FortesFit:

FLEXIBLE SED FITTING WITH A BAYESIAN BACKBONE

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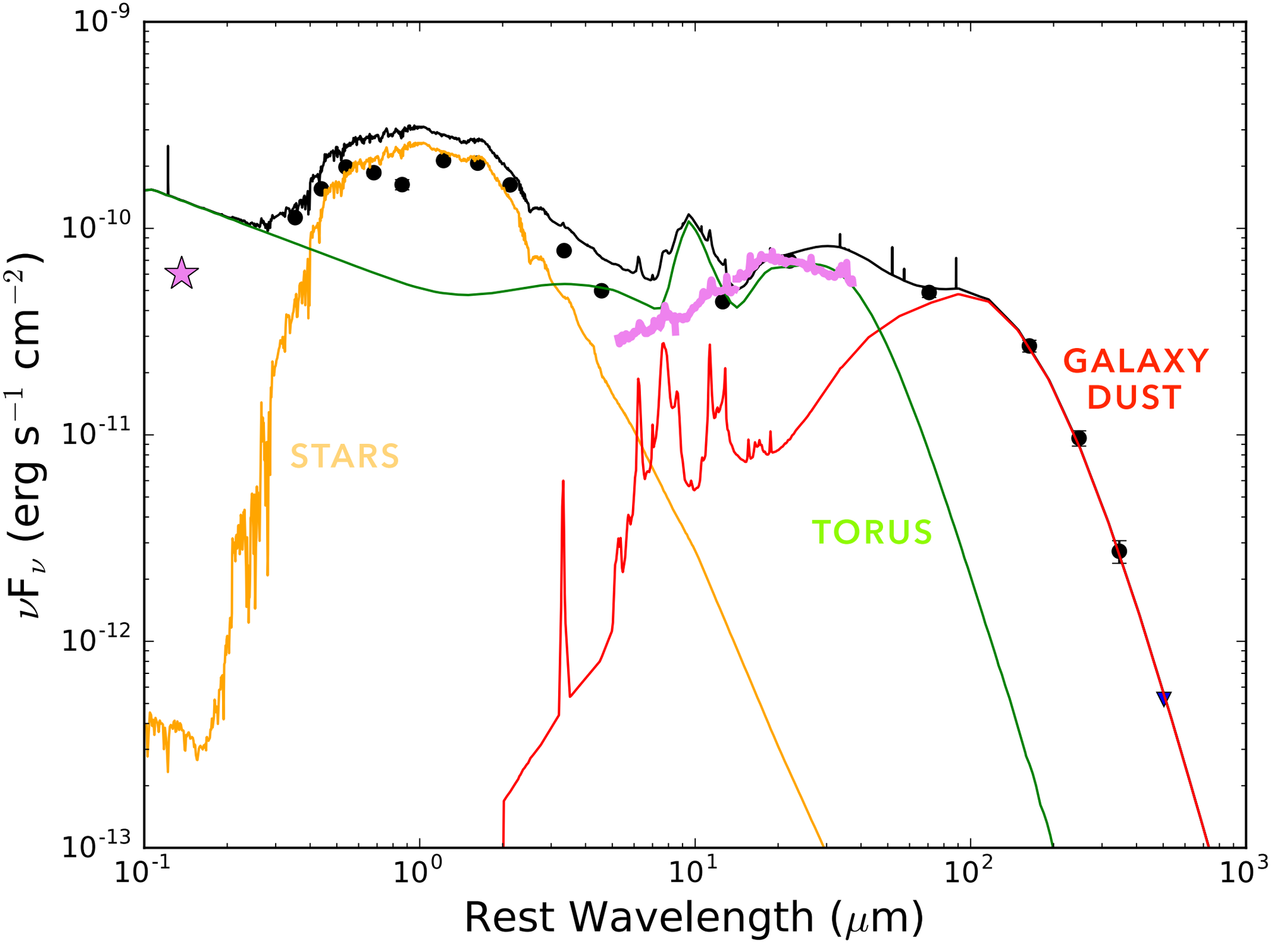
FORTESFIT: from '*fortis*', Latin for '*strong*'

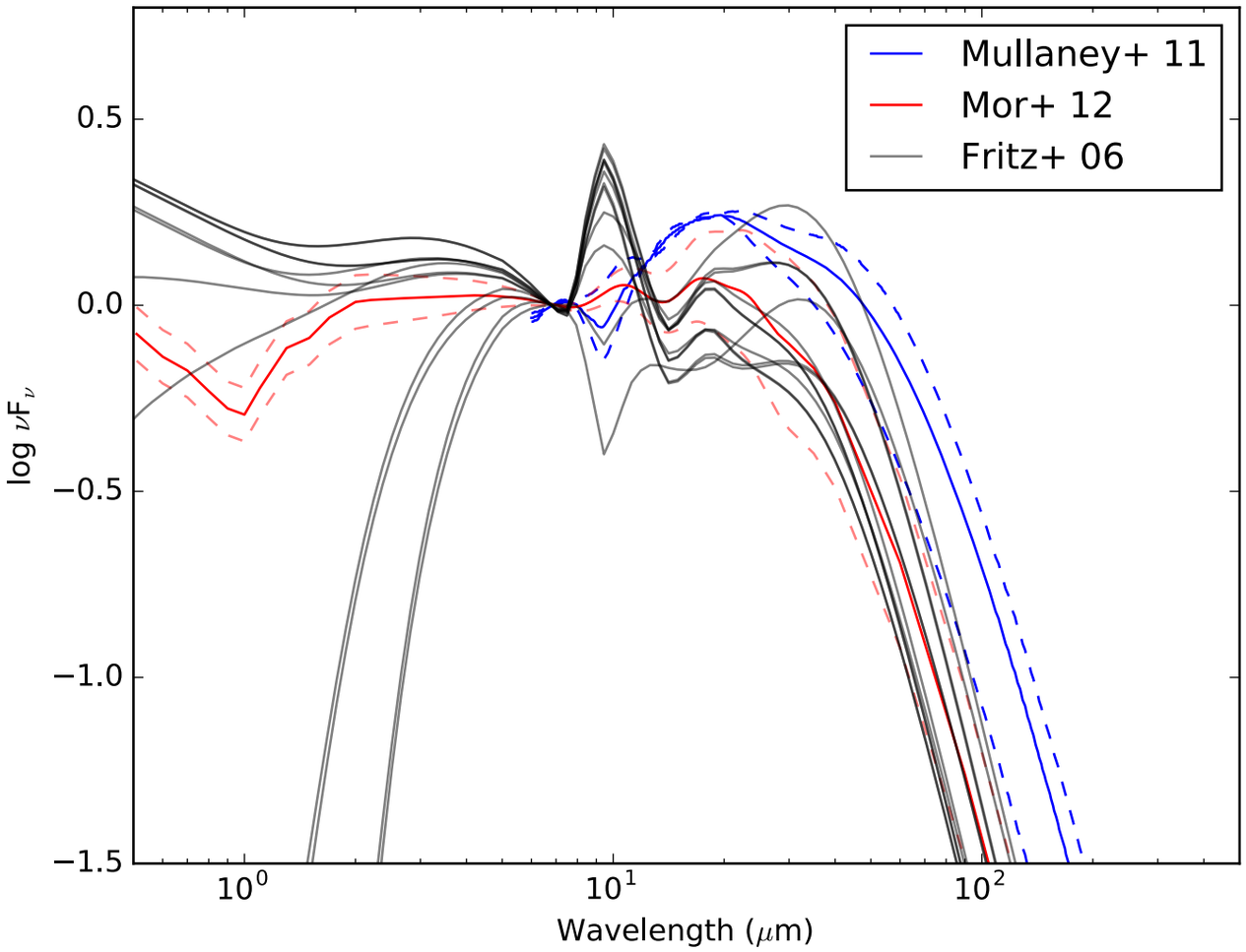
Why? Some motivation and my path to FortesFit.

How? The basic elements of FortesFit, with examples, and how you can make it work for you.

Whither? Current projects, and future development.

