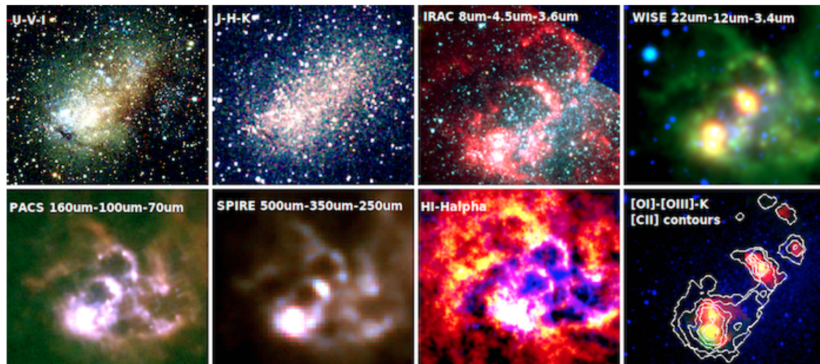


The electron density distribution in the Local Group dwarf galaxy IC 10

Fiorella Lucia Polles SOFIA Science Centre, USRA

Suzanne Madden, Vianney Lebouteiller, Christian Fischer, Dario Fadda, Nick Abel, Keith Doore, Frederic Galliano, James Jackson, Randolph Klein, Alfred Krabbe, William Vacca

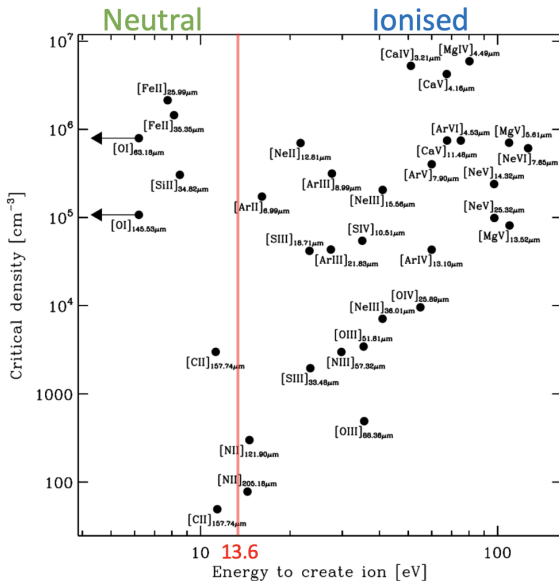


Our Galactic Ecosystem - March 3, 2022

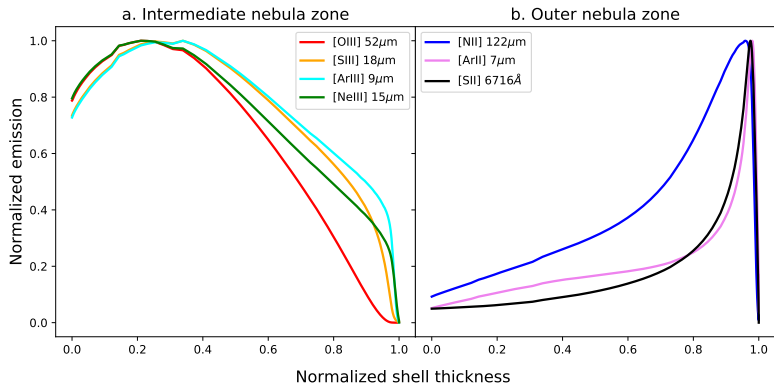
Scientific context

- Knowledge of **the density distributions** to infer the **structure of the interstellar medium (ISM)** and **quantify the ionizing radiation escaping the ISM** in a low-metallicity environment.
- The **physics of the distant universe**: the nearby galaxies help us to investigate the properties of the unresolved high-redshift galaxies.
- What are we looking at with an **unresolved spectrum**? Is it an **average property** or is it the **dominant phase**?

