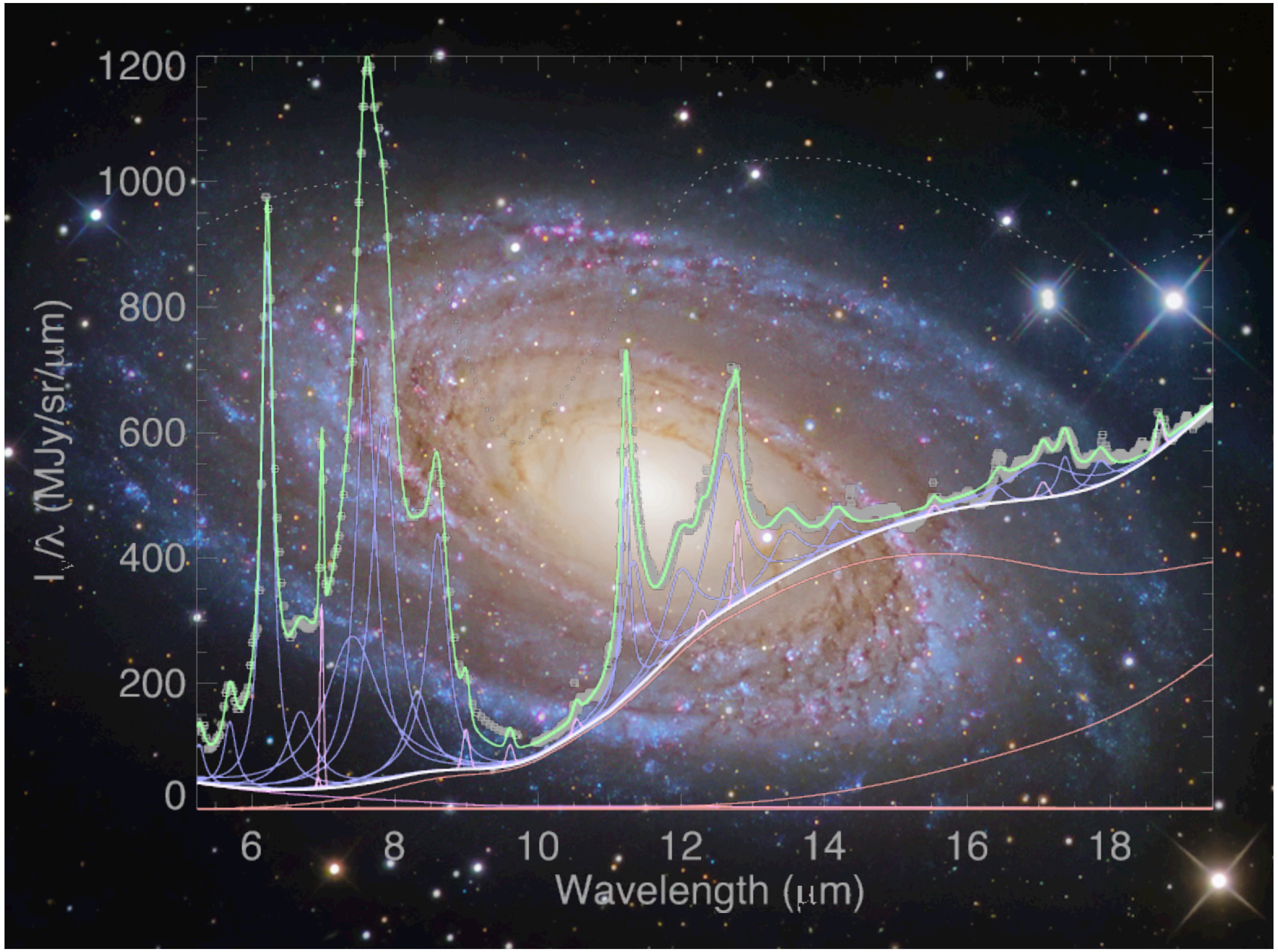
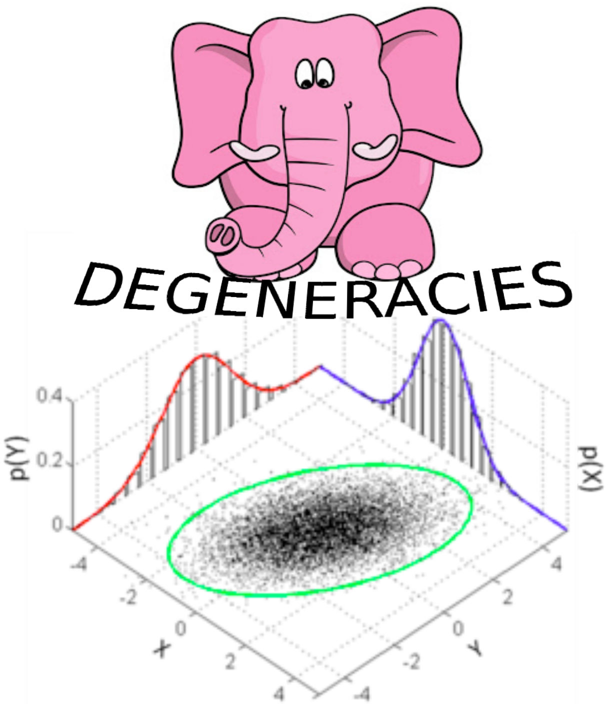
A **model-independent** AGN-host **decomposition** for mid-infrared **spectra**

