Carbon monoxide in an extremely metal-poor galaxy

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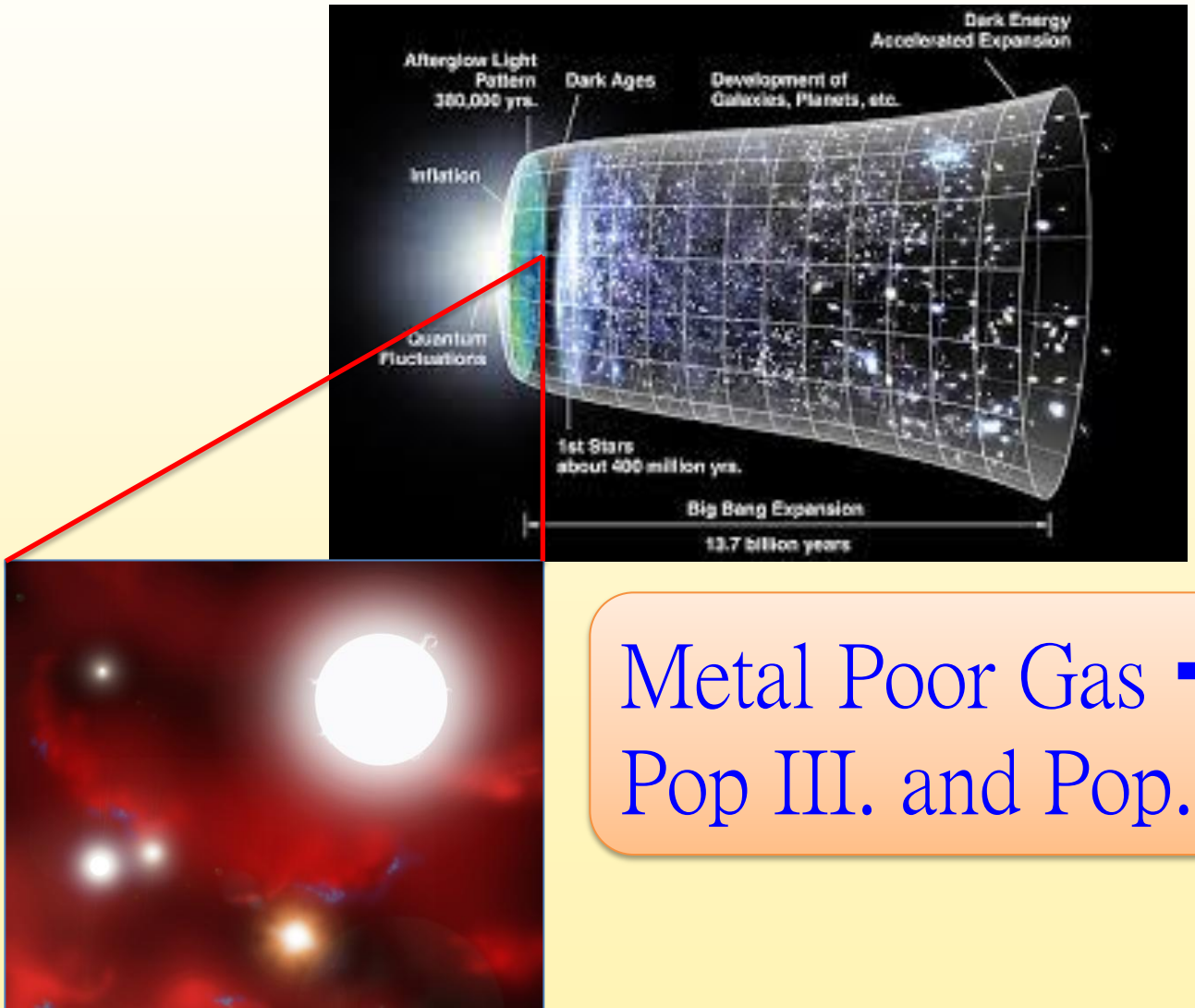
Collaborators: Junzhi Wang (SHAO), Yu Gao (PM), Qiusheng Gu (NJU)…

Introduction



Metal Poor Gas ➔
Pop III. and Pop. II stars.

Introduction

Cosmic Re-ionization:

Pop. III stars *initiate* the re-ionization; Pop. II stars *complete* the re-ionization.