Multi-phase ISM traced by infrared line emission

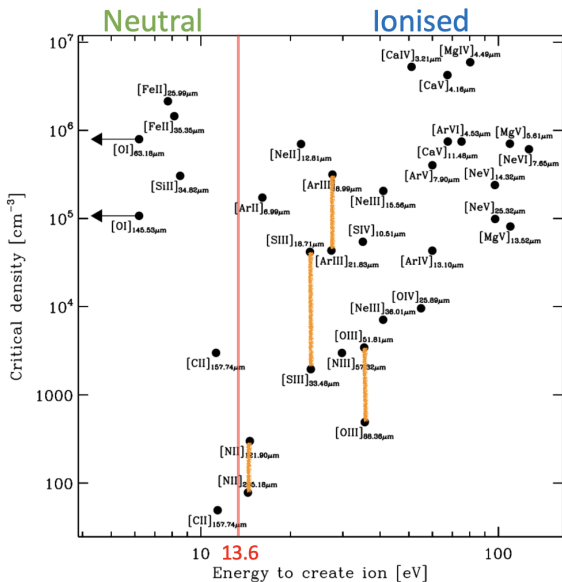


Various layers



- **High-ionization** lines trace the ionised gas close to the ionizing source.
- Lines with **low excitation potential** trace the edge of the HII regions.

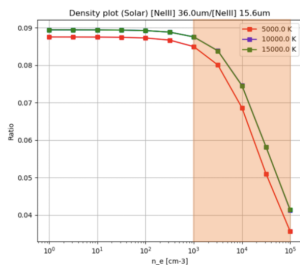
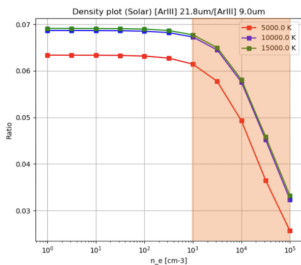
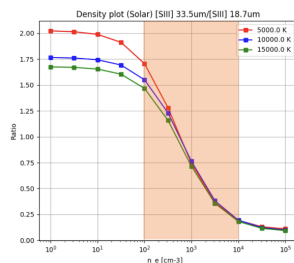
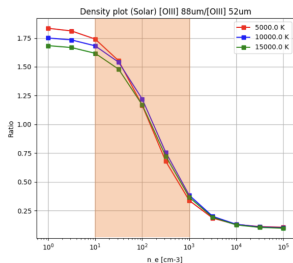
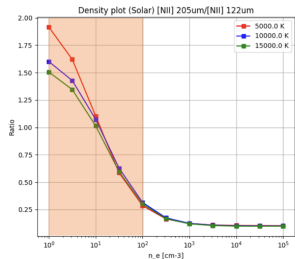
Infrared electron density diagnostics



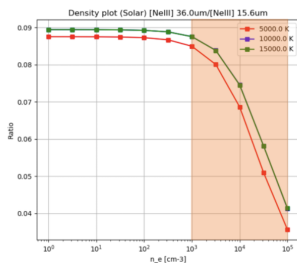
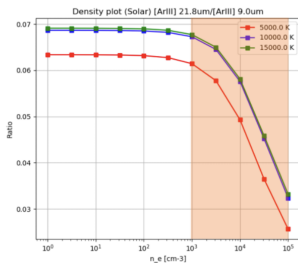
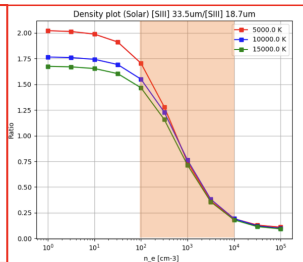
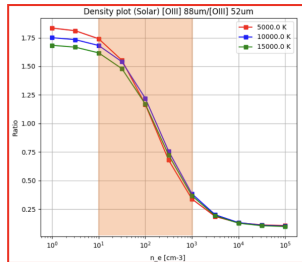
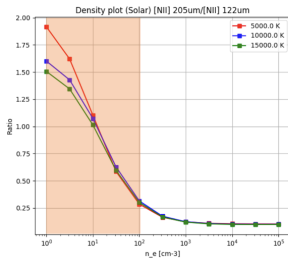
Density diagnostics

line ratios of the same ion
but different transitions.