Antonio Hernán Caballero





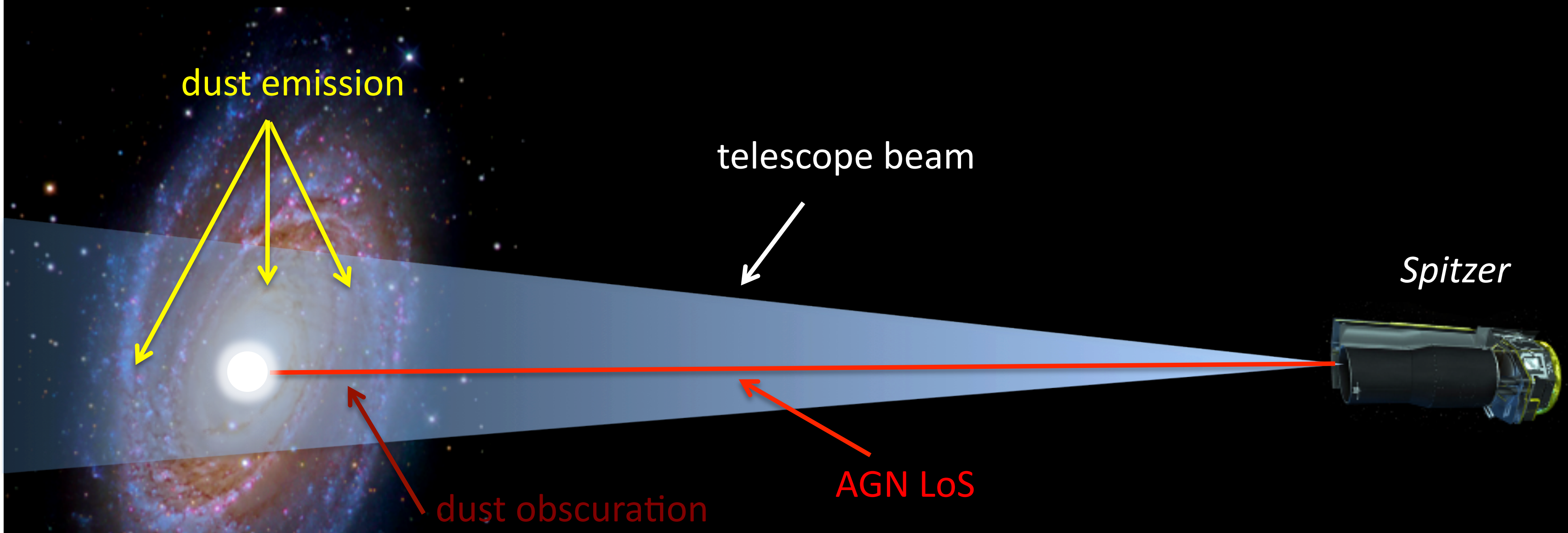
The impact of the host galaxy in AGN spectra

