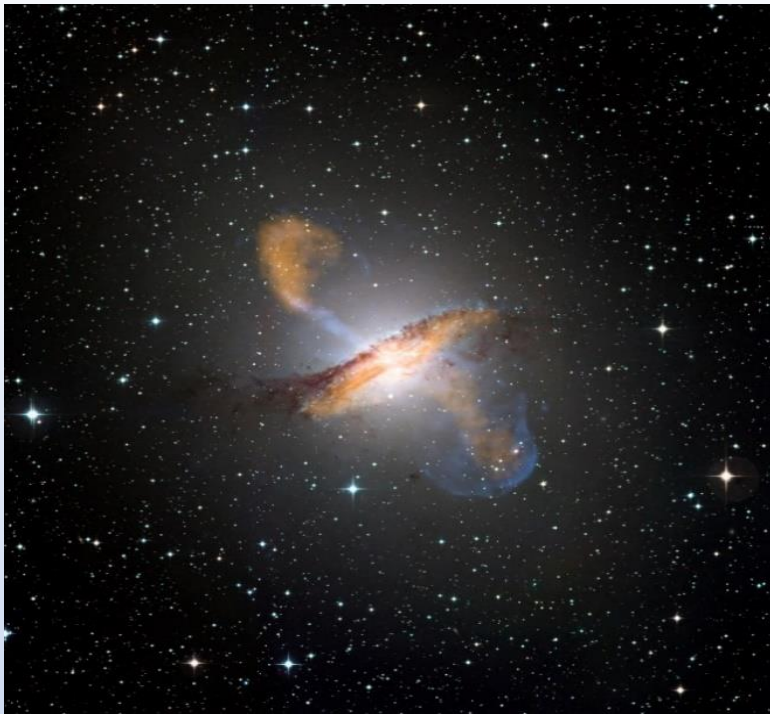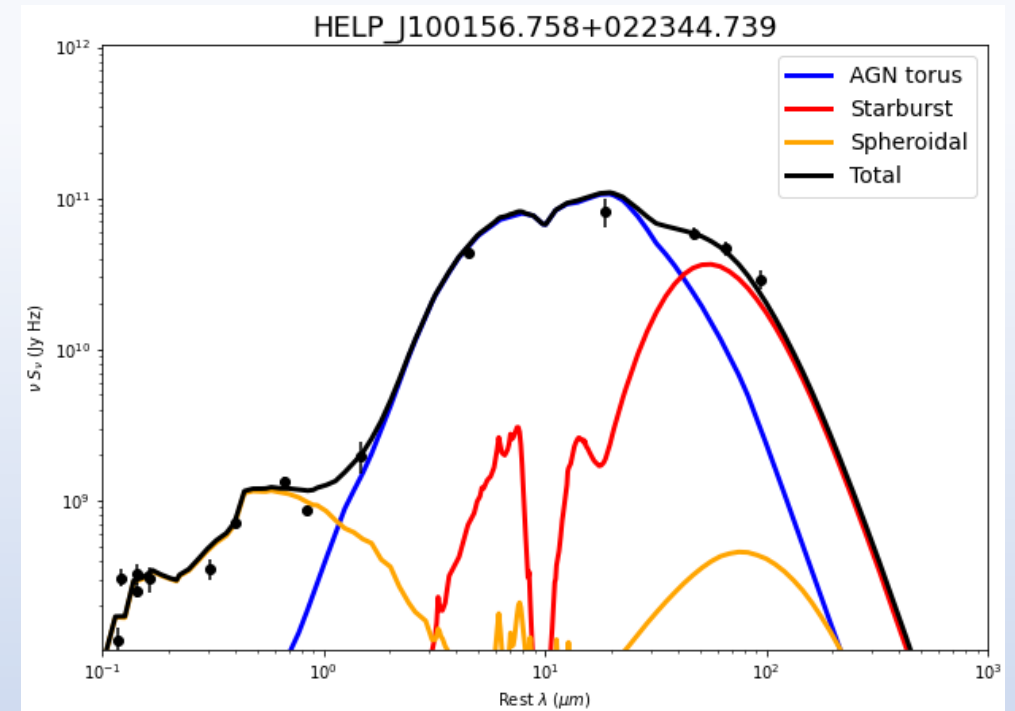# SMART

Charalambia Varnava

Two complementary ways of looking at galaxies:
Images (*left*) and Spectral Energy Distributions or SEDs (*right*)

Nearby radio galaxy Centaurus A

SED of an obscured hyperluminous quasar at z~4.3 (Varnava & Efstathiou, 2024)

SMART: Spectral energy distributions Markov chain Analysis with Radiative Transfer models

- A new Markov chain Monte Carlo (MCMC) SED fitting code, which fits SEDs *exclusively* with radiative transfer models. Available at: **https://github.com/ch-var/SMART**

- Takes comparable time to popular SED fitting methods based on energy balance (e.g. CIGALE, Noll et al. 2009; Boquien et al. 2019)

- Can be used to fit the SED of a galaxy at any redshift

- Promises to be very useful for analysing multiwavelength SEDs of galaxies and obscured active galactic nucleus (AGN) from a number of ground-based and spaceborn facilities, such as:


SPITZER
(IR)

HERSCHEL
(FIR to submillimetre)


JWST
(optical to MIR)

Novel Features of SMART

1. More physically motivated and versatile compared to popular energy balance methods, such as CIGALE (Noll et al., 2009; Boquien et al., 2019) and MAGPHYS (da Cunha et al., 2008), that do not take properly into account the effects of dust in a realistic geometry

2. The code is parallelized and considerably faster than other MCMC codes, such as SATMC (Johnson et al., 2013)

3. Makes use of four different types of pre-computed AGN torus libraries

4. Can optionally add a component of polar dust in the fitting

5. Designed to fit an SED in comparable time with a spheroidal or disc host galaxy model

6. Can fit part of a galaxy and, if necessary, switch off any of the four components (AGN torus, starburst, spheroidal/disc, polar dust)

7. Can fix any of the model parameters
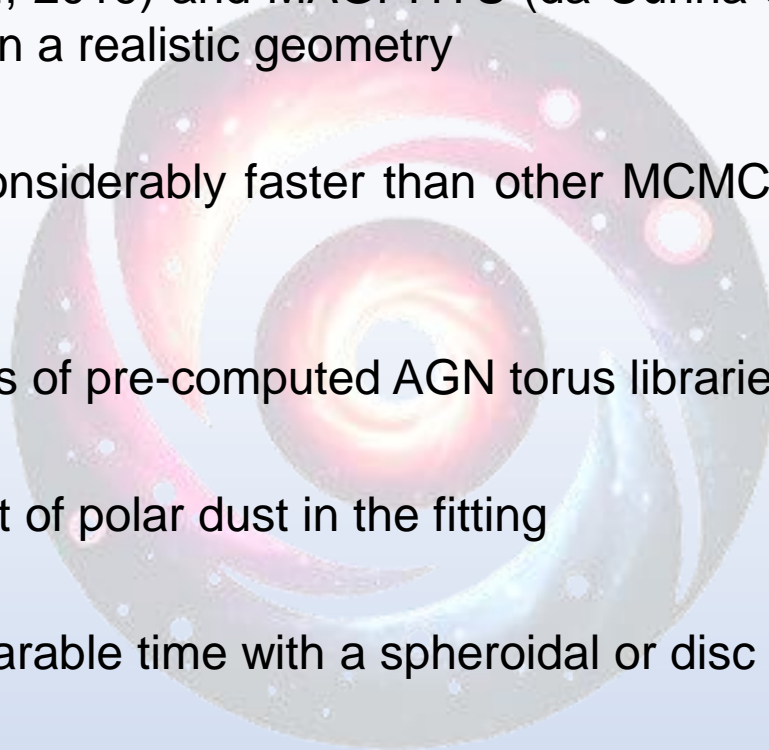
Description of SMART

- A new method for fitting radiative transfer models to data, using an MCMC code

- As an MCMC sampler it utilizes the publicly available *emcee* code (Foreman-Mackey et al., 2013)

- Fits the ultraviolet to submillimetre SEDs *exclusively* with radiative transfer models that currently constitute four types of pre-computed libraries:

  o Starburst (Efstathiou et al., 2000;

    Efstathiou & Siebenmorgen, 2009)