NGC 5548 WITH CIGALE



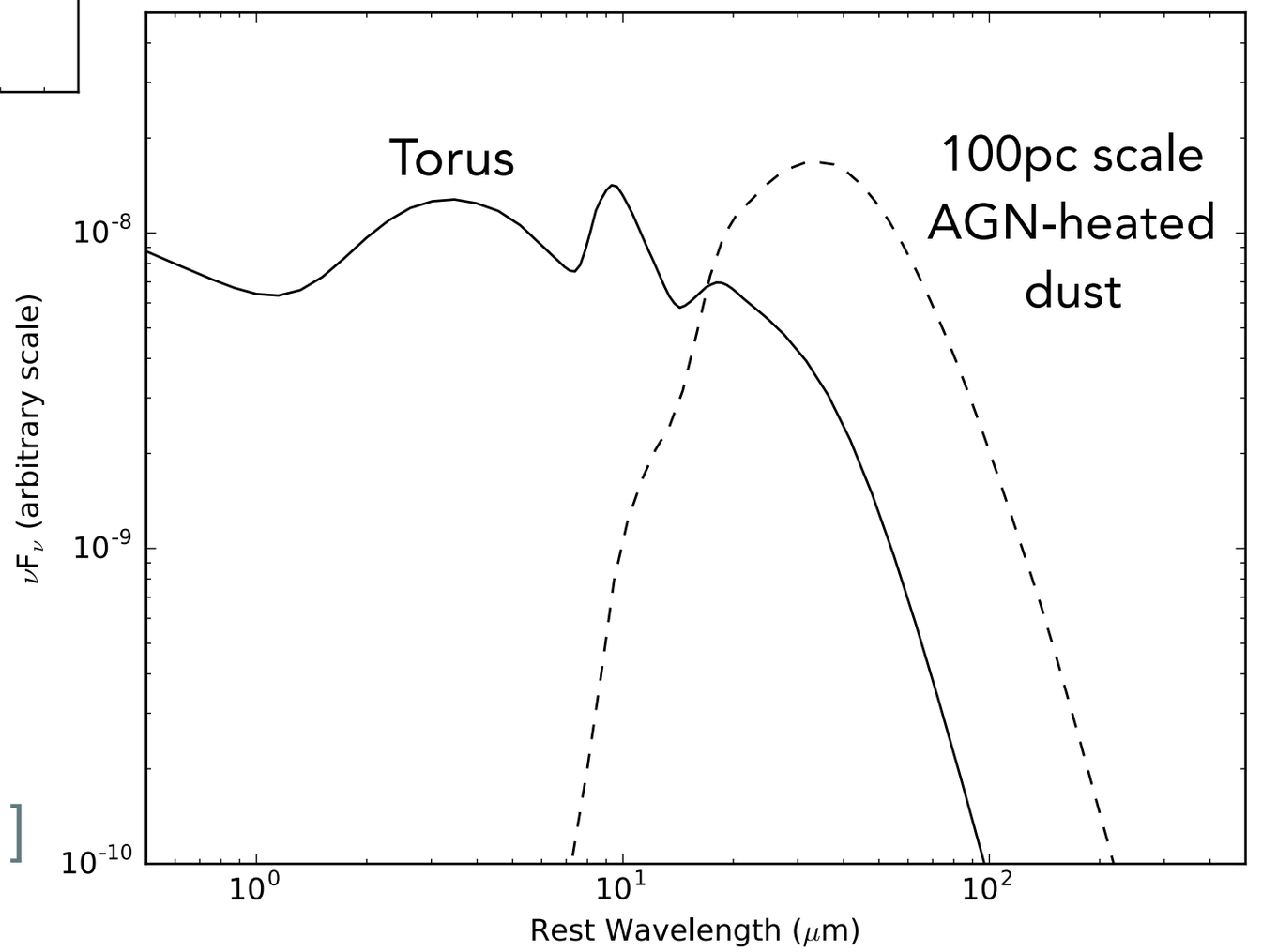


Torus models are differ systematically from empirically constrained AGN SEDs.

Real AGN have extended dust that can be important at FIR wavelengths.

Schweitzer+ 2008, Mor & Netzer 2012

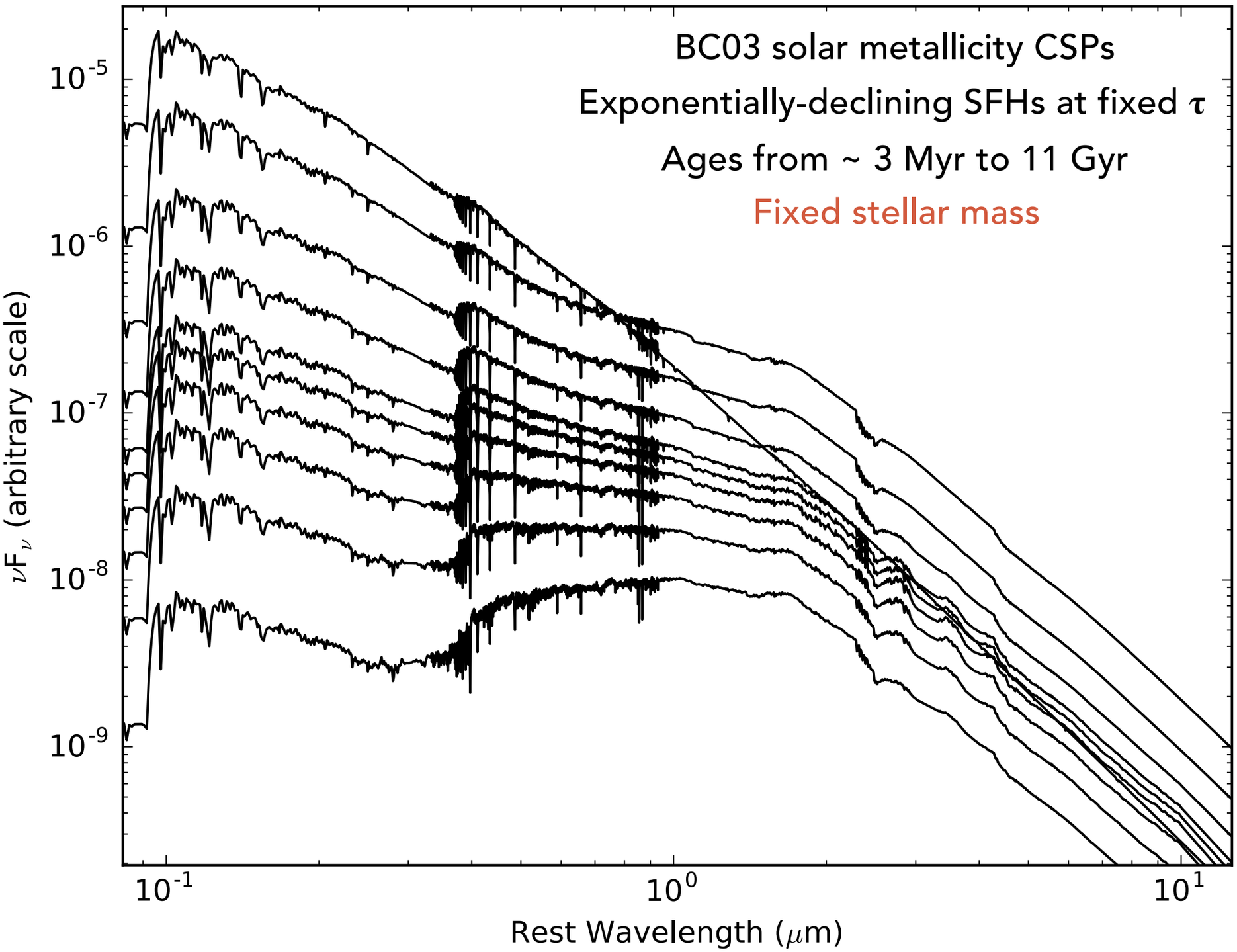
[Rosario & Stalveski, in prep.]



THINGS I LEARNED

Most astronomical SED models can be described by a number of “shape parameters” and a single “scale parameter”.

DESCRIBING SED MODELS



THINGS I LEARNED

Most astronomical SED models can be described by a number of "shape parameters" and a single "scale parameter".

The richness of ancillary data often allows various "priors", either from other wavelengths or from population properties ("hierarchical"). The hard part is accurately casting the priors into forms that directly constrain models.

