

Are we alone in the Universe?

Class 7.

Emrah Kalemci

ekalemci@sabanciuniv.edu

Office: FENS G018

Sabanci University, FENS

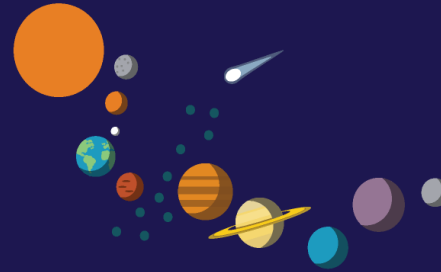
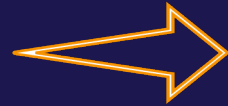


High School Summer Course, 2023

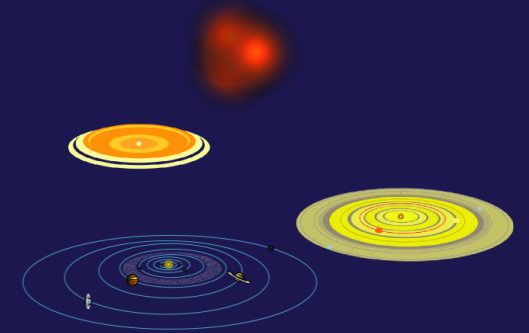
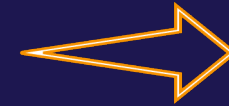
Our Map:



What are there in the Universe?
Scales involved in describing Universe



Our planet and Solar system



How did the Solar system form?
Is it unique?

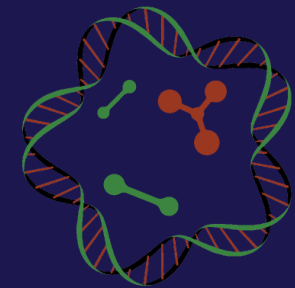
Are we alone in the universe?



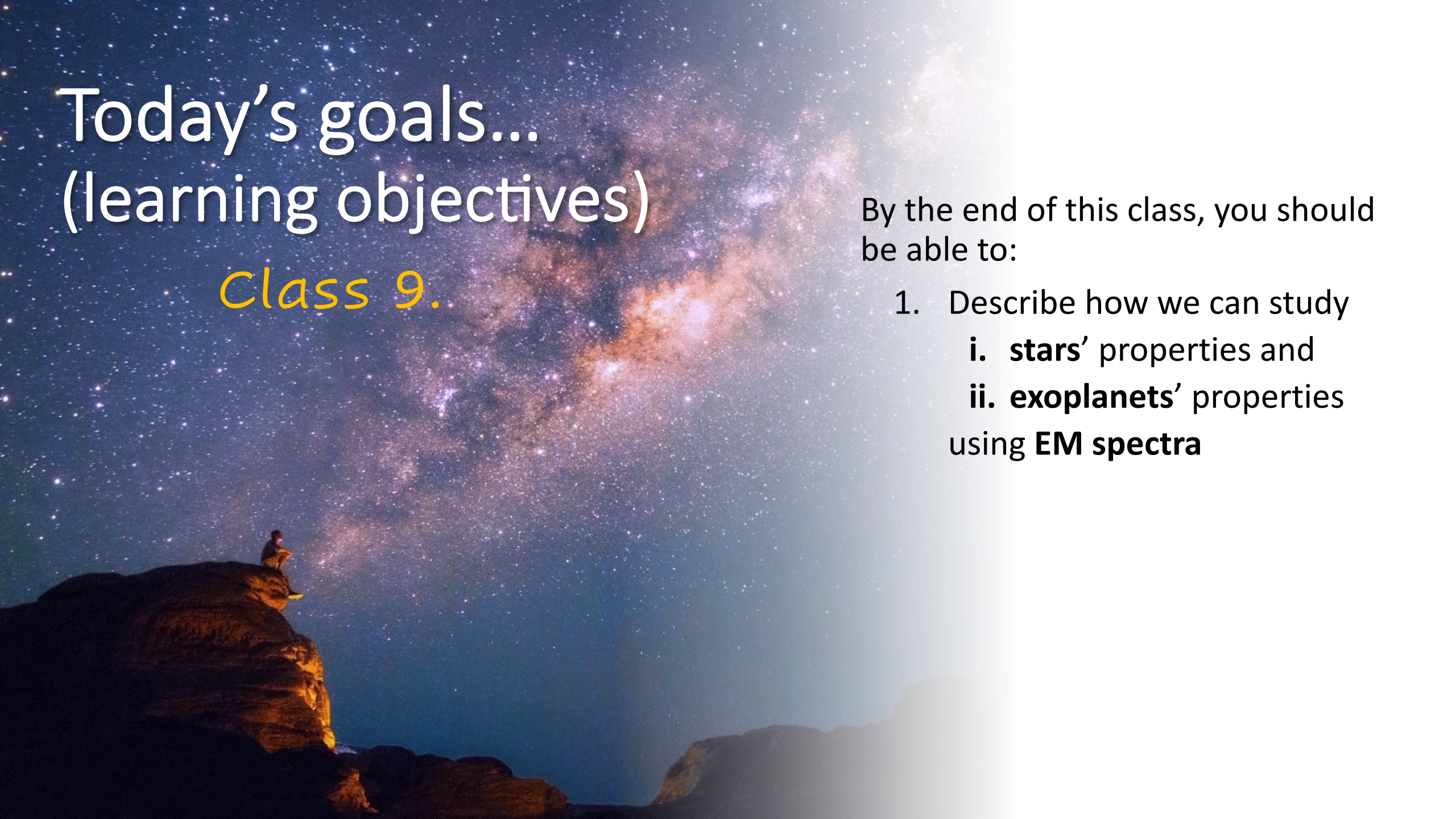
What form of life would you look for and how? Possibility of life on other planets.



