



Mapping Oxygen in the Universe



Effects of Herbig-Haro objects and bars on the oxygen abundance in the Orion Nebula

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Collaborators:

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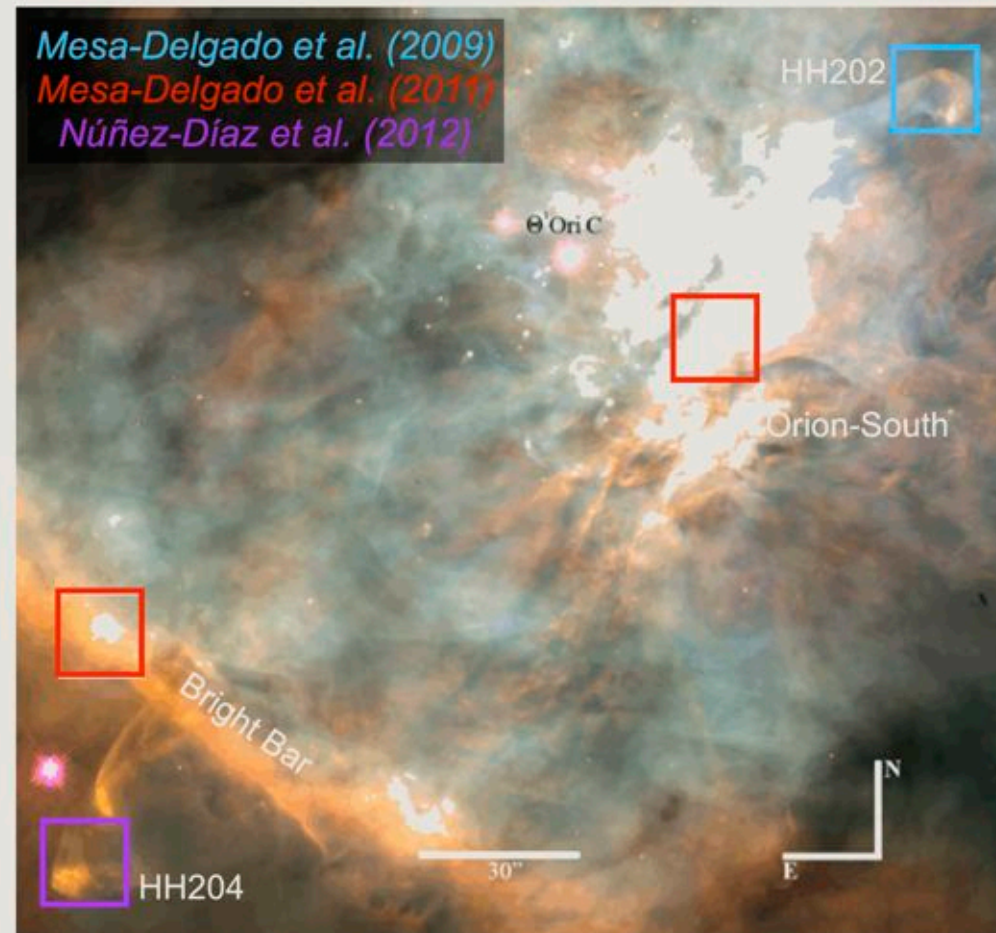
Puerto de la Cruz, 15th May 2012

Motivation

- ✿ Evidences of small-spatial scale variations (e.g. *Pogge et al. 1992; O'Dell et al. 2003; Rubin et al. 2003; Mesa-Delgado et al. 2008*).
- ✿ Related with morphological structures.
- ✿ Do they have effects on the chemical composition?
- ✿ Best candidate: the Orion Nebula.

Observations

- ✿ Potsdam Multi-Aperture Spectrograph (PMAS, *Roth et al. 2005*) at 3.5m Telescope (Calar Alto)
- ✿ FoV: 16"x16" / 1" sampling
- ✿ V600 grating
- ✿ $\Delta\lambda$: 3500-5100 and 5700-7200 Å
- ✿ Effective resolution: 3.6 Å

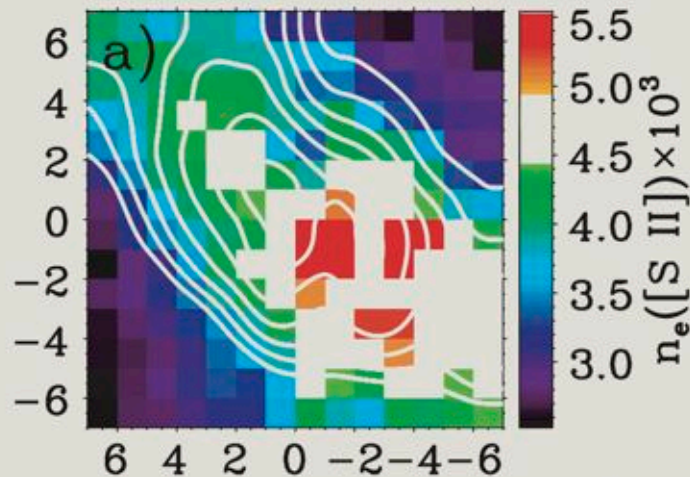


Spatial Maps

- ⚙ Emission line fluxes.
- ⚙ Extinction coefficient: $H\gamma/H\beta$ and $H\delta/H\beta$.
- ⚙ Electron density: $[SII] \lambda 6731/\lambda 6717$ line ratio
- ⚙ Electron temperatures: $[OIII] \lambda 5007/\lambda 4363$ and $[NII] \lambda 6584/\lambda 5755$ line ratios.
- ⚙ Abundances: O^+/H^+ , O^{2+}/H^+ , O/H .