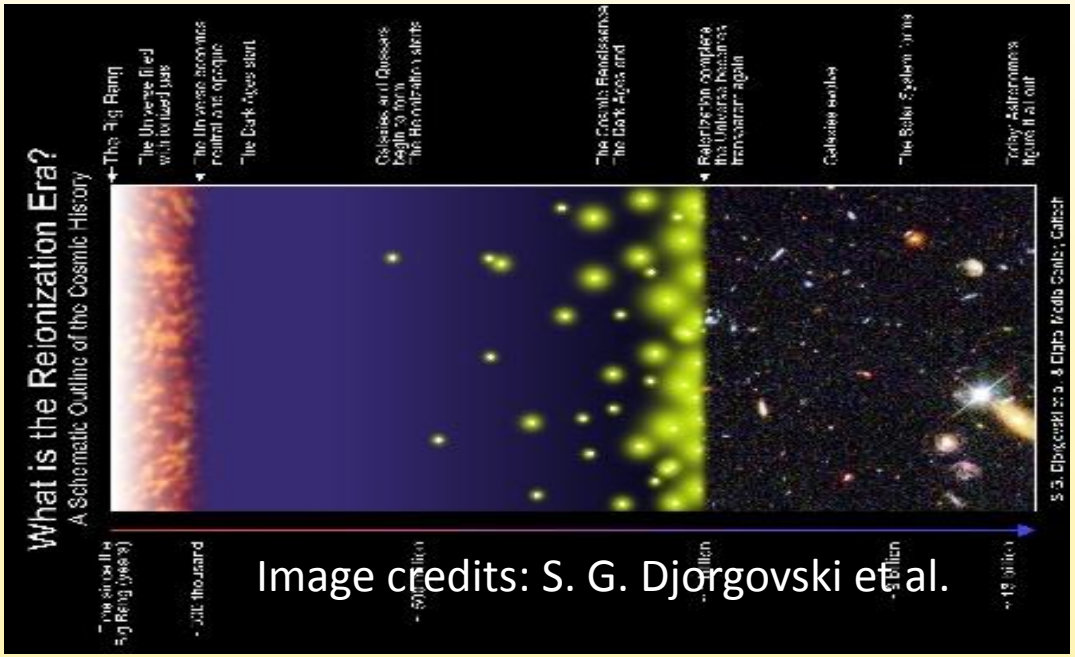


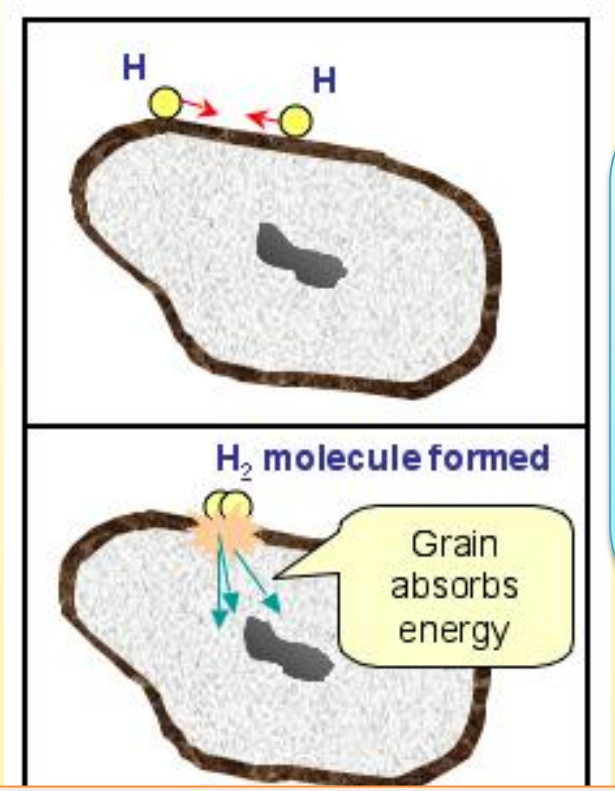
Image credits: S. G. Djorgovski et al.

Introduction

All star formation in present-day Spirals takes place in clouds of molecular gas.

Introduction

Is this true for star formation in the early Universe when metals are scarce?