1) Obscuration by dust in AGN line of sight

- multiplicative factor
- depends on composition, column density

2) Dilution by emission in integration aperture

- additive component
- depends on angular resolution, luminosity

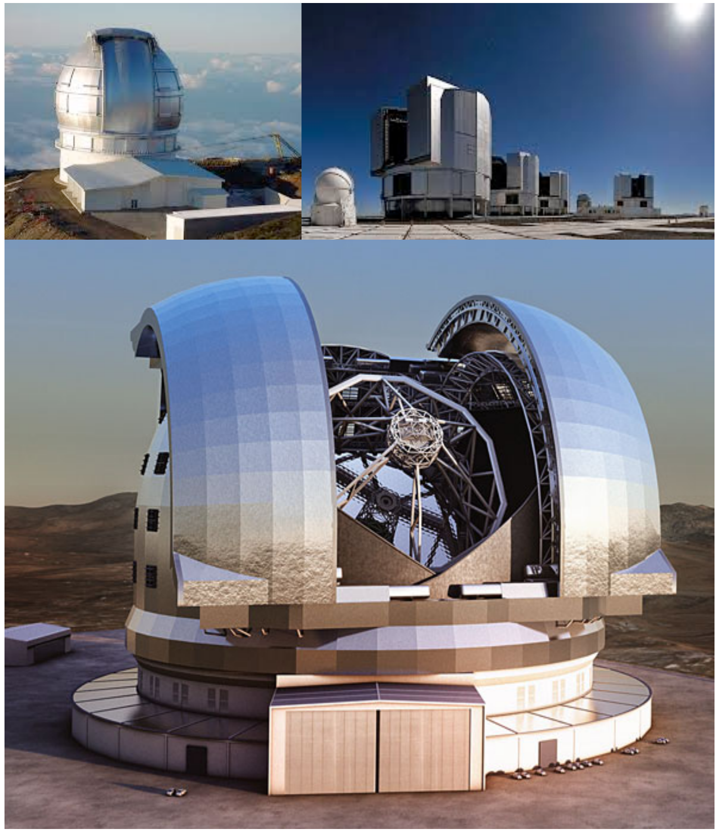


Observed AGN spectrum depends on angular resolution

High res: observed = intrinsic x obscuration

Low res: observed = intrinsic x obscuration + host emission

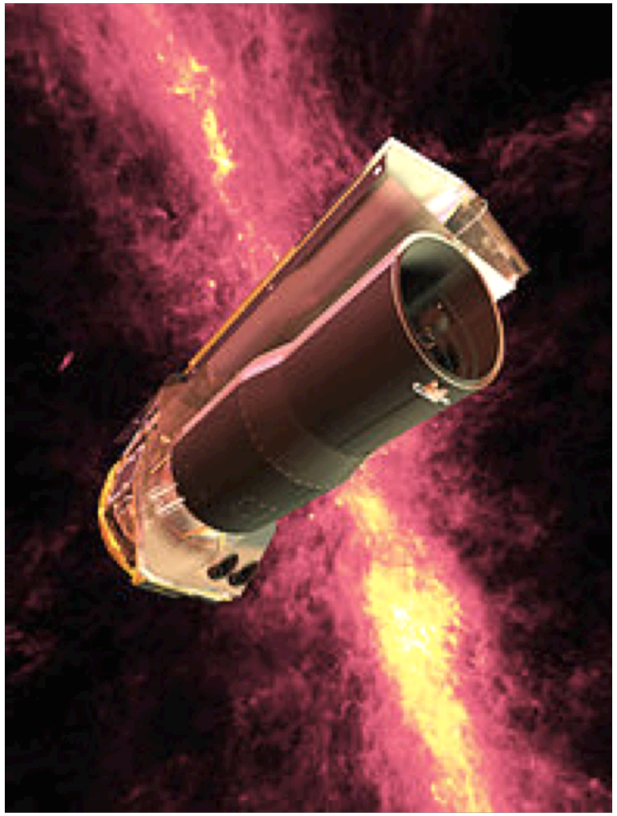
Intrinsic AGN spectrum is UNOBSERVABLE



Ground based mid-IR observations

High spatial resolution (<0.5”)
Low sensitivity (~1Jy)
Small spectral coverage (atm. windows)

Limited to local AGN



Space based mid-IR observations

Low spatial resolution (~5”)
High sensitivity (~1mJy)
Larger spectral coverage

Applicable to high redshift AGN

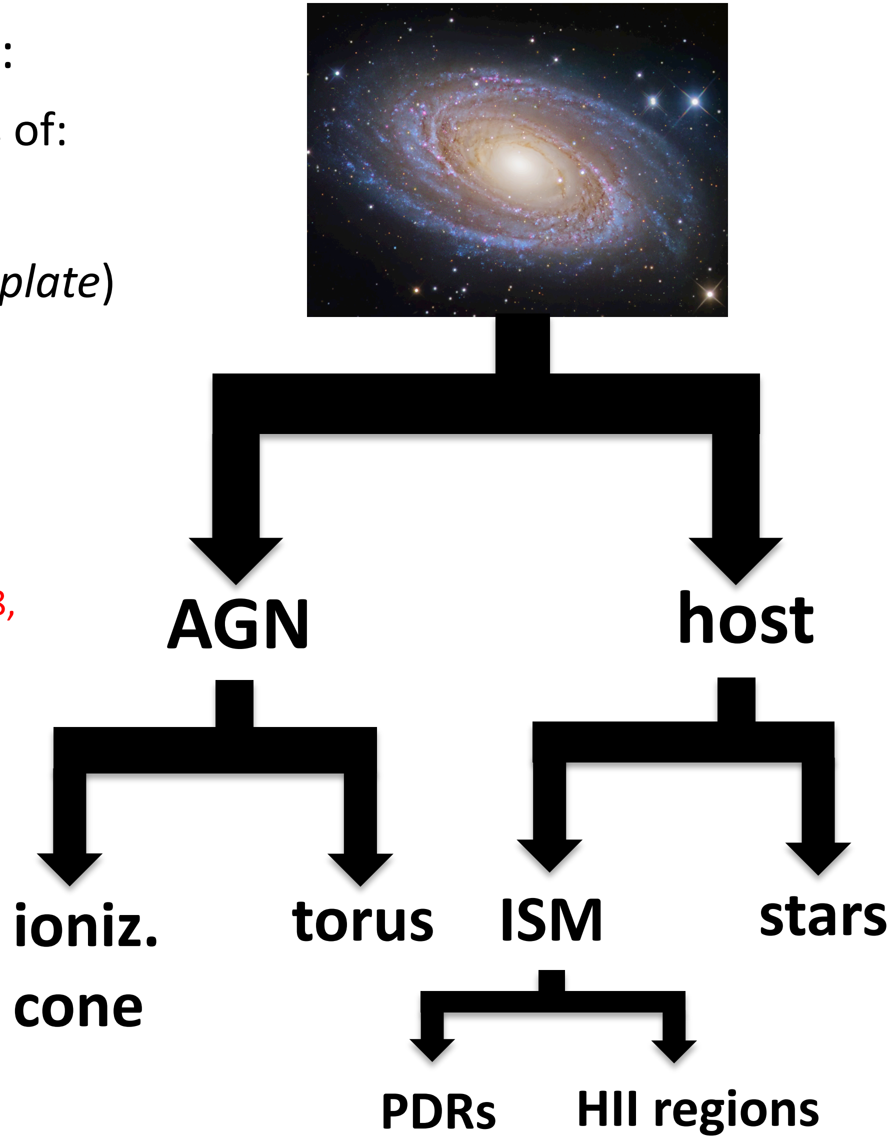
Spectral decomposition

Sum of physical components represented by:

- **empirical templates**, derived from observations of:
  - single source (*e.g. M82*)
  - multiple similar sources (*e.g. starburst template*)
- **numerical models** (*e.g. torus model*)
- **analytical models** (*e.g. power-law*)

Huge diversity of decomposition models:

Laurent+00, Tran+00, Lutz+04, Sajina+07, Smith+07, Nardini+08, Hernán-Caballero+09, Veilleux+09, Mullaney+11, Alonso-Herrero+12, Feltre+13, Pope+13, Ruiz+13, Shi+14, …



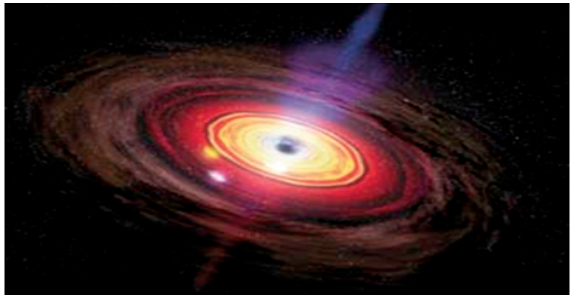
The issue with obscuration:

