# Spatial resolution effects on the characterisation of star forming galaxies

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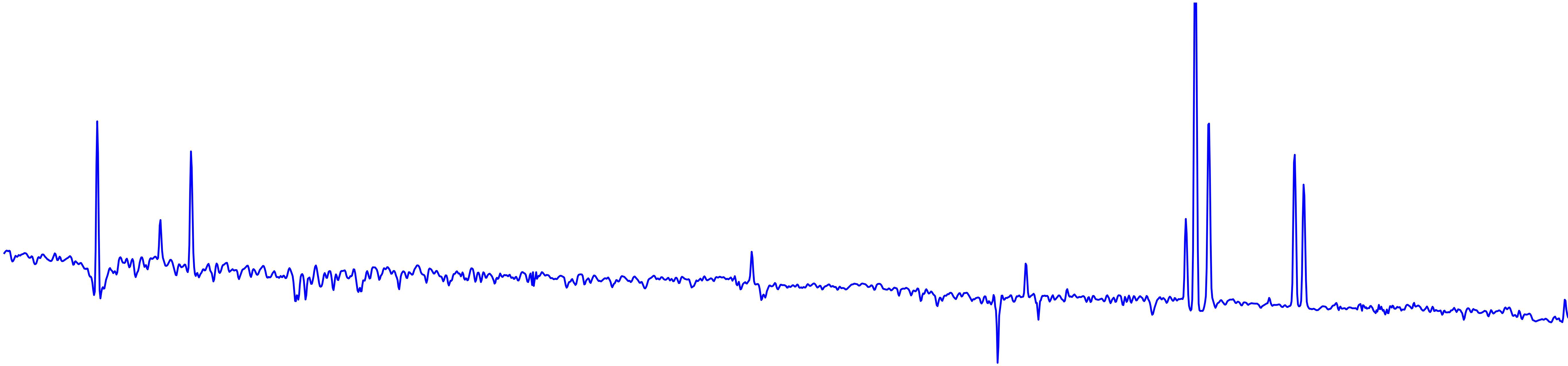

# Why Emission Line Galaxies ?

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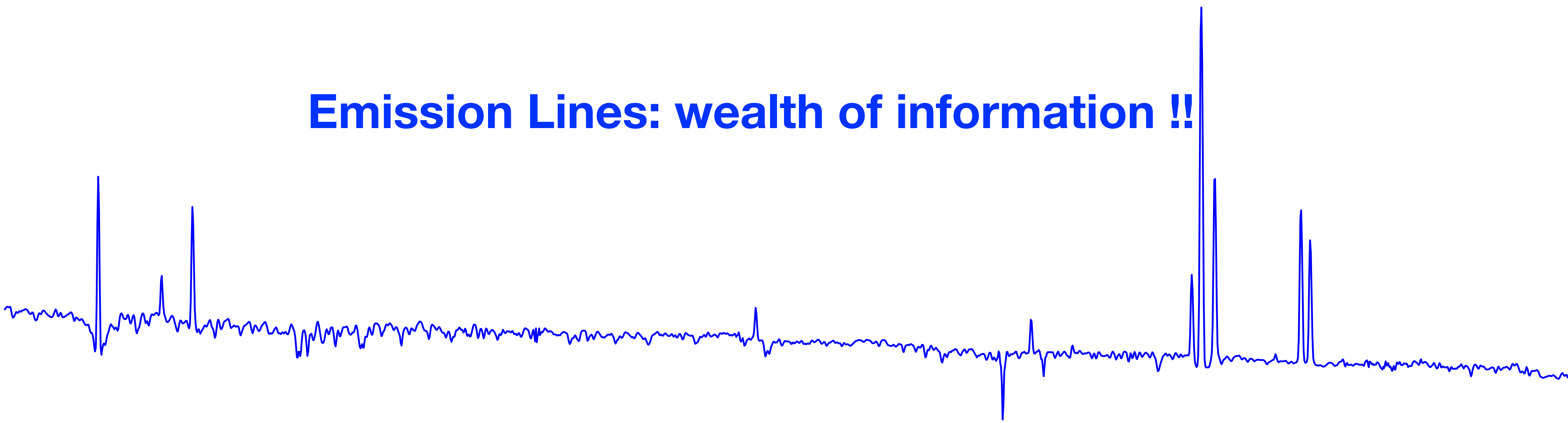
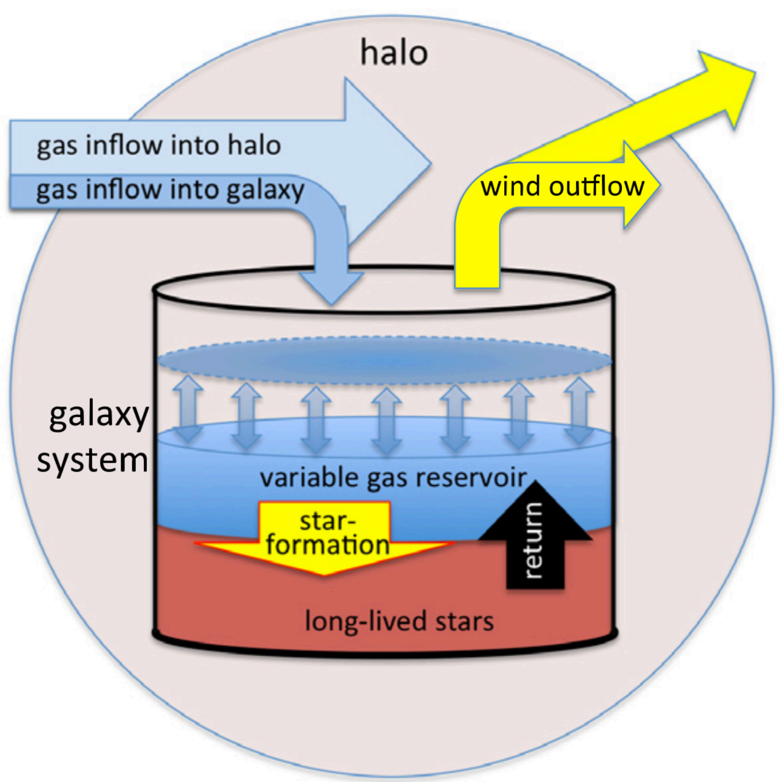


**Emission Lines: wealth of information !!**

**Interplay between chemical abundance, gas kinematics & star-formation**

**Bathtub Model**
Lilly 2013




**Galaxy Formation & Evolution**

# Why Emission Line Galaxies ?

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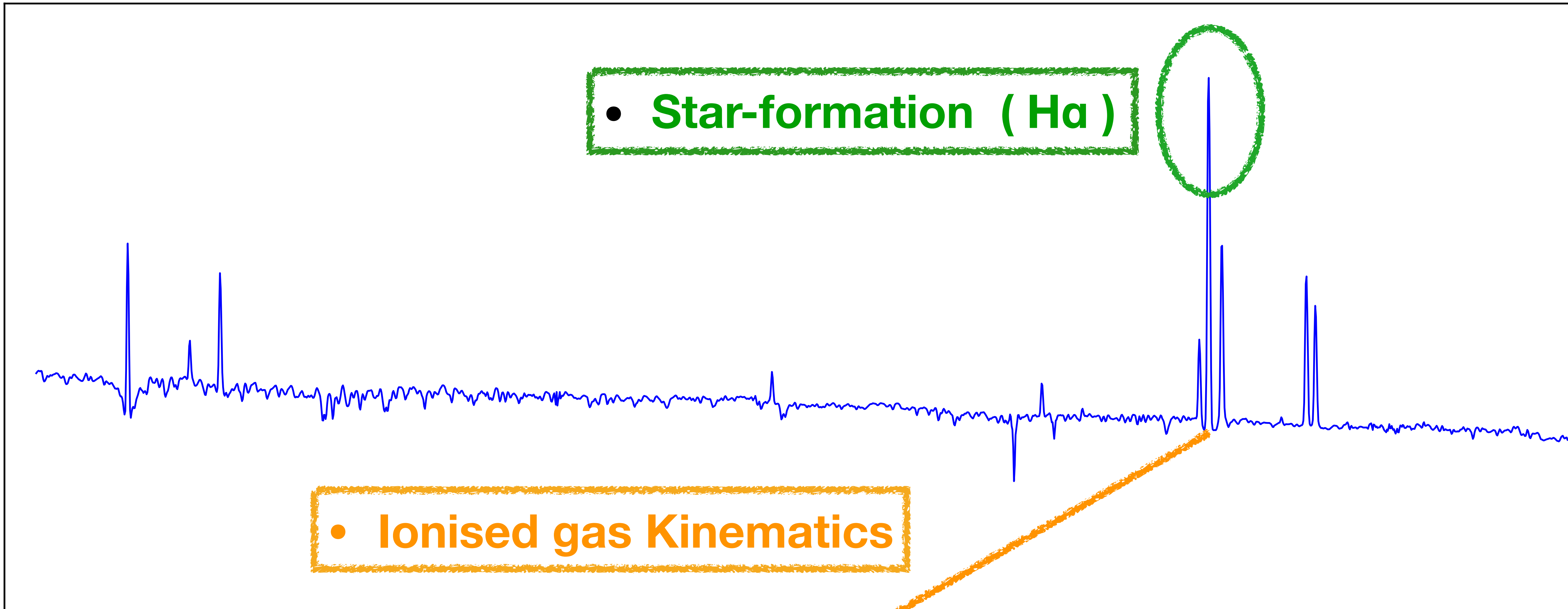