How can we look for ET life?
Atom and EM spectrum.



What is life?
How did life on Earth begin? Building blocks of life, first form of life on Earth.

A person is sitting on a dark rock in the foreground, looking up at a vast night sky filled with stars. The Milky Way galaxy is visible as a bright, colorful band of light stretching across the sky. The background is a gradient from dark blue to white.

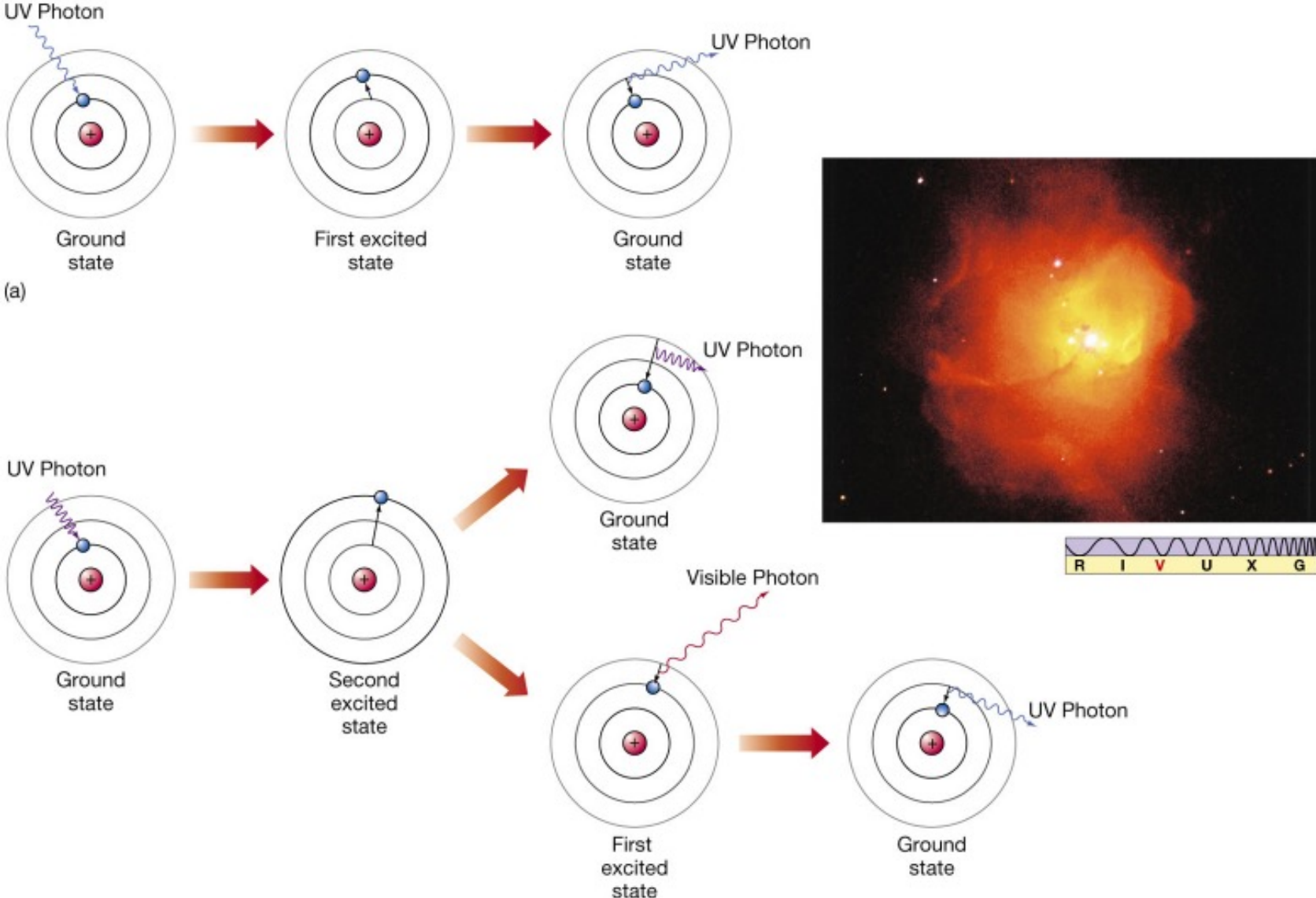
Today's goals... (learning objectives)

Class 9.