Formation on surface of dust grains

$e + H \rightarrow H^- + h\nu$

$H^- + H \rightarrow H_2 + e$

$H^- + H \rightarrow H_2^+ + h\nu$

$H_2^+ + H \rightarrow H_2 + H^+$

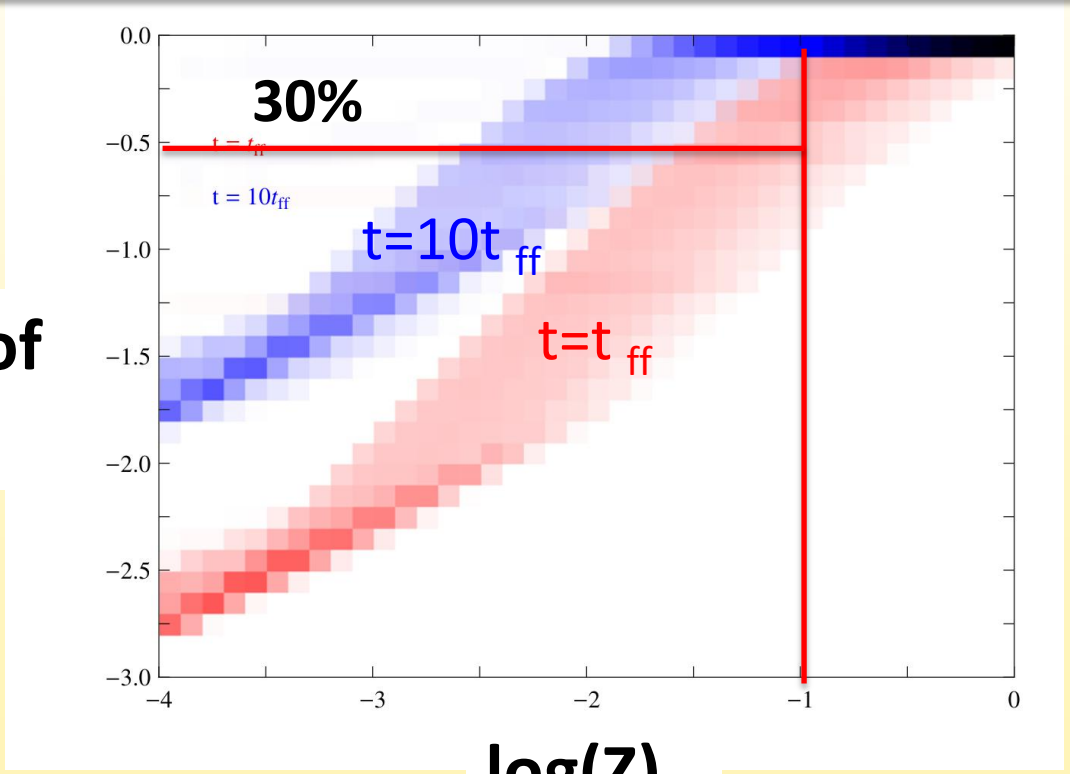
$3H \rightarrow H_2 + H$

$2H + H_2 \rightarrow 2H_2$

Gas phase reaction (Saslaw & Zipoy 1967; Peebles & Dicke 1968),

Introduction

Some models predict that stars can form in atomic gas below 10% Solar metallicty (Krumholz et al. 2012, Glover et al. 2012).



Introduction

- **Current facilities are limited in the abilities to probing star formation in the early Universe!**

- **Using nearby extremely metal poor galaxies as local laboratories.**

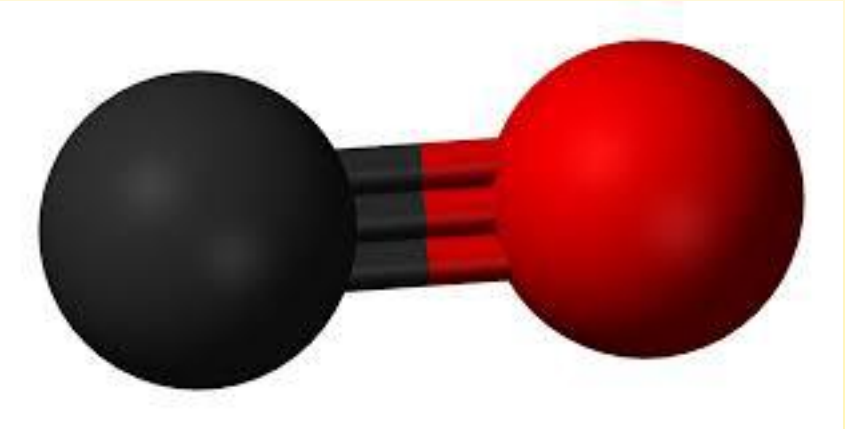
Extremely metal poor galaxies: $Z < 1/10\ Z_{\odot}$

CARBON MONOXIDE

CO is the most accessible tracer of cold molecular gas in which star formation takes place.

