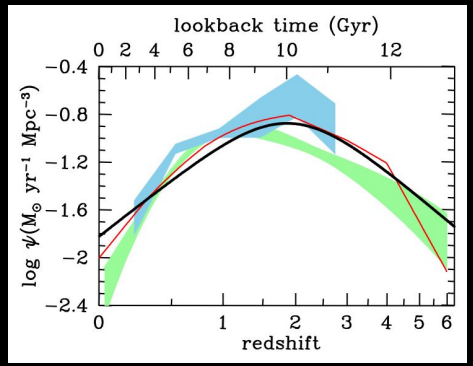
Questions

- How do AGN properties evolve with redshift?
  - Luminosity
  - Amount of obscuration
  - Geometry of obscurer

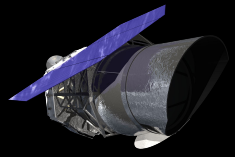
- What kind of observations should you make to constrain these properties?

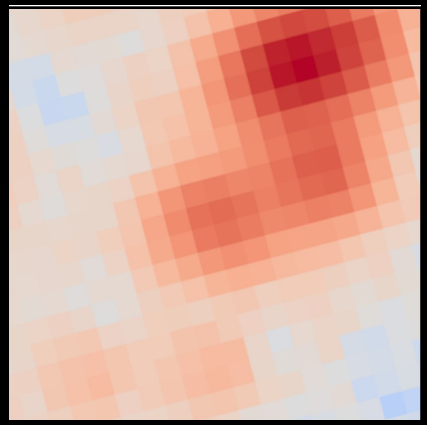


Harrison, 14

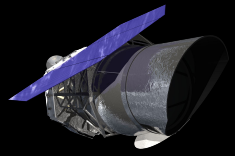


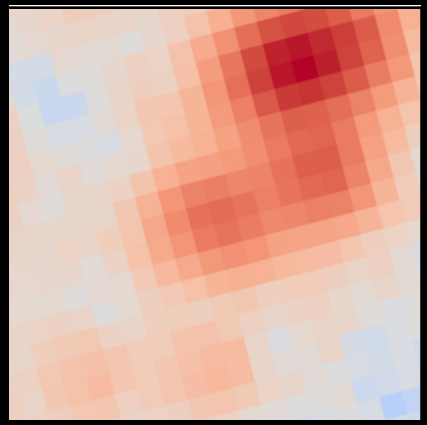
Madau & Dickinson, 14

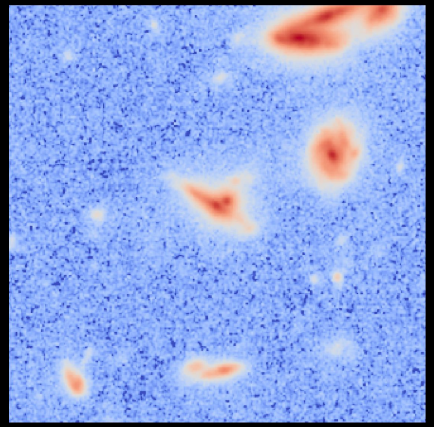




IRAC 3.6μm image

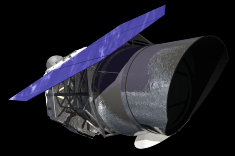


