Notes from Nancy Houk (Univ. Michigan)

Spectral Classification			Luminosity Class		
O5-O9	• HeI very weak or absent at O 5 • HeII very weak or absent at B 0		• O 5 - O 8 no luminosity class distinguishable • HeII 4541 ≈ in I and V		
		HeI 4471/ HeII 4541		CIII 4068/ SiIV 4089	CIII 4650/ HeII 4686
	O 7	=			
	O 9	≳	I	>	>
			III	≳	≳
			V	=	=
				HeI 4387/ HeII 4541	
			I	HeI 4387 absent	
			III	≲	
			V	≥	
O 9.5	• HeII 4541 weaker than in O 9, and may be absent. • HeII 4200 ≈ HeI 4387 except in dwarfs where HeI 4387 is stronger. (HeII 4200 ≤ HeI 4387 at short exposures)			CIII 4068/ SiIV 4089	HeII 4686
			I	< *	Invisible
			II	<	
			III	≈	Invisible
			V	<	≲ CIII 4650
				SiIV-HeI 4119/ HeI 4144	HeI 4387/ NIII 4516 **
			I	≥	≳
			II	≥	≳
	* True for I b also ** Not so good		III	≲	>
			V	≤	λ4516 absent
B 0	• HeII 4200 absent or very much fainter than HeI 4387. • SiIV 4089 is stronger than SiIII 4552. • Blend near CIII 4650 is sharply defined on the violet side.			HeI 4009/ SiIV 4089	OII 4072/ SiIV 4089
			I	<<	<
			II	=	≈
			V	≳	≤
				SiIV-HeI 4119/ HeI 4144	
			I	>	
			II	≈	
			V	≲	
B 0.5	• Blend at λλ4640-50 is strongest at the red edge and is intermediate in appearance between B 0 and B 1. • SiIII 4552 is ≤ SiIV 4089			NII 3995/ HeI 4009	SiIV-HeI 4119/ HeI 4144
			I	≤	≥
			III	<	=
			V	λ3995 absent	<
				OII 4349/ HeI 4387	OII 4416/ HeI 4387
			I	≳	>
			III	≲	≈
			V	<	<<

<table>
<tr><td>B 1</td><td>• Broad blend near OII 4070-6 is well marked (especially in super giants).
• SiIII 4552 is stronger than SiIV 4089.
• λλ4640-50 blend is fairly uniform in intensity: red edge may still be slightly stronger.</td><td>• SiII lines and H line wings are luminosity indicators.<table><tr><td></td><td>NII 3995/ HeI 4009</td><td>HeI 4121/ HeI 4144</td></tr><tr><td>I</td><td>=</td><td>></td></tr><tr><td>II</td><td><</td><td>≈</td></tr><tr><td>V</td><td>λ3995 absent</td><td><</td></tr><tr><td></td><td>OII 4416/ HeI 4144</td><td>OII 4416/ HeI 4387</td></tr><tr><td>I</td><td>≈</td><td>≤</td></tr><tr><td>III</td><td><</td><td><</td></tr><tr><td>V</td><td>λ4416 absent</td><td>λ4416 absent</td></tr></table></td></tr>
<tr><td>B 2</td><td>• Blend near OII 4072 is weaker than at B 1.
• SiII 4128 – 4130 is fainter than in class B 3.</td><td>• Appearance of H line wings.<table><tr><td></td><td>NII 3995/ HeI 4009</td><td>HeI 4121/ HeI 4144</td></tr><tr><td>I</td><td>></td><td>≤</td></tr><tr><td>II</td><td>≤</td><td>≤</td></tr><tr><td>III</td><td><</td><td><</td></tr><tr><td>V</td><td><</td><td><</td></tr><tr><td></td><td colspan="2">SiII 4552/ HeI 4387</td></tr><tr><td>I</td><td colspan="2">≤</td></tr><tr><td>II</td><td colspan="2">≤</td></tr><tr><td>III</td><td colspan="2"><</td></tr><tr><td>V</td><td colspan="2"><<</td></tr></table></td></tr>
<tr><td>B 3</td><td>• SiII blend at 4128-30 is ≤ to HeI 4121 and is stronger than at B 2 relative to HeI 4121.</td><td>• H lines stronger in dwarfs.<table><tr><td></td><td>NII 3995/ HeI 4009</td><td>HeI 4121/ HeI 4144</td></tr><tr><td>I</td><td>≤</td><td>=</td></tr><tr><td>V</td><td><<</td><td><<</td></tr></table></td></tr>
<tr><td>B 5</td><td>• The SiII 4128-30 blend is stronger relative to HeI 4144 than in corresponding luminosity class at B 3, still weaker than HeI 4144.</td><td>• H lines stronger in dwarfs.<table><tr><td></td><td>HeI 4471 / MgII 4481</td></tr><tr><td>I a</td><td>≈</td></tr><tr><td>V</td><td>></td></tr></table></td></tr>
<tr><td>B 8</td><td>• HeI 4026 > SiII 4129
• HeI series λλ 4387, 4144, 4009 has become much fainter than at B 5.
• SiII 4129 is stronger relative to HeI 4144 than in the same luminosity class at B 5.
• For dwarfs (at least) the CaII K line is ≤ in intensity to HeI 4026.</td><td>• Only luminosity criterion is the wings of the H lines. (Increasing with decreasing luminosity)
• HeI 4471/ MgII 4481 is no longer a good criterion as it was in B 5.</td></tr>
<tr><td>B 9</td><td>• HeI 4026 is fainter than CaII K line.</td><td>• Only luminosity criterion is the wings of the H lines. (Increasing</td></tr>
</table>