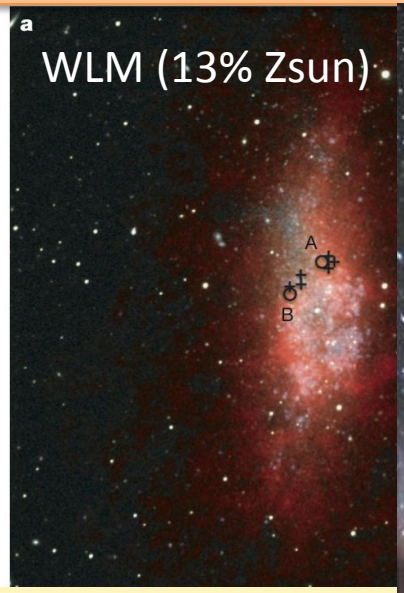
$L_{CO} \times \alpha_{CO} = H_2$ mass

CO Dipole Mom. excited at very low T.

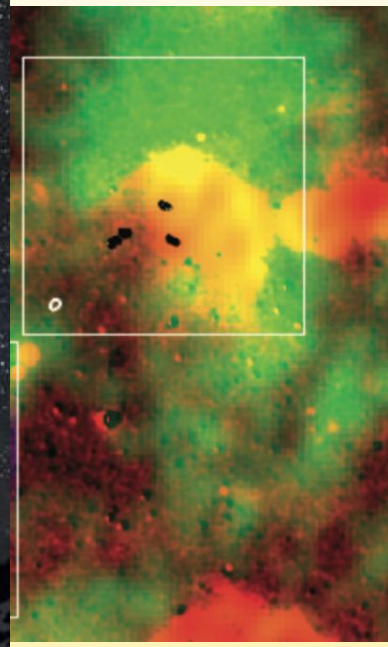


CARBON MONOXIDE

No CO has been seen < 10% Solar, arising questions if star forms in molecular gas or just in atomic gas.