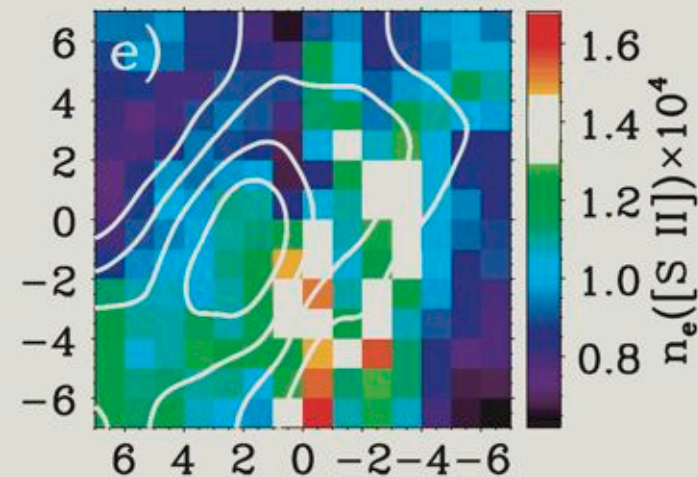
Mapping Bars

Bright Bar



Density peaks $\sim 6,000 \text{ cm}^{-3}$

Orion-S

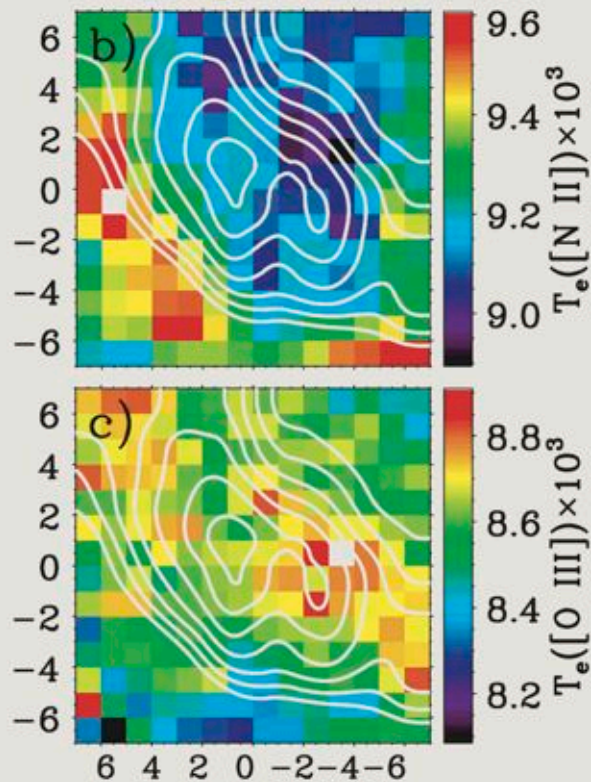


Density peaks $\sim 16,000 \text{ cm}^{-3}$

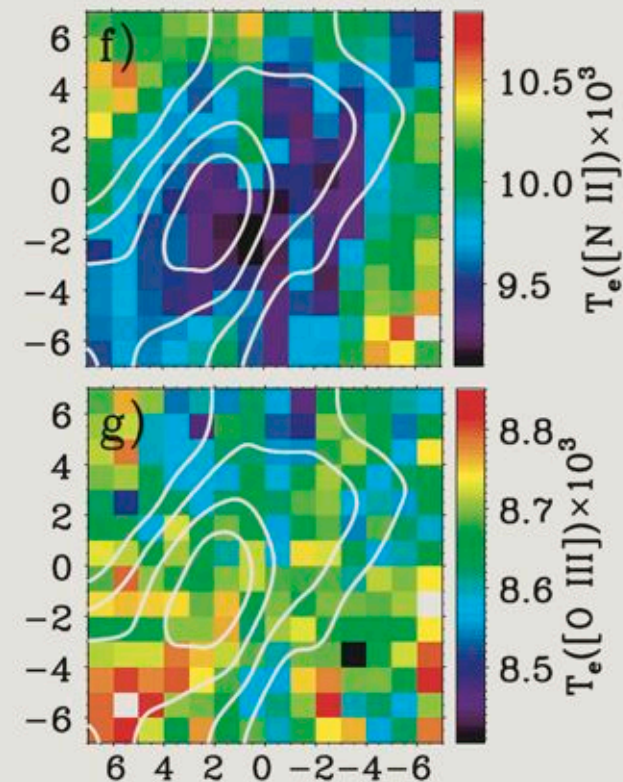
- Highest values are of about high-density limit of [SII] line ratio.
- Nominal values of density could not be correct.
- $n_e(\text{[FeIII]})$ points to similar densities, but larger uncertainties.