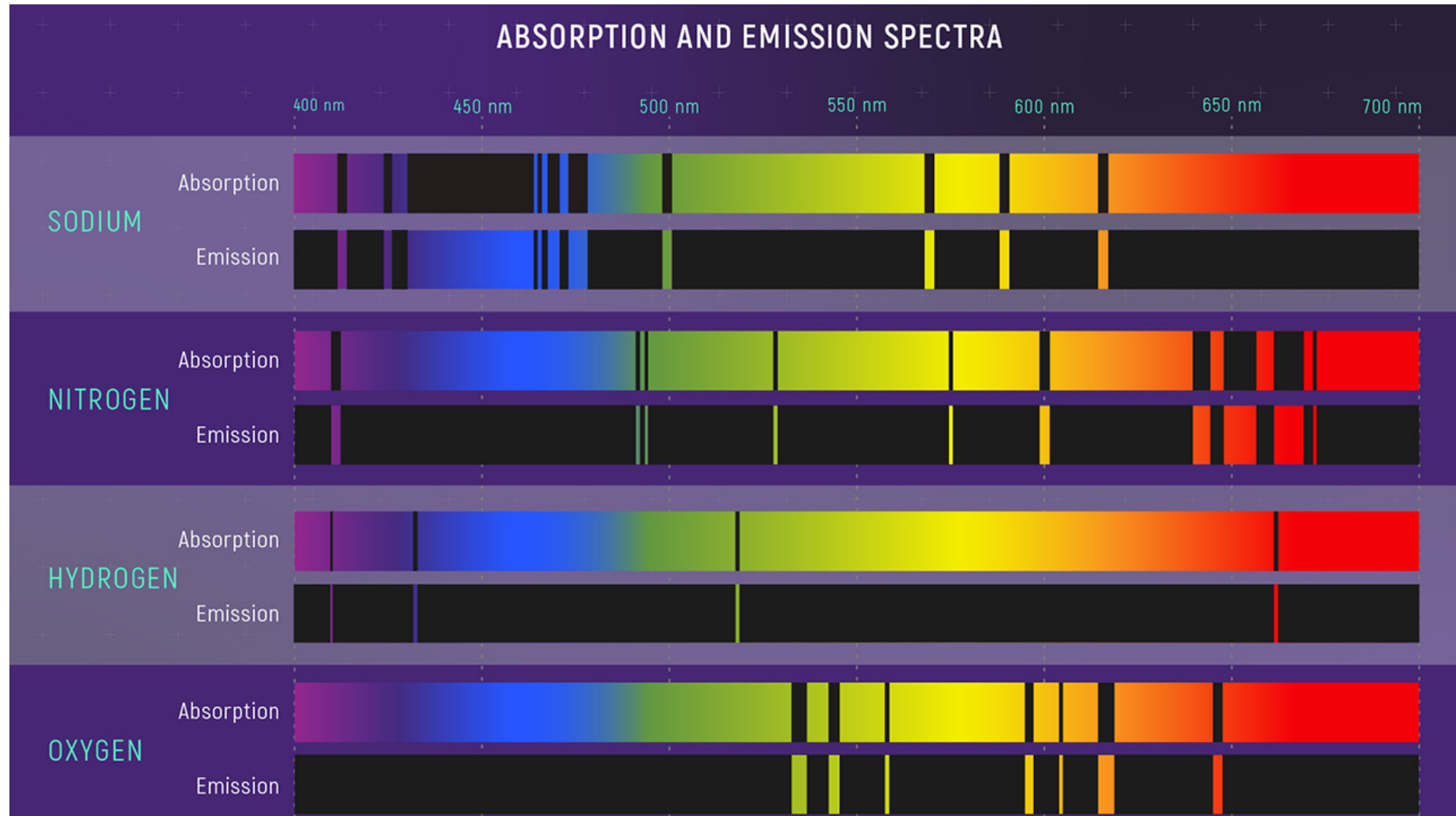
By the end of this class, you should be able to:

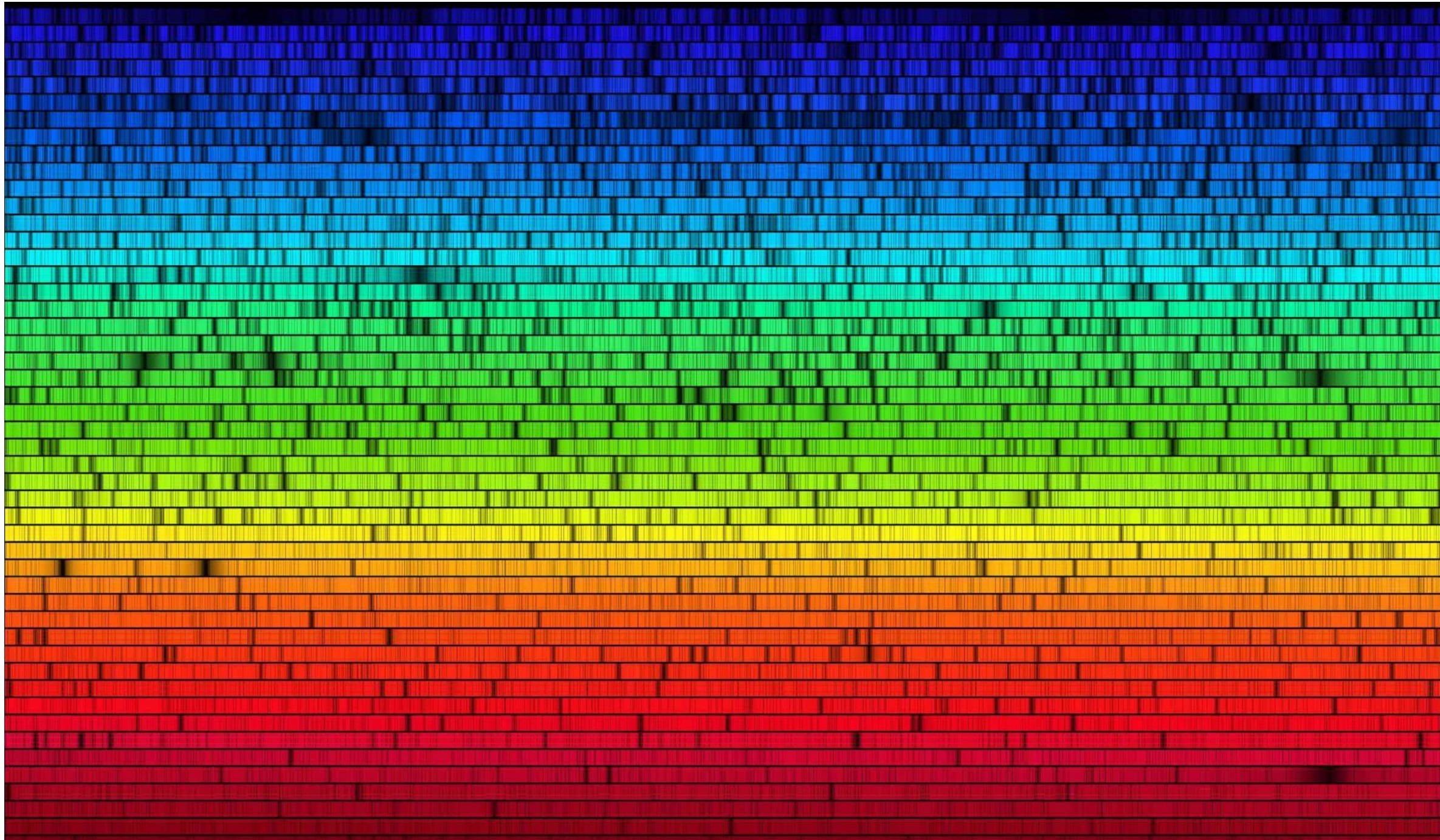
1. Describe how we can study
 - i. **stars'** properties and
 - ii. **exoplanets'** propertiesusing **EM spectra**

