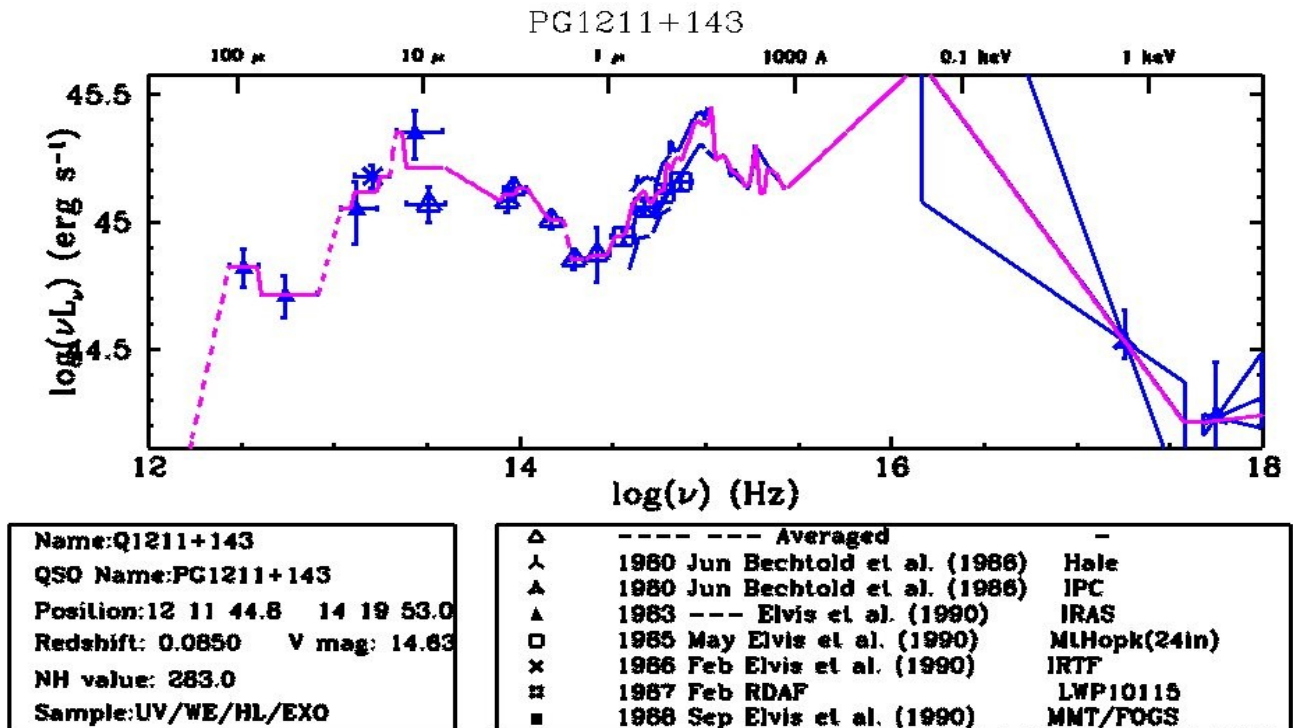# Analysing Spectral Energy Distributions

Jonathan McDowell (CfA)

- Requirements study for VAO SED tool development. Tool will be designed for both Web access and local desktop usage.

- Collaboration between CfA, NED, STSci, NRAO....)

Finding data for the SED

- First step: interface with NED and fit models to NED SEDs

- Collaboration with IPAC to develop NED SED server

- Collaboration with NRAO for data discovery protocol

- Collaboration with STScI for visualization (SpecView)

- VO search: "SSA" Simple Spectral Access servers (in development)

- VO search: "Cone search" catalog servers (and successors)

- Local user data: FITS, VOTable, ascii tables

- Generate photometry points and 1-D spectra ('segments')

  - extract photometry from CCD images into catalogs (tables)