    – independent of redshift

  o AGN torus

    – independent of redshift
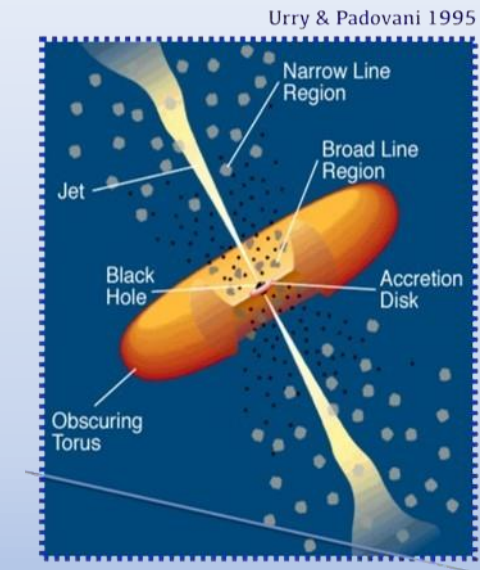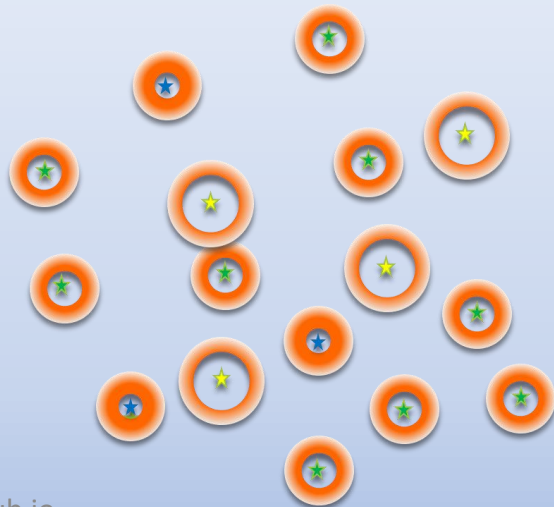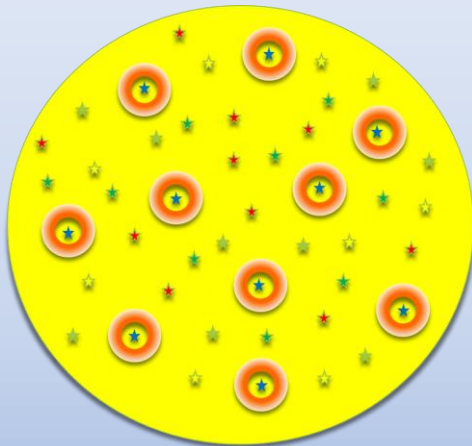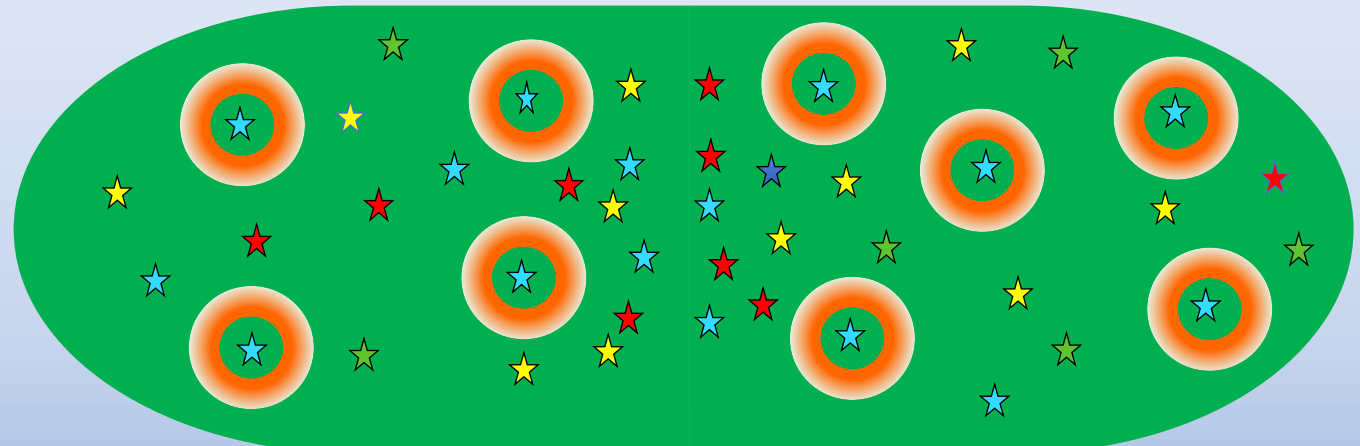
Description of SMART

o AGN polar dust (Efstathiou et al., 1995)

    – independent of redshift

    – optionally incorporated in **SMART**

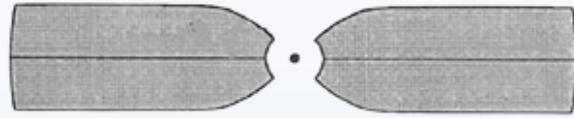o Spheroidal (Efstathiou et al., 2021)

    – dependent on redshift

o Disc (Efstathiou et al., in preparation)

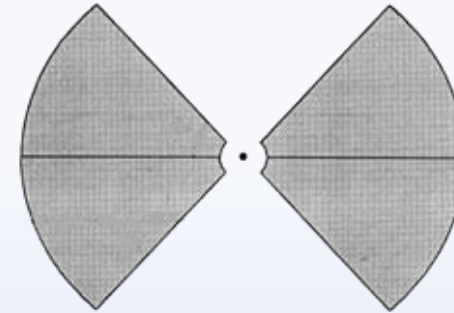   – dependent on redshift

Description of SMART

- Allows us to explore the impact of four different AGN torus models and therefore constrain the properties of the obscuring torus:
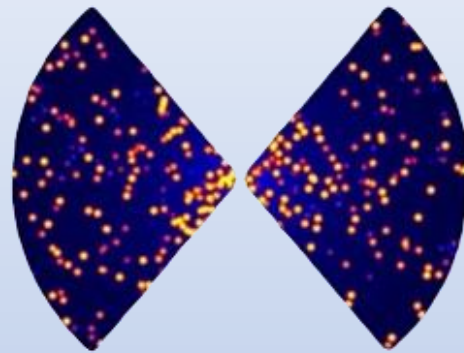

CYGNUS
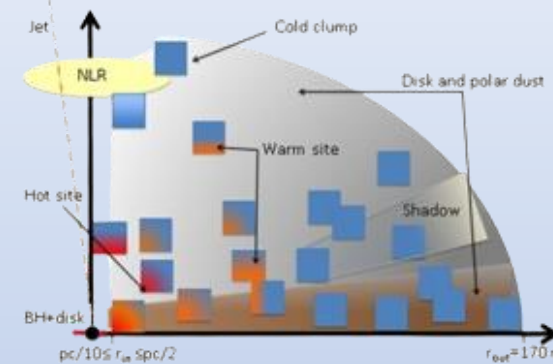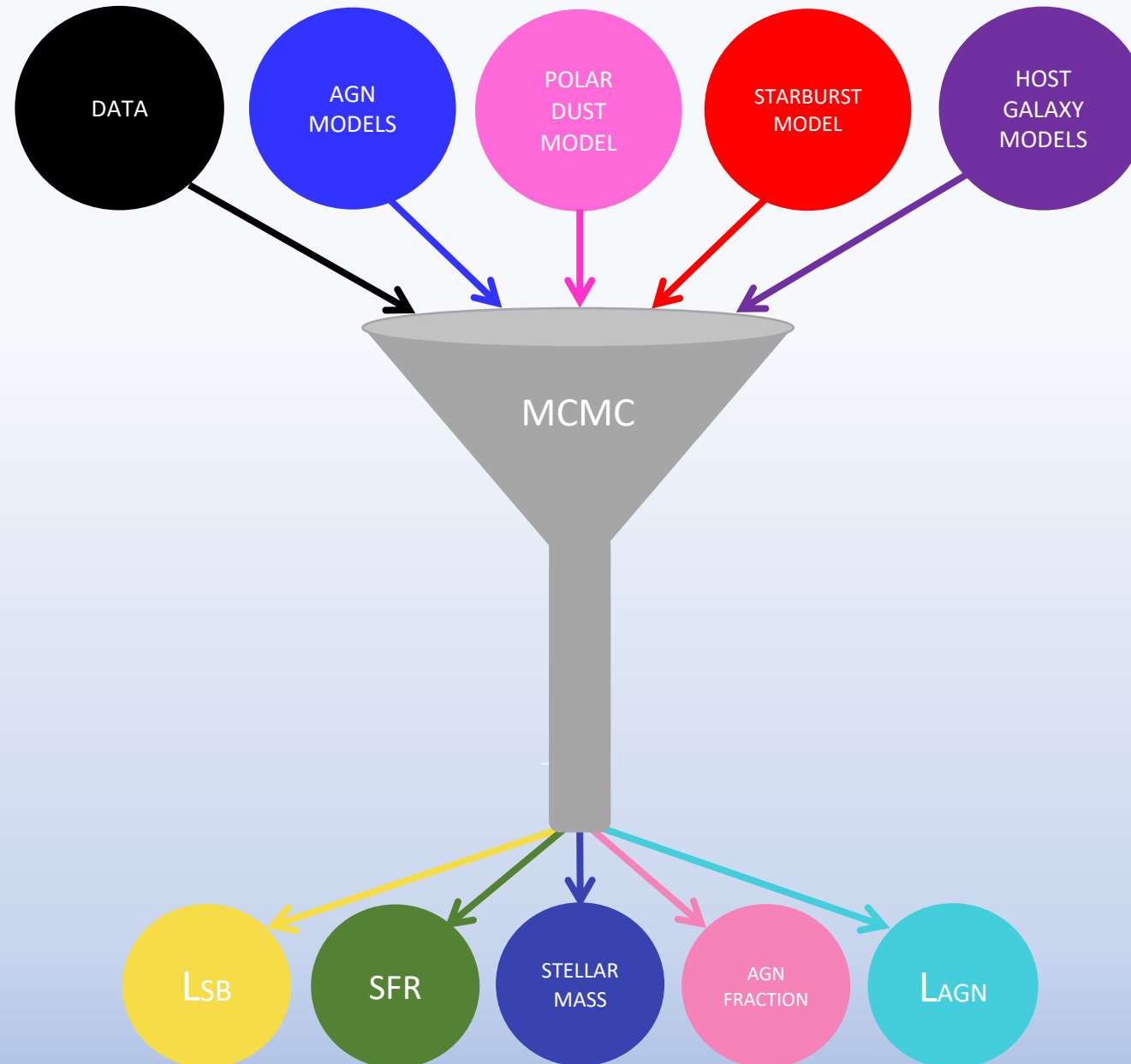(Efstathiou & Rowan-Robinson, 1995)