Mapping Bars

Bright Bar

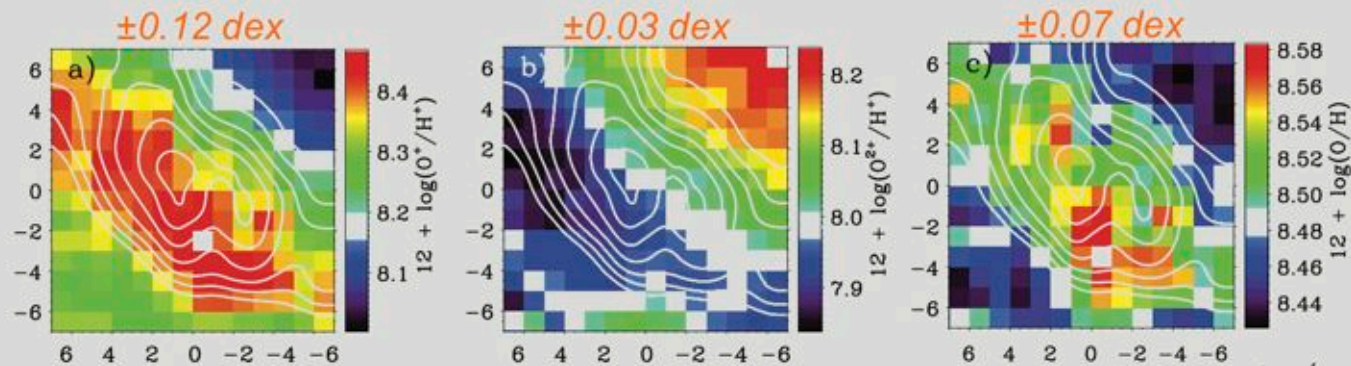


Orion-S

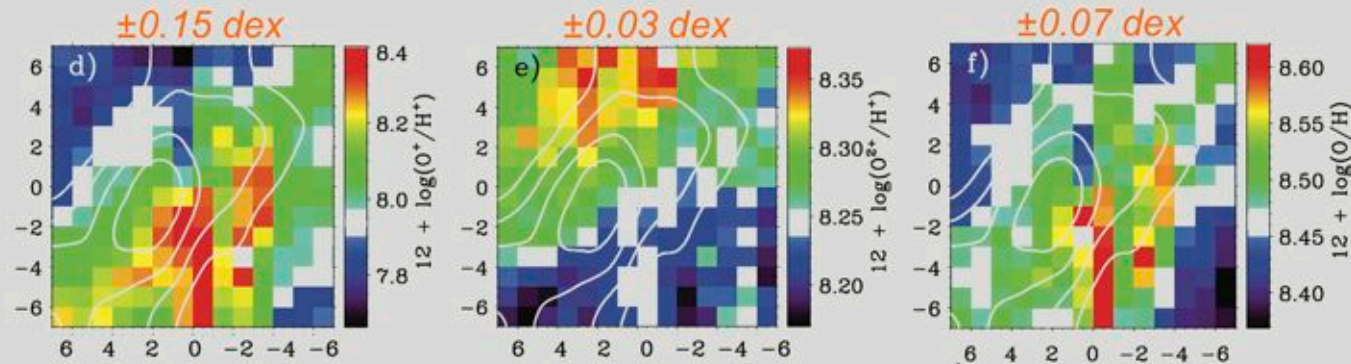


Mapping Bars

Bright Bar

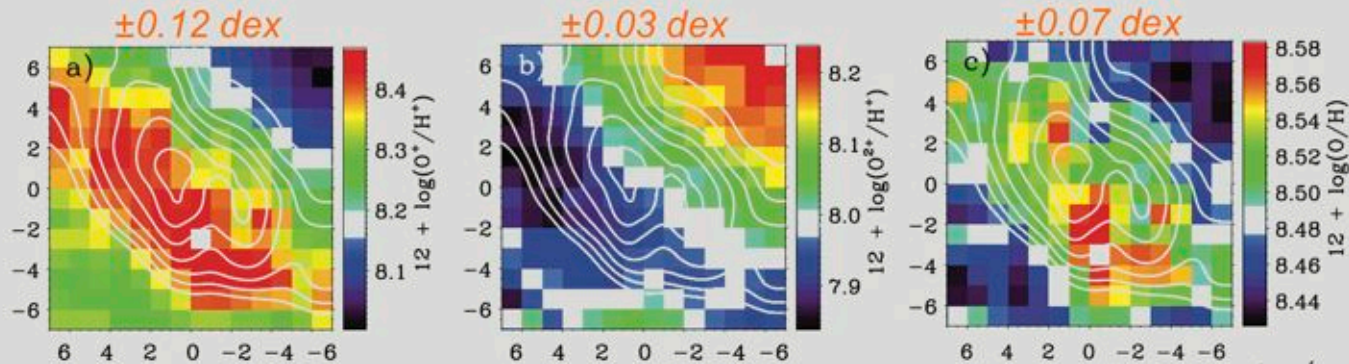


Orion-S

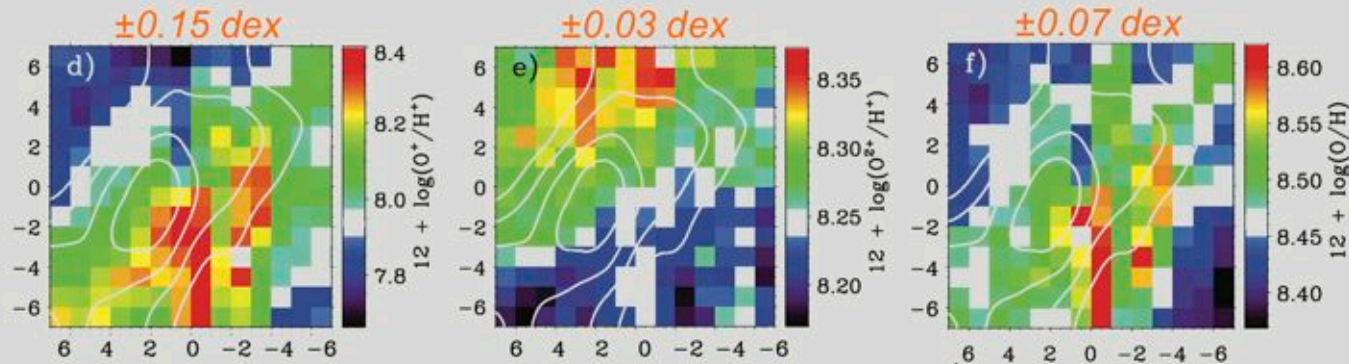


Mapping Bars

Bright Bar



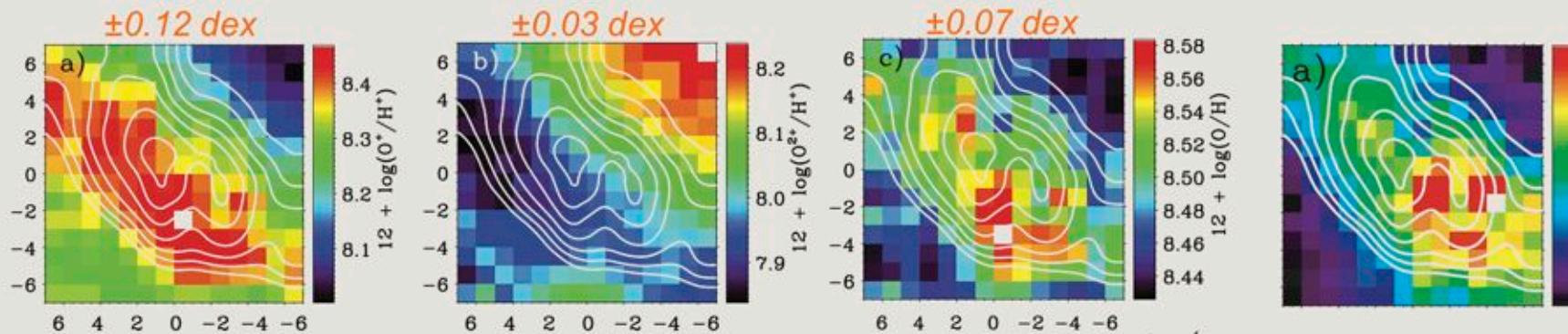
Orion-S



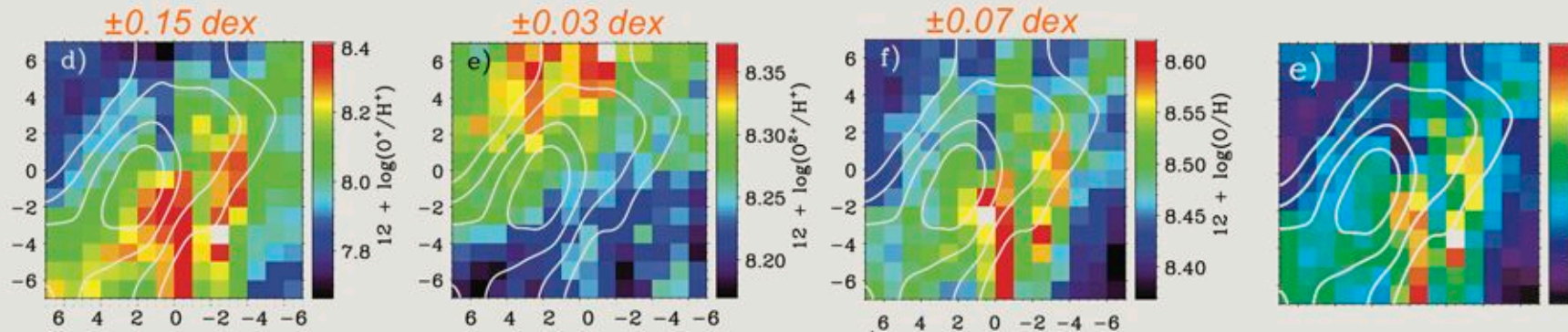
- O/H have structure.
- Average O/H:
 - Bright Bar 8.49 ± 0.03
 - Orion-S 8.48 ± 0.05