Elmegreen et al. 2

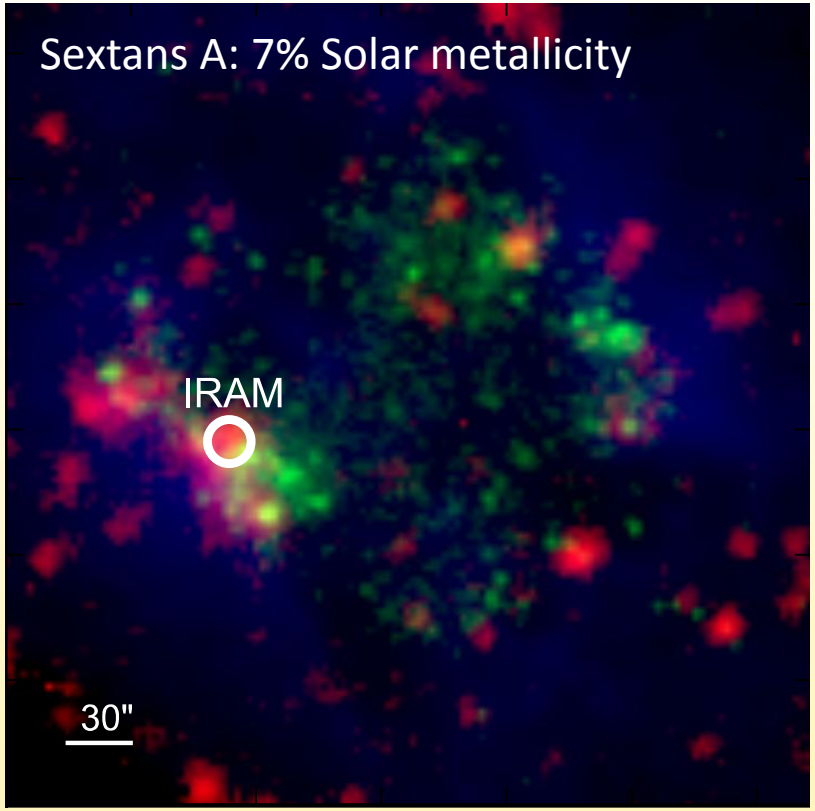


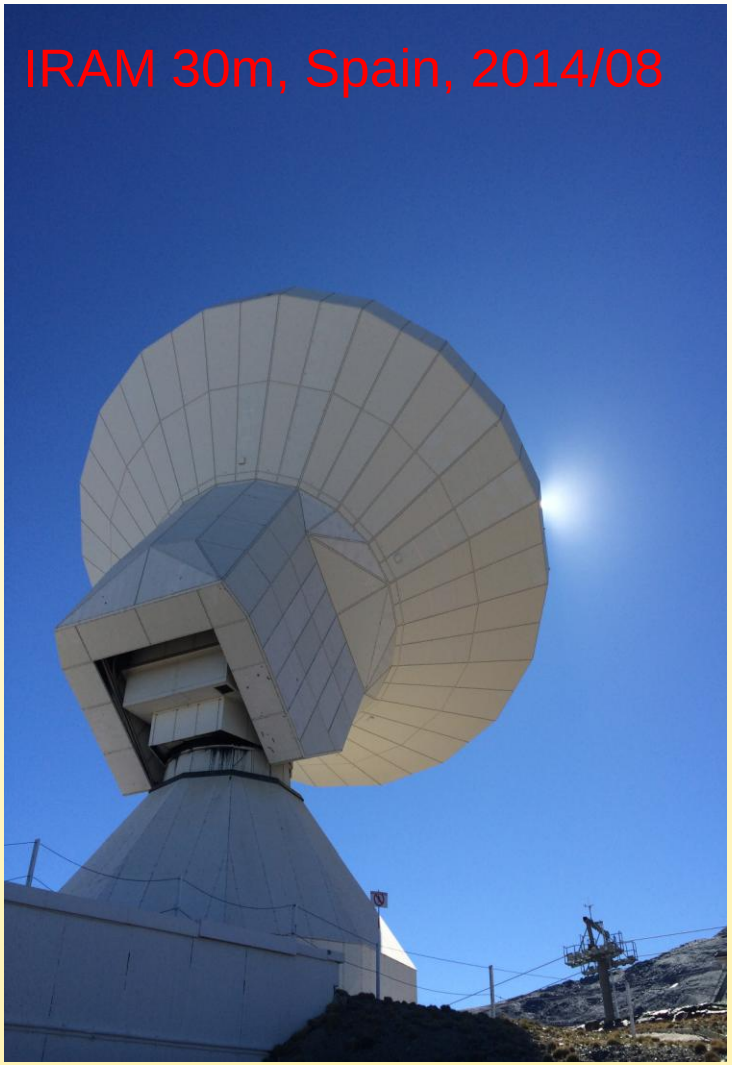
5 Nature, 525, 219

CARBON MONOXIDE

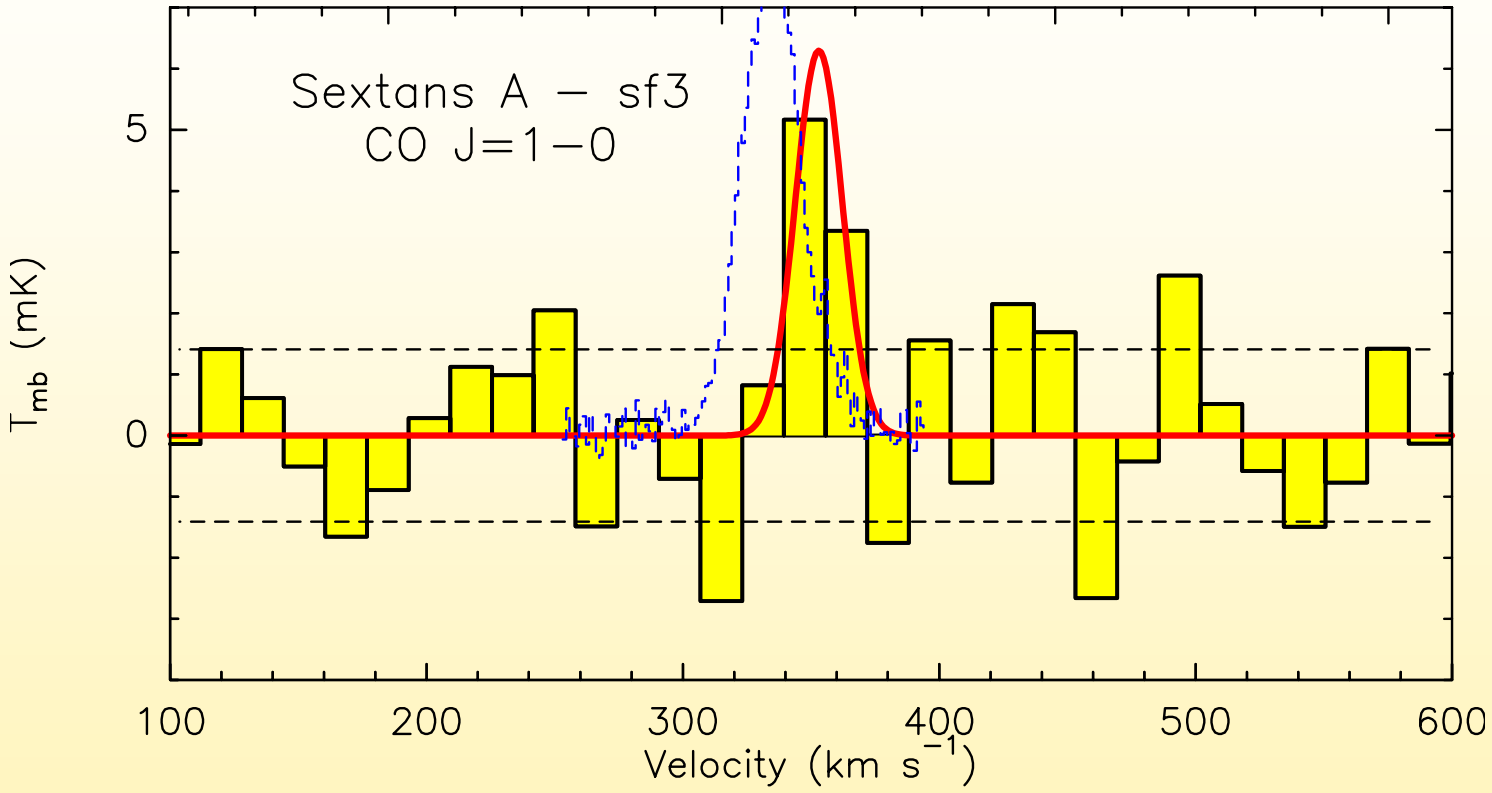
• Leroy +2007	PdBI	Failed
• Schruba+2012	IRAM 30m	Failed
• Warren+2015	CARMA	Failed
• Amorin+2016	IRAM 30m	Failed
• ALMA archive	ALMA (Sextans A, 10 mins)	Failed
• ALMA archive	ALMA (Sextans A, 1 hrs)	Failed
• Hunt et al. 2015	ALMA (SBS 0335, 2.6 hrs)	Failed
• ALMA archive	ALMA (SBS 0335, 2.7 hrs)	??