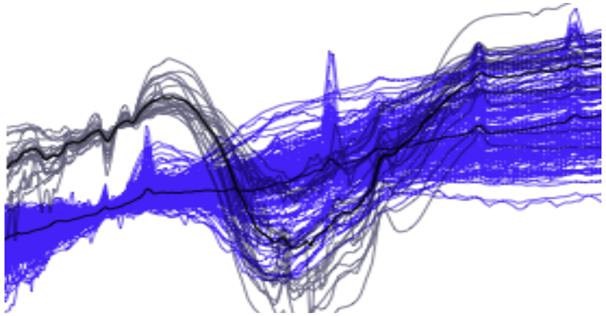
- obscuration is multiplicative term
- non-linear function → minimization problem
- mid-IR extinction law is poorly known
- applied to each component separately

Decomposition model of DeblendIRS

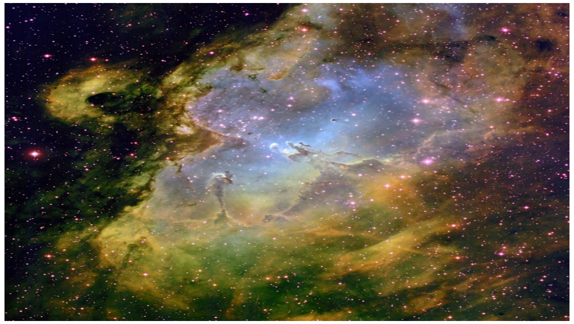
Spectrum fitted with linear combination of templates: $f_{i,j,k}(\lambda) = af_i^{\mathrm{star}}(\lambda) + bf_j^{\mathrm{PAH}}(\lambda) + cf_k^{\mathrm{AGN}}(\lambda)$

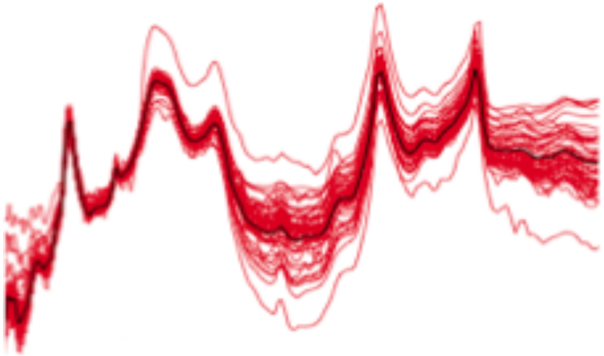
Extinction already included by Nature in the templates (observed spectra)



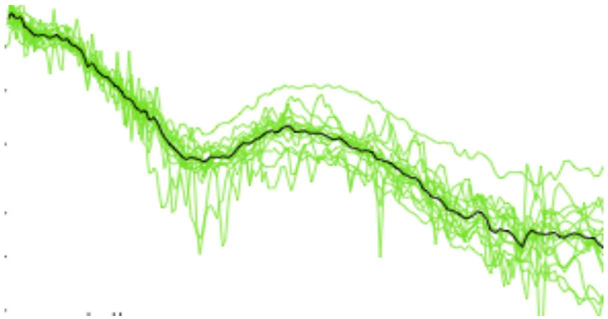


181 “pure-AGN” templates





56 “pure-PAH” templates



19 “pure-stellar” templates

181 x 56 x 19 = 192584 template combinations!

Decomposition examples

Hatziminaoglou et al. (2015)