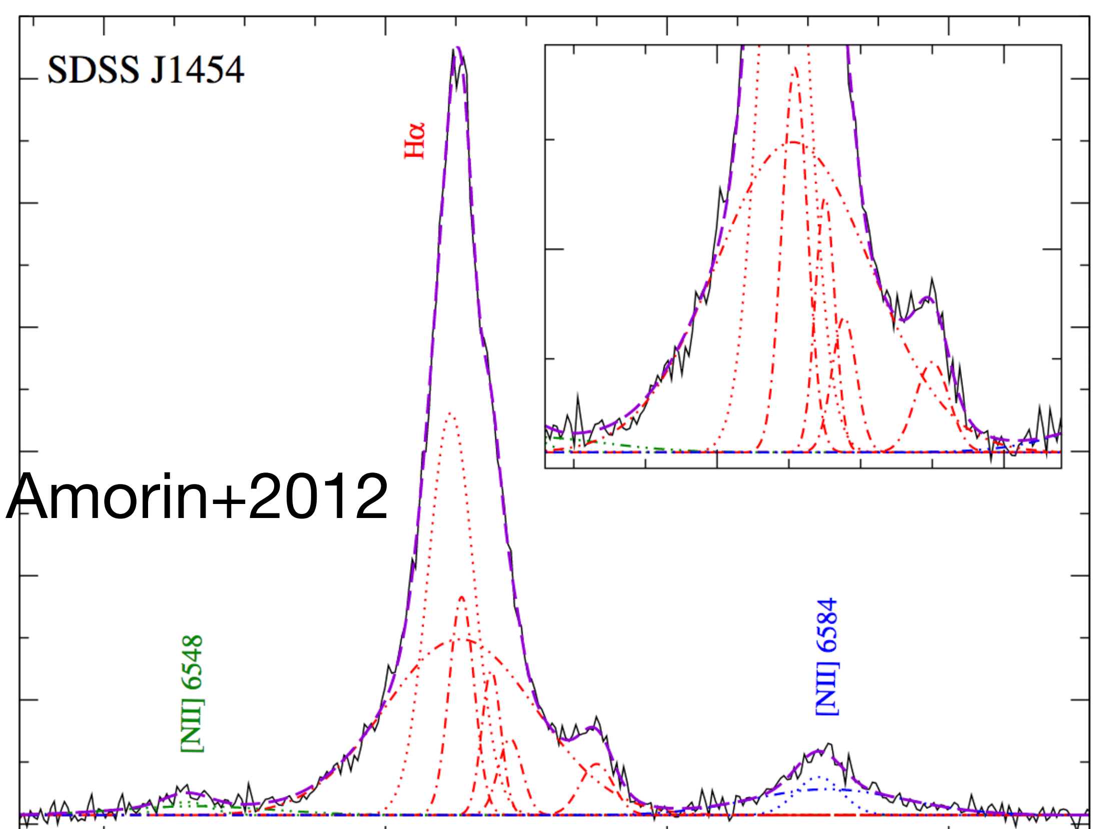


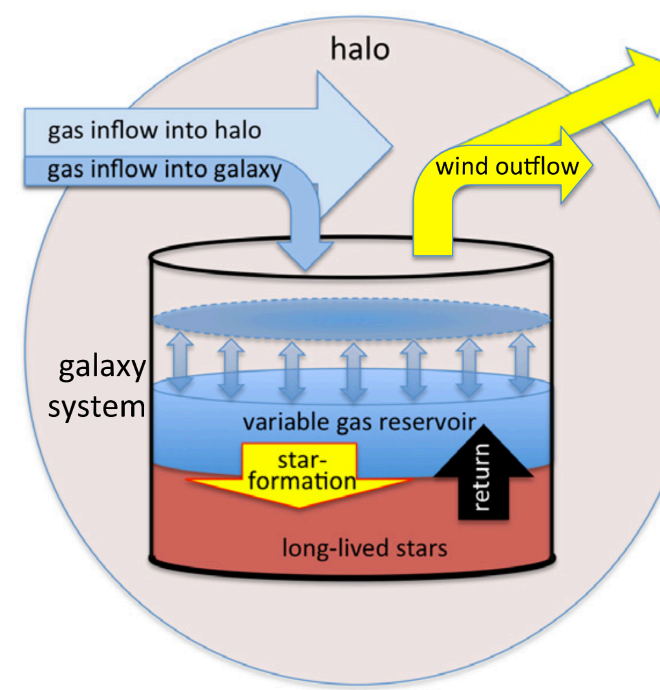

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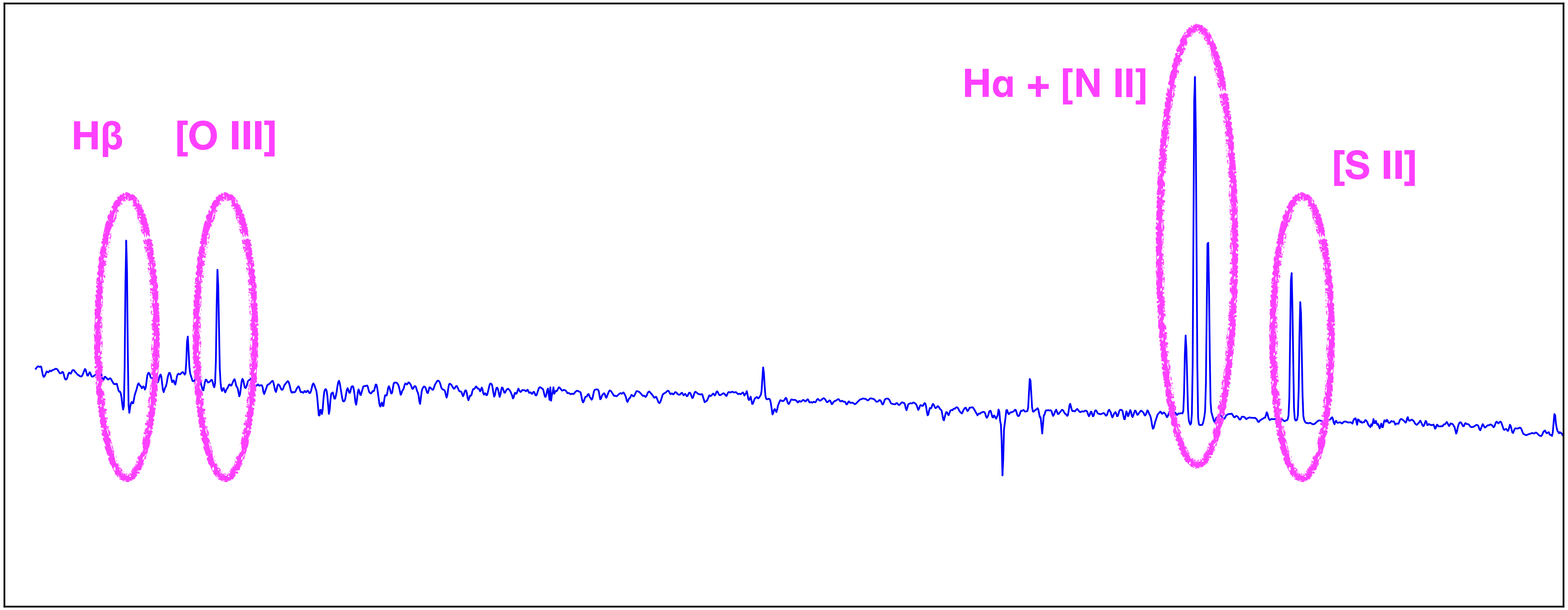
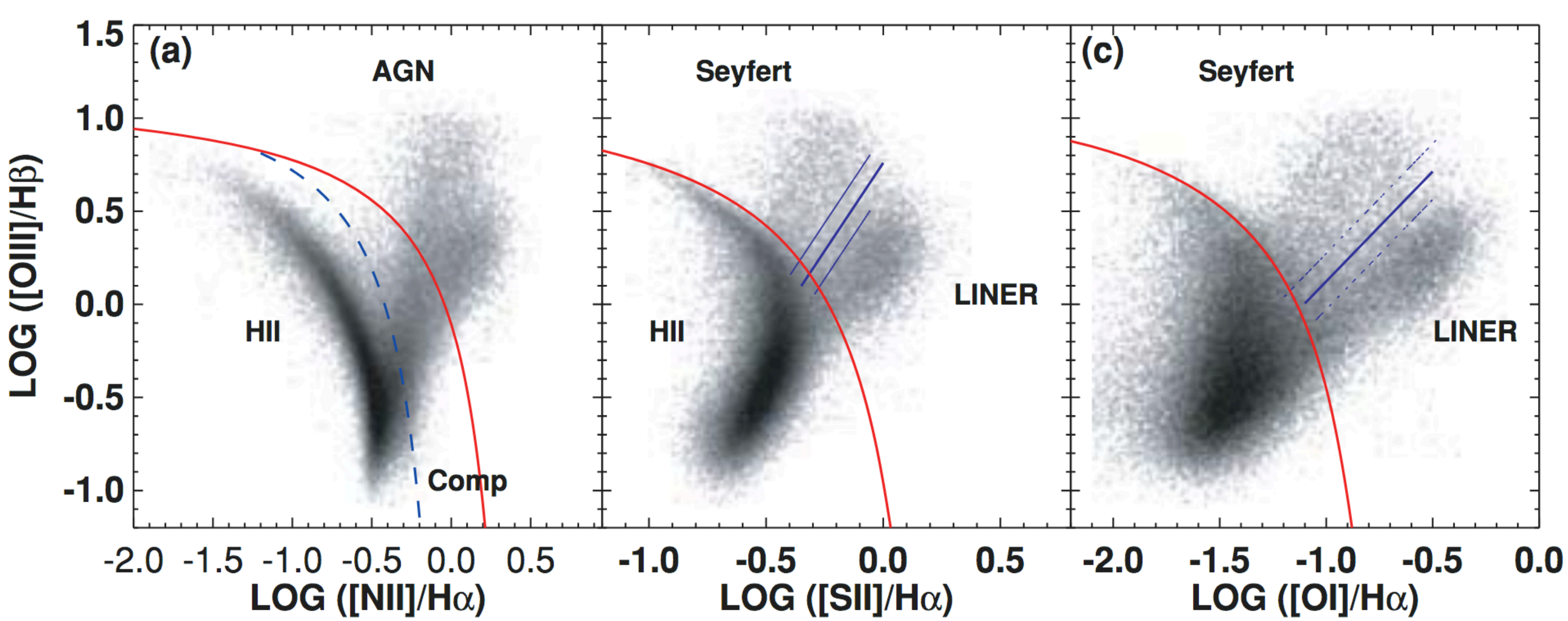
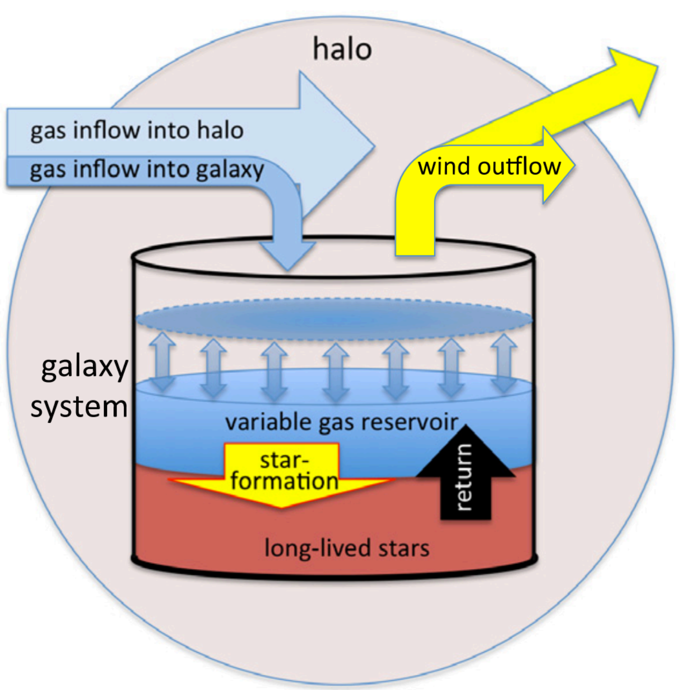
# Why Emission Line Galaxies ?




- **Ionisation Mechanism**

**Kewley+2006**



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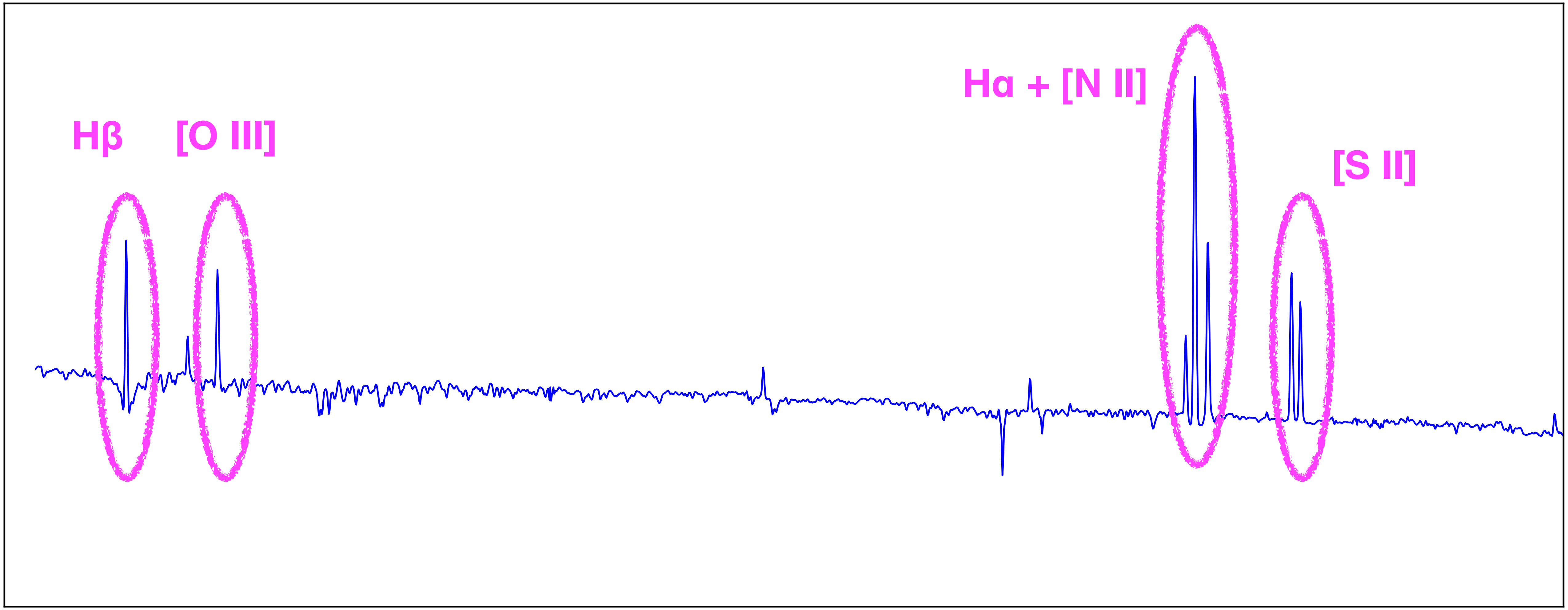
# Why Emission Line Galaxies ?

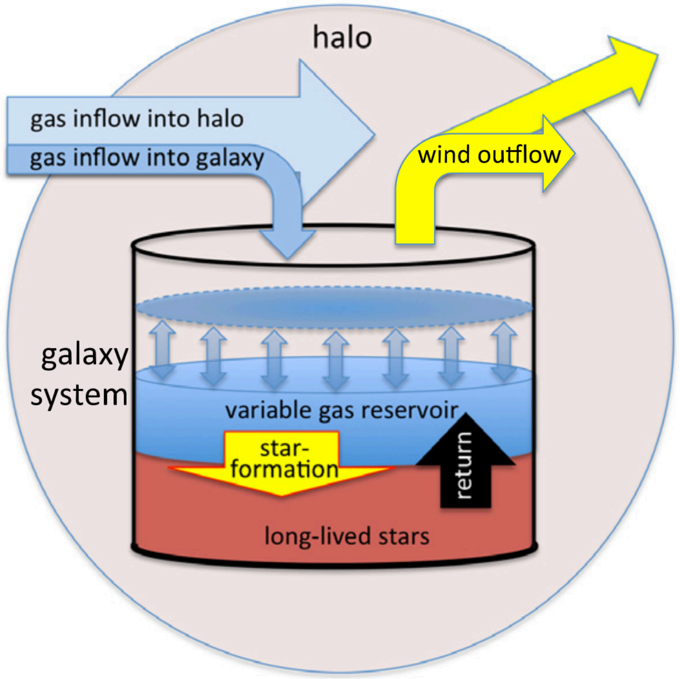



- Gas-phase metallicity

1. Direct method (Te)
2. Indirect-Strong lines method

O3N2: Pettini+2004
N2: Pettini+2004
N2S2: Dopita+2016
R23: McGaugh+1991

…many more



# Why Emission Line Galaxies ?

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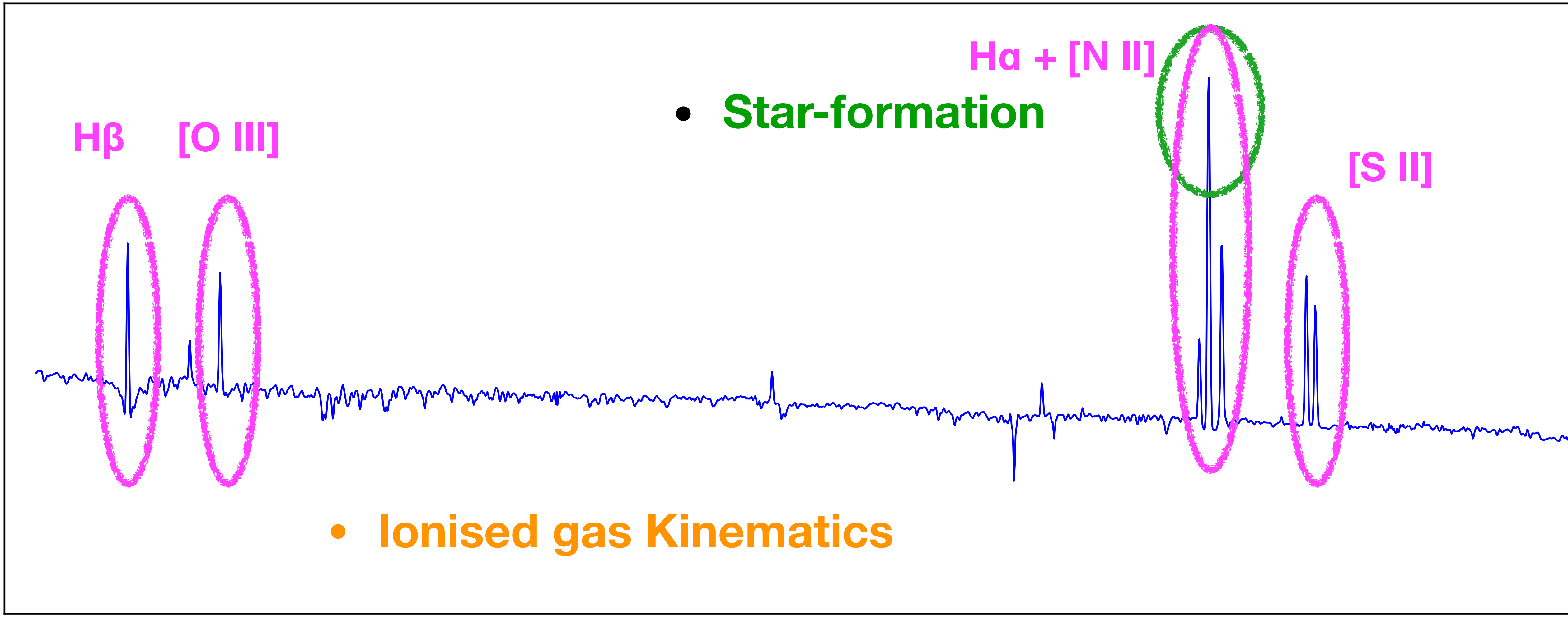
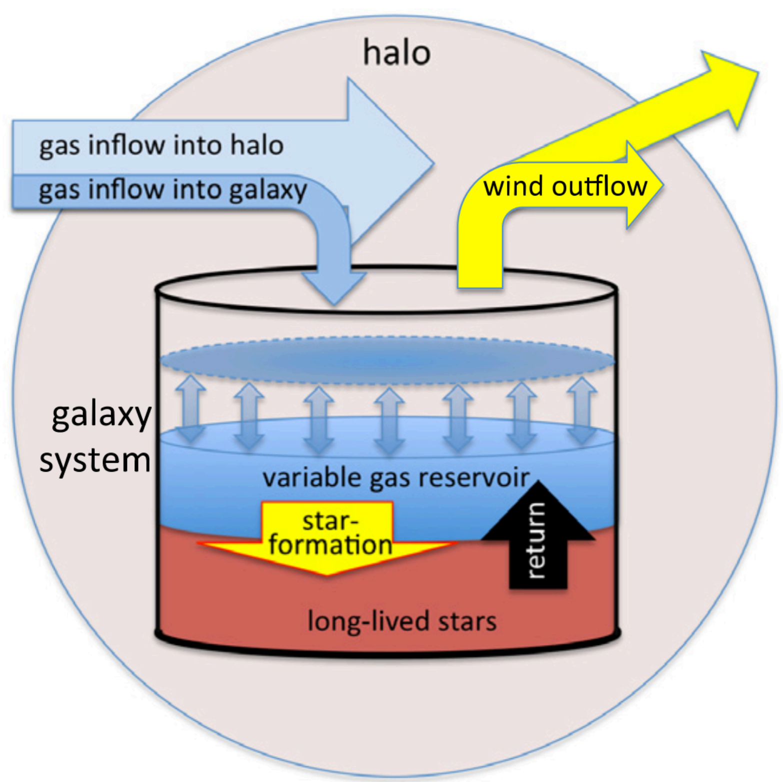