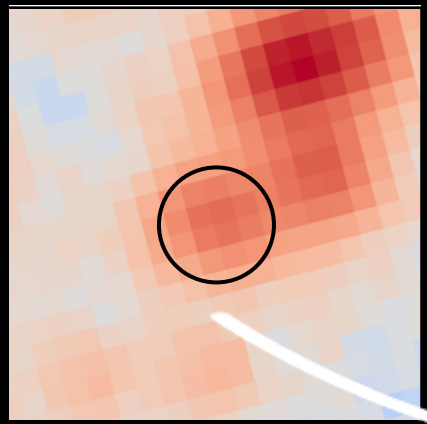


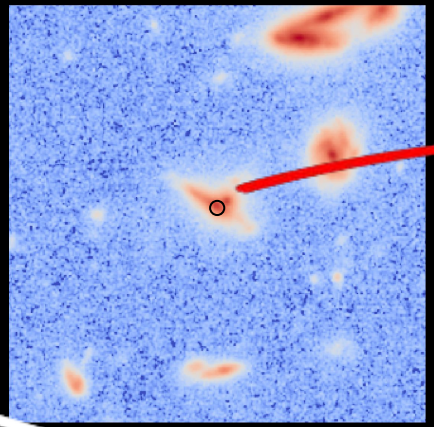


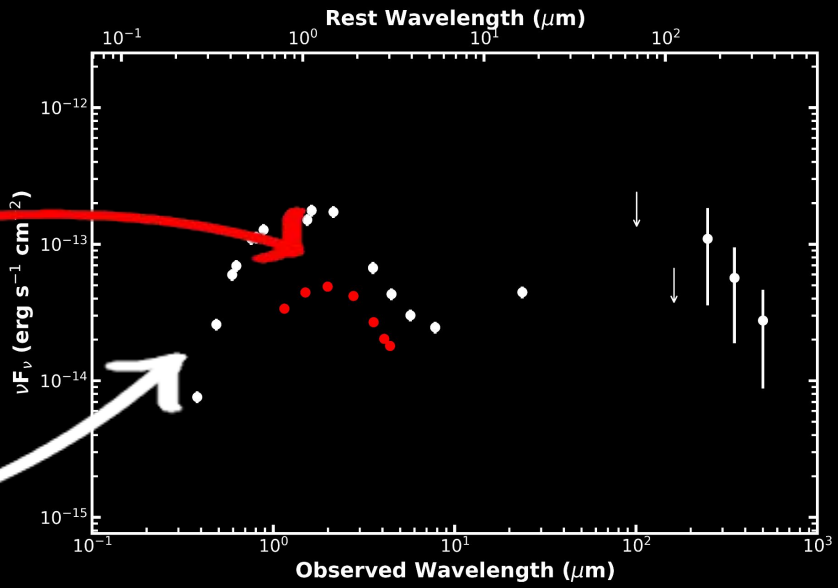
IRAC 3.6μm image

NIRCam 3.56μm image









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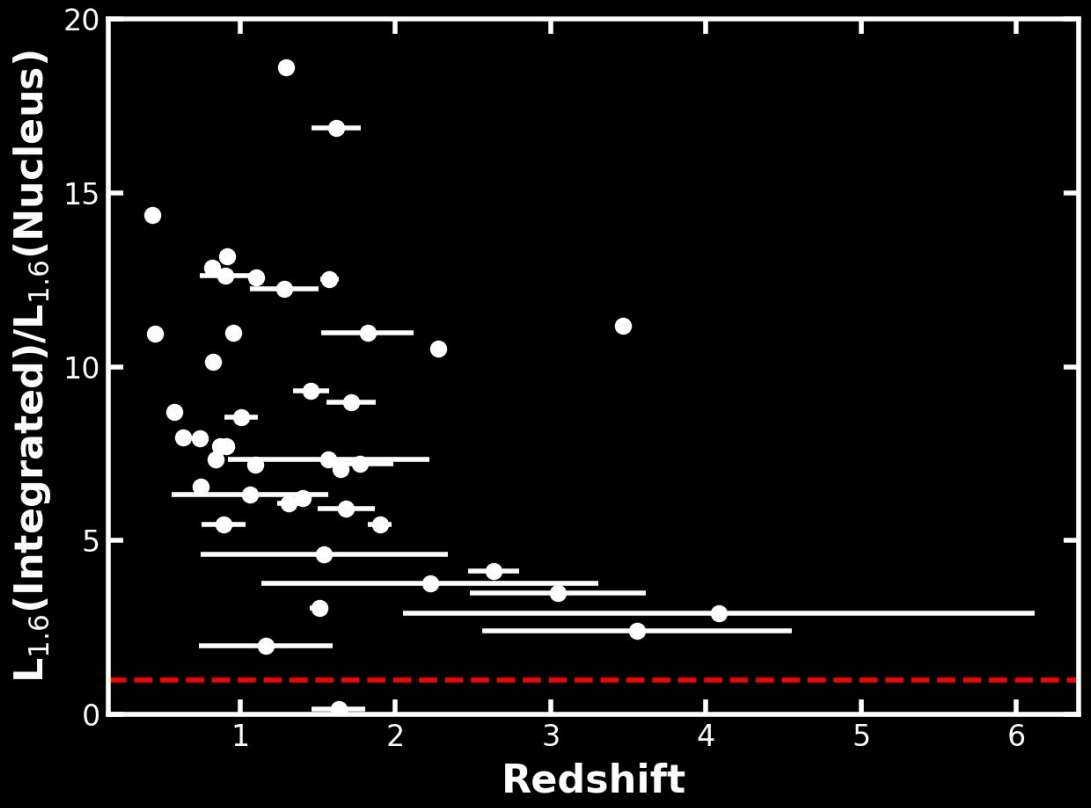
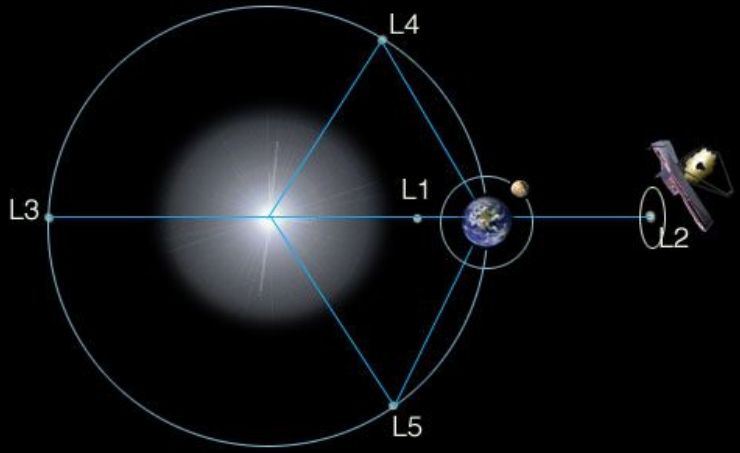
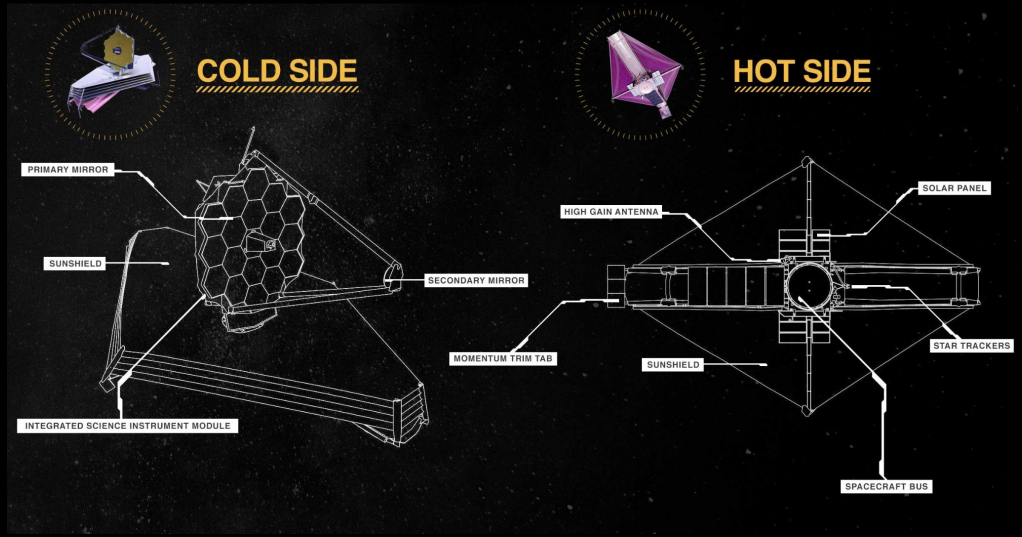
NIRCam 3.56μm image


20
15
10
5
0
1
2
3
4
5
6
Redshift
L1.6(Integrated)/L1.6(Nucleus)

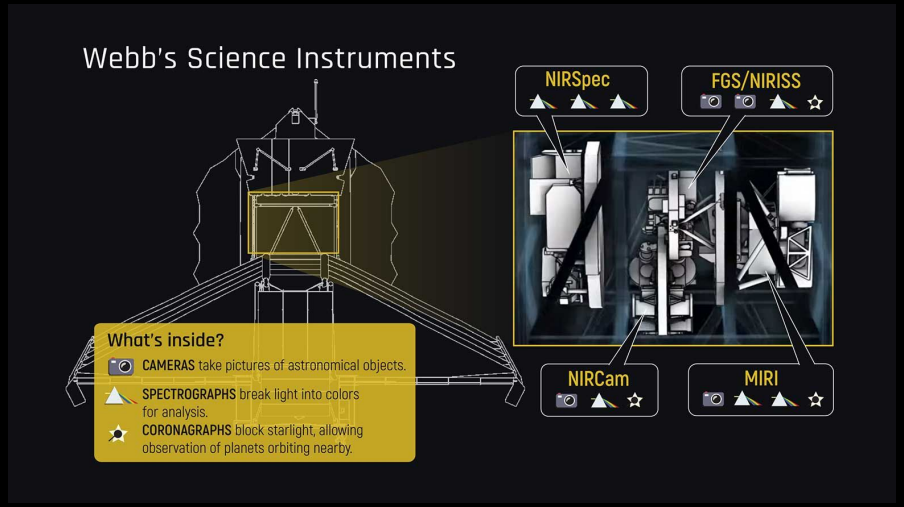
Overview of JWST

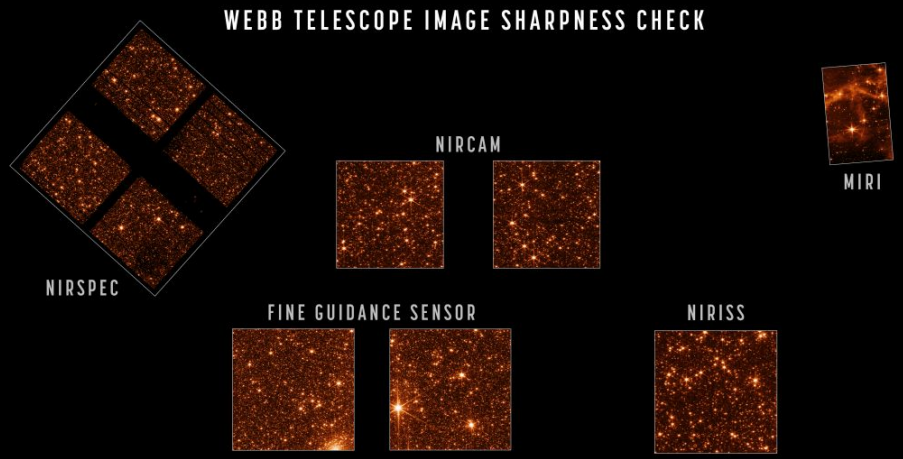
Where is JWST?

