Chromospheric Emission Lines: Rules of Formation

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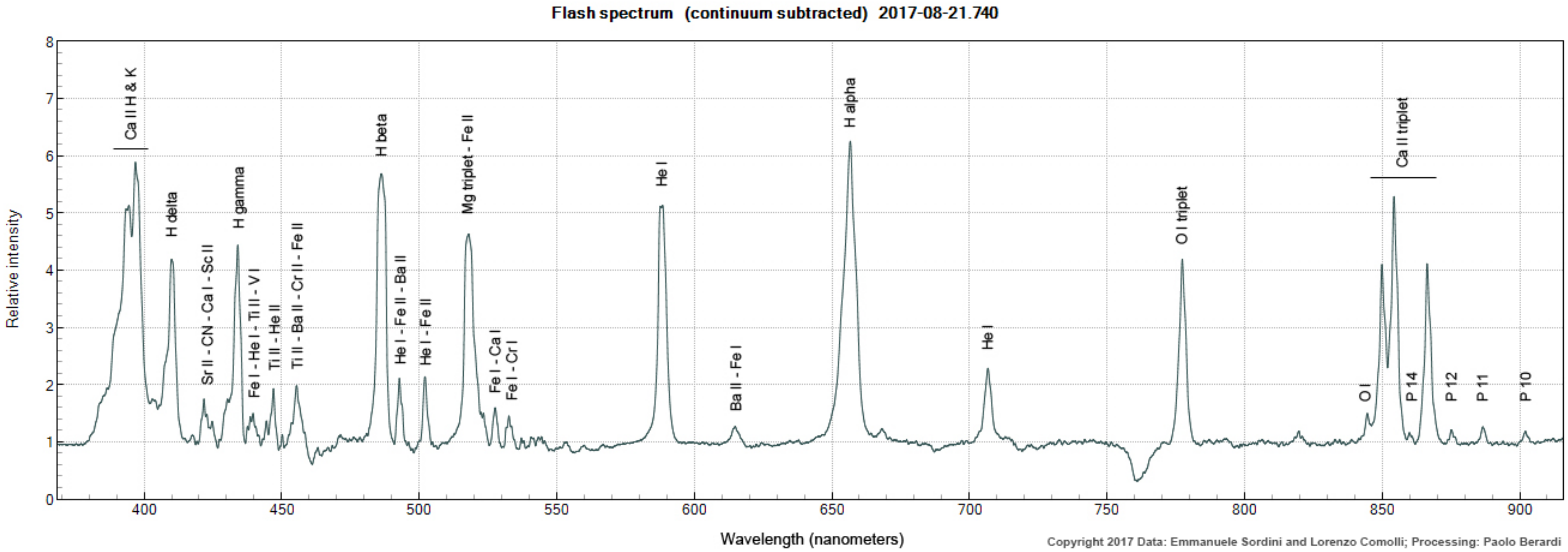