  - fit fluxes to X-ray data

  - extract and calibrate 1D spectrum from long slit data

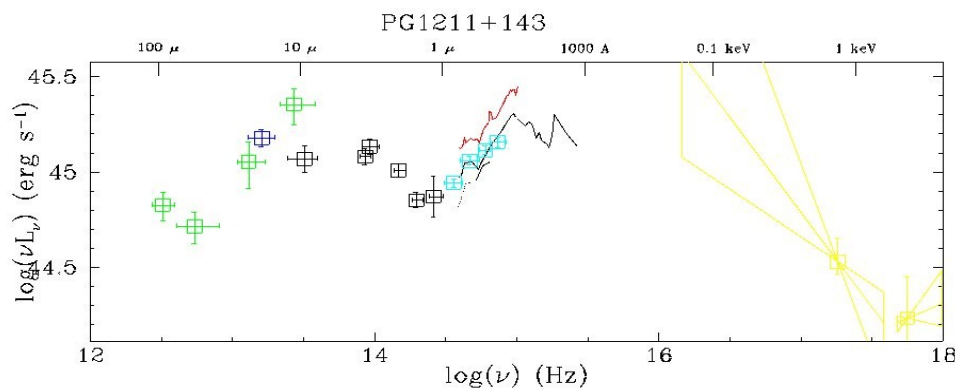 - *This part not our problem for now – use existing tools*

Building the SED

- Assemble aggregate SED
  - convert each segment to VO format
  - collect in one file with all metadata
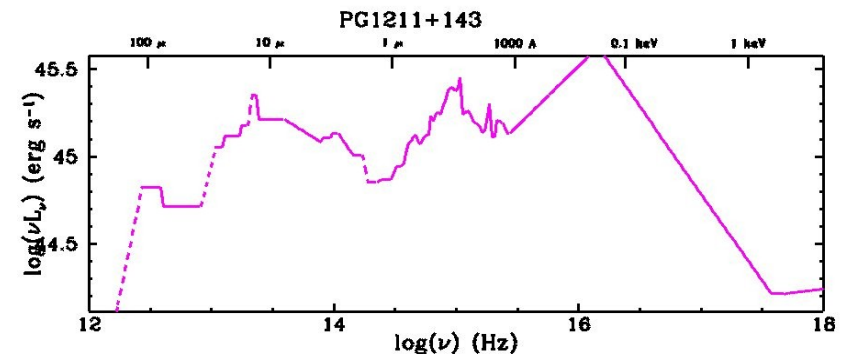- Create uniform SED
  - time average/blend phot. and spectra in each wavelength bin
  - interpolate across missing ranges?

SED analysis

SED Fitting capabilites - proposed for Year 1

Fit SED to template library
Fit SED to parameterized models
 - Sherpa model suite
Evaluate goodness of fit,
confidence

SED Analysis capabilities (later)

Deredden SED
Convert to LSR/rest frame
Estimate integrated
fluxes/luminosities
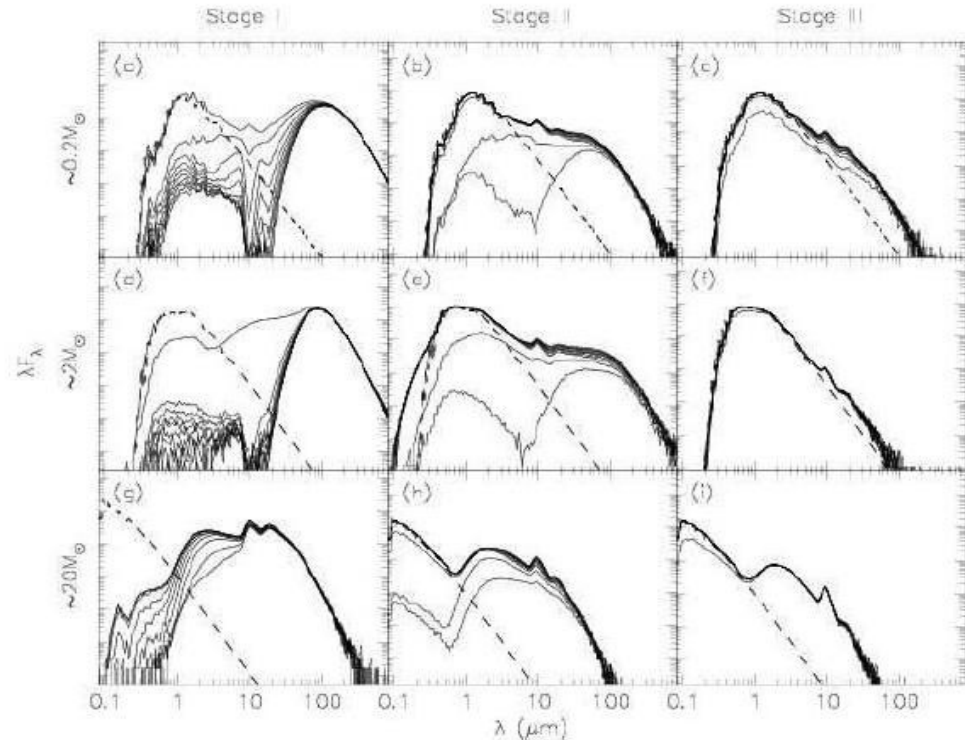Smooth SED