Fritz et al. (2006)

SKIRTOR
(Stalevski et al., 2016)

Siebenmorgen et al. (2015)

The SMART Method

Models used by SMART

STARBURST

Efstathiou+00

HOST GALAXY

Disc

Efstathiou23

POLAR DUST

Efstathiou06

AGN

Spheroidal

Efstathiou+21

CYGNUS

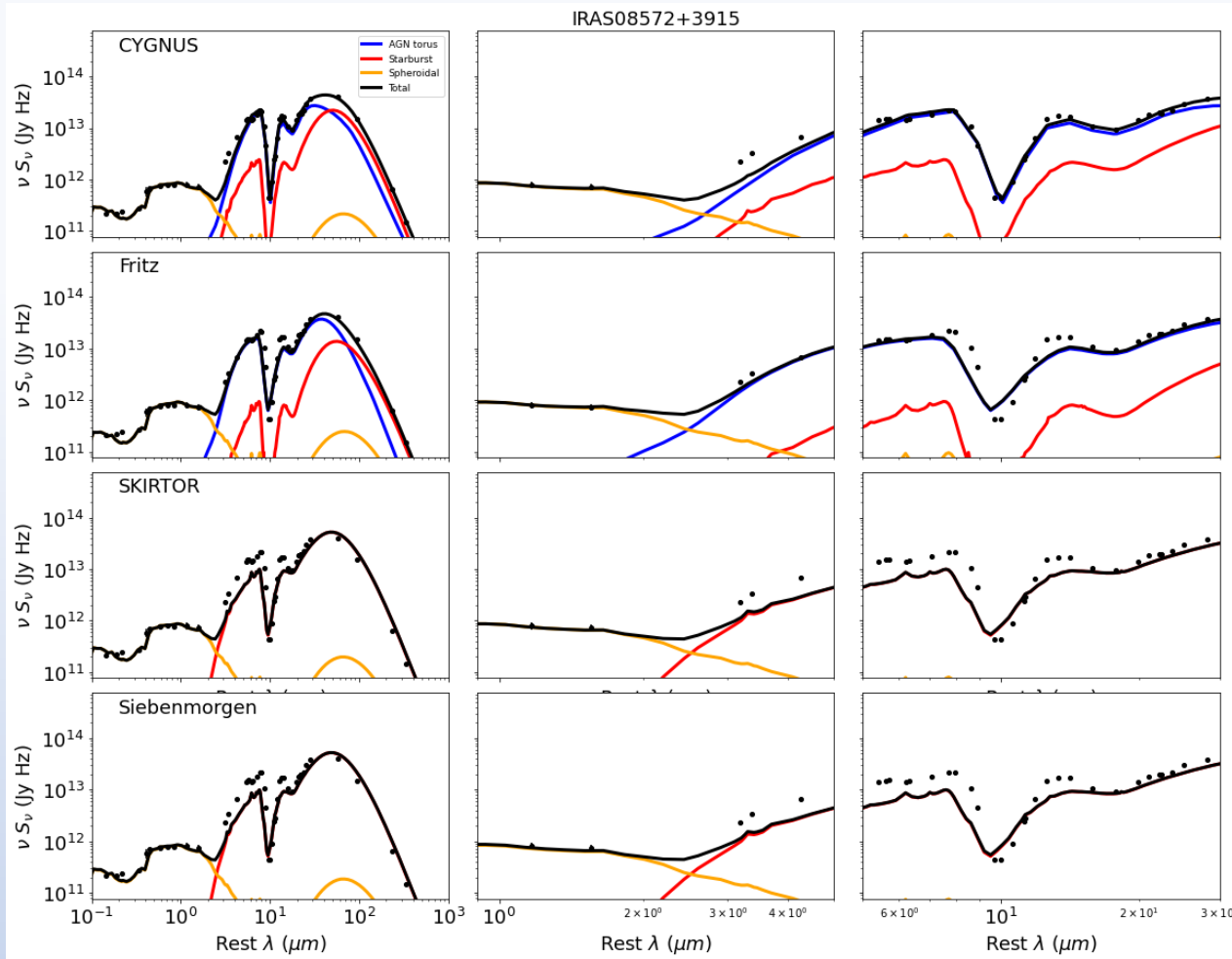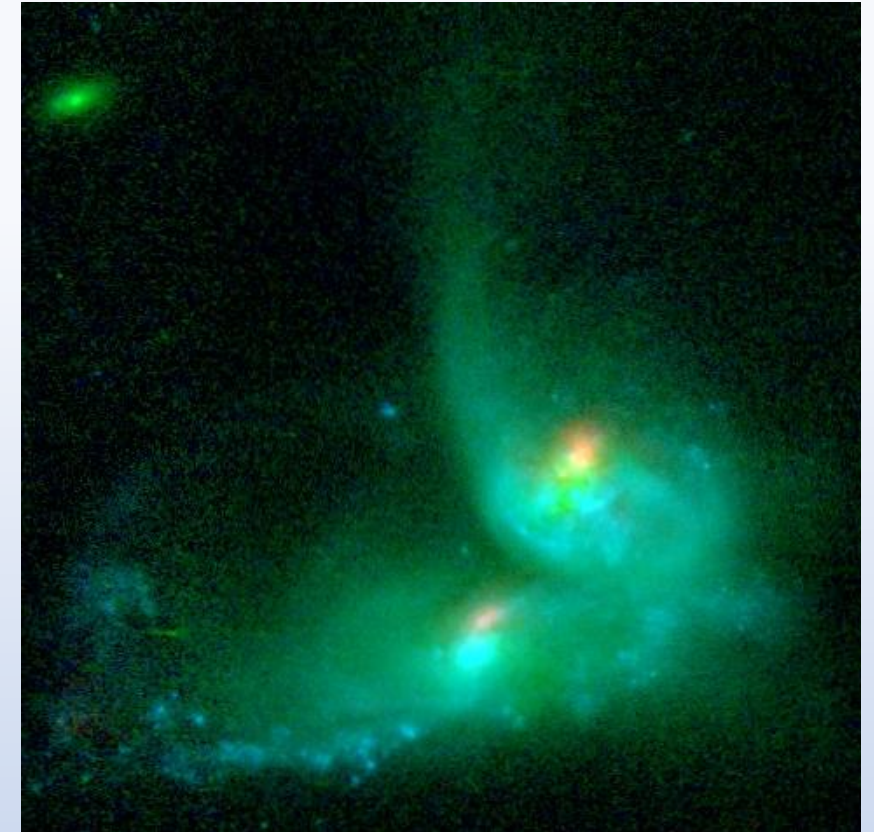Efstathiou &
Rowan-Robinson
1995

Siebenmorgen
et al.

2015

Fritz et al.

