Comparing [CII], CO and HI dynamics in nearby galaxies

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COMPARING [C II], H I, AND CO DYNAMICS OF NEARBY GALAXIES

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THE IMPACT OF THE GAS DISTRIBUTION ON THE DETERMINATION OF DYNAMICAL MASSES OF GALAXIES USING UNRESOLVED OBSERVATIONS

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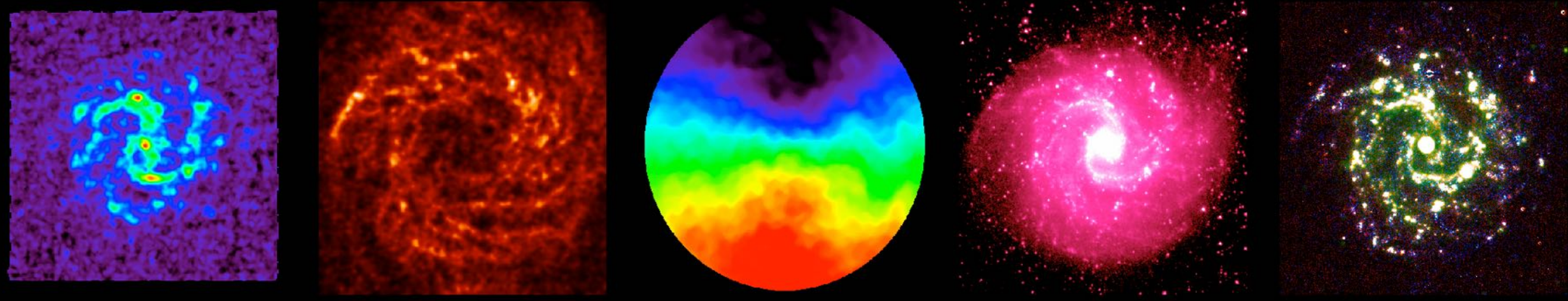
- dynamics of gas in galaxies: HI
- extended, constant surf dens
- but faint beyond z~0.2

- use CO: bright, but more compact, exponential
- but even this difficult at z>5 or so

Molecular Gas
Peak CO intensity
From HERACLES

Kinematics
Here from HI line
Also from CO

Recent Star Formation
Composite of **FUV** (GALEX),
mid-IR (SINGS/LVL),
and **Hα** (SINGS/LVL)



NGC 628

Atomic Gas
VLA 21cm data THINGS + new
& archival

Old Stars
Near infrared intensity
From SINGS and LVL

HERACLES survey (Leroy et al 2011)

- use C^+ or [CII] 158 μm or ~1900 GHz
- main cooling line ISM, usually brightest
- can be 50,000 times brighter than CO
- in ALMA bands between z~1 and ~20

- at high z observations will be not or marginally resolved

- dynamics information most likely from global profiles (integrated spectra)

- global profiles do not give spatial information and depend on tracer

- real problem: what is [CII] distribution?

- problem: z=0 only from space

- can make different arguments

- [CII] associated with ionised gas, ionised associated with SF,
  CO associated with SF,
  [CII] ↔ CO

- [CII] main cooling line of ISM: [CII] ↔ HI

- need resolved observations

(but this talk will not be about the detailed [CII] physics)

- global profile from integrated flux in velocity bins

- depends on rotation curve and tracer distribution

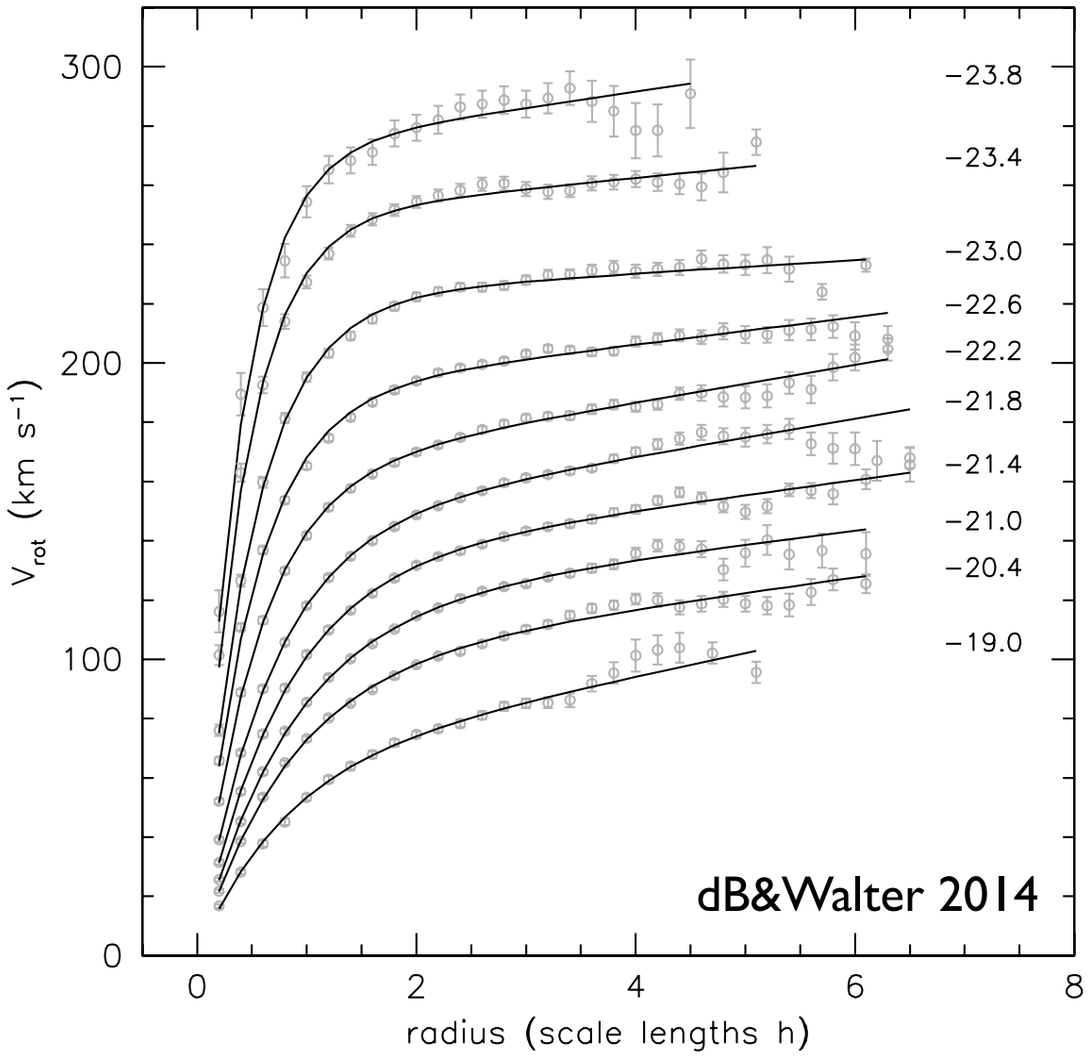
- dynamical mass: $M \sim V^2R$

- what is V and what is effective R

- dB & Walter (2014): use model rotation curves and radial density distributions

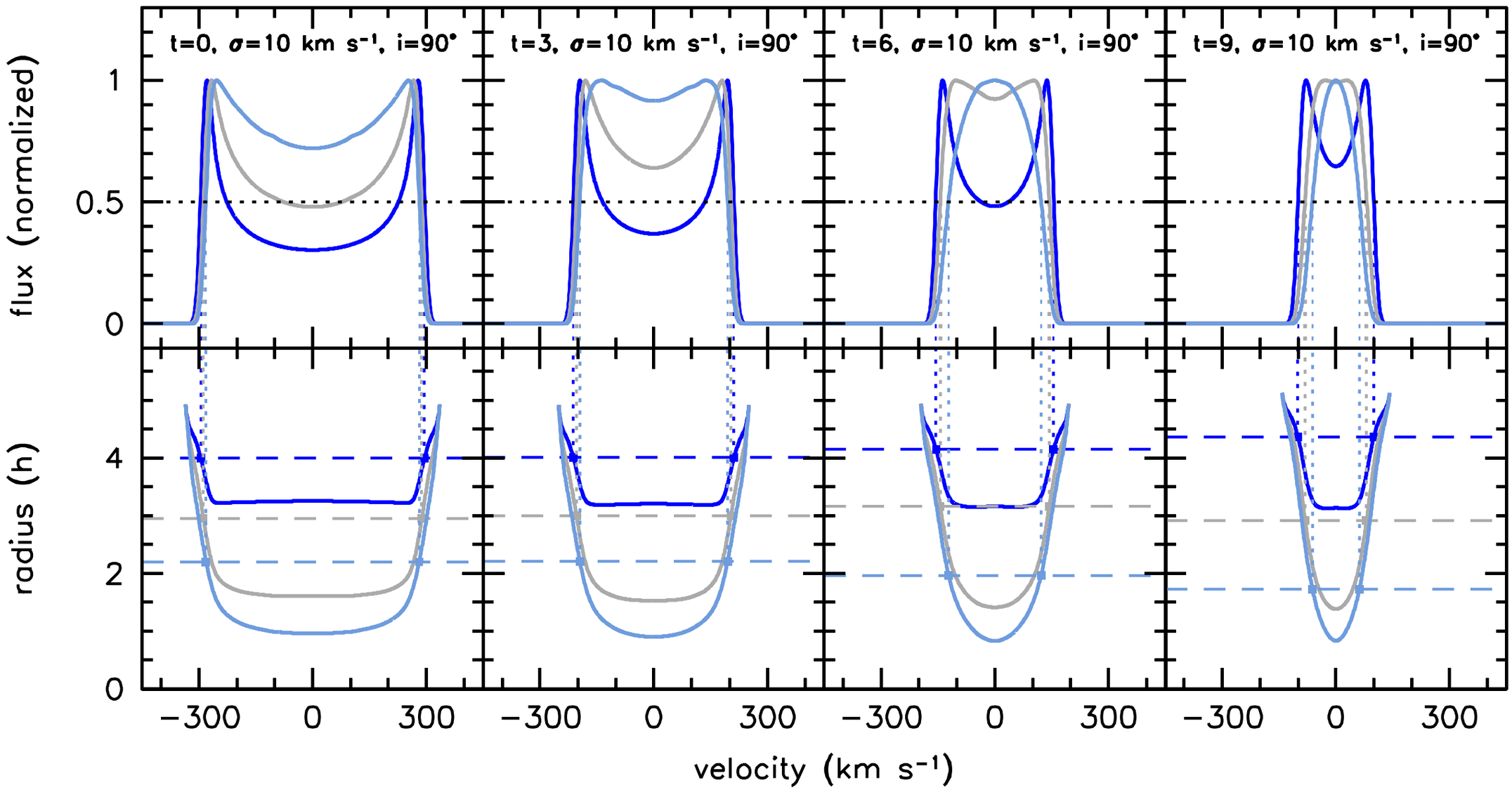
- assume Freeman disk and test ℓ = (h/4, h/2, h, 2h, 4h)

- also flat distribution (HI) and ℓ = 0.64h (CO; Schruba et al 2011)