Atomic Excitation



Spectral lines = Fingerprints of elements





**QUANTUM for FUN,
Literally....**



PERIODIC TABLE OF THE ELEMENTS

Emission Spectra of the Elements

PERIOD	GROUP 1 IA		GROUP NUMBERS IUPAC RECOMMENDATION (1985)										GROUP NUMBERS CHEMICAL ABSTRACT SERVICE (1986)						GROUP 18 VIIIA	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18		
1	1 1.0079 H HYDROGEN																	2 4.0026 He HELIUM		
2	3 6.941 Li LITHIUM	4 9.0122 Be BERYLLIUM											5 10.811 B BORON	6 12.011 C CARBON	7 14.007 N NITROGEN	8 15.999 O OXYGEN	9 18.998 F FLUORINE	10 20.180 Ne NEON		
3	11 22.990 Na SODIUM	12 24.305 Mg MAGNESIUM											13 26.982 Al ALUMINIUM	14 28.086 Si SILICON	15 30.974 P PHOSPHORUS	16 32.065 S SULPHUR	17 35.453 Cl CHLORINE	18 39.948 Ar ARGON		
4	19 39.098 K POTASSIUM	20 40.078 Ca CALCIUM	21 44.956 Sc SCANDIUM	22 47.867 Ti TITANIUM	23 50.942 V VANADIUM	24 51.996 Cr CHROMIUM	25 54.938 Mn MANGANESE	26 55.845 Fe IRON	27 58.933 Co COBALT	28 58.693 Ni NICKEL	29 63.546 Cu COPPER	30 65.38 Zn ZINC	31 69.723 Ga GALLIUM	32 72.64 Ge GERMANIUM	33 74.922 As ARSENIC	34 78.96 Se SELENIUM	35 79.904 Br BROMINE	36 83.798 Kr KRYPTON		
5	37 85.468 Rb RUBIDIUM	38 87.62 Sr STRONTIUM	39 88.906 Y YTTRIUM	40 91.224 Zr ZIRCONIUM	41 92.906 Nb NIOBIUM	42 95.96 Mo MOLYBDENUM	43 (98) Tc TECHNETIUM	44 101.07 Ru RUTHENIUM	45 102.91 Rh RHODIUM	46 106.42 Pd PALLADIUM	47 107.87 Ag SILVER	48 112.41 Cd CADMIUM	49 114.82 In INDIUM	50 118.71 Sn TIN	51 121.76 Sb ANTIMONY	52 127.60 Te TELLURIUM	53 126.90 I IODINE	54 131.29 Xe XENON		
6	55 132.91 Cs CAESIUM	56 137.33 Ba BARIUM	57-71 La-Lu Lanthanide	72 178.49 Hf HAFNIUM	73 180.95 Ta TANTALUM	74 183.84 W TUNGSTEN	75 186.21 Re RHENIUM	76 190.23 Os OSMIUM	77 192.22 Ir IRIDIUM	78 195.08 Pt PLATINUM	79 198.97 Au GOLD	80 200.59 Hg MERCURY	81 204.38 Tl THALLIUM	82 207.2 Pb LEAD	83 208.98 Bi BISMUTH	84 (209) Po POLONIUM	85 (210) At ASTATINE	86 (222) Rn RADON		
7	87 (223) Fr FRANCIUM	88 (226) Ra RADIUM	89-103 Ac-Lr Actinide	104 (267) Rf RUTHERFORDIUM	105 (268) Db DUBNIUM	106 (271) Sg SEABORGIUM	107 (272) Bh BOHRIUM	108 (277) Hs HASSIUM	109 (276) Mt MEITNERIUM	110 (281) Ds DARMSTADIUM	111 (280) Rg ROENTGENIUM	112 (285) Cn COPERNICIUM	113 (...) Uut UNUNTRIUM	114 (287) Fl FLEROVIUM	115 (...) Uup UNUNPENTIUM	116 (291) Lv LIVERMORIUM	117 (...) Uus UNUNSEPTIUM	118 (...) Uuo UNUNOCTIUM		

