

# Topic E

## Part 5. "Spectral Classes"

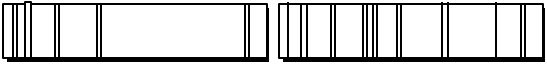
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## Stellar Spectra

Recall

- Majority — absorption (dark) line
- But line patterns & "strengths" differ



Star #1                      Star #2

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## Angelo Secchi's Classification

Observes 4000 spectra (1863 ff.)  
Criteria: General arrangement of dark lines

- I Heavy dark hydrogen lines
- II Solar type, many less intense lines not hydrogen
- III Numerous lines with wide bands at red end
- IV Strong bands at violet end
- V Weak hydrogen lines, few other lines

You do not need to know this scheme

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## Henry Draper System

- Basis of modern spectral classification
- Developed at Harvard (circa. 1885 – 1925)
- Key player — Annie Jump Cannon
  - 1923: Voted one of 12 greatest living American women
  - *Annie J. Cannon Award*: Amer. Assoc. of Women annual award to a woman beginning her astronomy career
  - Dr. Elizabeth Lada, UF Assoc. Prof. Astron. (given 1992)

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## A Little History

Henry Draper	(1872) Wealth amateur astronomer Obtains first spectrogram
Draper Estate	(1886) Many large endowments to Harvard after Draper's death
Wilamina Fleming & Antonia Maury	(1890) First Draper Catalog (10,000 stars) Elaborates on Secchi's scheme
Annie J. Cannon	(1896) Modifies & expands system Eventually published as HD Catalog Basis of modern system

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## The Henry Draper System


- Eventually published in Harvard Annals
  - Originally 225,000 stars (later 133,000 stars added)
  - Nearly all stars down to magnitude +9
- Cyclopedia Payne (1920s)
  - Shows mathematically temperature determines spectral class
  - Demonstrates hydrogen dominates stars composition
- Expanded in 1940s
  - By Morgan, Keenan & Edith Kellman (now called MK System)
  - Recent modifications by Nancy Houk (Univ. Michigan)

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## Spectra Are Different

Why do stellar spectra differ?

- Can you guess?
- Possible answer: Different *chemical compositions*
- Is this correct?: No!
- Correct answer: Different *temperatures*




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## The Spectral Sequence

Modern spectra classes arranged

- By appearance of dark lines
- In a continuous sequence
- Reflects changing *surface temperature* !



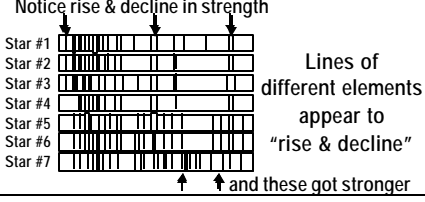
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## Sequence “Linear”

Spectral lines of different elements . . .


*Do not change appearance independently*

Notice rise & decline in strength



Lines of different elements appear to “rise & decline”


↑ ↑ and these got stronger



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## Conclusion

- Spectral lines of different elements
  - Do *not* independently change
- *So one physical condition mostly sets appearance*
  - Temperature
- If stars had very different chemical compositions
  - Expect more *random changes* in appearance of lines



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## Actually Three Factors

Why stellar spectra differ:

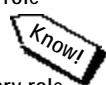

Primary

1) Temperature . . . . . primary role

Secondary

2) Pressure . . . . . secondary role



3) Chemical composition . . . . . minor role

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## The Spectral Sequence

- Designation of main classes
  - By capital letters (originally about 20)
  - Some classes omitted or consolidated
  - Others rearranged
- Result
  - Seven main classes remain

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### Early & Late

- Refers to approximate position in sequence
  - Early — hotter stars
  - Late — cooler stars
- Can use comparatively — examples
  - O is earlier than B
  - B is later than O
  - G stars are moderately late stars

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### The Sun's Spectral Class

- The Sun is a G2 star — know this!
 

Main Spectral Class  $\uparrow\uparrow$  Subtype
- Other examples (need *not* know)
 

• Sirius	A1	See
• Betelgeuse	M2	<i>Study Guide</i>
• Polaris	F8	<i>Table 11, Note #8</i>

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### Terminology Table 11

(Study Guide, Table 11, Notes #4 – 7)

**Note #** 4

- 4. Metals Any element not H or He!
- 5. Molecules Two or more joined atoms
- 6. Ionization Process of removing electrons

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### 7. Ionization States Table 11

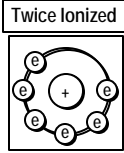
**Note #** 7

- Roman numerals used:
 

I	= neutral atom
II	= one electron removed
III	= two electrons removed, etc.
- Examples
 

OI = neutral oxygen, OII = once ionized, OIII = twice, etc.