SED Template Fitting

Use cases:
 - object classification
 - photometric redshifts
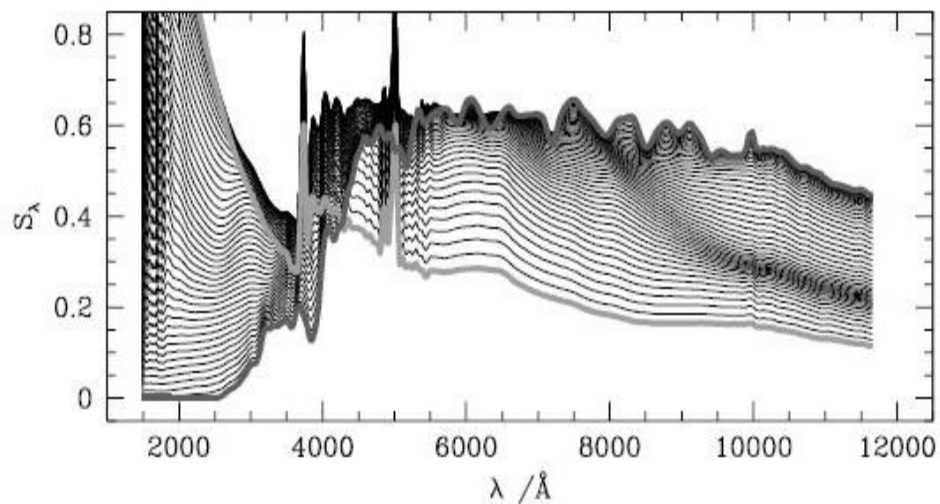
Needs:
 - Ability to define standard libraries of template SEDs, find them and read them in

 - Ability to find the best fit in this library to your SED, read off model parameters of that best fit

 - Should support mixture models (best fit = 0.2 * model A + 0.8 * model B)

Young star templates
Robitaille et al 2006

Galaxy templates for SDSS photometric redshifts (Csabai et al 2002)

SED Model Fitting

Use cases:
  - object classification
  - decompose SED into physical components
  - estimate luminosities

Needs:
  - Ability to define analytic-expression models, multiplicative and additive

 - Library of standard models (blackbody, power law, accretion disk...)