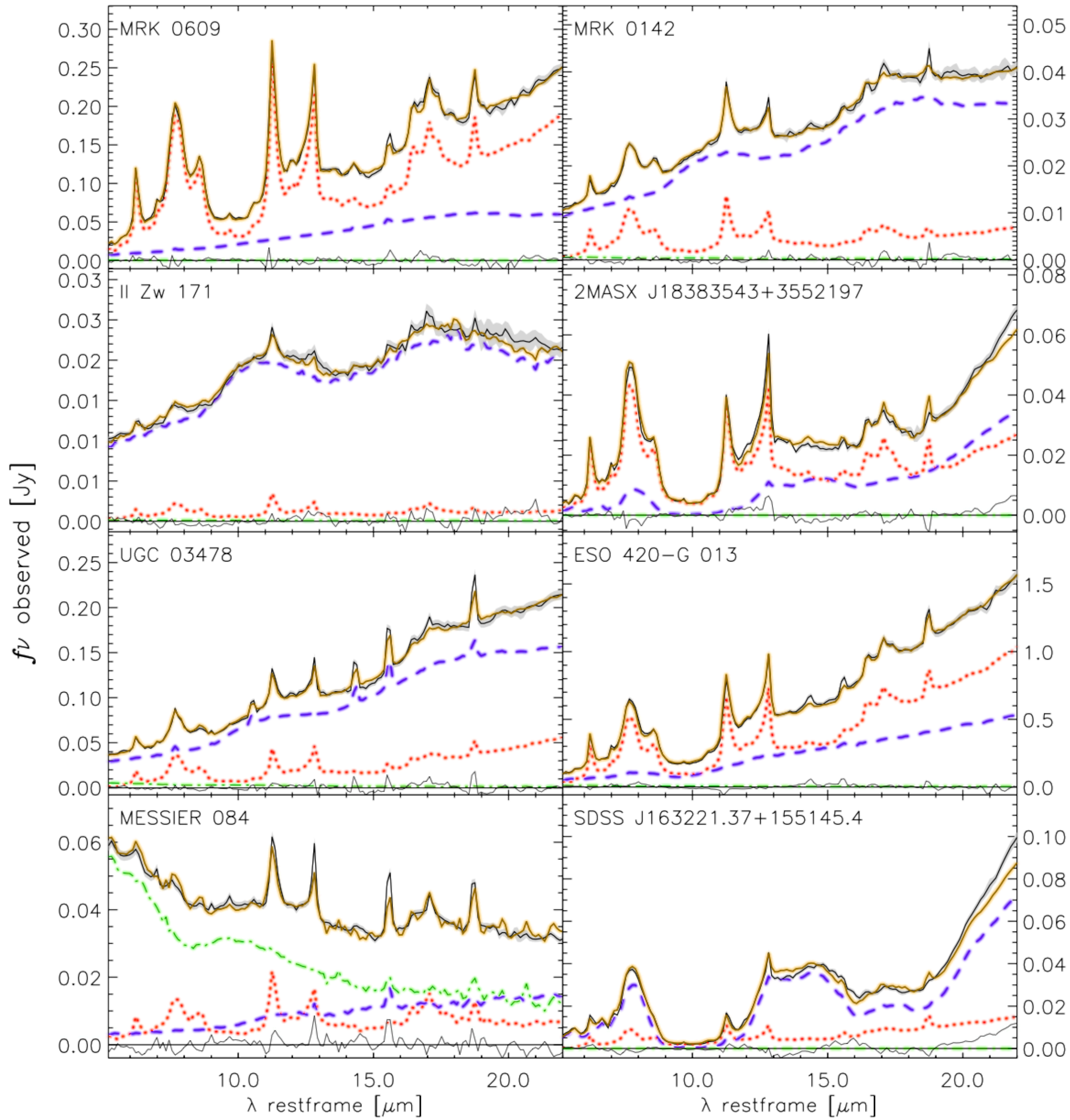
typical **residual <5%**

$\chi^2>1$ due to high S/N (>=20)

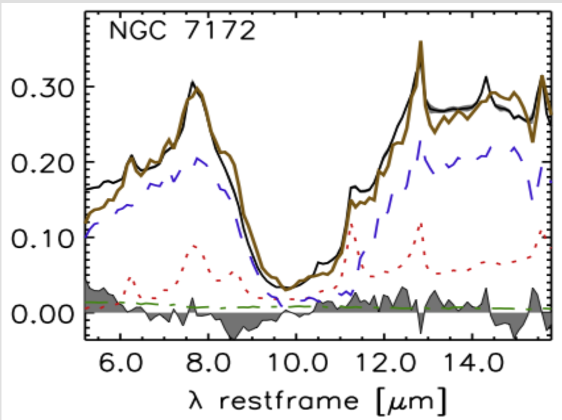
Residuals >> noise

Residuals dominated by granularity of template set

Larger residuals for emission lines and PAH bands due to source-to-source variations in line ratios



