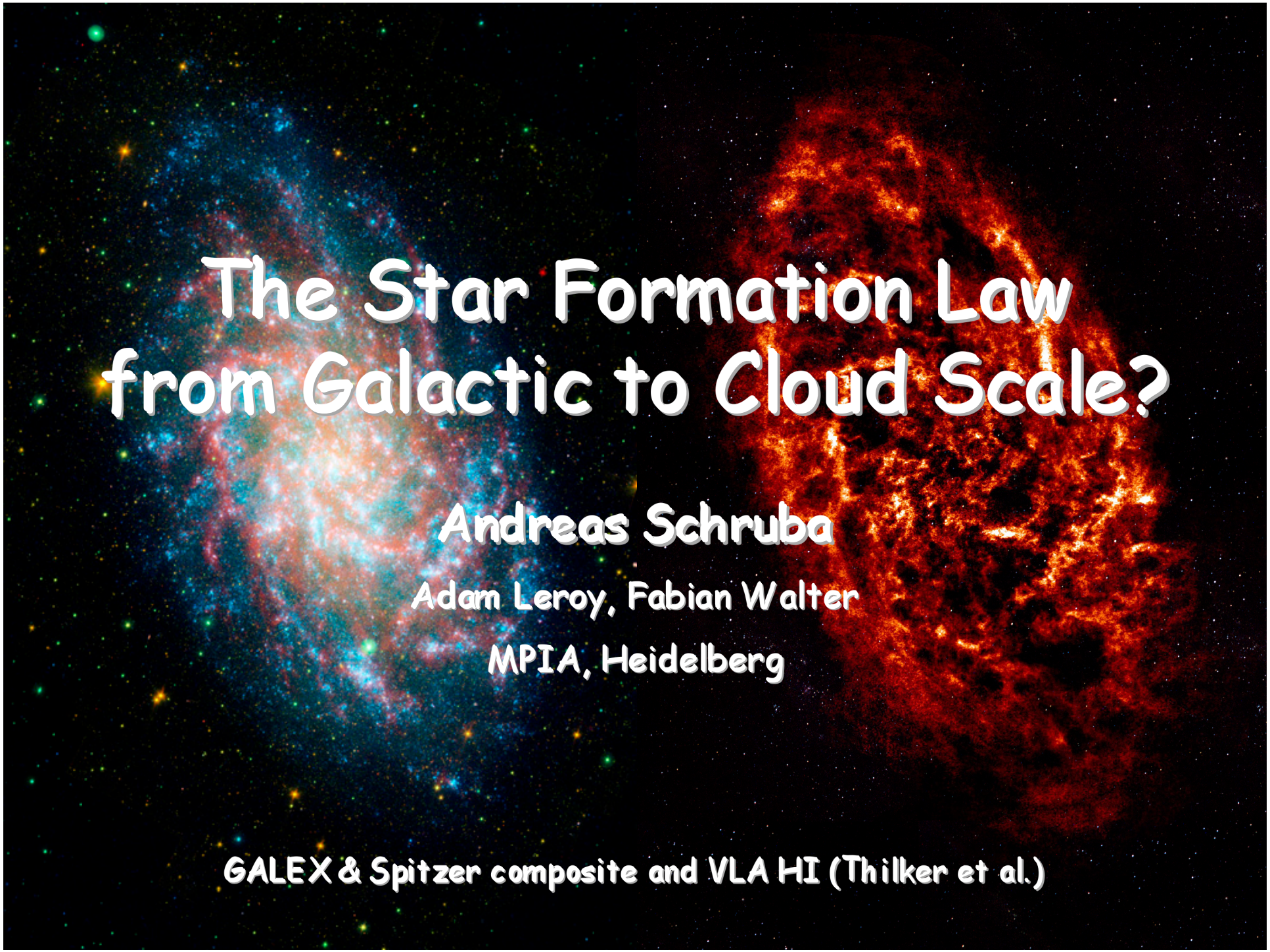
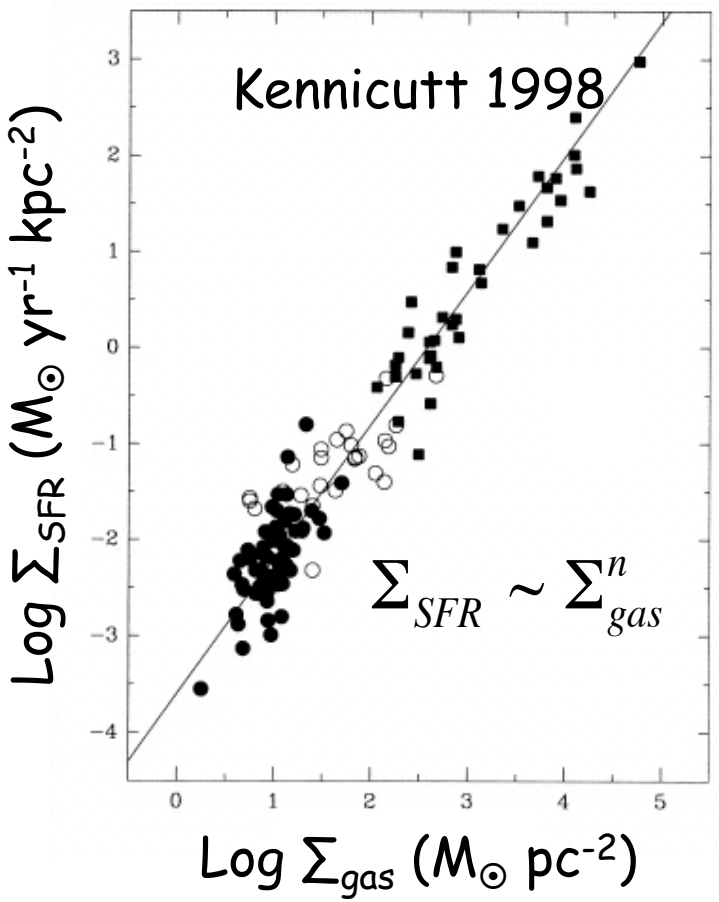

The Star Formation Law
from Galactic to Cloud Scale?
Andreas Schruba
Adam Leroy, Fabian Walter
MPIA, Heidelberg
GALEX & Spitzer composite and VLA HI (Thilker et al.)

Star Formation Law

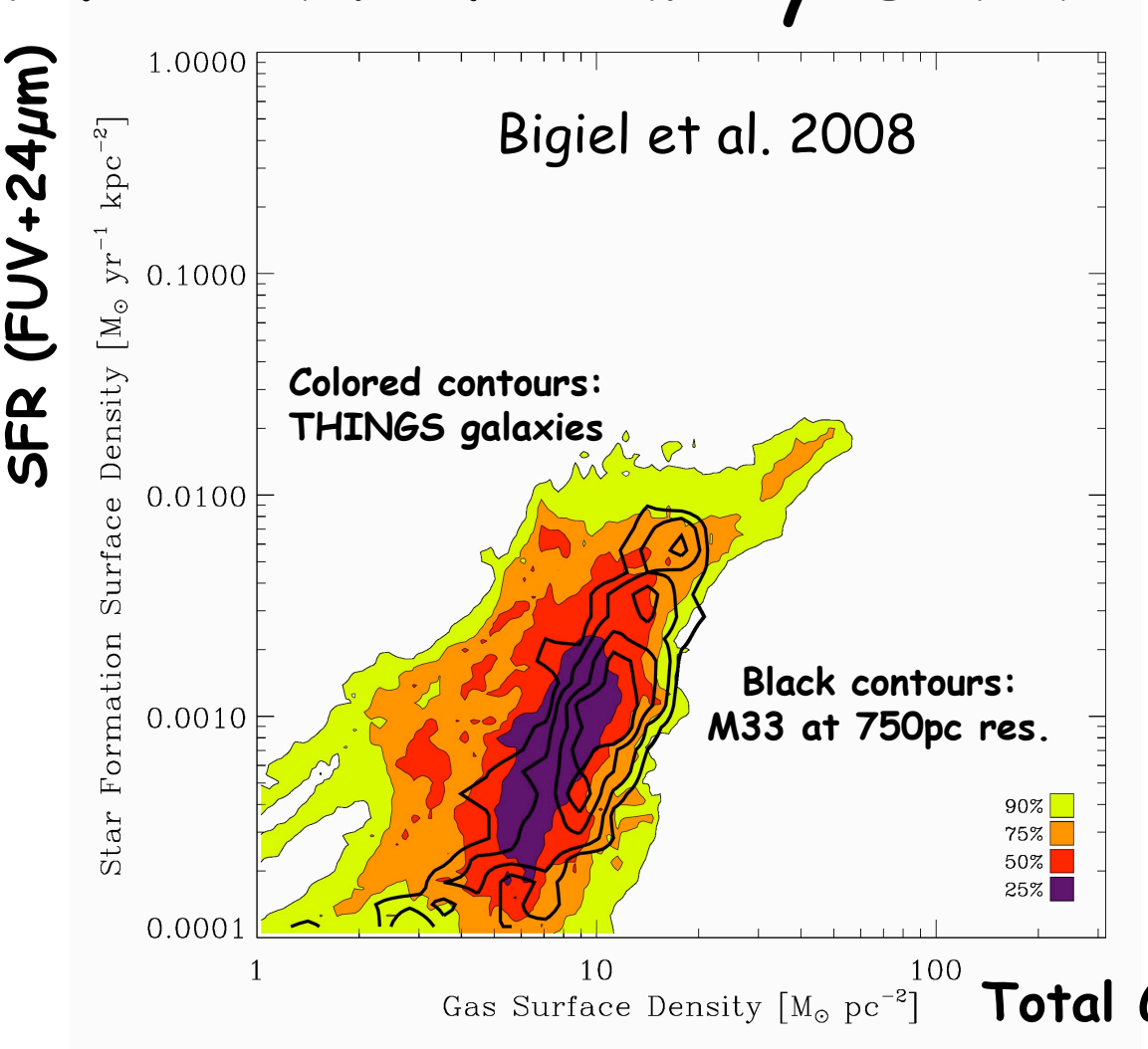
… the global picture



… the small scale picture

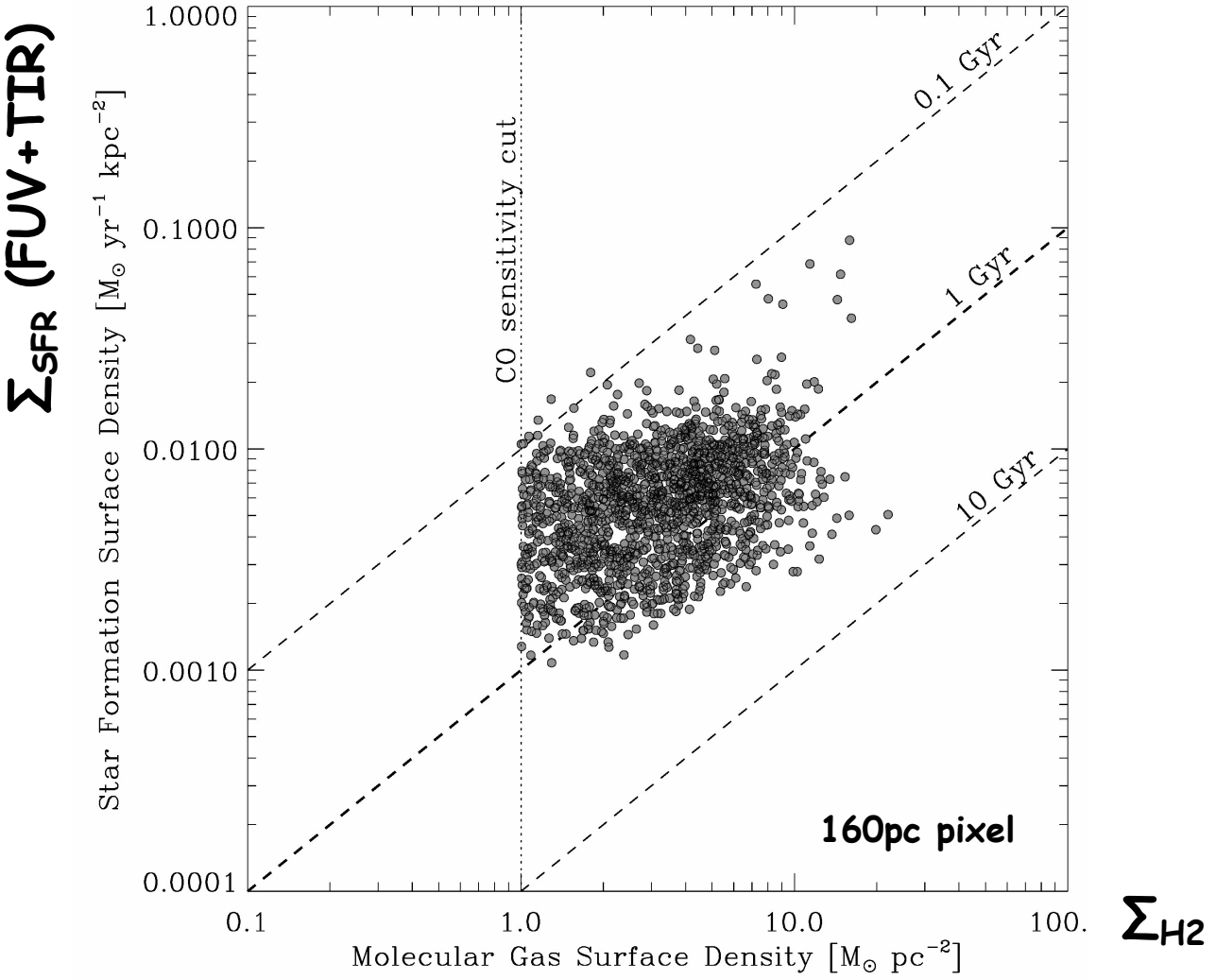
Newly formed stars and molecular gas are displaced
=> scaling relation has to end at some spatial scale