2006

SKIRTOR

Stalevski+16
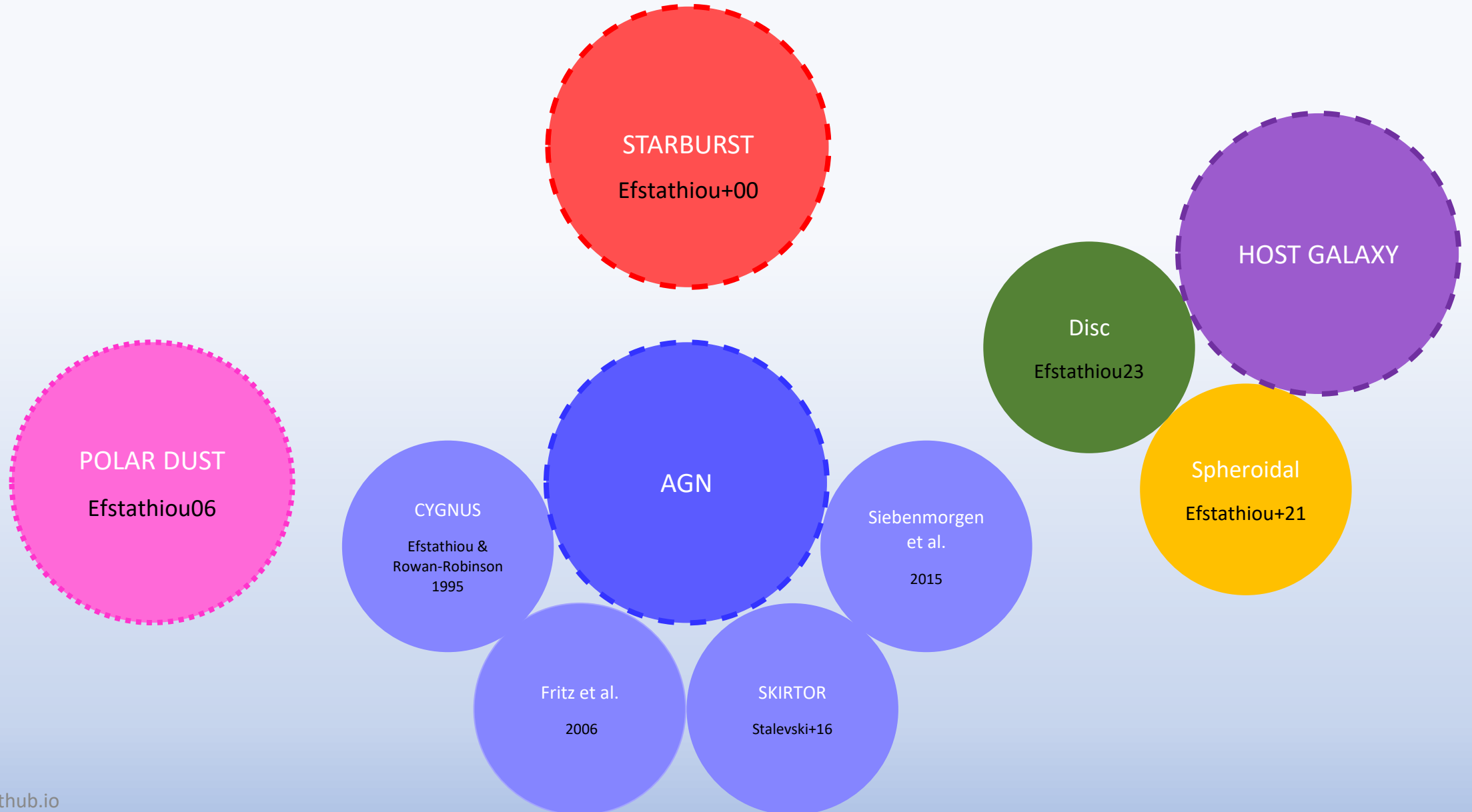
Comparison SED fit plots of the deeply obscured ultraluminous infrared galaxy (ULIRG) IRAS 08572+3915
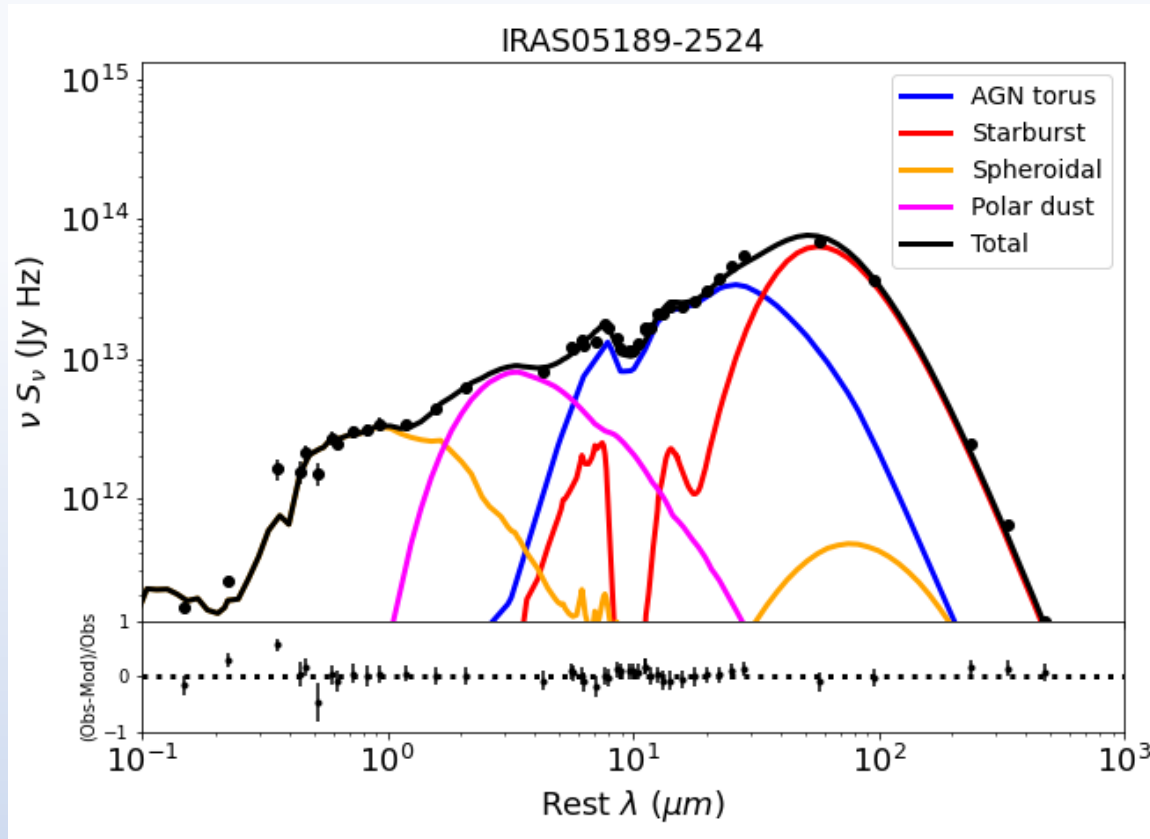## (Varnava & Efstathiou, 2024)

Comparison SED fit plots of IRAS 08572+3915: AGN torus (blue), starburst (red), spheroidal host (orange), total (black)
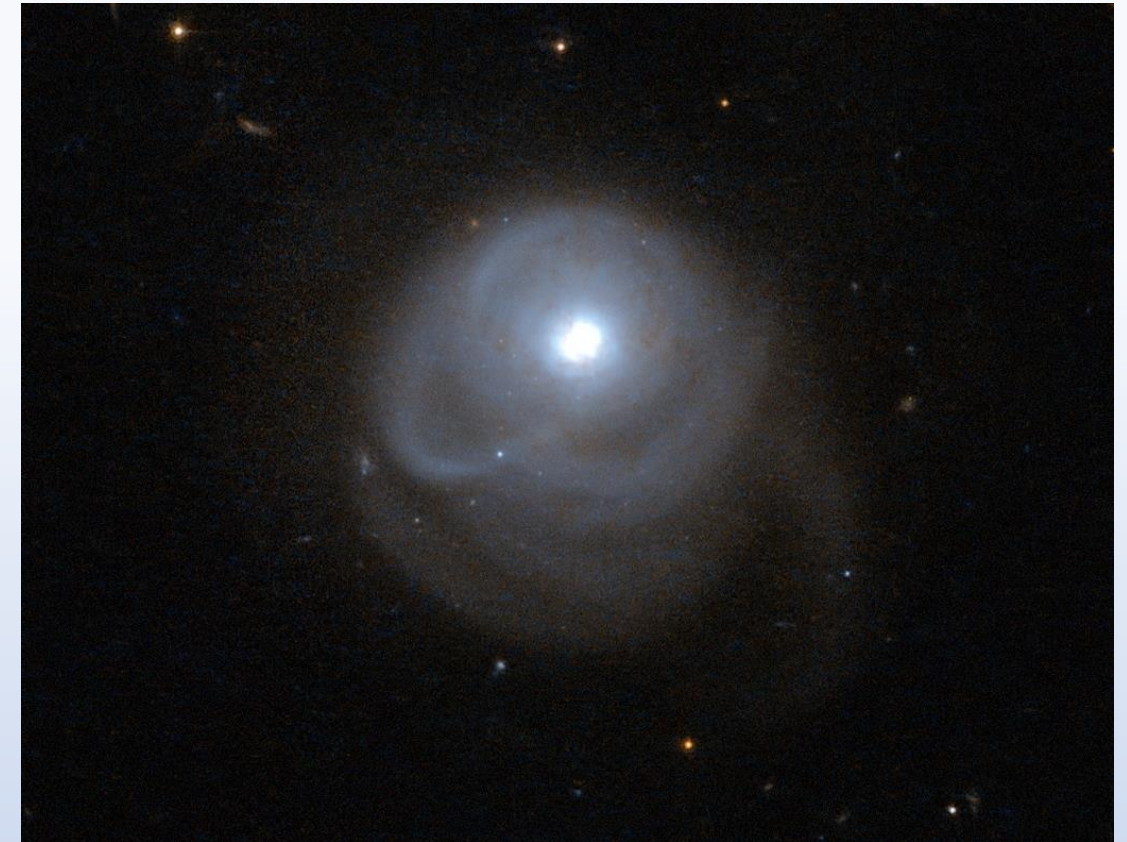
Optical Hubble Space Telescope image of IRAS 08572+3915