Mediocre fits in some sources with very deep silicates

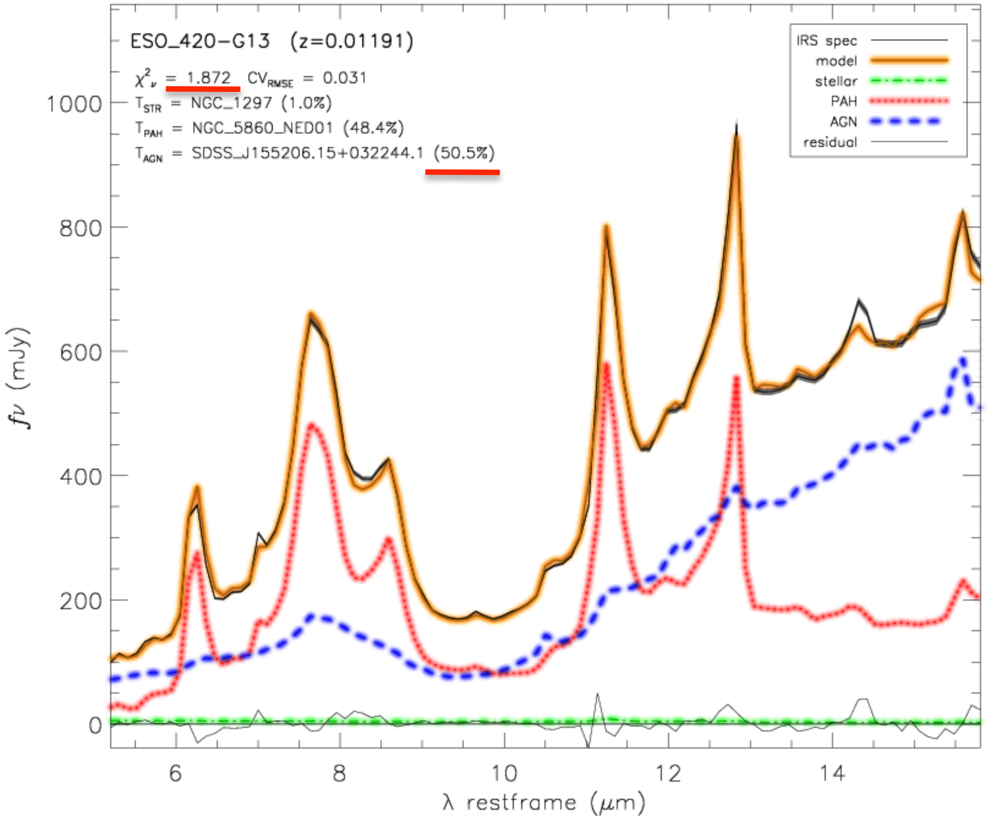


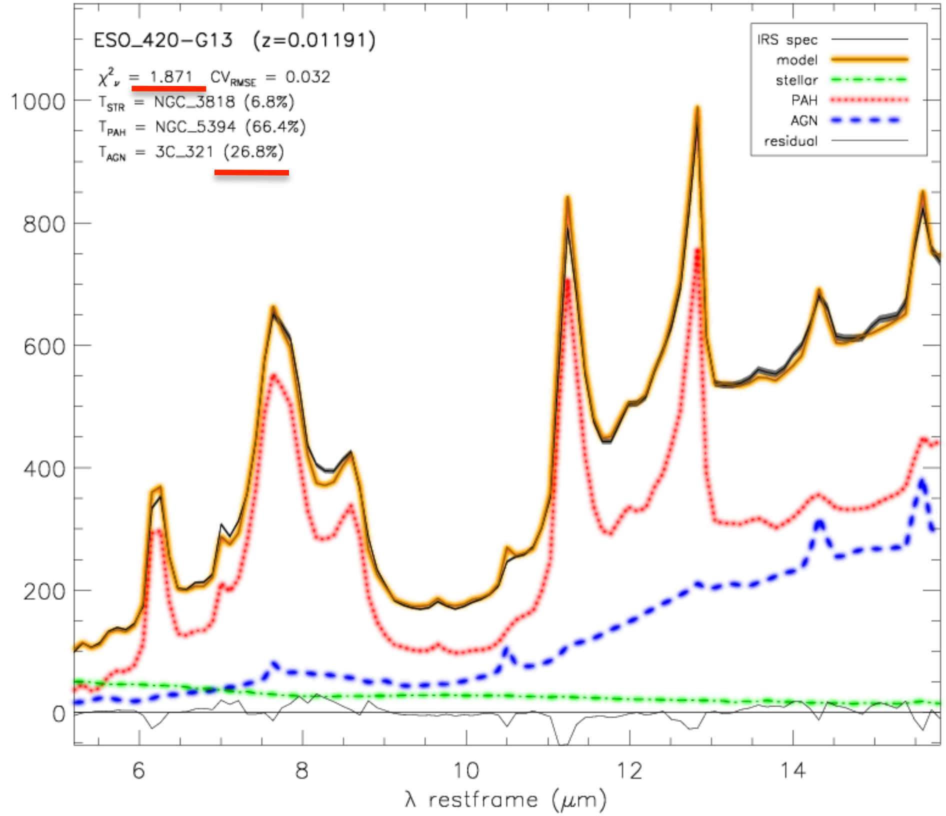
The problem with degeneracy

Different template combinations can produce similar composite spectra with same χ^2

$$STR_1 + PAH_1 + AGN_1 \approx STR_2 + PAH_2 + AGN_2$$

This degeneracy affects other decomposition methods too, but is usually **overlooked**





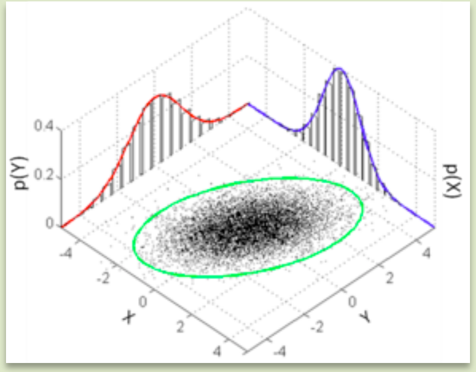
Estimation of uncertainties including degeneracy

Sources of uncertainty in spectral decomposition results (and how to deal with them):

- Noise in the data → error propagation / MC simulations
- Bias in the models / incompleteness in the template set → find better ones!
- Degeneracy among components/parameters → **marginalized probability distributions**

Marginalization of joint probability distribution

We can recover the probability distribution of any single variable from a joint distribution by summing (discrete case) or integrating (continuous case) over all the other variables.

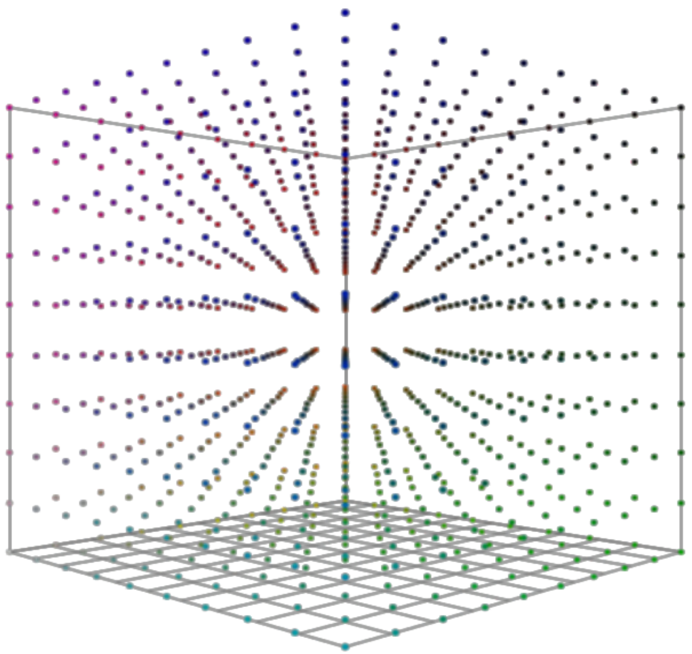


"Bayesian" SED-fitting tools:

MAGPHYS (daCunha et al. 2008)

BayesCLUMPY (Asensio Ramos & Ramos Almeida 2009)

CIGALE (Noll et al. 2009)