M= -23.8 -22.6 -21.4 -19.0

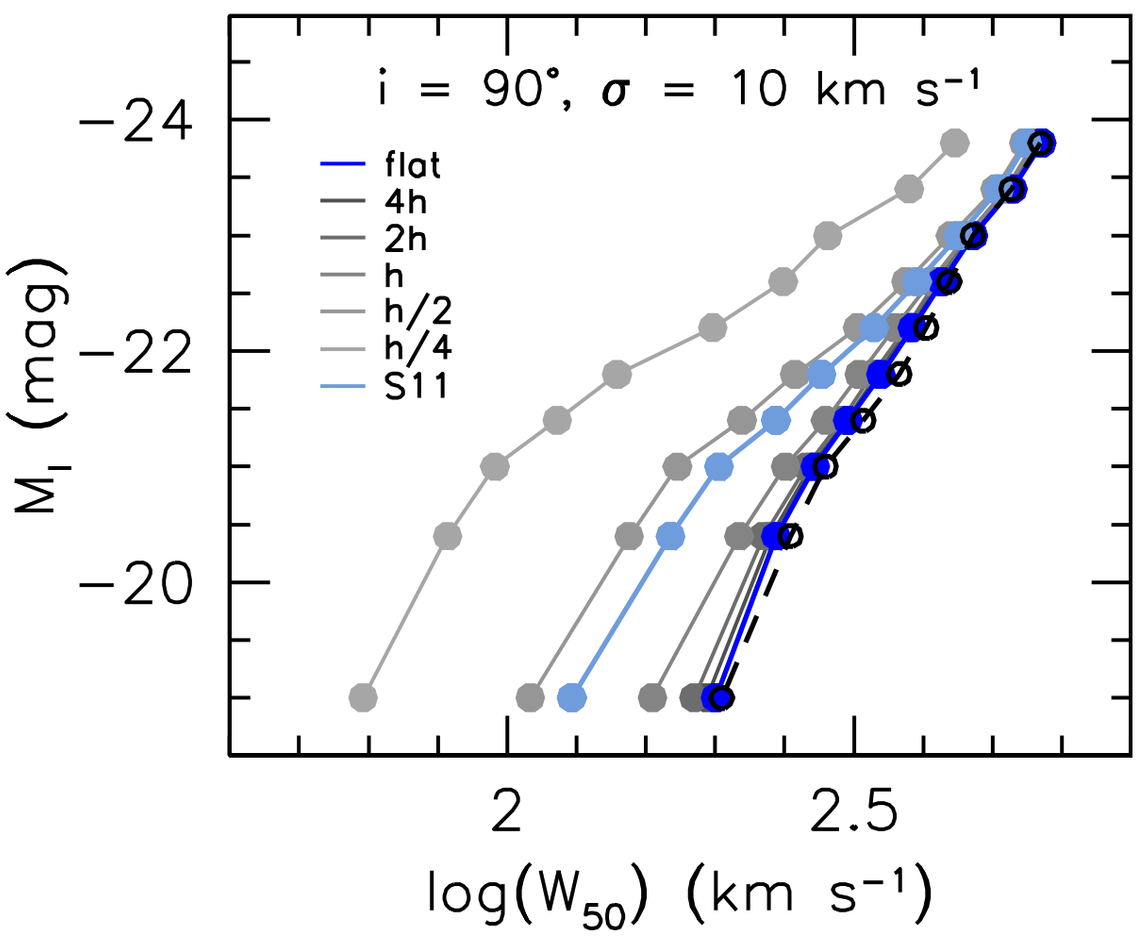
S11
h
flat

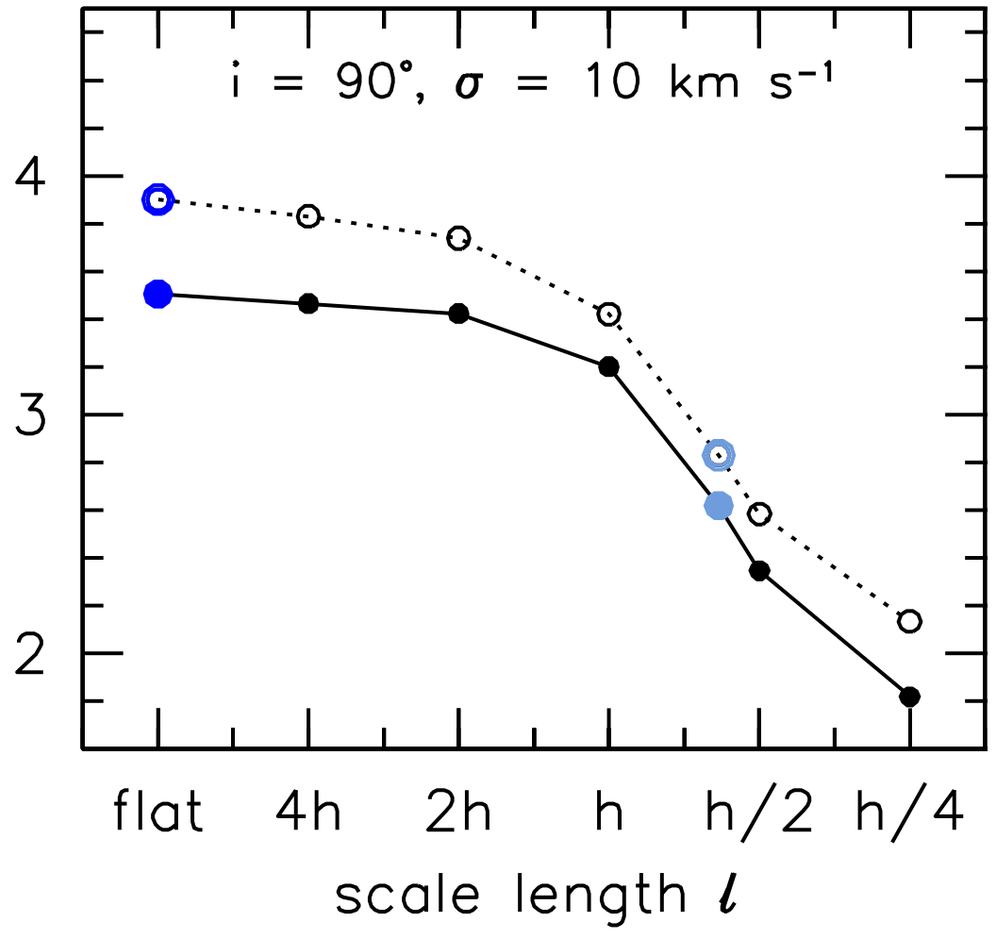


flat
h
S11

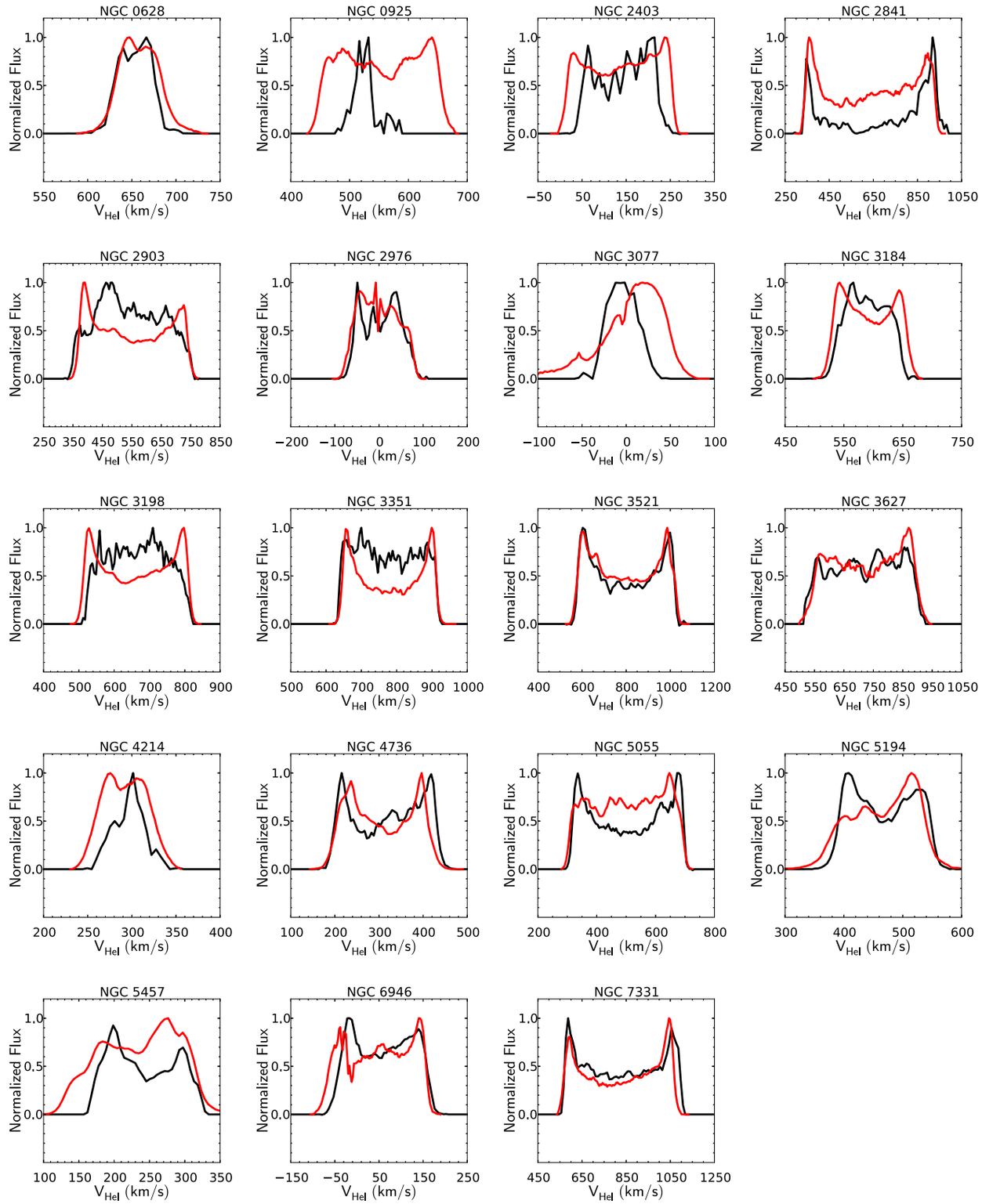
dB&Walter 2014

- measurable effect on slope of Tully-Fisher





- compare THINGS (HI) and HERACLES (CO)