PRIOR INFORMATION ABOUNDS

Credit:
Optical: NASA/HST;
X-ray: NASA/SRON/CXC/SAO

NGC 5548

Local Seyfert; D = 34 Mpc

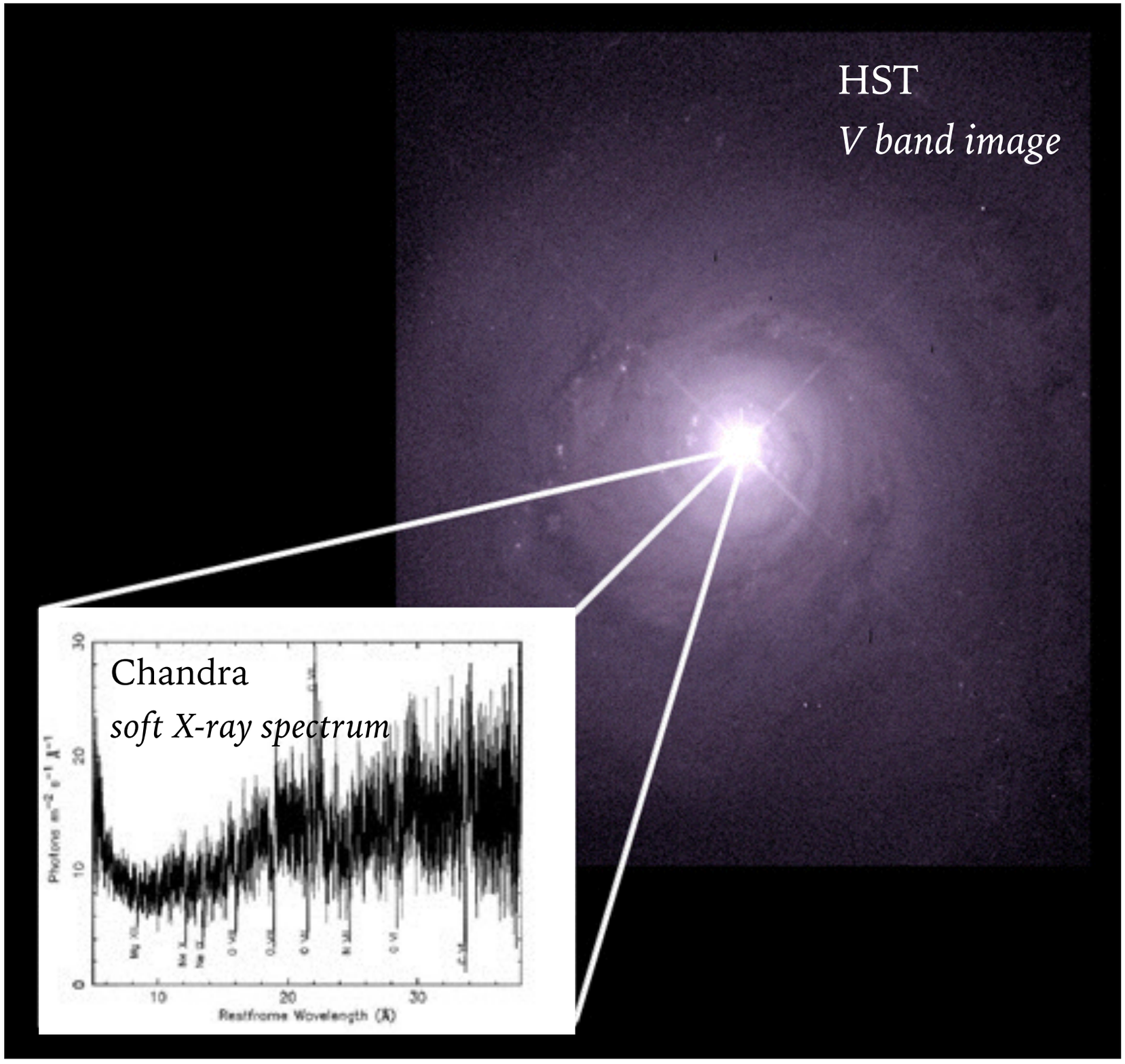
Classic reverberation mapping target for black hole mass

Huge campaign of multi-band HST monitoring

Years of X-ray spectroscopy

High and low resolution MIR spectra from *Spitzer*/IRS

Impressive amount of multi-wavelength data.



ENTER FORTESFIT

github.com/vikalibrate/FortesFit

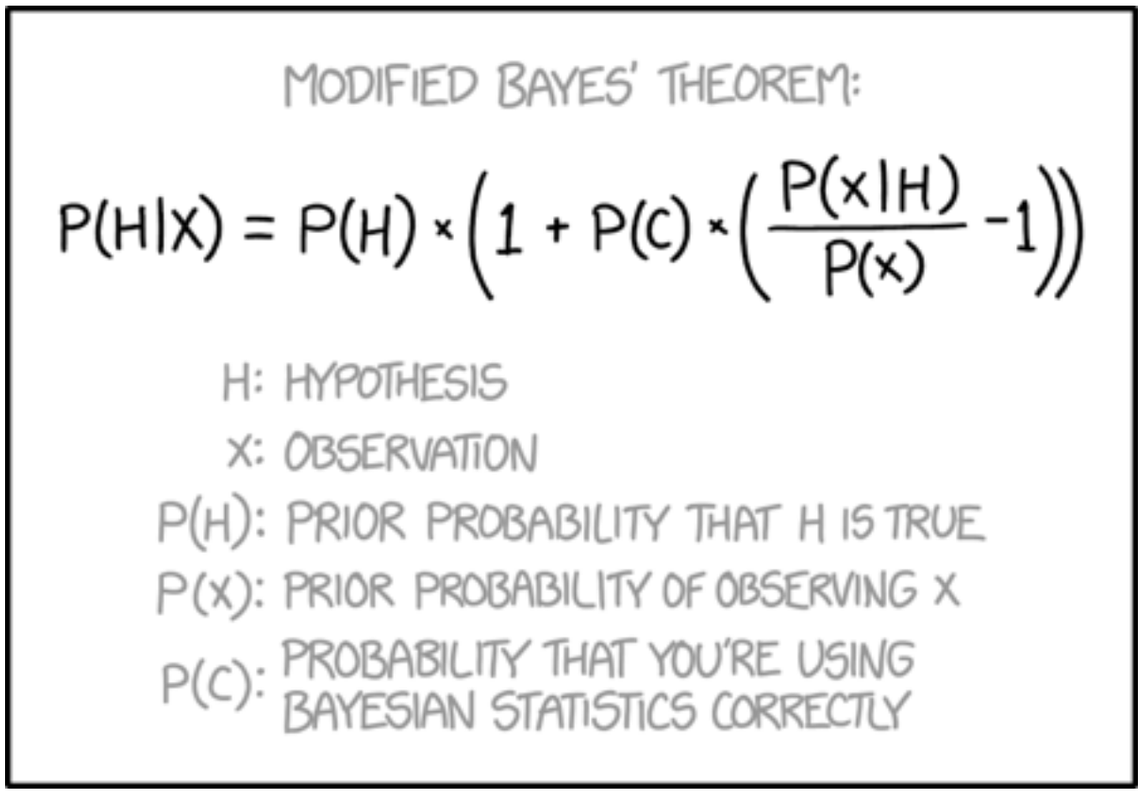
FortesFit is a package written in Python 3.

Users interact through various classes and their methods, similar to AstroPy or Matplotlib. Some Python programming is necessary to use it, as well as some basic familiarity with AstroPy.

Installs through PyPI (pip). Contributions are very welcome! Co-dev and test by branching the source code from GitHub.

FortesFit is fundamentally Bayesian.

from XKCD



KEY ELEMENTS

The Model:

A multifarious class that defines components of an SED model.

These are **"registered"** before any fitting. The user supplies a function that returns a particular model SED given a set of model parameters (+ redshifts + filters).

Models are stored to disk in HDF5 format, and can be used in **multiple fits**. Their contents can be **examined, visualised**, and the filters can be **updated**. They can be used in **simulated photometry** applications (*active JWST, DESI, and XMM-XXL simulations*).

Multiple "Models" are typically combined in a fit.

The user can add **"dependencies"** - quantities that depend on the principal model parameters and can be used to define priors. E.g., SFR or dust-absorbed stellar luminosity in SPS models, which are co-dependent on SFH and extinction.

KEY ELEMENTS

The Prior:

Every parameter in FortesFit takes a prior.

If one isn't specified, it is assumed to the uninformative. Scale parameters **require** priors.

Priors can also be applied on **dependencies**. This modifies the prior probability distribution of main parameters.

Prior specification is very **flexible**. Any continuous prior distribution in the SciPy stats module can be used. A 1D grid can be used. (*In development: multi-dimensional co-variant priors)*.

Photometric redshift P(z) can be used as a prior. If the SED constrains the redshift, the posterior will reflect it.

KEY ELEMENTS

The Engine:

FortesFit comes with **EMCEE** out-of-the-box, and support for **MultiNest** (a third-party C library).

It's modular design allows **new engines** to be added with only minor development.

MultiNest is a Nested Sampling implementation with evaluates Bayesian evidence for **accurate comparisons of model performance**.