- Method to incorporate user-defined codes as models

- Optimization algorithms and infrastructure

- Ways to inspect variation of fit statistic in parameter space
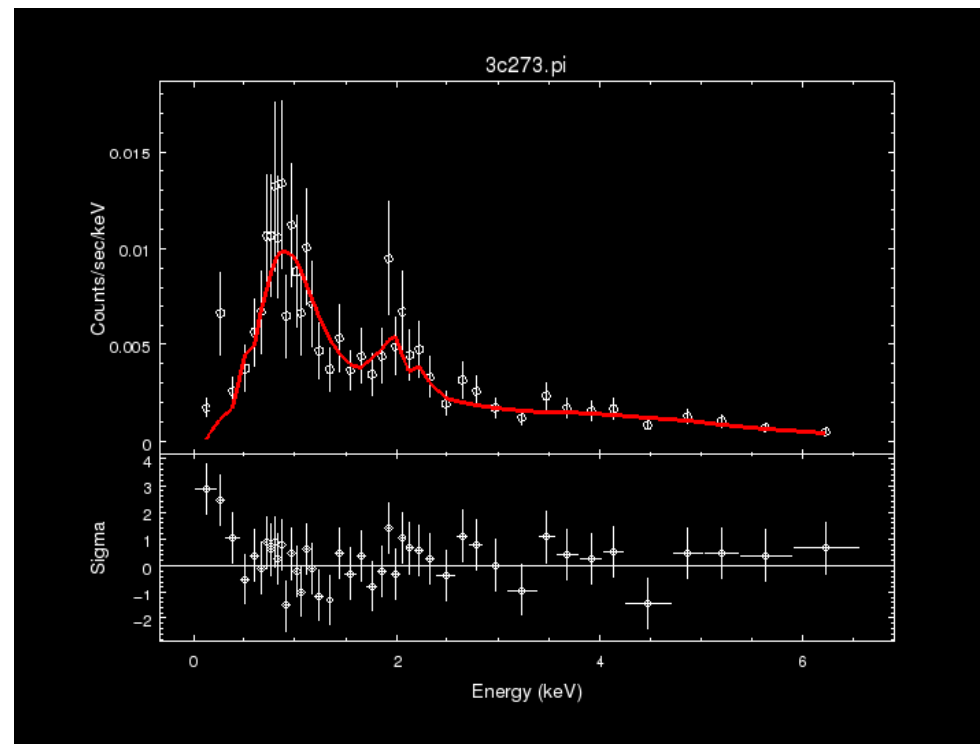
Fitting of spectral data using Sherpa (Poisson regime)
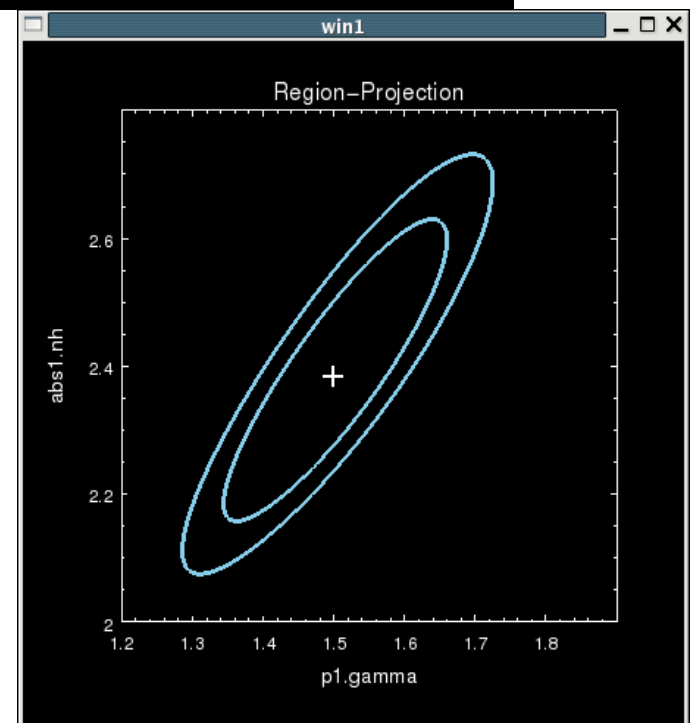
Dereddening