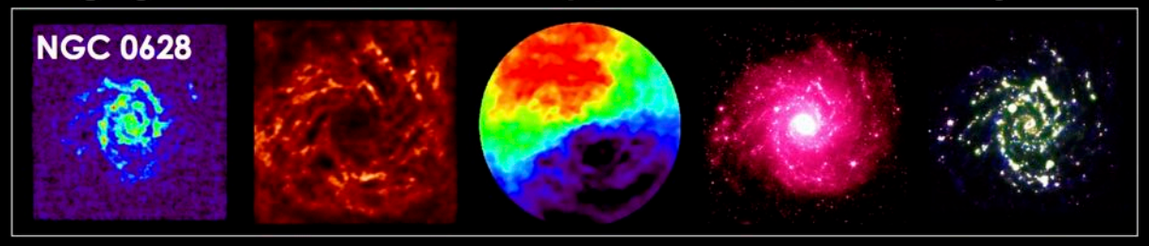
Frank et al 2015

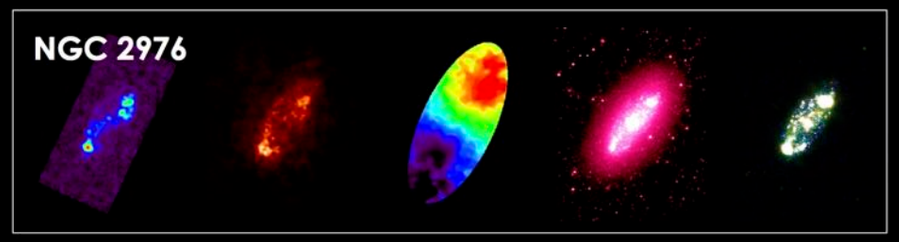
- Compare CO, HI, [CII]
- ***HI: THINGS***: ~11”, 2.6 or 5.2 km/s
- ***CO: HERACLES***: 13”, 5.2 km/s
- ***[CII]: KINGFISH*** (PACS, Herschel): 14”, 239 km/s, major axis strips
- ***[CII] SOFIA:*** 14”, 5 km/s, pointings in galaxies
- Overlap galaxies where all three present

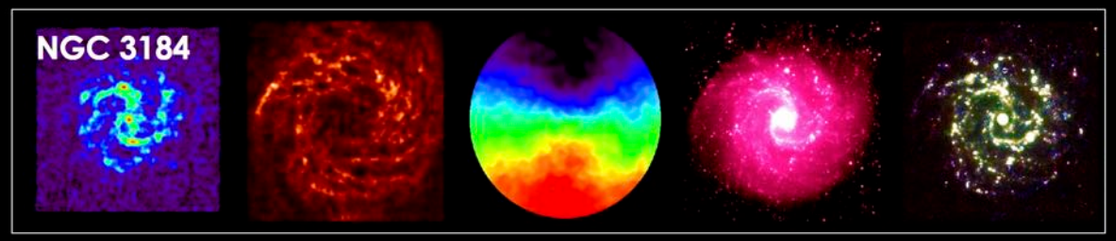
PROPERTIES OF SAMPLE GALAXIES.

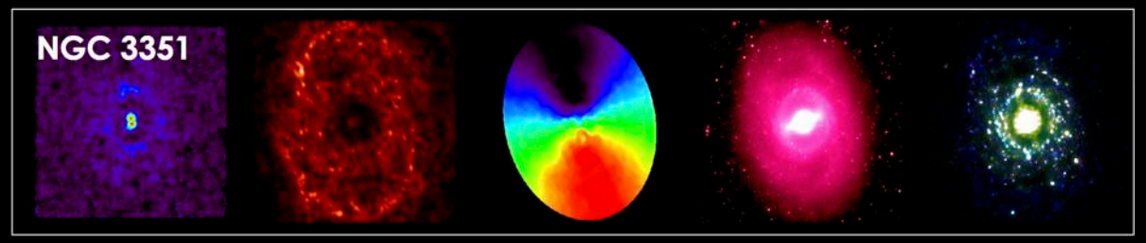
Name	D (Mpc)	M_B (mag)	i (°)	$\log D_{25}$ ($\log 0.1'$)
(1)	(2)	(3)	(4)	(5)
NGC 0628	7.3	−19.97	7	1.99
NGC 2976	3.6	−17.78	65	1.86
NGC 3184	11.1	−19.92	16	1.87
NGC 3351	10.1	−19.88	41	1.86
NGC 3521	10.7	−20.94	73	1.92
NGC 3627	9.3	−20.74	62	2.01
NGC 4736	4.7	−19.80	41	1.89
NGC 5055	10.1	−21.12	59	2.07
NGC 5457	7.4	−21.05	18	2.38
NGC 6946	5.9	−20.61	33	2.06