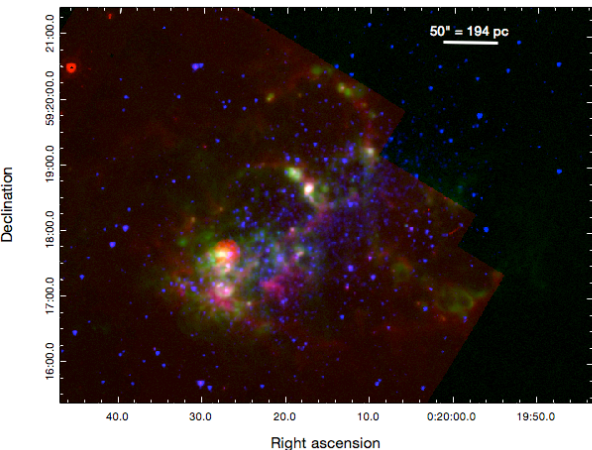
Infrared electron density diagnostics



Infrared electron density diagnostics



IC 10 - general properties



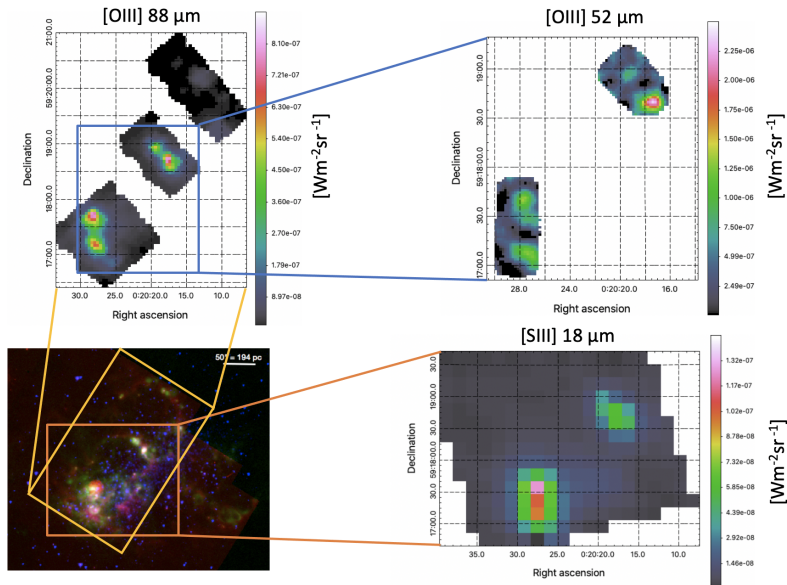
- $Z = 1/3 Z_{\odot}$ ($Z_{SMC} < Z_{IC10} < Z_{LMC}$) (Lozinskaya et al. 2009)
- large population of Wolf-Rayet stars (Massey & Holmes 2002)
- Distance ~ 700 kpc \Rightarrow we can choose the different scales and see which phase dominant.

PAH (*Spitzer*/IRAC4, $8 \mu\text{m}$)

H_{α} (1.8 m Perkins Telescope; Hunter & Elmegreen 2004)

stars (*Spitzer*/IRAC1, $3.6 \mu\text{m}$)

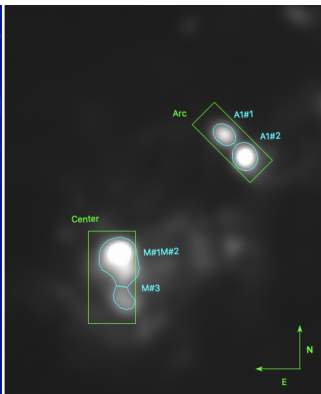
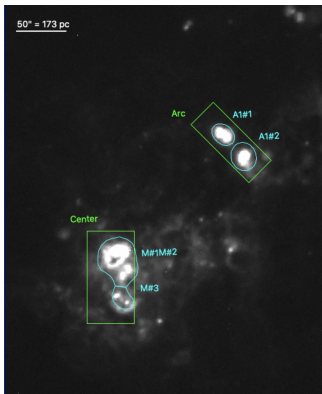
Data set: *Herschel/PACS*, *SOFIA/FIFI-LS* and *Spitzer/IRS*



Selected Clumps and Regions

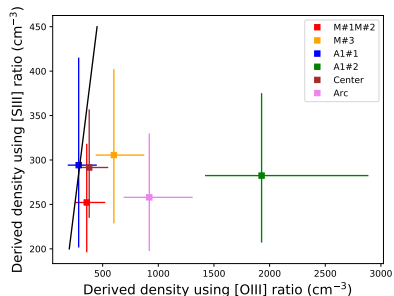
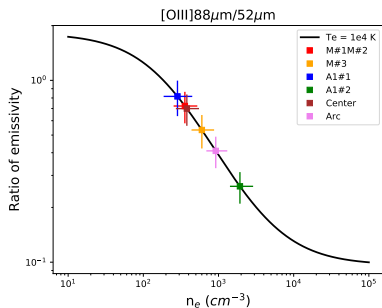
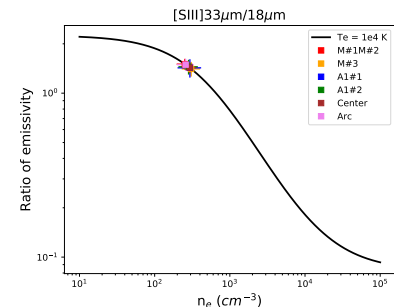
H α