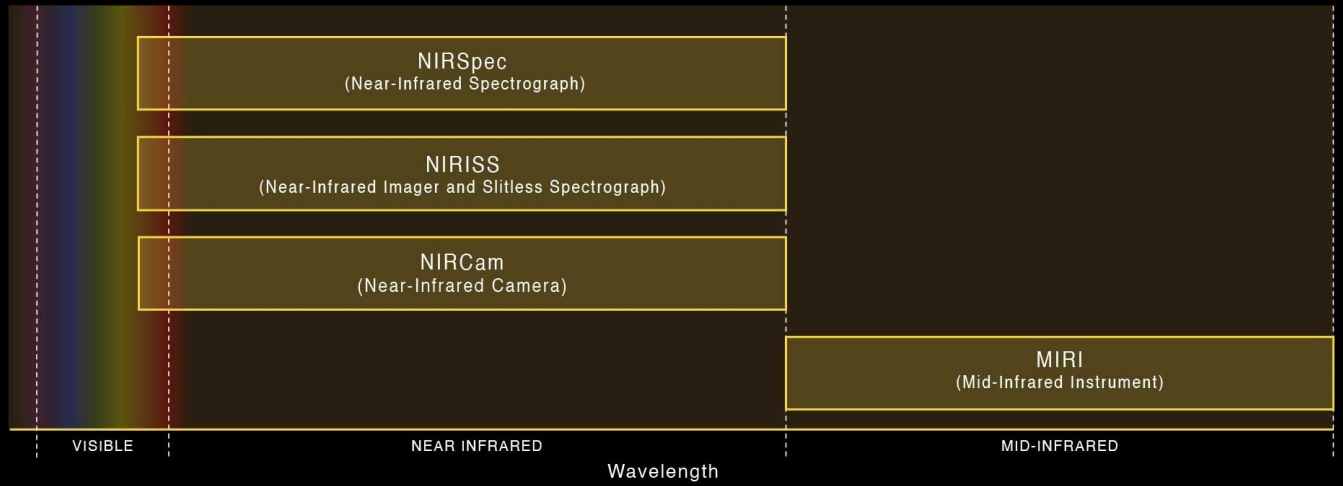




Credit: STScI



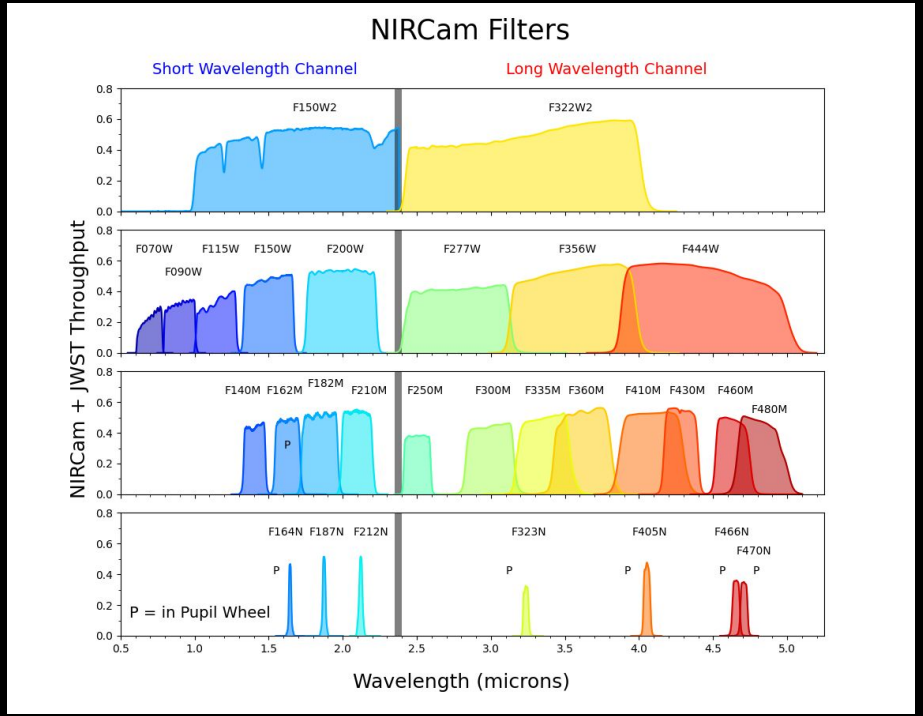




Credit: STScI

NIRCam

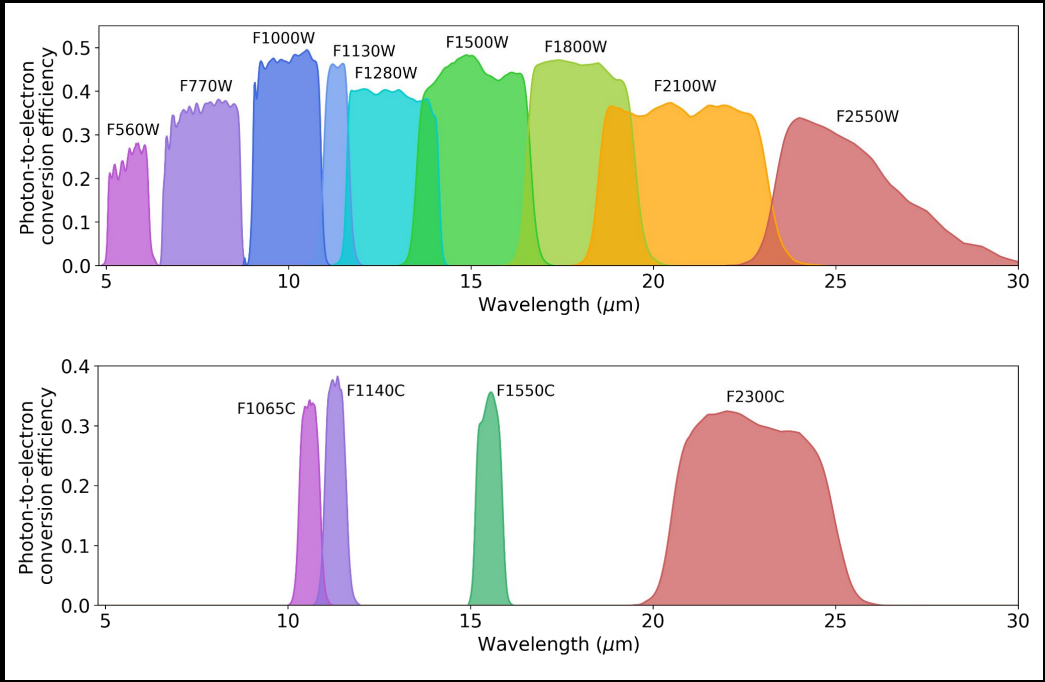
- Two imaging modules
- Operating range: 0.6 to 5.0 μm
- Total area: 9.7 arcmin^2
- Resolution: 0.07” at 2 μm
- 29 filters divided between SW and LW
- Slitless GRISM spectroscopy resolution: R ~ 1600 at 4 micron



Credit: JDox

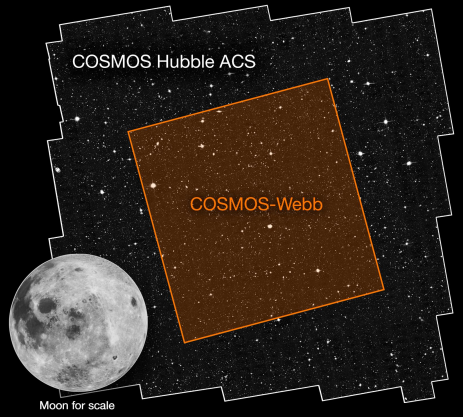
MIRI

- Operating range: 4.9 to 27.9 μm
- Total area: 2.3 arcmin^2
- Resolution: 0.11”
- 13 filters
- Slitted and slitless spectroscopy ~100 at 7.5 μm
- IFU spectroscopy