M33 and Nearby Galaxies

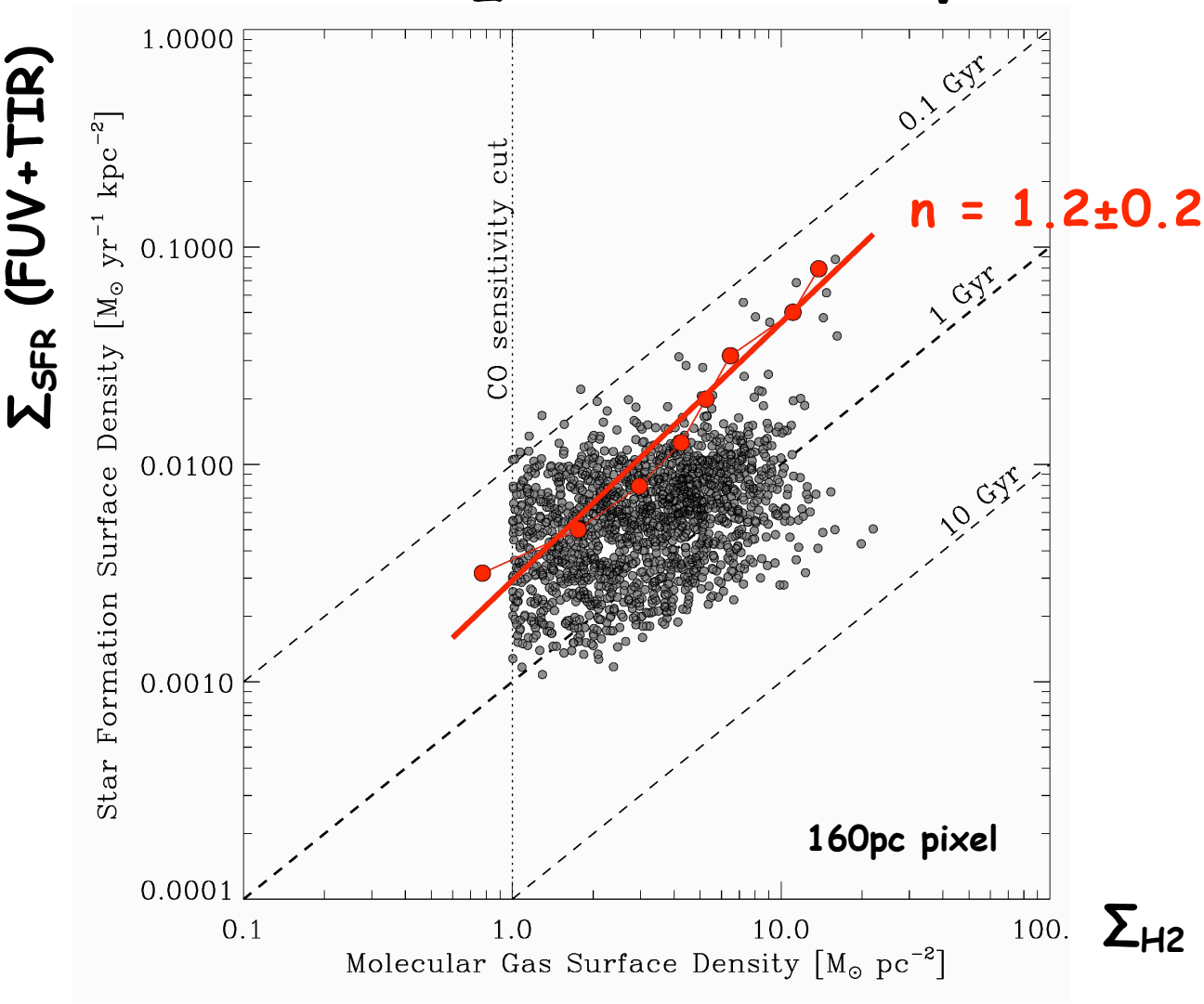


HI: Deul & van der Hulst; CO: Rosolowsky et al. ; IR: Gerhz et al. ; FUV: Thilker et al.

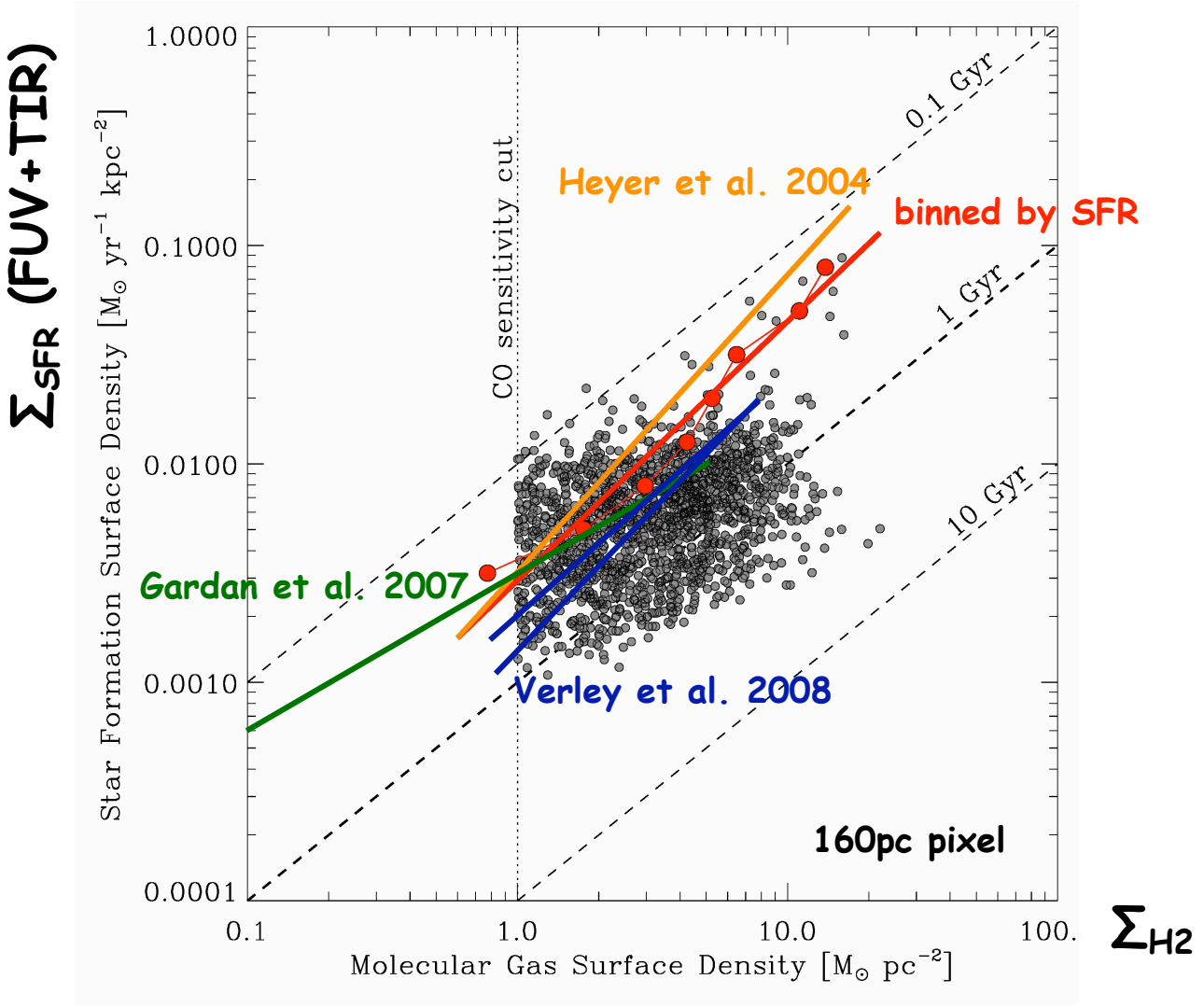
SFR vs. H_2 Pixel-by-Pixel



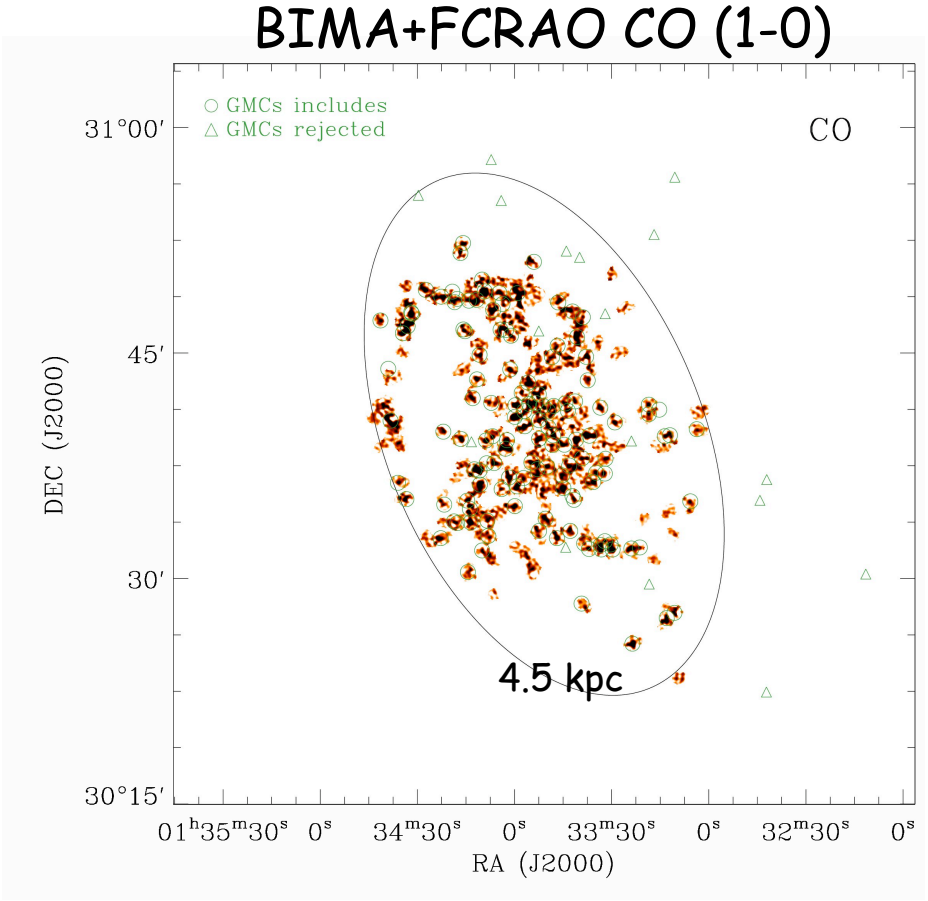
SFR vs. H_2 binned by SFR



SFR vs. H_2 Radial Profiles



CO Map & GMC Catalog



CO data is signal masked

$X_{CO} = 2 \times 10^{20}$ cm^{-2} (K km s^{-1})$^{-1}$

Heavy elements: ×1.36

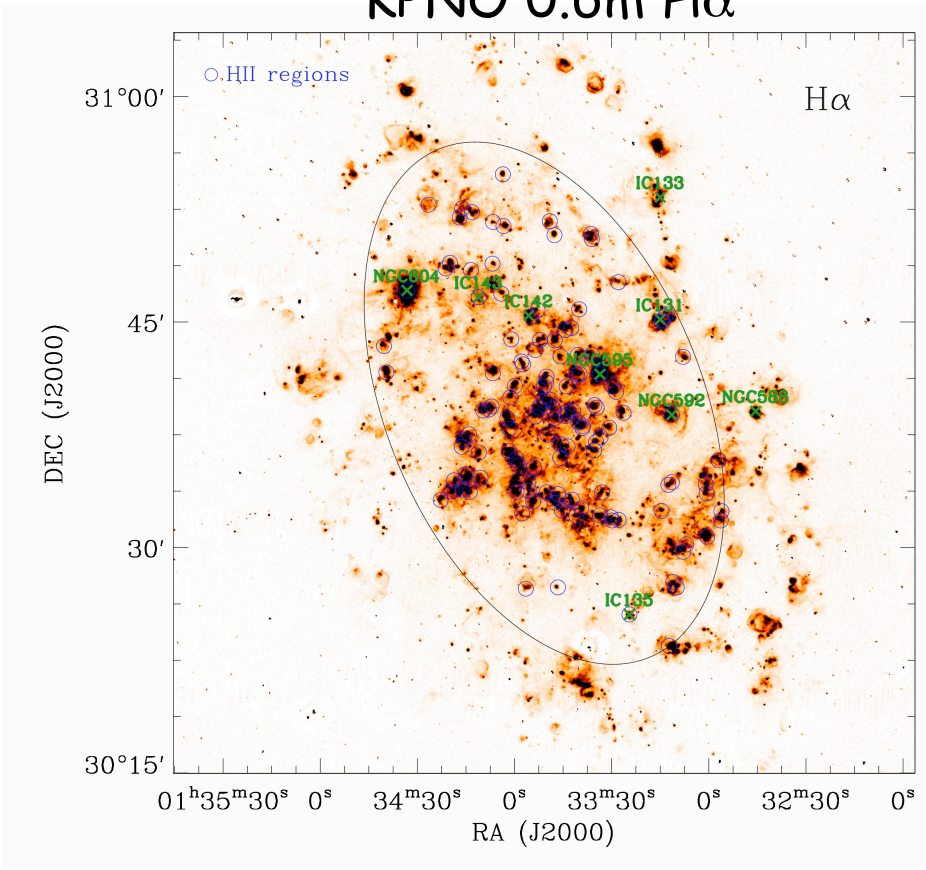
GMC Catalog from Rosolowsky et al 2007

132 positions that overlap with signal masked CO map (circles)

Rosolowsky et al. 2007 combining data from
BIMA: Engargiola et al. 2003 and FCRAO: Heyer et al. 2004