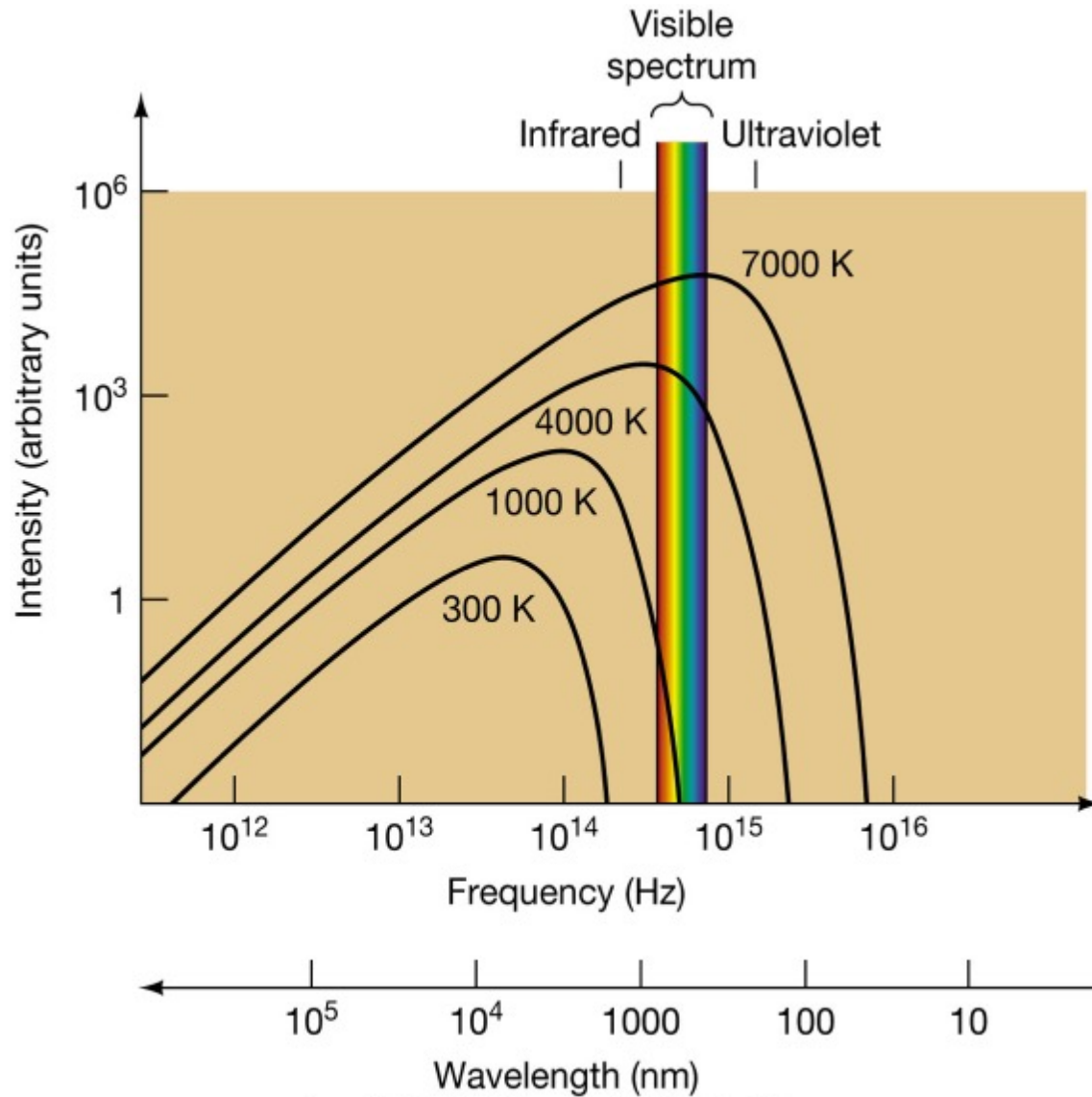
LANTHANIDE

57 138.91 La LANTHANUM	58 140.12 Ce CERIUM	59 140.91 Pr PRASEODYMIUM	60 144.24 Nd NEODYMIUM	61 (145) Pm PROMETHIUM	62 150.36 Sm SAMARIUM	63 151.96 Eu EUROPIUM	64 157.25 Gd GADOLINIUM	65 158.93 Tb TERBIUM	66 162.50 Dy DYSPROSIUM	67 164.93 Ho HOLMIUM	68 167.26 Er ERBIUM	69 168.93 Tm THULIUM	70 173.05 Yb YTTERBIUM	71 174.97 Lu LUTETIUM
--	-------------------------------------	---	--	--	---------------------------------------	---------------------------------------	---	--------------------------------------	---	--------------------------------------	-------------------------------------	--------------------------------------	--	---------------------------------------

ACTINIDE

89 (227) Ac ACTINIUM	90 232.04 Th THORIUM	91 231.04 Pa PROTACTINIUM	92 238.03 U URANIUM	93 (237) Np NEPTUNIUM	94 (244) Pu PLUTONIUM	95 (243) Am AMERICIUM	96 (247) Cm CURIUM	97 (247) Bk BERKELIUM	98 (251) Cf CALIFORNIUM	99 (252) Es EINSTEINIUM	100 (257) Fm FERMIUM	101 (258) Md MENDELEVIUM	102 (259) No NOBELIUM	103 (262) Lr LAWRENCIUM
--------------------------------------	--------------------------------------	---	-------------------------------------	---------------------------------------	---------------------------------------	---------------------------------------	------------------------------------	---------------------------------------	---	---	--------------------------------------	--	---------------------------------------	---

Blackbody Radiation



Copyright © 2005 Pearson Prentice Hall, Inc.