- Ionisation Mechanism
- Gas-phase metallicity




**Galaxy Formation & Evolution**

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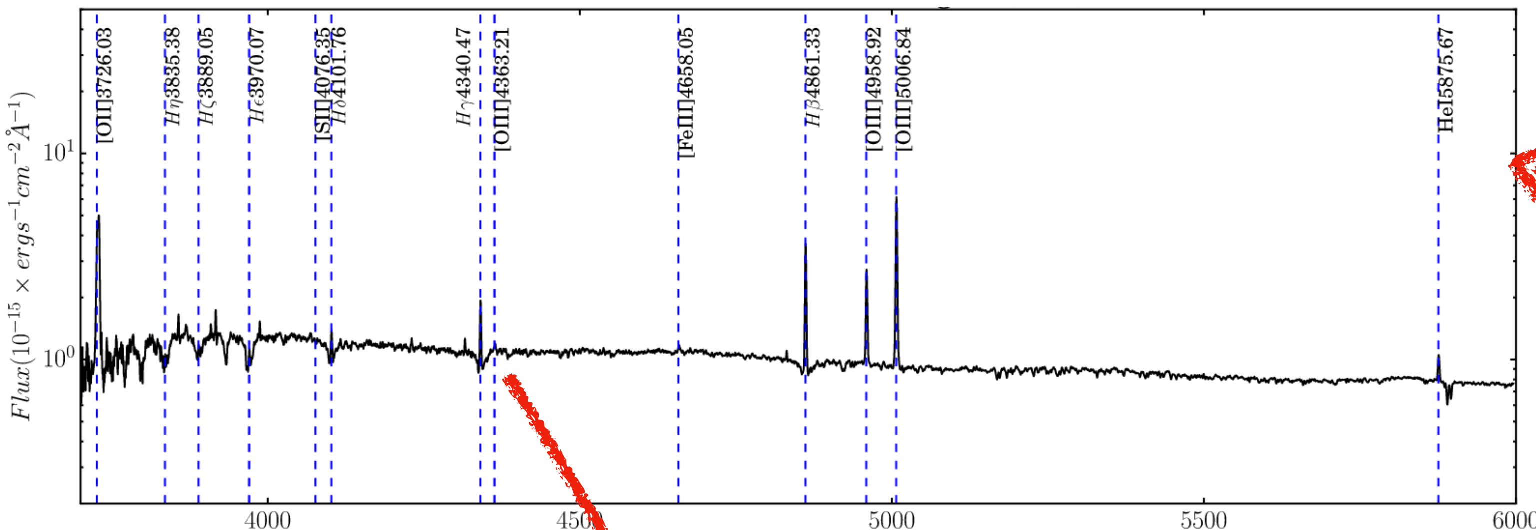
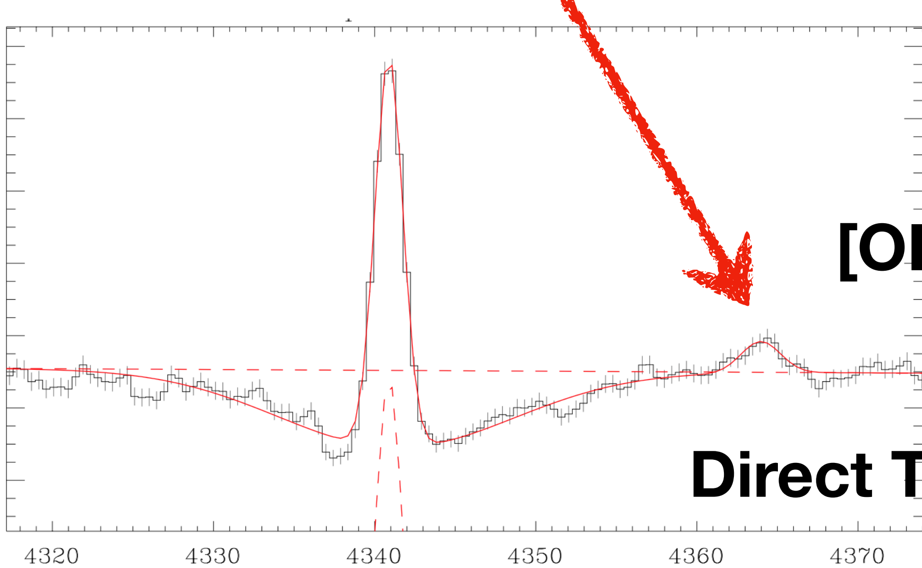
# My questions?
# -> Reliability of metallicity diagnostics

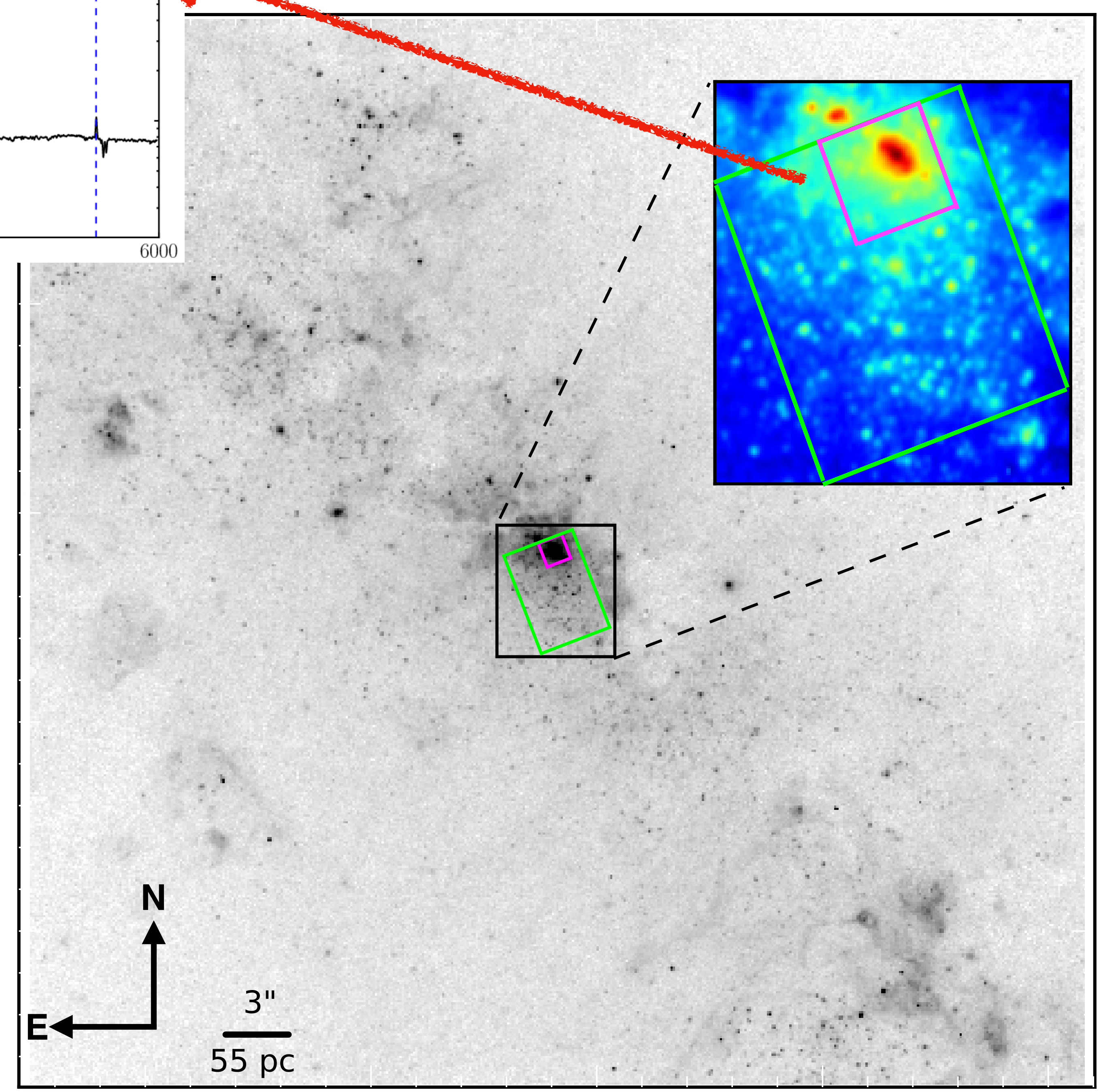



**Example of test case**
**Blue Compact Dwarf: NGC 4449**
**GMOS-N IFU**




**[OIII] 4363**

**Direct Te method**




**Kumari+2017**
**MNRAS.470.4618K**

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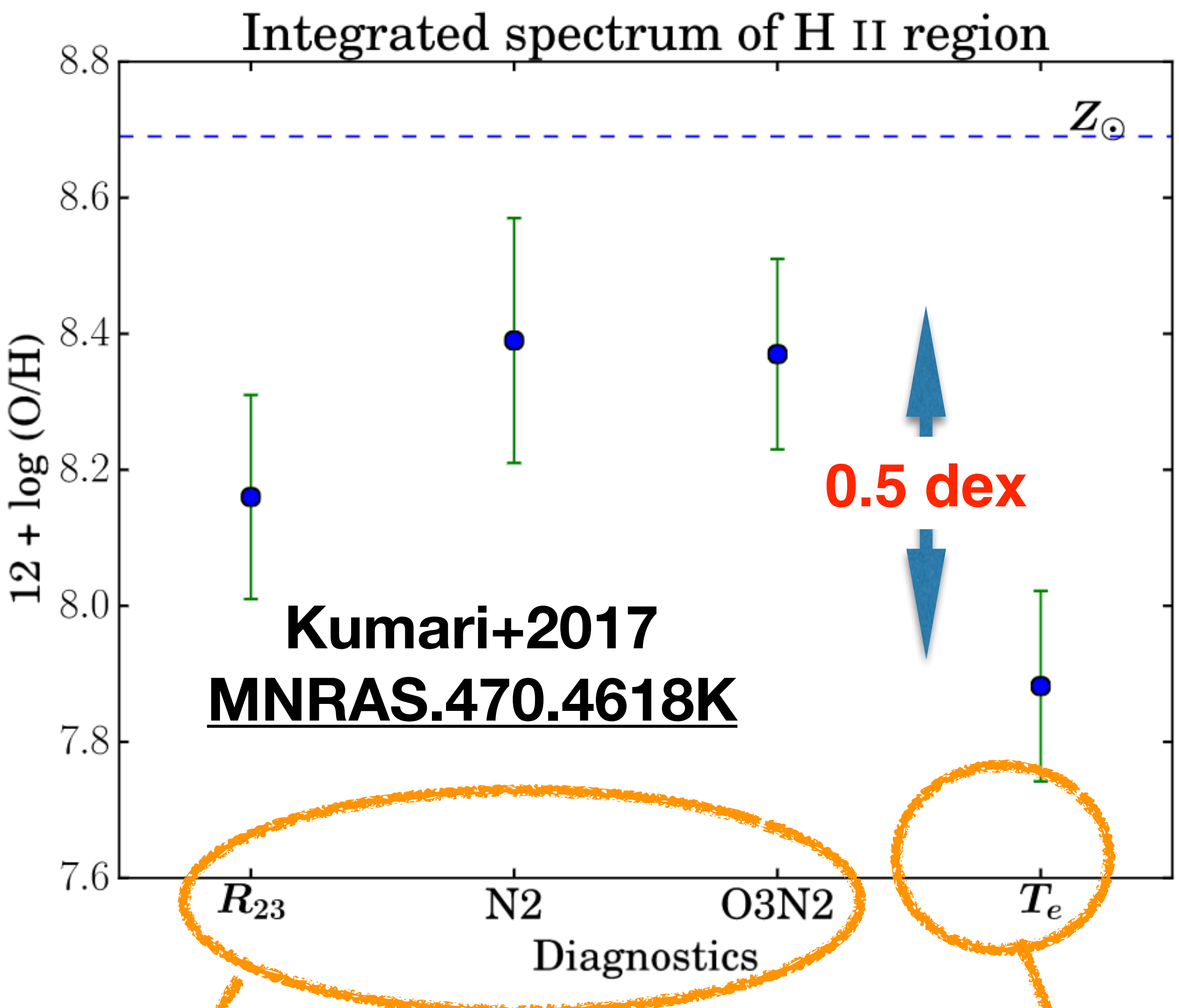
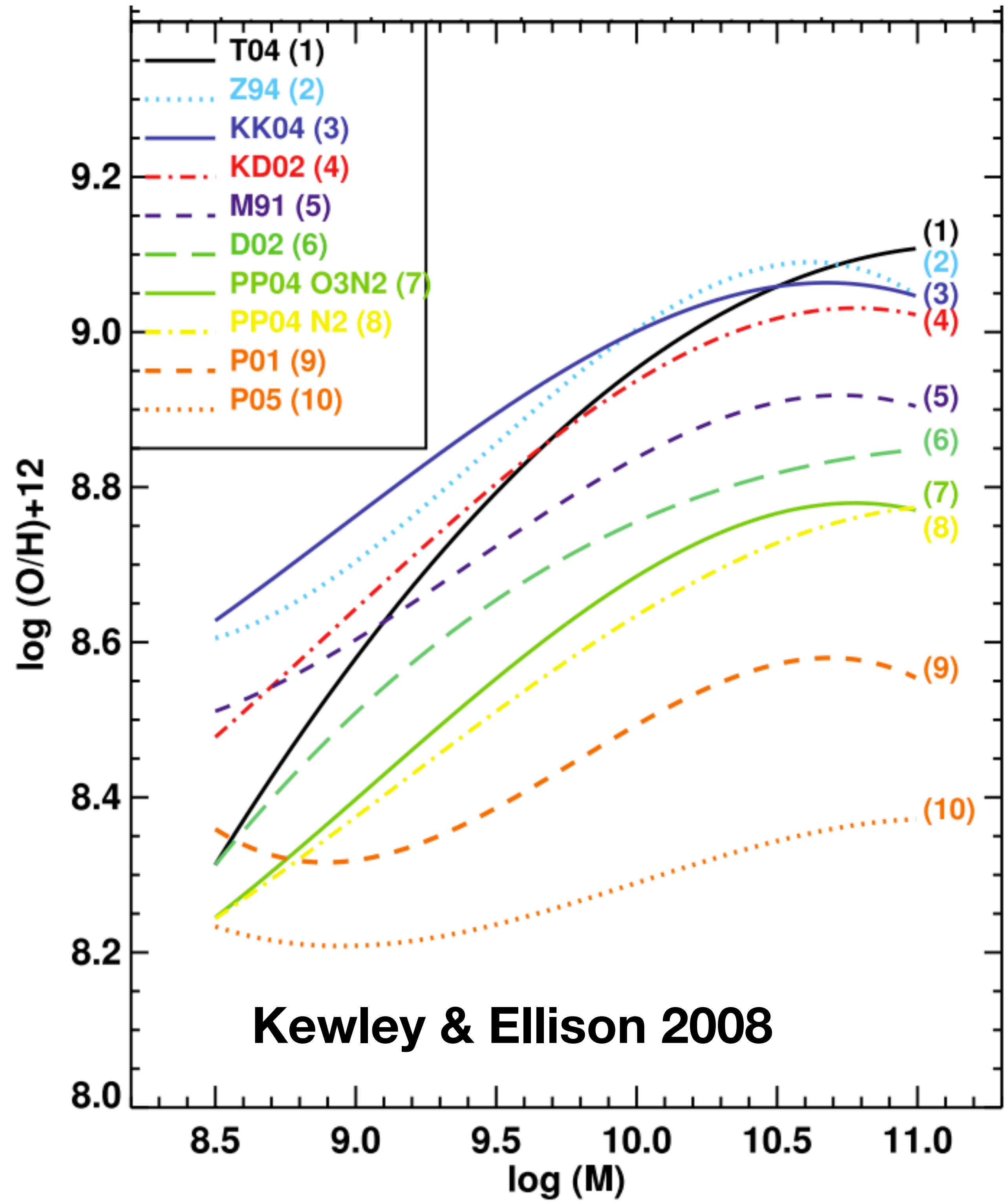
# My questions ?