Hα Map & HII Regions

KPNO 0.6m Hα

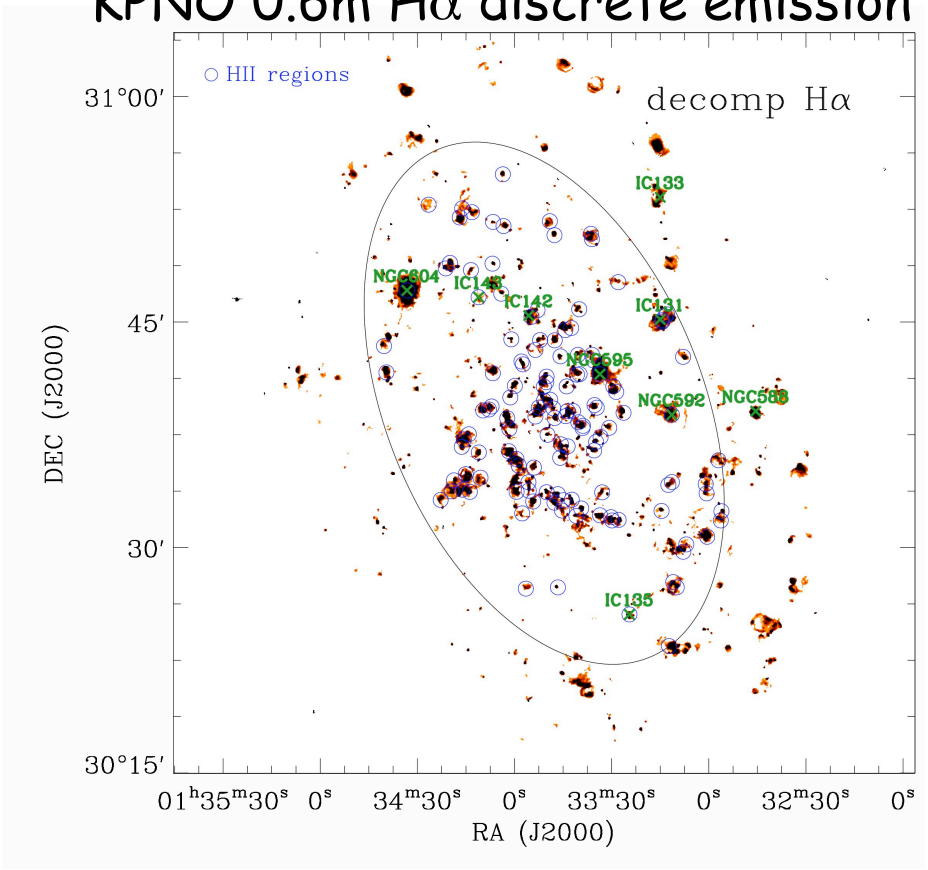


Greenawalt 1998 and Hoopes & Walterbos 2000

Hα: continuum subtracted and diffuse-emission-subtracted

Hα Map & HII Regions

KPNO 0.6m Hα discrete emission



Greenawalt 1998 and Hoopes & Walterbos 2000

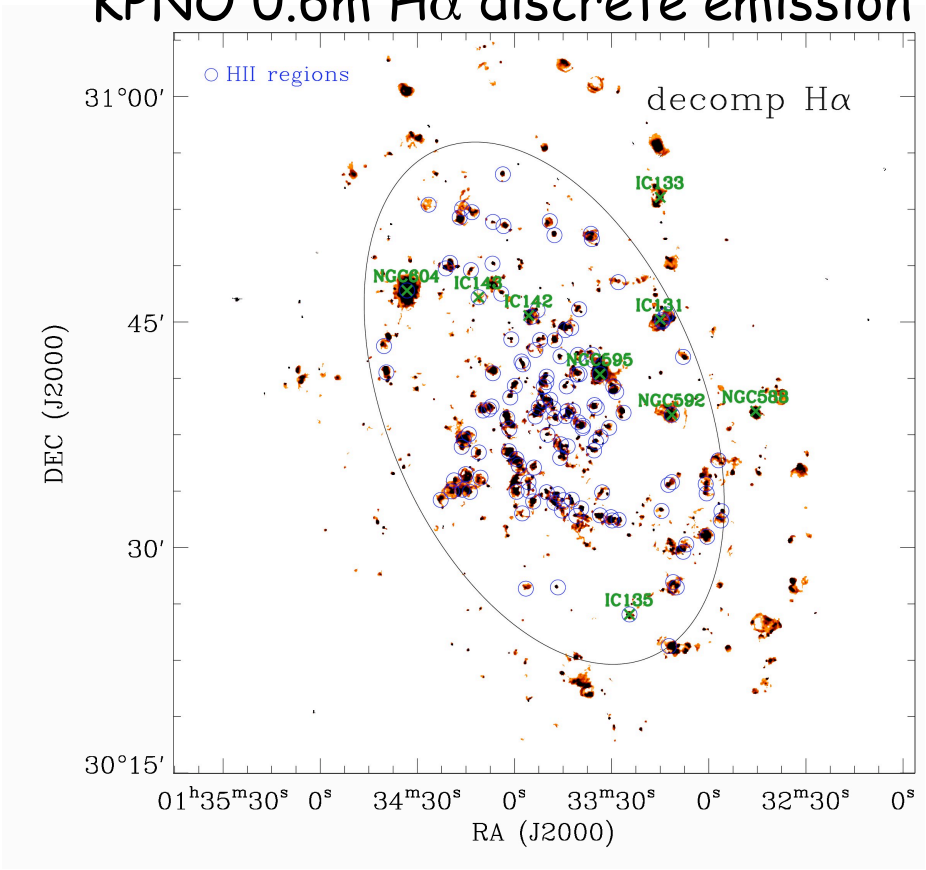
Hα: continuum subtracted and diffuse-emission-subtracted

HII regions catalog from Hodge et al. 2002

-> 132 brigthest complexes

SFR (Hα+24μm)

KPNO 0.6m Hα discrete emission



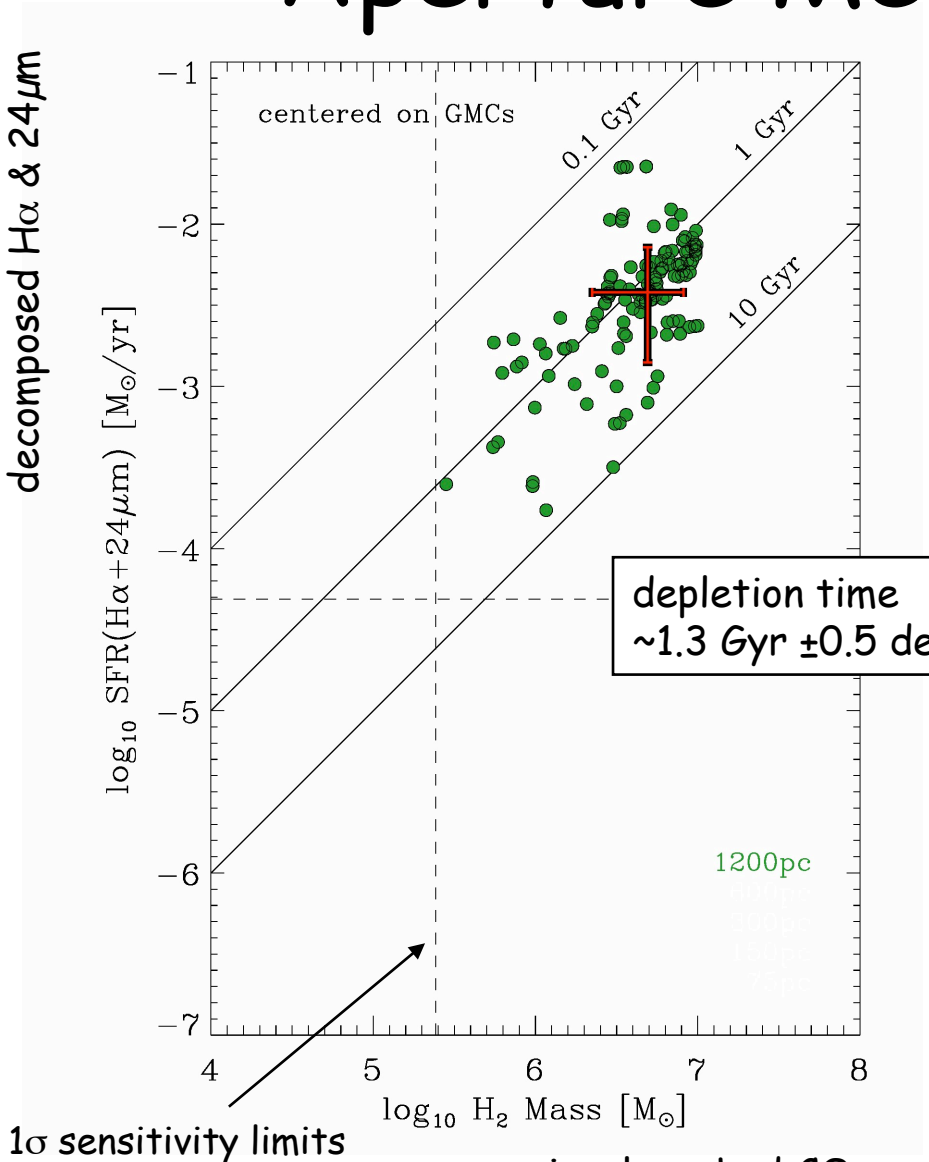
Grenawalt 1998 and Hoopes & Walterbos 2000