- Variations above quoted errors.
- Structure O/H $\approx \text{O}^+/\text{H}^+ \approx n_e$.

Mapping Bars

Bright Bar

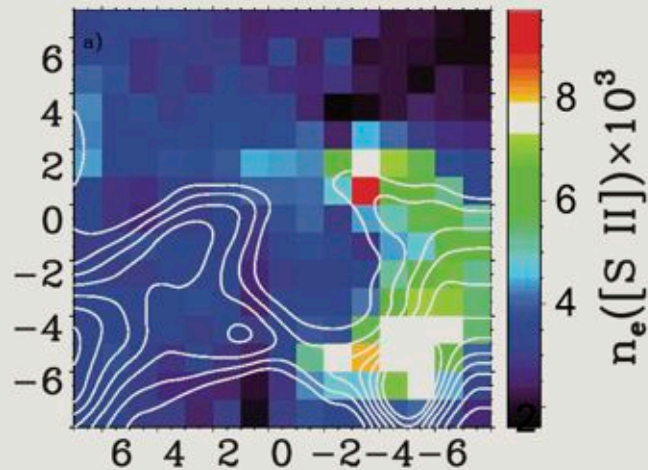


Orion-S

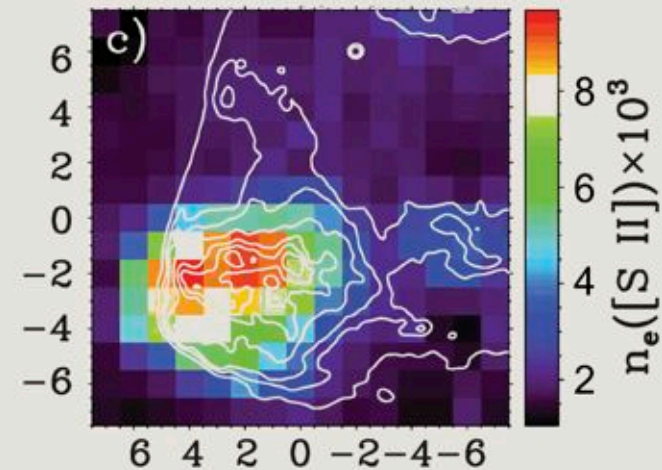


Mapping HH Objects

HH202



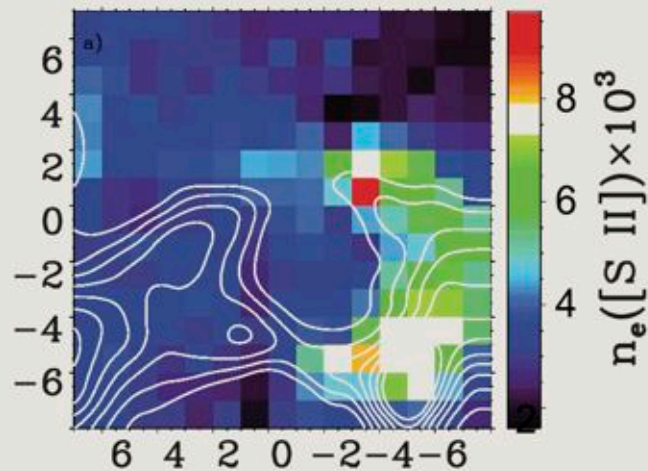
HH204



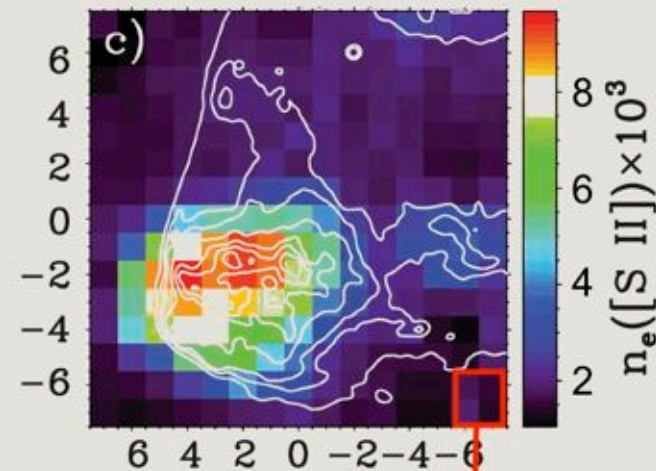
- Density peaks $\sim 9,000 \text{ cm}^{-3}$.
- Similar effects observed in the Bars.
- Are densities real?