BCD: NGC 4449




Kumari+2017
MNRAS.470.4618K

## 1. Which of the indirect metallicity calibration is/are correct?




Kewley & Ellison 2008

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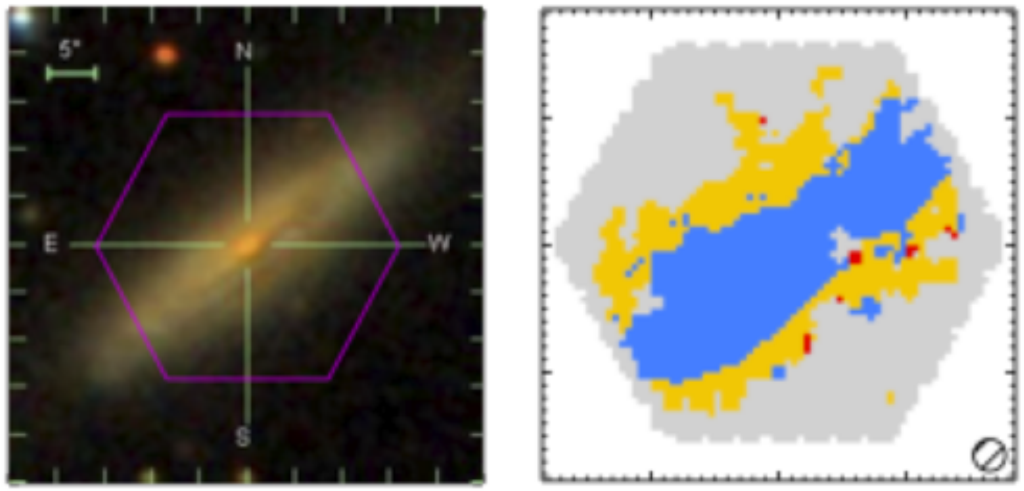
# My questions?
# -> Reliability of metallicity diagnostics

1. Which of the indirect metallicity calibration is/are correct?

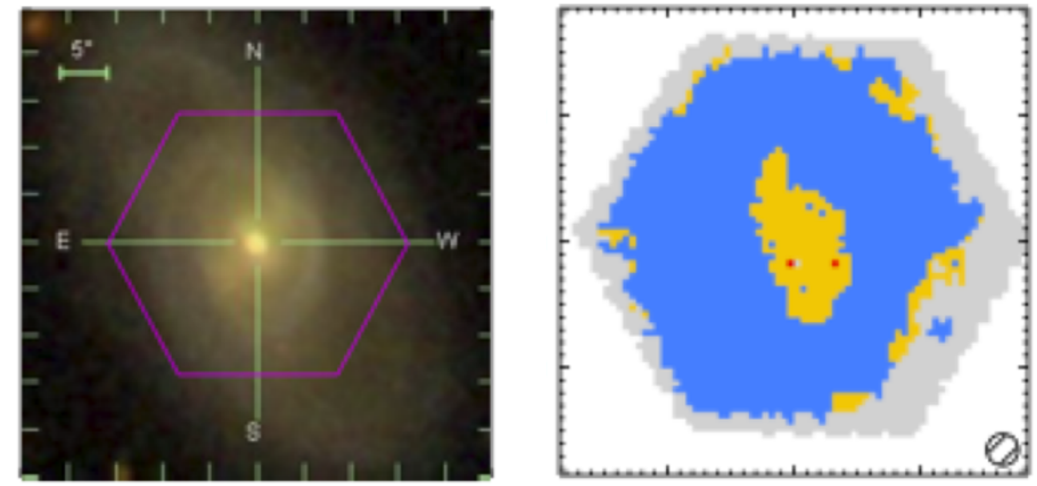
**Metallicity Diagnostics : calibrated on HII/SF regions**

2. Which of these metallicity diagnostics can reliably measure the metallicity of regions contaminated by Diffuse Ionised Gas (DIG)?

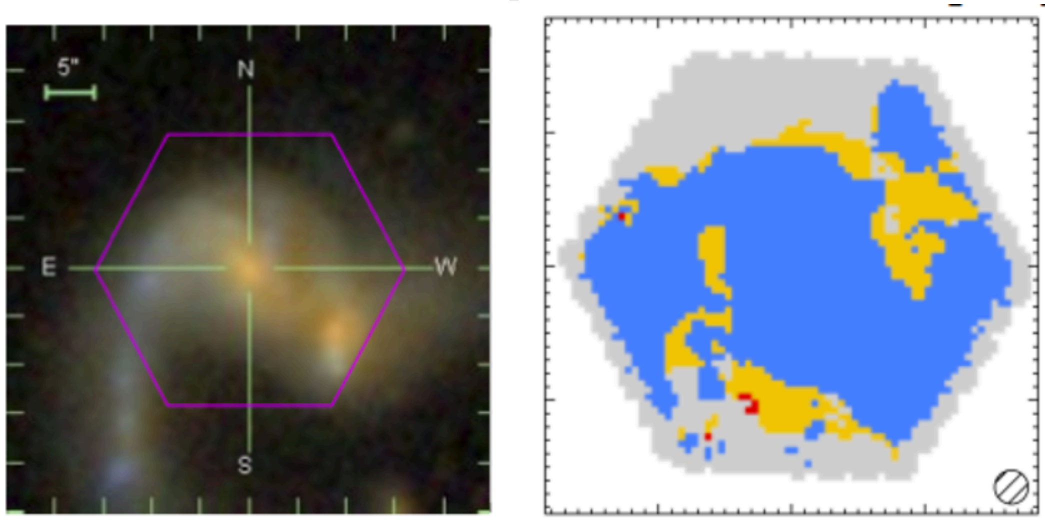
# DIG in MW
# & external galaxies



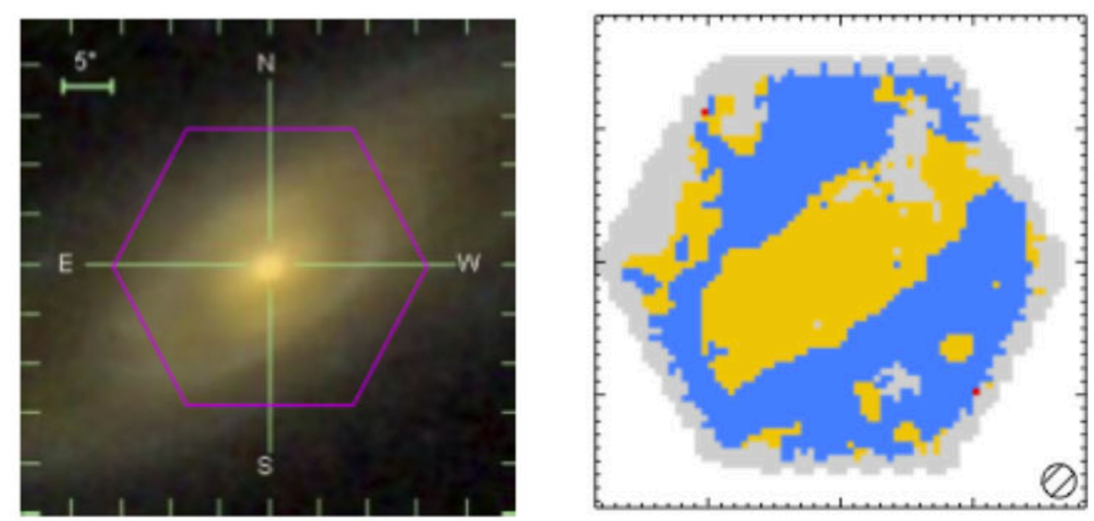

extraplanar




central




merger




larger central

Belfiore+2016 (from MANGA survey)

<u>Several works on DIG:</u>

Reynolds 1990, 1991, Walterbos & Braun 1994, Greenawalt 1998, Madsen 2006, Oey2007, Stasinska 2008, Blanc 2009, Kaplan 2016, Belfiore 2016a, b, Zhang 2017, Sanders 2017 etc.

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# Diffuse Ionised Gas

**Why is everybody interested?**

Line ratios (DIG) and excitation different than in HII regions

→ Affects metallicity diagnostics

→ **Impact on:**
Metallicity Scaling relations

- M Z relation
- M-Z-SFR relation
- Metallicity gradients

(… and also affects the determination of Star Formation Rates)

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# Diffuse Ionised Gas

**This is a major problem at high-z where integrated spectra or poor angular resolution mix-up DIG with HII regions !!**

**Line ratios (DIG) and excitation different than HII regions**

→ **Affects metallicity diagnostics**

→ **<u>Impact on:</u>**
**Metallicity Scaling relations**

- **M Z relation**
- **M-Z-SFR relation**
- **Metallicity gradients**

**(… and also affects the determination of Star Formation Rates)**

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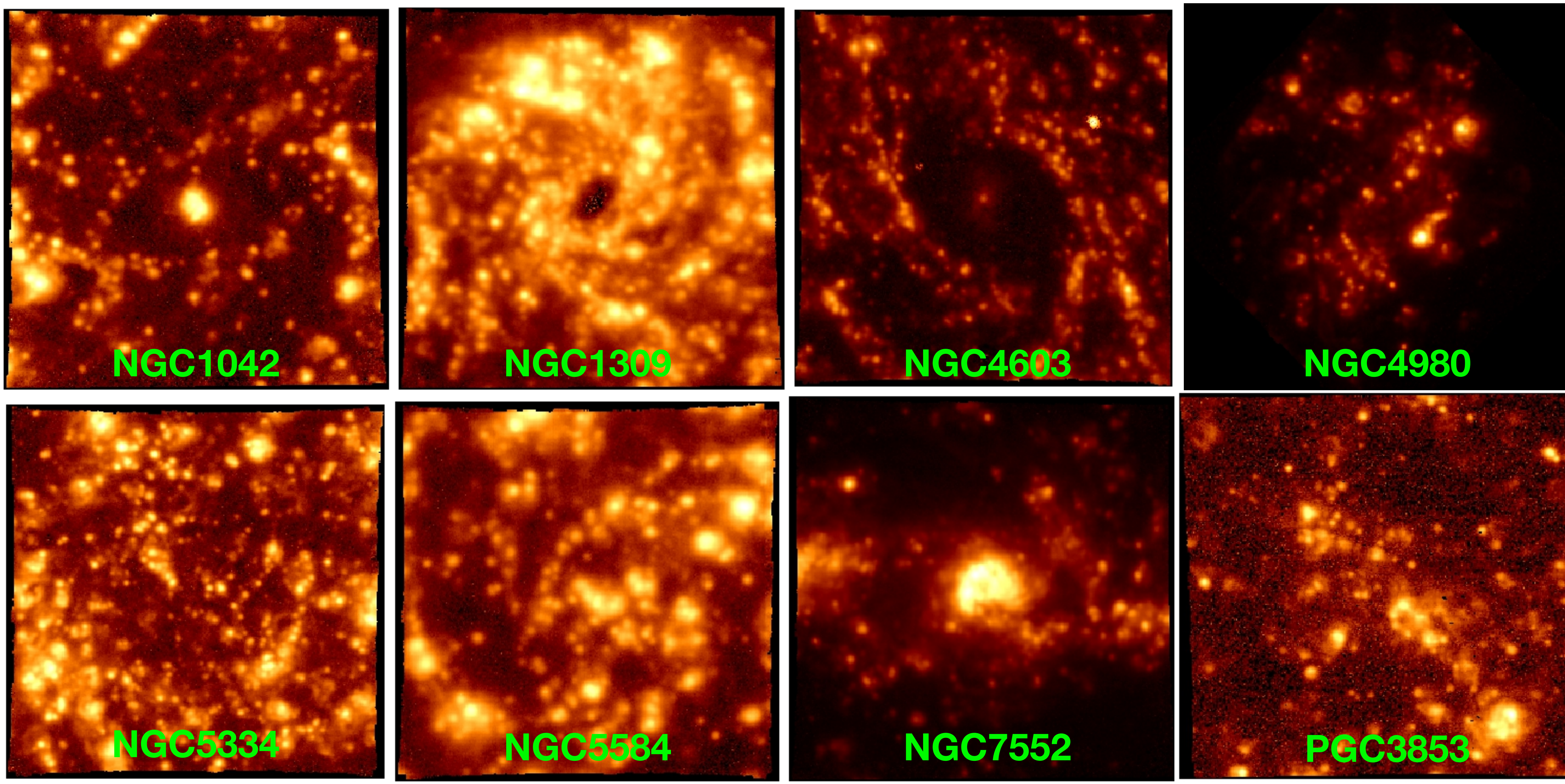
# Using MUSE data to investigate DIG effects