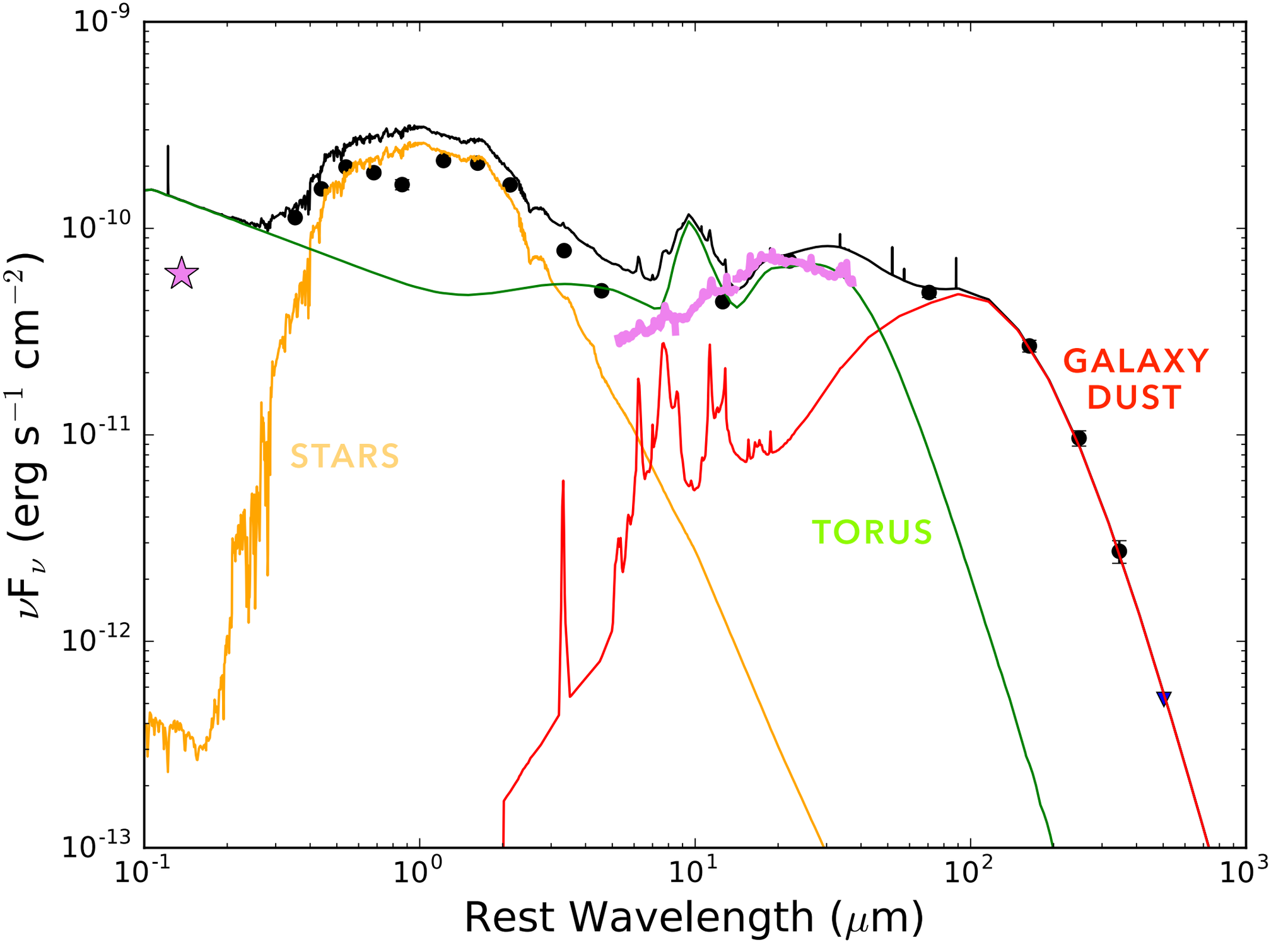
Currently **gaussian likelihoods** (including limits) are assumed, but this can be expanded.

The Outputs:

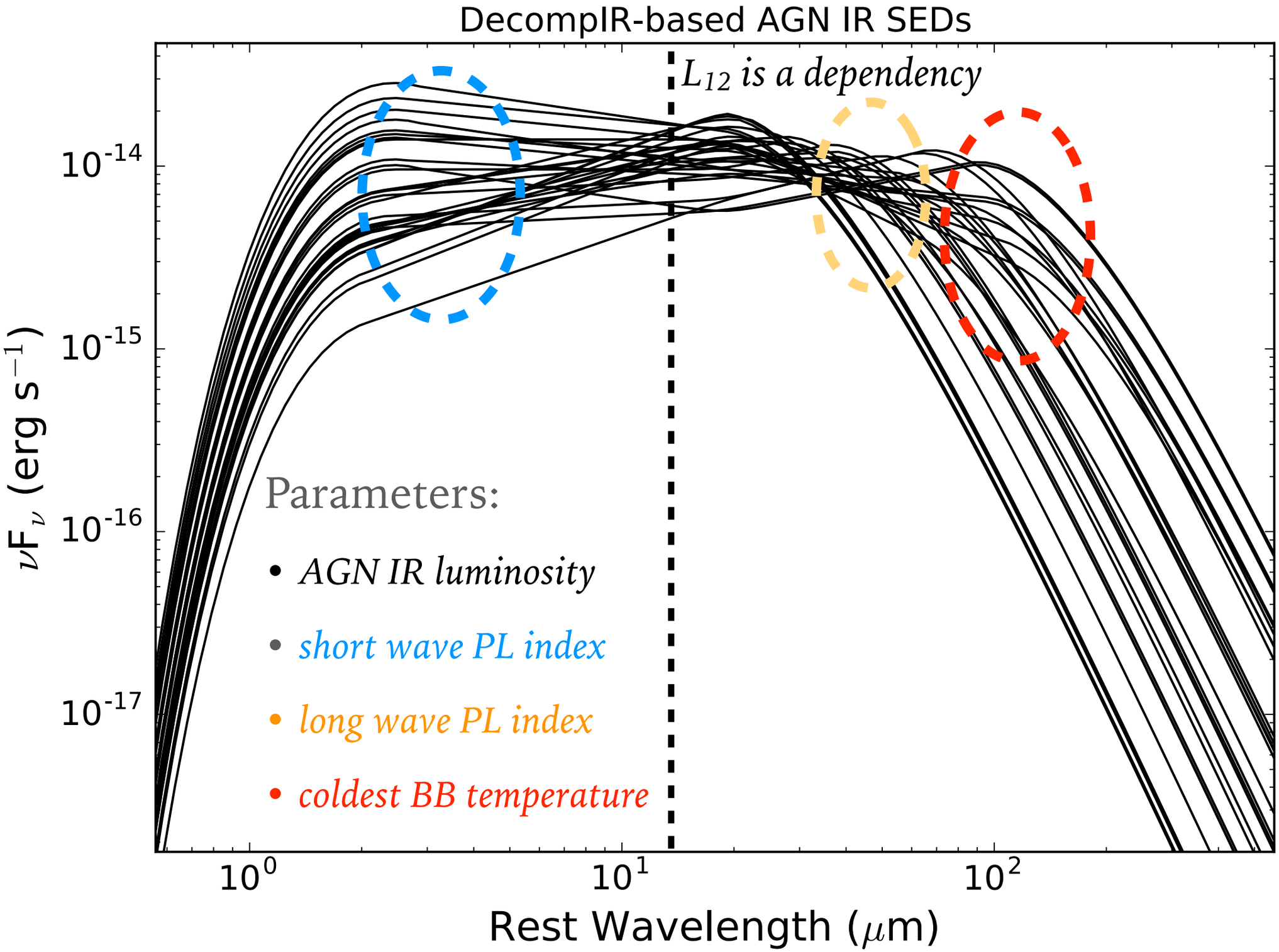
MCMC chains are stored in HDF5 format.

A post-processing module gives **higher level access** to the outputs *(summary statistics, relative entropy)*, visualisation of the fit convergence, corner plots, marginalised posteriors and "model SEDs".

NGC 5548 REVISITED



FLEXIBLE AGN MODELS: FORTES-AGN



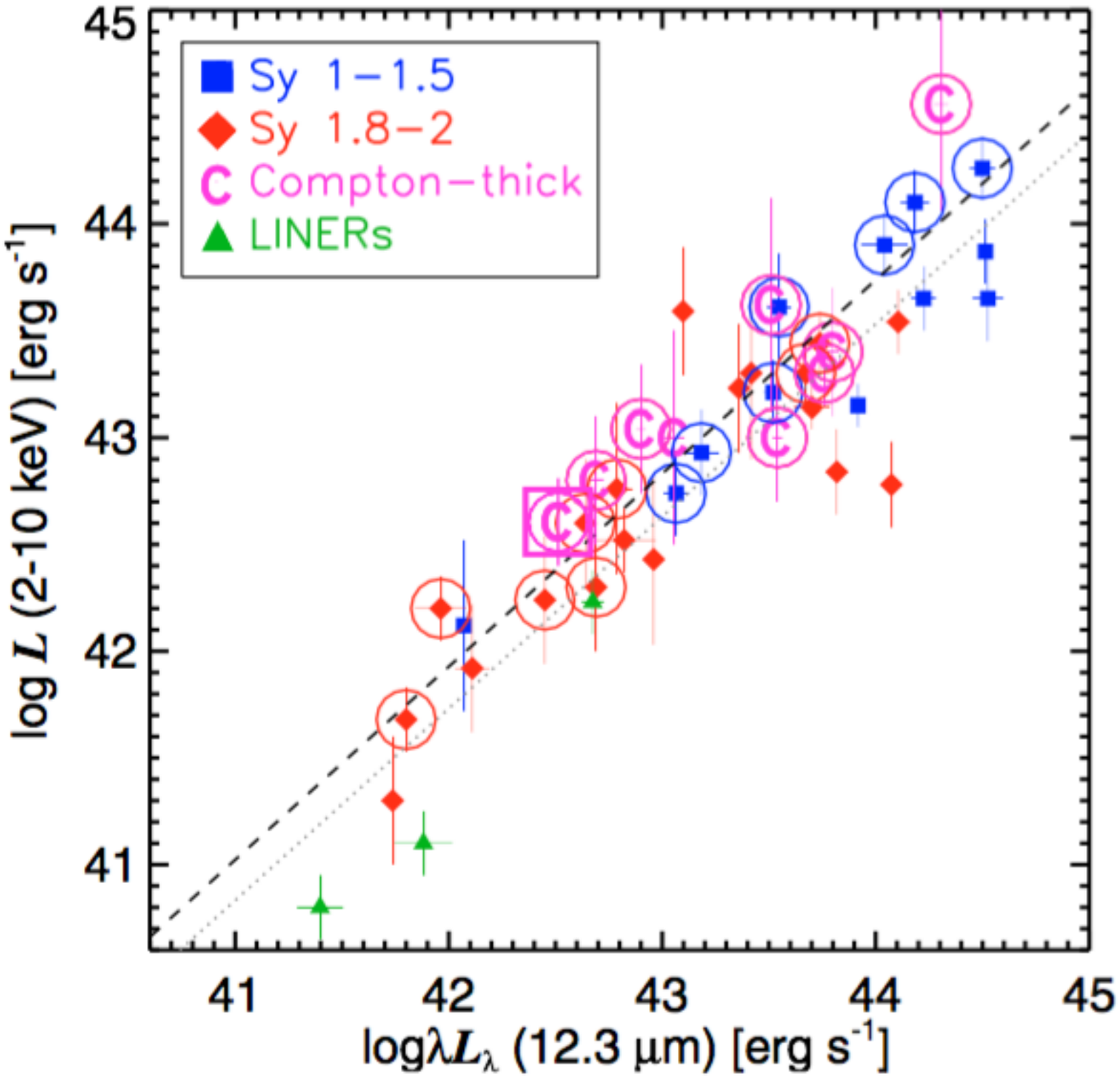
FLEXIBLE AGN MODELS: FORTES-AGN

[Gandhi+ (2009)]

The X-ray MIR correlation has been established and validated at high spatial resolution.