**Twice Ionized**



**Question: What's wrong with HIII?**

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### Notation In Table 11

- Hydrogen & Helium: H I, He I and He II
- Metals: Me I, Me II, Me III, Me IV, etc.
- Except Calcium: Ca I, Ca II  
(Explain later)

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### Major Use of Spectral Classes

- Classifying spectra means . . .  
Ranking stars by *temperature*
- Table 11, Column 8 gives . . .  
Approx. temperatures for major classes
- Even if temperatures uncertain . . .  
*Spectral class orders star by temperature*

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### Table 11: Know Features

**Study carefully at home**

	H	He	Metals	Ca II	Molecules
O	Weak	He II	Highly Ionized	Note	
B	Moderate	Mod. He I	Highly Ionized	absence of some lines	
A	<b>Strongest</b>		Ionized		
F	Moderate		Increasing Me I	Moderate	
G	Relatively Weak	Note	Many Me I	<b>Very Strong</b>	Weak
K	Weak		Mostly Me I	Weak	Strong
M	Very Weak		Very Strong Me I		<b>Very Strong</b>

Notice the rise & decline of line strengths increasing Me I

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### Table 11: Know Features

**Make up own scheme**

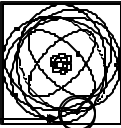
	H	He	Metals	Ca II	Molecules
O	Weaker	Ionized	More		
B		Neutral		Absent	
A	<b>Strongest</b>	<b>Absent</b>	Ions	Weaker	
F					Absent
G	Weaker		Neutrals	<b>Strongest</b>	Weaker
K					
M			More	Weaker	<b>Strongest</b>

Why trends? — see next slide

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### Origin of Spectral Lines

- Atoms surrounded by electron clouds
- Lines due to changing electron energy states
- Some atoms easily energized ("excited") to make lines



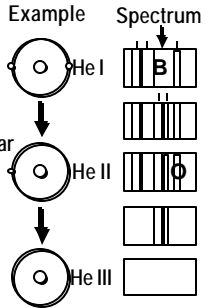
If Excitation Energy	Resulting Lines
- Small (many metals)	Arise at cooler temperatures
- Moderate (hydrogen)	Stronger at higher temperatures
- High (helium)	Appear only at high temperatures

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### Effect of Ionization

- Too much energy causes ionization
- Result
  - Lines from . . .
  - One ionization state begin to disappear
  - Next ionization state begin to appear
- If all electrons lost
  - All lines of element disappear

Example Spectrum



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### Table 11: Know Features

**Make up own scheme**

	H	He	Metals	Ca II	Molecules
O	Weaker	Ionized	More		
B		Neutral		Absent	
A	<b>Strongest</b>	<b>Absent</b>	Ions	Weaker	
F					Absent
G	Weaker		Neutrals	<b>Strongest</b>	Weaker
K					
M			More	Weaker	<b>Strongest</b>

If know scheme, should be able to answer this question

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### Example Question


A stellar spectrum shows *weak hydrogen lines*. The spectral class is probably

(1) O (2) A (3) G (4) Either A or G (5) Either O or M

Why?

### “Cool Stellar Atmospheres”

*Simple molecules* appear (as “bands”)

Examples  G to M spectra

Carbon Molecules (C <sub>2</sub> ),	Cyanogen (CN)
Hydrocarbon (CH),	Hydroxyl (OH)
Titanium Oxide (TiO),	Vanadium Oxide (VO)
Zirconium Oxide (ZrO),	Water Molecules (H <sub>2</sub> O)


*Note!*

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### Number of Lines

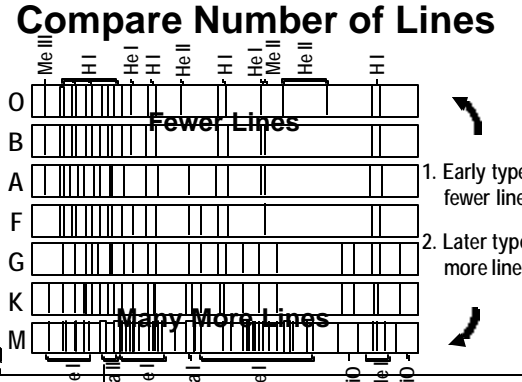
Early and late type spectra show different numbers of lines (in visible):

- Early Type Spectra: Fewer lines
- Late Type Spectra: Many more lines (esp. metals)

Hence, late spectra look more complex 

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### Compare Number of Lines




1. Early types fewer lines

2. Later type more lines

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### Why?

Historically: Typical stellar spectra were made only in *visible* (usually violet to yellow-green!) i.e., *excluded UV and IR ends*



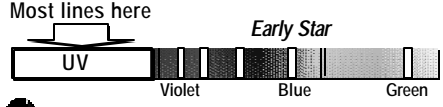
visible from violet to yellow-green

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### Consequence: Early Stars

Most metals *ionized*

- But most lines of ionized metals in UV
- So *don't* see them!




Most lines here *Early Star*

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### Consequence: Late Stars

Most metals *neutral*

- Most lines of neutral metals in visible
- So *do* see them!



*Late Star*

Many lines here

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