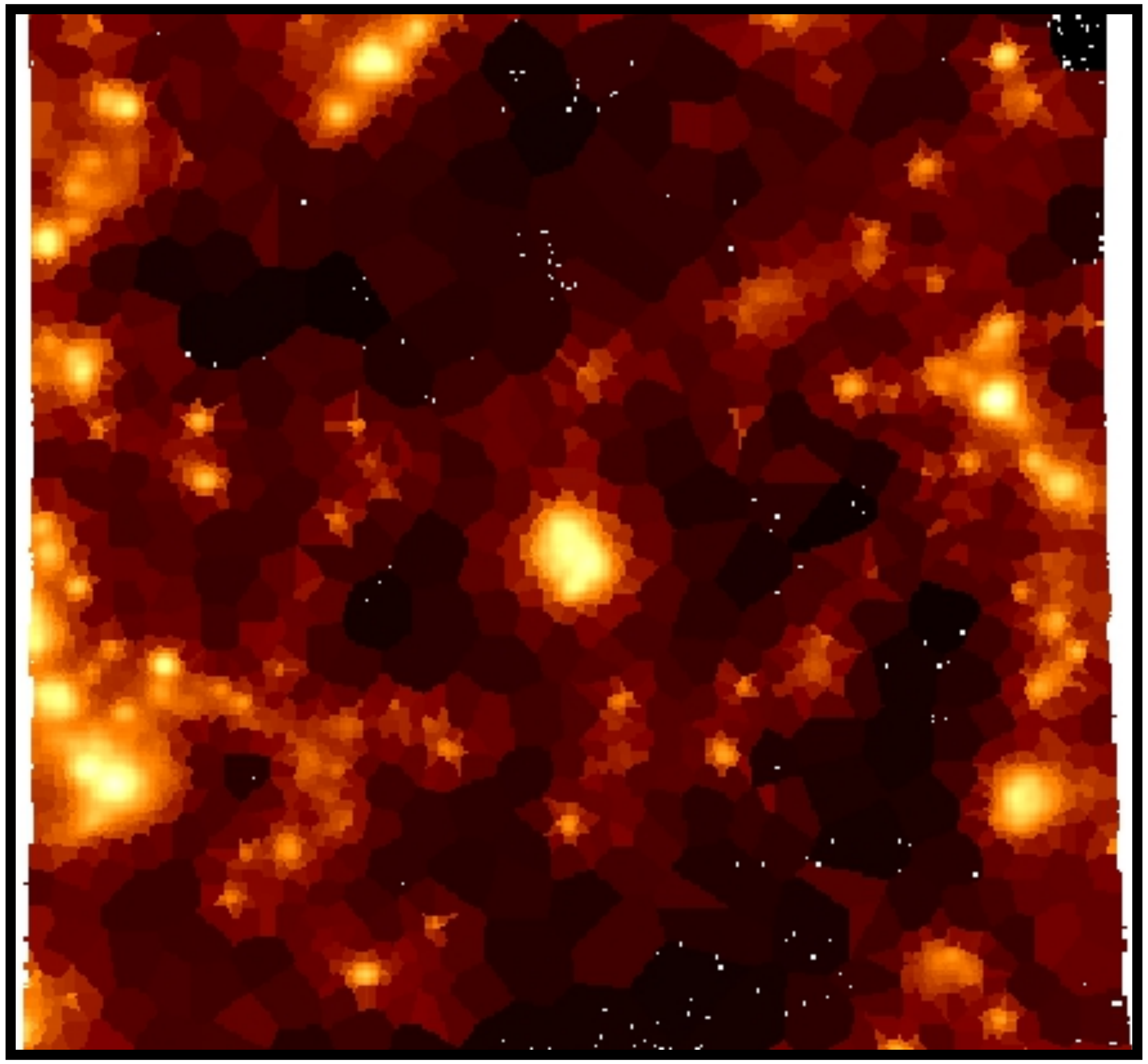


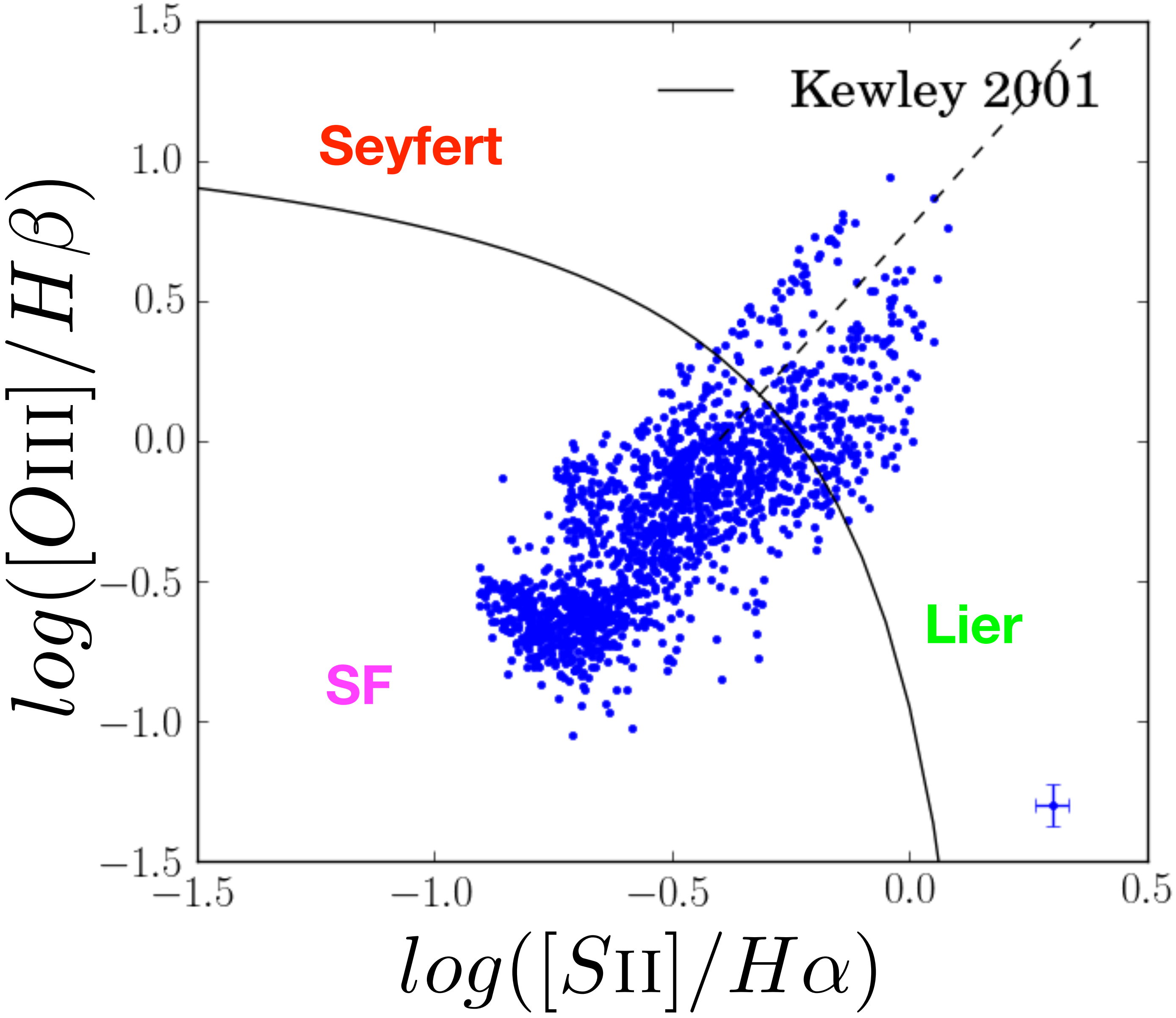

**Hα maps**

**10-30 pc per pixel**

**Map physical and chemical properties of DIG & HII regions**

# Voronoi binning





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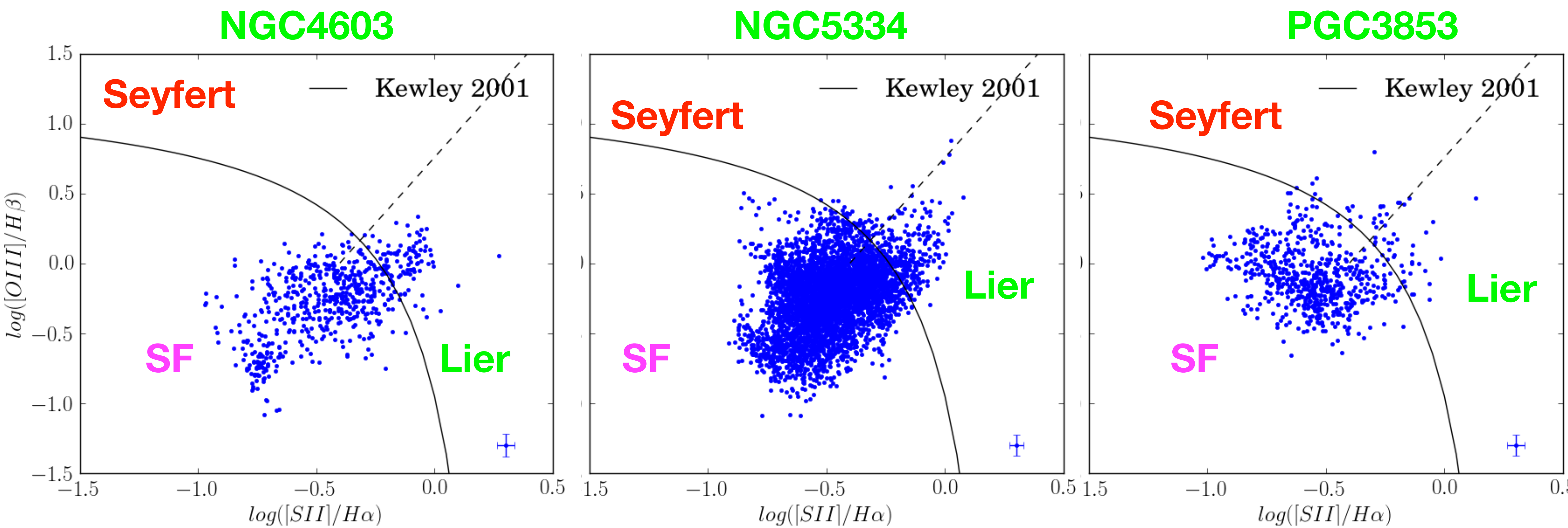


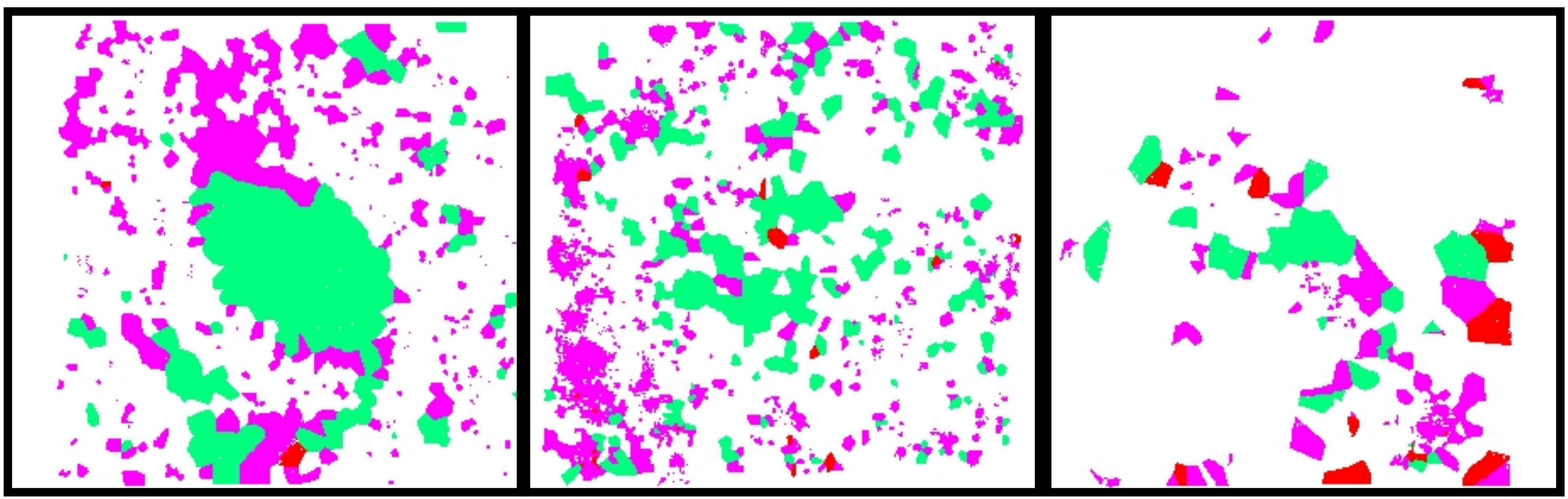

**resolved [SII]-BPT diagnostic**

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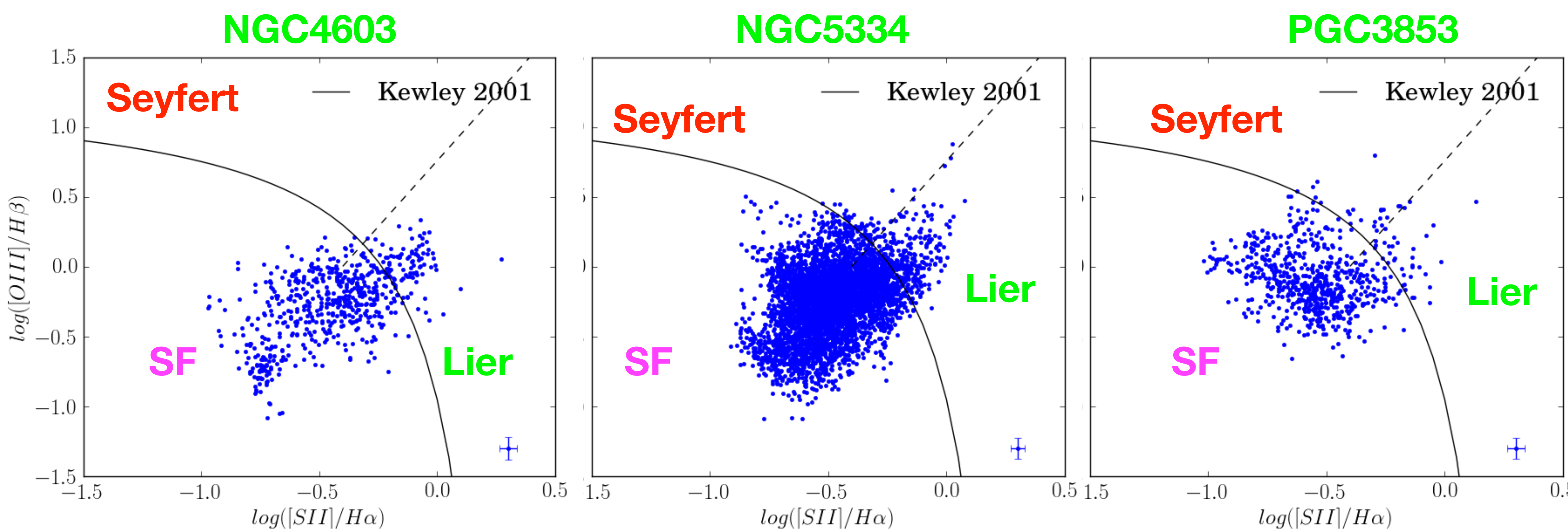


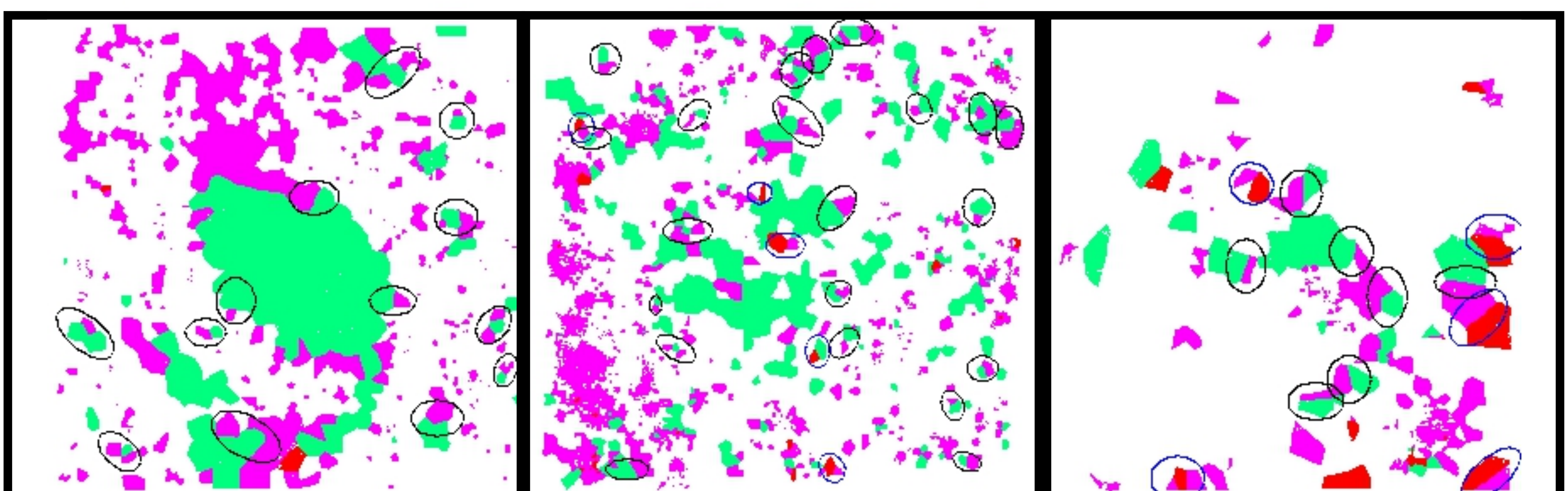

**SN production and cooling timescales longer than dynamical times internal to these small regions** → **Expected chemically homogeneous HII-DIG/Seyfert pairs**

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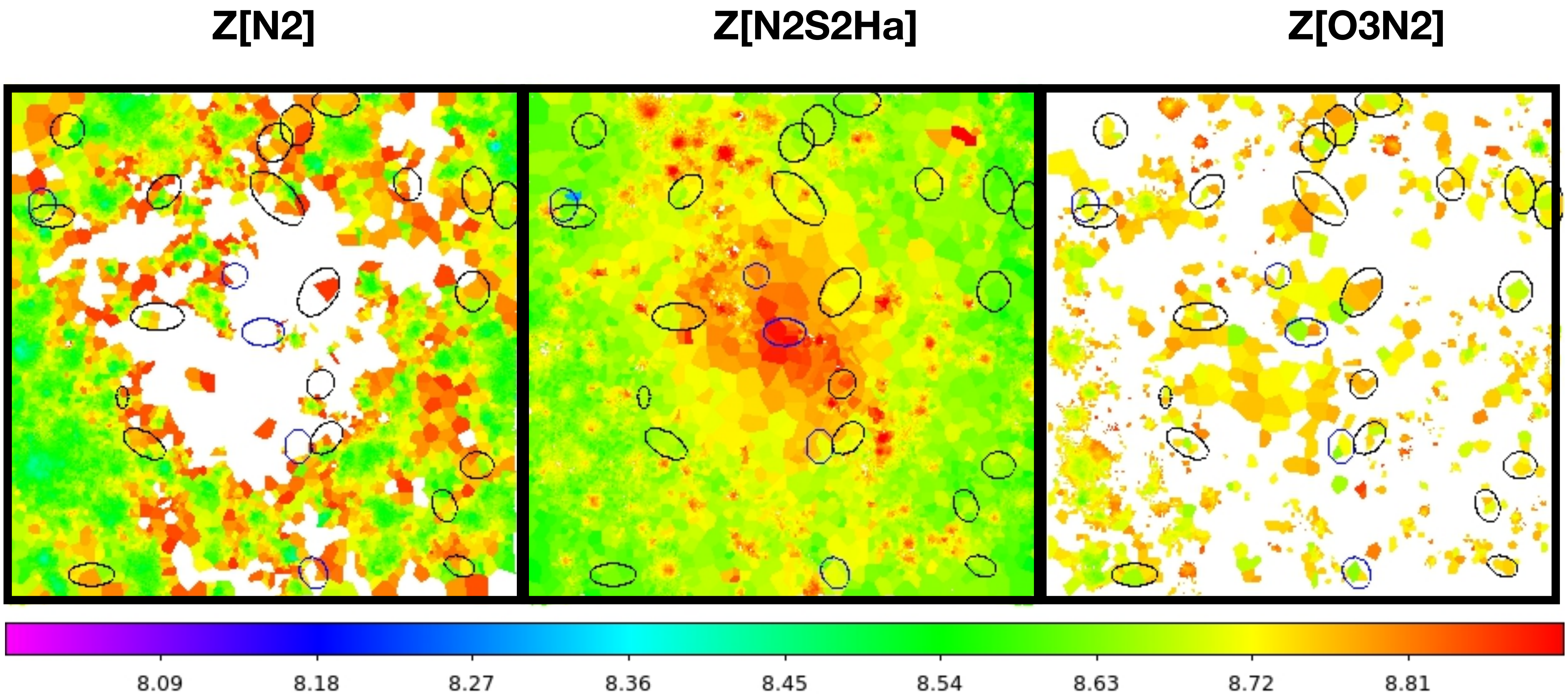
# NGC5334