H α convolved to 9.5''



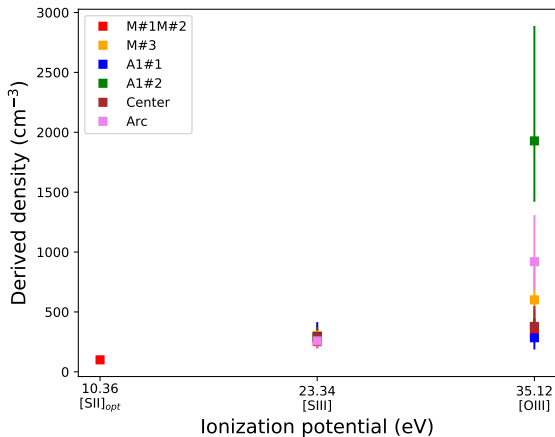
- **Regions:** coincide with the two area covered by [OIII] 52 μm map: *Center* and *Arc*.
- **Clumps:** threshold at intensity of $5.5 \times 10^{-8} \text{ Wm}^{-2} \text{sr}^{-1}$. We traced limit to separate the first clump, *M#1M#2*, from the second clump, *M#3*.

Estimated electron densities: $n_{e[SIII]}$ and $n_{e[OIII]}$



- $n_{e[SIII]}$: [200 - 300] cm^{-3}
 → very similar values for all the regions
- $n_{e[OIII]}$: [350 - \sim 2000] cm^{-3}
 ⇒ two different gas components:
 $n_{e[OIII]}$ values are higher than $n_{e[SIII]}$ values.

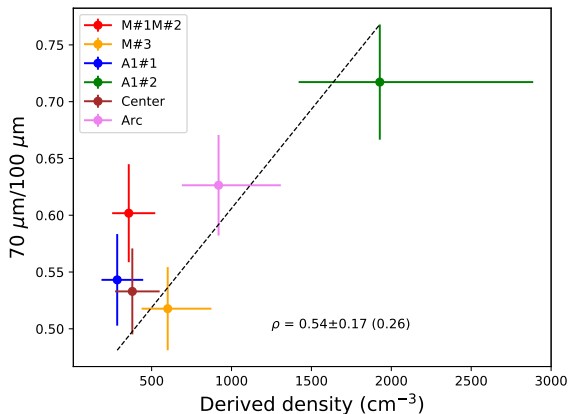
Density stratification



Highest densities traced by the ions with the highest ionization potential

⇒ denser clouds closer to the ionizing source.

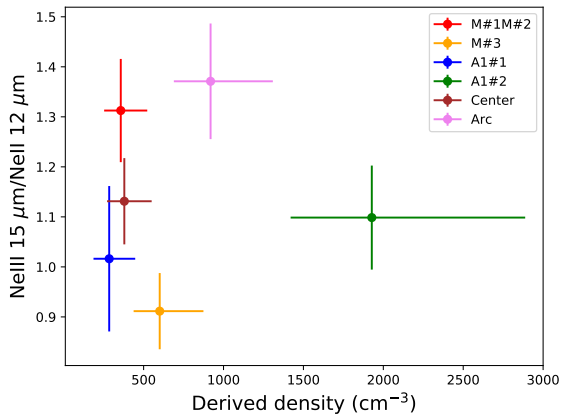
Relation between density traced by [OIII] and ionising source



Higher densities at higher dust temperatures

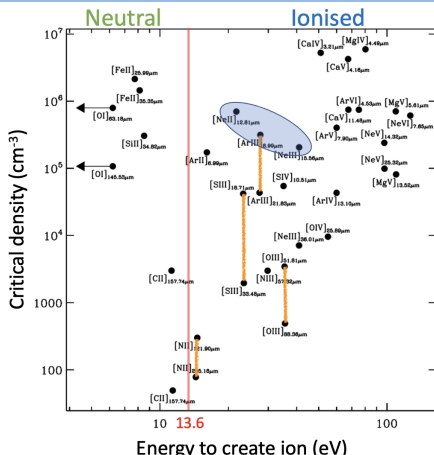
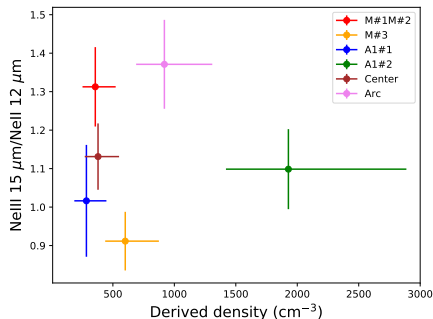
⇒ denser region in more energetic environment.

