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Astrophysical X-Ray Lasers

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1. What are astrophysical lasers?

Astrophysical lasers are quantum-electronic space objects, that occur in space plasmas and which prime way of production is due to electron population inversion. Population inversion is plausible in a lasing event as the lifetime of an upper electronic level must be larger than the lifetime of a lower electronic level [1].

Fig. 1: Lagoon Nebula, space object where astrophysical lasers have been detected.

2. Line photo-pumping

When two elements have coincident excitation lines at the same wavelength, it can lead to photo-pumping through stimulated transitions. If the excitation of the pumped element produces a population inversion, line photo-pumping is responsible for lasing.

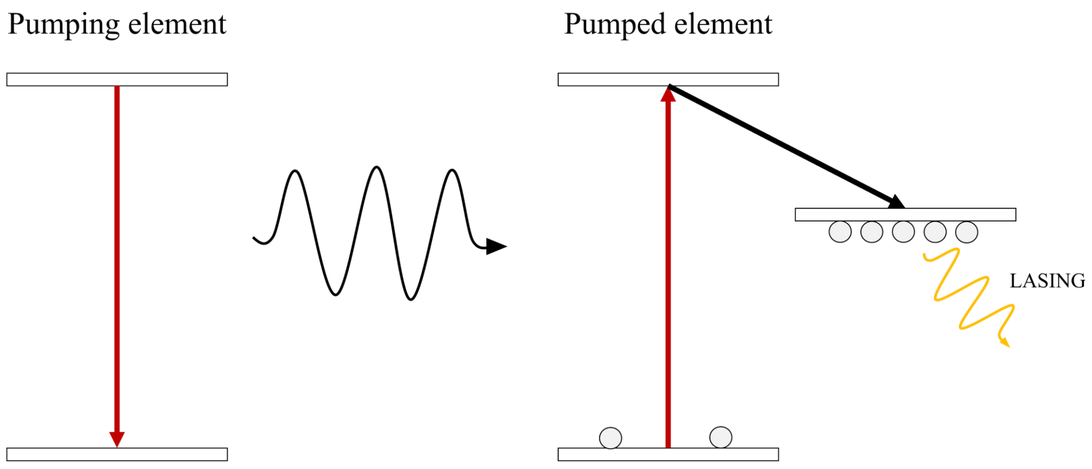

Fig. 2: Representation of a photo-pumping system able to produce lasing due to a population inversion in its intermediate energy level.

3. Aims of the project

1. Find different candidate elements that could produce lasing in space.
2. Detect computationally if they produce compatible lines that increment in intensity due to photo-pumping.
3. Identify if these lines have been observed in any space conditions.

4. Process

1. Find elements that have coincidence lines**.**
2. Use GALAXY, a code that calculates the ionisation and excitation of plasma [2], to find the line intensities, using the information of the elements with different plasma conditions.
3. Compare the results for a not photo-pumped system and a photo-pumped system.
4. Identify the lines in a real system.