Doing science with JWST

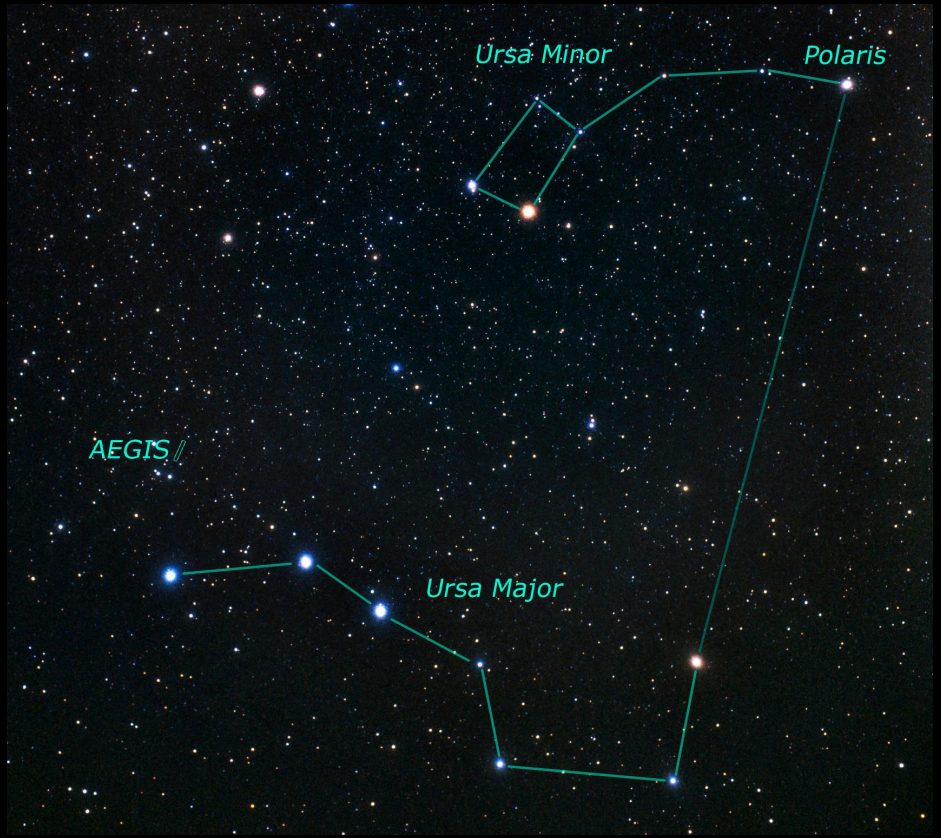
- MAST portal for accessing raw files: https://mast.stsci.edu/portal/Mashup/Clients/Mast/Portal.html
- JDox for user documentation: https://jwst-docs.stsci.edu/
- Existing large public surveys:
  - CEERS (AEGIS/EGS)
  - COSMOS-Web (COSMOS. Largest so far!)
  - JADES (GOODS-N and GOODS-S)
  - PRIMER (COSMOS and UDS field)
- Call for cycle 4 later this year (?)

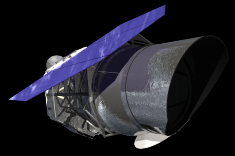


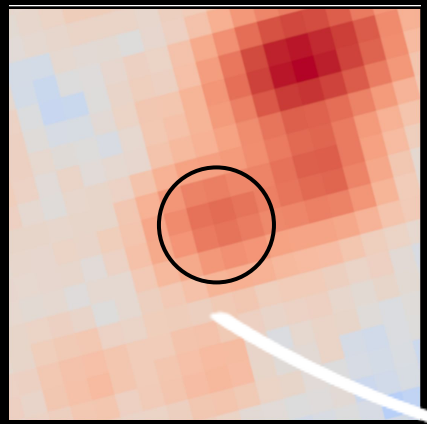
JADES JWST ADVANCED DEEP EXTRAGALACTIC SURVEY

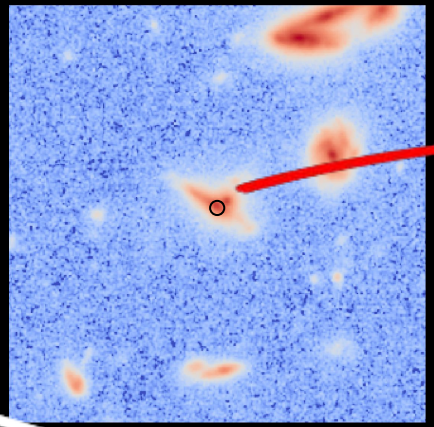
Cosmic Evolution Early Release Science Survey
CEERS