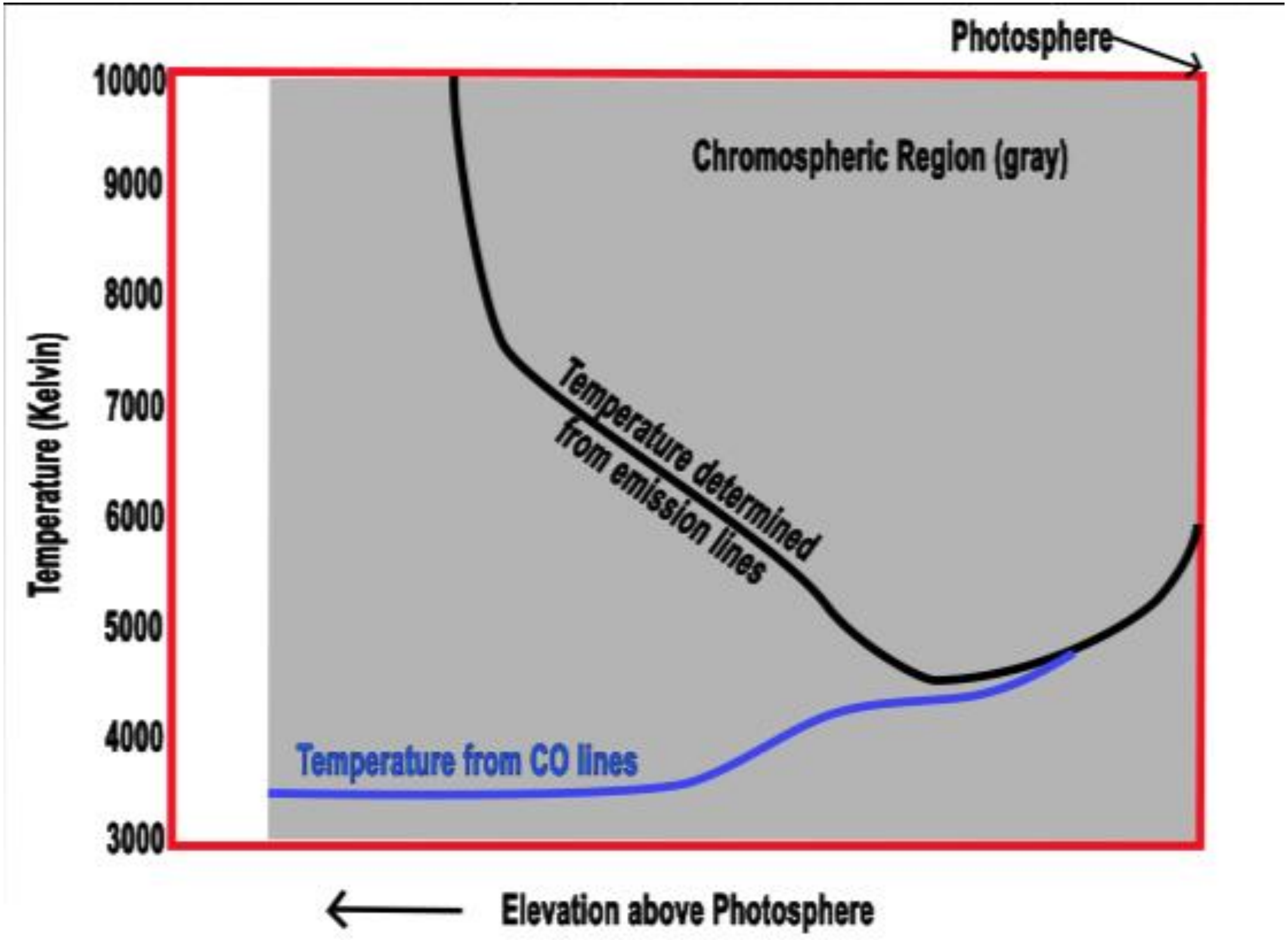
This spectrum is a collaboration between Lorenzo Comolli and Emmanuele Sordini; processing Paolo Berardi
http://www.astrosurf.com/comolli/ecl17-11a.png

1. **Emission lines in the chromosphere have always been viewed as randomly produced, manifesting only local temperature.**

2. **Use of the Saha equation in the chromosphere can lead to errors of 100 trillion times in the ratio of ions observed (H. Zirin, The Solar Atmosphere, Blaisdell Publishing, Waltham, MA, 1966, p. 72).**

3. **The emission lines in the chromosphere do not result from processes in thermal equilibrium. Therefore, they cannot be used to set chromospheric temperatures and the Saha equation should not be applied.**

4. **Infrared carbon monoxide (CO) absorption lines in the chromosphere indicate that this region of the Sun is cooling with elevation, not heating. These lines are much more likely to be in thermal equilibrium.**



Adapted from: H. Uitenbroek, The CO Fundamental Vibration-Rotation Lines in the Solar Spectrum. II. Non-LTE Transfer Modeling in Static and Dynamic Atmospheres. Astrophys. J., v. 536(1), 481-493.

The intense emission lines in the chromosphere are not a product of random absorption and emission. They are indicative of condensation reactions involving metal hydrides!

Such reactions are exothermic in nature.
Since no conductive path is available to dissipate heat, photons are emitted.

$$Ca^{+}\ (3p^{6}3d^{1}) + H \rightarrow CaH^{+}$$

OR

$$Ca^{+}\ (3p^{6}4s^{1}) + H \rightarrow CaH^{+}$$

It is the ground state of the transition which matters because the metal returns to that state after the delivery of the hydrogen atom or proton!

$$CaH^{+} + CHS \rightarrow CHS\text{-}H\text{-}Ca^{+*} \rightarrow CHS\text{-}H + Ca^{+*}$$

$$Ca^{+*} \rightarrow Ca^{+} + h\upsilon$$

In this way, protons and hydrogen atoms can be recaptured by the Sun!

P.M. Robitaille, The Liquid Metallic Hydrogen Model of the Sun and the Solar Atmosphere IV. On the Nature of the Chromosphere. Progr. Phys. 2013, v. 3, L15-L21.