SED fit plot of a ULIRG associated with polar dust, IRAS 05189-2524 (Varnava & Efstathiou, 2024)
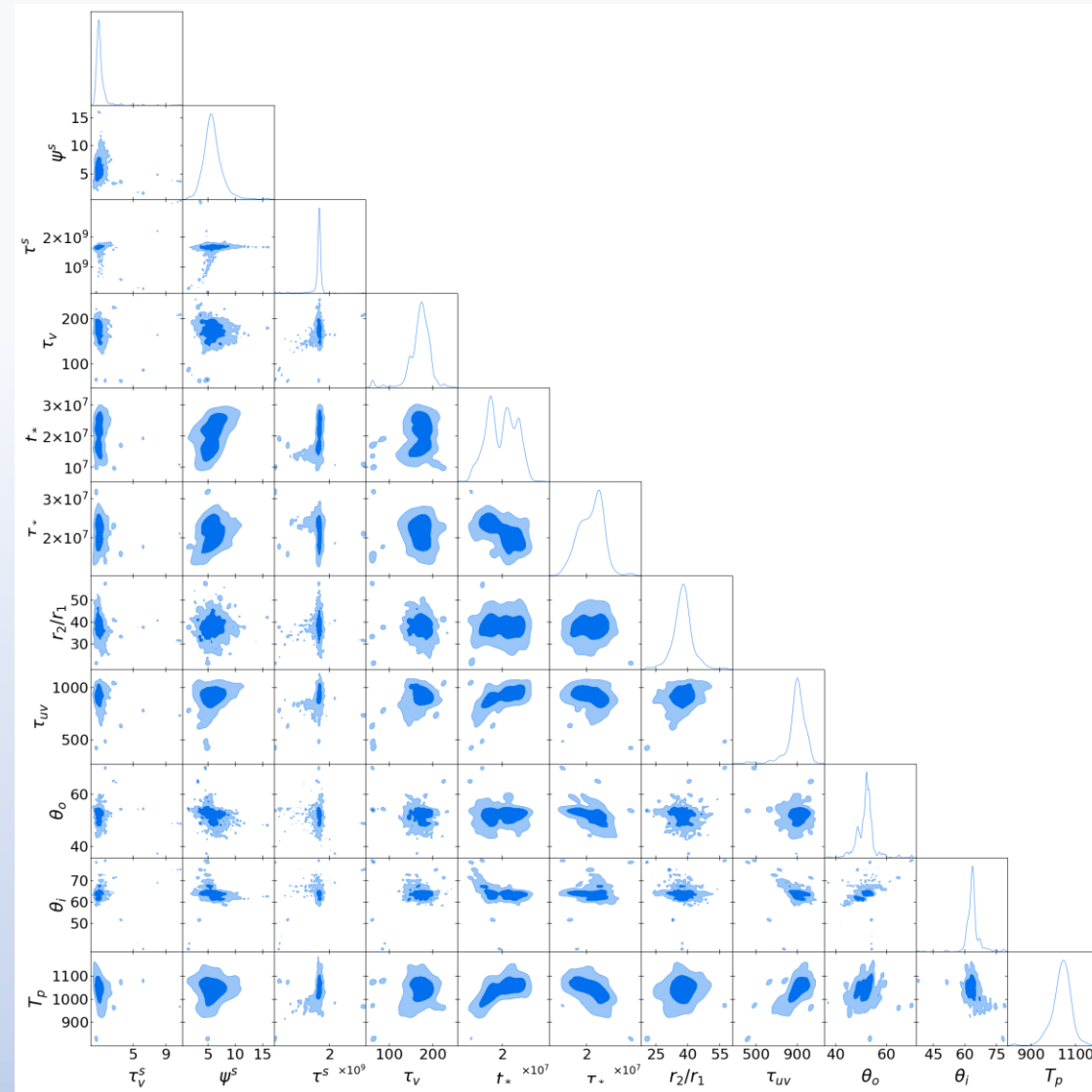

SED fit plot of IRAS 05189-2524: AGN torus (blue), starburst (red), spheroidal host (orange), polar dust (magenta), total (black)
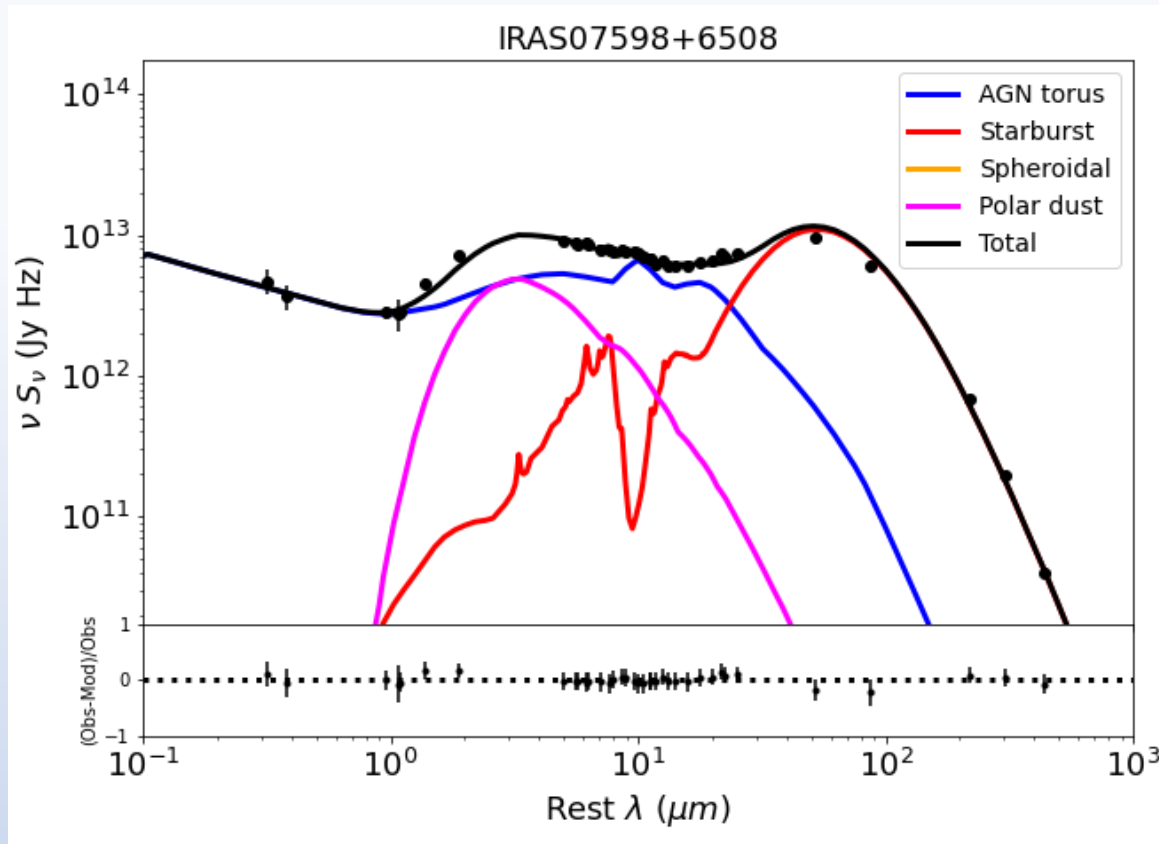
Optical Hubble Space Telescope Image of IRAS 05189-2524

Corner plot for the SED fit of the ULIRG IRAS 05189-2524
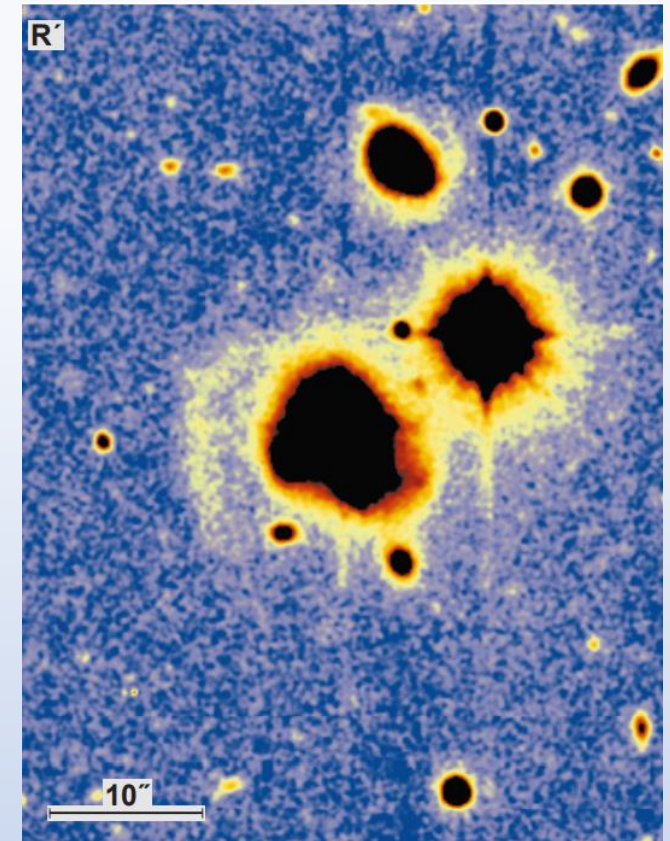# (Varnava & Efstathiou, 2024)