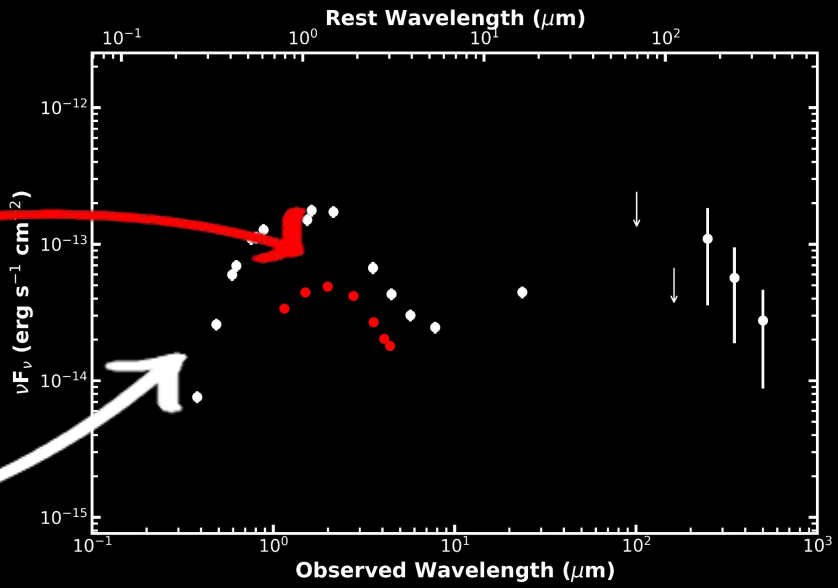
Sample selection









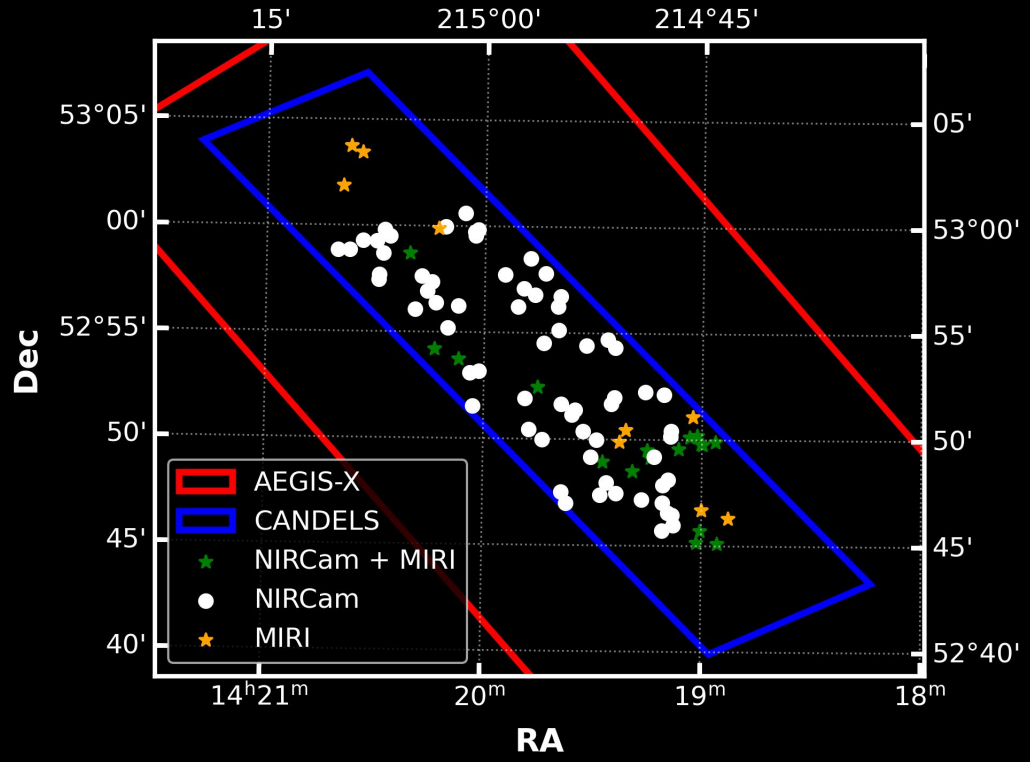


IRAC 3.6μm image

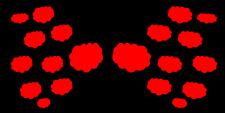
NIRCam 3.56μm image

Our sample

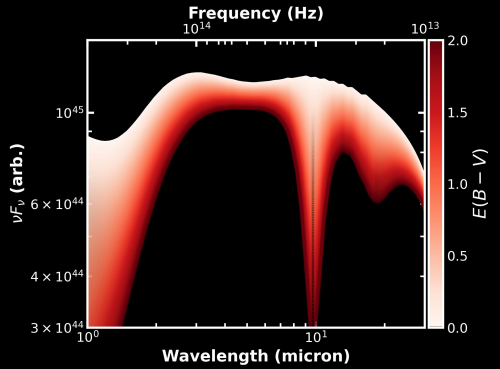
- Extended Groth Strip (EGS)
- JWST coverage due to CEERS
- Ancillary data
  - X-ray: AEGIS-X
  - UV-Optical: CANDELS
  - Far-IR: HELP
- 92 sources: 66 NIRCam, 9 MIRI, 17 both
- X-ray luminosity > 10^{42} erg/s
- $0.4 < z < 3$