<table>
<tr><td>B 9</td><td>• HeI 4471 is considerably fainter than MgII 4481. (At I, slightly)
• HeI 4026 ≥ SiII 4129.</td><td>with decreasing luminosity)</td></tr>
<tr><td>A 0</td><td>• The lines of HeI are faint or absent in the dwarfs.
• HeI 4026 is faint or absent and is weaker than SiII 4129.</td><td>• Appearance of wings of H lines.
• Mg II 4481 >> Fe II 4385 in IV.
• Mg II 4481 ≈ Fe II 4385 in I b.
• The strongest enhanced lines of Fe are faintly present in the main sequence stars and increase in strength with increasing luminosity.</td></tr>
<tr><td>A 1</td><td>• The metallic lines stronger than at A 0.
• The blend MnI 4030-4 is first well seen in this class.
• MgII 4481 ≤ FeII 4385.
• FeII 4385 is stronger than in A 0.</td><td>• Appearance of H line wings.</td></tr>
<tr><td>A 2</td><td>• MgII 4481 ≥ FeII 4385
• SiII 4128-32 >> MnI 4030-4</td><td>• Appearance of H line wings.
• Intensity of blend centered near λ4555. (stronger in dwarf)
• Above NOT for Super giants.
<table><tr><td></td><td>SiII 4128-32/ λλ4171-9</td></tr><tr><td>I</td><td>></td></tr><tr><td>V</td><td>></td></tr></table></td></tr>
<tr><td>A 3</td><td>• MnI 4030-4 ≤ SiII 4128-32
• λ4300 ≈ FeII 4385

* discontinuity</td><td><table><tr><td></td><td>λ4417/ MgII4481</td><td>λ4175/ MnI 4032 *</td></tr><tr><td>II-III</td><td>>></td><td>≈</td></tr><tr><td>V</td><td>≥</td><td><<</td></tr><tr><td></td><td colspan="2">CaI 4226/ MgII 4481</td></tr><tr><td>II-III</td><td colspan="2">></td></tr><tr><td>V</td><td colspan="2">≈</td></tr></table></td></tr>
<tr><td>A 4</td><td>λ4300 ≥ FeII 4385</td><td><table><tr><td>V</td><td>OII 4416 = MgII 4481</td></tr></table></td></tr>
<tr><td>A 5</td><td>• MnI 4030-4 ≤ SiII 4128-32
• Use K and H lines, not blend ratio.
• λ4300 ≤ FeII 4385</td><td><table><tr><td></td><td>OII 4416/ MgII 4481</td></tr><tr><td>I</td><td>></td></tr><tr><td>III</td><td>≥</td></tr><tr><td>V</td><td>≤</td></tr></table></td></tr>
<tr><td>A 7</td><td>• K < H
• MnI 4030-4 ≥ SiII 4128-32
• λ4300 ≥ FeII 4385
• Almost all lines are blends at this dispersion.</td><td><table><tr><td></td><td>OII 4416/ MgII 4481</td></tr><tr><td>III</td><td>≤</td></tr><tr><td>V</td><td>≤</td></tr></table></td></tr>
<tr><td>F 0</td><td>• MnI 4030-4 > SiII 4128-32</td><td>• For Super giants: strong neutral metallic lines</td></tr>
</table>

F 0

- λ4300 > FeII 4385
- K > H
- Appearance of Spectrum around λ4300.