Relation between density traced by $[OIII]$ and ionising source



Hardness of the radiation field
 Any correlation between the ratio $[\text{NeIII}]/[\text{NeII}]$ and the electron density

Relation between density traced by [OIII] and ionising source



Different components?

- [NeIII]/[NeII]: $n_e \sim [10^5 - 10^6] \text{ cm}^{-3}$
- [OIII] 88/52: $n_e \sim [10 - 10^3] \text{ cm}^{-3}$

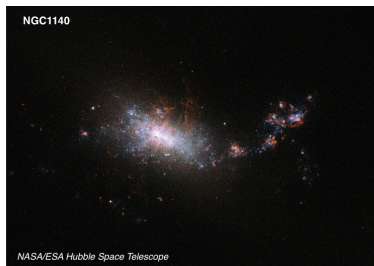
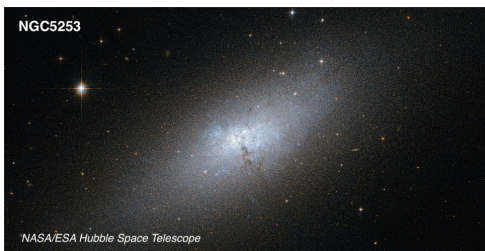
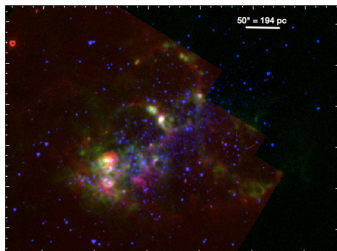
Are the ratios [NeIII]/[NeII] and [OIII]88/52 tracing different gas components?

Conclusions

- The gas traced by the [OIII] lines and the gas traced by [SIII] lines are **two different components**.
- The **denser gas is closer to the ionizing source**.
- **Denser region in more energetic environment**
- **No correlation** between the electron density traced by [OIII] ratio and hardness of the radiation field → are we looking at two different gas components?

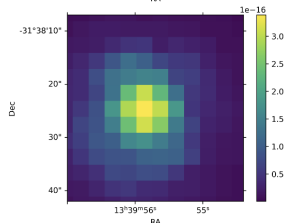
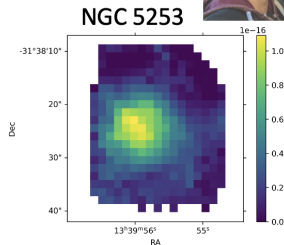
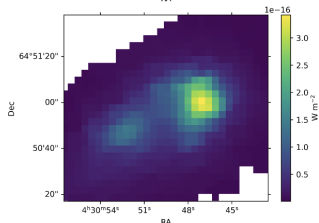
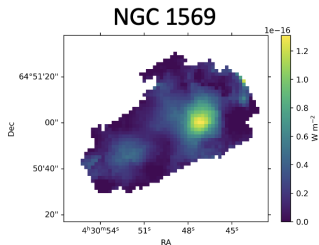
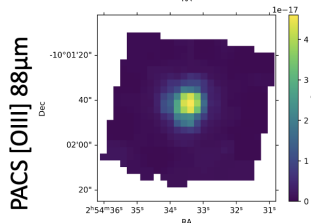
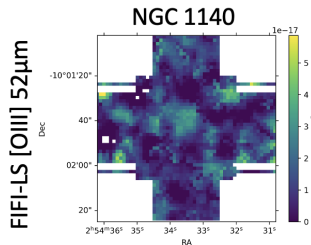
Electron density of the ionised gas in low-metallicity galaxies