I can take its form and scatter as the prior on L_{12}, given the well-known X-ray luminosity of the AGN.

But what about variability? This can be represented as a more complex prior model through FortesFit.



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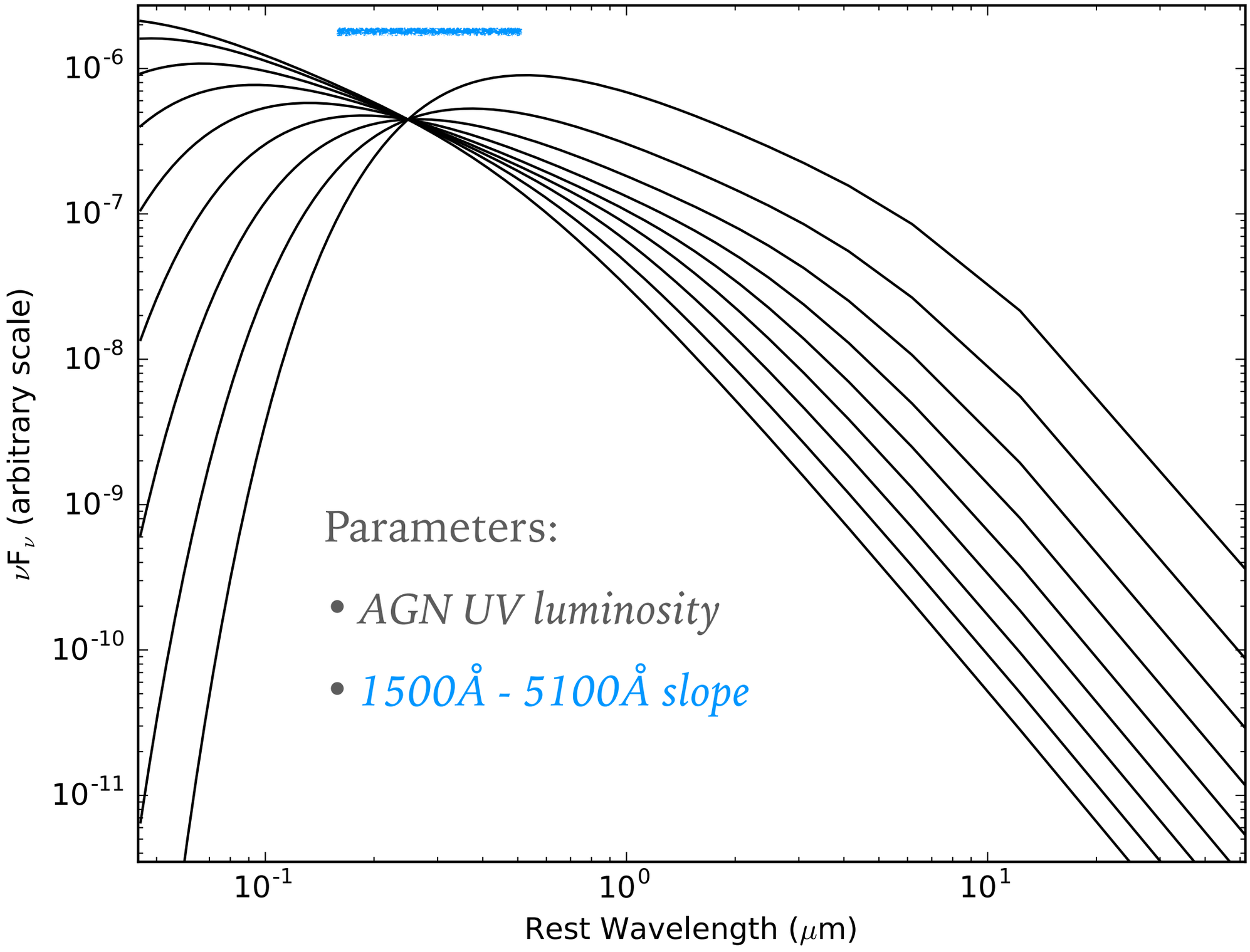
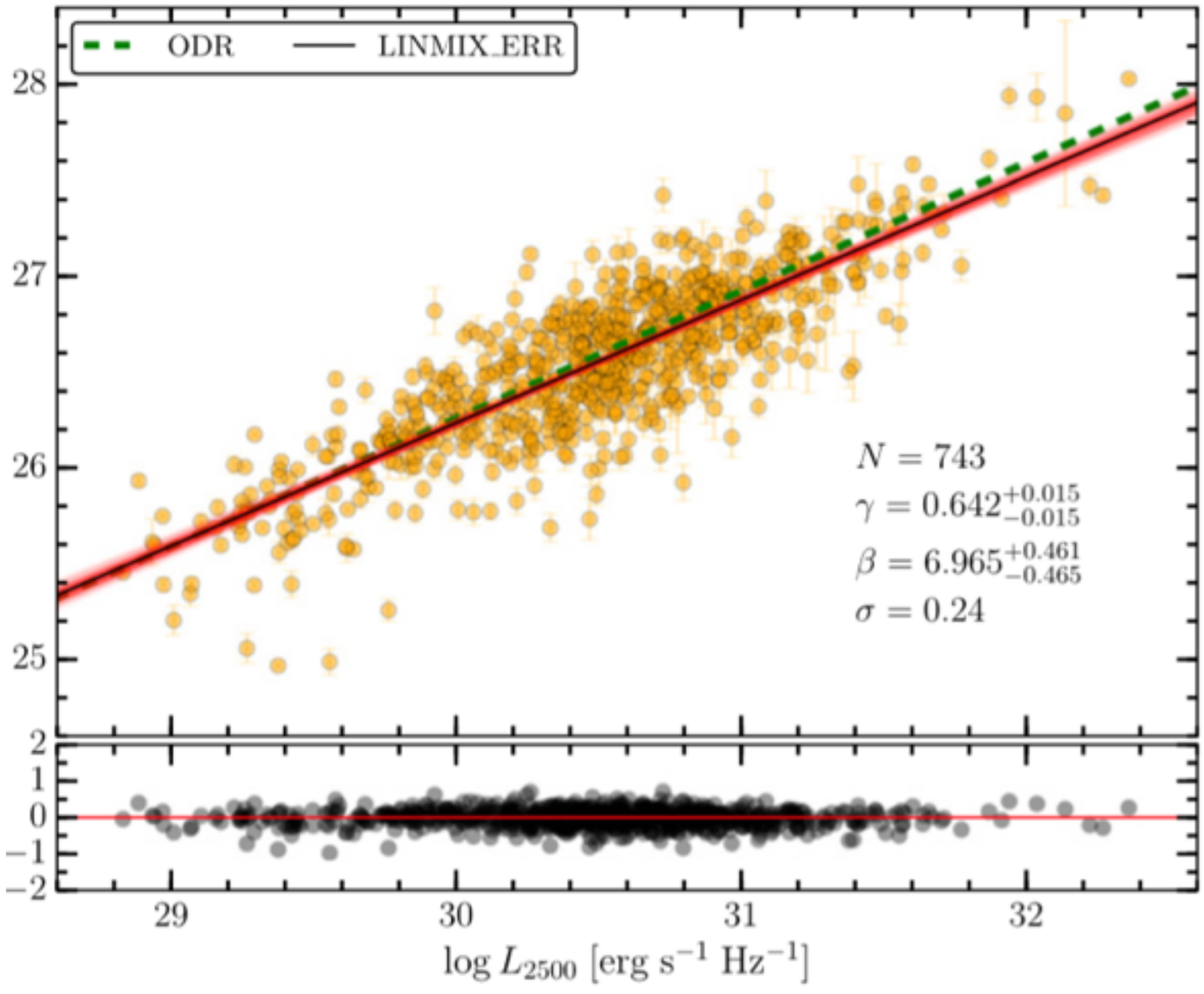


FLEXIBLE AGN MODELS: FORTES-AGN

[Lusso+ (2016)]

The X-ray UV correlation has been established and validated for luminous quasars.

I take it as a prior for the AGN's intrinsic UV luminosity.