Corner plot for the SED fit of IRAS 05189-2524

SED fit plot of a ULIRG with an unobscured quasar and also associated with polar dust, IRAS 07598+6508 (Varnava & Efstathiou, 2024)
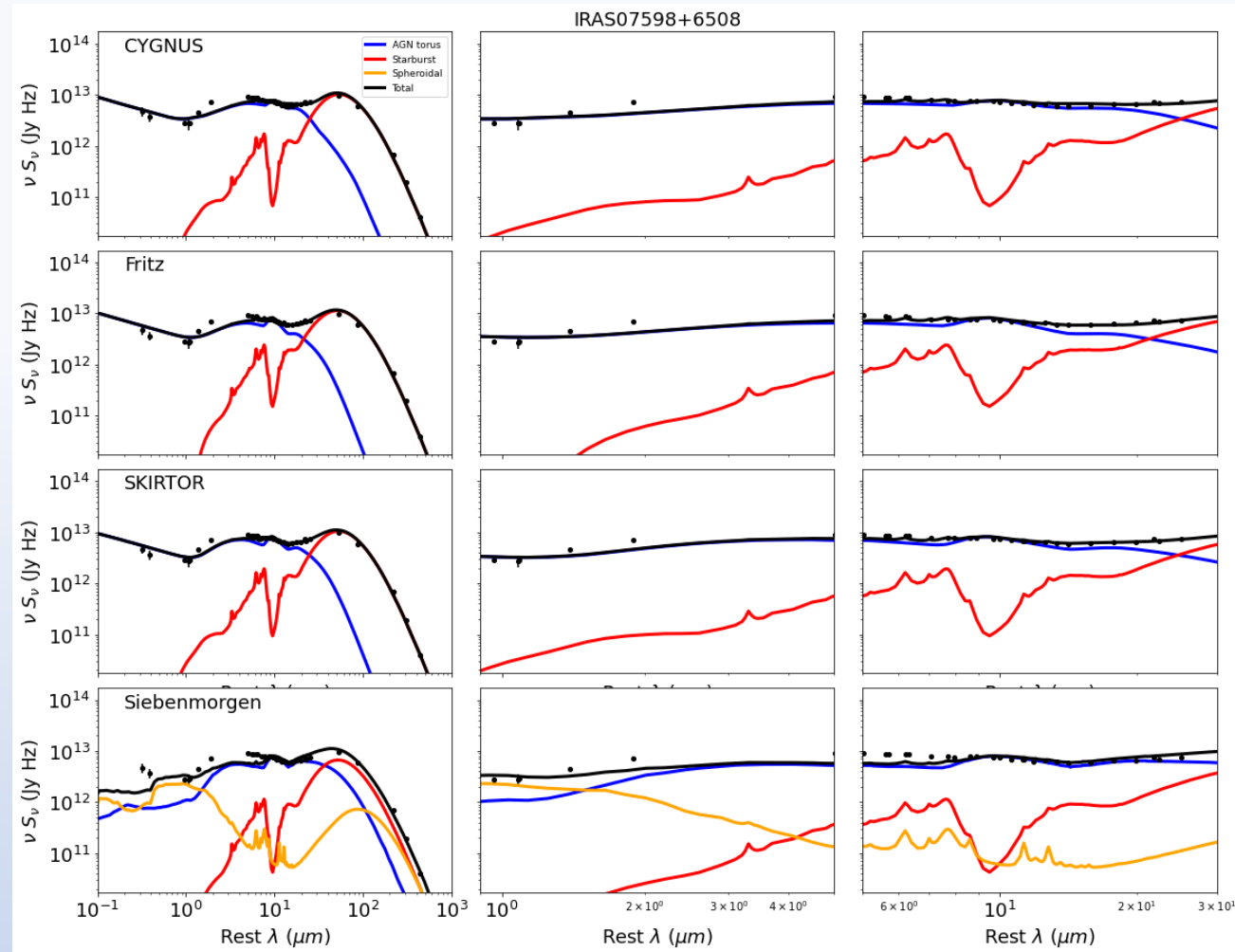

SED fit plot of IRAS 07598+6508: AGN torus (blue), starburst (red), spheroidal host (orange), polar dust (magenta), total (black)


R' image of IRAS 07598+6508 (Canalizo & Stockton, 2000)

Comparison SED fit plots of the ULIRG IRAS 07598+6508 without using the polar dust component (Varnava & Efstathiou, 2024)
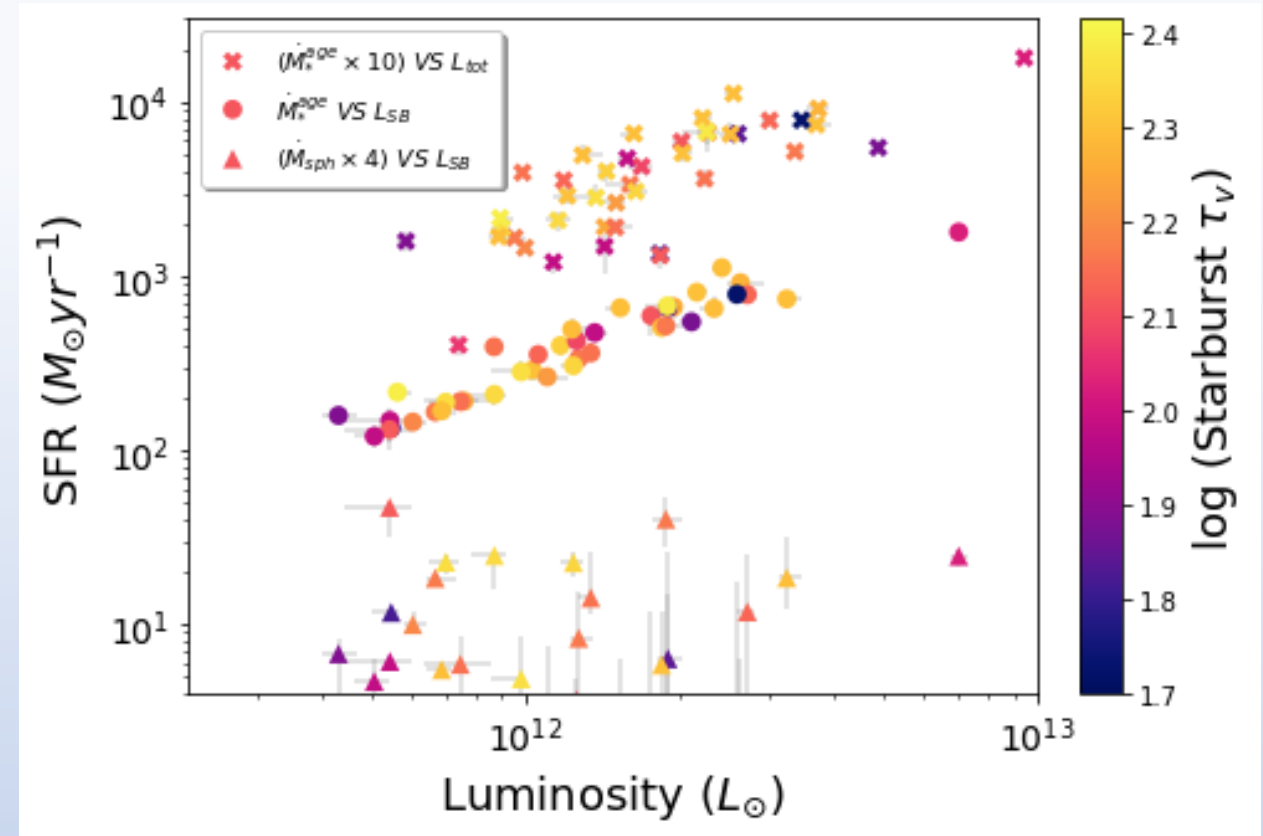

Comparison SED fit plots of IRAS 07598+6508 without using the polar dust component: AGN torus (blue), starburst (red), spheroidal host (orange), total (black)