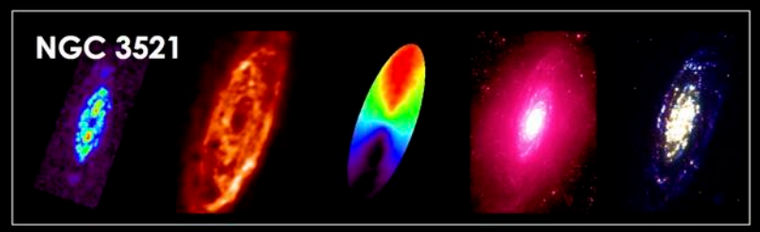
CO HI vel IR UV

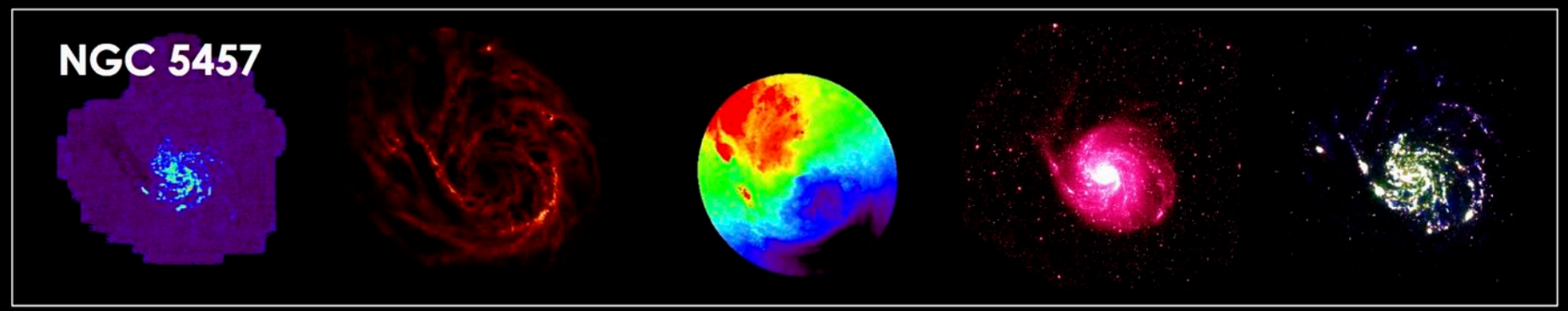


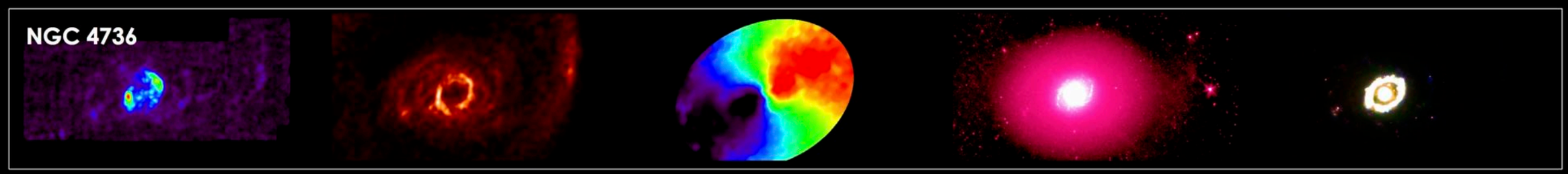


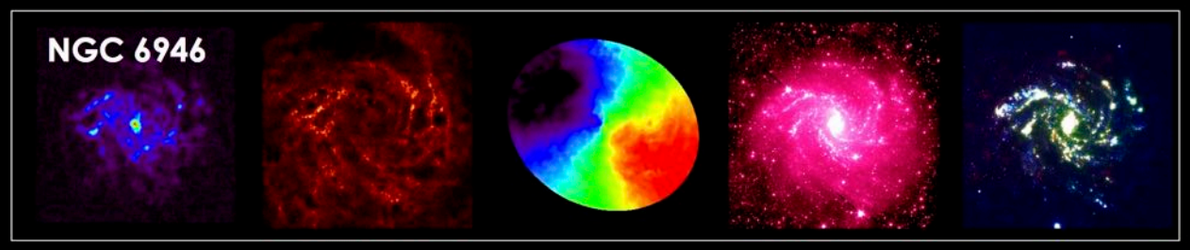


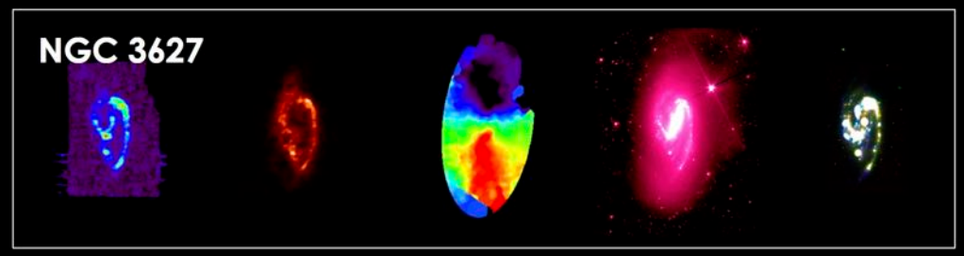


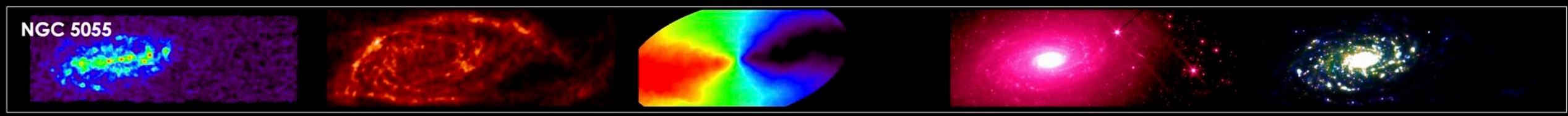


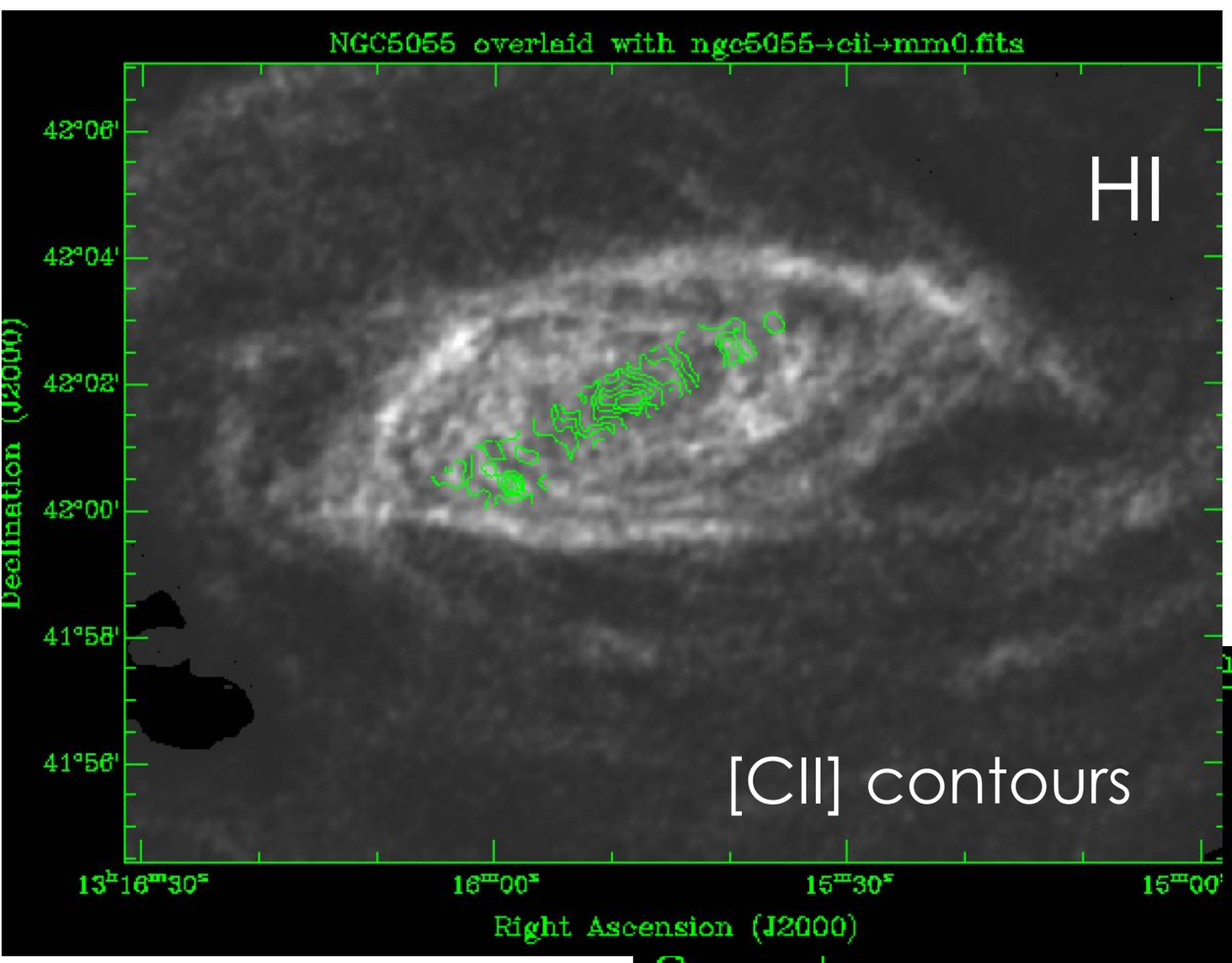






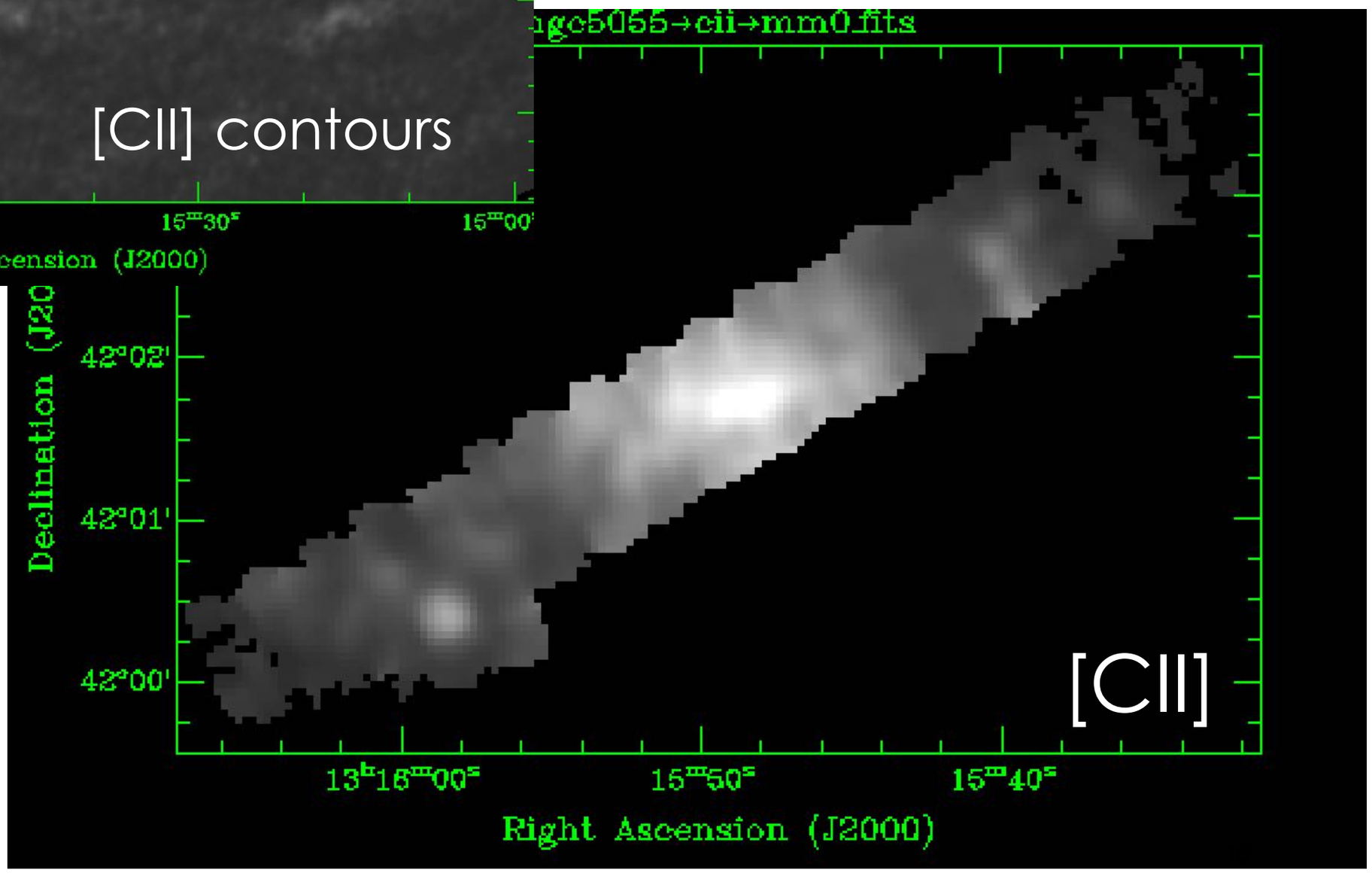






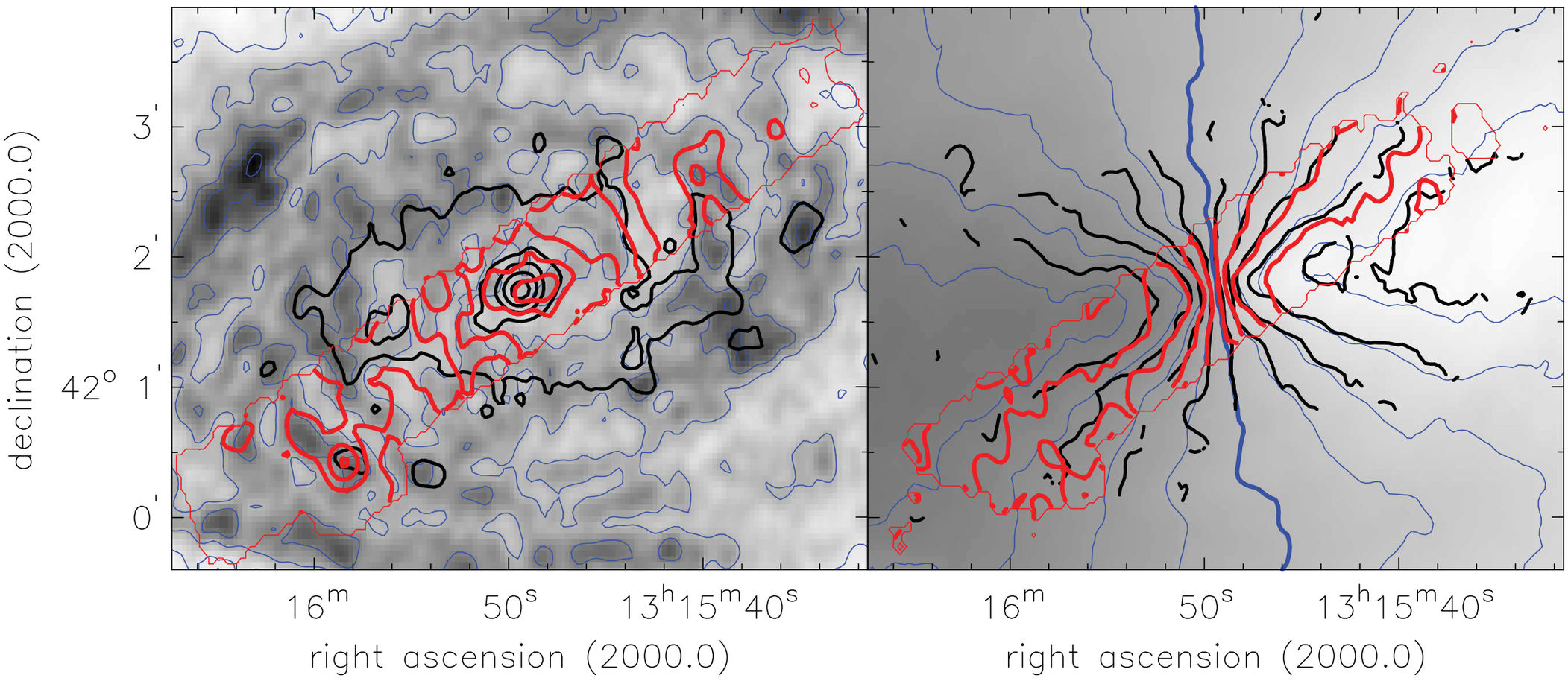
KINGFISH (Kennicutt et al 2011)
DR3, PACS, 12" resolution
strip maps along major axes