Species	λ Sun (nm)	λ NIST (nm)	Transition	
Ca II	393.39	393.39	3p6 4s → 3p6 4p	
Ca II	397.03	396.87	3p6 4s → 3p6 4p	
Mg I	516.73	516.73	3s 3p → 3s 4s	
Mg I	517.27	517.27	3s 3p → 3s 4s	
Mg I	518.36	518.36	3s 3p → 3s 4s	
Na I	588.95	588.99	3p6 3s → 3p6 3p	
Na I	589.6	589.59	3p6 3s → 3p6 3p	
O I	777.19	777.19	2s2 2p3 3s → 2s2 2p3 3p	Spec II
O I	777.41	777.41	2s2 2p3 3s → 2s2 2p3 3p	Spec.II
O 1	777.54	777.54	2s2 2p3 3s → 2s2 2p3 3p	Spec II
O I	844.63	844.63	2s2 2p3 3s → 2s2 2p3 3p	Spec II
O I	844.66	844.66	2s2 2p3 3s → 2s2 2p3 3p	Spec.II
O 1	844.68	844.68	2s2 2p3 3s → 2s2 2p3 3p	Spec II
Ca II	849.8	849.8	3p6 3d → 3p6 4p	Spec II
Ca II	854.21	854.21	3p6 3d → 3p6 4p	Spec II
Ca II	866.14	866.14	3p6 3d → 3p6 4p	Spec II

Now, you have to be a little bit of a detective:

Al I 394.403 nm $3s^2 3p^1 \rightarrow 3s^2 4s^1$
(note: Al II lines ($3s^2$) are not visible even though ionization requires only 5.9 eV, whereas Ca II ($3p^6 4s$) which requires ~6.11 eV are prominent! Mn II (e.g. 348.868 nm $3d^6$) and Mg II (e.g 438.464 nm $3p^6 4p$) are seen and require ~7.34 and ~7.64 eV)

NIII 409.736 nm $2s^2 3s^1 \rightarrow 2s^2 3p^1$
Fe I 483.955 nm $3d^7 4s^1 \rightarrow 3d^7 4p^1$ (ground state for Fe I in lab is $3d^6 4s^2$)
Fe I 516.227 nm $3d^7 4p^1 \rightarrow 3d^7 4d^1$
Cr I 425.435 nm $3d^5 4s^1 \rightarrow 3d^5 4p^1$ (Strong! Leaving from the lab ground state!)

The intensity of an emission line is related to the ability to form the hydride and deliver a hydrogen atom, molecule, or proton. It is not proportional to the concentration of a given element in the chromosphere.

He I, He II, Ca II, O Triplet, Mg I lines are intense because they most readily form the hydrides.

An example of a condensation reaction in the laboratory:

silver clusters @ 10 K, Neon environment

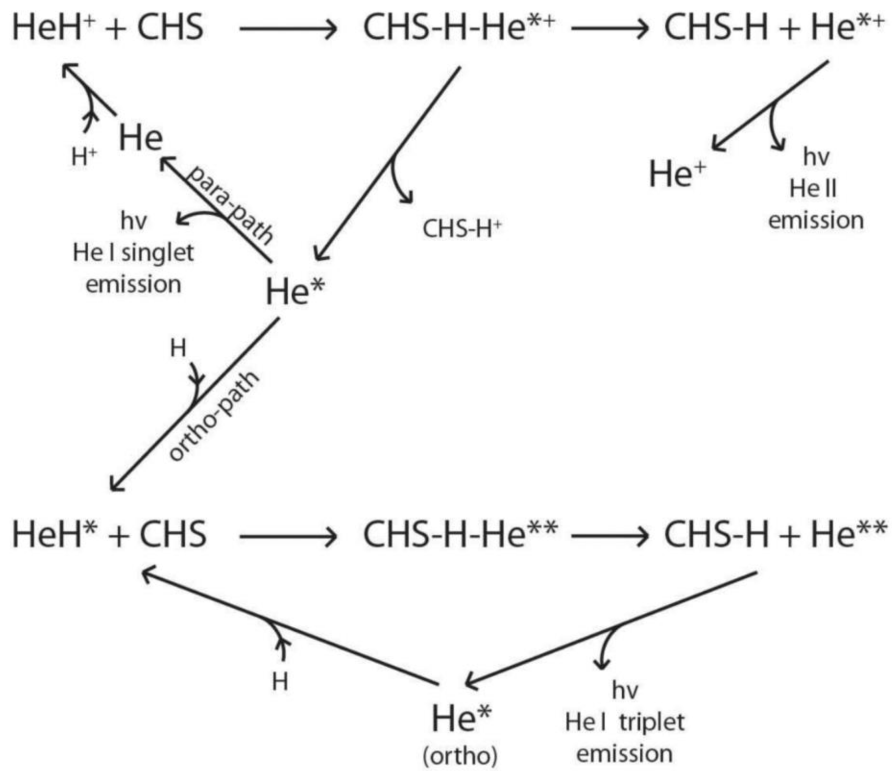
$$Ag_4 + Ag_4 \rightarrow Ag_8^* \rightarrow Ag_7 + Ag^*$$

$$Ag^* \rightarrow Ag + h\upsilon$$

Photons are emitted in the ultra violet in this case. But the thermal bath is at 10K!