Examples of selected extracted physical quantities for the HERschel Ultraluminous Infrared Galaxy Survey (HERUS) sample, using the CYGNUS combination of models (Varnava & Efstathiou, 2024)
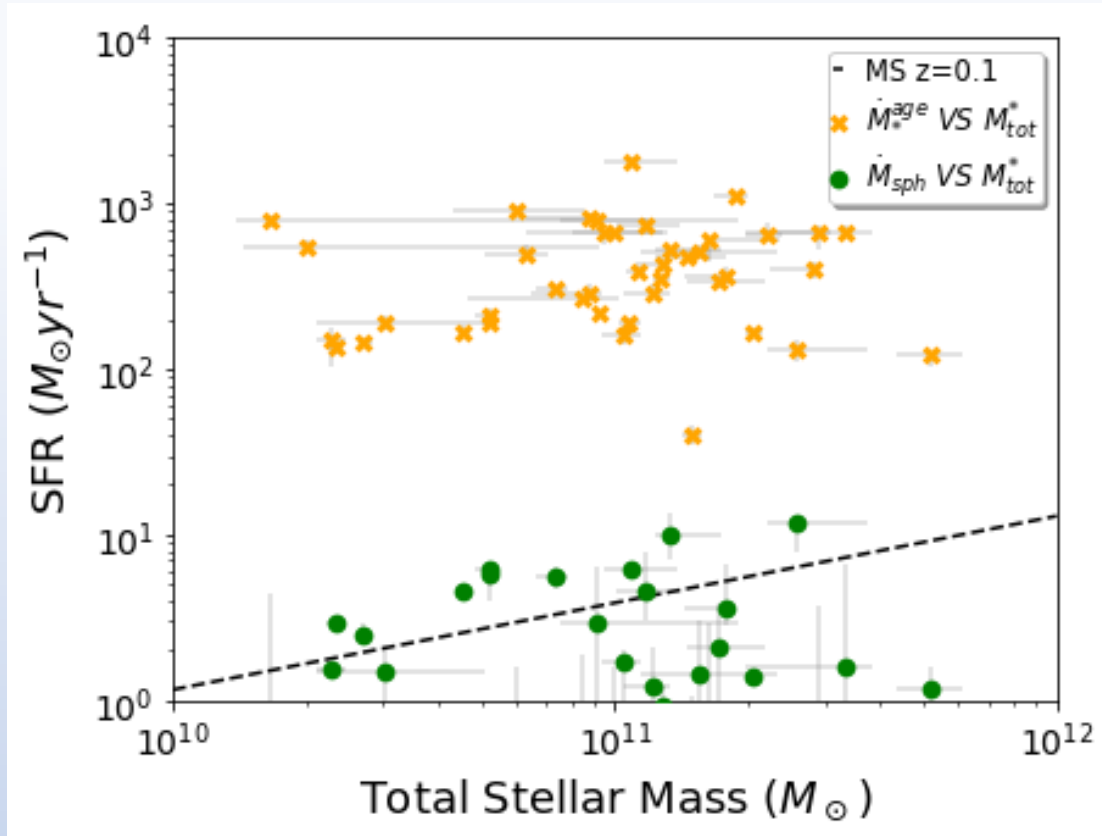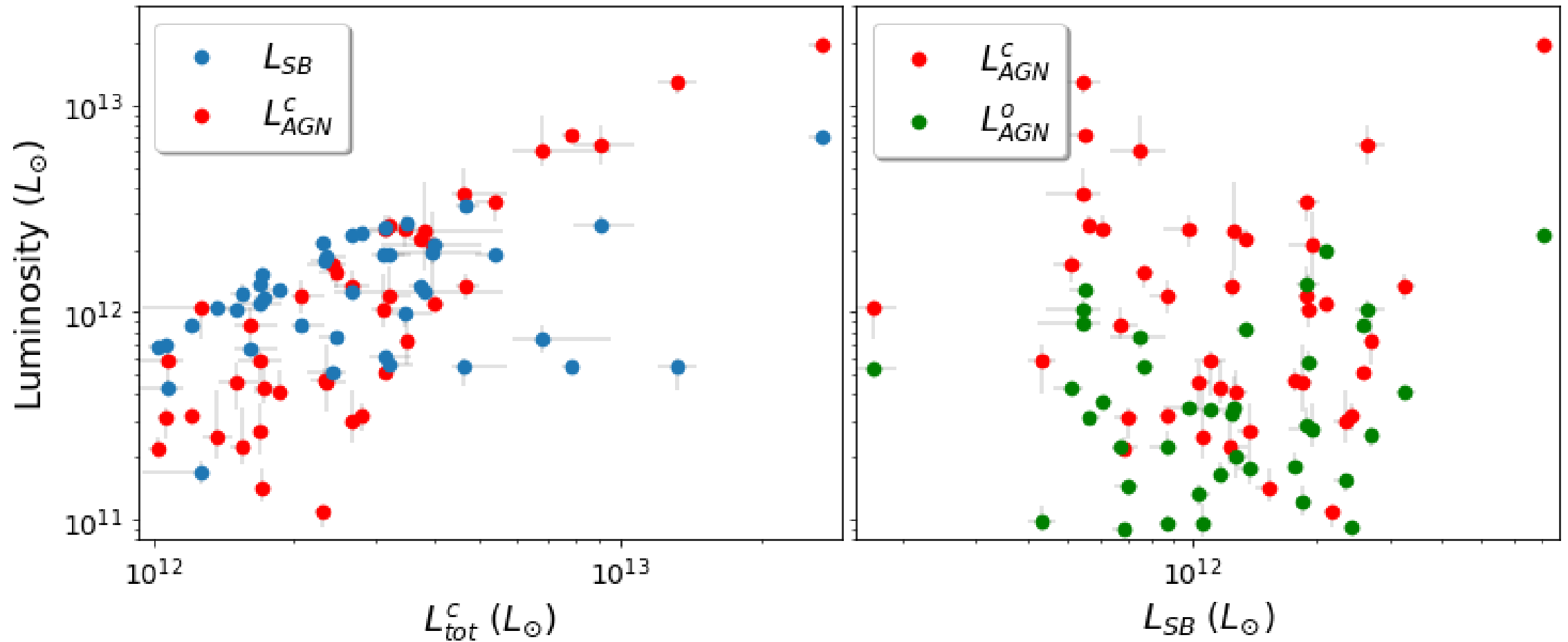

Starburst or host SFR against total stellar mass

*Starburst or host SFR against IR luminosities (starburst or total)*

Examples of selected extracted physical quantities for the HERUS sample, using the CYGNUS combination of models (Varnava & Efstathiou, 2024)


Left: Starburst and anisotropy-corrected AGN luminosity against total corrected IR luminosity

Right: Observed and anisotropy-corrected AGN luminosity against starburst luminosity