Mapping HH Objects

HH202



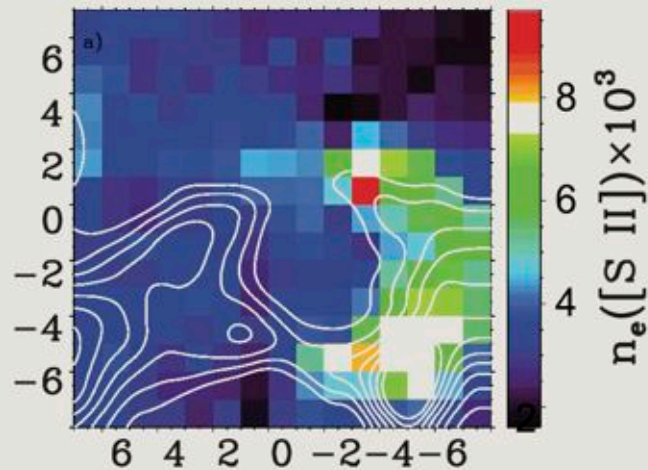
HH204



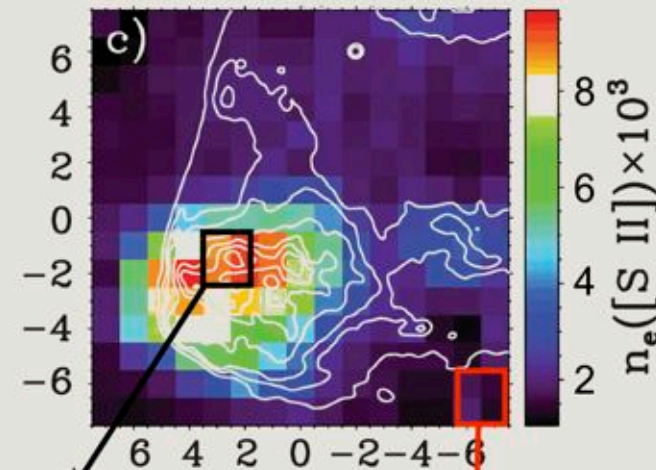
$n_e([SII]) = 1,400 \pm 300 \text{ cm}^{-3}$
 $n_e([FeIII]) = 2,800 \pm 1,900 \text{ cm}^{-3}$

Mapping HH Objects

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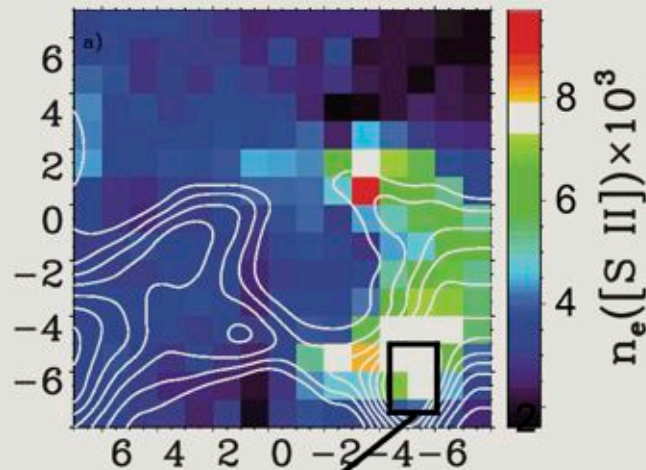


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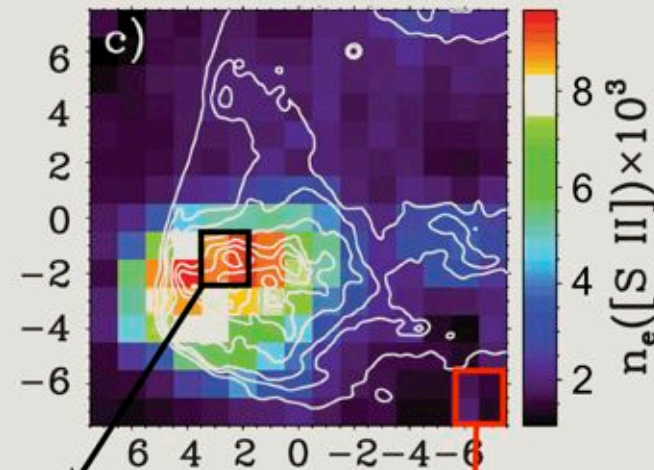
Mapping HH Objects

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High-resolution UVES spectroscopy
(Mesa-Delgado et al. 2009):
 $n_e(\text{background}) = 2,890 \pm 550 \text{ cm}^{-3}$
 $n_e(\text{gas flow}) = 17,430 \pm 2,360 \text{ cm}^{-3}$

