A Guide to AGN Emission and Absorption Lines and “What they mean”.

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Abstract

This is a (currently very) simple document which will hopefully/eventually be a pretty complete list of various AGN emission lines and ‘what they mean’. That is to say, when a paper reports a flux of a certain line, why is that line special?

1 Narrow vs. Broad Lines

Broad-Line Region. The lines arising here include hydrogen and helium recombination lines, permitted and semi-forbidden lines such as C IV and [C III (most of these in the emitted UV), and complex multiplets of Fe II. The lack of other lines suggests densities in excess of 107 cm^{-3}, and some considerations suggest values as high as 10^{11}. At these densities, recombination is a very efficient radiator; a typical BLR requires only 10^6 solar masses.

And Seyfert Galaxies. The spectra of Seyfert galaxies typically contain:

- Non-thermal continuum emission;
- Narrow ($\rightarrow$ low velocity), forbidden ($\rightarrow$ low density material) lines which do not vary detectably ($\rightarrow$ large emitting region)
- Broad ($\rightarrow$ high velocity), permitted lines which vary on fairly short timescales ($\rightarrow$ small emitting region)
- Also, strong emission in the radio, infrared, ultraviolet, and X-ray parts of the spectrum.

2 Type 1.5, 1.8 and 1.9s

In 1981, Donald Osterbrok introduced the notations Seyfert 1.5, 1.8 and 1.9, where the subclasses are based on the optical appearance of the spectrum, with the numerically larger subclasses having weaker broad-line components relative to the narrow lines. For example, Type 1.9 only shows a broad component in the H line, and not in higher order Balmer lines. In Type 1.8, very weak broad lines can be detected in the Hβ lines as well as H, even if they are very weak compared to the Hα. In Type 1.5, the strength of the Hα and Hβ lines are comparable.

From Roig et al. (2014): Variations in the relative strength and visibility of the Balmer lines have led some investigators to define more detailed subdivisions of Seyferts. Seyfert 1.5 galaxies have moderate- strength broad Hα and Hβ; Seyfert 1.8 have weak broad Hα and Hβ; and Seyfert 1.9 have weak broad Hα and only narrow Hβ (see Osterbrock & Ferland 2006; Ho 2008).

Table 1: Ionization Energies of some (mainly UV) emisson lines
[a]http://physics.nist.gov/PhysRefData/Handbook/Tables/heliumtable4_a.htm#4685.3769

Ion name	Wavelength / Angstroms	Ground Level	Ionized Level	Ionization Energy / eV
H I	912	$^2S\frac{1}{2}$	n/a	13.598
[O I]	1304	$^3P_2$	$2p^3\ ^4S^\circ_{\frac{3}{2}}$	13.618
Mg II	2800	$^2S_{\frac{1}{2}}$	$2p^6\ ^1S_0$	15.035
Fe II	1787	$^6D\frac{9}{2}$	$3d^6\ ^5D_4$	16.199
Si II	1260	$^2P^\circ_{\frac{1}{2}}$	$3s^2\ ^1S_0$	16.345
Al II	1671?	$^1S_0$	$3s\ ^2S_{\frac{1}{2}}$	18.829
Al III	1857	$^2S_{\frac{1}{2}}$	$2p^6\ ^1S_0$	28.448
[O II]	3727	$^4S^\circ_{\frac{3}{2}}$	$2p^2\ ^3P_0$	35.121
C III]	1909	$^1S_0$	$2s\ ^2S_{\frac{1}{2}}$	47.889
[a,b]He II	1640	$^2S_{\frac{1}{2}}$	n/a	54.417
[a,b]He II	4686			54.417
[O III]	5007	3P0	$2p\ 2P1/2$	54.93554
C IV	1548	$^2S_{\frac{1}{2}}$	$1s^2\ ^1S_0$	64.494
N V	1240	$^2S\ _{\frac{1}{2}}$	$1s^2\ ^1S_0$	97.890

From https://ned.ipac.caltech.edu/level5/Sept01/Veilleux/Veilleux5.html

Ion name	Wavelength / μm	Ground Level	Ionized Level	Ionization Energy / eV
[Ca VIII]	2.321			128
[Si VI]	1.962			167
[Si VII]	2.483			205
[Si IX]	3.935			303
[S IX]	1.252			328
[Si X]	1.430			351
[Si XI]	1.932			401

3 Ionization Line

NIST is your friend!!!
http://physics.nist.gov/PhysRefData/ASD/ionEnergy.html

THIS LINK!!!:
https://dept.astro.lsa.umich.edu/ cowley/ionen.htm

And also,
http://www.pa.uky.edu/∼verner/atom.html

3.1 High-Ionization Line

From Wu et al. (2012) "...are clearly AGNs as evidenced by strong, high-ionization emission lines such as O vi, C iv, and/or C iii]."