Hα: continuum subtracted and diffuse-emission-subtracted

MIPS 24μm (Gehrz et al. 2005, Gordon 2009) diffuse-subtraced as Hα

SFR(Hα+24μm) from Calzetti et al. 2007

Aperture Measurements



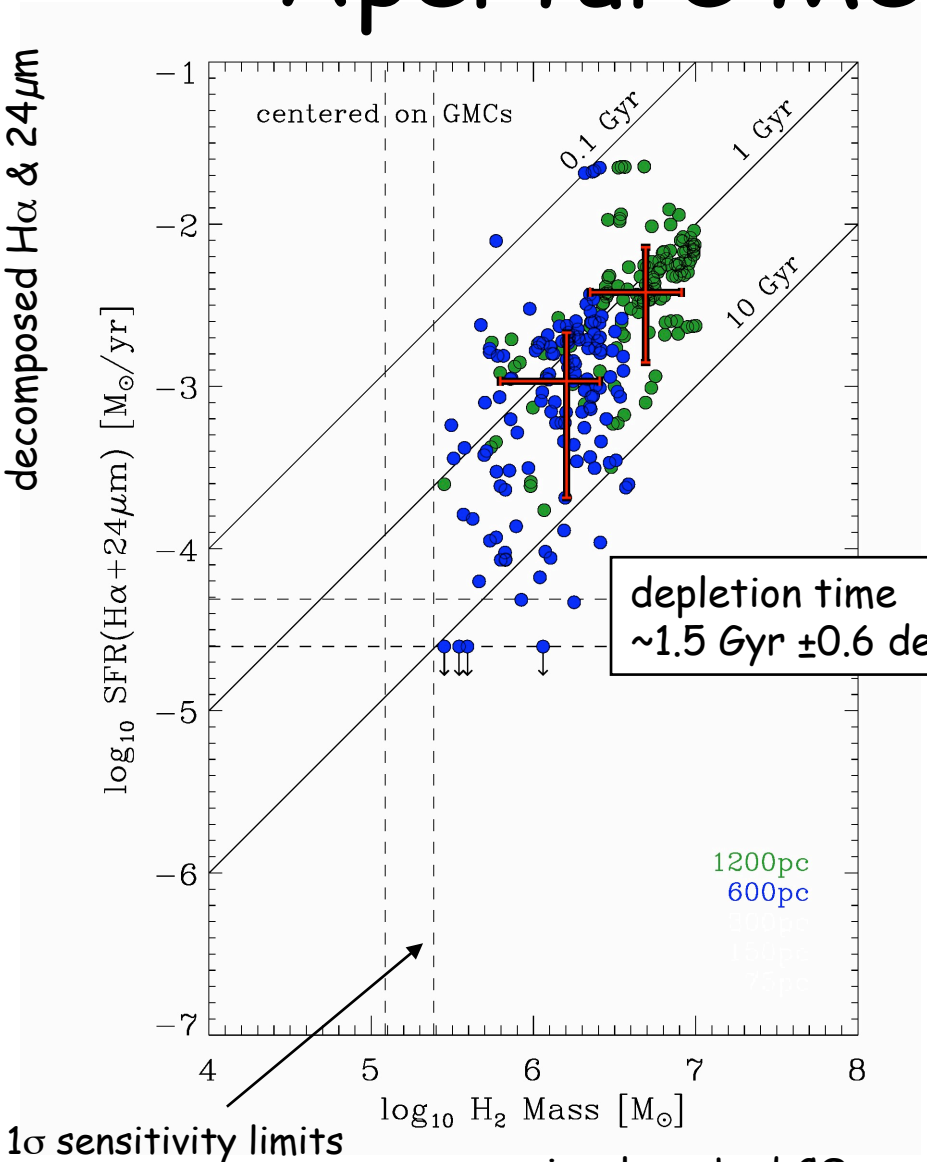
decomposed Hα & 24μm

depletion time
~1.3 Gyr ±0.5 dex

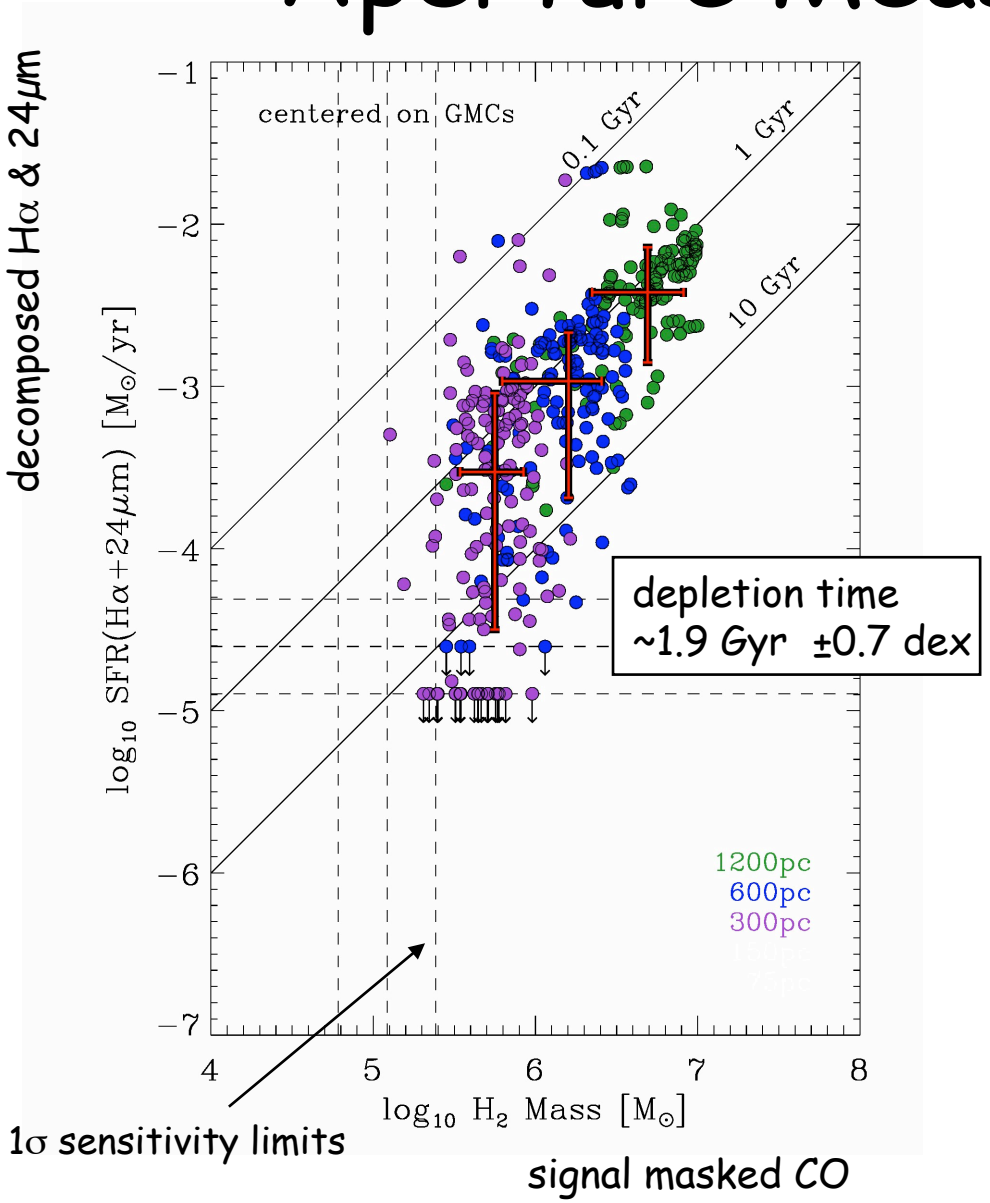
1σ sensitivity limits

signal masked CO

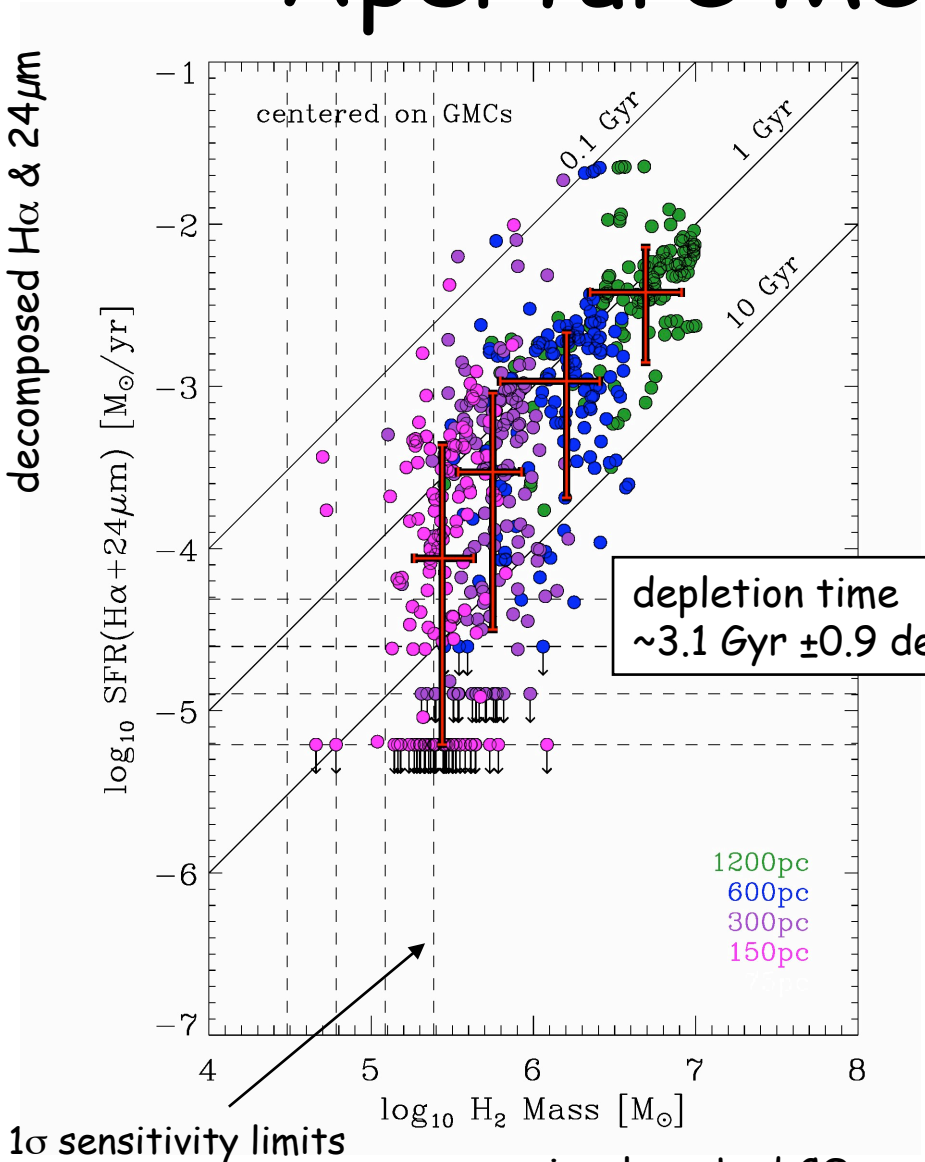
Aperture Measurements



Aperture Measurements



Aperture Measurements