Pilot sample: IC 10, NGC 5253, NGC 1140 and NGC 1569

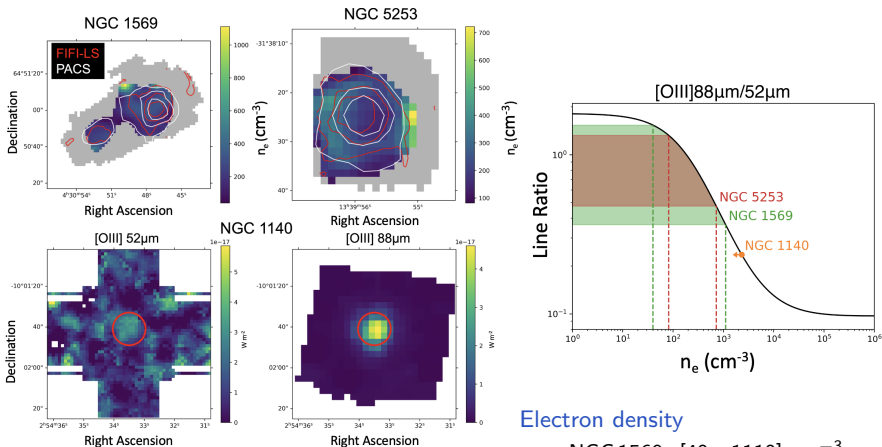


Electron density of the ionised gas in low-metallicity galaxies

Keith Doore
Ph.D. student
University of Arkansas



Electron density of the ionised gas in low-metallicity galaxies



Electron density

- NGC 1569: $[40 - 1110] \text{ cm}^{-3}$
- NGC 5253: $[80 - 720] \text{ cm}^{-3}$
- NGC 1140: upper limit of 2330 cm^{-3}



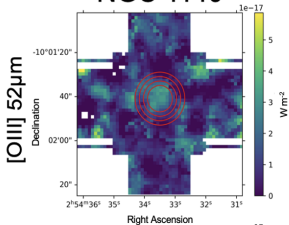
Keith Doore
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Electron density of the ionised gas in low-metallicity galaxies

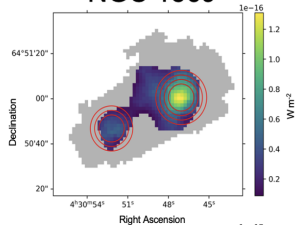
Keith Doore
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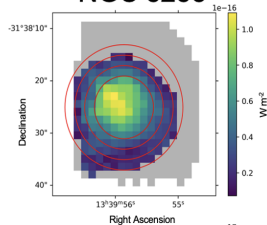
NGC 1140



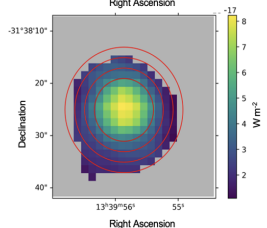
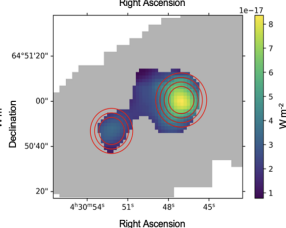
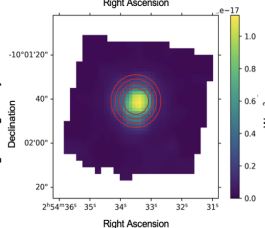
NGC 1569



NGC 5253



[O III] 88μm

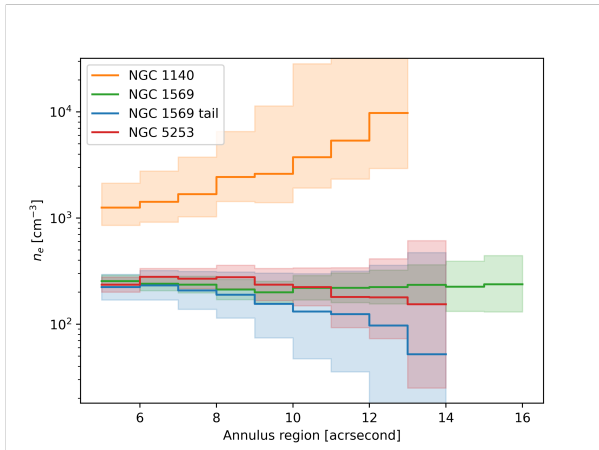


Electron density of the ionised gas in low-metallicity galaxies

Keith Doore

Ph.D. student

University of Arkansas



- NGC 1140: Increases with distance from central peak due to FIFI-LS noise
- NGC 1569: Minimal variation with distance from center
- NGC 5253: Electron density peaks outside of center of galaxy

Conclusions

- The gas traced by the [OIII] lines and the gas traced by [SIII] lines are **two different components**.
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- **Denser region in more energetic environment**
- **No correlation** between the electron density traced by [OIII] ratio and hardness of the radiation field → are we looking at two different gas components?

Thank you!

Contact: fpolles@usra.edu

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