## Metallicity maps assuming naively that the diagnostics applies also to the DIG (which is what is implicitly done at high-z)




**Constant Z expected in an ellipse**

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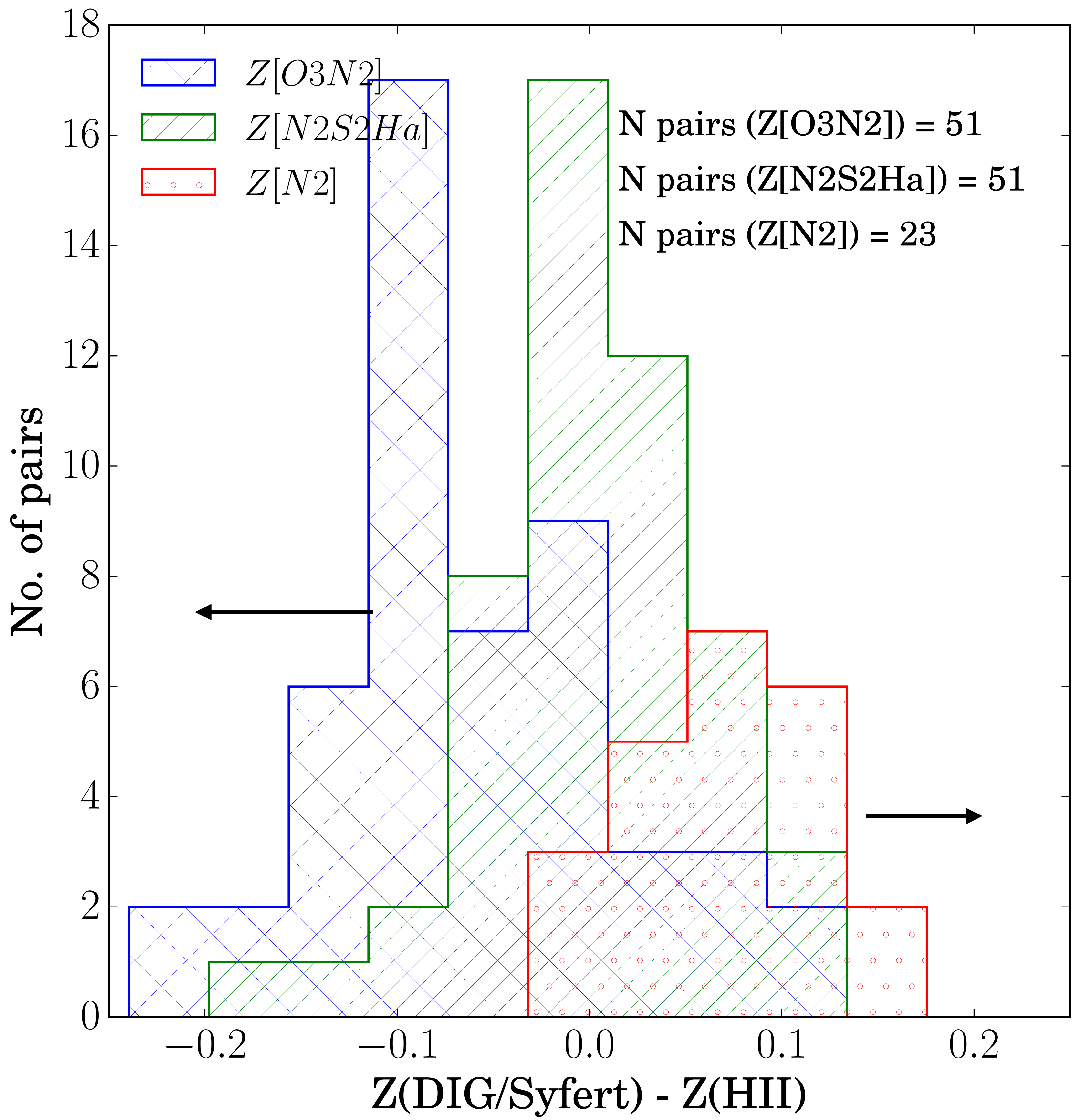


**The DIG introduce offsets and spread (these are only lower limits on the effect because we do not sample the whole range of DIG)**

**Kumari et al. (in prep)**

**For DIG:**
**O3N2 underestimates Z**
**N2 overestimates Z**
**Z[N2S2Ha]: large dispersion**

**Implications for high redshift studies where DIG and HII regions will be mixed**
**-> systematic differences of metallicity scaling relations relative to low-z simply arising from this effect**
**-> yet, these can be corrected (work in progress)**

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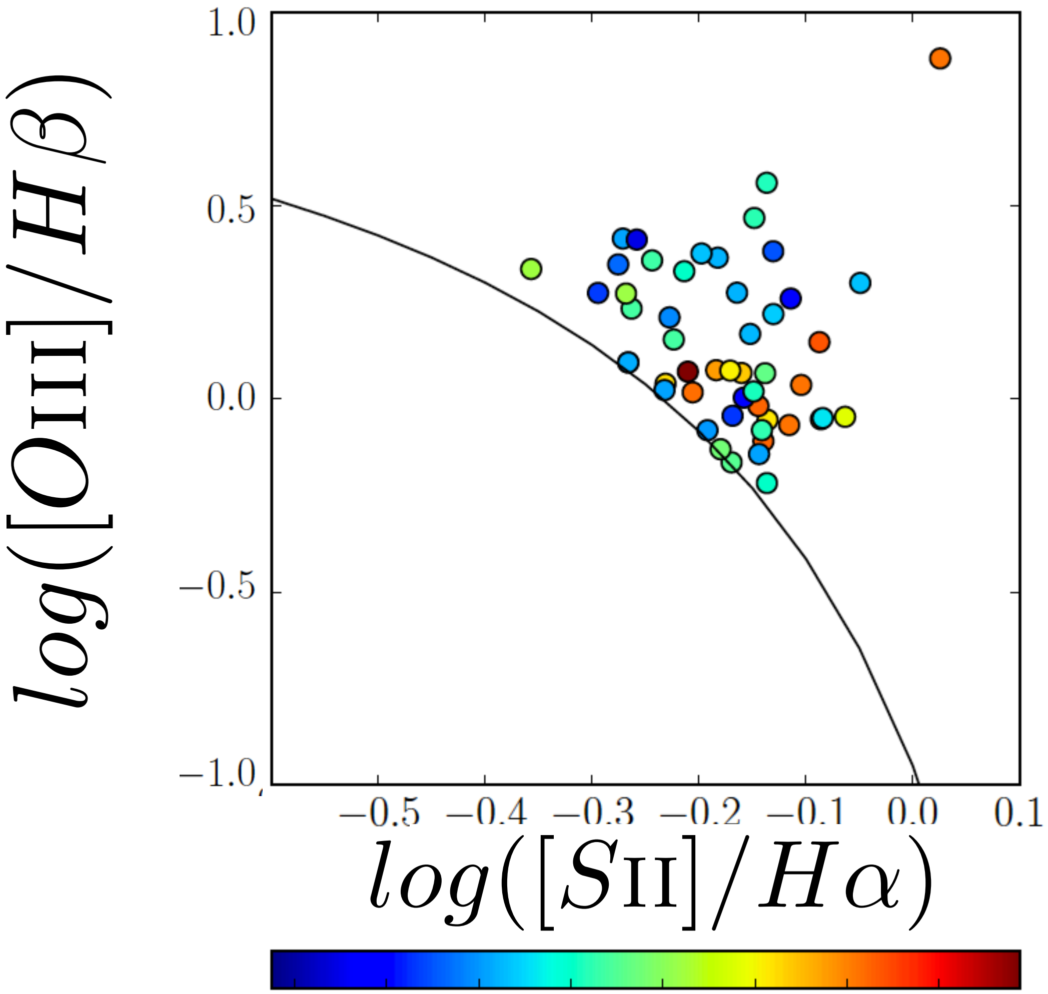
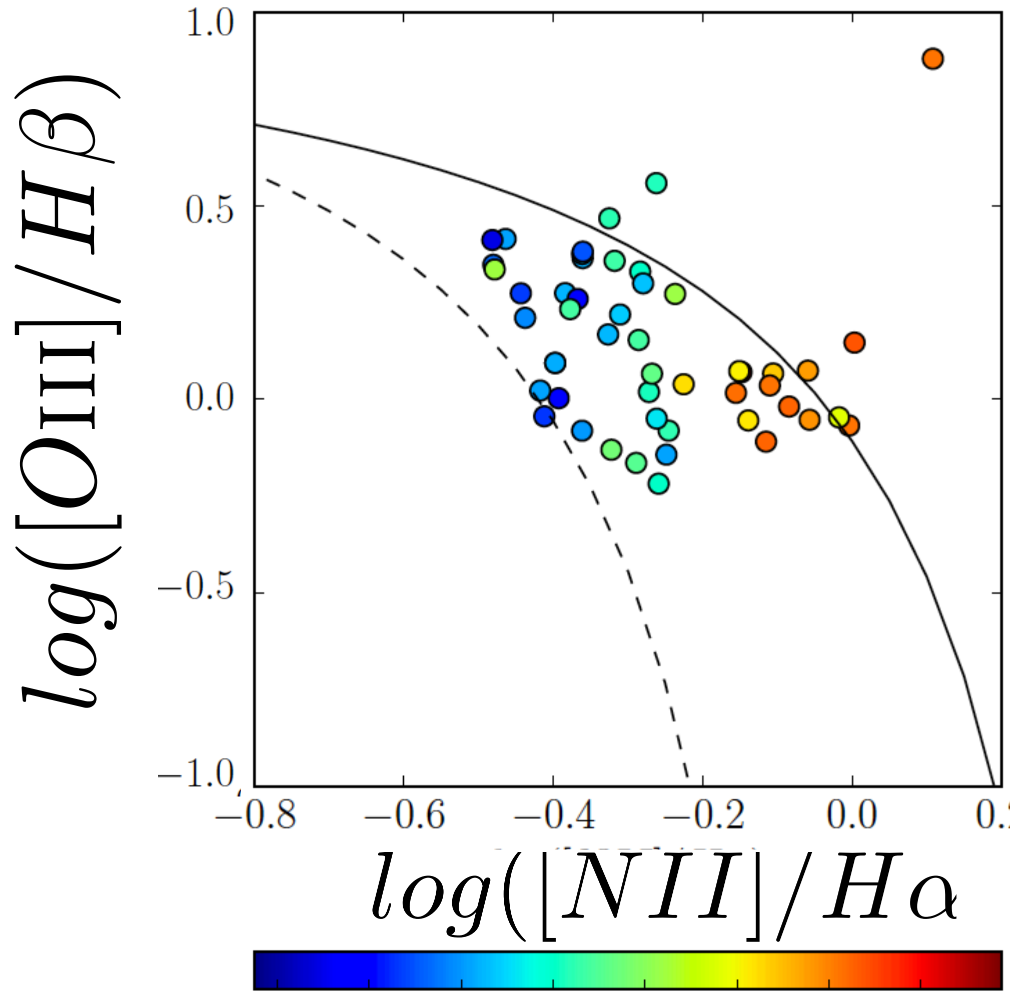



**Z[N2S2Ha]**




**Z[N2S2Ha]**

**-> the metallicity bias in the DIG region has a systemic trend in the N2-BPT diagram**

**-> can be used to correct and mitigate the effect**

**-> but the simple bare use of the diagnostics will introduce biases and scatter in high-z studies**

# The effect of spatial resolution on the star formation laws

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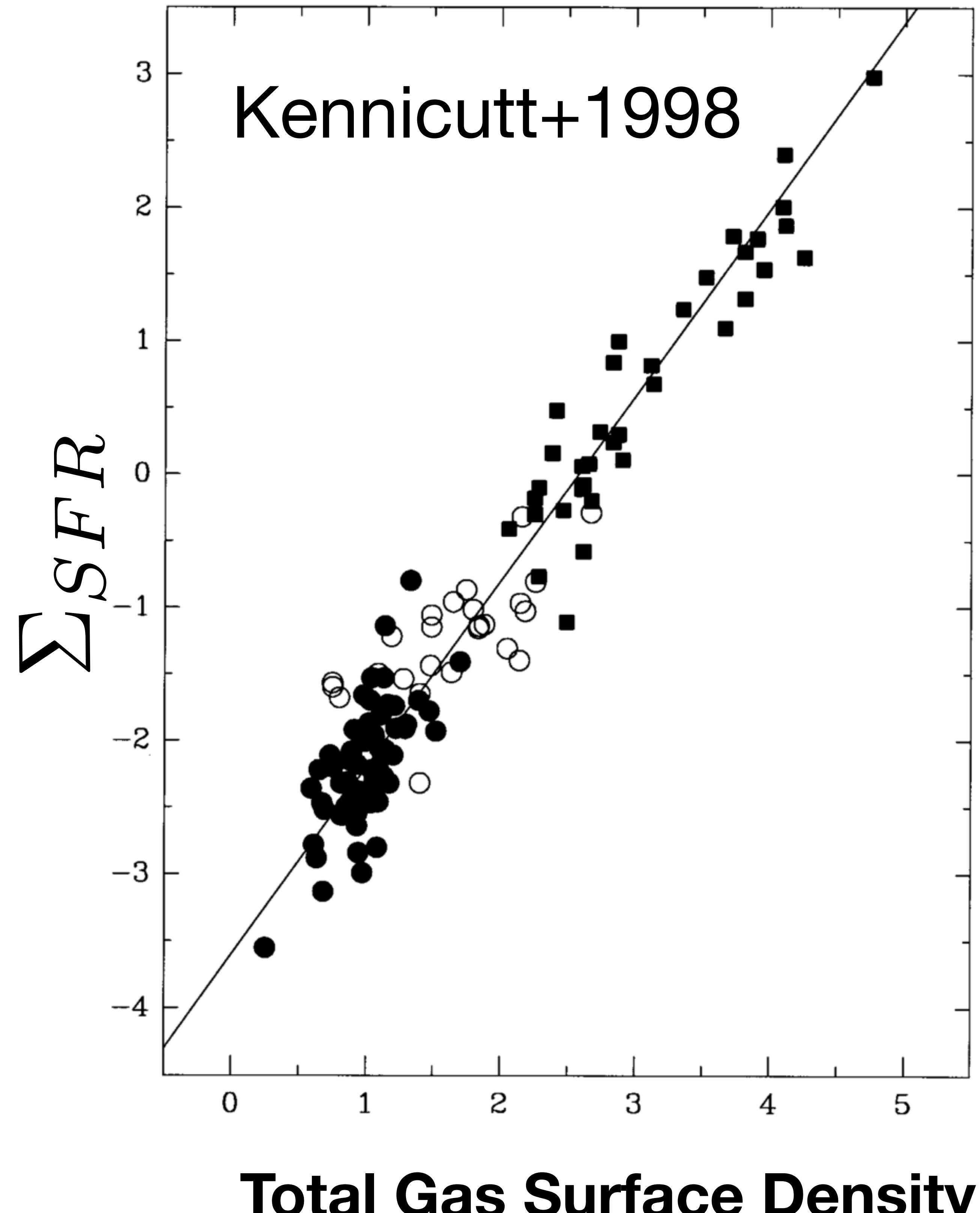
# Global Star-Formation Law

$$\Sigma_{\mathrm{SFR}} = A\Sigma_{\mathrm{gas}}^{N}$$

N = 1.4

**Schmidt-Kennicutt Law**



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# Spatially-resolved (sub-kpc) Star-formation LawS ?