Comparison SED fit plots of a luminous infrared galaxy associated with a spiral morphology, VV 340a (Varnava & Efstathiou, 2024)
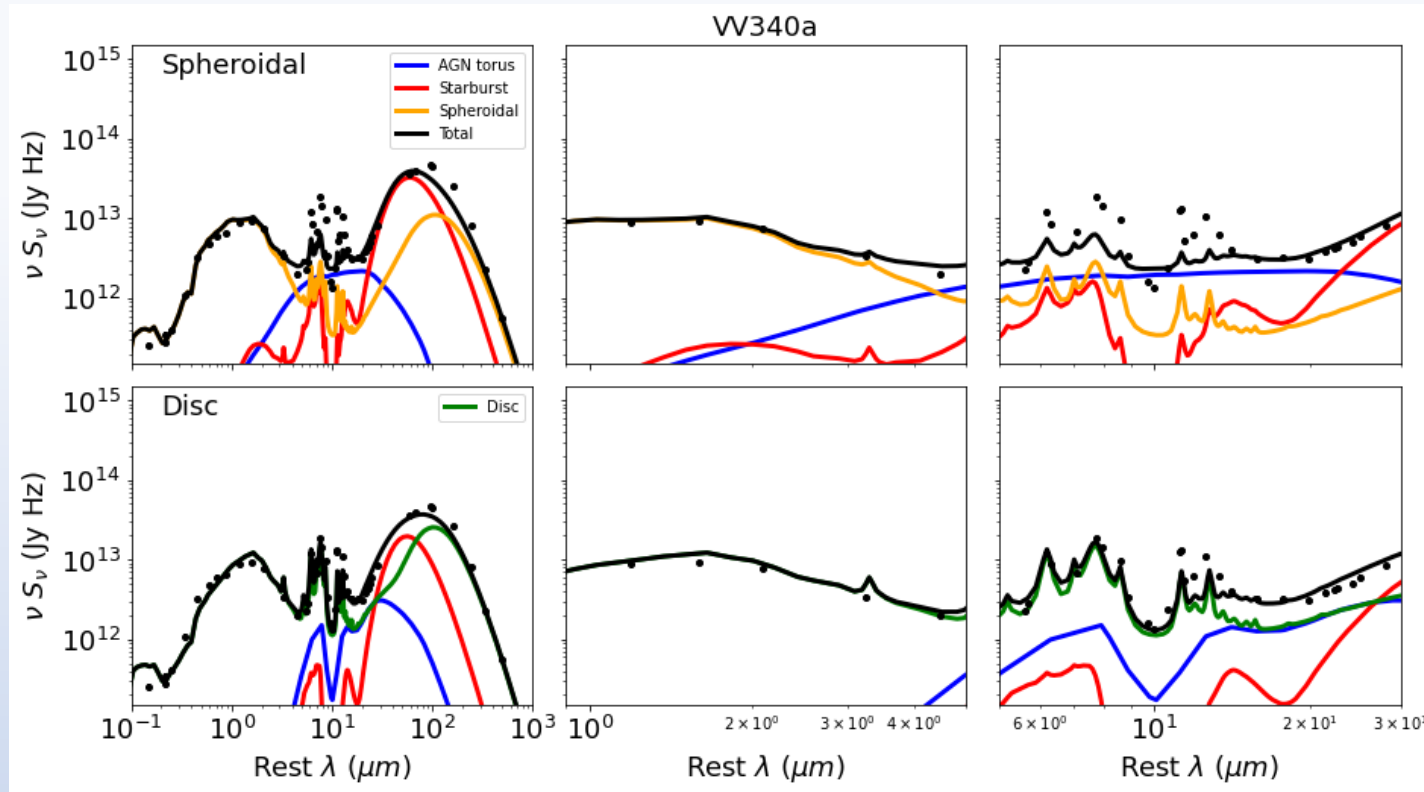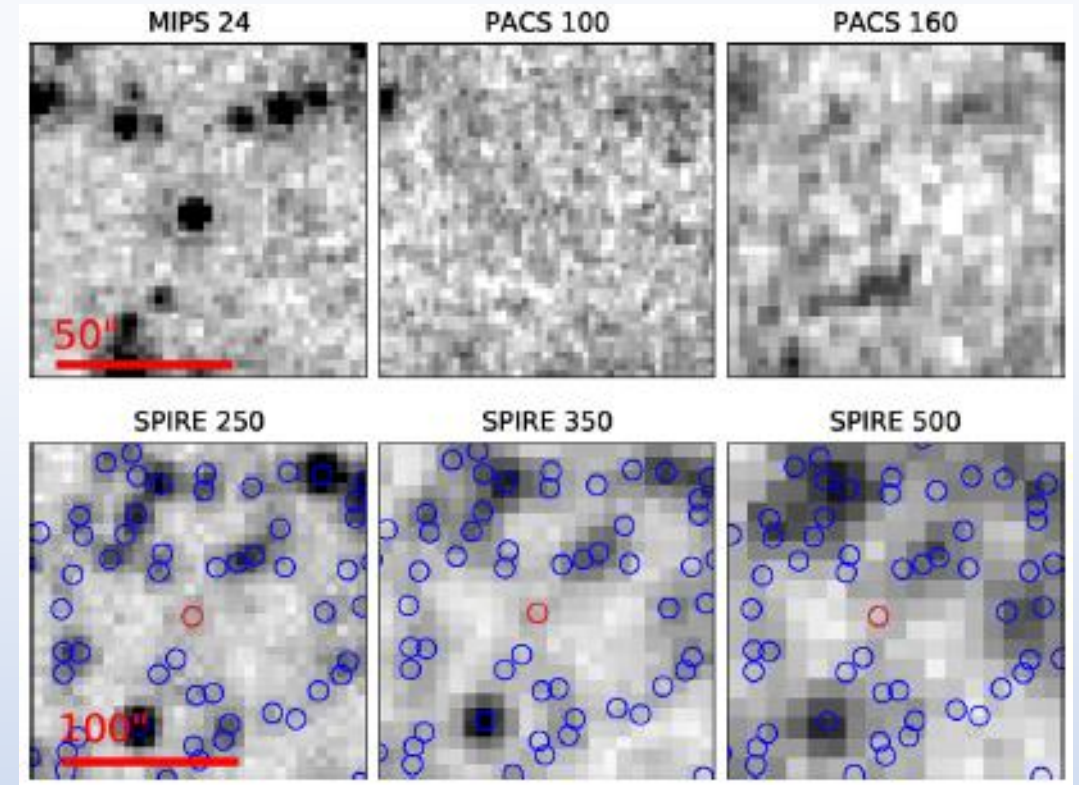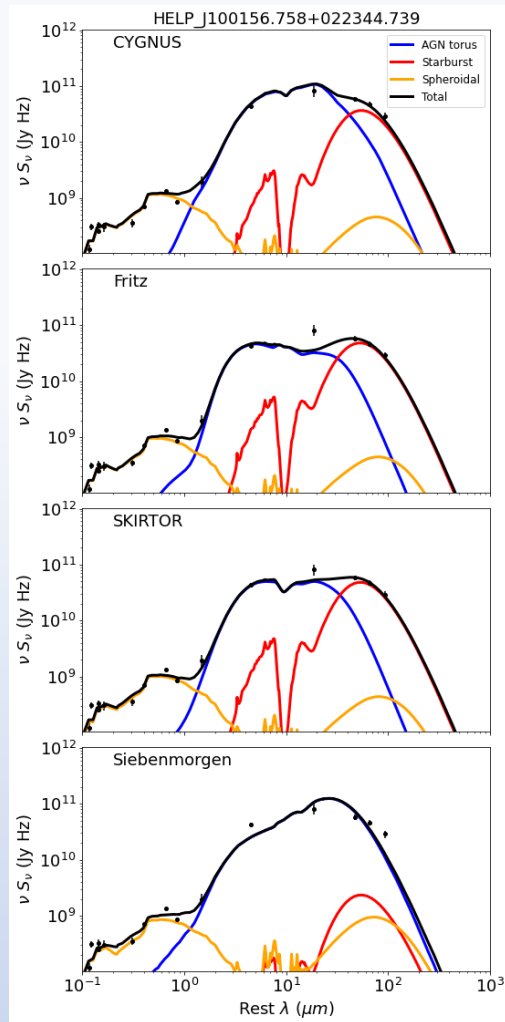

Comparison SED fit plots of VV 340a: AGN torus (blue), starburst (red), spheroidal host (orange), disc host (green), total (black)
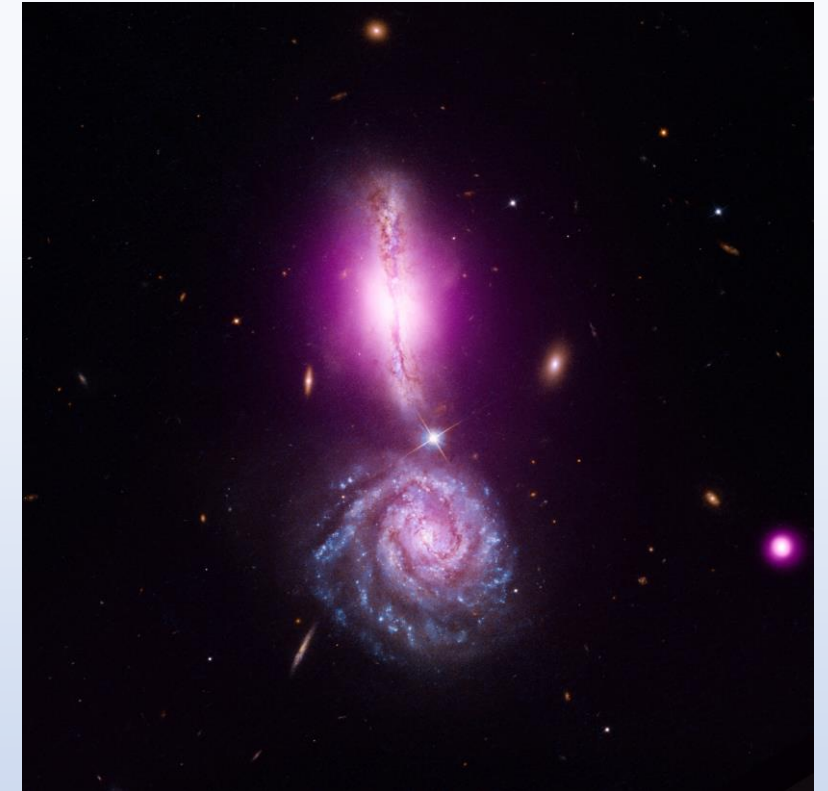
Composite image of X-ray data from Chandra (purple) and optical data from Hubble Space Telescope (red, green, blue) of VV 340

Comparison SED fit plots of the hyperluminous obscured quasar HELP_J100156.75+022344.7 at z~4.3 (Varnava & Efstathiou, 2024)

Comparison SED fit plots of HELP_J100156.75+022344.7: AGN torus (blue), starburst (red), spheroidal host (orange), total (black)

Postage stamps in various filters (Efstathiou et al., 2021)

Conclusions

- Developed a new fast MCMC SED fitting code, which uses *exclusively* radiative transfer models

- Takes comparable time to energy balance codes like CIGALE and MAGPHYS

- Tested with a range of obscured AGN in the redshift range ~0-7

- As **SMART** can fit with four different AGN torus models, it allows us to constrain the properties of the obscuring torus in AGN and quantify the uncertainties in AGN fraction and star formation rate

- Promises to be very useful for understanding galaxies and AGN at any redshift in the *JWST* era, as well as galaxy formation and evolution in general

can be found at:

https://doi.org/10.1093/mnras/stae1141

The code is available at:

https://github.com/ch-var/SMART

Thank you!

Charalambia Varnava

https://ch-var.github.io