NGC 5055



mom0

mom1

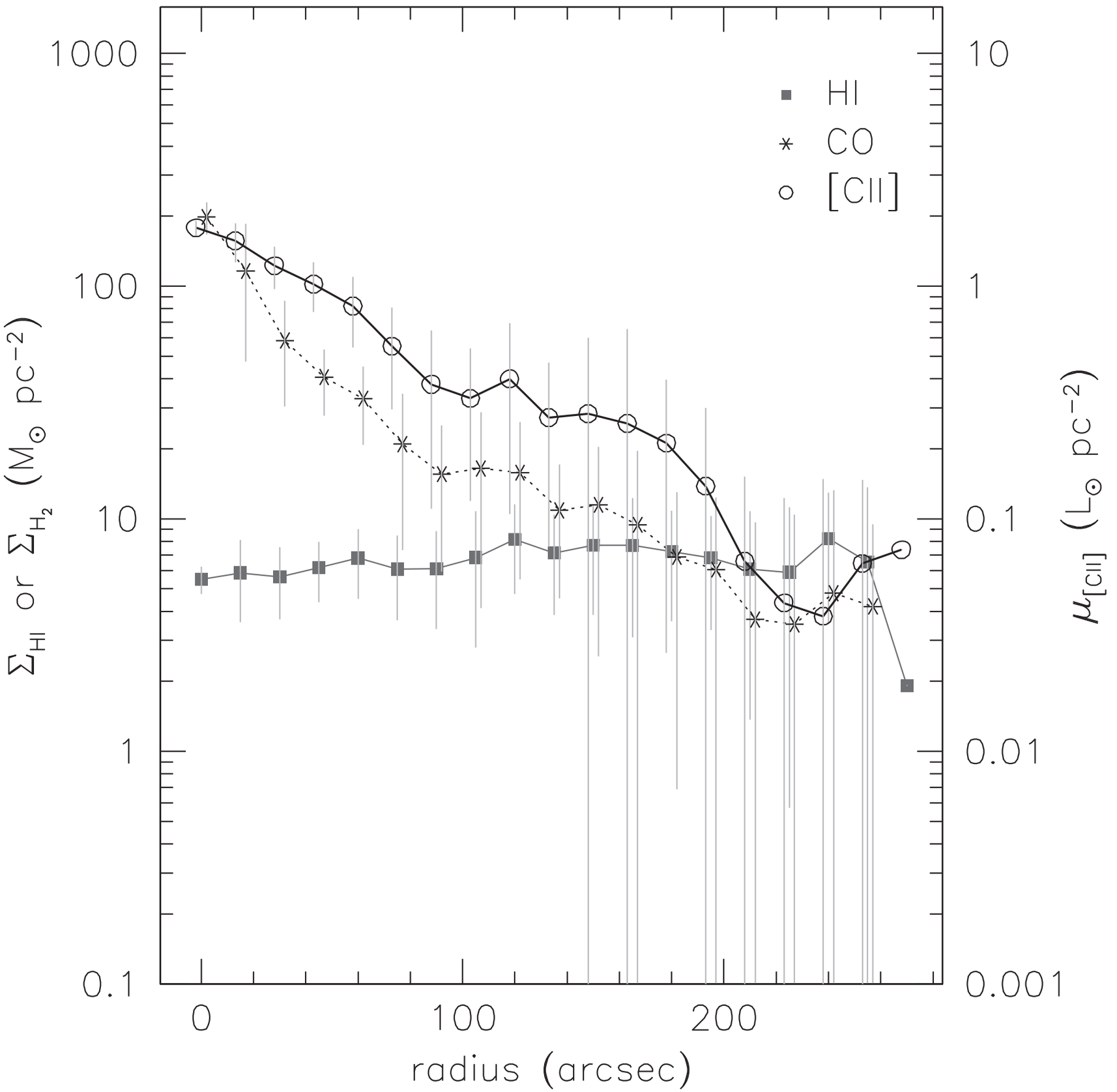


blue HI

black CO

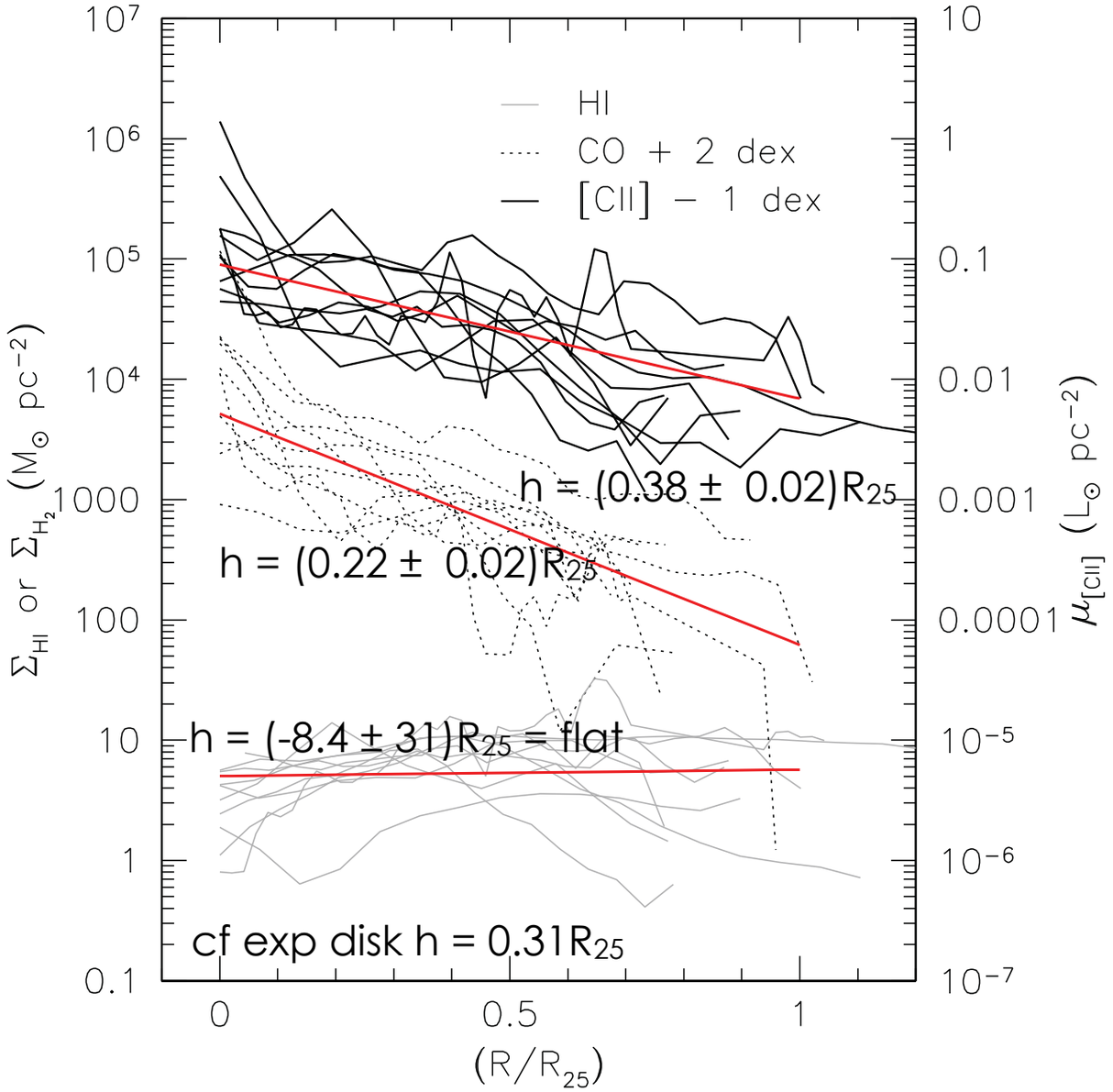
red [CII]

NGC 5055

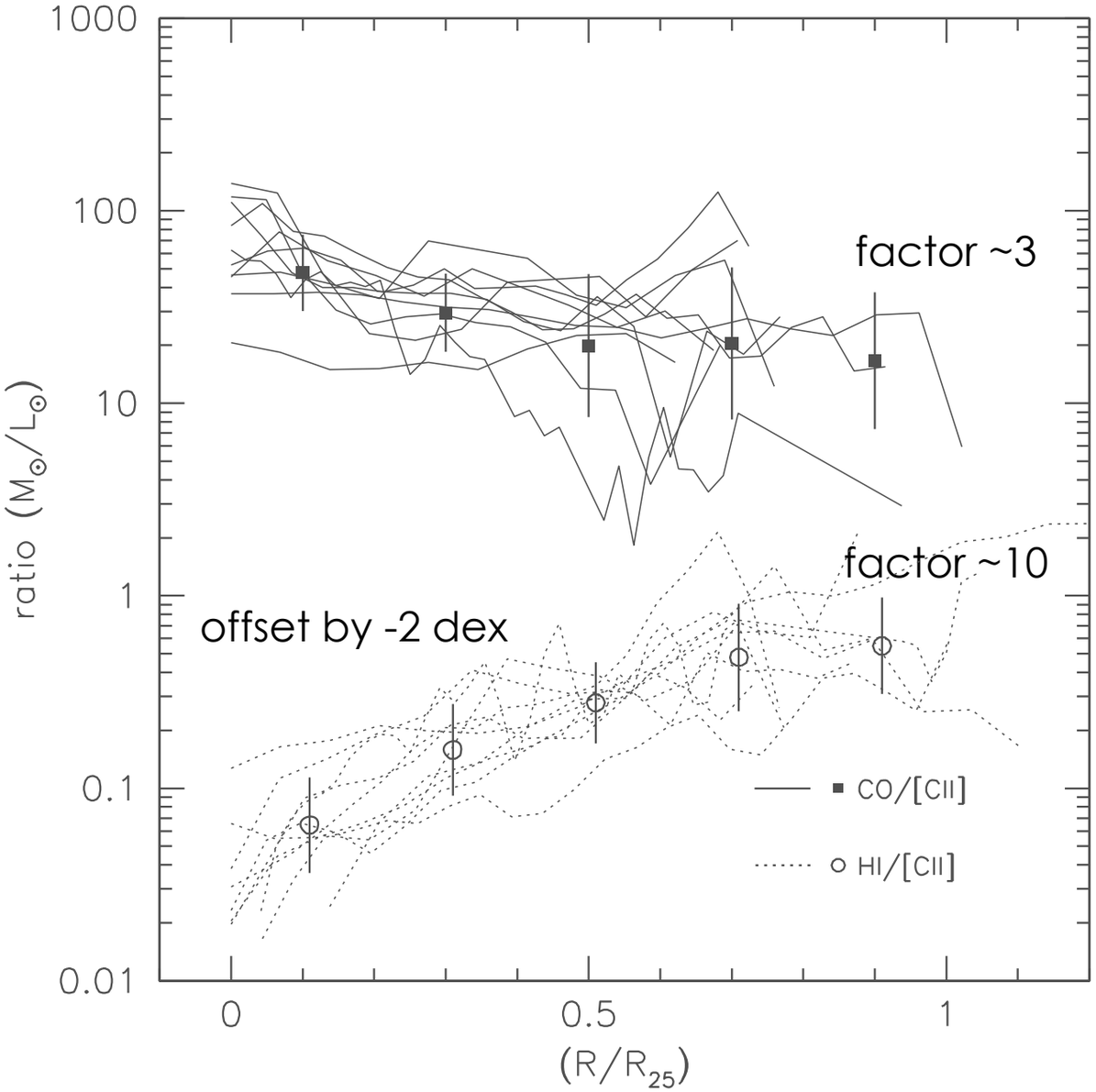


radial inclination-corrected surface density profile using known THINGS orientation parameters

