SPAMM – Spectral Properties of AGN Modeled through MCMC

Spectral Components

Nuclear Continuum

$$F_{\lambda,\mathrm{PL}} = F_{\mathrm{PL},0}\ (\frac{\lambda}{\lambda_0})^{\alpha} \tag{1}$$

where $F_{\mathrm{PL},0}$ is the power-law normalization, α is the power-law slope and λ_0 is the median wavelength of the data wavelength range.

Priors

Balmer Continuum

If we assume gas clouds with uniform temperature $\mathrm{T_e}$, that are partially optically thick, for wavelengths bluer than the Balmer edge ($\lambda_{\mathrm{BE}} = 3646$ Å, rest frame), the Balmer spectrum can be parameterized as (Grandi et al., 1982):

$$F_{\lambda,\mathrm{BC}} = F_{\mathrm{BE}}\ B_\lambda(\mathrm{T_e})\ (1 - \mathrm{e}^{-\tau_{\mathrm{BE}}(\frac{\lambda}{\lambda_{\mathrm{BE}}})^3}),\ \lambda < \lambda_{\mathrm{BE}} \tag{2}$$

where $B_\lambda(\mathrm{T_e})$ is the Planck function at the electron temperature $\mathrm{T_e}$, τ_{BE} is the optical depth at the Balmer edge, and F_{BE} is the normalized flux density at the Balmer edge.

Priors

FeII & FeIII

Linear combination of N broadened and scaled iron templates:

$$F_{\lambda,\mathrm{Fe}} = \sum_{\mathrm{i=1,..N}} F_{\mathrm{Fe,0,i}}\ \mathrm{FeTempl}_{\lambda,\mathrm{i}}(\sigma_i) \tag{3}$$

where $\mathrm{FeTempl}_{\lambda,\mathrm{i}}$ is the iron template, $F_{\mathrm{Fe,0,i}}$ is the template normalization, and σ_i is the width of the broadening kernel.

Priors

Host Galaxy

Linear combination of N galaxy templates:

$$F_{\lambda,\mathrm{Host}} = \sum_{\mathrm{i=1,..N}} F_{\mathrm{Host,0,i}}\ \mathrm{HostTempl}_{\lambda,\mathrm{i}} \tag{4}$$

where $\mathrm{HostTempl}_{\lambda,\mathrm{i}}$ is the host galaxy template, and $F_{\mathrm{Host,0,i}}$ is the template normalization.

Priors

Host Galaxy Reddening

Priors

Nuclear Reddening

Priors

Emission lines

Functional fitting to broad and narrow emission-line components.

- **Broad Emission Line List, $\boldsymbol{\lambda_{0,b}}$**
  - Lyα λ1215 (actual $\lambda = 1215.670$Å)
  - N V λ1240 (doublet at $\lambda\lambda$1238.808, 1242.796Å)
  - "1400 Feature": Si IV (doublet at $\lambda\lambda$1393.755, 1402.770Å) plus O IV] blend ($\lambda\lambda$1397.210, 1399.780, 1404.790, 1407.390Å)
  - N IV] λ1486 (actual $\lambda = 1486.500$Å)
  - C IV λ1549 (unresolved doublet at $\lambda\lambda$1548.188, 1550.762Å)
  - He II λ1640 (actual $\lambda = 1640.720$Å)
  - O III] λ1663 (doublet at $\lambda\lambda$1660.800, 1666.140Å)
  - C III] λ1909: actually a blend of Al III $\lambda\lambda$1854.720, 1862.780Å, Si III] $\lambda = 1892.030$Å, and C III] $\lambda = 1908.734$Å.
  - Mg II λ2798 (doublet at $\lambda\lambda$2796.350, 2803.530Å)
  - Hδ $\lambda = 4101.735$Å
  - Hγ $\lambda = 4340.450$Å
  - He II λ4686 (actual $\lambda = 4685.650$Å)
  - Hβ $\lambda = 4861.320$Å
  - He I λ4922 (actual $\lambda = 4921.9$Å)
  - He I $\lambda = 5016$Å
  - He I λ5876 (actual $\lambda = 5875.680$Å)
  - He I λ6678 (actual $\lambda = 6678.000$Å)
  - He I λ7065 (actual $\lambda = 7065.300$Å)
  - Hα $\lambda = 6562.780$Å
- **Narrow Emission Line List, $\boldsymbol{\lambda_{0,n}}$**
  - [Ne V] λ3425.900Å
  - [O II] $\lambda\lambda$3726.000, 3728.800Å
  - [Ne III] λ3868.800Å
  - He II (actual $\lambda = 4685.650$Å)
  - Hβ $\lambda = 4861.320$Å
  - [O III] $\lambda\lambda$4958.920, 5006.850Å
  - [N II] $\lambda\lambda$6548.060, 6583.39Å
  - Hα $\lambda = 6562.780$Å
  - [Si II] $\lambda\lambda$6716.420, 6730.780Å