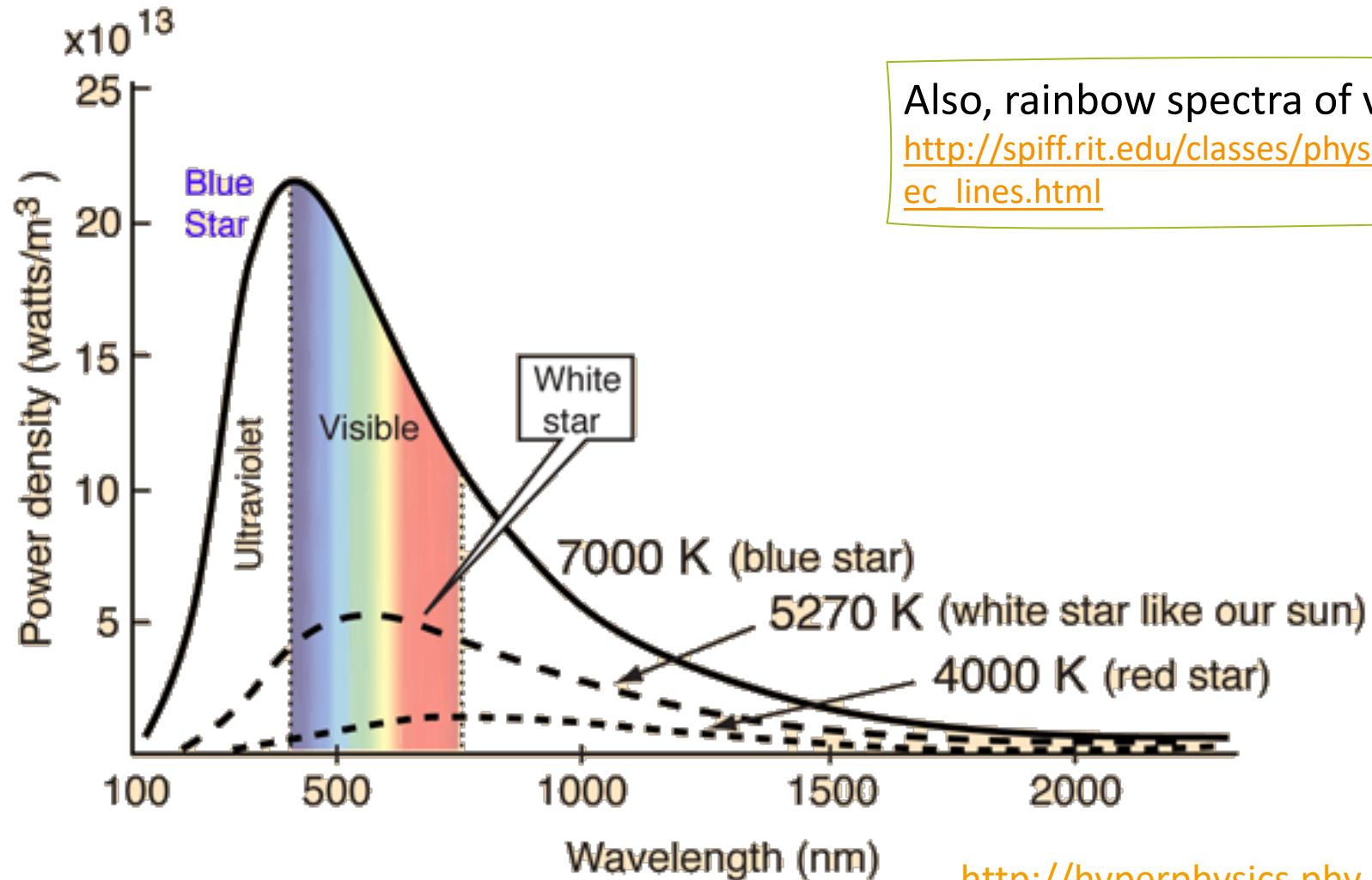
Black body Spectra

Wien's Law

$$\lambda_{\text{max}} = 0.29 \text{ cm} / T$$

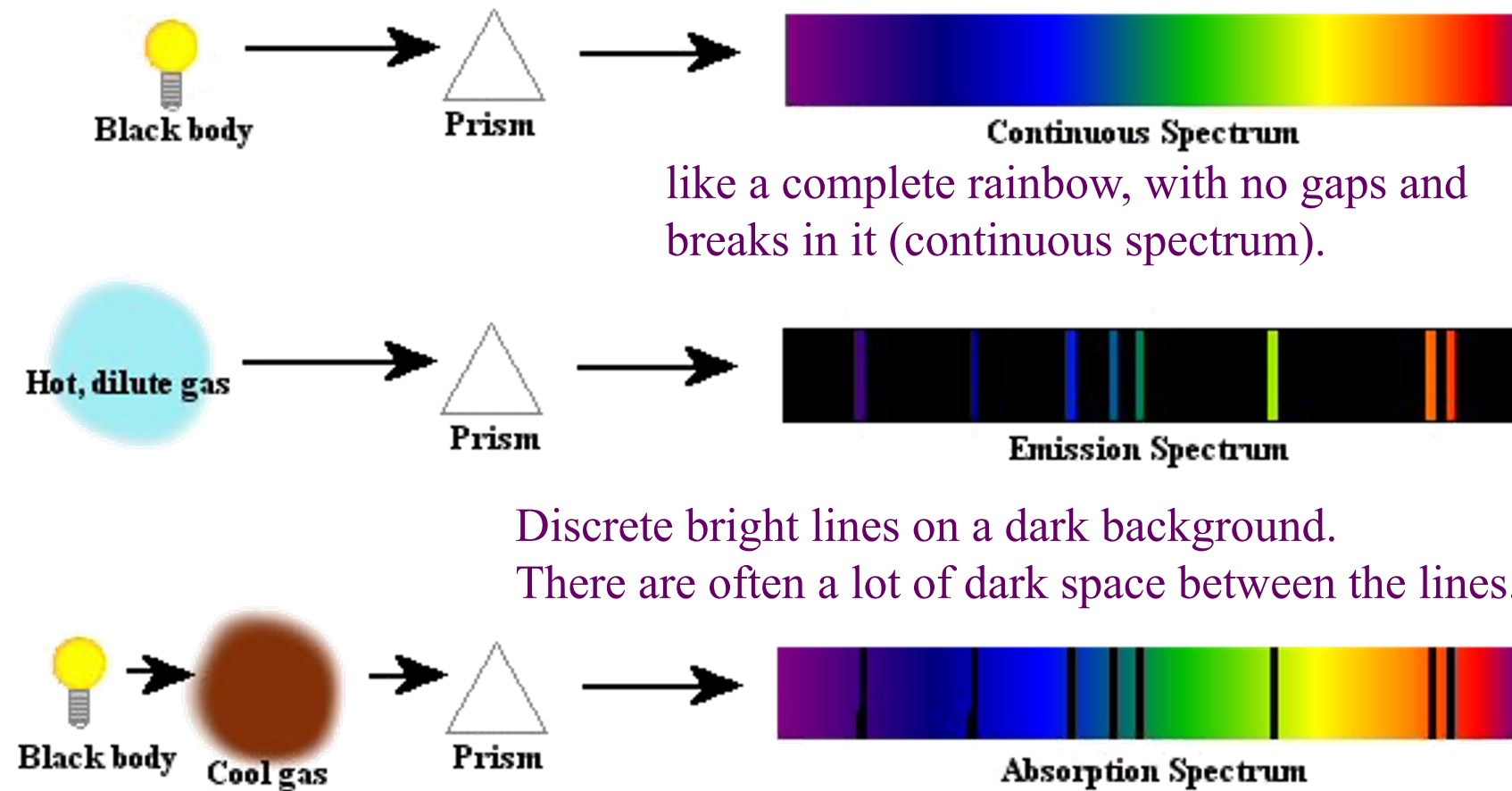
Black body radiation has a **continuous spectrum**