Use case: correct for foreground extinction for nearby or extragalactic objects
Extinction may be local to us, or on line of sight, or in the object (so apply in a rest frame somewhere between z=0 and the object)
 Need: Standard extinction law at all wavelengths (far IR to X-ray) parameterized by total dust and total hydrogen column
   Ability to supply alternate user-defined extinction laws for specified range of wavelengths
        Specify redshift at which extinction is to be applied
        Connection to VO service providing HI and dust estimates at given position (and velocity range, for galactic objects), accessing all-sky HI/dust databases?
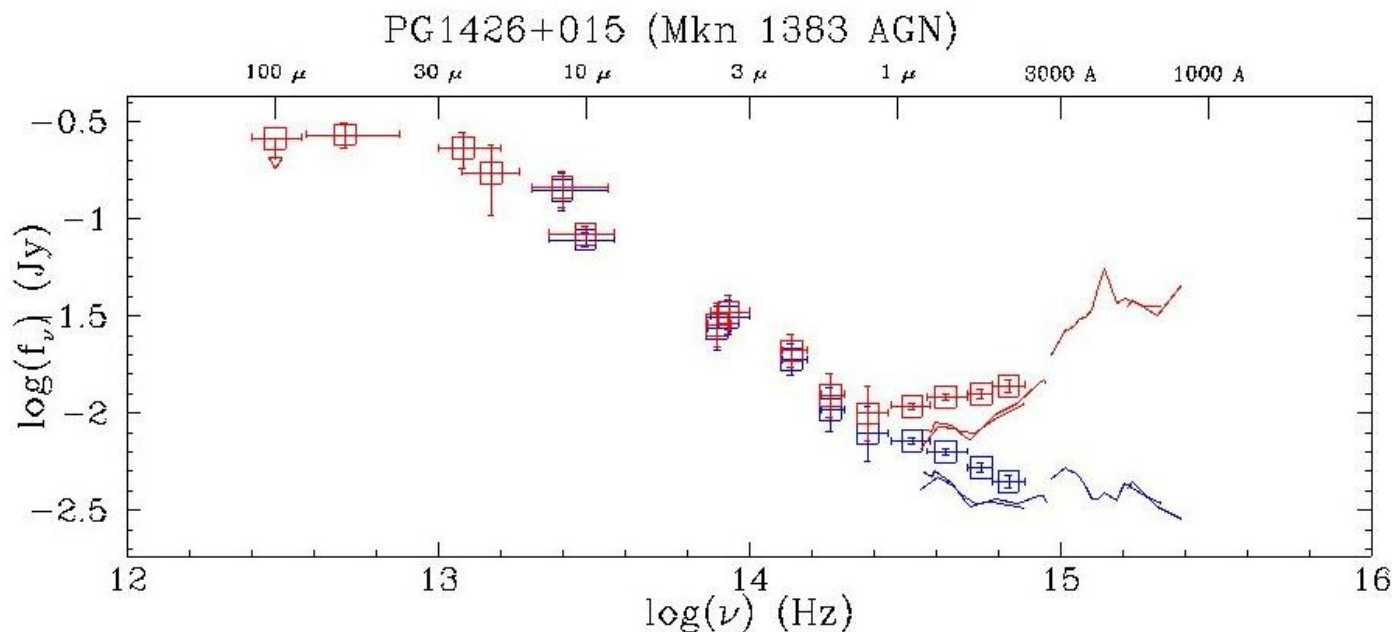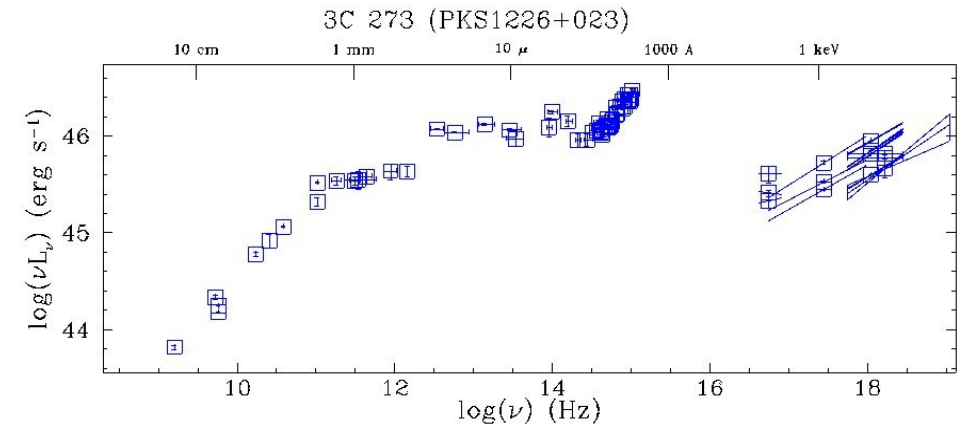