HH204

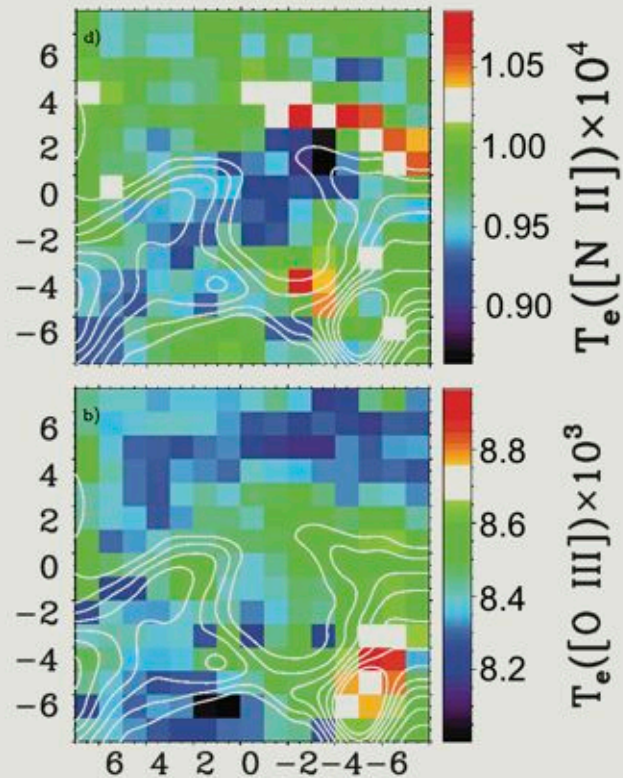


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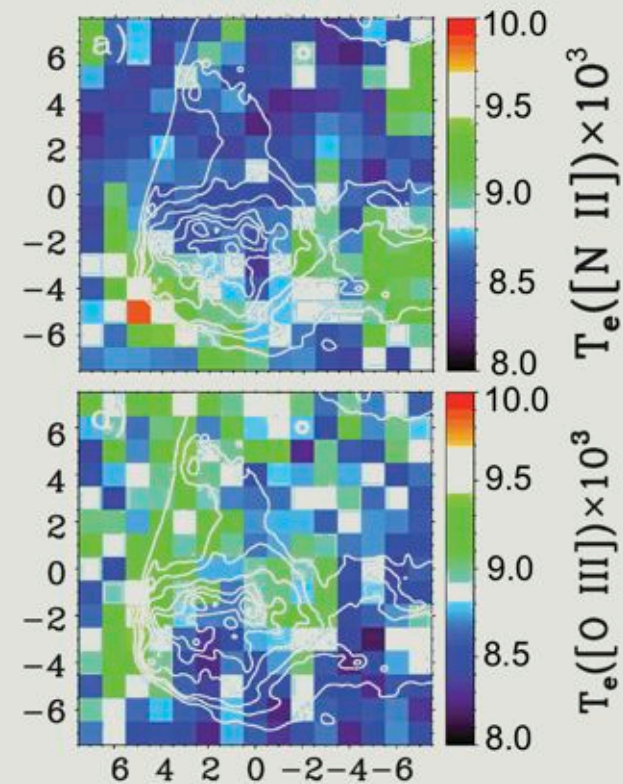
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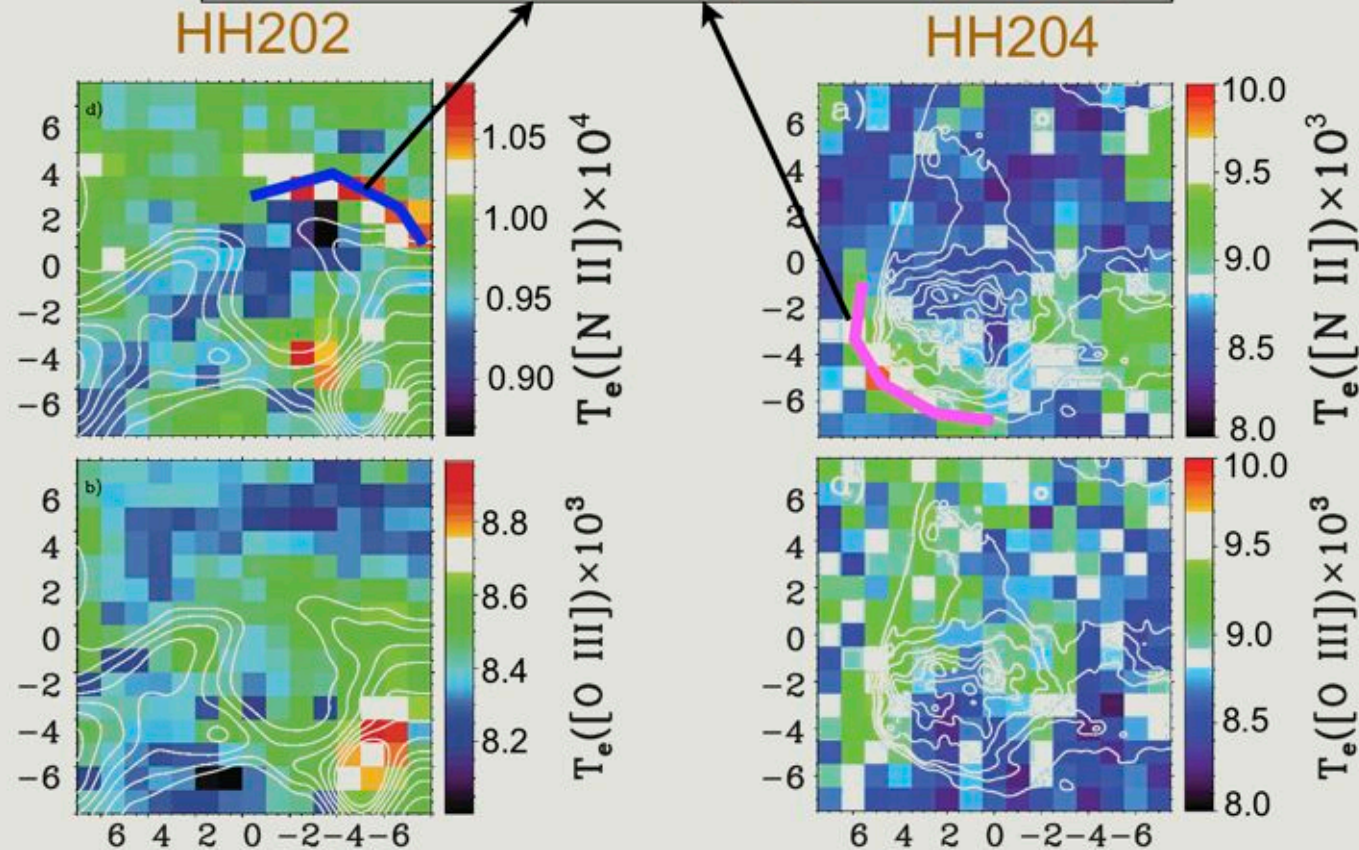


HH204



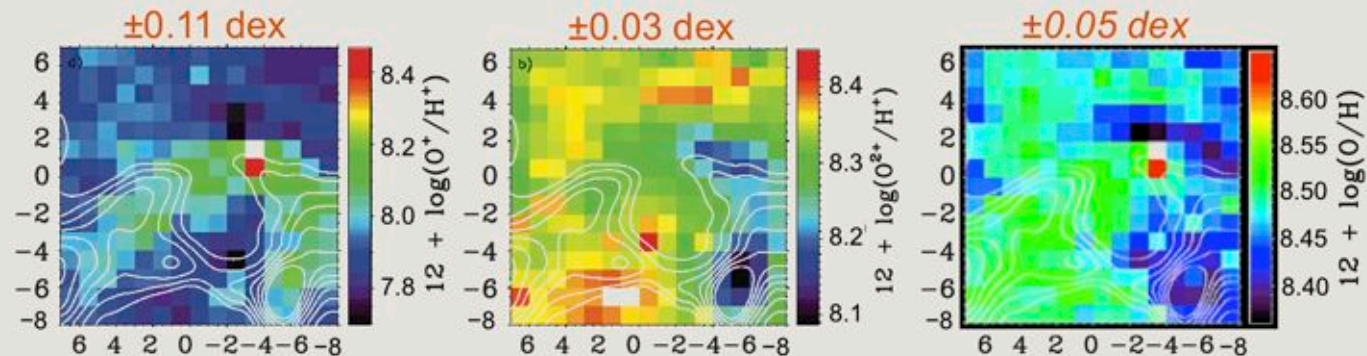
Mapping HH Objects

First time reported: high- T_e arcs predicted in photoionized HH models (*Raga & Reipurth 2004*).