Fitting Function Possibilities

- Narrow Lines
  - Single Gaussian with Prior (1)
  - Option (automatically test) for additional (broader) Gaussian to [O III] $\lambda\lambda 4959, 5007$ base.
- Broad Lines
  - Multiple Gaussians
  - Multiple Gauss-Hermite polynomials
  - Gaussian (very broad) plus Gauss-Hermite (broad)
  - Multiple Lorentzians

Functional Forms

- Gaussian:

$$F_\lambda = \frac{f_{\rm peak}}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{\lambda-\mu}{\sigma}\right)^2}, \tag{5}$$

  where the Gaussian FWHM$= 2\sqrt{2\ln 2}\sigma$ and $\mu = \lambda_0$(b,n).
  Free parameters: $f_{\rm peak}$ (peak flux), μ, σ.

- 66th Order Gauss-Hermite Polynomial:

$$F_\lambda = [f_{\rm peak}\alpha(w)/\sigma]\left(1 + \sum_{j=3}^{6} h_j H_j(w)\right), \tag{6}$$

$$w \equiv (\lambda - \mu)/\sigma, \tag{7}$$

$$\alpha(w) = e^{-\frac{1}{2}w^2}. \tag{8}$$

  where this follows the normalization of van der Marel & Franx (1993, ApJ, 407, 525; first equation). The H_j coefficients can be found in Cappellari et al. (2002, ApJ, 578, 787):

$$H_3(w) = \frac{w(2w^2-3)}{\sqrt{3}}, \tag{9}$$

$$H_4(w) = \frac{w^2(4w^2-12)+3}{2\sqrt{6}}, \tag{10}$$

$$H_5(w) = \frac{w[w^2(4w^2-20)+15]}{2\sqrt{15}}, \tag{11}$$

$$H_6(w) = \frac{w^2[w^2(8w^2-60)+90]-15}{12\sqrt{5}}. \tag{12}$$

  Free parameters: $f_{\rm peak}$, μ, σ, h_3, h_4, h_5, h_6.

- Lorentzian

$$F_\lambda = \frac{f_{\rm peak}}{\pi} \frac{\frac{1}{2}\sigma}{(\lambda-\mu)^2 + (\frac{1}{2}\sigma)^2}, \tag{13}$$

where $\mu = \lambda_0$(b,n) and the Lorentzian FWHM $= \sigma = 2 f_{\rm peak}/(\pi F(\mu))$.

Priors

1. Width of narrow forbidden lines tied together and FWHM <1200km s^{-1}
2. Narrow emission line redshift solution, i.e., $\mu = \lambda_{0,n}(1+z) \pm \Delta\mu$ is constant.
3. Narrow line doublet ratios fixed:
   - [O II] $\lambda\lambda$3726.000, 3728.800Å; ??:??
   - [O III] $\lambda\lambda$4958.920, 5006.850Å; 1:3
   - [Si II] $\lambda\lambda$6716.420, 6730.780Å; ??:??
   - [N II] $\lambda\lambda$6548.060, 6583.39Å; ??;??
4. Fluxes must be non-negative.
5. Tie together the widths of Broad lines of identical species, e.g., He II λ1640 and He II λ4686? (To be discussed).
6. assumptions about CIV redshelf?? Additional HeII component?
7. Suggested Parameter Space to searched (to be discussed)
   - $f_{\rm peak}/f_{\rm cont}$ = [0, 1.d4, 1.d-3]
   - $\mu = \lambda_{0,n}(1+z) \pm 1000\,{\rm km\,s^{-1}}; \Delta\mu \sim f$(pixscale)
   - σ = [100, 3.d4]; $\Delta\sigma \sim f$(pixscale)
   - h_j = [-0.3, 0.3, 1.d-3]