Effect of 0.3 mag dereddening on UV SED of quasar (in Elvis et al 1994 database)

3C 273 (PKS1226+023)
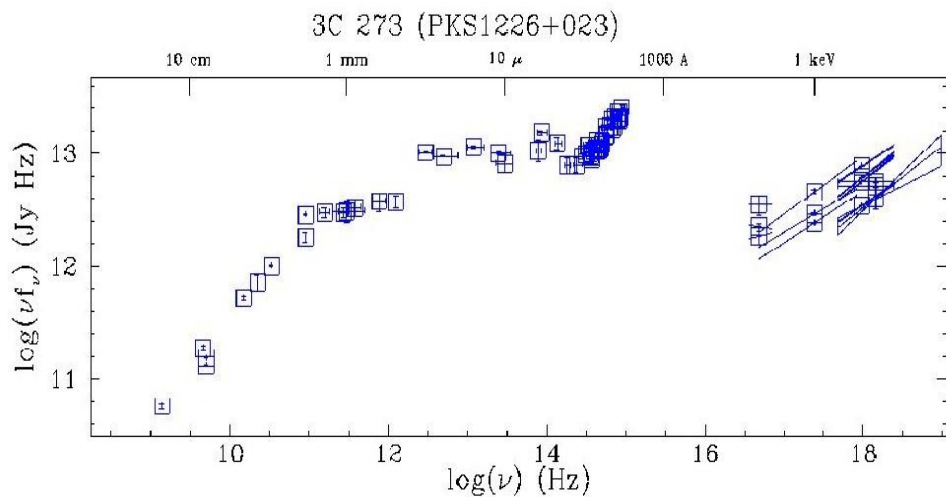
Read in observed 3C273 SED

Transform to rest frame using preferred cosmological parameters and known z=0.158

3C 273 (PKS1226+023)

Name:Q1226+023
QSO Name:3C 273 (PKS1226+023)
Position:12 26 33.2   02 19 43.2
Redshift: 0.1580   V mag: 12.86
NH value: 180.0
Sample:UV/WE/Pic/HL

TIGER V7.0(3G) (2010 Nov 29 15:58:57)

Edit z to z=6.0 and transform back to observed frame: What would a 3C273-ish QSO appear like if it were at z=6?

3C 273 (PKS1226+023)

Name:Q1226+023
QSO Name:3C 273 (PKS1226+023)
Position:12 26 33.2   02 19 43.2
Redshift: 6.0000   V mag: 12.86
NH value: 180.0
Sample:UV/WE/Pic/HL

TIGER V7.0(3G) (2010 Nov 29 16:02:12)

Host galaxy subtraction

Q1351+69 (Mkn 279 AGN)