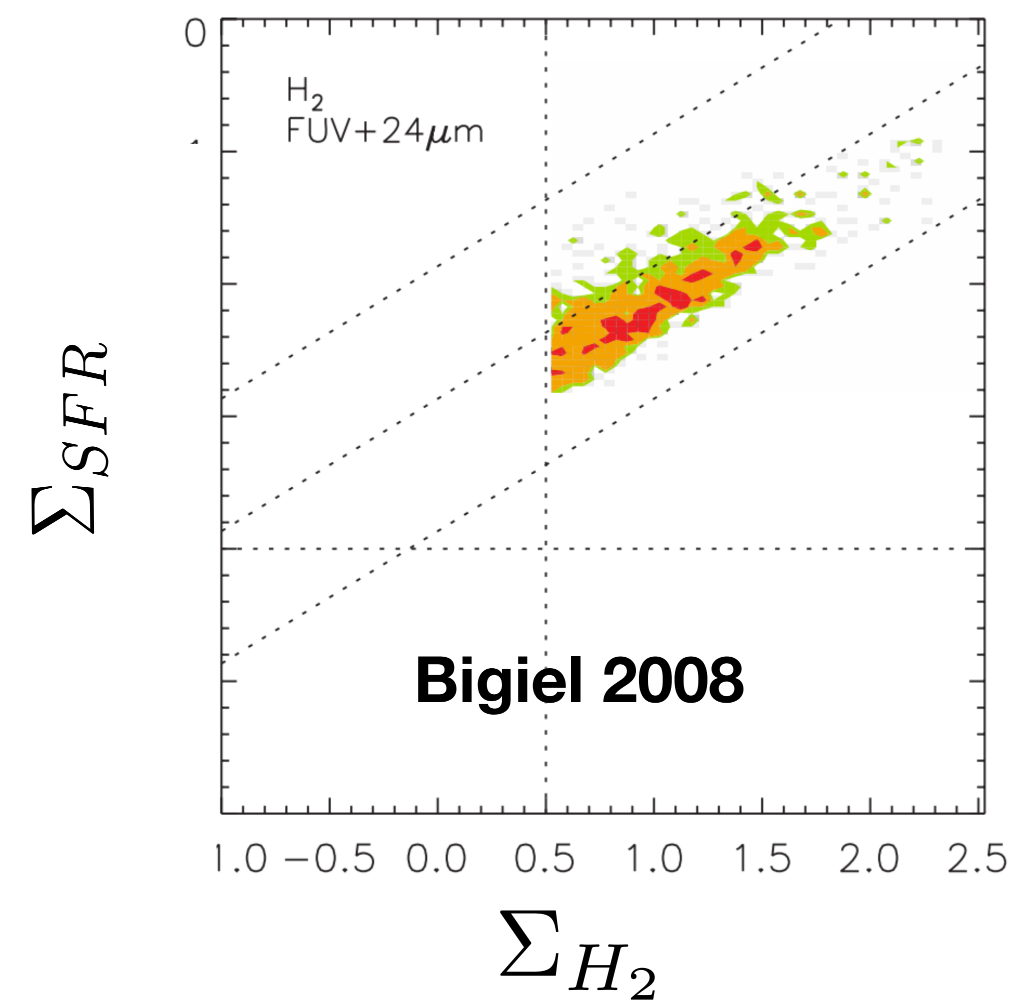
**Atomic Gas**: saturation and no correlation with SFRD

## Molecular Gas

**Sub-linear**
Shetty et al. 2013, 2014

**Linear**
Bigiel et al. 2008, 2011
Leroy et al. 2012

**Super-Linear**
Kennicutt et al. 2007
Momose et al. 2014




**Yet, these previous studies have not taken into account the Diffuse Background**

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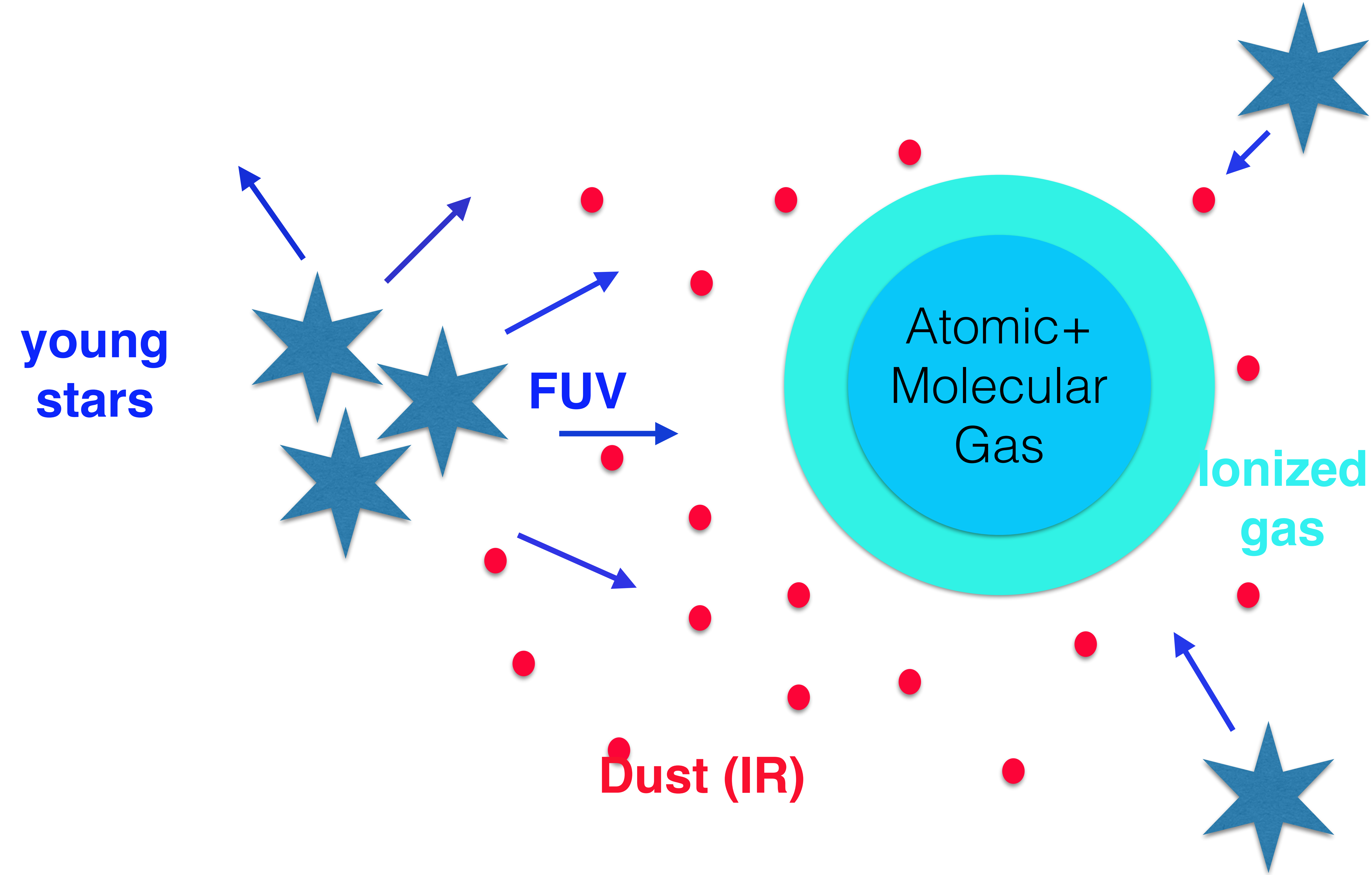
# What is the Diffuse Background?



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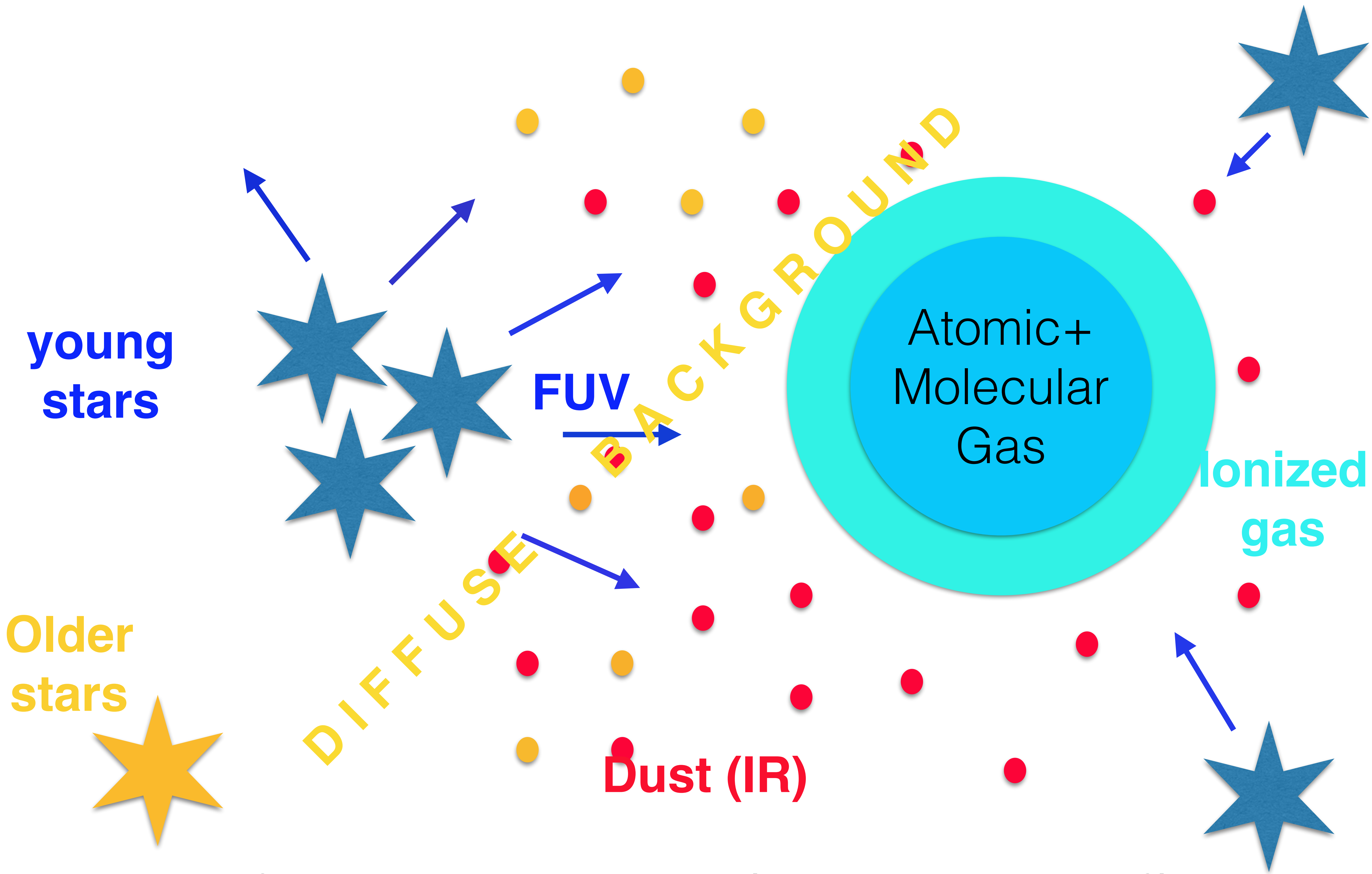


Affects both the SF tracers and the gas tracers (possibly linked to the DIG)

# Diffuse Background Estimation

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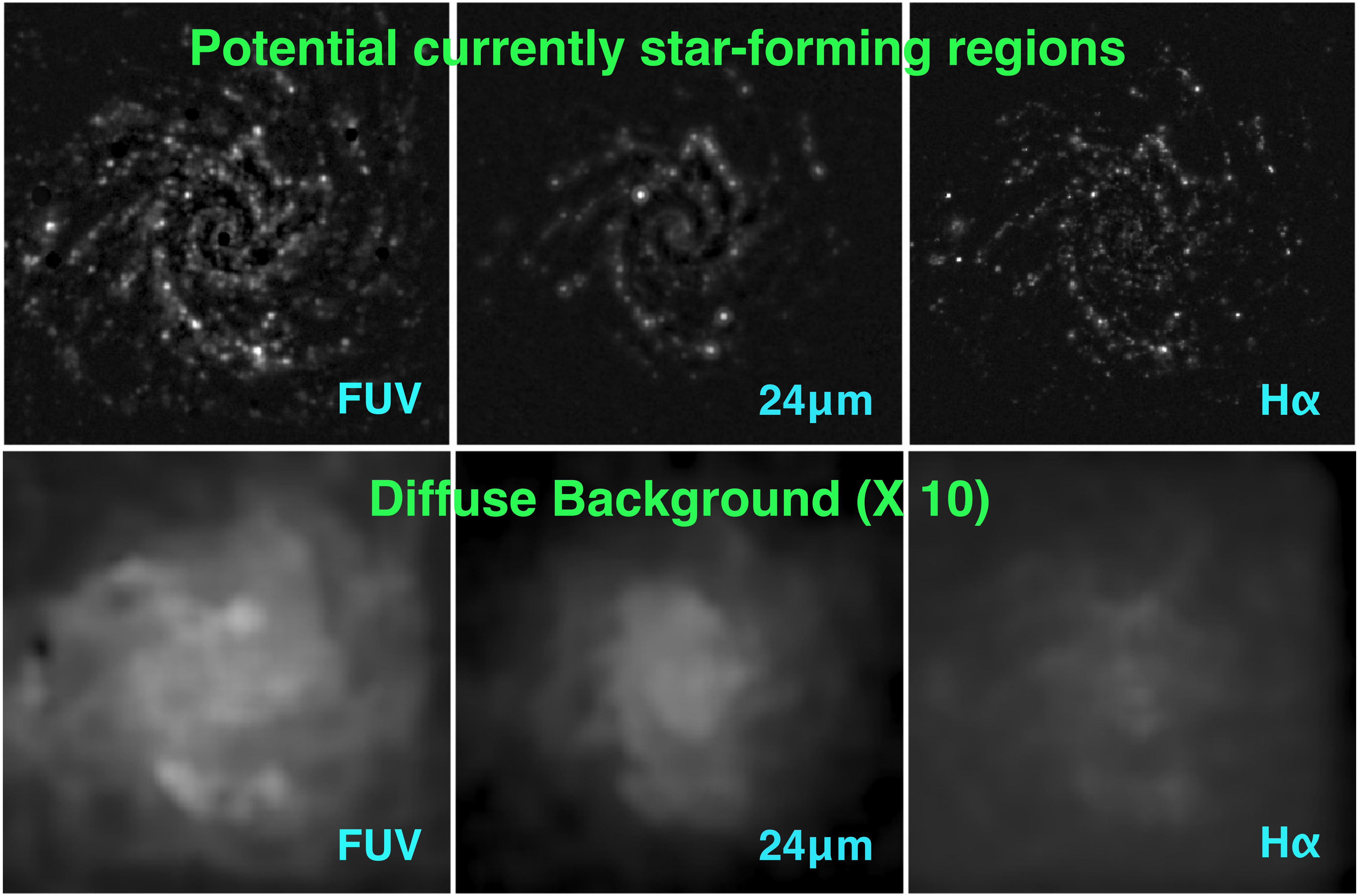