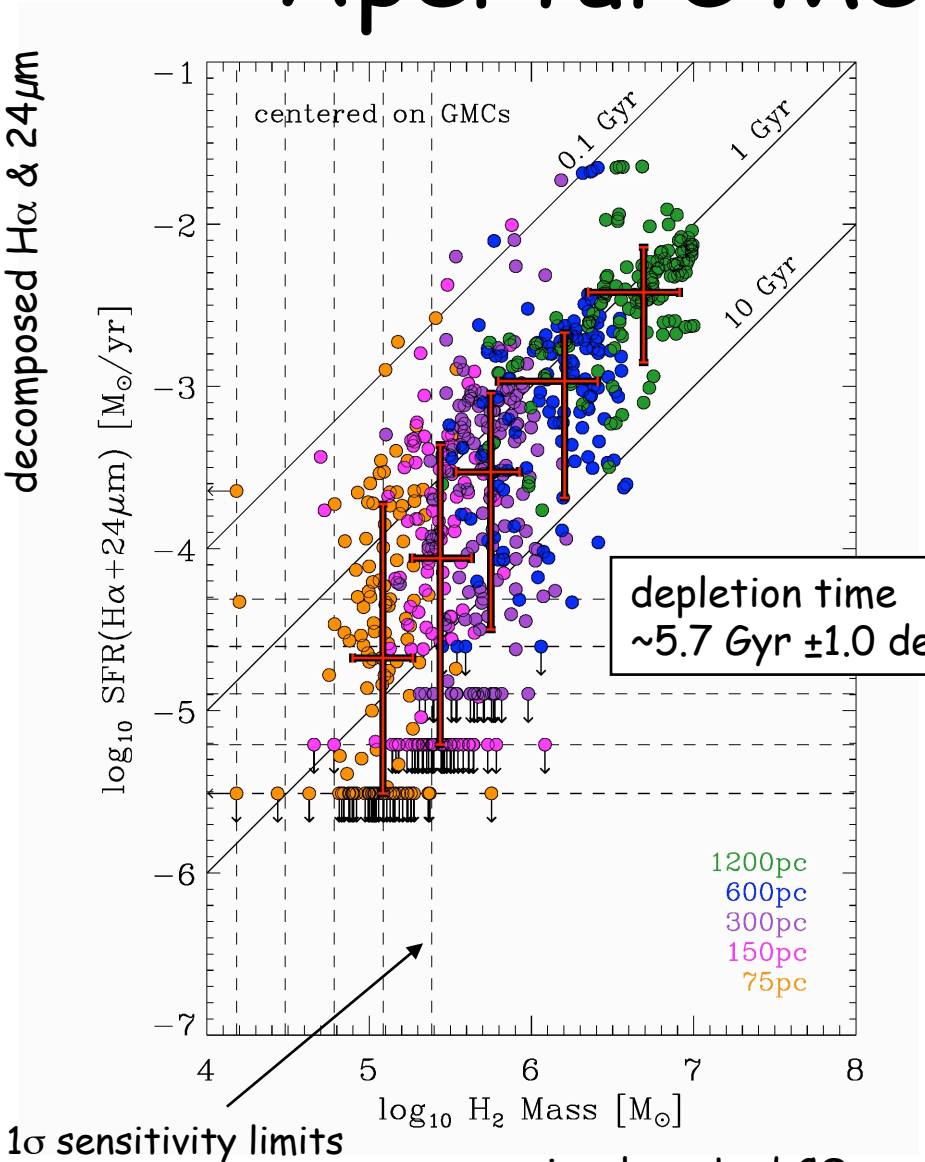


decomposed Hα & 24μm

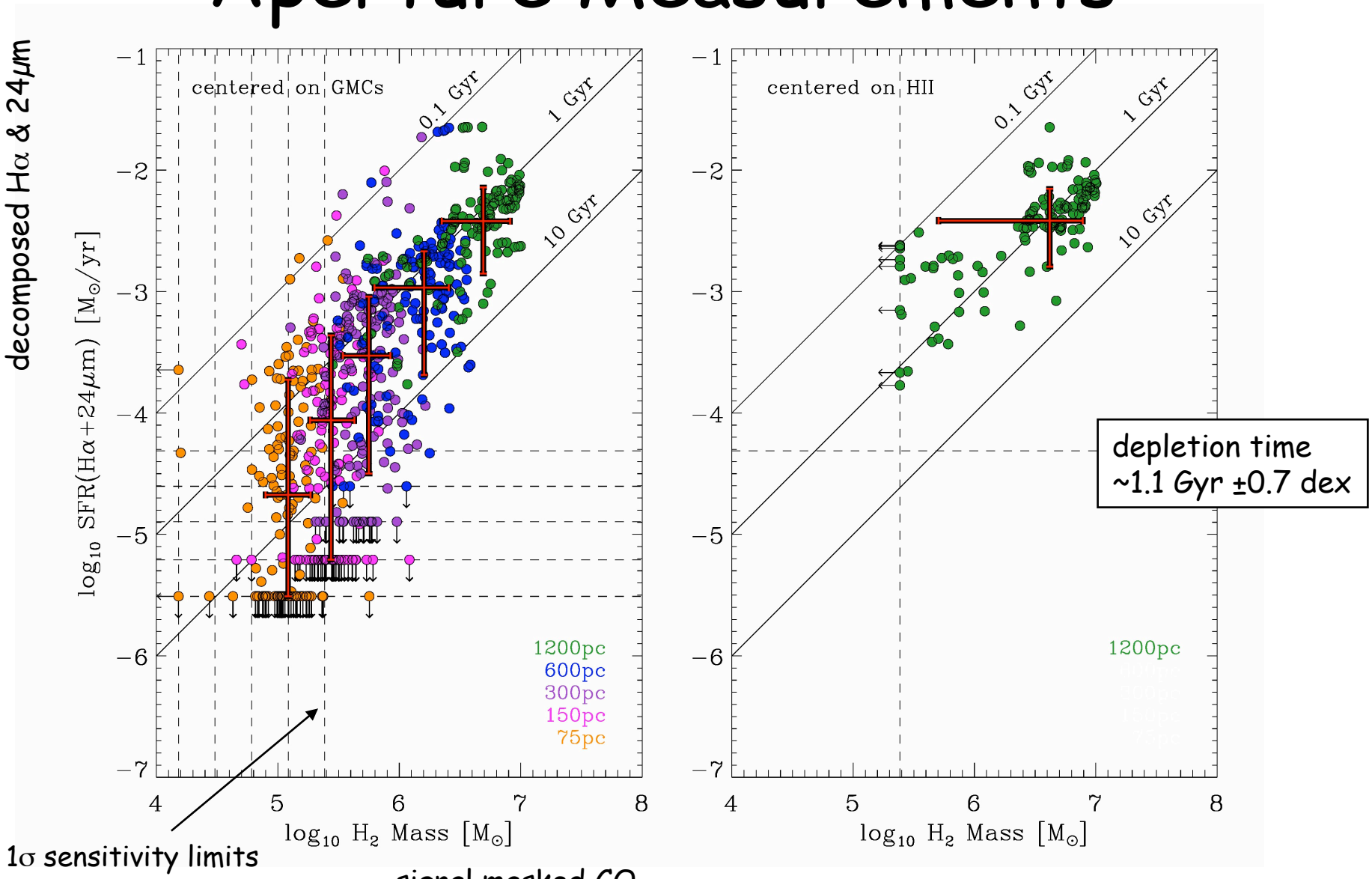
1σ sensitivity limits

signal masked CO

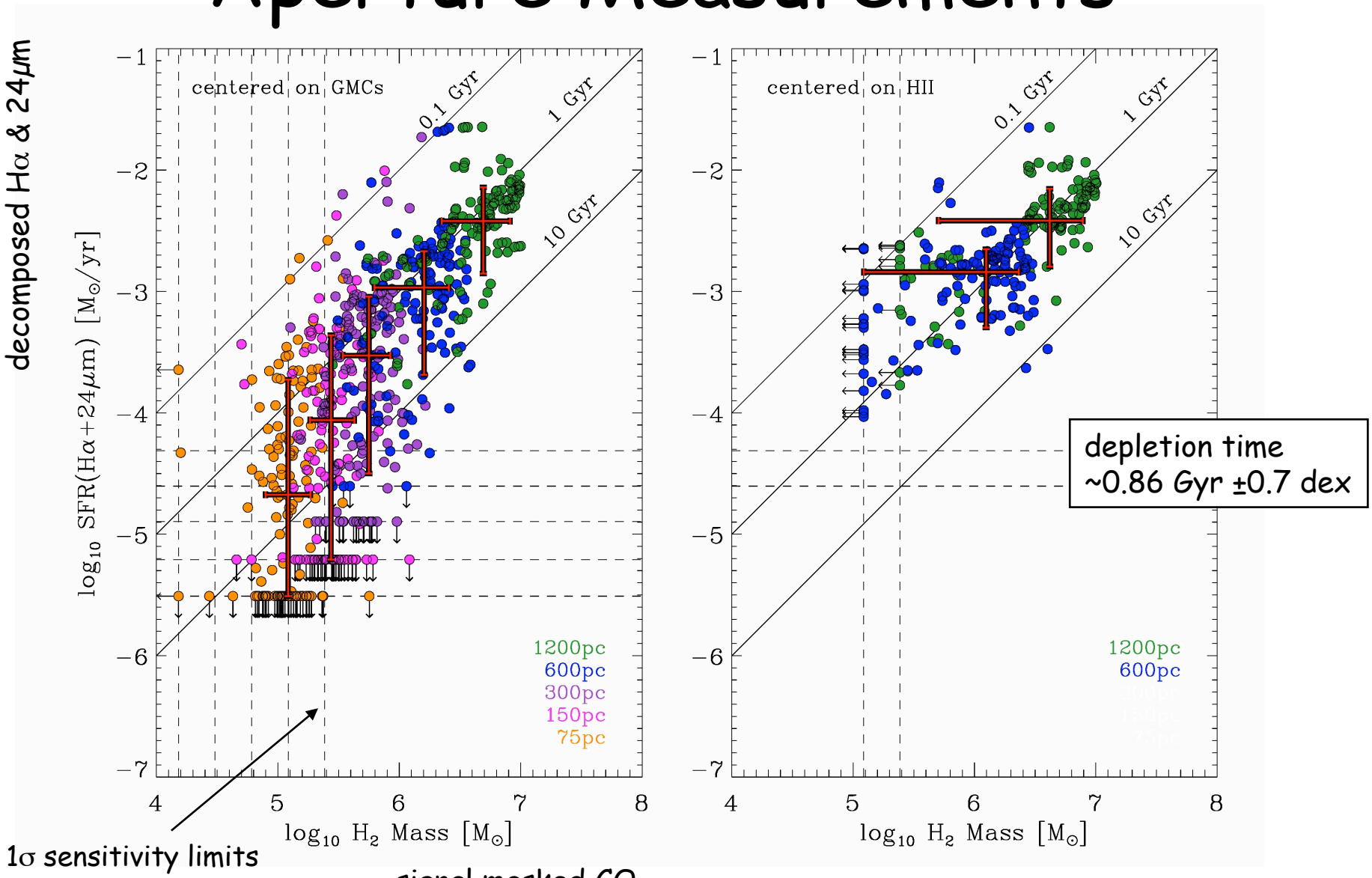
Aperture Measurements



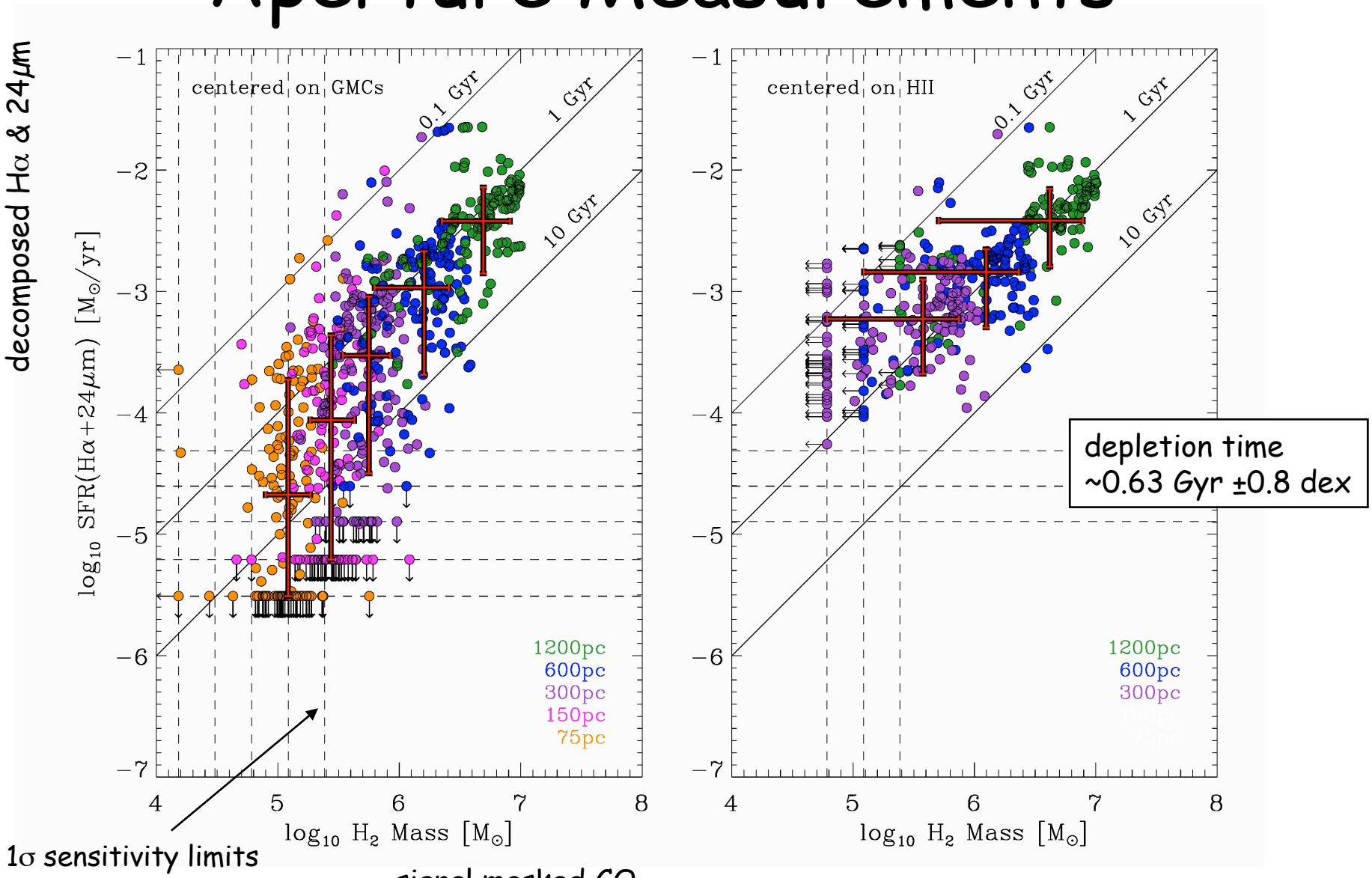
Aperture Measurements



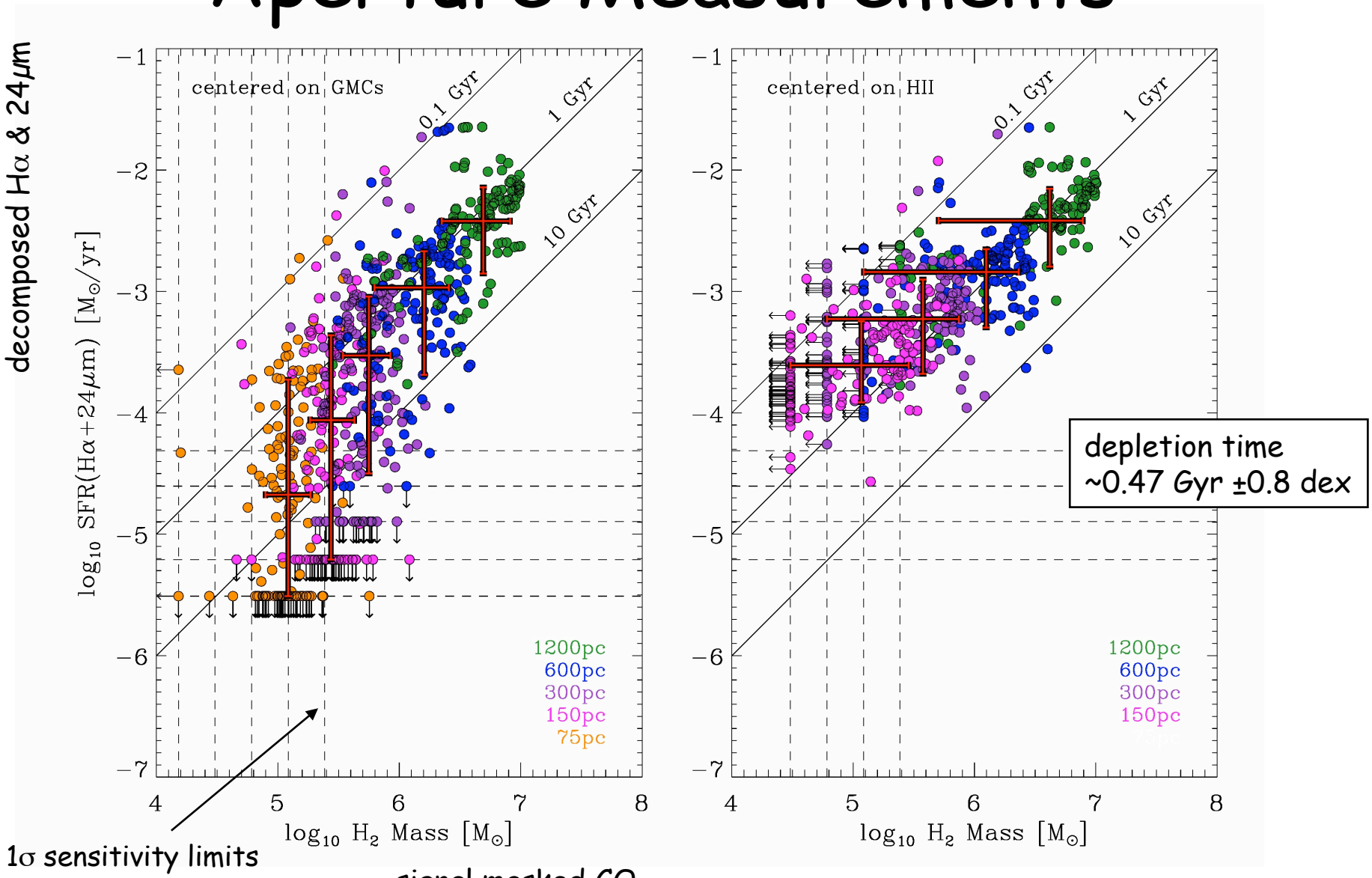
Aperture Measurements



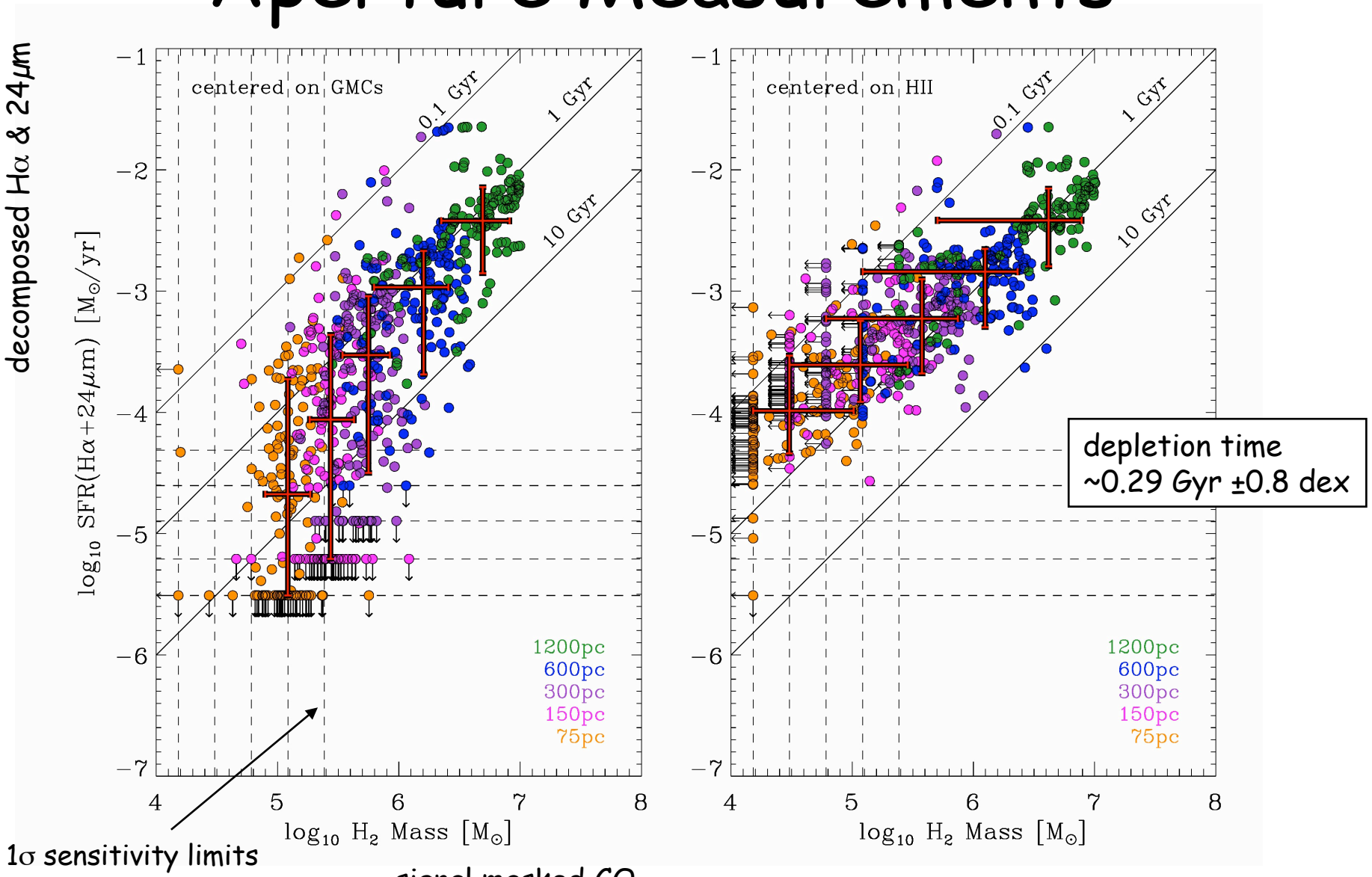
Aperture Measurements



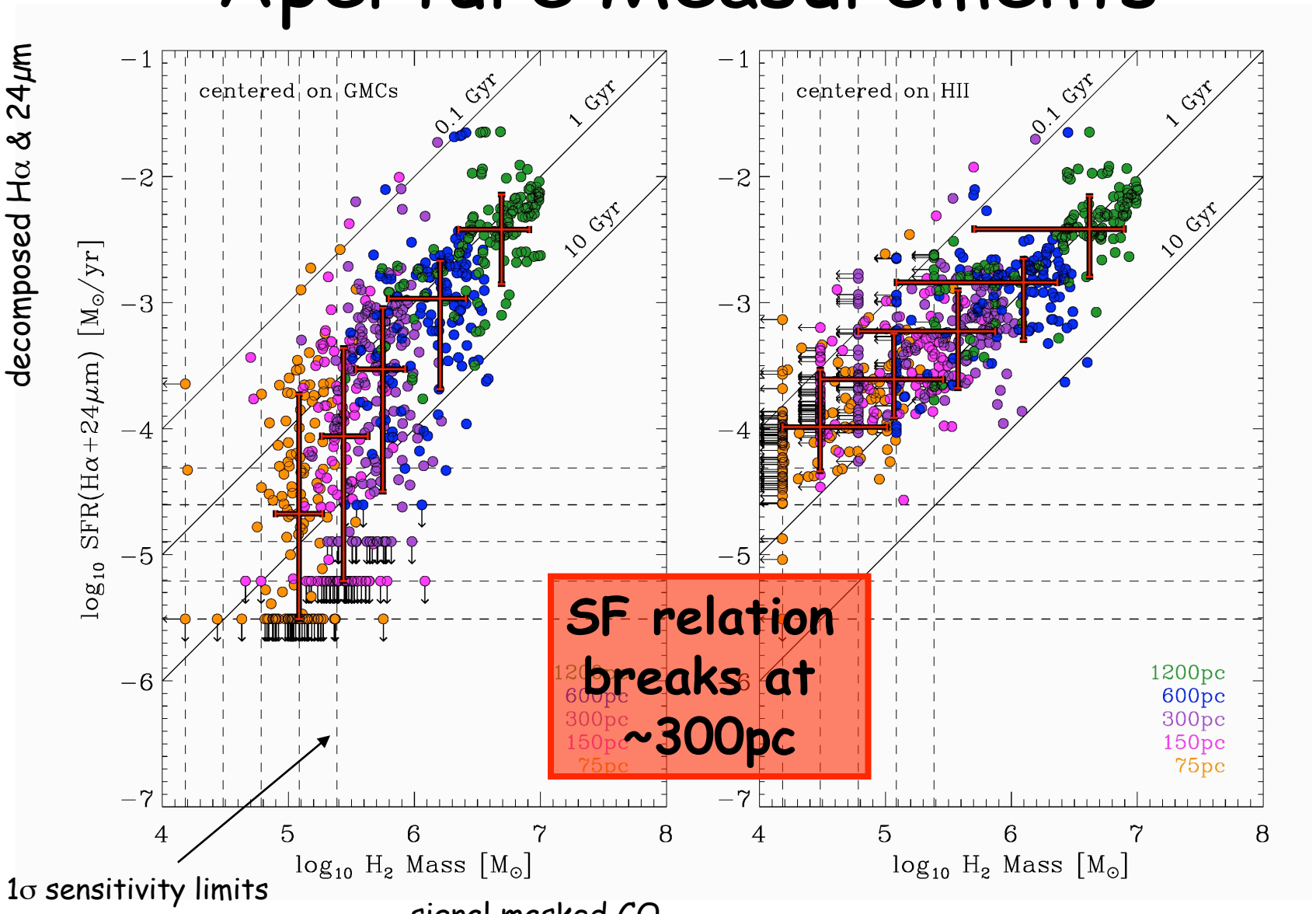
Aperture Measurements