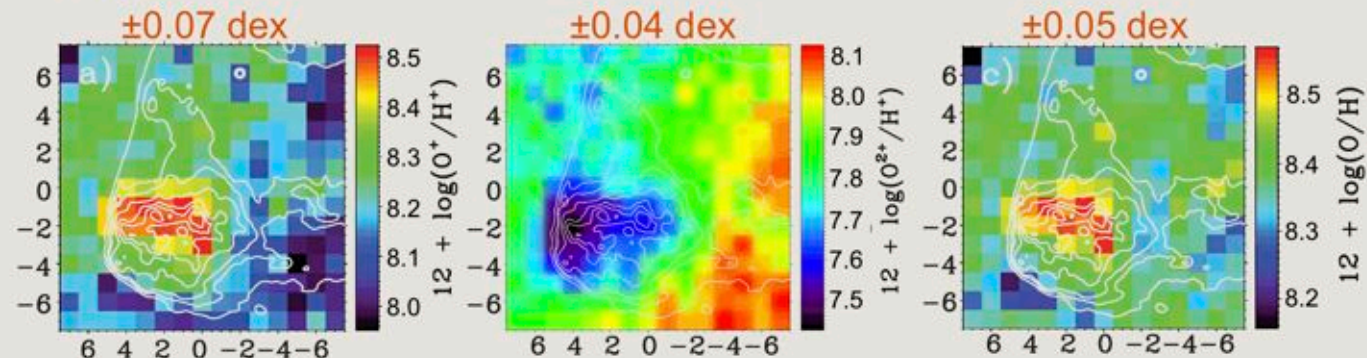


Mapping HH Objects

HH202

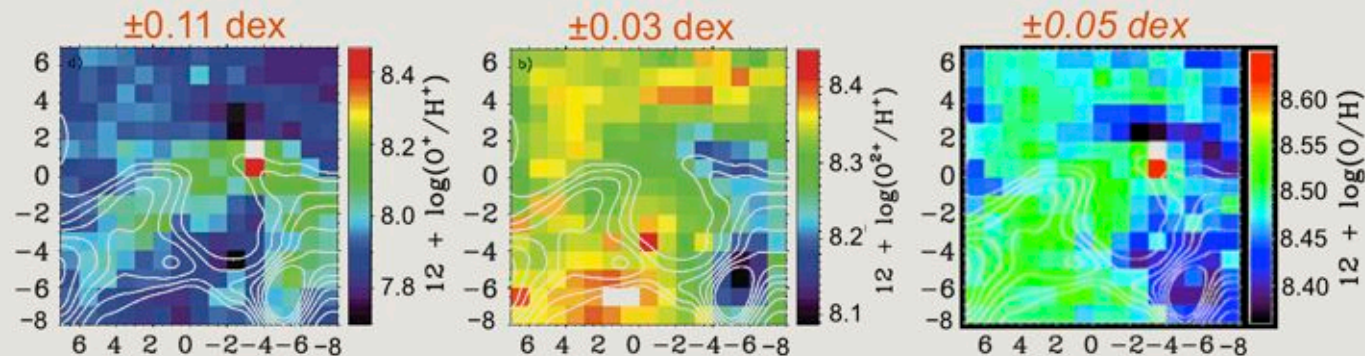


HH204

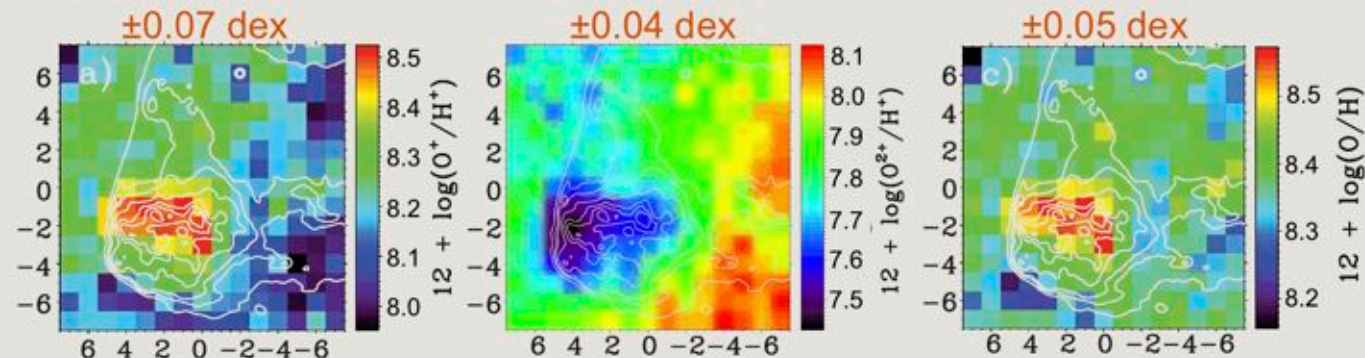


Mapping HH Objects

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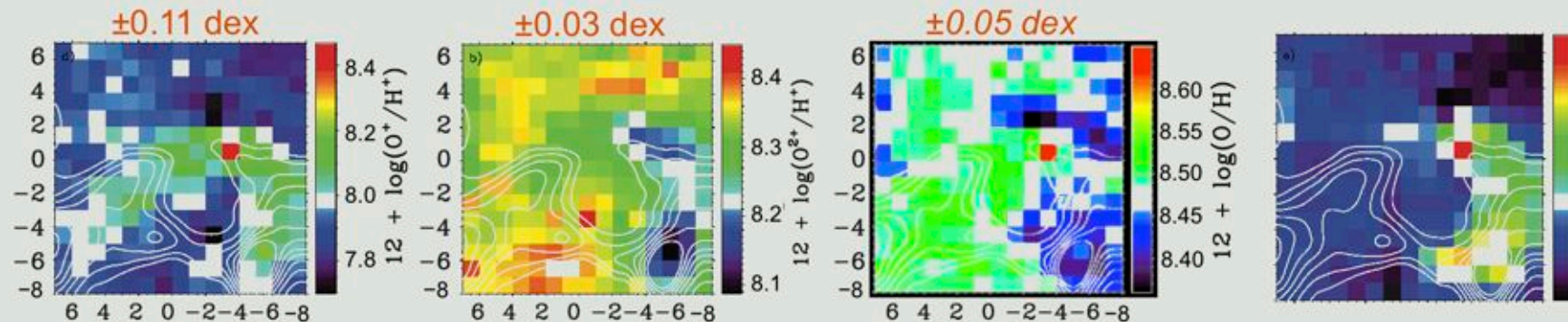
HH204