CARBON MONOXIDE





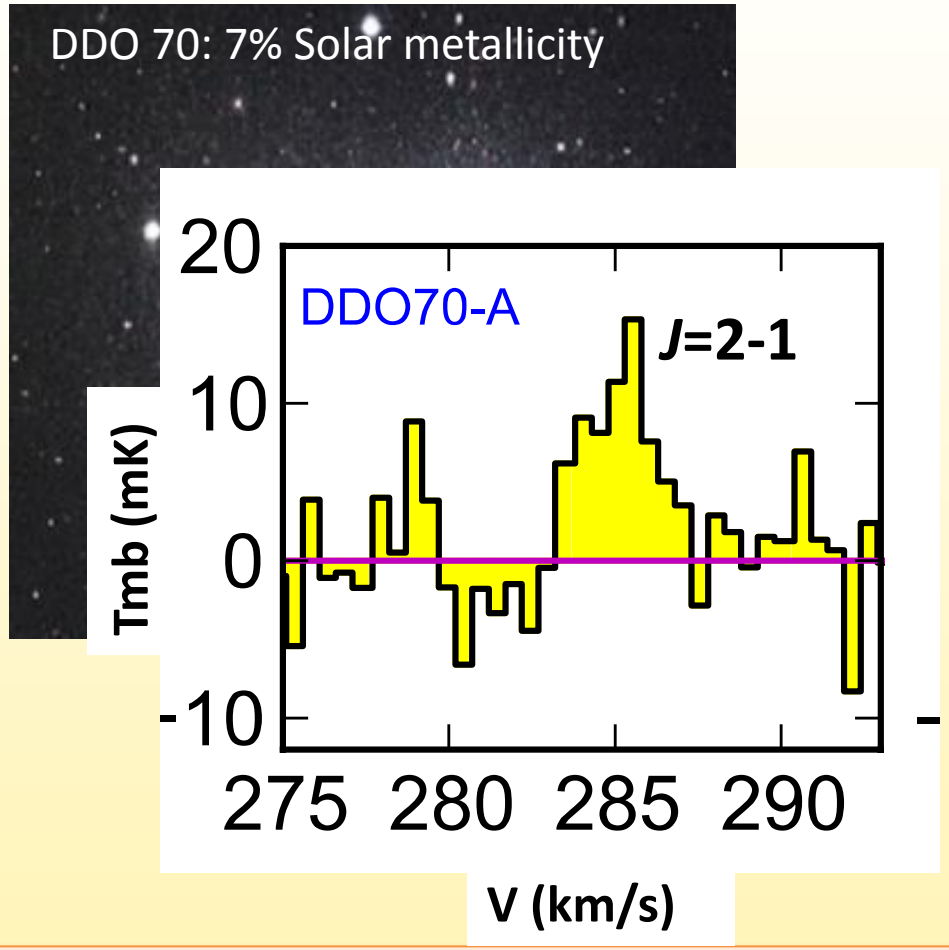
CARBON MONOXIDE



An upperlimit is placed (Shi et al. 2015, ApJL, 804, 11) ◦

CARBON MONOXIDE:

IRAM-30m 60 hrs approved



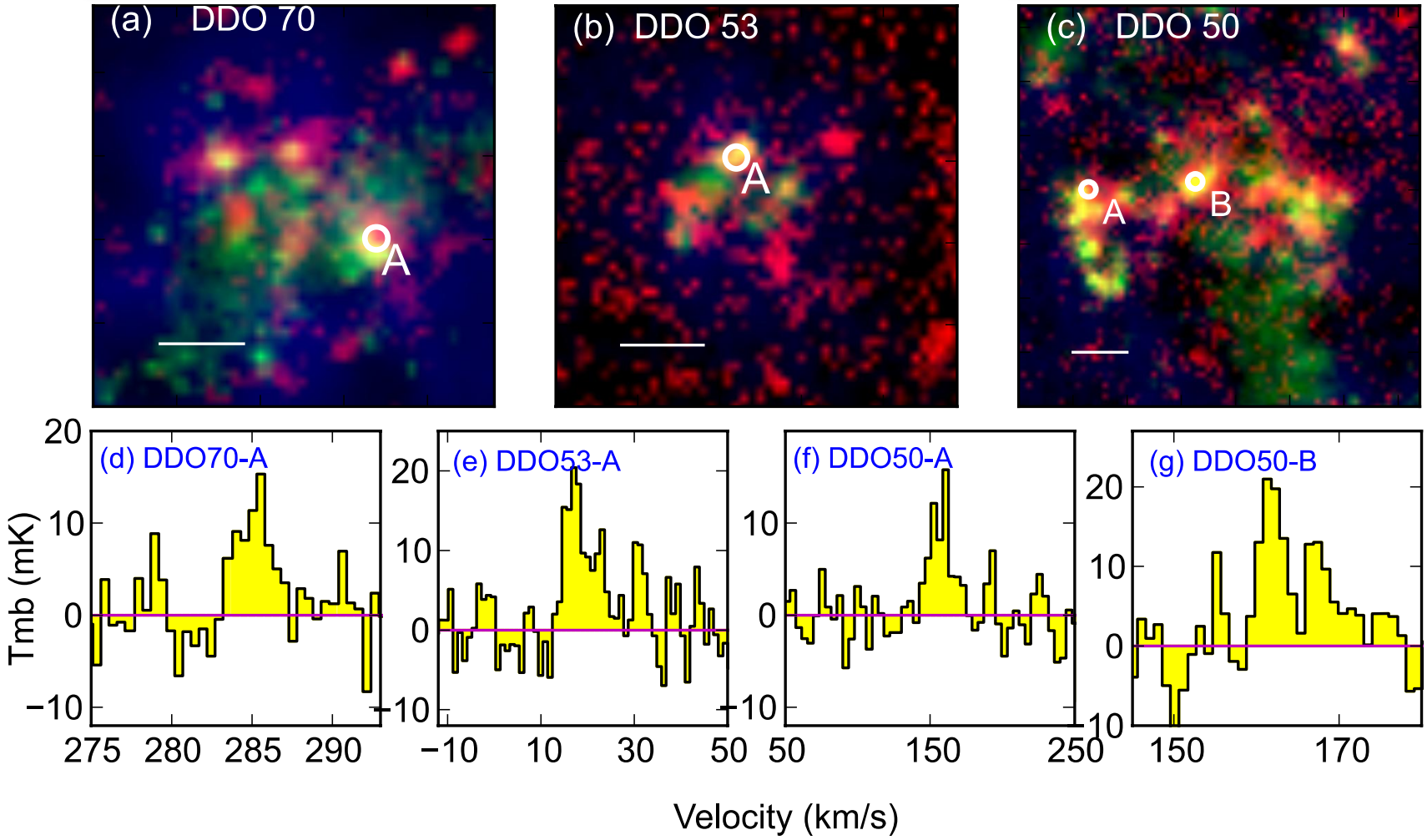
The first detection of CO below 10% Solar metallicity