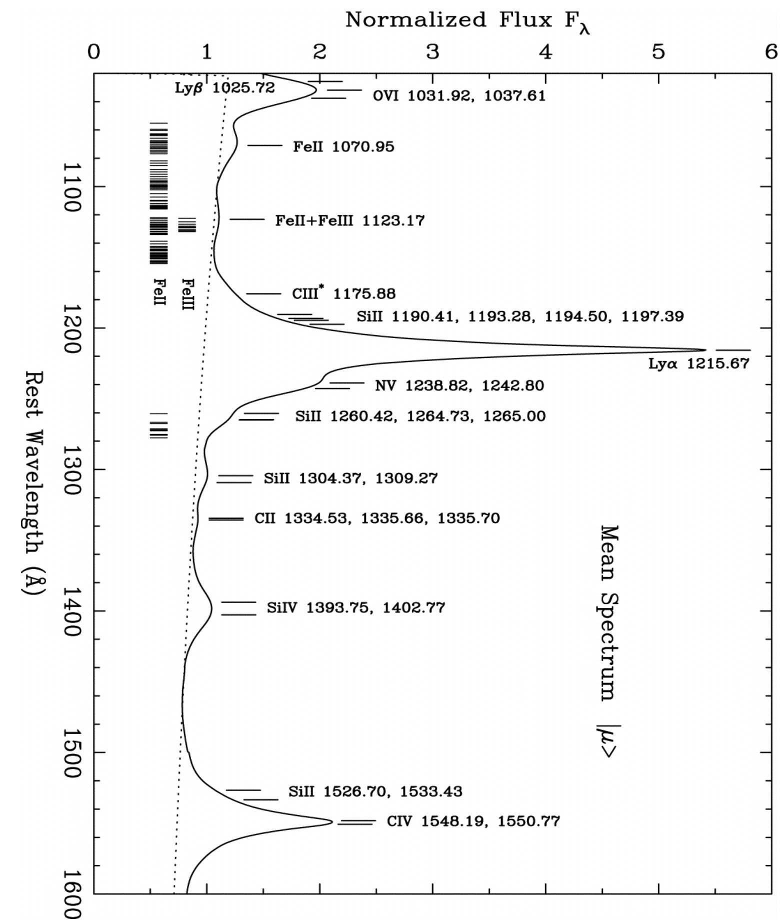

Figure 1: From Suzuki et al. (2005): Mean spectrum of 50 HST quasar spectra. The spectrum is normalized near 1280Å. The wavelengths are taken from Morton (1991), except for Fe II , Fe III , and C III] * lines, which are observed wavelengths from Tytler et al. (2004a). The tick marks shown below the spectrum are the wavelengths of the Fe II and Fe III multiplet. The dotted line is the power-law continuum approximation. Note that the emission lines do exist in the Lyα wavelength region. We also note that the wavelength separation of the Si IV doublet at λ1400 is relatively large and makes the line profile broad.