Modelling

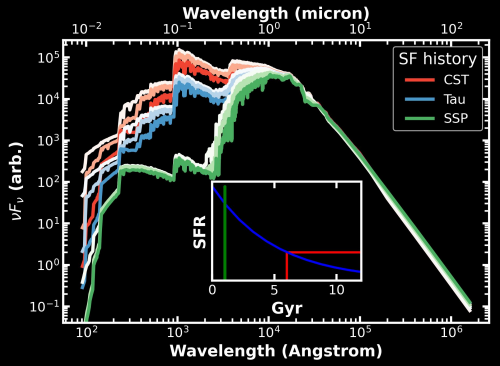


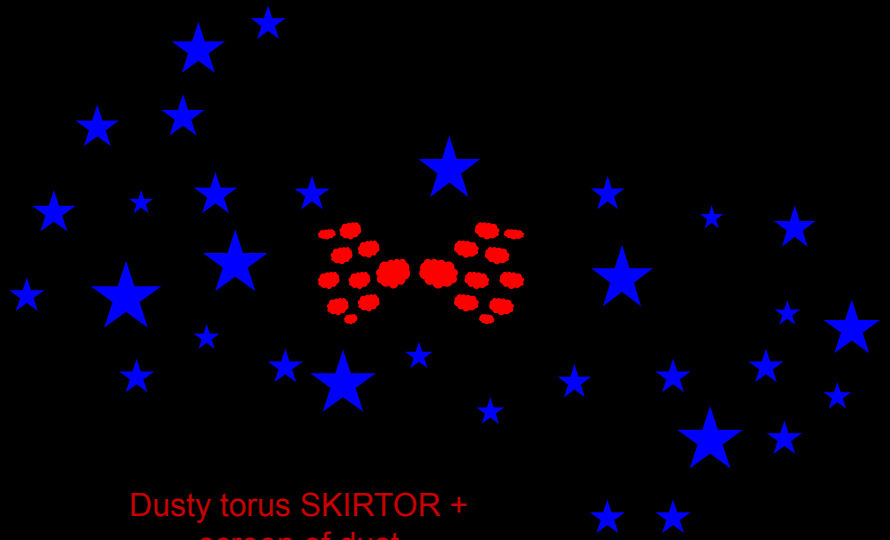
Dusty torus SKIRTOR +
screen of dust



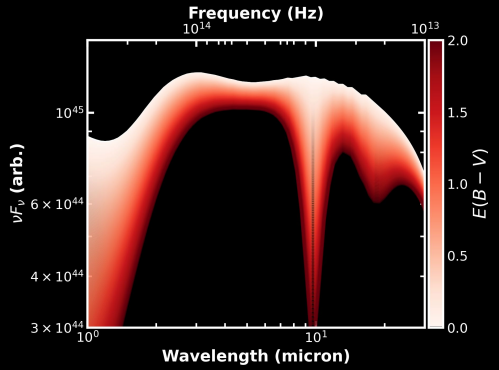
*not to scale

Stellar population with exponentially decaying SFR + attenuation



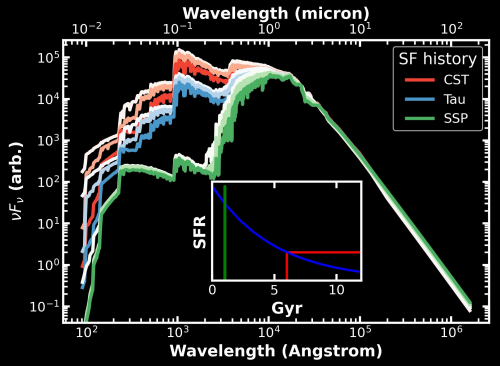


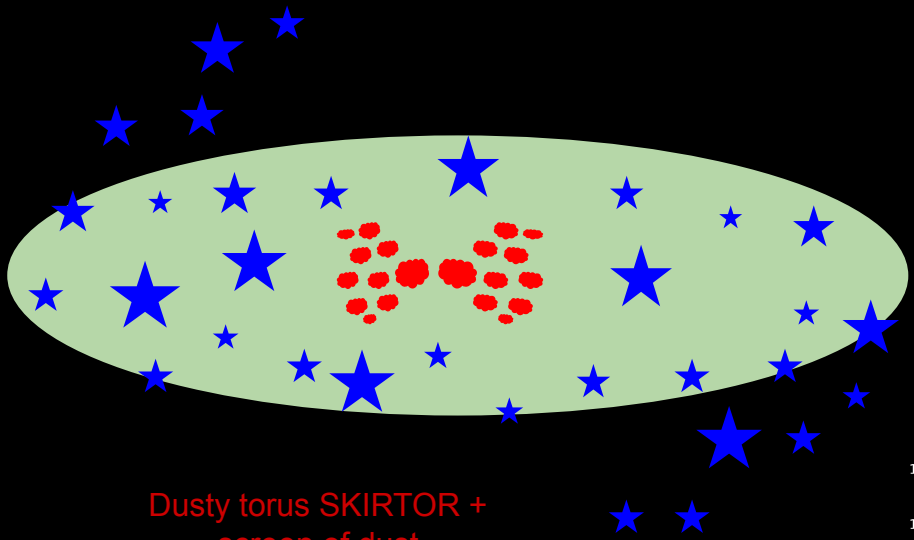
Dusty torus SKIRTOR + screen of dust



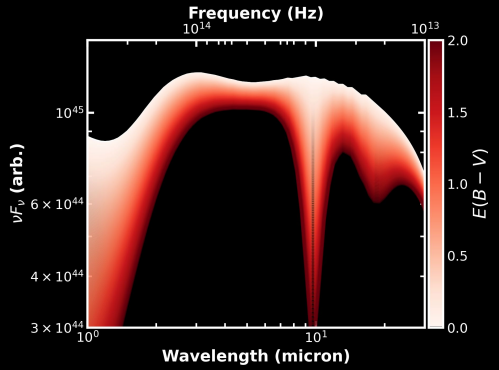
*not to scale

Stellar population with exponentially decaying SFR + attenuation

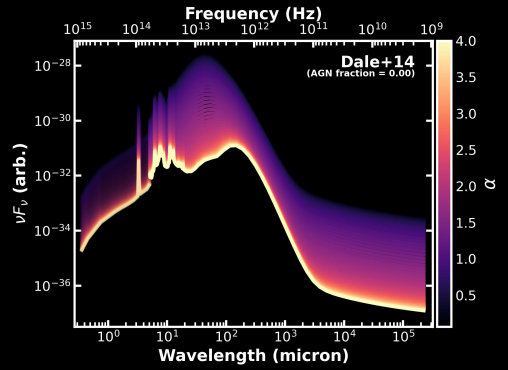




Dusty torus SKIRTOR + screen of dust



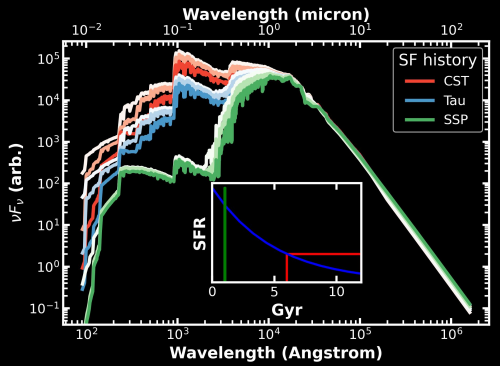
Warm Galaxy Dust emission with a variety of dust temperatures

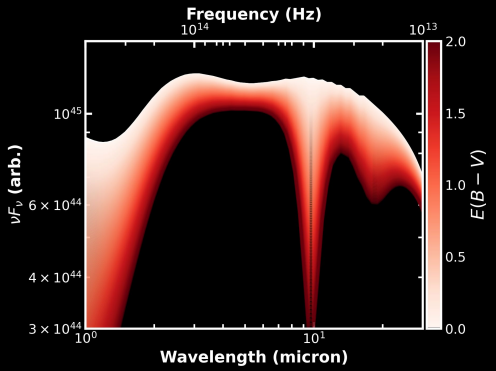


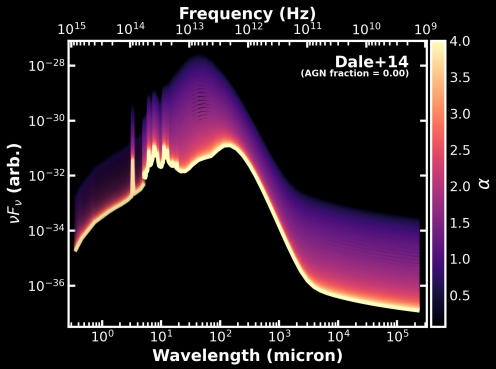
*not to scale

FortesFit (users, testers, developers welcome!)

- Flexible SED fitting with Bayesian backbone.
- Models are first “registered” by the user.
  - Calculate SED given a set of parameters, filters, and redshift
- Models are described by a number of “shape parameters” and a single “scale parameter”
- Scale parameters very useful for derived quantities or dependencies
- Priors can be specified using scipy distributions or histograms. P(z) can be a prior but not a photometric redshift fitter.
- Powerful Bayesian inference engine MultiNest (upgrade to Ultranest coming soon!)







Scale parameter: Stellar mass
Shape parameters:
> log(age)
> log(timescale)
> E(B-V)

Scale parameter: L2500
Shape parameters:
> opening angle (oa)
> inclination (i)
> optical depth (t)
> Rout/Rin
> Dust distribution (p & q)
> E(B-V)

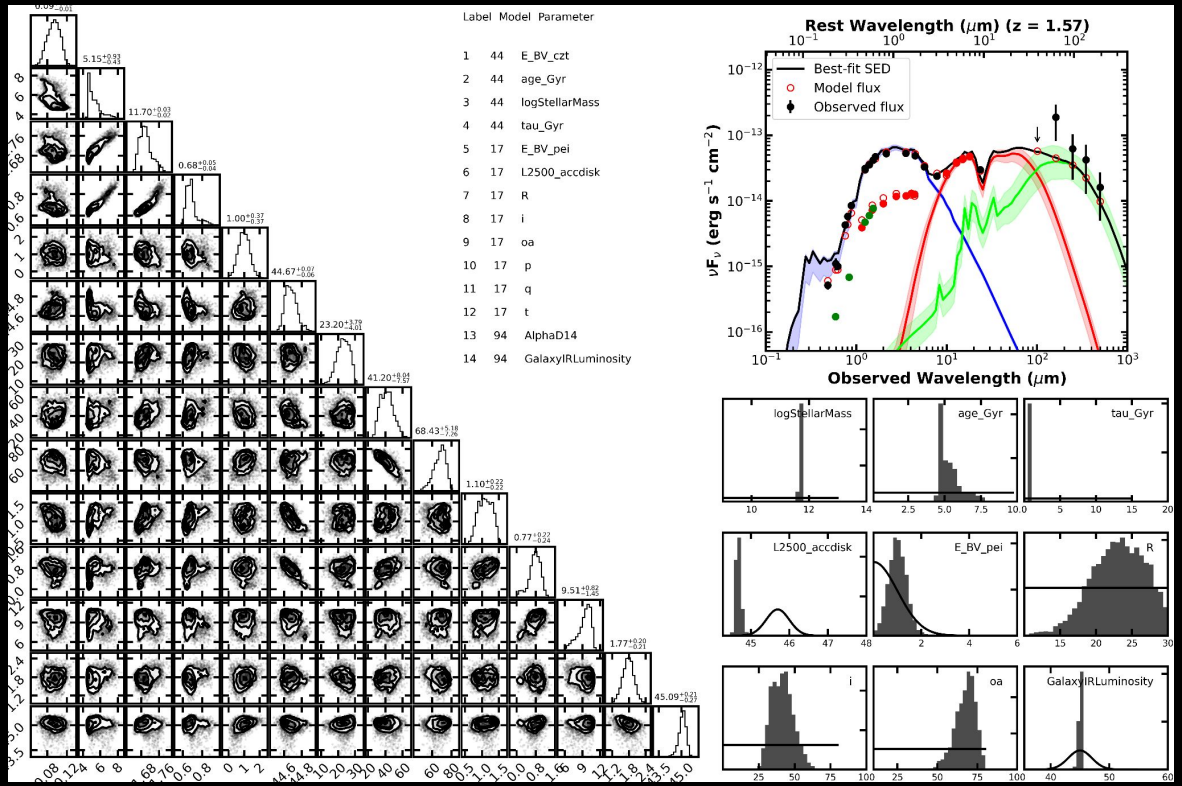
Scale parameter: Total IR lumin
Shape parameter:
> Dust temperature