Star's Spectrum: **Blackbody** Spectrum



Also, rainbow spectra of various temperatures:
http://spiff.rit.edu/classes/phys301/lectures/spec_lines/spec_lines.html

Different Types of Spectra



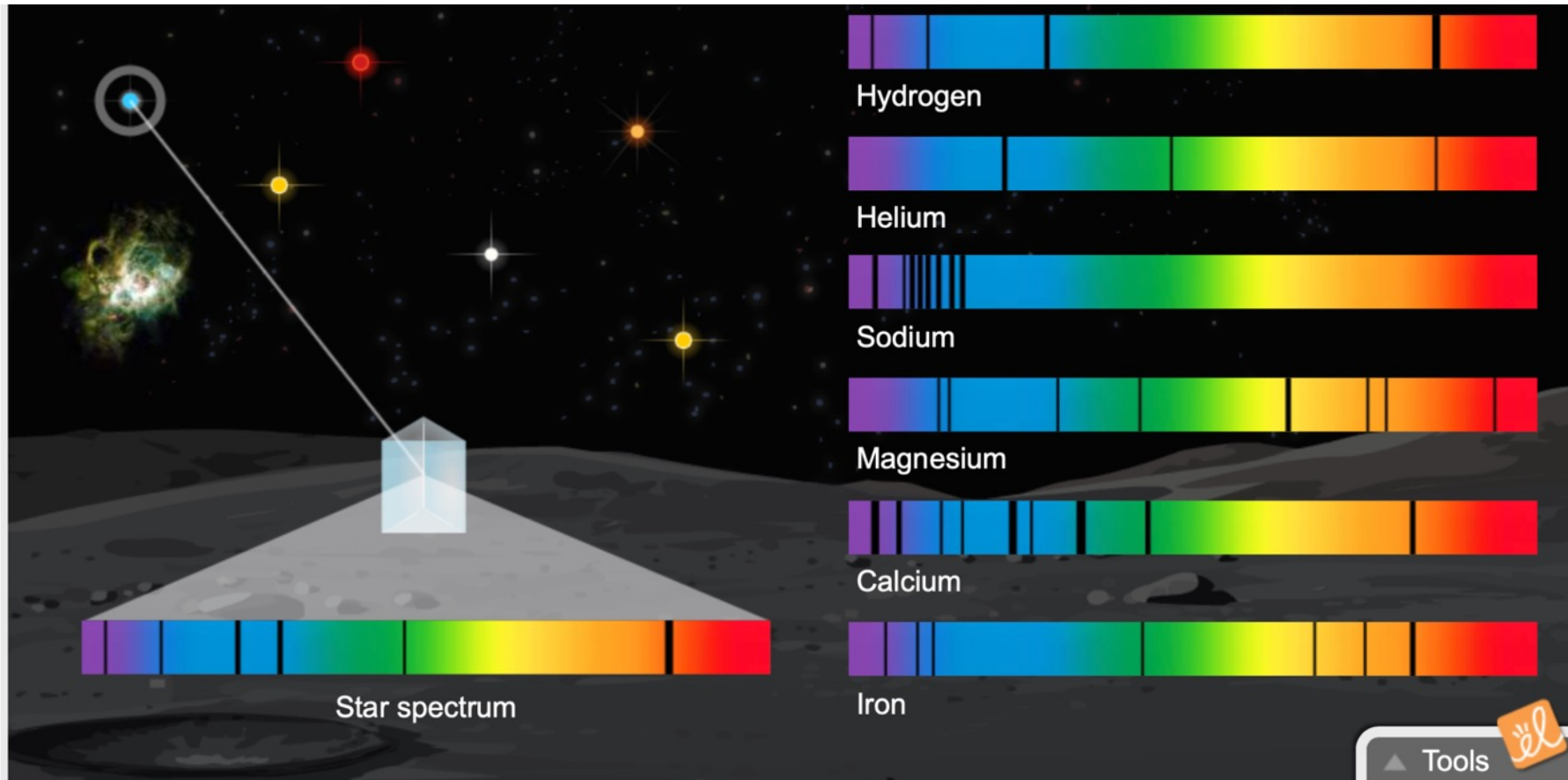
like a complete rainbow, with no gaps and breaks in it (continuous spectrum).

Discrete bright lines on a dark background.
There are often a lot of dark space between the lines.