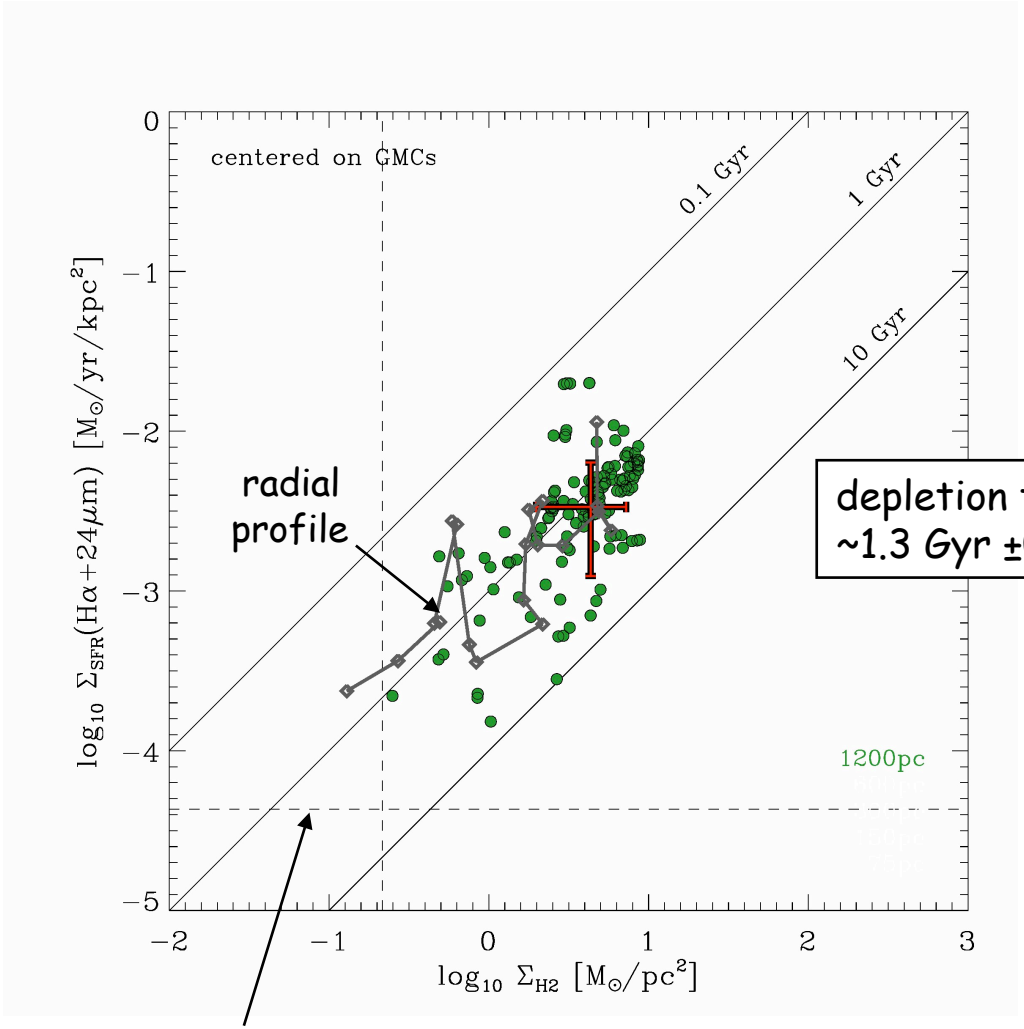
Aperture Measurements



Aperture Measurements



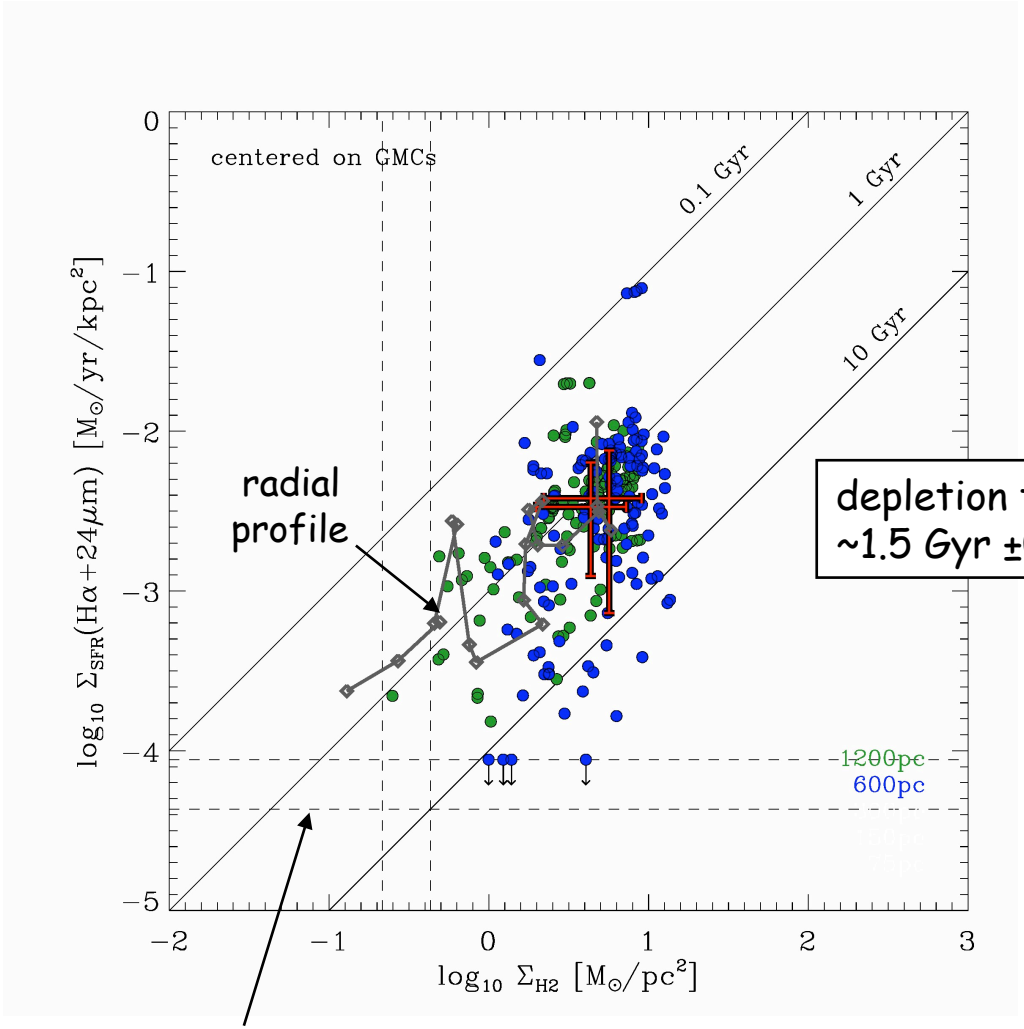
SFR & H_2 Surface Density



1σ sensitivity limits

(surface densities not inclination corrected)

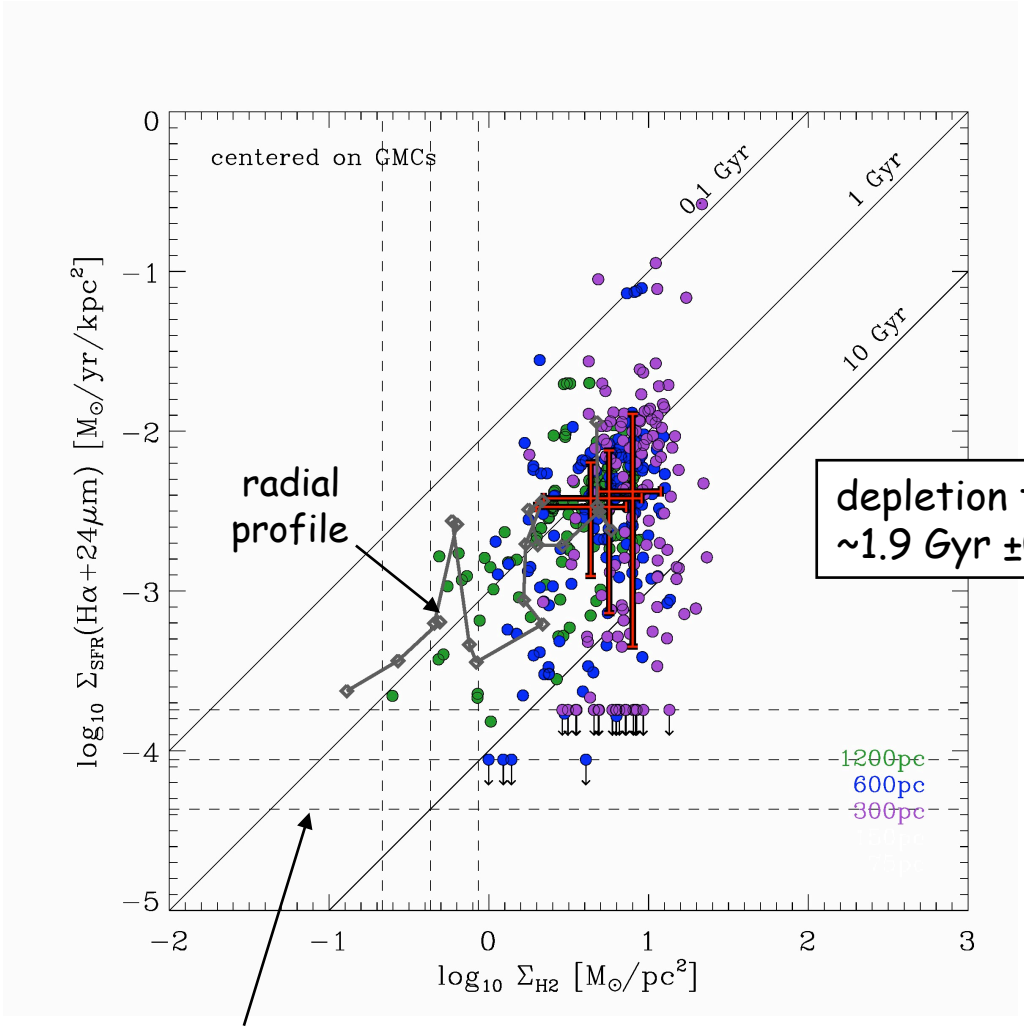
SFR & H_2 Surface Density



1σ sensitivity limits

(surface densities not inclination corrected)

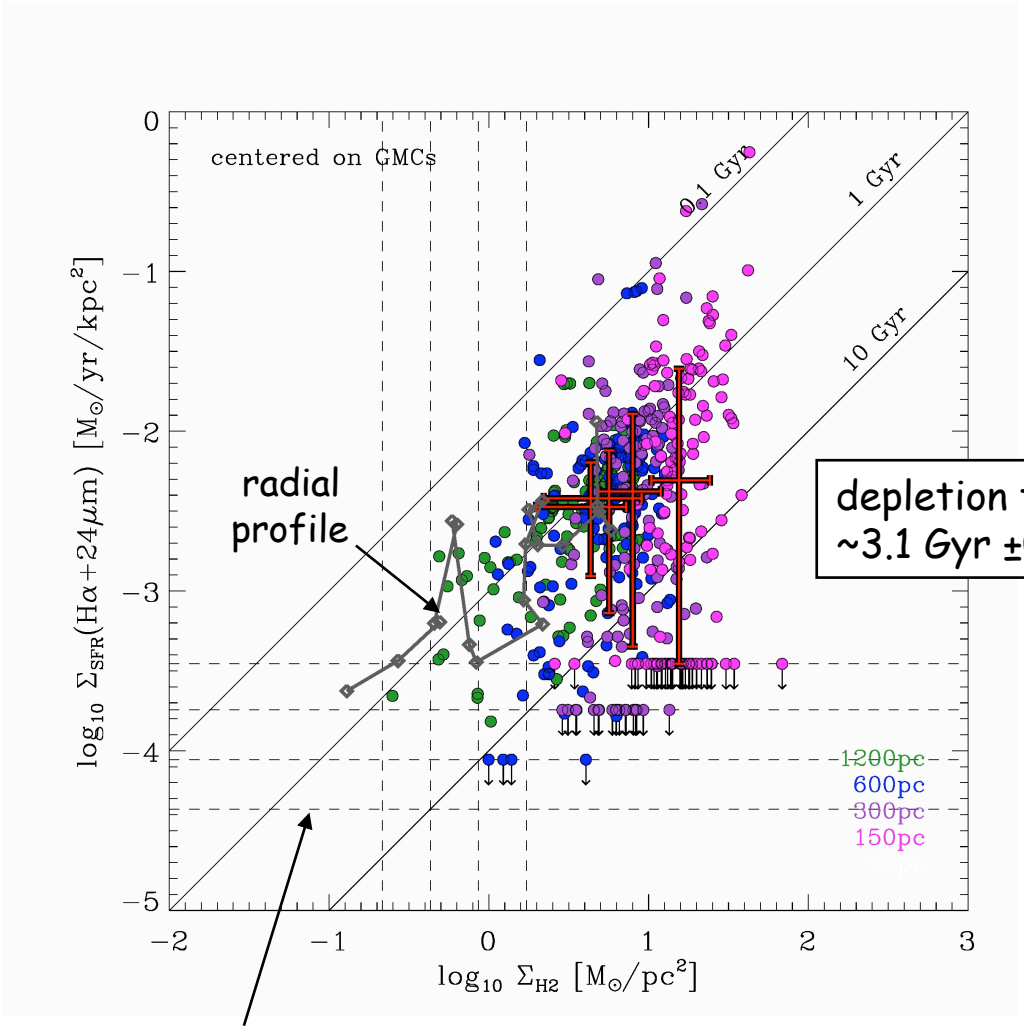
SFR & H_2 Surface Density



1σ sensitivity limits

(surface densities not inclination corrected)