https://skirtor.streamlit.app/

*not to scale

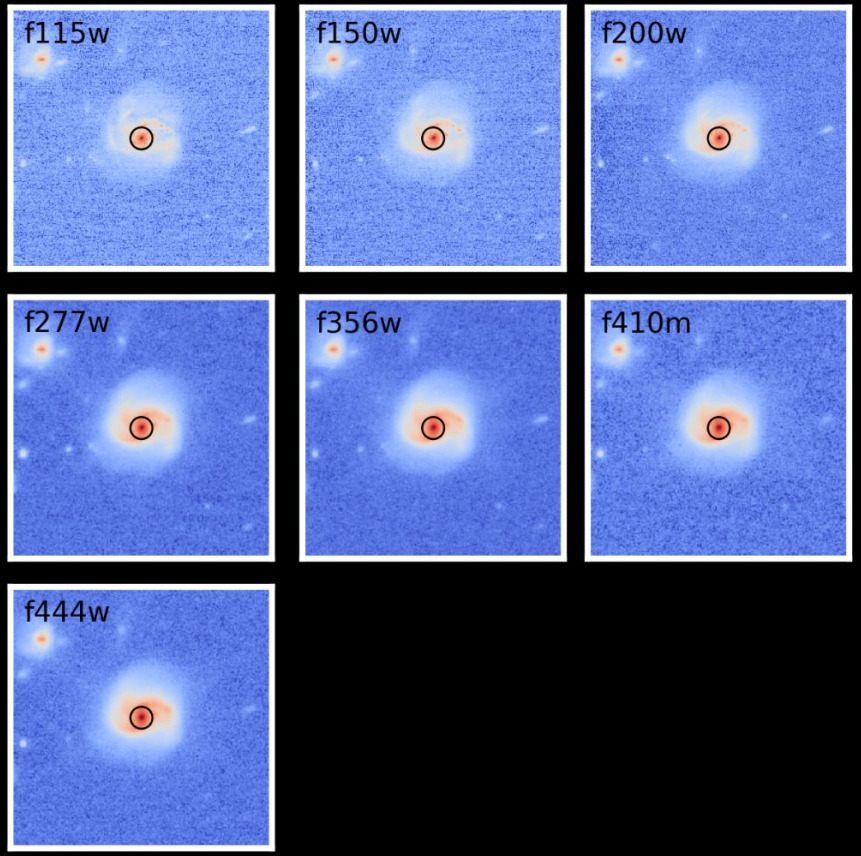
FortesFit (users, testers, developers welcome!)

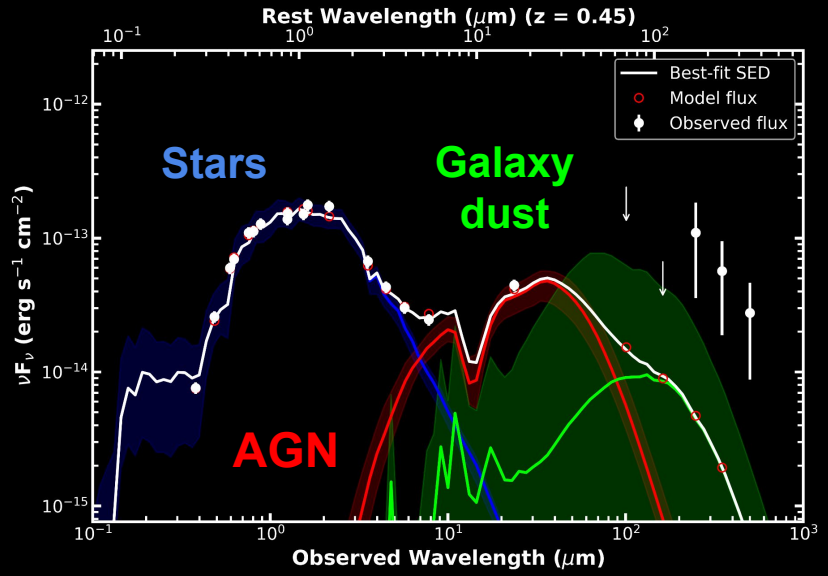
- Output stored in HDF5 format.
- Marginalized posteriors, SED plots, diagnostic information (summary statistics, KLD, evidence etc).



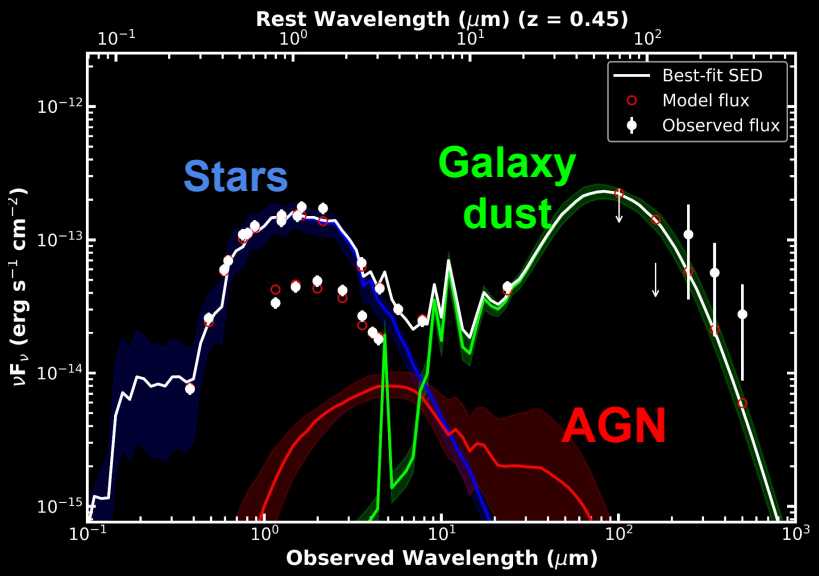
Results

(In prep.)