Table 2: Ionization Energies of some (mainly UV) emisson lines

Ion name	Wavelength / Angstroms	Ground Level	Ionized Level	Ionization Energy / eV
H I	912	$^2\mathrm{S}\frac{1}{2}$	n/a	13.598
Lyβ	1025.72	$1s\ ^2\mathrm{S}$	$n = 3$	12.0875
Lyα	1215.67	$1s\ ^2\mathrm{S}$	$n = 2$	10.198
N V	1240	$^2\mathrm{S}_{\frac{1}{2}}$	$1s^2\ ^1\mathrm{S}_0$	97.890
Si II	1260	$^2\mathrm{P}^\circ_{\frac{1}{2}}$	$3s^2\ ^1\mathrm{S}_0$	16.345
[O I]	1304	$^3\mathrm{P}_2$	$2p^3\ ^4\mathrm{S}^\circ_{\frac{3}{2}}$	13.618
C IV	1548	$^2\mathrm{S}_{\frac{1}{2}}$	$1s^2\ ^1\mathrm{S}_0$	64.494
He II	1640	$^2\mathrm{S}_{\frac{1}{2}}$	n/a	54.417
Al II	1671?	$^1\mathrm{S}_0$	$3s\ ^2\mathrm{S}_{\frac{1}{2}}$	18.829
Fe II	1787	$^6\mathrm{D}\frac{9}{2}$	$3d^6\ ^5\mathrm{D}_4$	16.199
Al III	1857	$^2\mathrm{S}_{\frac{1}{2}}$	$2p^6\ ^1\mathrm{S}_0$	28.448
C III]	1909	$^1\mathrm{S}_0$	$2s\ ^2\mathrm{S}_{\frac{1}{2}}$	47.889
Mg II	2800	$^2\mathrm{S}_{\frac{1}{2}}$	$2p^6\ ^1\mathrm{S}_0$	15.035
[O II]	3727	$^4\mathrm{S}^\circ_{\frac{3}{2}}$	$2p^2\ ^3\mathrm{P}_0$	35.121
[O III]	5007	3P0	$2p\ 2P1/2$	54.93554

"High-ionization BALQSOs (HiBALs) contain strong, broad absorption troughs shortward of high-ionization emission lines and are typically identified through the presence of C IV absorption troughs (Trump et al., 2006)."

3.2 Low-Ionization Line

"LoBALs are QSOs that have BALs from ions at lower ionization states such as Al III or Mg II " (Gibson et al., 2009)

Table 3: The Lines

Name	Wavelength / Å	Transition	Rest Passband	Interpreation	Reference
Lyman-α	1215.67	2 to 1	~FUV	Major QSO line	1
Lyman-β	1025.18	3 to 1	~FUV		1
Lyman-γ	972.02	4 to 1	~FUV		1
Lyman Limit	911.27	∞ to 1	~FUV		1
H-α	6563.	3 to 2	R,r	Recent major SF or AGN activity	2
H-β	4861.	4 to 2	B,V,g		2
H-γ	4341.	5 to 2	U,B,u		2
H-δ	4102.	6 to 2	~FUV	Previous SF history	3
Balmer Limit	3646.	∞ to 2	~FUV		2
HI	3646.	∞ to 2	~FUV		2
HII	3646.	∞ to 2	~FUV		2
HeI	3646.	∞ to 2	~FUV		2
HeII	3646.	∞ to 2	~FUV		2
HeIII	3646.	∞ to 2	~FUV		2
CIV	3646.	∞ to 2	~FUV	Major QSO line	2
OII	3646.	∞ to 2	~FUV	Major QSO line	2
OIII	3646.	∞ to 2	~FUV	Recent major SF line	2
OIII	5007.	∞ to 2	~FUV	Recent major SF line	2
Ca II H	3999.	∞ to 2	~FUV	Old stellar pop	3
Ca II K	4001.	∞ to 2	~FUV	Old stellar pop	3
NII	5007.	∞ to 2	~FUV		2
NeV	3646.	∞ to 2	~FUV	Major QSO line	2
[OIII λ 5007/ Hβ] [NII λ 6583/ Hα]				"BPT" diagram reliable tool for determining source of line emission from a galaxy visually differentiate between Seyferts, LINERs and SF gals. However, only at "low" redshifts since need Hα, (not at $z \sim 1$). Modified BPT with $(U - B)$ colour replacing [NII λ 6583/ Hα] e.g. Montero-Dorta, 0801.2769.	2, 4, 5 2,4,5
[SII λ 6583/ Hα]		∞ to 2	~FUV	Major QSO line	2,4. 5
[α/Fe]	3646.	∞ to 2	~FUV	Major QSO line	2
NV	1???.67	2 to 1	~FUV	Major QSO line	1
SiIV	1???.67	2 to 1	~FUV	Major QSO line	1
CIV	1???.67	2 to 1	~FUV	Major QSO line	1
CIII]	1???.67	2 to 1	~FUV	Major QSO line	1
MgII	1???.67	2 to 1	~FUV	Major QSO line	1