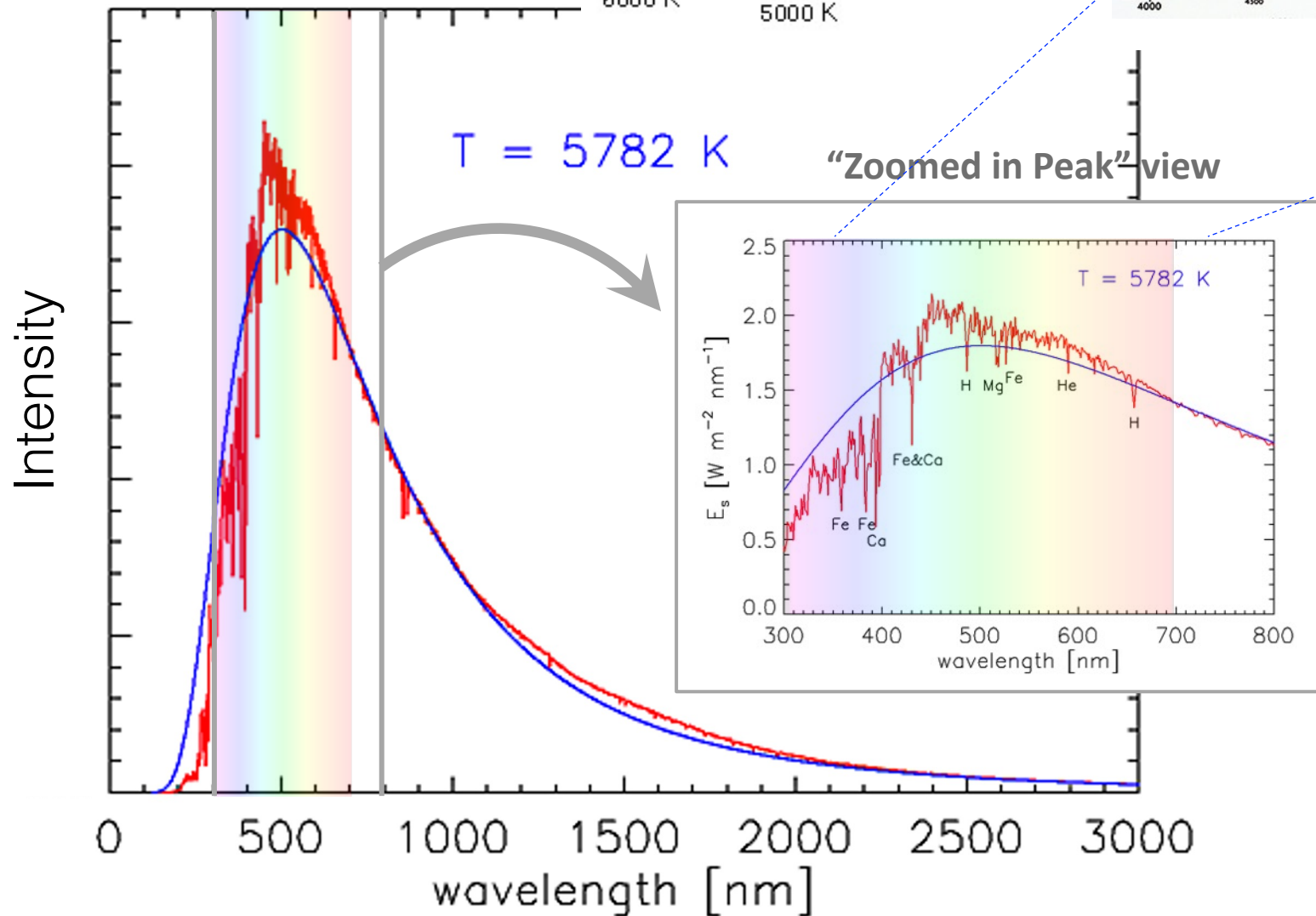
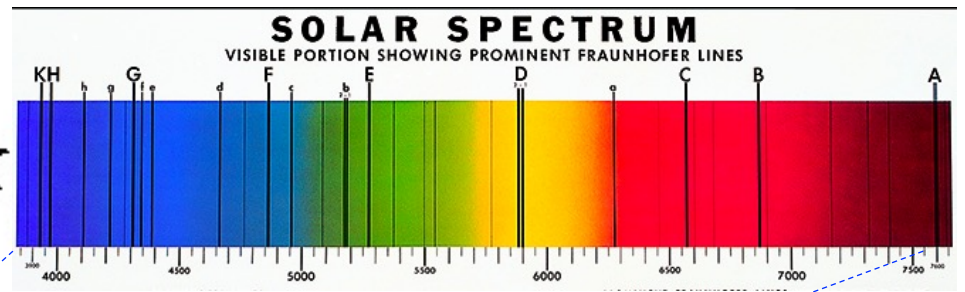
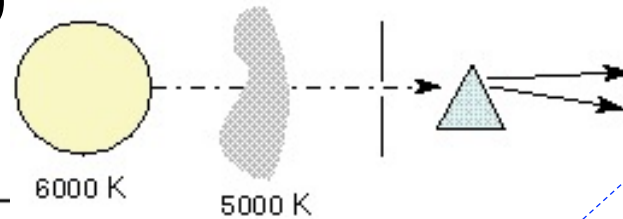
Dark lines (certain wavelengths is absorbed) on a bright background.

Absorption Spectrum of a Star

Question: Which elements are in the atmosphere of this star?



Actual Solar Spectrum



Using Spectrum, we can learn:

- presence of certain elements
- temperature, T
 $\lambda_{\text{peak}} = (2.9 \times 10^{-3} \text{ m}\cdot\text{K})/T$
- source of the EM emission
- (orbital) speeds involved

Absorption due to:

- atoms \rightarrow thin lines
- molecules \rightarrow broad lines