NGC 5055

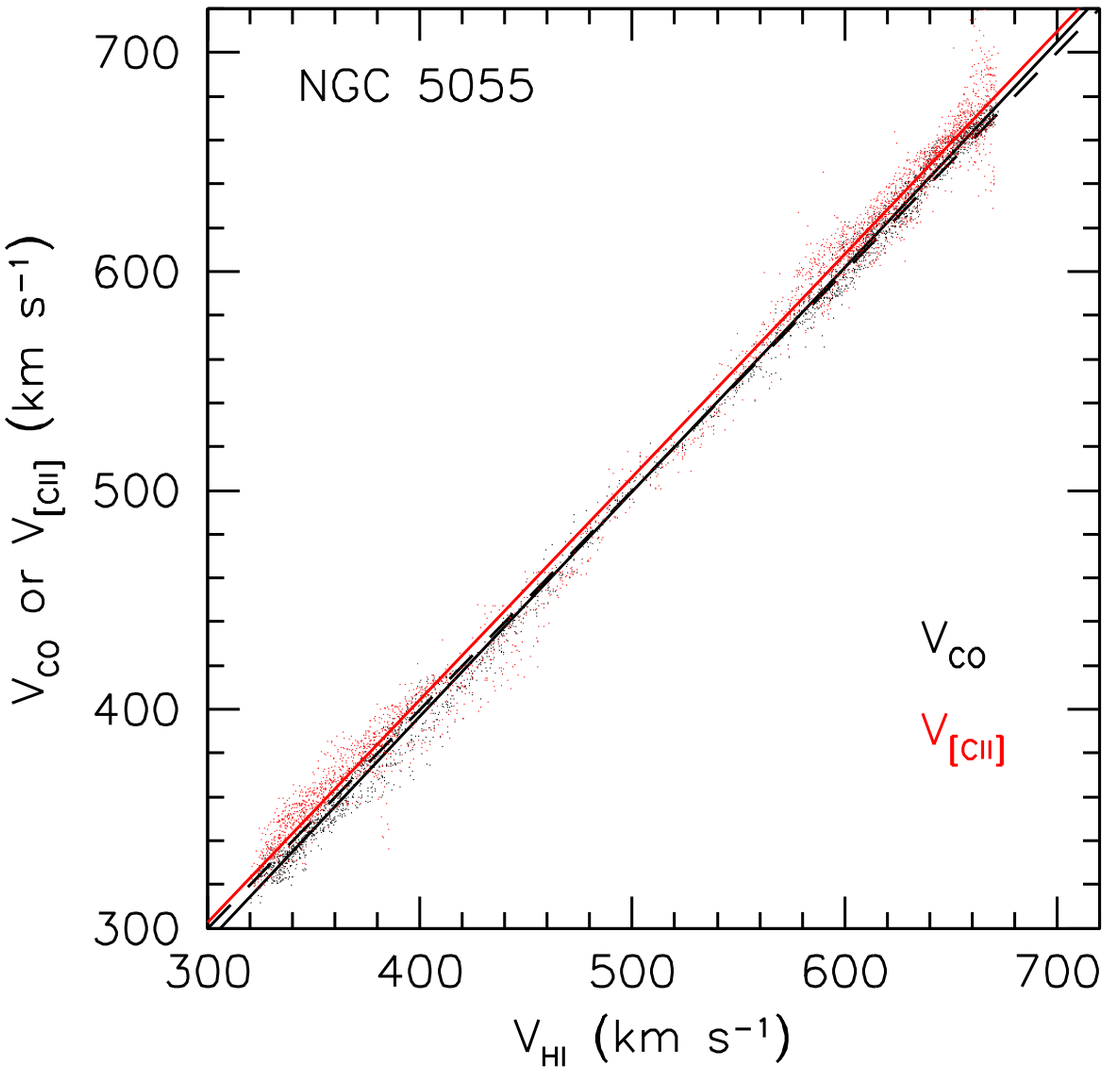


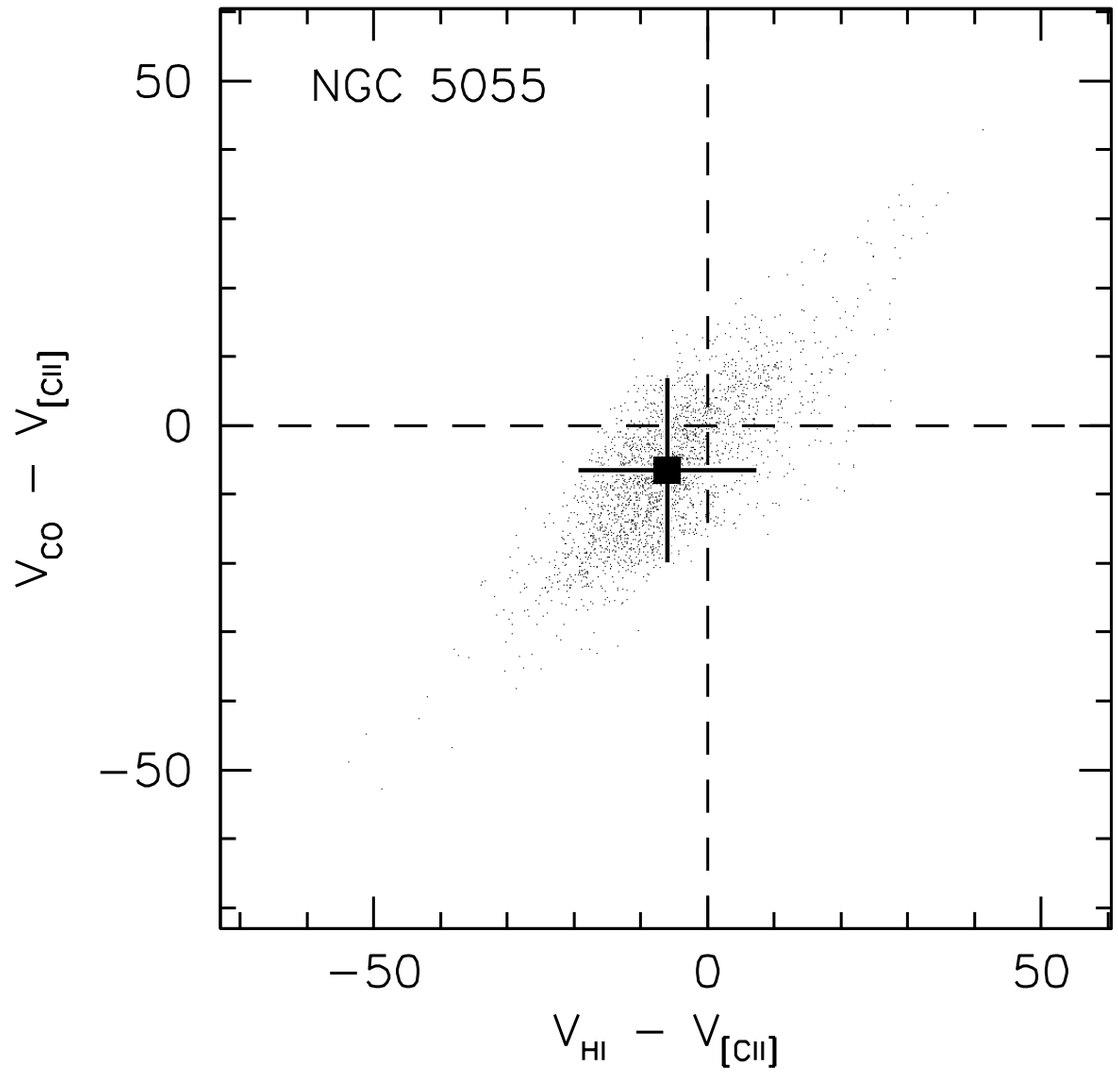
trends also hold for outer disk only,
so not caused by possibly different inner parts



[CII] follows CO more closely,
and comparable to optical

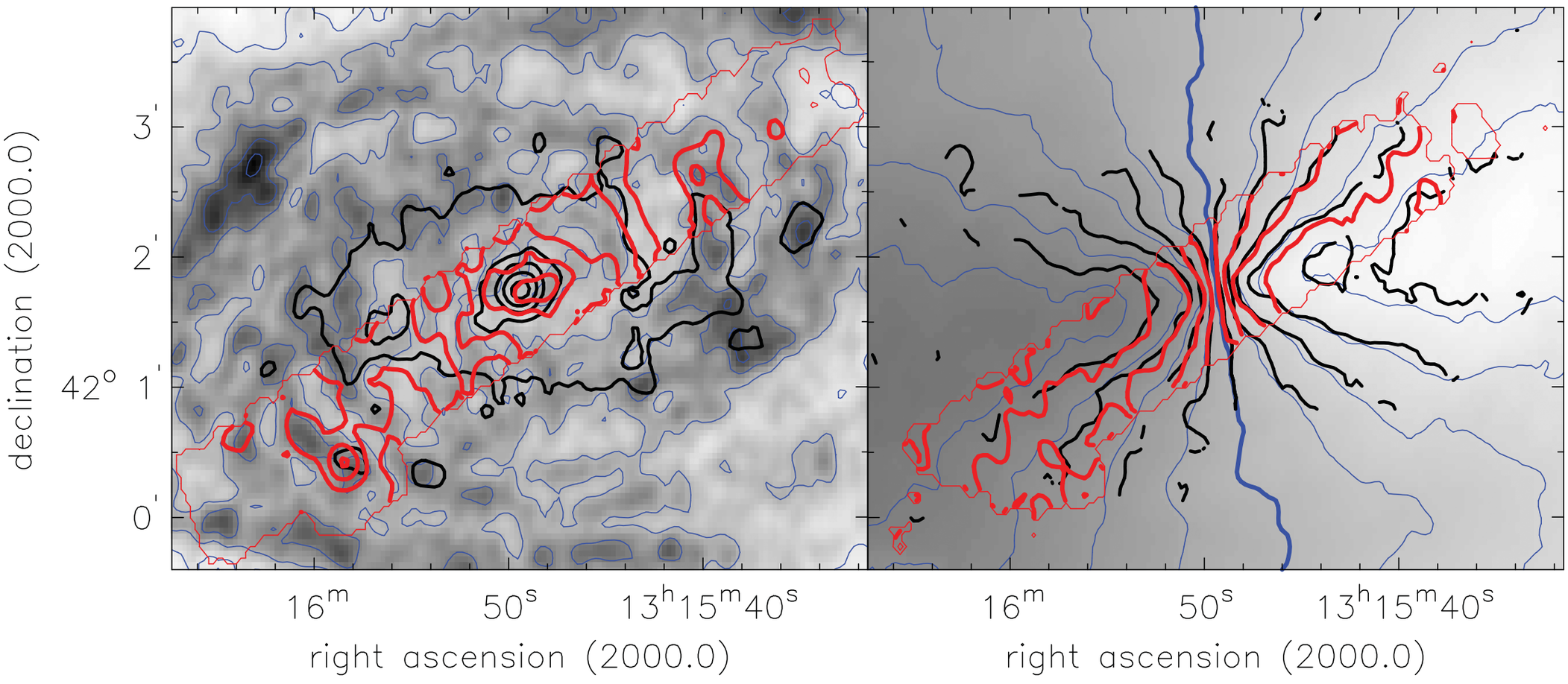
- [CII] follows CO more closely than HI
- consistent with [CII] tracer of SF


NGC 5055
700
600
500
400
300
300
400
500
600
700
V_{co} or $V_{[CII]}$ (km s^{-1})
V_{HI} (km s^{-1})
V_{co}
$V_{[CII]}$