*Red side

	OII 4416/ MgII 4481	TiII 4444/ MgII 4481
I	>	≥
III	≥	≈
V	≤	<<
	FeII 4172/ CaI 4226	FeII 4172/ SiII 4132*
I	>	>
III	≤	≈
V	≤	<

F 2

- λ4300 ≥ FeII 4385
- K ≥ H

F 6

- Fe I 4045 << Hδ
- Ca I 4226 << Hδ, Hγ 4340

* Good

- Types III, IV, and V distinguishable without ambiguity.

	SrII 4077/ CaI 4226	FeII4172/ λ4272 *
III	≥	>
IV	≈	
V	≤	≈
	SrII 4077/ FeI 4045 *	SrII 4007/ FeI 4063 *
III	≈	>
V	≤	≈

F 8

- FeI 4045 < Hδ
- CaI 4226 ≤ Hγ 4340

	SrII 4077/ CaI 4226	FeI 4045/ SrII 4077
III	≳	≤
IV	≲	≲
V	≤	≥
	FeII 4172/ FeI 4383	
III	>	
IV	≥	
V	≤	

- Enhanced lines stronger in I a than in I b.

	SrII 4077/ Hδ	FeII 4385/ FeI 4325
I a	≥	>>
I b	≤	>
III	<<	<
	TiII 4444/ FeI 4325	
I a	>>	
I b	>	
III	<<	

G 0

- FeI 4045 ≲ Hδ
- FeI 4325 < Hγ 4340
- CaI 4226 < Hγ 4340

* Blend

- For high luminosity stars SrII 4077 ≈ Hδ

	FeI 4063/ SrII 4077	HeI 4144/ SrII 4077
IV	≤	<<
V	≈	≳

	λλ4200/ λλ4272	SrII 4077/ Hδ
III		≤
IV	>	
V	≲	<<

G 2

- FeI 4045 ≲ Hδ
- CaI 4226 = Hγ 4340
- FeI 4325 ≲ Hγ 4340

	SrII 4077/ CaI 4226	SrII 4077/ FeI 4045
III	≤	≲
	SrII 4077/ Hδ	
I b	≥	

G 3

For I b:

- SrII 4077 > CaI 4226
- CN break at λ 4215 easily visible.

- After you have apparent luminosity, for accurate spectral type λ 4272: each side of G band from G5-K2.

G 5

- MnI 4030-4 ≲ λλ4300 (violet side of G band)
- FeI 4325 ≲ Hγ 4340 (lower weight)
- HeI 4144 ≈ Hδ*
- λ4096 << Hδ*

* Except for super giants
** Red

	FeI 4063/ SrII 4077	SrII 4077/ HeI 4144
III	<	>
IV	≥	≈
V	≳	≤

	SrII 4077/ λ4085	CN4215/ λ4250
III	>>	>
IV	≥	≳
V	≈	≲

	SrII 4077/ SiII4132**	SrII4077/ CaI 4226
III	>>	≲
IV	≈	<
V	<	<<

G 8

- MnI 4030-4 > λλ4300 (violet)
- FeI 4325 ≳ Hγ 4340*
- λ4096 > Hδ*

* Except for super giants
** Red; band changes to line from III to V
♦ Blends

	FeI 4045/ SrII 4077	FeI 4063/ SrII 4077
III	≳	<
IV	>	≥
V	>>	>

	SrII 4077/ HeI 4144	CN break
III	>	Clear
IV	≈	Visible
V	<	Absent

	SrII 4077/ SiII 4132**	λ4176/ λ4200 ♦
II	>>	>
IV	>	≤
V	<	<

K 0

- MnI 4030-4 > λλ4300 (violet)
- FeI 4325 >> Hγ 4340
- λ4096 ≤ Hδ

	MnI 4030-4/ λ4178	FeI 4063/ SrII 4077
II	≲	<
III-IV	≳	≤
IV	>	≥
V	>>	>

	SrII 4077/ HeI 4144	CN break
II	>	Very great
III-IV	≥	Still striking
IV	≲	Noticeable
V	≤	Absent

	SiII 4132 blend line
II	Very weak, broad
III-IV	Visible, broad
IV	A bit narrower
V	Band

K 1

- At I, the CN break at 4215 has its greatest intensity.

