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

Nicholas P. Ross

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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 **?**: 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

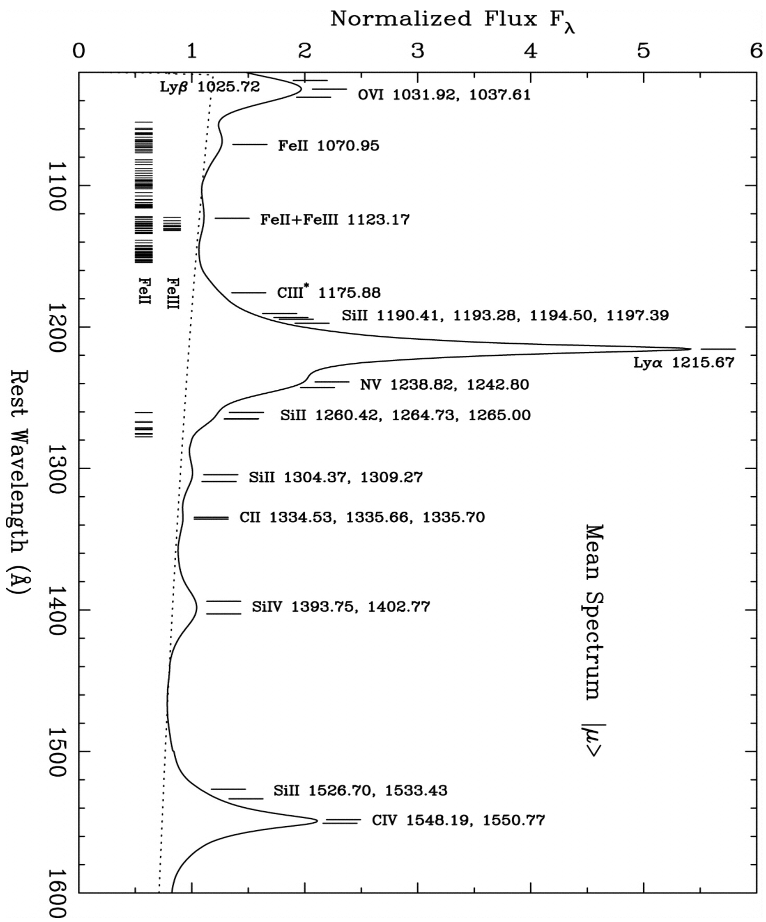

Figure 1: From **?**: Mean spectrum of 50 HST quasar spectra. The spectrum is normalized near 1280Å. The wavelengths are taken from Morton (1991), except for Fe II , Fe III , and C III] * lines, which are observed wavelengths from Tytler et al. (2004a). The tick marks shown below the spectrum are the 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	$^2S_{\frac{1}{2}}$	n/a	13.598
Lyβ	1025.72	$1s\ ^2S$	$n = 3$	12.0875
Lyα	1215.67	$1s\ ^2S$	$n = 2$	10.198
N V	1240	$^2S_{\frac{1}{2}}$	$1s^2\ ^1S_0$	97.890
Si II	1260	$^2P^\circ_{\frac{1}{2}}$	$3s^2\ ^1S_0$	16.345
[O I]	1304	$^3P_2$	$2p^3\ ^4S^\circ_{\frac{3}{2}}$	13.618
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Mg II	2800	$^2S_{\frac{1}{2}}$	$2p^6\ ^1S_0$	15.035
[O II]	3727	$^4S^\circ_{\frac{3}{2}}$	$2p^2\ ^3P_0$	35.121
[O III]	5007	3P0	$2p\ 2P1/2$	54.93554

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]."

"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 (**?**)."

3.2 Low-Ionization Line

"LoBALs are QSOs that have BALs from ions at lower ionization states such as Al III or Mg II " (**?**)

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 IR fine-structure lines

e.g. arXiv:1903.00946v1, Section 3::
1 coronal region line: [SiVII] 6.50 m; 8 AGN fine-structure emission lines: [NeVI]7.65, [ArV]7.90, [CaV]11.48, [ArV]13.09, [MgV]13.50, [NeV] 14.32, [NeV] 24.31 and [OIV] 25.89 m;

5 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.
? for NGC 4151.
? for NGC 4151.
?
?
?
?
? for NGC 7582.
? for Mrk 590.

6 MgII

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

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

IONIZATION POTENTIALS[a]