NGC 5055
50
0
−50
−50
0
50
$V_{co} - V_{[CII]}$
$V_{HI} - V_{[CII]}$

mom0

mom1



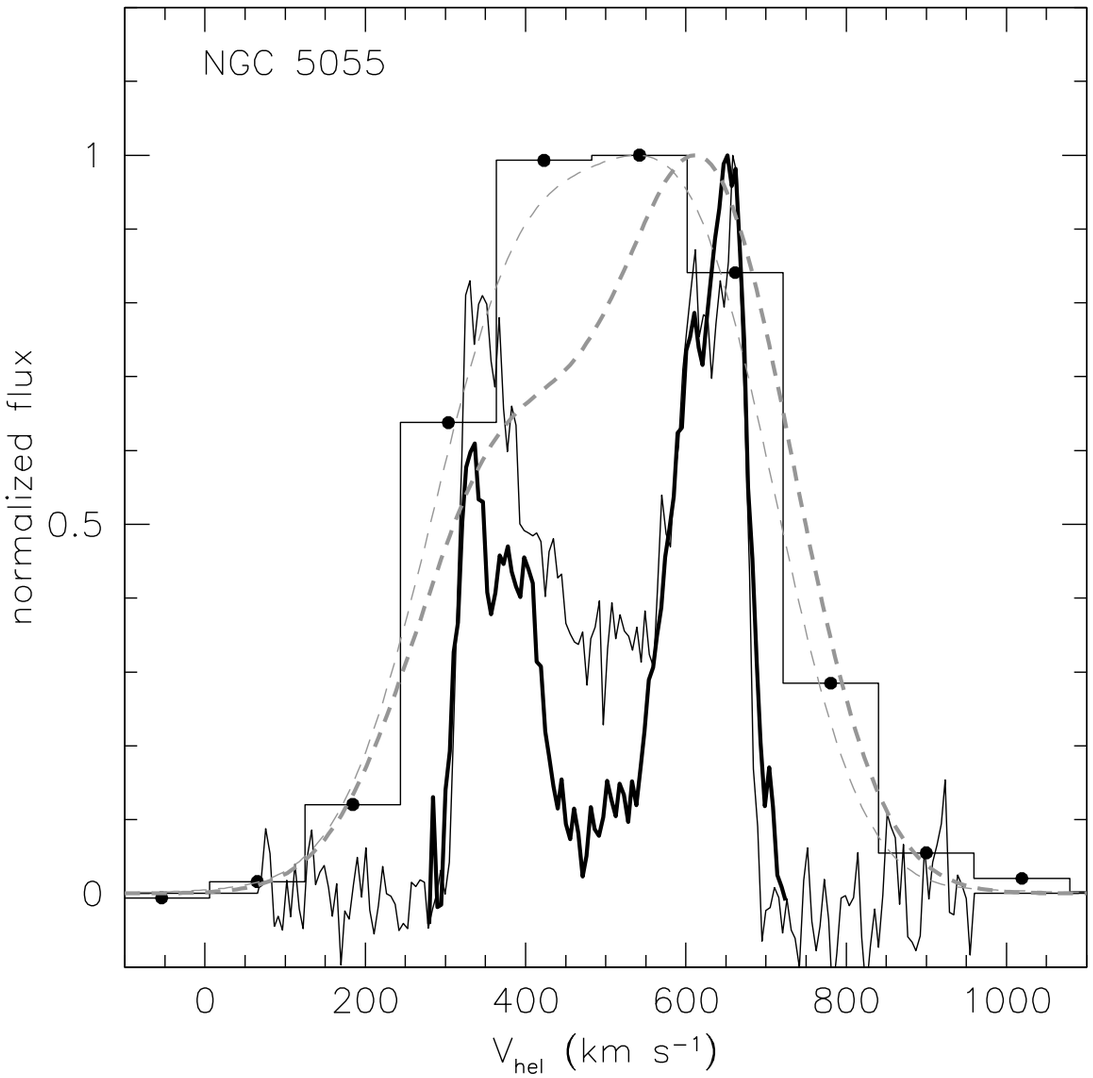
blue HI

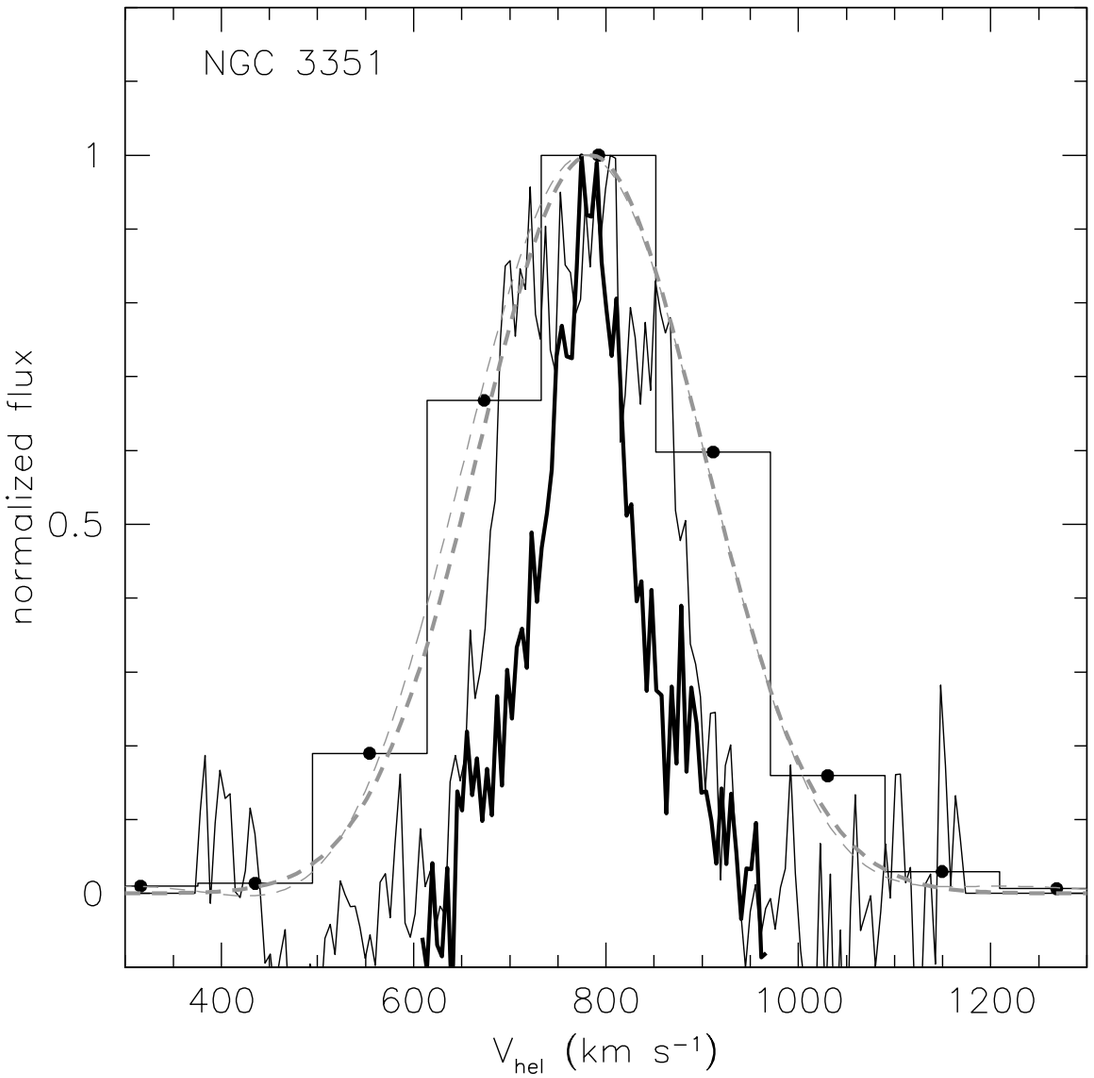
black CO

red [CII]

NGC 5055

global “strip” profiles





thick: HI (also smoothed)
thin: CO (also smoothed)
histo: [CII]

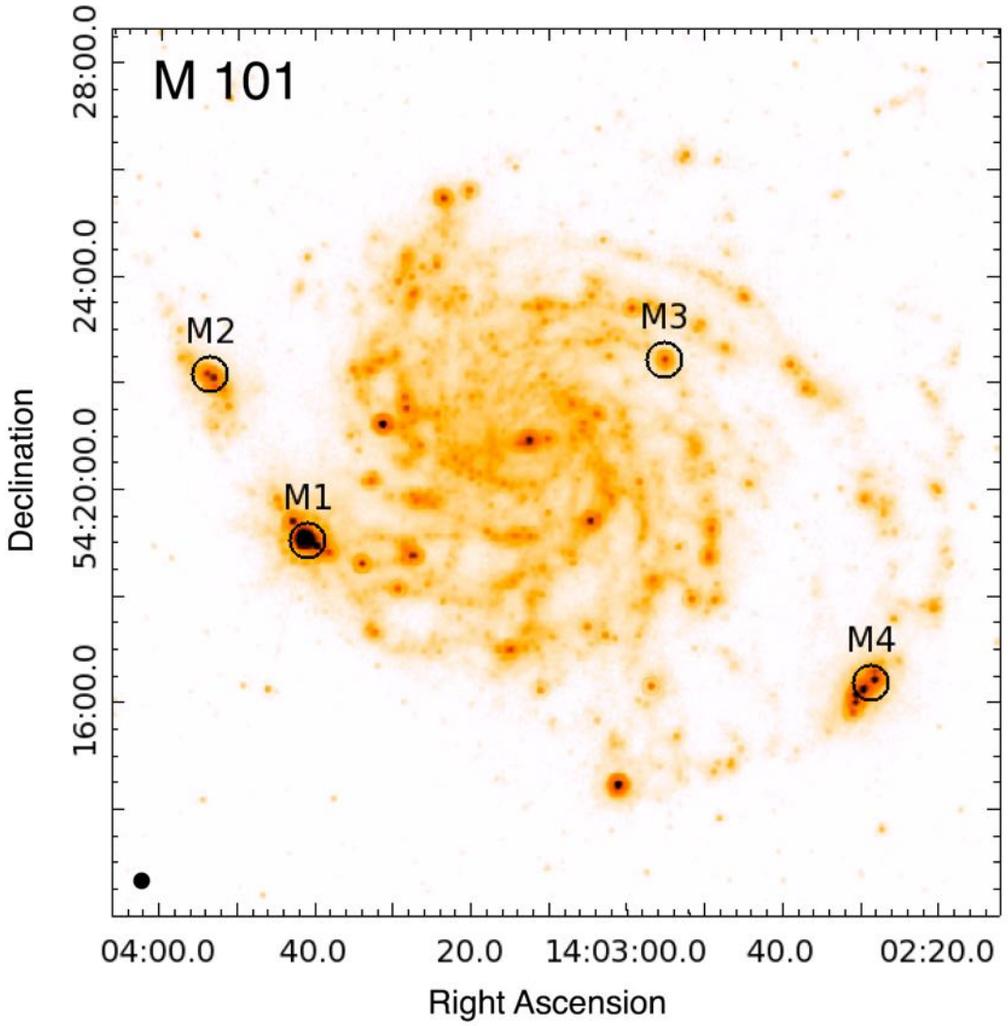
- For NGC 5055 we see better agreement with CO
- Other galaxies not enough velocity width