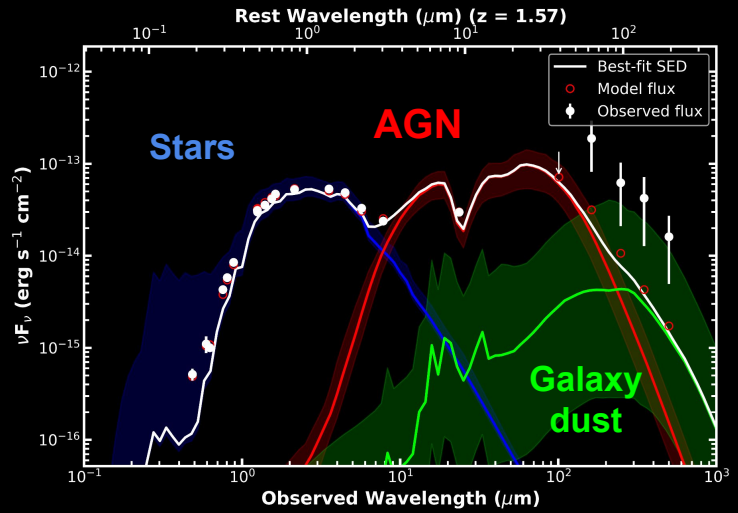


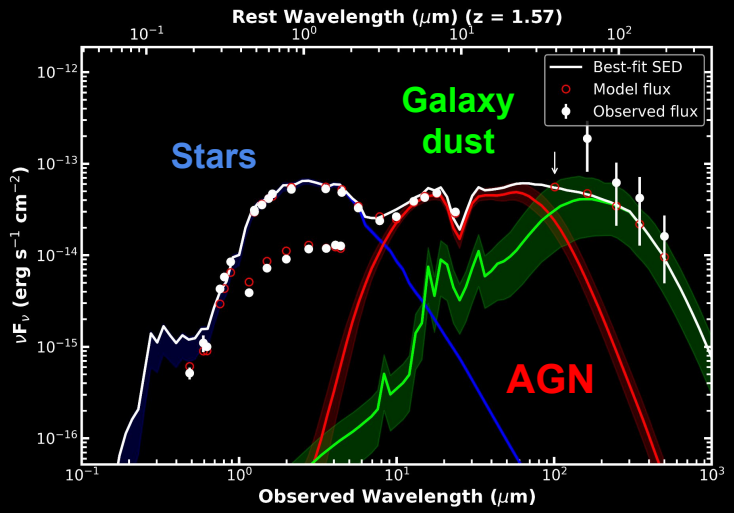
Without JWST

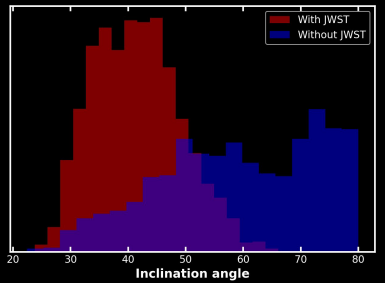


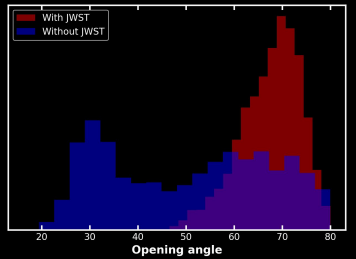
With JWST

Nuclear photometry using NIRCam (~1 micron to ~5 micron) is useful for tying down the AGN luminosity.







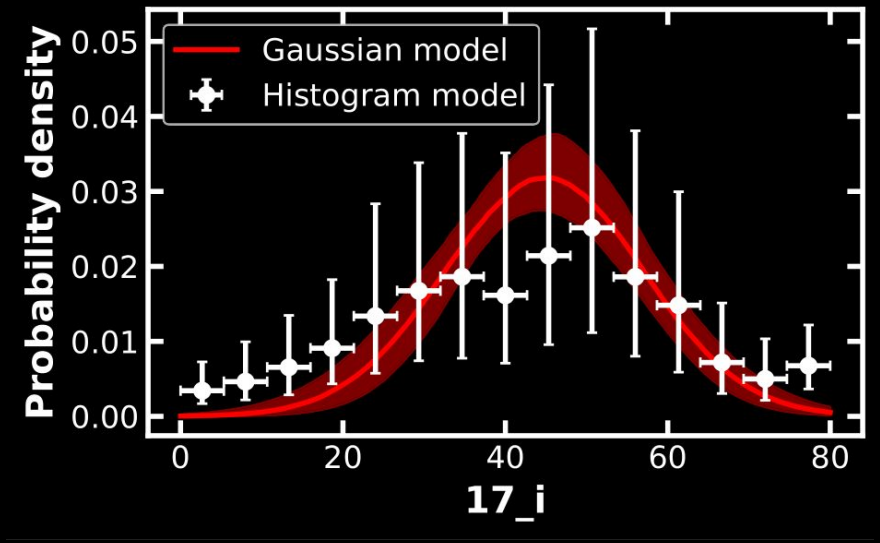


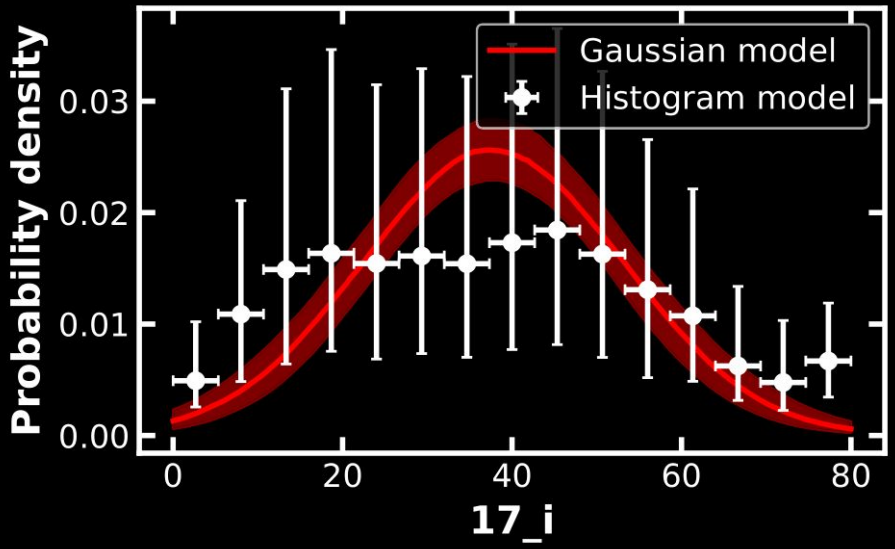
Without JWST

With JWST

MIRI photometry (~6 micron to ~21 micron) is crucial for inferring geometrical parameters of the torus.

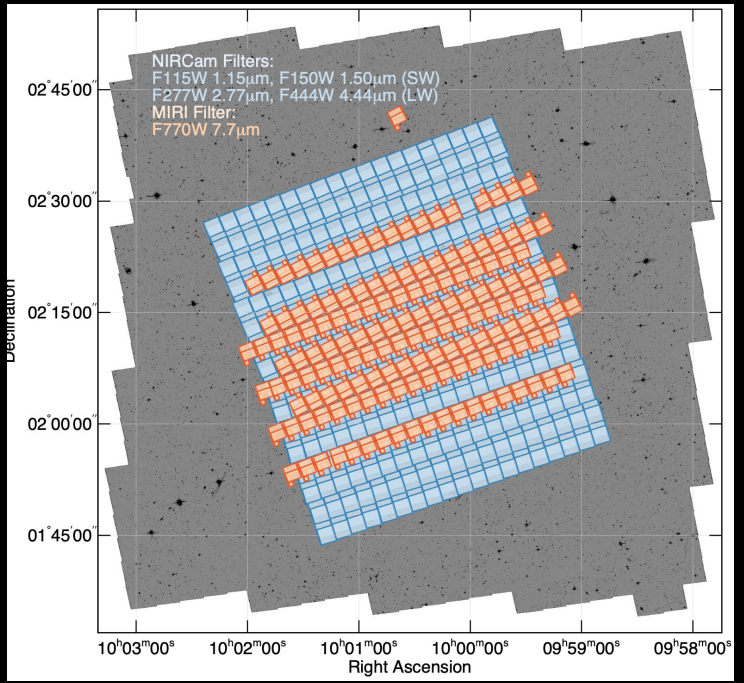
Population statistics





Summary and future direction

- First study looking at the resolved IR photometry of AGN sample at high redshifts using robust SED fitting framework.
- Significant gain to be made by adding JWST photometry but the importance of individual filters is unclear.
- Hierarchical Bayesian modelling to study evolution.
- Expand the study to a larger statistically significant sample using COSMOS.
- (Galaxy morphology/modelling?)



Footprint of the COSMOS-Web program
Casey+, 22

Newcastle University

Galaxy, AGN, and sonification group

Thank you!

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