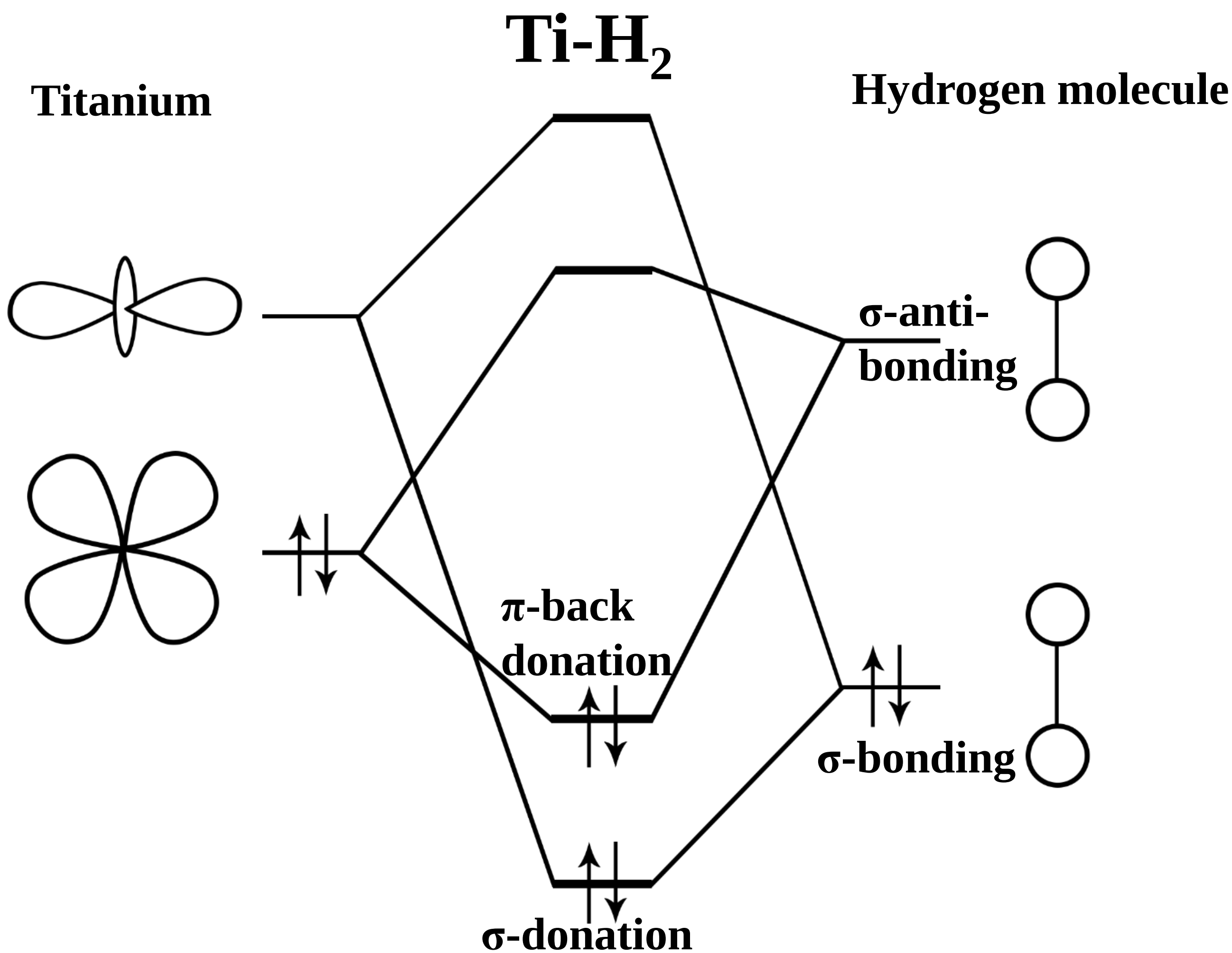
I. Rabin, W. Schulze, and G. Ertl, Light Emission during the agglomeration of silver clusters in noble gas matrices, J. Chemical Phys., 1998, 108, 5137-5142.

When He captures a proton, it leads to an activated HeH^{+*}, which must emit light to enter the ground state (see Eq. 1, in ApJ, 1982, 255, 489-496). Assuming it does not relax back before it can react, you could have the following:



P.M. Robitaille, The Liquid Metallic Hydrogen Model of the Sun and the Solar Atmosphere VI. Helium in the Chromosphere. Progr. Phys. 2013, v. 3, L26-L29.

Two electron transitions should not occur in random processes. They are suggesting the bonding of a hydrogen molecule known in inorganic chemistry.



Ti I @ 415.964 nm in ApJSS, 1968, 150(17), 1-364, if as recorded, originates from $3d^3(2D)4s \rightarrow 3d4s^24p$