	FeI 4045/ SrII 4077	λ4101/ λ4144
I	≤	≈
II	≥	<
III	>	<<

	FeI 4325/ Hγ 4340
I	≤
II	≥
III	>

<table>
<tr><td>K 2</td><td>• CrI 4290 < λ4299
• CaI 4226 > FeI 4325
• G band split. Red easily visible as stronger.</td><td></td><td>FeI 4063/
SrII 4077</td><td>FeI 4071/
SrII 4077</td></tr>
<tr><td></td><td></td><td>III</td><td>≥</td><td><</td></tr>
<tr><td></td><td></td><td>V</td><td>>></td><td>≥</td></tr>
<tr><td></td><td></td><td></td><td colspan="2">CN break</td></tr>
<tr><td></td><td></td><td>III</td><td colspan="2">Very noticeable</td></tr>
<tr><td></td><td></td><td>V</td><td colspan="2">Absent</td></tr>
<tr><td>K 3</td><td>• FeI 4383 > λ4406
• λ 4299 > CrI 4290
• CaI 4226 > FeI 4325</td><td colspan="3">• Hi-luminosity: CN break no longer a luminosity indicator</td></tr>
<tr><td></td><td></td><td></td><td>FeI 4063/
SrII 4077</td><td>CN 4215/
λ4260</td></tr>
<tr><td></td><td></td><td>III</td><td>≳</td><td>≥</td></tr>
<tr><td></td><td></td><td>V</td><td>></td><td><</td></tr>
<tr><td></td><td></td><td></td><td colspan="2">CN break</td></tr>
<tr><td></td><td></td><td>III</td><td colspan="2">Very clear</td></tr>
<tr><td></td><td></td><td>V</td><td colspan="2">Absent</td></tr>
<tr><td></td><td></td><td></td><td>FeI 4045/
SrII 4077</td><td>FeI 4063/
SrII 4077</td></tr>
<tr><td></td><td></td><td>I ab</td><td>≤</td><td><</td></tr>
<tr><td></td><td></td><td>I-II</td><td>≥</td><td><</td></tr>
<tr><td></td><td></td><td>II</td><td>></td><td>≈</td></tr>
<tr><td></td><td></td><td>III</td><td>>></td><td>≥</td></tr>
<tr><td></td><td></td><td></td><td>FeI 4325/
Hγ 4340</td><td>Violet/Red *</td></tr>
<tr><td></td><td></td><td>I ab</td><td>≤</td><td>≈</td></tr>
<tr><td></td><td></td><td>I-II</td><td>≳</td><td>≈</td></tr>
<tr><td></td><td></td><td>II</td><td>≥</td><td>≤</td></tr>
<tr><td></td><td>*2 blends to violet of λ4144</td><td>III</td><td>></td><td><</td></tr>
<tr><td>K 5</td><td>• CaI 4226 >> FeI 4325
• CrI 4290 ≥ λ4299
• FeI 4383 ≈ λ4406</td><td></td><td>FeI 4063/
SrII 4077</td><td>CN 4215/
λ4260</td></tr>
<tr><td></td><td></td><td>III</td><td>≈</td><td>≥</td></tr>
<tr><td></td><td></td><td>V</td><td>></td><td>≤</td></tr>
<tr><td></td><td></td><td></td><td colspan="2">Violet / Red *</td></tr>
<tr><td></td><td>*2 blends to violet of λ4144</td><td>III</td><td colspan="2">≤</td></tr>
<tr><td>M 2</td><td>• Strength of TiO bands.

* If line indent is correct.</td><td colspan="3">• Negative absolute magnitude effect in Ca I 4226
• For I b:
FeI 4045 ≤ SrII 4077
CN 4215 > λ4250
FeI 4376 < FeI 4383 *
FeI 4383 ≤ λ4390</td></tr>
</table>

Notes

≡	The appearancec of the spectra of Giants and dwarfs vary greatly for the spectral classes that follow.
>>	♦ Much greater than
>	♦ Greater than
≥	♦ Slightly greater than
≳	♦ Very slightly greater than
<<	♦ Much less than
<	♦ Less than
≤	♦ Slightly less than
≲	♦ Very slightly less than
λ	♦ Unknown element line
λλ	♦ Unknown element blend