Z	Element	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XXI
		Spectrum																				
1	H	13.598																				
2	He	24.587	54.416																			
3	Li	5.392	75.638	122.451																		
4	Be	9.322	18.211	153.893	217.713																	
5	B	8.298	25.154	37.930	259.368	340.217																
6	C	11.260	24.383	47.887	64.492	392.077	489.981															
7	N	14.534	29.601	47.448	77.472	97.888	552.057	667.029														
8	O	13.618	35.116	54.934	77.412	113.896	138.116	739.315	871.387													
9	F	17.422	34.970	62.707	87.138	114.240	157.161	185.182	953.886	1103.089												
10	Ne	21.564	40.962	63.45	97.11	126.21	157.93	207.27	239.09	1195.797	1362.164											
11	Na	5.139	47.286	71.64	98.91	138.39	172.15	208.47	264.18	299.87	1465.091	1648.659										
12	Mg	7.646	15.035	80.143	109.24	141.26	186.50	224.94	265.90	327.95	367.53	1761.802	1962.613									
13	Al	5.986	18.828	28.447	119.99	153.71	190.47	241.43	284.59	330.21	398.57	442.07	2085.983	2304.080								
14	Si	8.151	16.345	33.492	45.141	166.77	205.05	246.52	303.17	351.10	401.43	476.06	523.50	2437.676	2673.108							
15	P	10.486	19.725	30.18	51.37	65.023	230.43	263.22	309.41	371.73	424.50	479.57	560.41	611.85	2816.943	3069.762						
16	S	10.360	23.33	34.83	47.30	72.68	88.049	280.93	328.23	379.10	447.09	504.78	564.65	651.63	707.14	3223.836	3494.099					
17	Cl	12.967	23.81	39.61	53.46	67.8	98.03	114.193	348.28	400.05	455.62	529.26	591.97	656.69	749.74	809.39	3658.425	3946.193				
18	Ar	15.759	27.629	40.74	59.81	75.02	91.007	124.319	143.456	422.44	478.68	538.95	618.24	686.09	755.73	854.75	918	4120.778	4426.114			
19	K	4.341	31.625	45.72	60.91	82.66	100.0	117.56	154.86	175.814	503.44	564.13	629.09	714.02	787.13	861.77	968	1034	4610.955	4933.931		
20	Ca	6.113	11.871	50.908	67.10	84.41	108.78	127.7	147.24	188.54	211.270	591.25	656.39	726.03	816.61	895.12	974	1087	1157	5129.045	5469.738	
21	Sc	6.54	12.80	24.76	73.47	91.66	111.1	138.0	158.7	180.02	225.32	249.832	685.89	755.47	829.79	926.00						
22	Ti	6.82	13.58	27.491	43.266	99.22	119.36	140.8	168.5	193.2	215.91	265.23	291.497	787.33	861.33	940.36						
23	V	6.74	14.65	29.310	46.707	65.23	128.12	150.17	173.7	205.8	230.5	255.04	308.25	336.267	895.58	974.02						
24	Cr	6.766	16.50	30.96	49.1	69.3	90.56	161.1	184.7	209.3	244.4	270.8	298.0	355	384.30	1010.64						
25	Mn	7.435	15.640	33.667	51.2	72.4	95	119.27	196.46	221.8	248.3	286.0	314.4	343.6	404	435.3	1136.2					
26	Fe	7.870	16.18	30.651	54.8	75.0	99	125	151.06	235.04	262.1	290.4	330.8	361.0	392.2	457	489.5	1266.1				
27	Co	7.86	17.06	33.50	51.3	79.5	102	129	157	186.13	276	305	336	379	411	444	512	546.8	1403.0			
28	Ni	7.635	18.168	35.17	54.9	75.5	108	133	162	193	224.5	321.2	352	384	430	464	499	571	607.2	1547		
29	Cu	7.726	20.292	36.83	55.2	79.9	103	139	166	199	232	266	368.8	401	435	484	520	557	633	671	1698	
30	Zn	9.394	17.964	39.722	59.4	82.6	108	134	174	203	238	274	310.8	419.7	454	490	542	579	619	698	738	1856
31	Ga	5.999	20.51	30.71	64																	
32	Ge	7.899	15.934	34.22	45.71	93.5																
33	As	9.81	18.633	28.351	50.13	62.63	127.6															
34	Se	9.752	21.19	30.820	42.944	68.3	81.70	155.4														
35	Br	11.814	21.8	36	47.3	59.7	88.6	103.0	192.8													
36	Kr	13.999	24.359	36.95	52.5	64.7	78.5	111.0	126	230.39												
37	Rb	4.177	27.28	40	52.6	71.0	84.4	99.2	136	150	277.1											
38	Sr	5.695	11.030	43.6	57	71.6	90.8	106	122.3	162	177	324.1										
39	Y	6.38	12.24	20.52	61.8	77.0	93.0	116	129	146.52	191	206	374.0									
40	Zr	6.84	13.13	22.99	34.34	81.5																
41	Nb	6.88	14.32	25.04	38.3	50.55	102.6	125														
42	Mo	7.099	16.15	27.16	46.4	61.2	68	126.8	153													
43	Te	7.28	15.26	29.54																		
44	Ru	7.37	16.76	28.47																		
45	Rh	7.46	18.08	31.06																		
46	Pd	8.34	19.43	32.93																		
47	Ag	7.576	21.49	34.83																		

Figure 2: Property profile of the diverse library compared to the compound pool.

7 HST/COS lines

From Miller et al. arXiv:809.03114v1
Distance, Energy, and Variability of Quasar Outflows: Two HST/COS epochs of LBQS 1206+1052 H i,
C iii,
N iii,
N v,
O vi,
Si ii,
Si iii,
P v,
S iii,
S iv,
S vi

e.g. Their figure 1 shows:: S VI 945
Ly δ 950
Ly γ 973
C III 977
N III 990
N III* 992
N III 991
S III 1012
S III* 1016
Ly β 1026
O VI 1032
O VI 1037
S IV 1063
S IV* 1073
PV 1118
PV 1128
Si III 1207
Ly α
N V 1239
N V 1243
N V 1240
Si II 1260
Si II* 1265

8 Notes, Links and To Dos...

9 "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

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