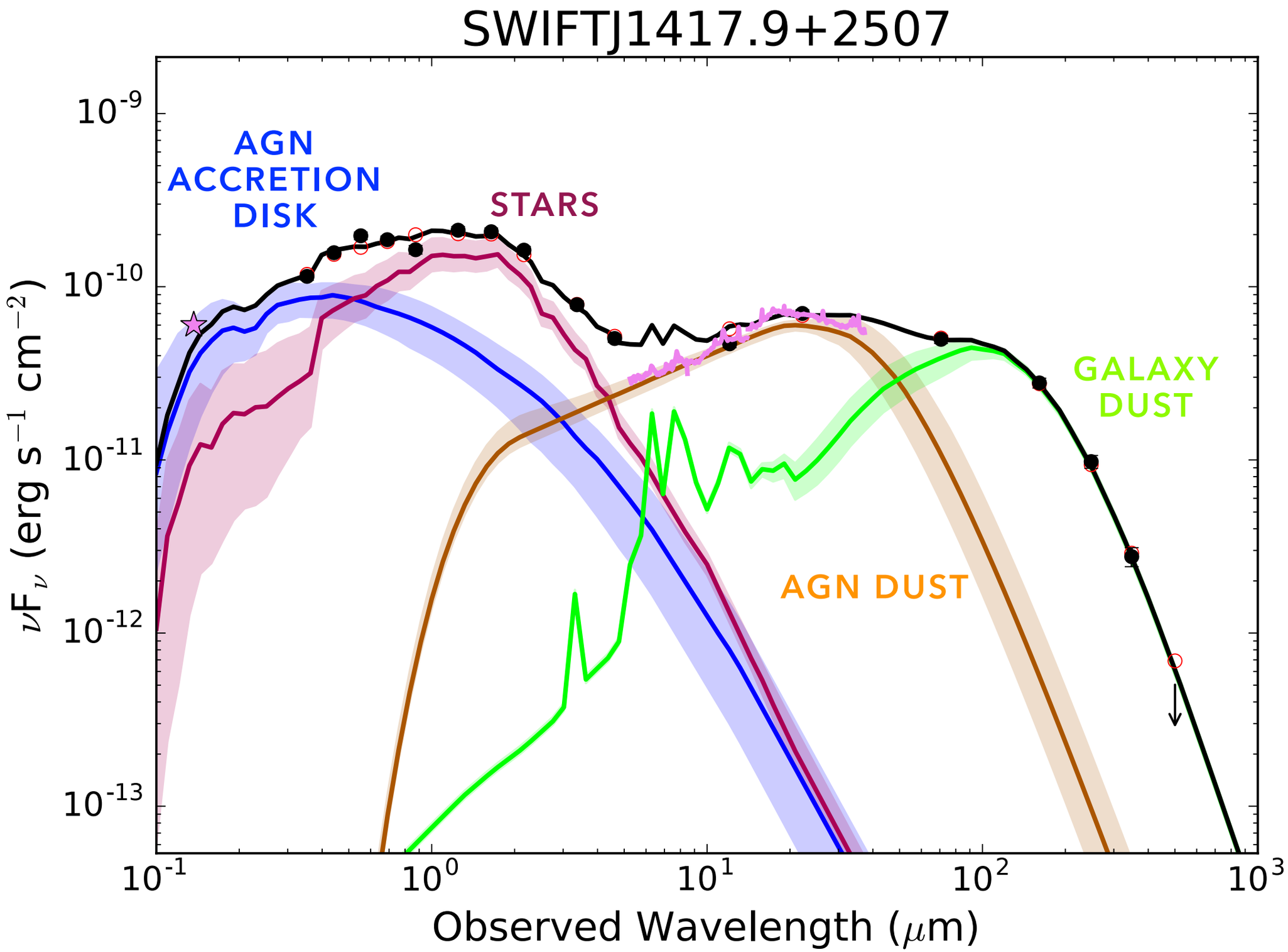


NGC 5548 WITH FORTESFIT

Label	Model	Parameter
1	19	E_BV
2	19	Luminosity2500
3	19	R_15_51
4	40	A_V
5	40	Age
6	40	StellarMass
7	40	Tau
8	36	AGNIRLuminosity
9	36	BlackBodyPeak
10	36	LongWaveSlope
11	36	ShortWaveSlope
12	88	AlphaD14
13	88	GalaxyIRLuminosity

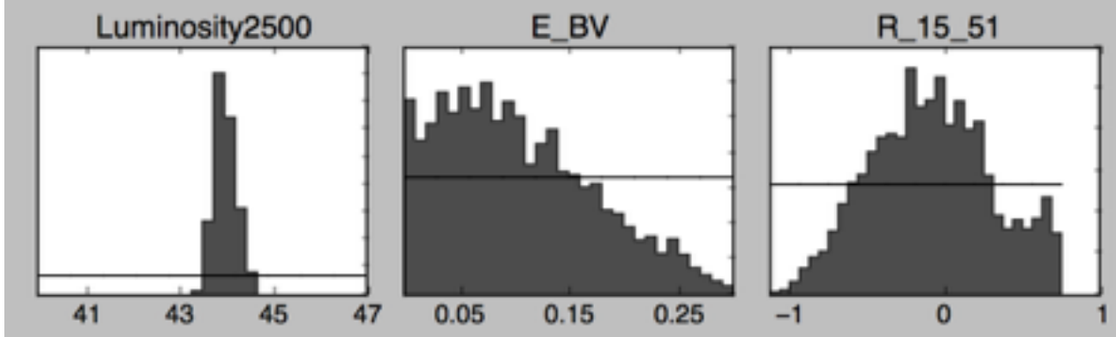
This 13 parameter fit
with 400 live points in MultiNest
took 30 minutes
on a single core on my laptop.