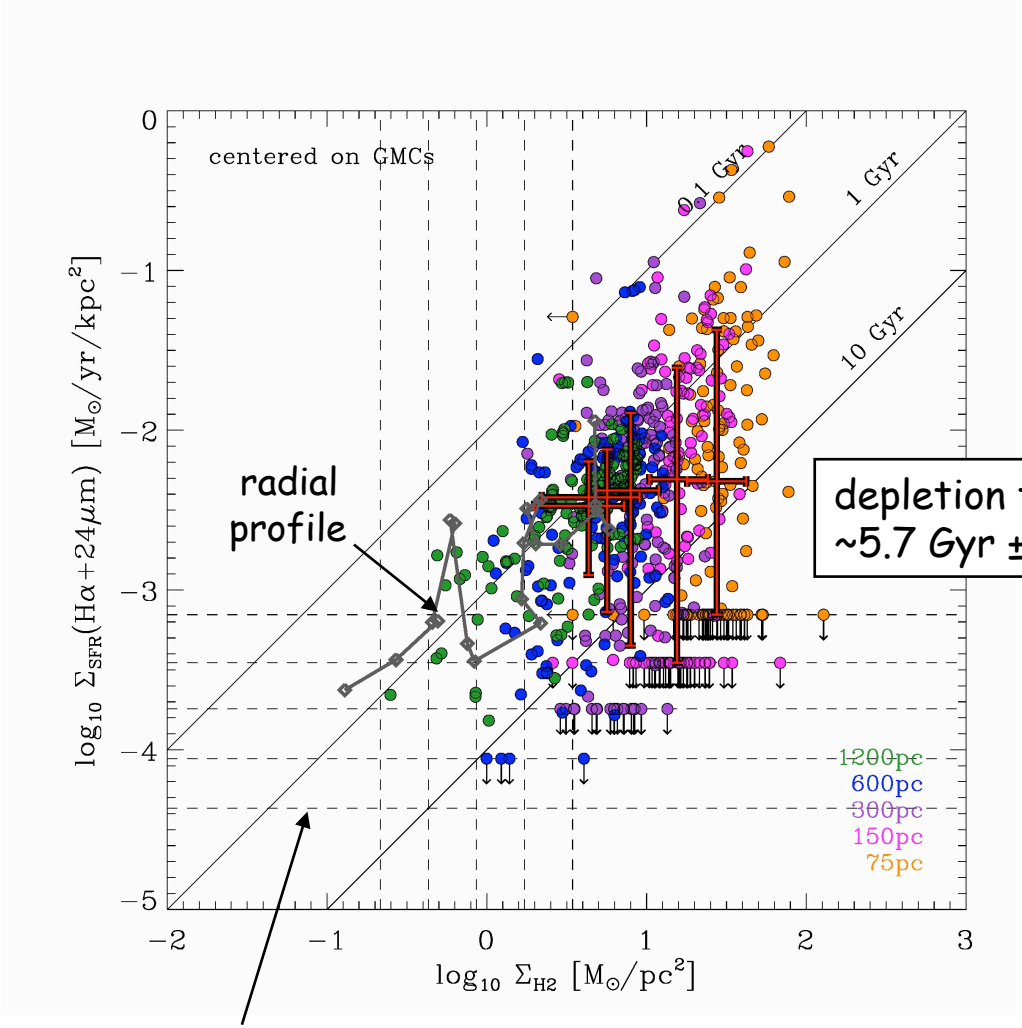
SFR & H_2 Surface Density



1σ sensitivity limits

(surface densities not inclination corrected)

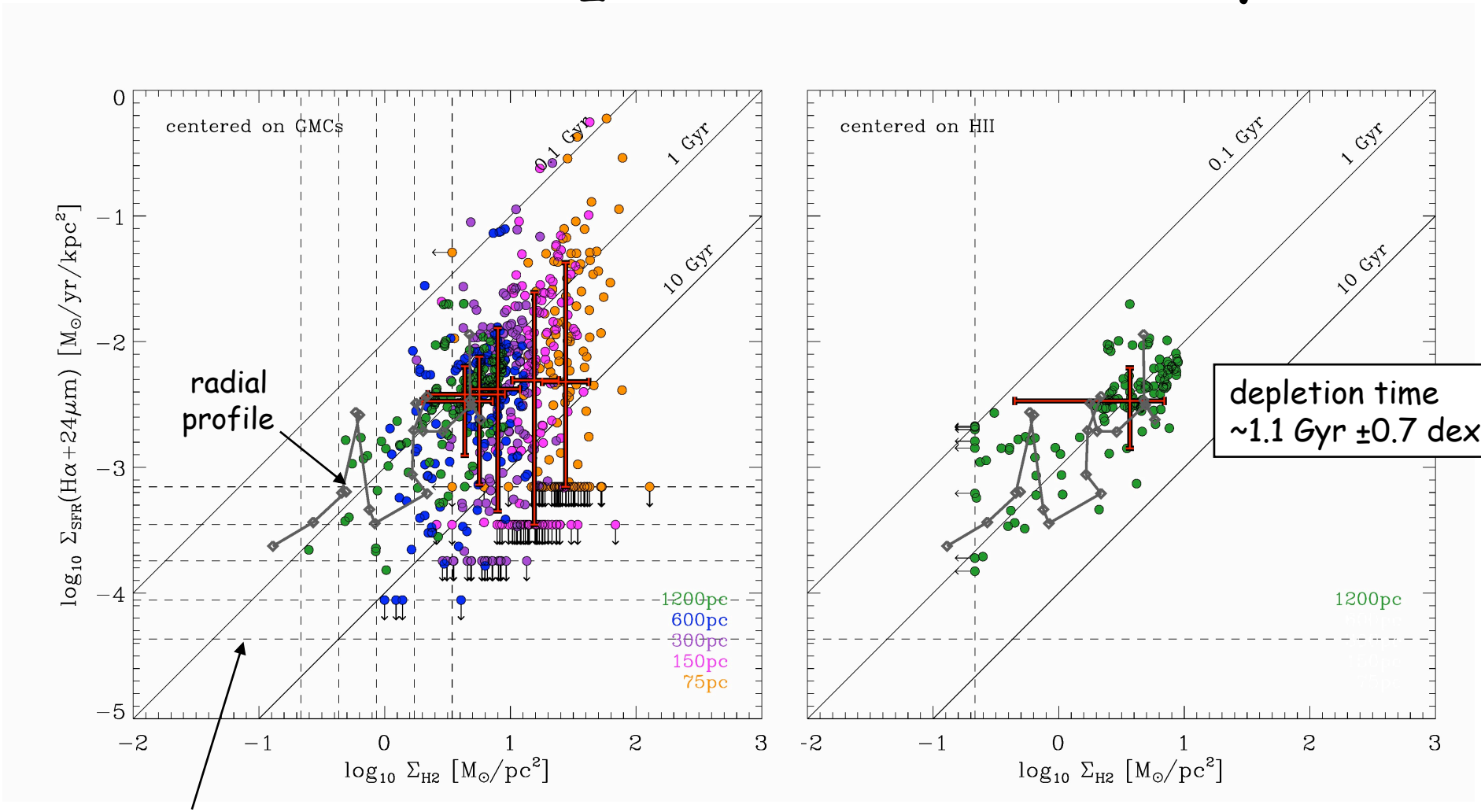
SFR & H_2 Surface Density



1σ sensitivity limits

(surface densities not inclination corrected)

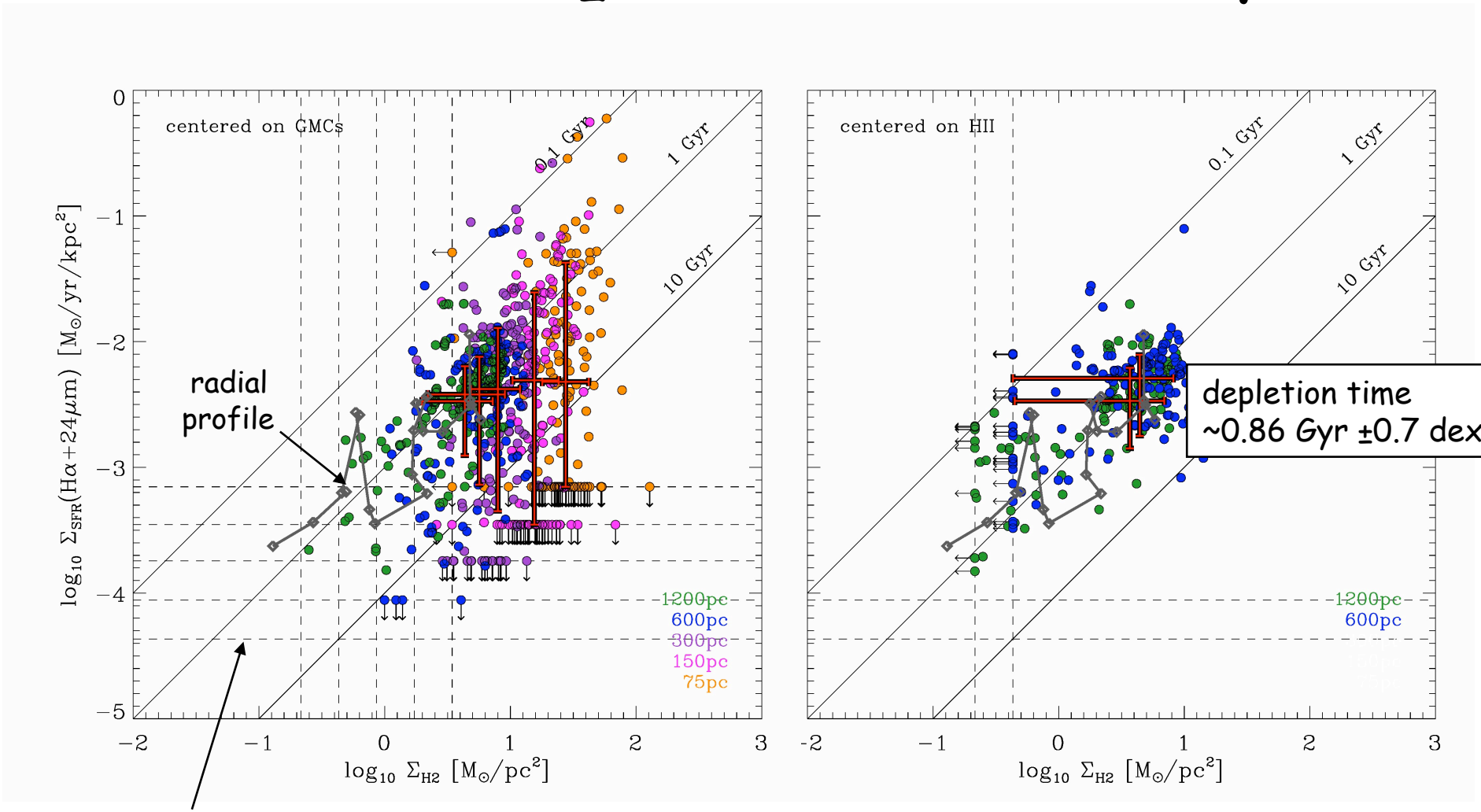
SFR & H_2 Surface Density



1σ sensitivity limits

(surface densities not inclination corrected)