http://casu.ast.cam.ac.uk/publications/nebulosity-filter

# Hα images – **Multiwavelength Data**

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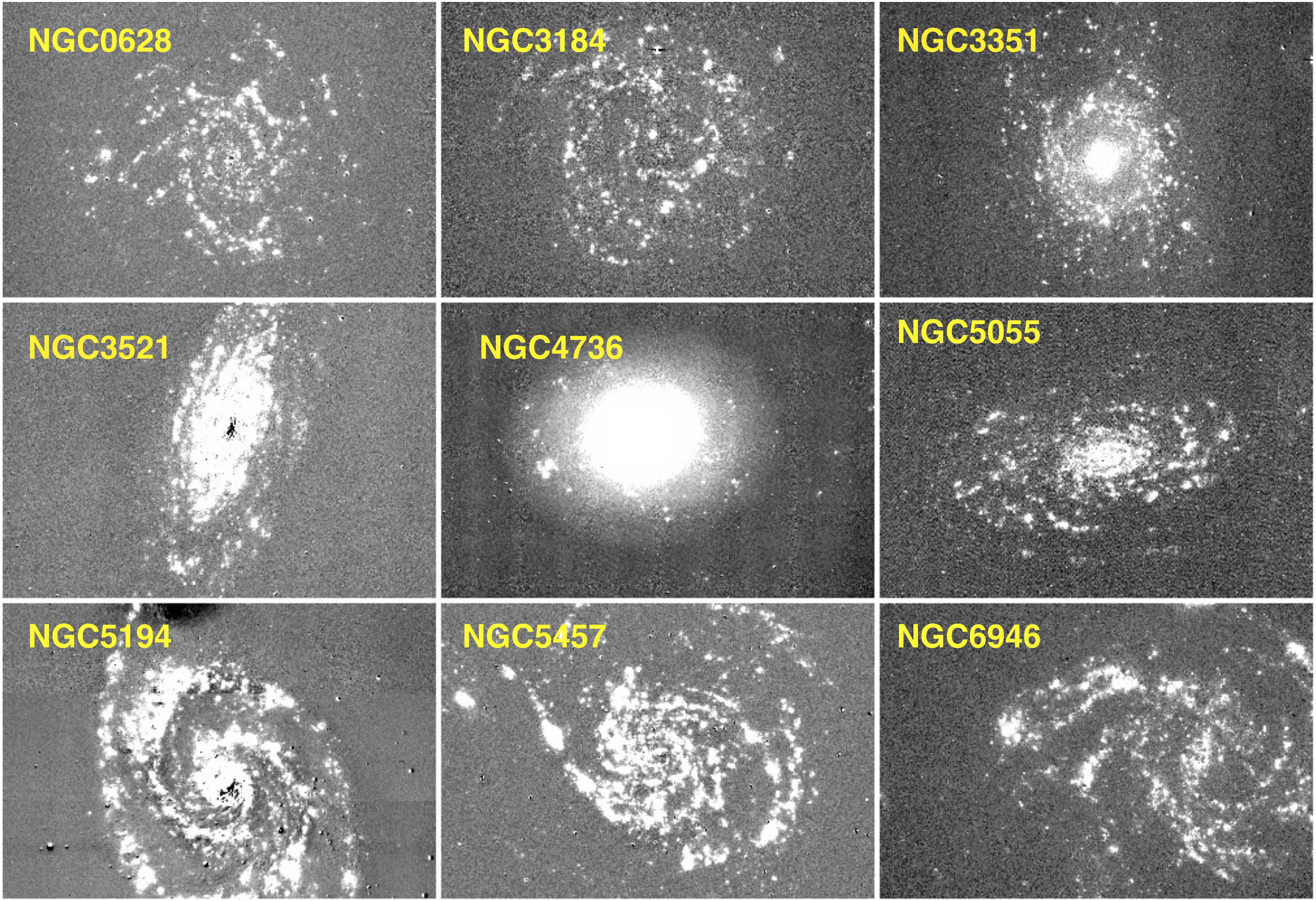

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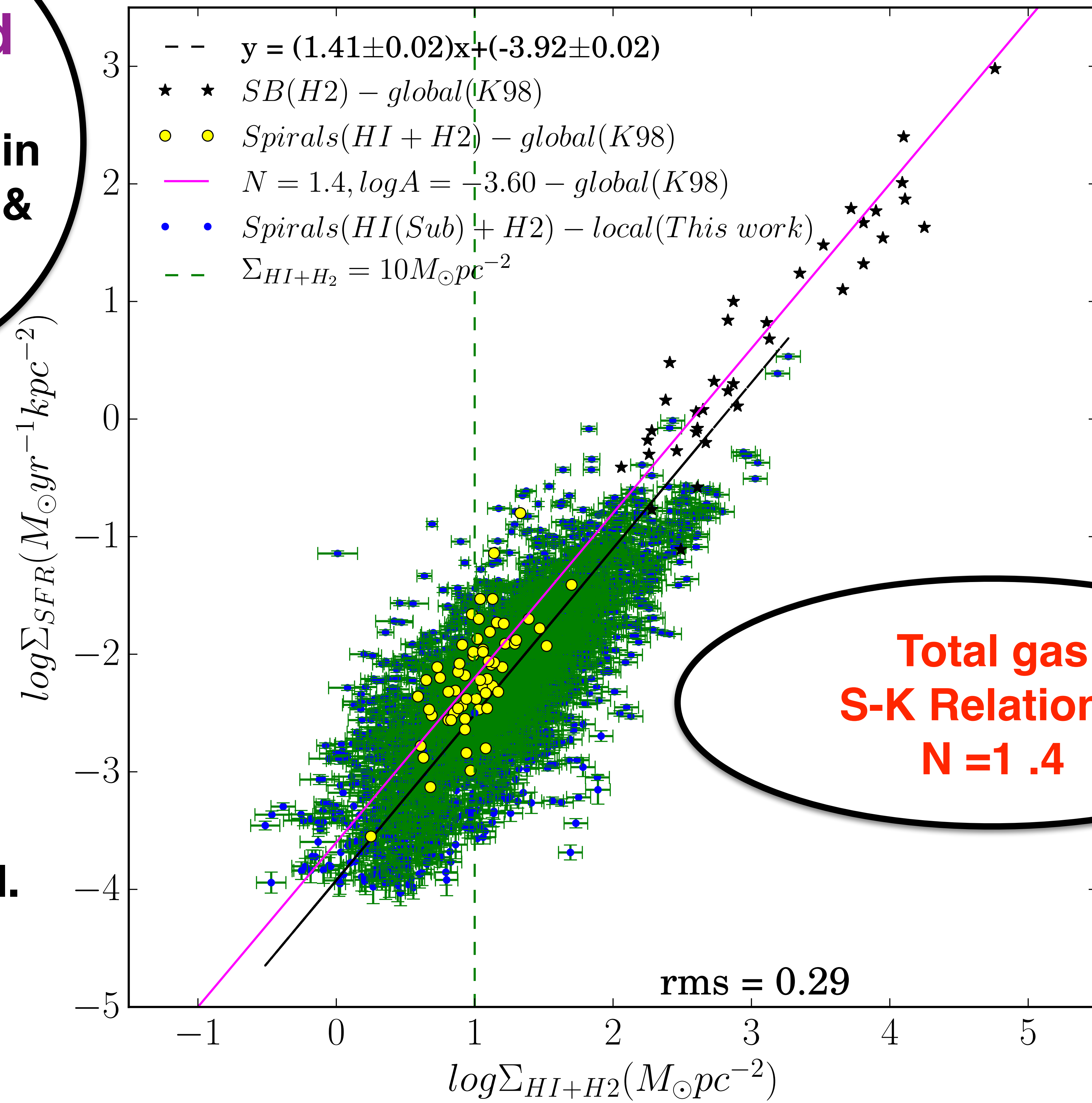
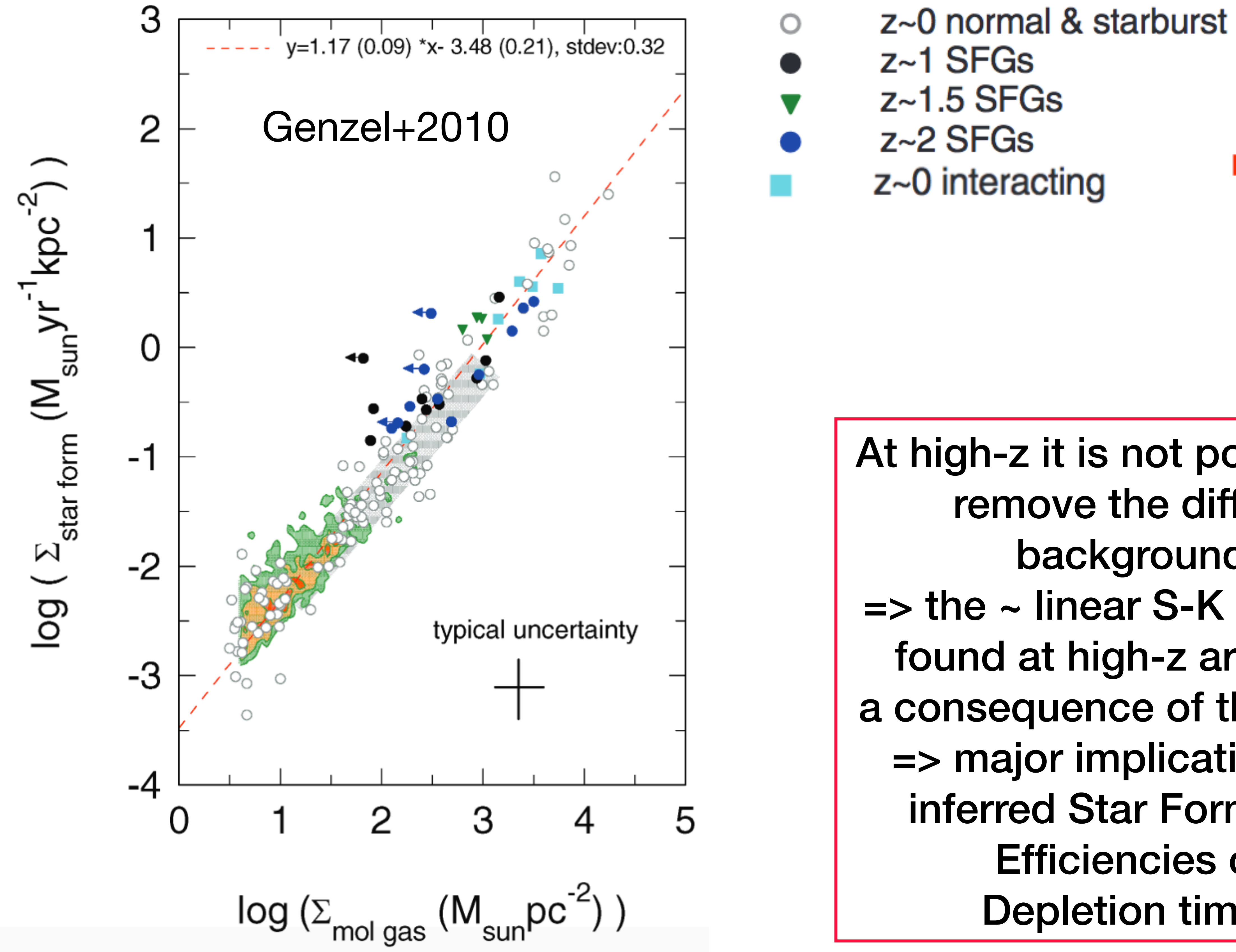
Removed Diffuse Background in SFR tracers & atomic gas




Total gas S-K Relation !! N =1 .4

Kumari et al. (submitted)




At high-z it is not possible to remove the diffuse background
=> the ~ linear S-K relations found at high-z are likely a consequence of this effect
=> major implications for inferred Star Formation Efficiencies or Depletion times

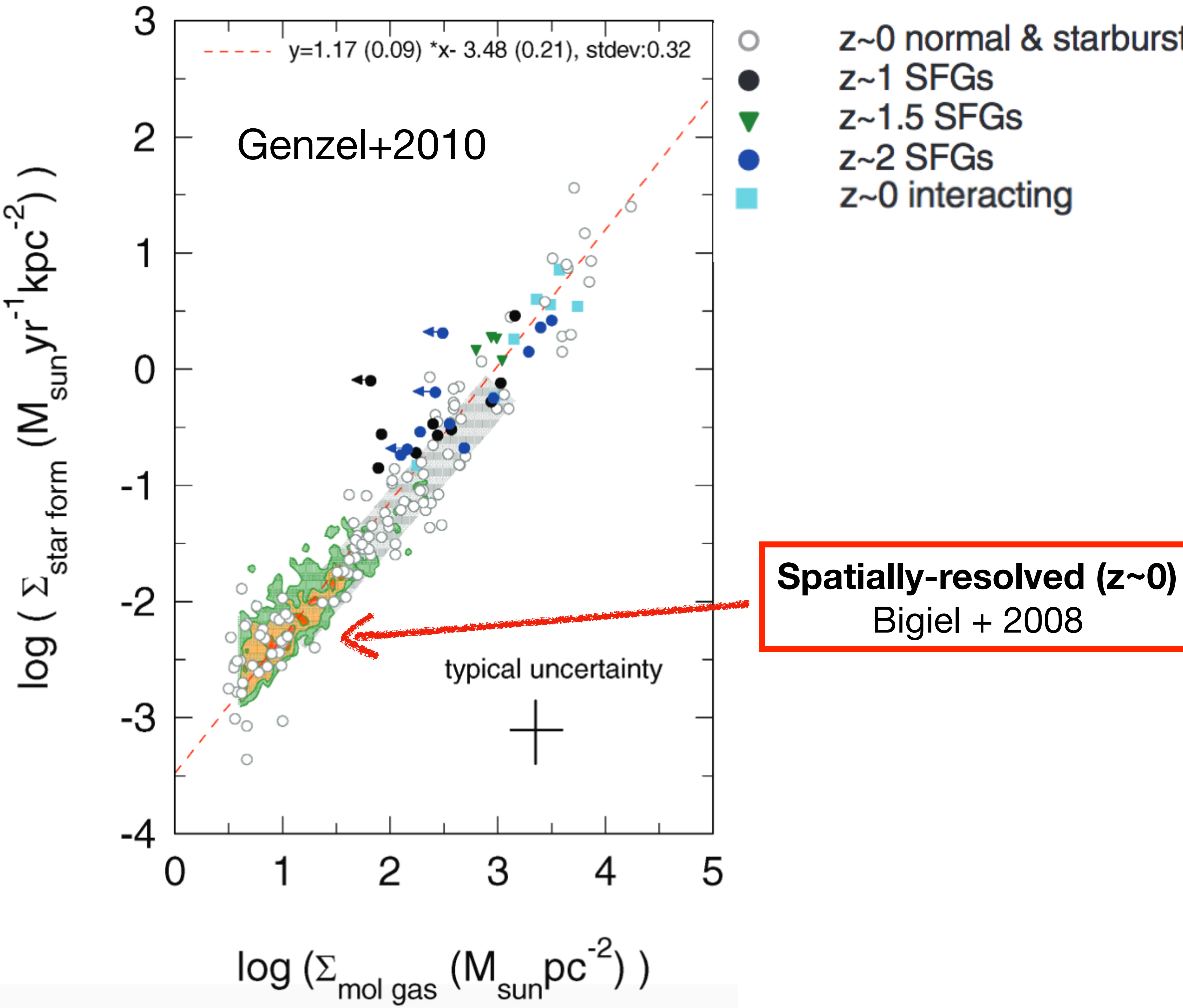
# Summary

- Subtraction of Diffuse background :
  Spatially Resolved Schmidt Law same as Global Schmidt-Kennicutt Law -> super-linear relation (slope~1.4)
- Metallicity of Diffuse Ionised Gas needs correction !
- Be careful before using these recipes for spatially-resolved analysis at high redshifts !

**Thanks for your attention !!**

**For details, contact:** nkumari@ast.cam.ac.uk

# Molecular gas Schmidt Relation over cosmic time ~ linear (N ~ 1)




**Spatially-resolved (z~0)**
Bigiel + 2008