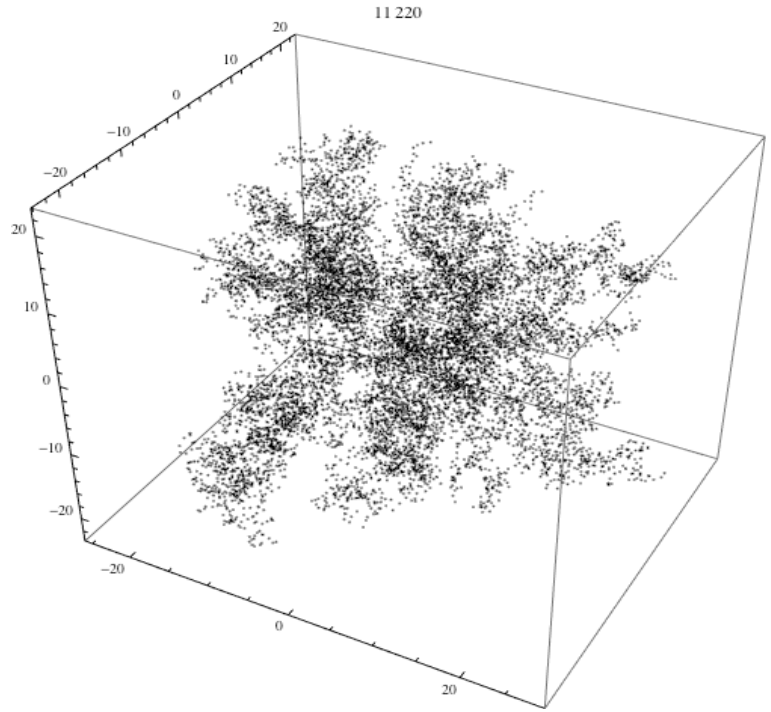


Numerical models

Homogeneous sampling of parameter space

Resolution limited by computing power

PDF integrates parameter space
(marginalized PDF)



Empirical templates

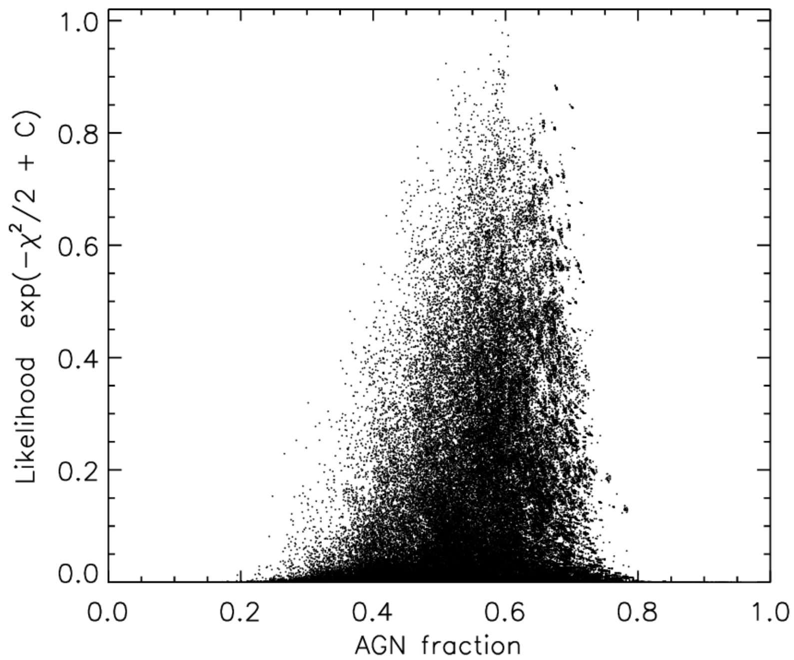
Very inhomogeneous sampling

Resolution limited by available observations

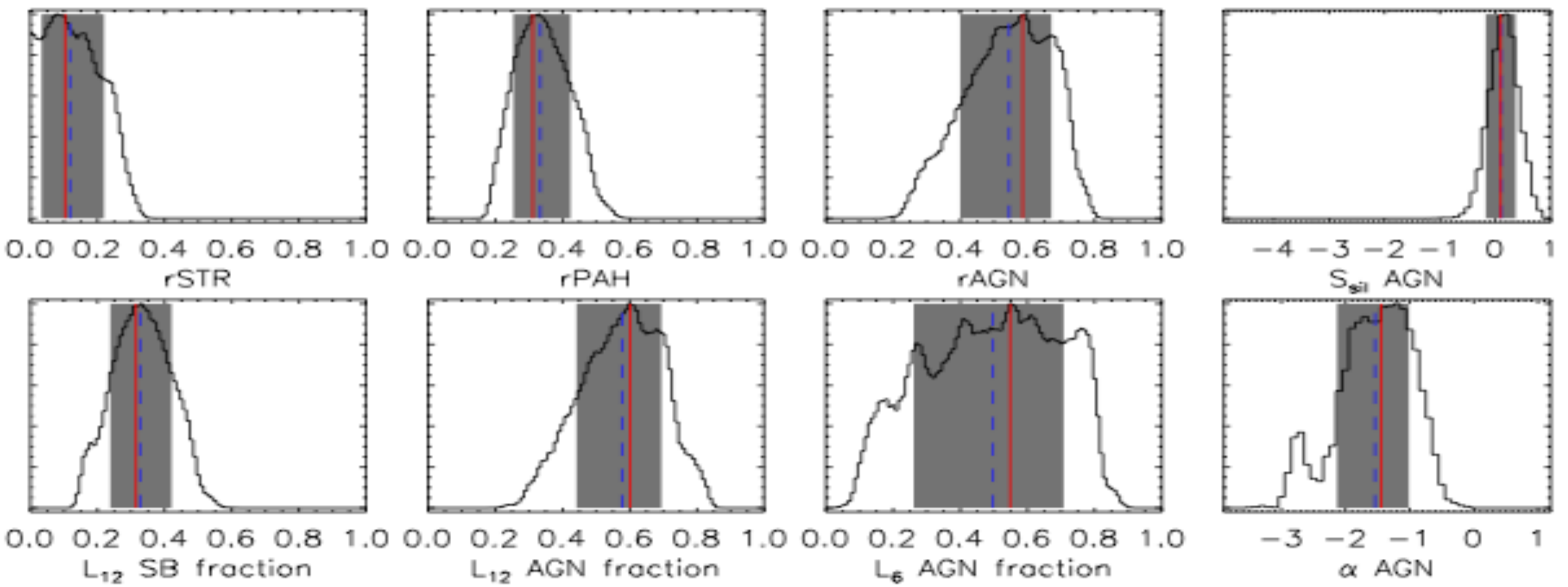
PDF estimated with “max” method
(Noll et al. 2009)