5. Results

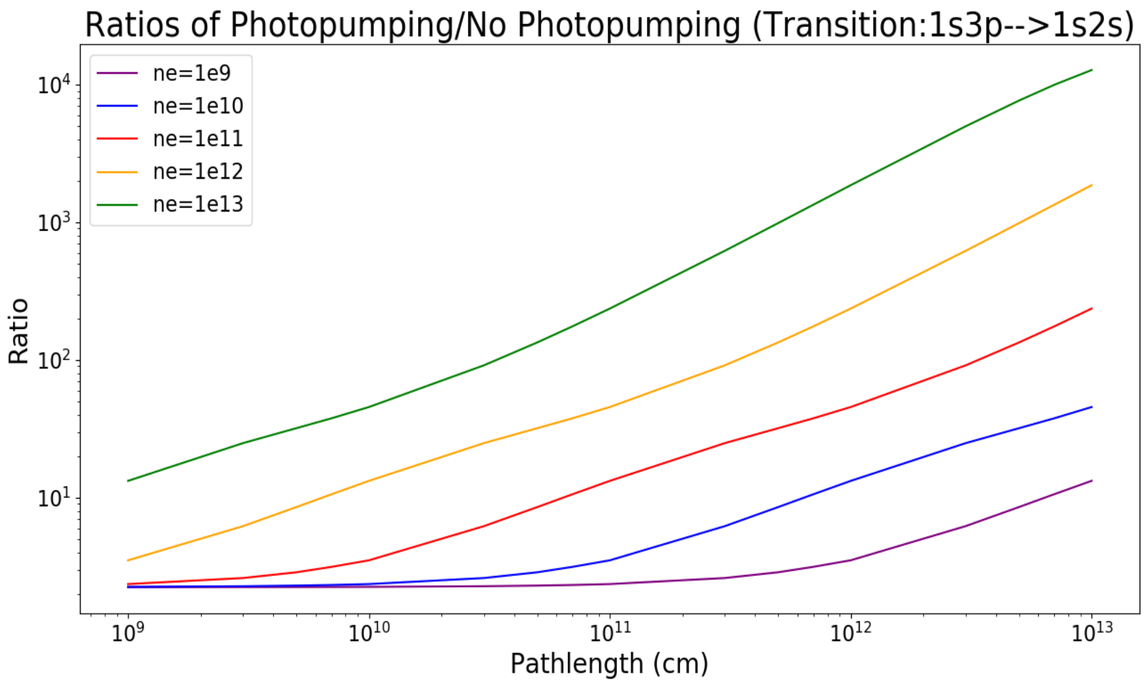

Fig. 3: Ratios of the intensities of the photo-pumped Si-Al system over the not photo-pumped Si-Al system. Calculations made with GALAXY. n_e represents the electron density, with units of cm^{-3}.

- The photo-pumped system is built by He-like silicon (pumping element) and He-like aluminium (pumped element), at a pumping wavelength of 6.648 Å [3], having a lasing line of 42.610 Å [4].
- There is an increment in intensity of the lines due to photo-pumping.
- These lines have not been found in an astrophysical system. However, they have been identified under laboratory conditions.

6. Further research

- Identify if the studied Si-Al system could create an astrophysical laser.
- Analyse other systems, such as the Li-like iron and H-like aluminium system, which has several lines that can be candidates for space lasing in the X-Ray regime.

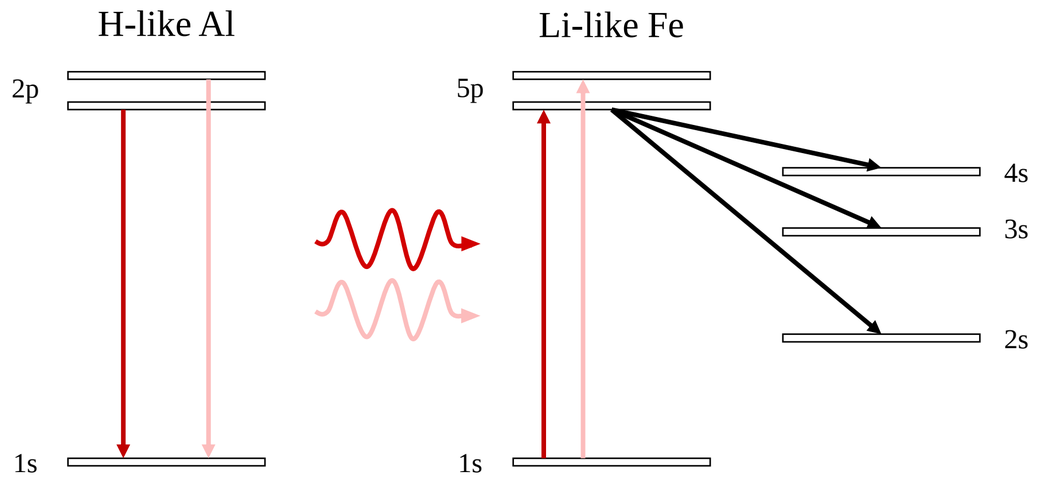

Fig. 4: Scheme of the Fe-Al system, which has two coincidence lines and the possible transitions [5].

References

[1] Letokhov V, Johansson S. *Astrophysical Lasers.* Oxford: Oxford University Press; 2008.
[2] Rose SJ. The non-LTE excitation/ionization code GALAXY. *Journal of physics.B, Atomic, molecular, and optical physics.* 1998; 31 (9): 2129-2144. 10.1088/0953-4075/31/9/024.
[3] F. Chapline G. Line-Coincidence Schemes For Producing Laser Action at Soft-X-Ray Wavelengths. ; January 12, 1983.
[4] Acton LW. *Rocket Spectogram in a Solar Flare in the 10-100 A Region.* 1985.
[5] Gouveia A, Al'miev IR, Hawreliak J. *Absorption spectroscopy of Al XIII Ly-alpha radiation by an Fe XXIV plasma.*