4 CLAGN and CLQ Mini-lit review

This is just a quick section for a mini CLAGN and CLQ literature review. A lot of these references are from Steph LaMassa's "Hidden Monsters" talk: http://www.dartmouth.edu/ hiddenmonsters/presentations_tab.php

Tohline & Osterbrock (1976) for NGC 7603.
Penston & Perez (1984) for NGC 4151.
Goodrich (1995) for NGC 4151.
Tran et al. (1992)
Storchi-Bergmann et al. (1993)
Eracleous & Halpern (2001)
Shappee et al. (2014)
Aretxaga et al. (1999) for NGC 7582.
Denney et al. (2014) for Mrk 590.

5 MgII

This is just a quick mini-section on the MgII line.

6 Notes, Links and To Dos...

7 “Manual” References and Links

Morton, D. C. 1991, ApJS, 77, 119 Tytler, D., OMeara, J. M., Suzuki, N., Kirkman, D., Lubin, D., & Orin, A.. 2004a, AJ, 128, 1058
see also::
https://arxiv.org/abs/1703.04250v1

References

Aretxaga I., Joguet B., Kunth D., Melnick J., Terlevich R. J., 1999, ApJ Lett., 519, L123

Denney K. D., et al., 2014, ApJ, 796, 134

Eracleous M., Halpern J. P., 2001, ApJ, 554, 240

Gibson R. R., et al., 2009, ApJ, 692, 758

Goodrich R. W., 1995, ApJ, 440, 141

Penston M. V., Perez E., 1984, MNRAS, 211, 33P

Roig B., Blanton M. R., Ross N. P., 2014, ApJ, 781, 72

Shappee B. J., et al., 2014, ApJ, 788, 48

Storchi-Bergmann T., Baldwin J. A., Wilson A. S., 1993, ApJ Lett., 410, L11

Suzuki N., Tytler D., Kirkman D., O'Meara J. M., Lubin D., 2005, ApJ, 618, 592

Tohline J. E., Osterbrock D. E., 1976, ApJ Lett., 210, L117

Tran H. D., Osterbrock D. E., Martel A., 1992, AJ, 104, 2072

Trump J. R., et al., 2006, ApJS, 165, 1

Table 4: The Lines, in increasing Wavelength (Basis for this table from SDSS SkyServer Schema Browser, SpecLineNames view `http://casjobs.sdss.org/dr6/en/help/browser/browser.asp`)

name	value	description
UNKNOWN	0	0.00
OVI_1033	1033	1033.82
Lya_1215	1215	1215.67
NV_1241	1241	1240.81
OI_1306	1306	1305.53
CII_1335	1335	1335.31
SiIV_1398	1398	1397.61
SiIV_OIV_1400	1400	1399.80
CIV_1549	1549	1549.48
HeII_1640	1640	1640.40
OIII_1666	1666	1665.85
AlIII_1857	1857	1857.40
CIII_1909	1909	1908.73
CII_2326	2326	2326.00
NeIV_2439	2439	2439.50
MgII_2799	2799	2799.12
NeV_3347	3347	3346.79
NeV_3427	3427	3426.85
OII_3727	3727	3727.09
OII_3730	3730	3729.88
Hh_3799	3799	3798.98
Oy_3836	3836	3836.47
HeI_3889	3889	3889.00
CaII K_3935	3935	3934.78
CAII H_3970	3970	3969.59
He_3971	3971	3971.19
SII_4072	4072	4072.30
Hd_4103	4103	4102.89
G_4306	4306	4305.61
Hg_4342	4342	4341.68
OIII_4364	4364	4364.44
Hb_4863	4863	4862.68
OIII_4933	4933	4932.60
OIII_4960	4960	4960.30
OIII_5008	5008	5008.24
Mg_5177	5177	5176.70
Na_5896	5896	5895.60
OI_6302	6302	6302.05
OI_6366	6366	6365.54
NI_6529	6529	6529.03
NII_6550	6550	6549.86
Ha_6565	6565	6564.61
NII_6585	6585	6585.27
Li_6708	6708	6707.89
SII_6718	6718	6718.29
SII_6733	6733	6732.67
CaII_8500	8500	8500.36
CaII_8544	8544	8544.44
CaII_8665	8665	8664.52