Name:Q1351+695
QSO Name:Q1351+69 (Mkn 279 AGN)
Position:13 51 53.6   69 33 13.0
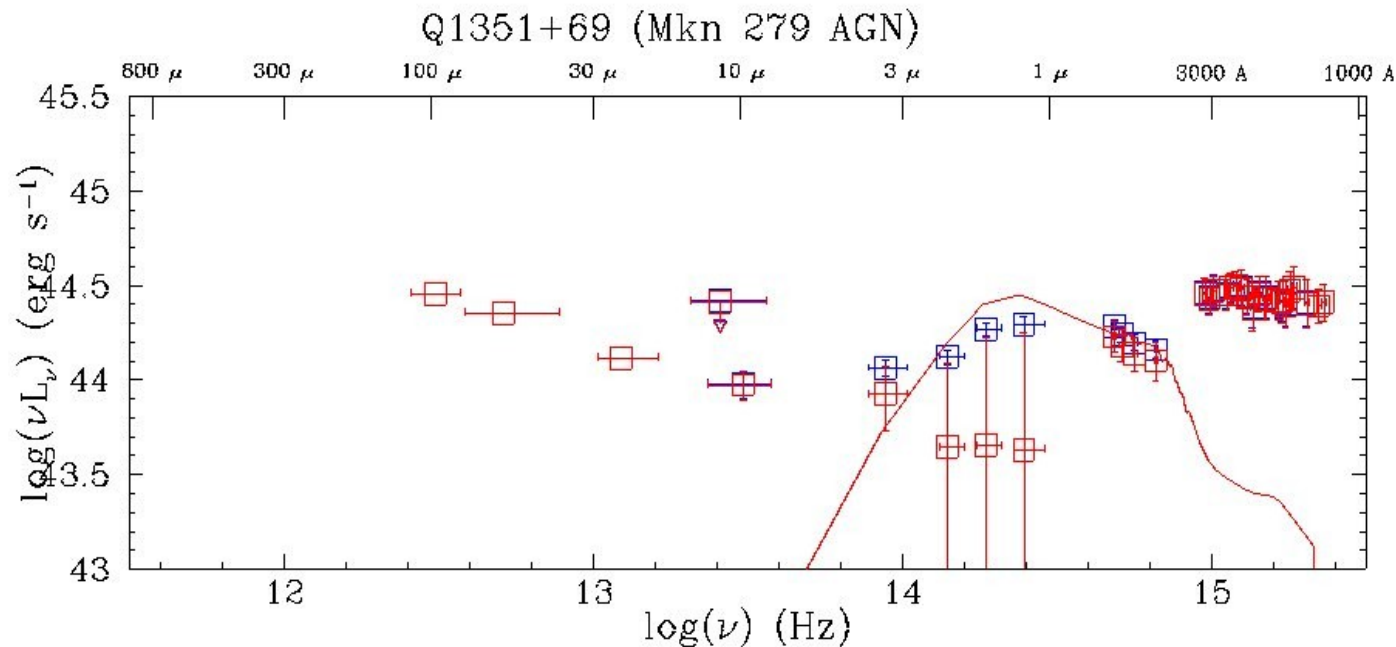Redshift: 0.0310   V mag: 14.58
NH value: 164.0
Sample:UV

TIGER V7.0(3G) (2010 Nov 29 16:18:53)

Deredden, transform to rest frame
Fit galaxy template normalization based on imaging data (magnitude of surrounding
 host galaxy 'fuzz')
Subtract template point-by-point assuming uniform galaxy spatial brightness and
point source AGN – take into account aperture size of each point separately

Population analysis: Just how unusual is your object?

Fig. 37(a)