Obtaining PDFs with the 'max' method

1. Calculate likelihood for all template combinations
2. Group them according to calculated value for the parameter of interest
3. Choose highest likelihood in each bin
4. Normalize to obtain probabilities



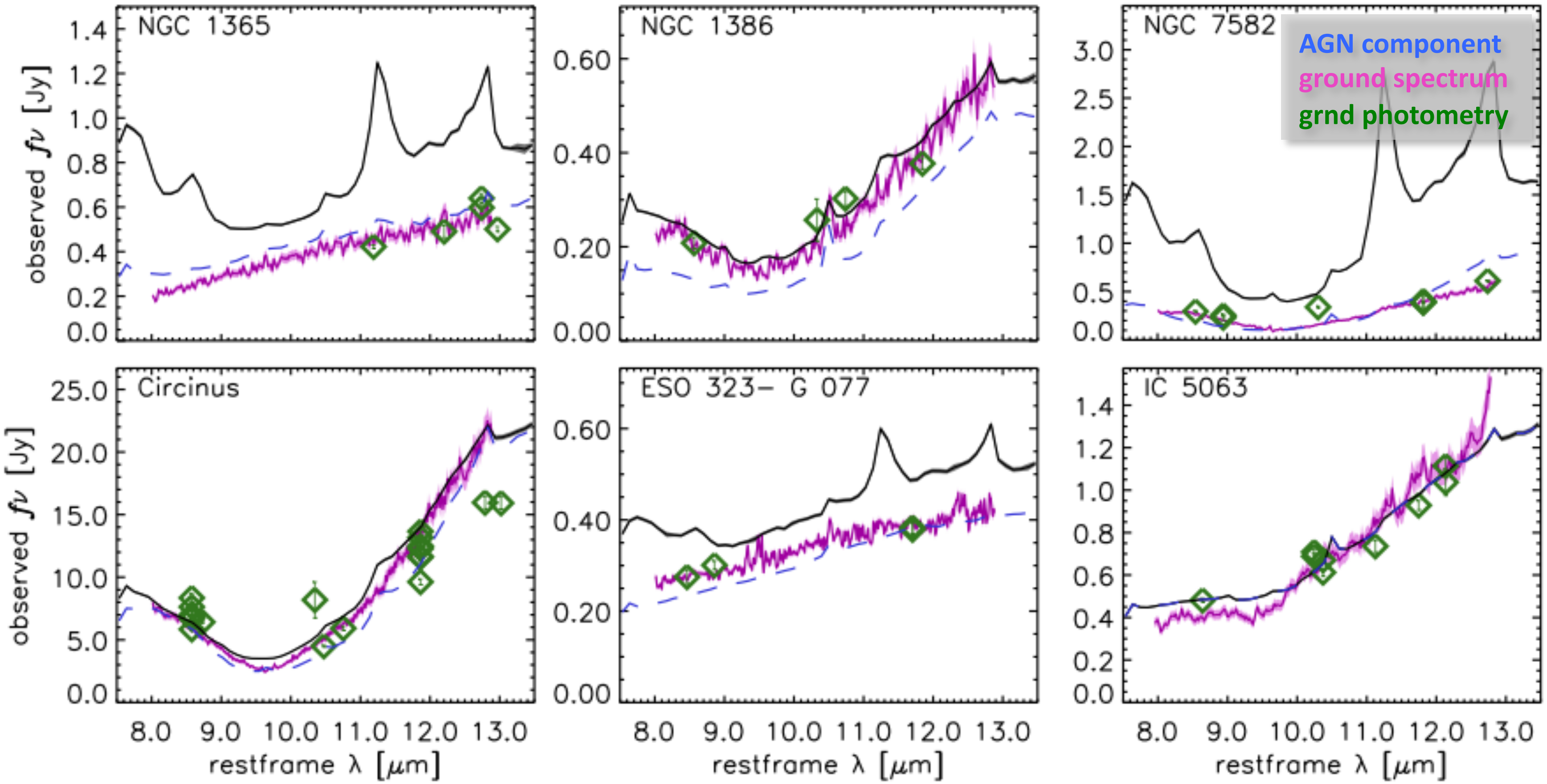
PDFs are obtained for model parameters **and** ***properties of the components or fitting model***



Comparison with ground-based nuclear spectroscopy

AGN spectra derived from decomposition match the nuclear spectra and photometry of nearby Seyferts obtained from ground-based sub-arsecond resolution observations

Hernán-Caballero et al. (2015)



Summary

- Intrinsic AGN spectrum unobservable due to LoS obscuration

- Circumnuclear host emission removable with spectral decomposition

- Decomposition using libraries of spectra as templates:
  - very good fits in general (exception: deeply obscured sources)
  - no need to model extinction separately
  - proper treatment of degeneracy with joint PDF marginalization
  - AGN components can be directly compared to observed nuclear spectra

Further info:

Resolving the Active Galactic Nucleus and host emission in the mid-infrared using a model-independent spectral decomposition. **Hernán-Caballero et al. (2015), ApJ, 803, 109**

Download deblendIRS:

www.denebola.org/ahc/deblendIRS →

IDL/GDL source code
templates
documentation
sample data