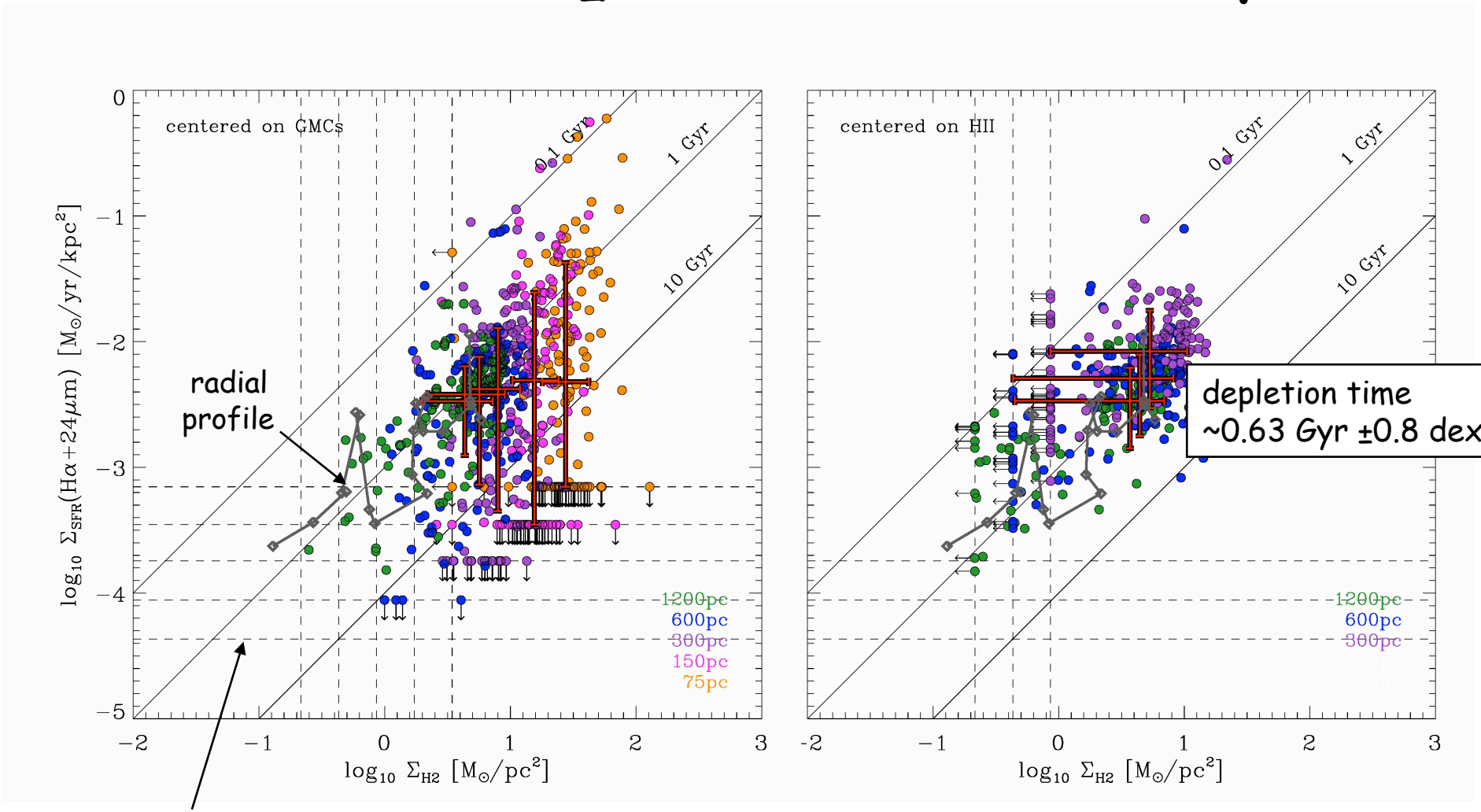
SFR & H_2 Surface Density



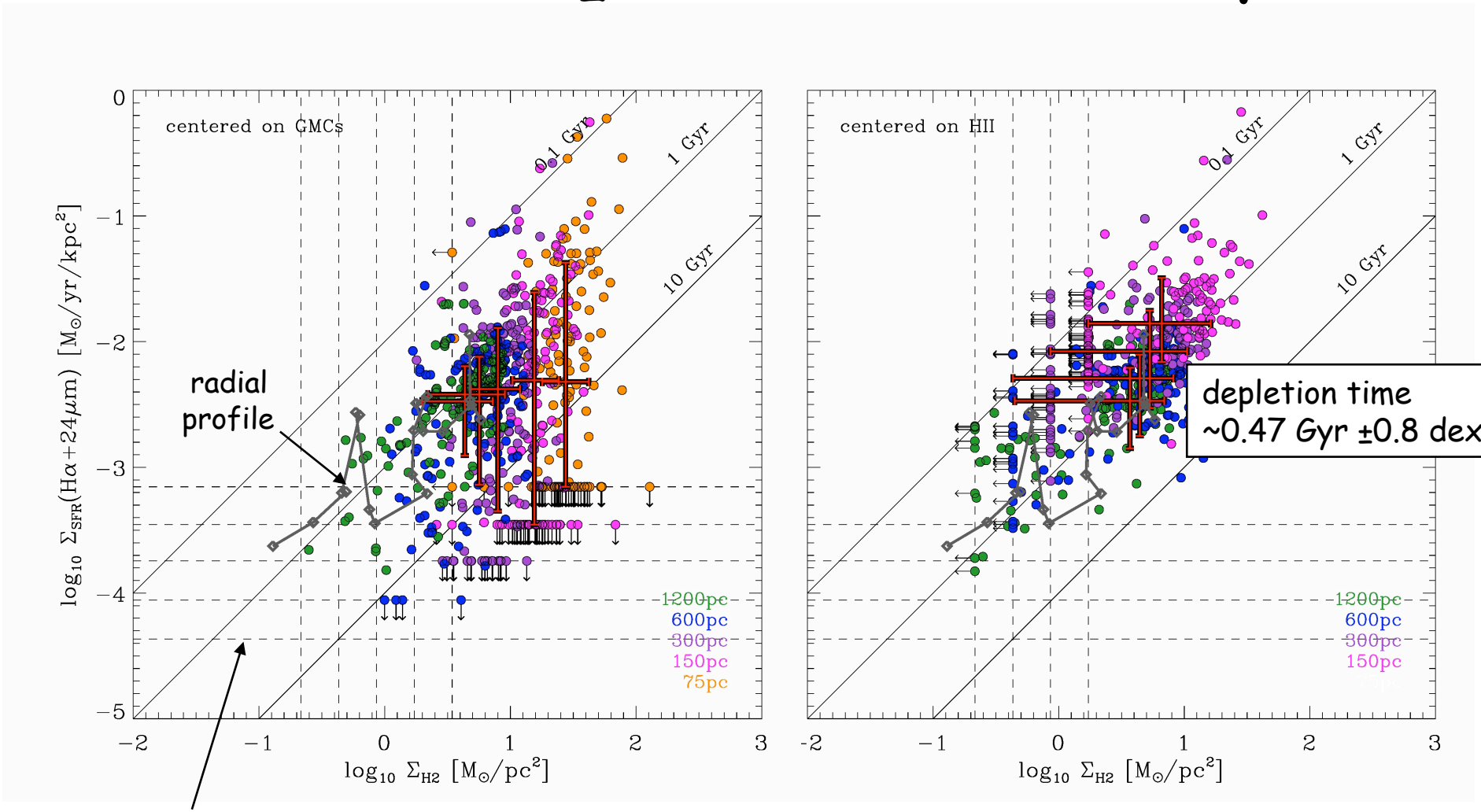
1σ sensitivity limits

(surface densities not inclination corrected)

SFR & H_2 Surface Density



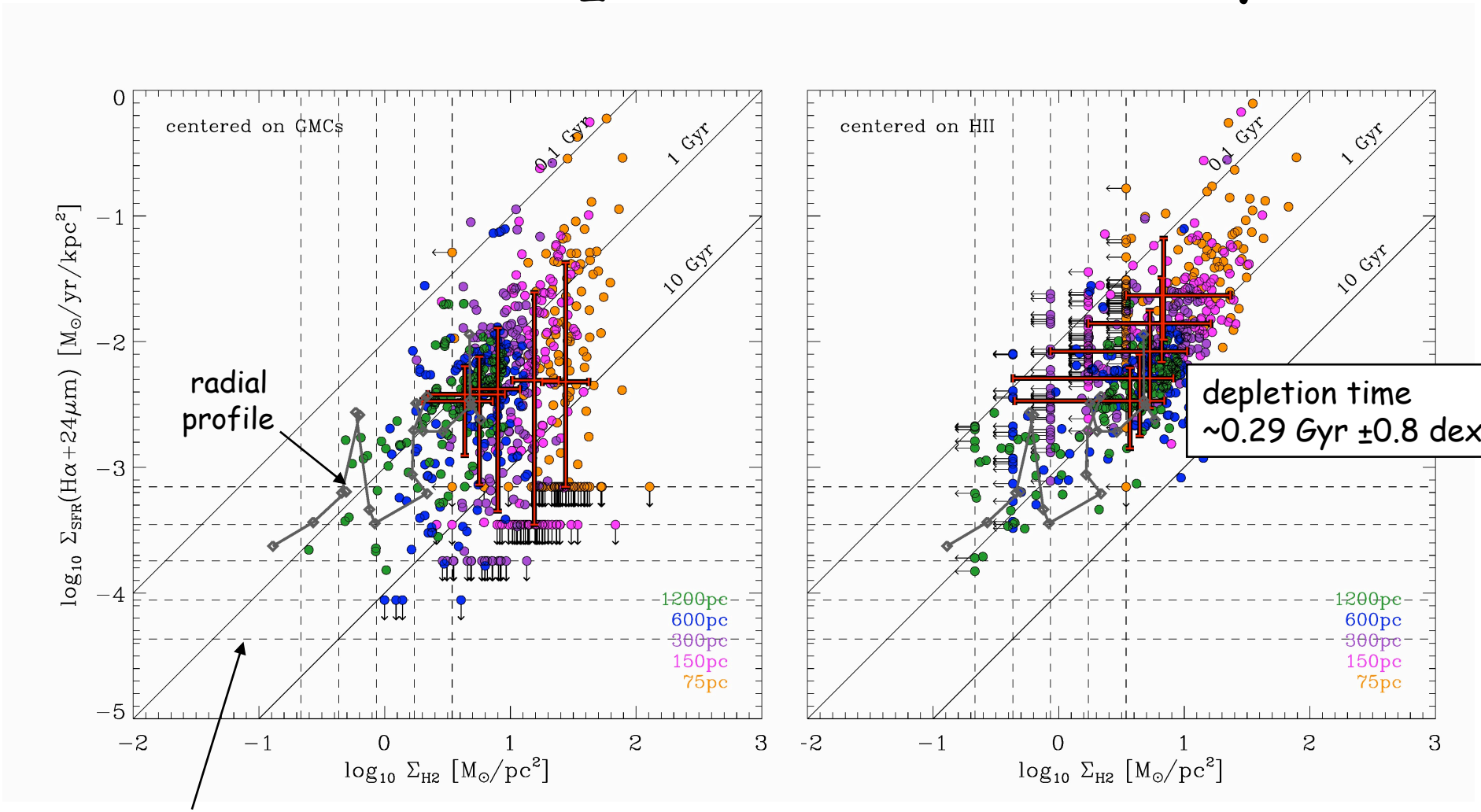
SFR & H_2 Surface Density



1σ sensitivity limits

(surface densities not inclination corrected)

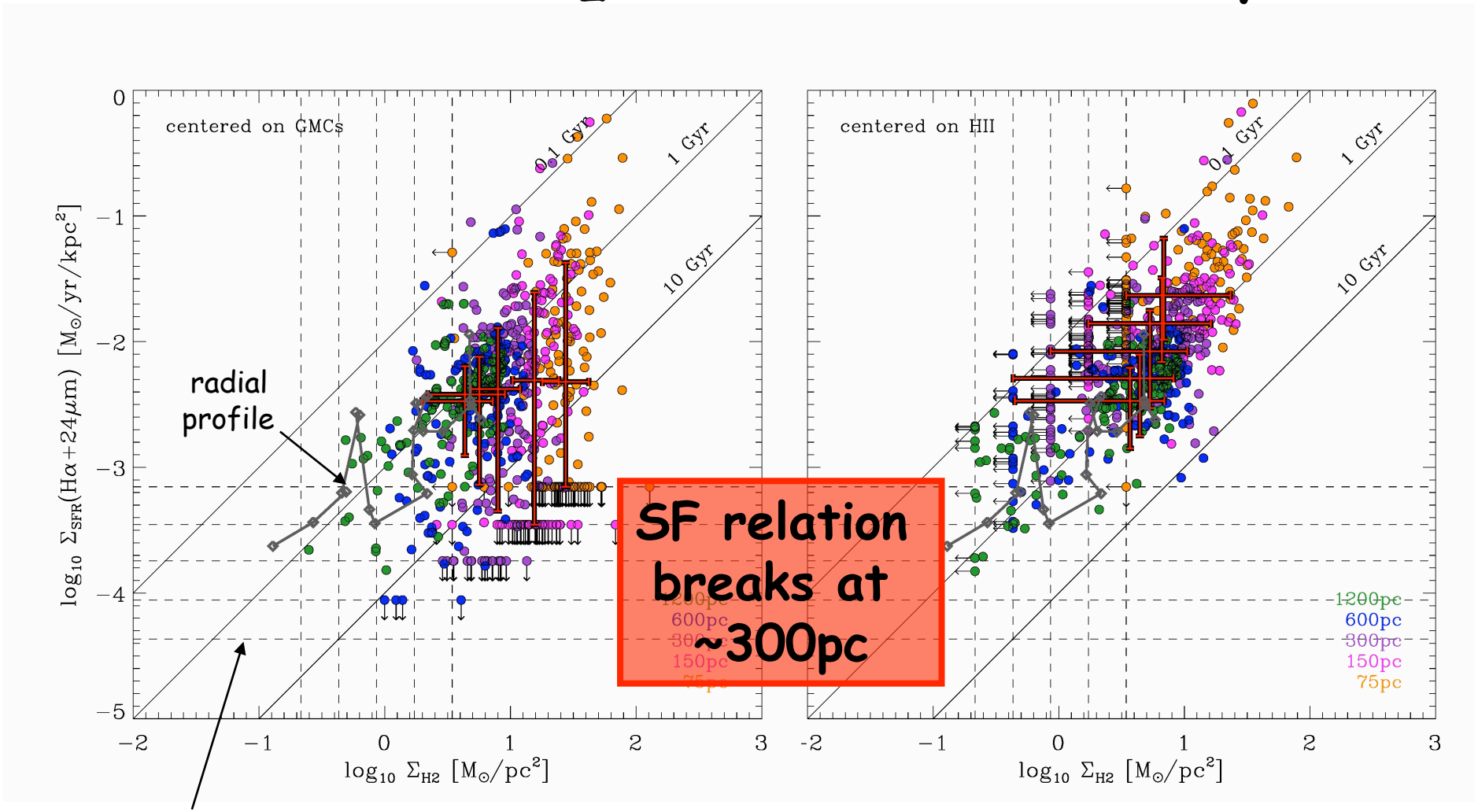
SFR & H_2 Surface Density



1σ sensitivity limits

(surface densities not inclination corrected)

SFR & H_2 Surface Density



1σ sensitivity limits

(surface densities not inclination corrected)

Summary

- M33 obeys molecular SF relation on kpc scales:
  - radial profiles, binned profiles, kpc subregions

- Depletion times vary 1 order of magnitude on kpc scale

Aperture size	Depletion time [Gyr]	
	centered on GMCs	centered on HII
1200 pc	0.5 ≤ 1.3 ≤ 5.0	0.2 ≤ 1.1 ≤ 2.0
300 pc	0.5 ≤ 1.9 ≤ …	… ≤ 0.6 ≤ 1.8
75 pc	0.5 ≤ 5.7 ≤ …	… ≤ 0.3 ≤ 1.0

- No SF relation seen on scales below ~300pc,
  - neither for GMCs nor for HII regions

SFR on Cloud Scale
- How much gas? -

MW: well known X_{CO} ~ 1.5-3.0×10^{20} cm^{-2} (K km s^{-1})$^{-1}$

(Dame'01, Strong&Mattox'96, Solomon'87,…)

M33: - from virial masses: X_{M33} ~ X_{MW} (Rosolowsky'03)

- but dust gives higher X_{CO} (Israel'97, Leroy'09 in prep.)
- Metal vs X_{CO} (Wilson'96, Israel'97, Arimoto'99,…)

OQs: - virial vs dust/C+ cloud masses

- pure molecular or atomic & molecular clouds

SFR on Cloud Scale
- How do stars form from gas? -

MW: - stars form from a small dense part of cloud (SFR vs HCN, HCO+, CS,...) (Johnstone'99-09, Overview by Carsten)

- SFE/τ_{ff} ~ const at many densities (Krumholz & Tan'06)

OQs: - cloud lifetime unknown: 5 Myr (Tamburro'08), 10-20 Myr (Engargiola'03), 30 Myr (Fukui'09)

- SF in dense part vs cloud mass?
- IMF populated for given gas mass (Corbelli'08)

Data & Catalogs

CO: BIMA (Engargiola et al. 2003) + FCRAO (Heyer et al. 2004)

Ha: KPNO 0.6m (Greenawalt 1998, Hoopes & Walterbos 2000)

IR: MIPS 24μm (Gehrz et al. 2005, Gordon 2009)

GMC catalog: Rosolowsky et al. 2007

HII region catalog: Hodge et al. 2002

Factors

- Distance: 840 kpc
- Inclination: 55 deg
- PA: 22.5 deg

- X_{CO} = $2x10^{20}$ cm^{-2} $(K\ km\ s^{-1})^{-1}$
- Heavy elements: factor 1.36

- SFR(Ha+24μm) (Calzetti et al. 2007)
  SFR[$M_\odot$ yr^{-1} kpc^{-2}] = $5.3x10^{-5}$
  *(L_{Ha}[10^{36} erg s^{-1} kpc^{-2}] + 15150*L_{24}[MJy sr^{-1}])

Gas & SF SD for more THINGS