NGC 5548 WITH FORTESFIT

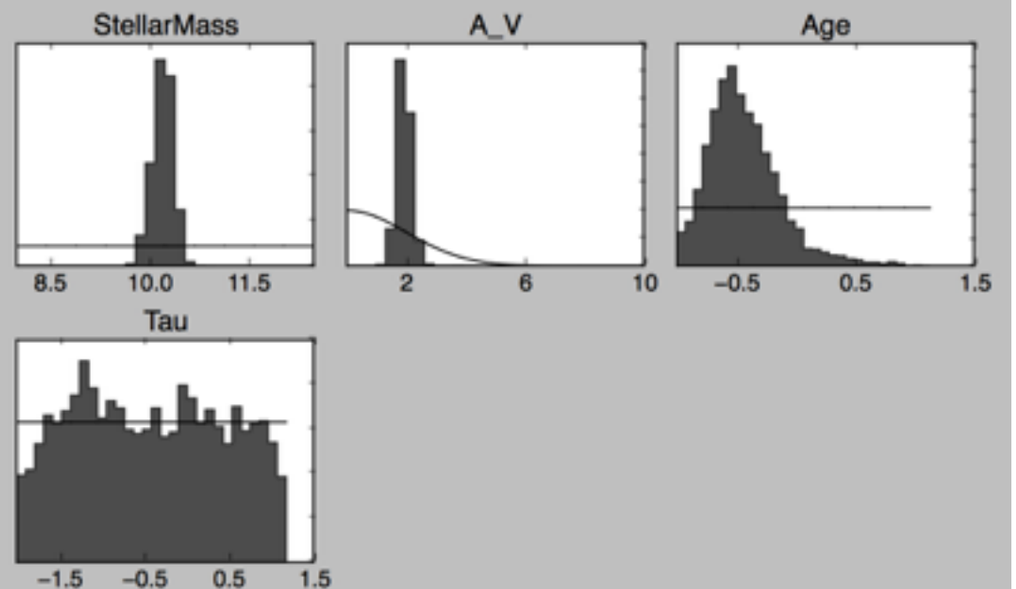


NGC 5548 WITH FORTESFIT

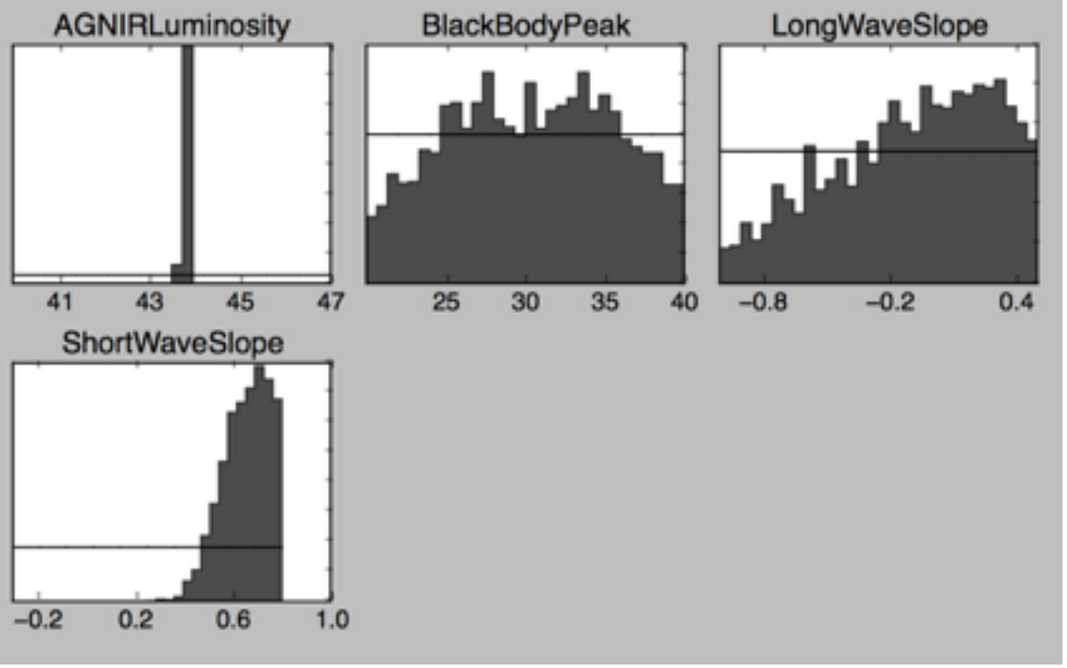
Accretion disk model parameters



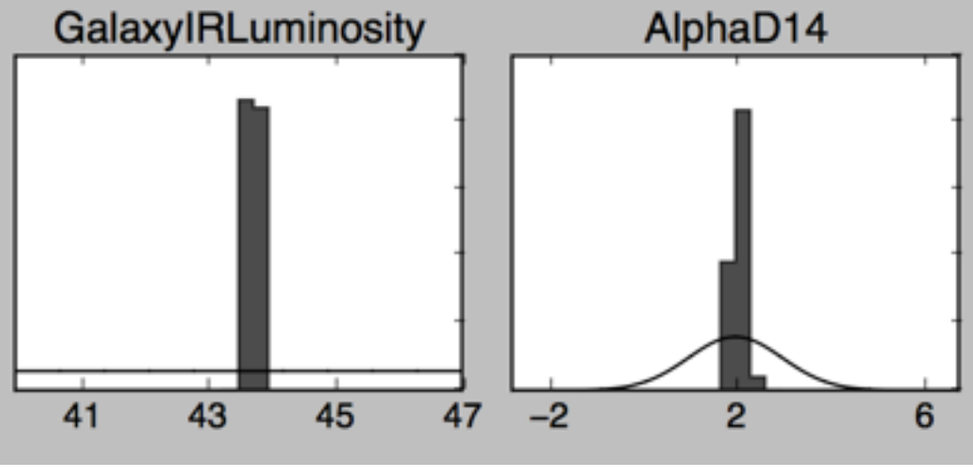
Stellar population model parameters



AGN dust model parameters

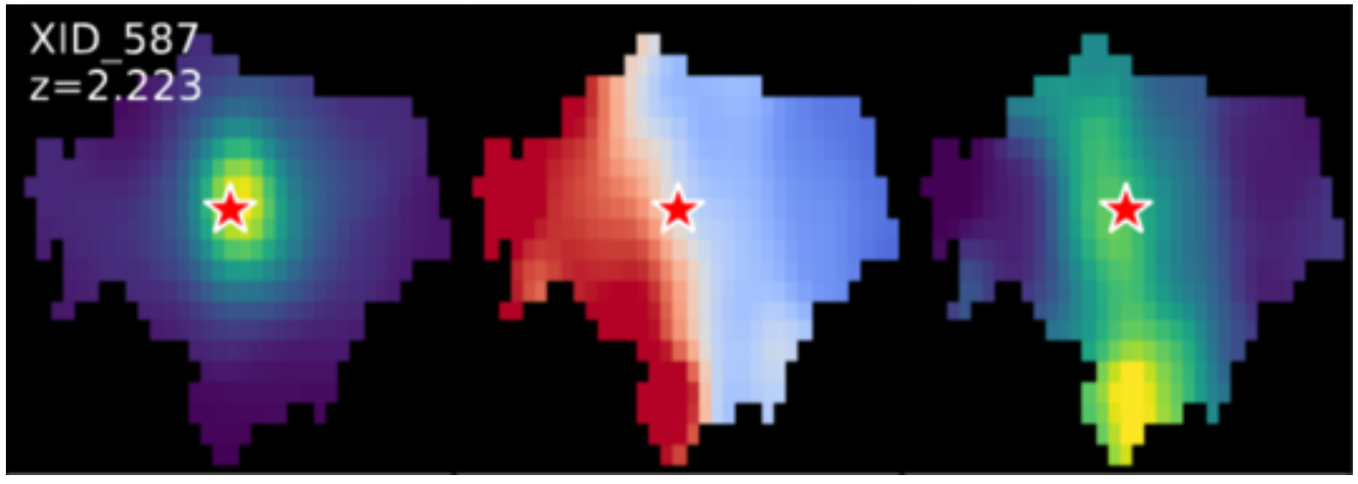


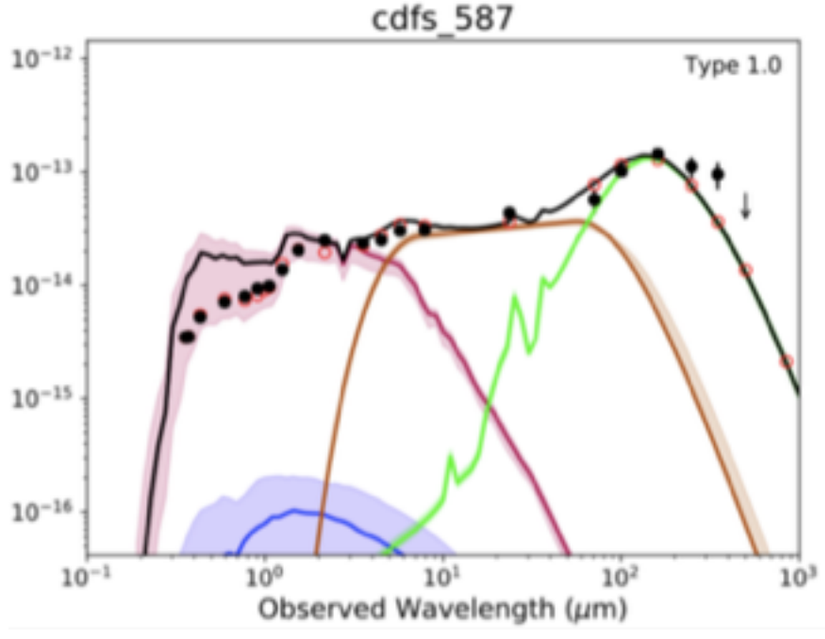
Galaxy dust model parameters

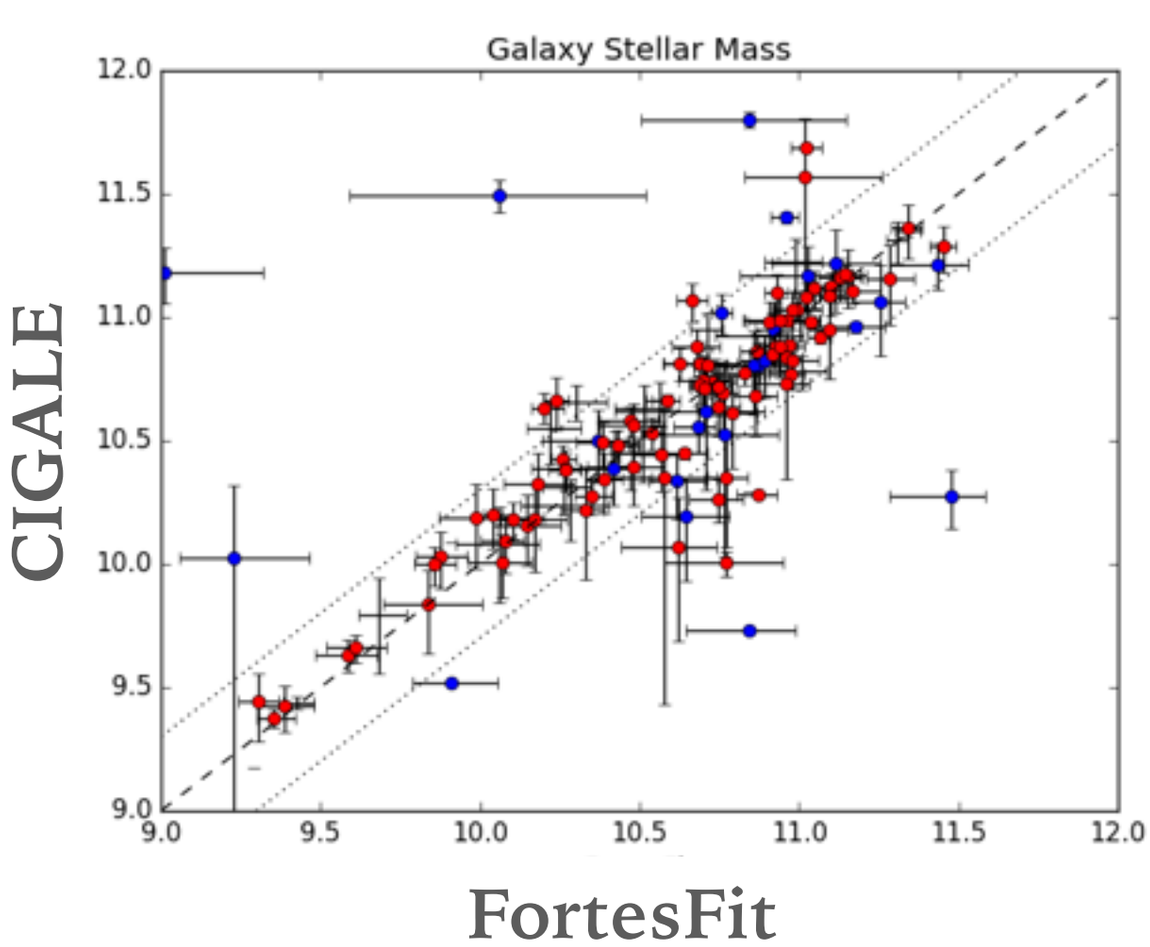


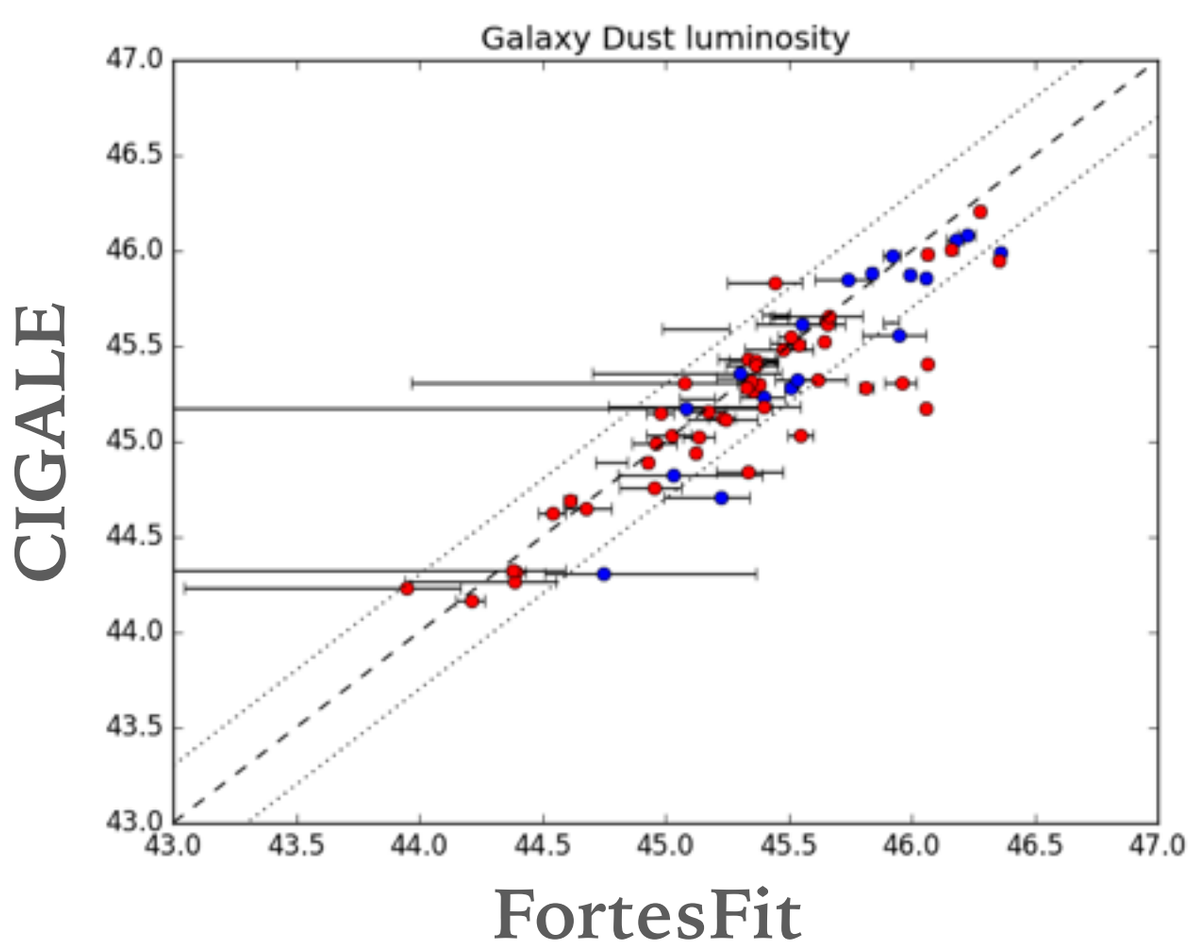
CURRENT PROJECTS: KMOS AGN Survey at High-z [KASHZ]

[Harrison+ (2016), Scholtz+ in prep., Rosario+ in prep.]



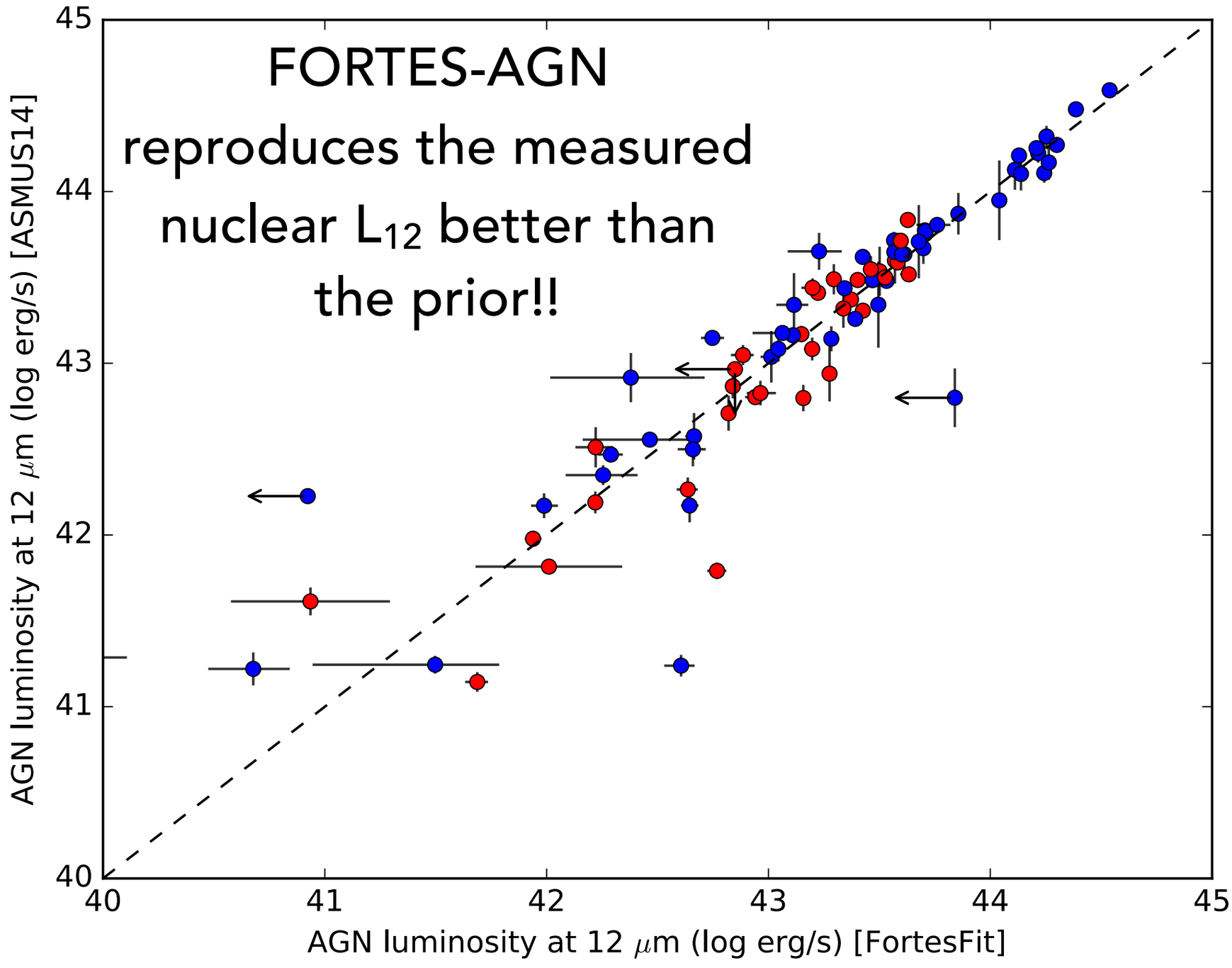






CURRENT PROJECTS: BAT AGN Spectroscopic Survey [BASS]

[Koss+ (2017), Rosario+ in prep.]



THINGS YOU'VE LEARNED

FortesFit is a **powerful interface** to incorporate and test SED models on real-world data. Astronomical applications are **potentially very wide,** beyond extragalactic studies.

Information from independent analyses of spectroscopy or non-traditional wavelengths can be **taken into account using flexible priors**.

FORTES-AGN is a prototype for a **community-driven way to distribute models**. If modellers package their libraries with a Python script that FortesFit can "register", interested users can download and maintain their **own library of diverse SED models** tailored to their own redshift range and filters of interest.