Quasar Energy Distribution Dispersion
Normalized by 1.5 micron luminosity
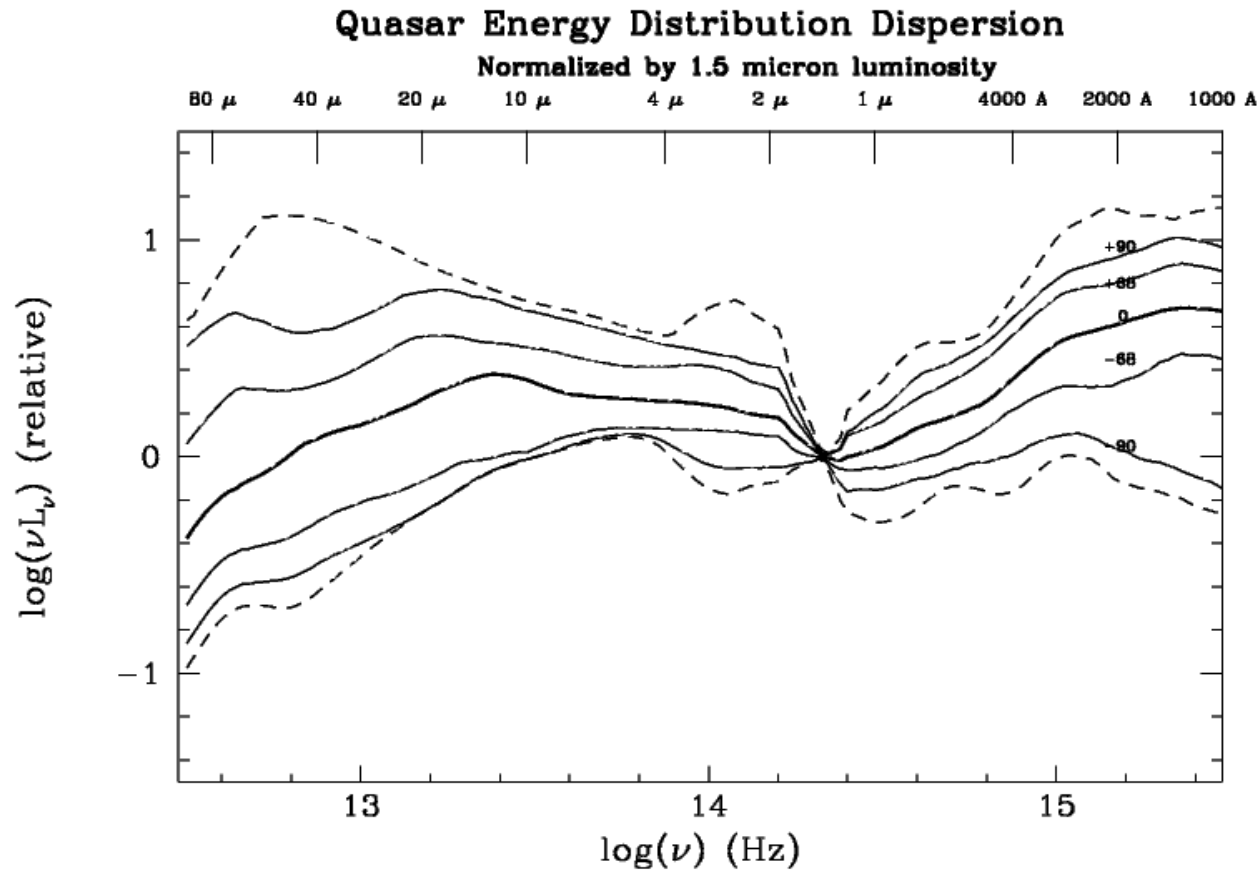
From Elvis et al (1994)

- Calculate median and quantile SEDs of a population
- Handle upper limits e.g. using Kaplan-Meier estimator (Feigelson ASURV, etc.)
- Normalize at a wavelength or by integrated L in a band

SED Visualization

Basic interaction

Plot the SED
Zoom, replot, select intervals
Inspect metadata of points
Save and print plots

Basic editing

Flag points and segments
Adjust or delete
Export modified SED

One possible architecture

Remote | Local

NED Database

NED VO-SED Exporter

Sherpa Fit Engine

User Data Files

Other VO services and clients

SAMP

Local SED Client

User Output SED files

SSA Servers (spectral archives)

Interface

User Interaction or Script

ConeSearch Servers (catalog photometry)

Local Specview

Remote Users over Web

User Plots

—— **Data Flow**

—— **VO Request Messages**

Remote | **Local**

NED Database → NED VO-SED Exporter

Sherpa (Modeling & Fitting)

User Data Files

VO Services/ Clients

SED Client

Tool User (GUI or Script)

Interface

SSA Servers (Spectral archives)

Specview (Editing/Visualization)

Web User

Cone Search Servers (catalog photometry)

Plots

— Data

— VO Request Msg

Further capabilities

SED building:
  intrinsic capability to ingest integral field spectra, model grid spectra
  extract photometry from images, measure flux in region
  access data from VO simple image access

SED analysis:

  algorithms for rebinning SED
  user-defined models
  population analysis – arrays of SEDs, population statistics, quantiles
  SED classification and clustering
  Cosmological tools: take SED and move it in redshift