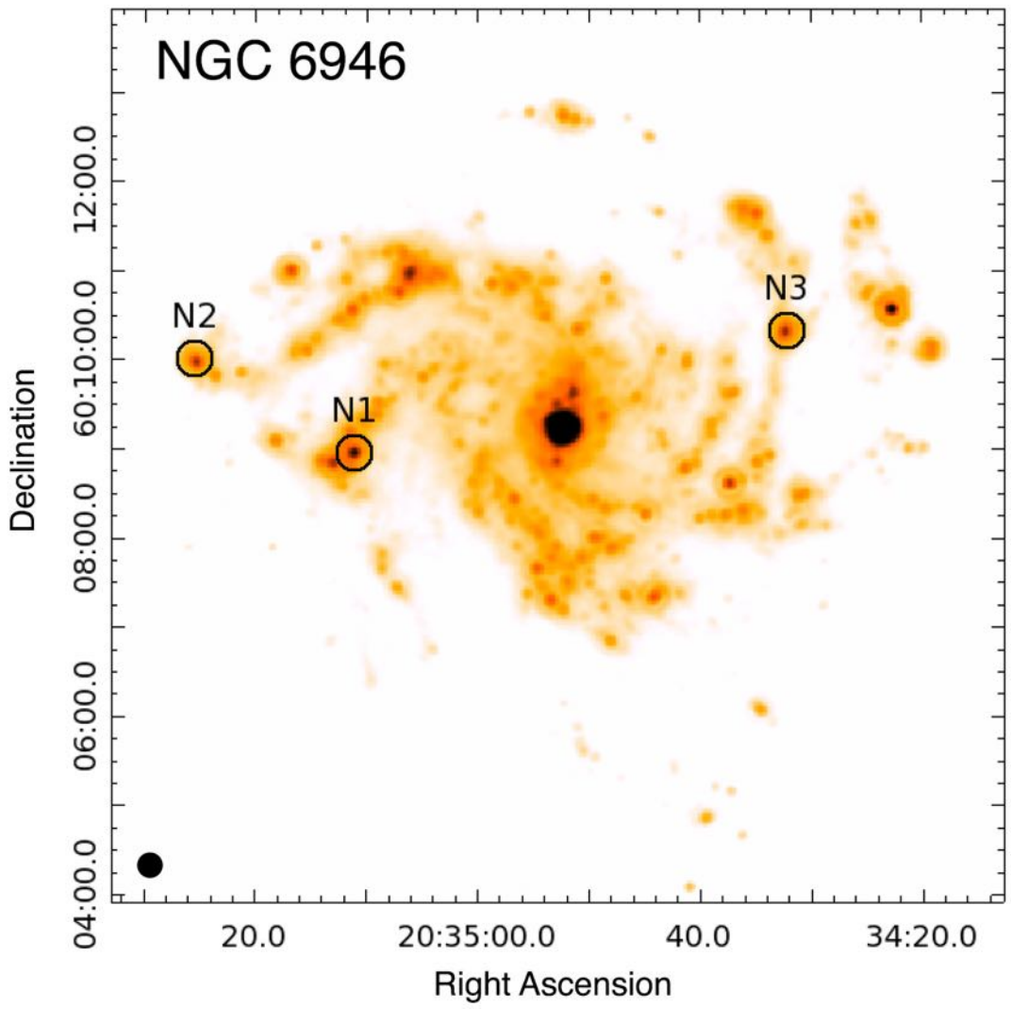
Smaller scales: SOFIA data

- probe SF regions in nearby galaxies
- [CII] observed with GREAT in 2014
- PI Herrara-Camus

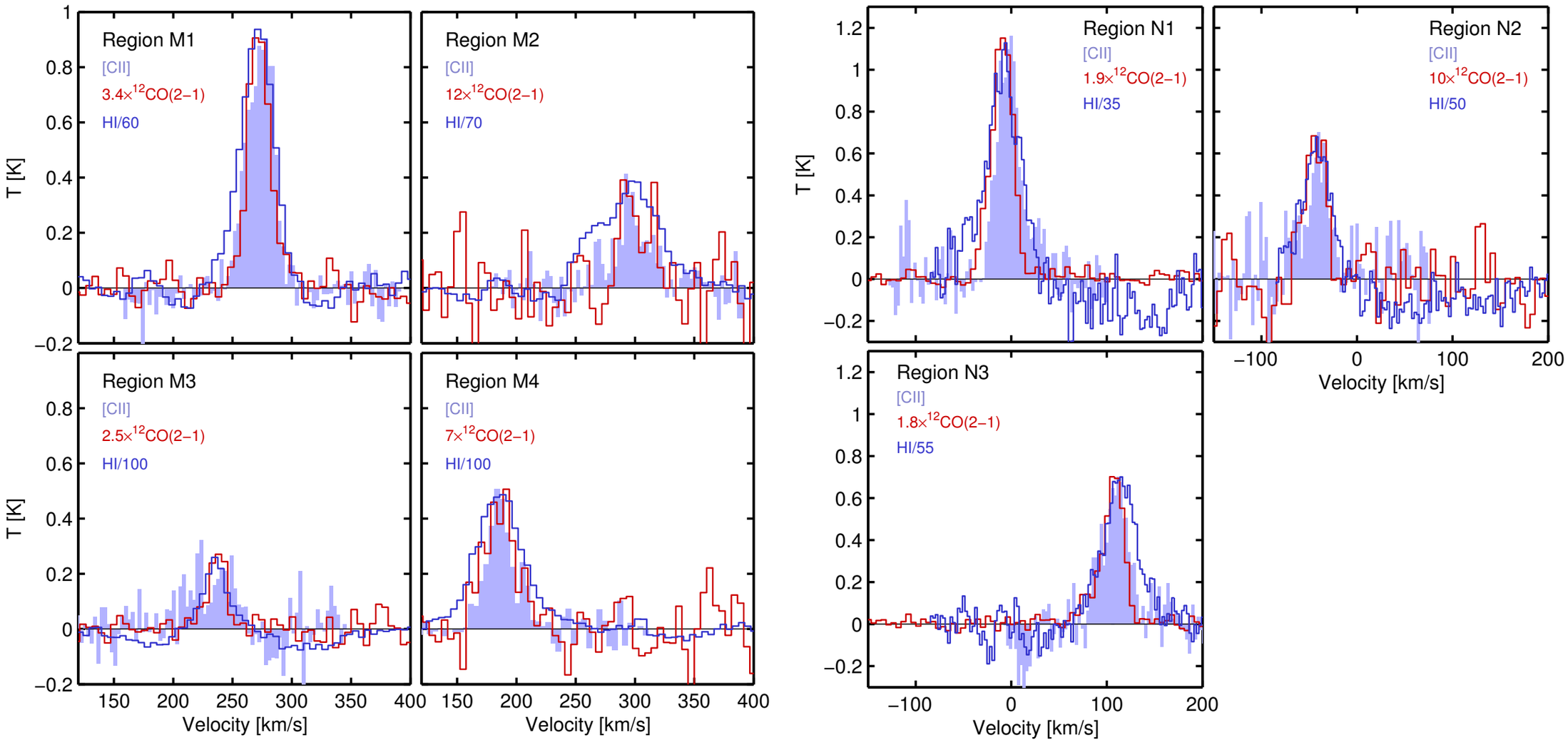
- radial profiles show CO-[CII] agreement in 2D
- test 3D - check velocities and dispersions at higher angular and velocity resolution

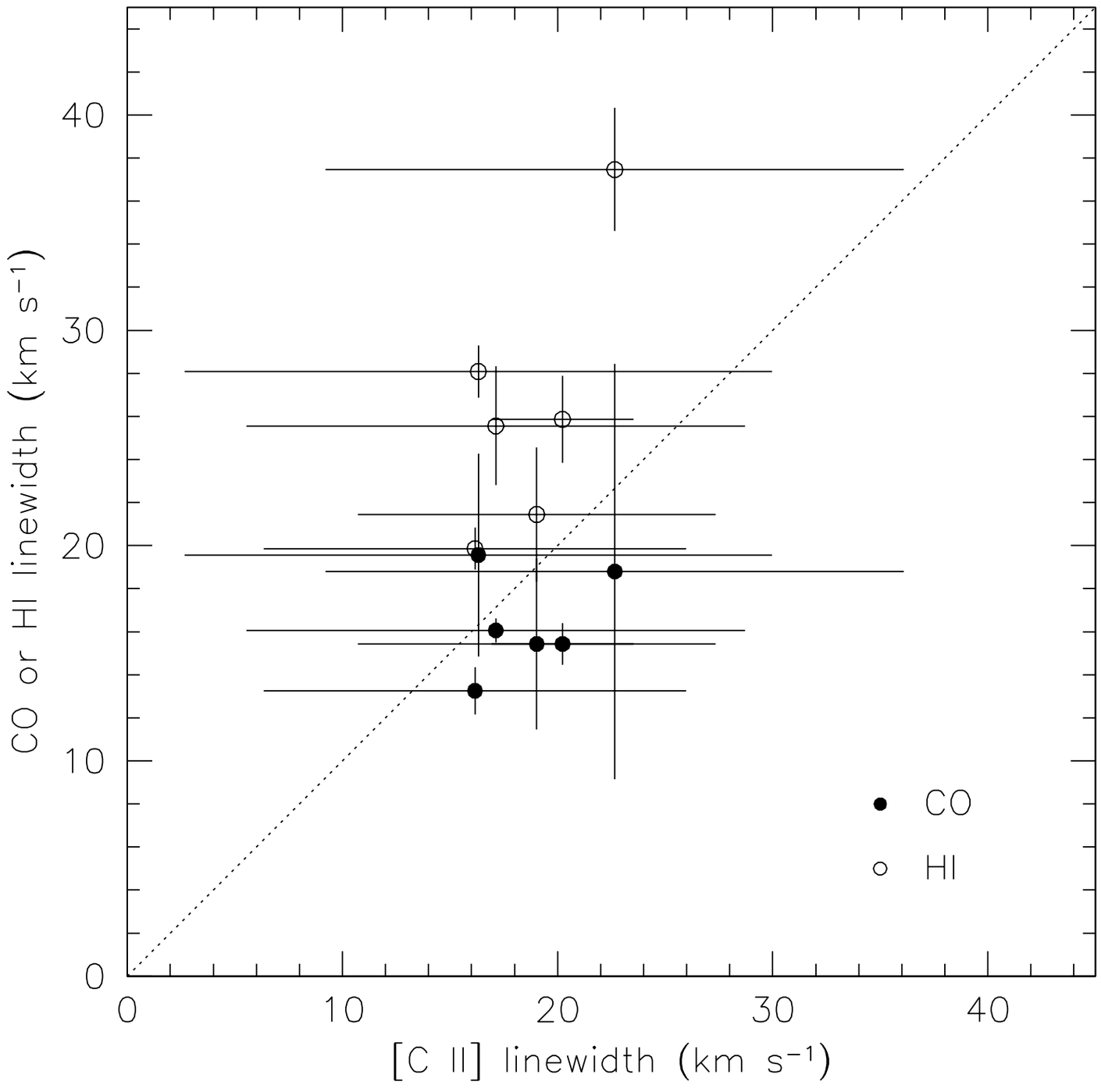
Smaller scales: SOFIA data





Smaller scales: SOFIA data





- [CII] dispersions closer to CO
- mean velocities agree

Summary

- [CII] radial surface density follows CO more closely than HI
- Integrated spectrum agrees
- Assuming CO, HI, [CII], SFR relations hold, [CII] observations at high z should be treated more like CO *)

*for "normal" galaxies, probably not for ultra-low Z or ULIRGS