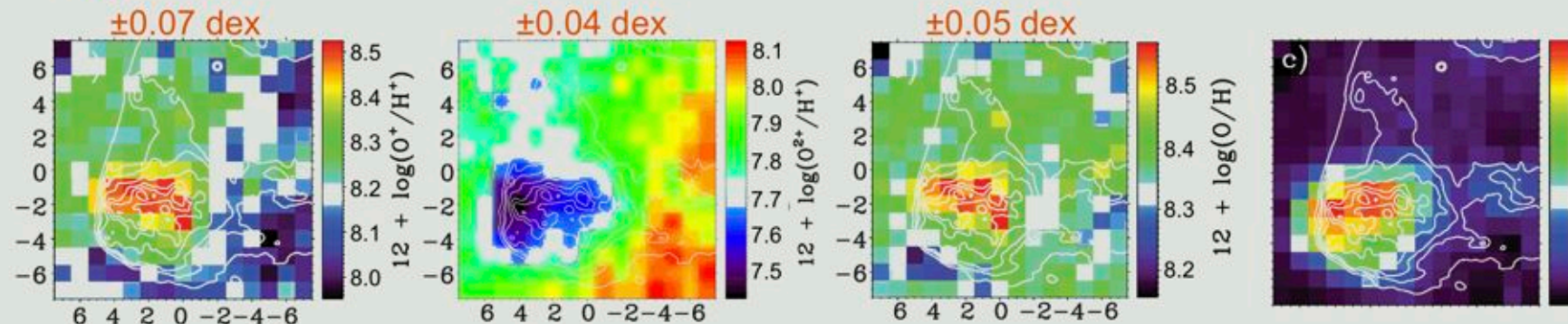
- O/H have structure.
- Average O/H:
 - HH202 8.48 ± 0.04
 - HH204 8.40 ± 0.10
- Minimum O/H at the high- T_e arcs
- Structure O/H $\approx \text{O}^+/\text{H}^+ \approx n_e$.

Mapping HH Objects

HH202

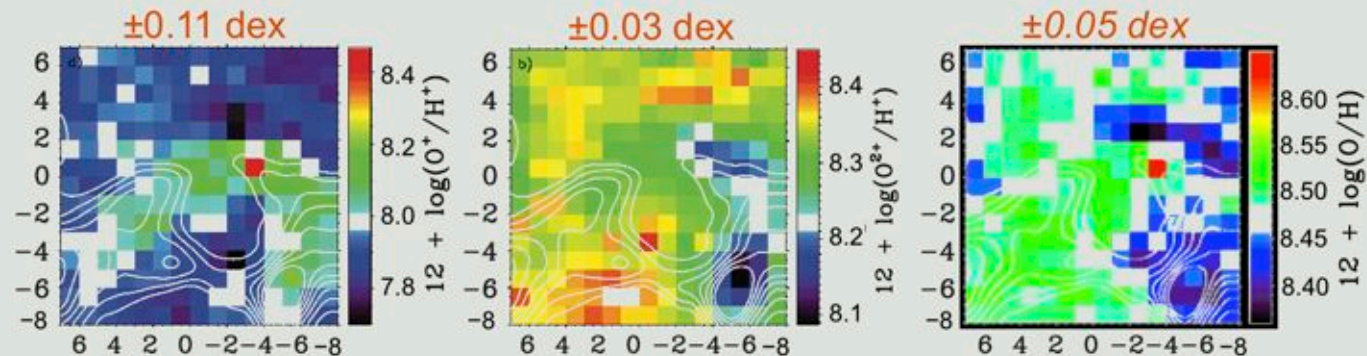


HH204



Mapping HH Objects

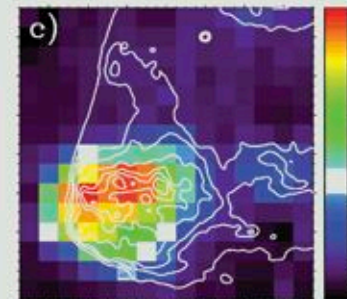
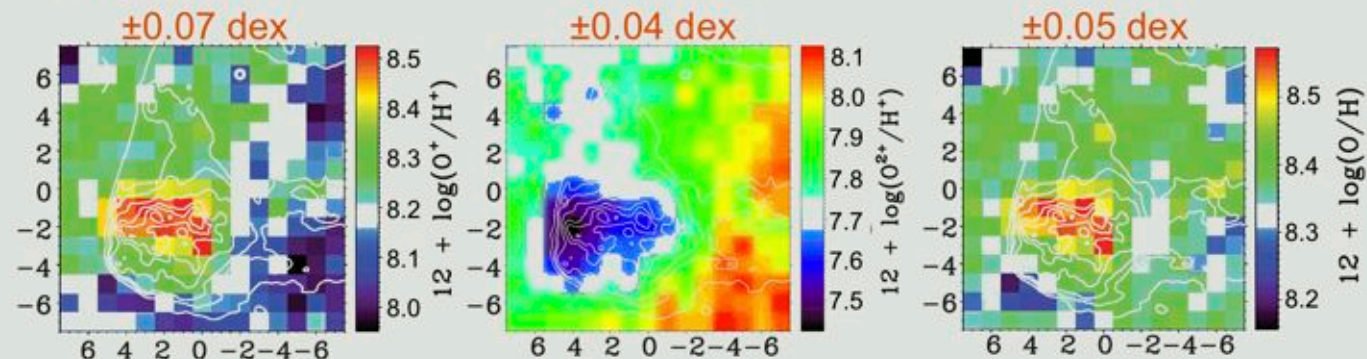
HH202



Well, not exactly! Now,
we also have effects
of high-Te arcs.



HH204



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Summary

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- ⚙ Discover of shock-heated areas at the leading working surface of photoionized HH objects.

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- ⚙ The obvious: HII regions are complex.
- ⚙ Incorrect density values are affecting determinations based on low critical density lines.
- ⚙ Discover of shock-heated areas at the leading working surface of photoionized HH objects.
- ⚙ High- T_e arcs modify the elemental oxygen abundance of Orion.

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Thanks!!!