Watching Aurora in Passive Galaxies:

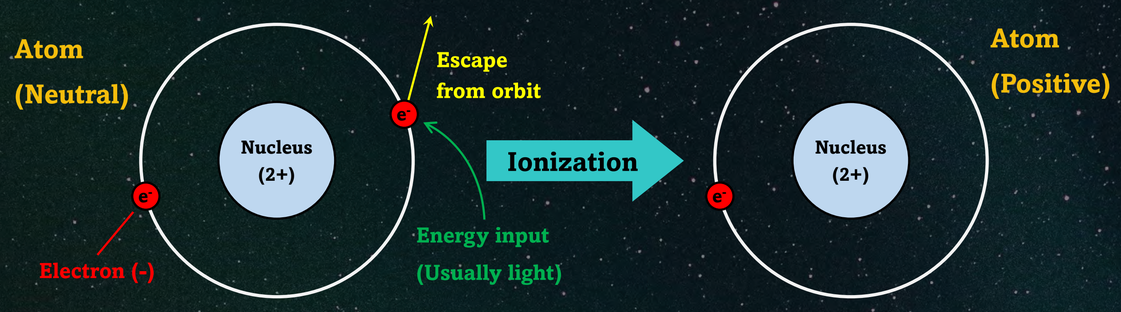
Temperature measurement and constraint on ionization source

Man Yin Leo Lee and Renbin Yan

Department of Physics, The Chinese University of Hong Kong

What is ionization?

- In the interstellar medium, **ionization** refers to the process describing an atom losing electrons and becoming positively charged due to external energy input.
- There are **different levels of ionizations**. Atoms can lose single or multiple electrons depending on the energy input.



Types of galaxies

Type: **Spiral galaxy**

Shape: **Spiral and disky**

Star-formation: **Many**

Age: **Young**

Type: **Elliptical galaxy**

Shape: **Ellipsoidal**

Star-formation: **None**

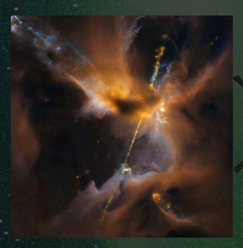
Age: **Old**

Scientific Problem

- **Low-ionization Emission Line Regions** (LIERs) are regions that contain large amounts of low-level ionized atoms.
- LIERs are found in **elliptical galaxies** which are old and evolved. Ionization sources of these LIERs **remain unknown**.
- **Active Galactic Nuclei** were thought to be the source of ionization but spatially resolved observation proved that LIERs extend outside the nuclear region.
- Different sources inject energy differently, giving the interstellar medium **different temperatures**, providing astronomers a way to solve the mystery.
- Popular candidates: (1) **Light from old stars**, (2) **Supersonic shocks induced by collisions between gas clouds**.

LIERs observed outside nuclear region

Active Galactic Nuclei

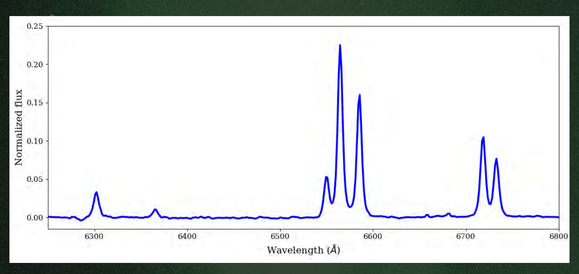


Interstellar shocks

Old stars

Methodology

- Light we see is added up by light in **different wavelengths**.
- Different wavelengths of light can be decomposed by a **spectrograph**.
- Auroral light is from **certain wavelengths** and is **dependent on the temperature** of the origin.
- By measuring the amount of light in those wavelengths, **the strength of auroral light can be obtained**.
- The plot of strength versus wavelength is called **a spectrum**.



Part of a stacked spectrum from the sampled galaxies

Auroral lines

1. Name: **[NII] λ5755**
   Color: Green
2. **[SII] λλ4068,4076**
   Color: Purple
3. **[OII] λλ7320, 7330**
   Color: Red
4. **[OIII] λ4363**
   Color: Blue

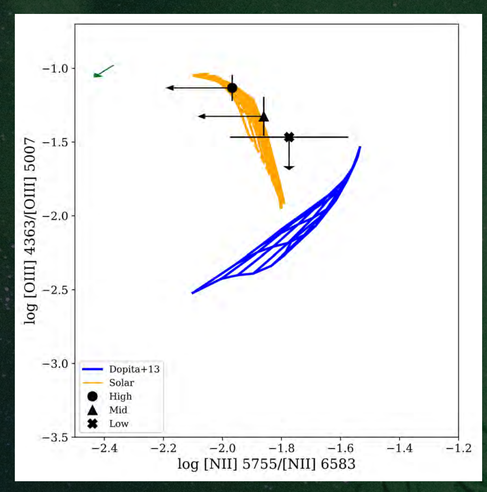
Element — Wavelength (in 10^{-10}m)

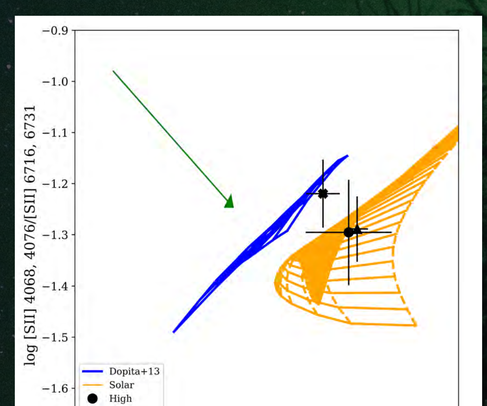
[OII] λλ3727, 3729

Ionization state — Wavelength (2nd line if applicable)

Results

- The measured auroral line strengths are plotted against each other and **compared to the models** of the two popular candidates.
- The temperatures derived from different sets of data (Black) seems to **be more consistent with models of shocks** originating from collisions between clouds (Orange) than photoionization by old stars (Blue).
- Nevertheless, some data points are **not well measured** or **inconsistent with the shock models**.





Future directions

- Investigate the possibility of **different ionization sources** in different parts of the galaxy or different galaxies.
- Improve **the model** and make **deeper observations**.

Photo credit: ESA / Hubble

We acknowledge financial support by the Direct Grant from CUHK Faculty of Science.

Reference:

Yan, R. (2018). Shocks or photoionization: Direct temperature measurements of the low-ionization gas in quiescent galaxies. Monthly Notices of the Royal Astronomical Society, 481(1), 476–493.