CARBON MONOXIDE

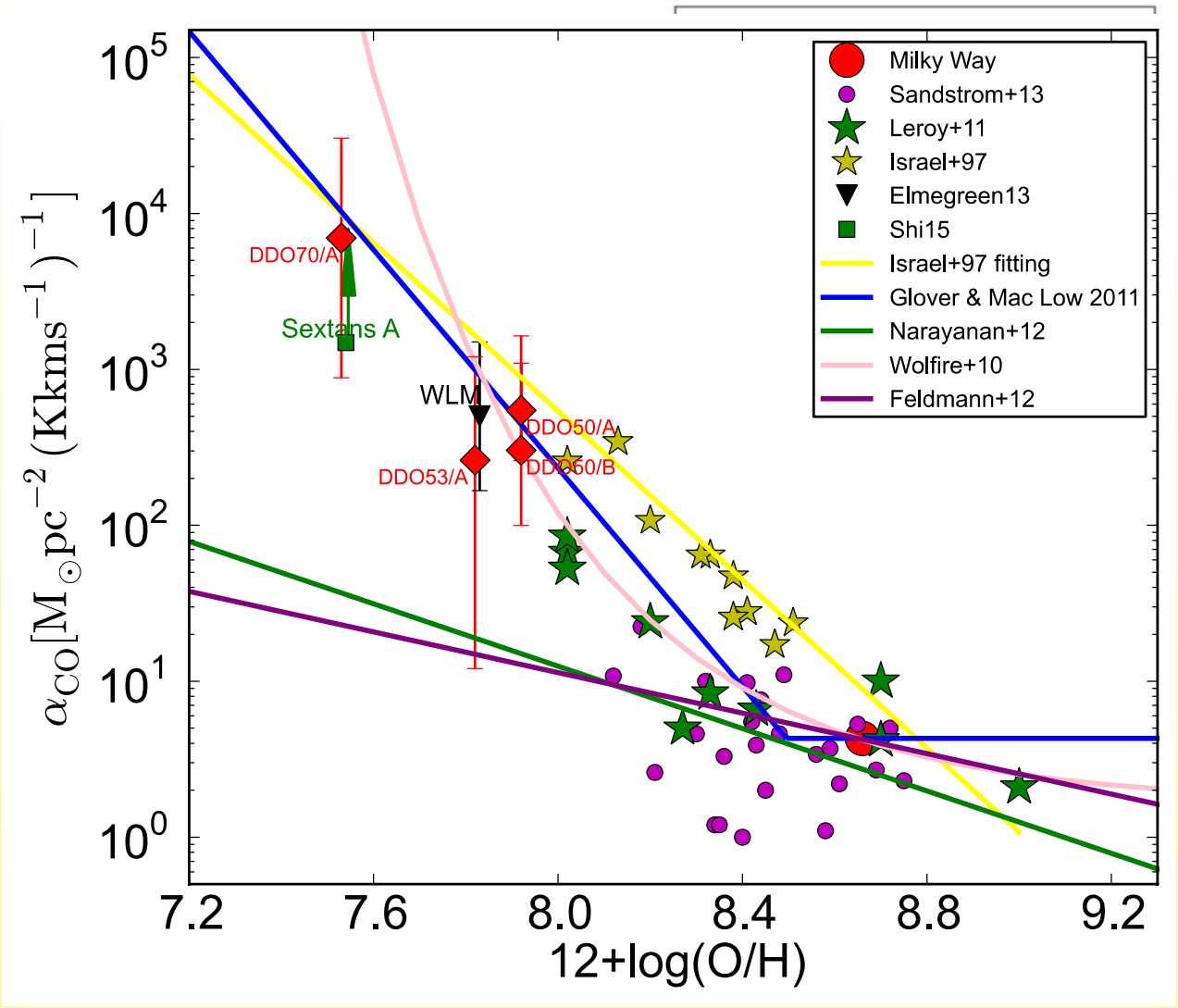
DDO70(7%Zsun)

DDO53(13%Zsun

DDO50(18%Zsun)



CARBON MONOXIDE



CARBON MONOXIDE

- Approved ALMA cycle-4 proposal (PI: Yong Shi, grade A)

- 0.1” = 0.7 pc
- 0.3 km/s
- 3 mJy to reach S/N=5

Summary

- The detection of CO at extremely low metallicity offers a direct evidence for the existence of molecular gas in extremely metal poor galaxies.

- CO could be still a tracer of molecular gas at very low metallicity with the conversion factor significantly larger than the Milky-Way value.