Relation between molecular cloud and star formation

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How molecular cloud affect star formation?

- density of molecular cloud…
- velocity dispersion of molecular cloud…
- etc.

Kennicutt-Schmidt law

$$\Sigma_{SFR} \propto \left(\Sigma_{\rho}\right)^{p}$$

where Σ_{ρ} is surface density of molecular cloud

is this relation still exist in single galaxy?

if so, how about p?

is it variant with different place of galaxy?

Estimate star formation rate

Use infrared data from Spitzer telescope

$$\frac{\Sigma_{SFR}}{\left(M_{\odot} yr^{-1}\right)} = \frac{\nu L_{\nu}[8\mu m(dust)]}{1.57 \times 10^{9} L_{\odot}}$$

Estimate density of molecular cloud

Use CO emission from ALMA achieve

$$N_{H_2} = X \int T_{MB} \left(CO[1-0] \right) dv$$

where X is called the conversion factor

Conversion factor

Typically, conversion factor $X \approx 2.3 \times 10^{20} \left[K \cdot km / s \right]^{-1} cm^{-2}$

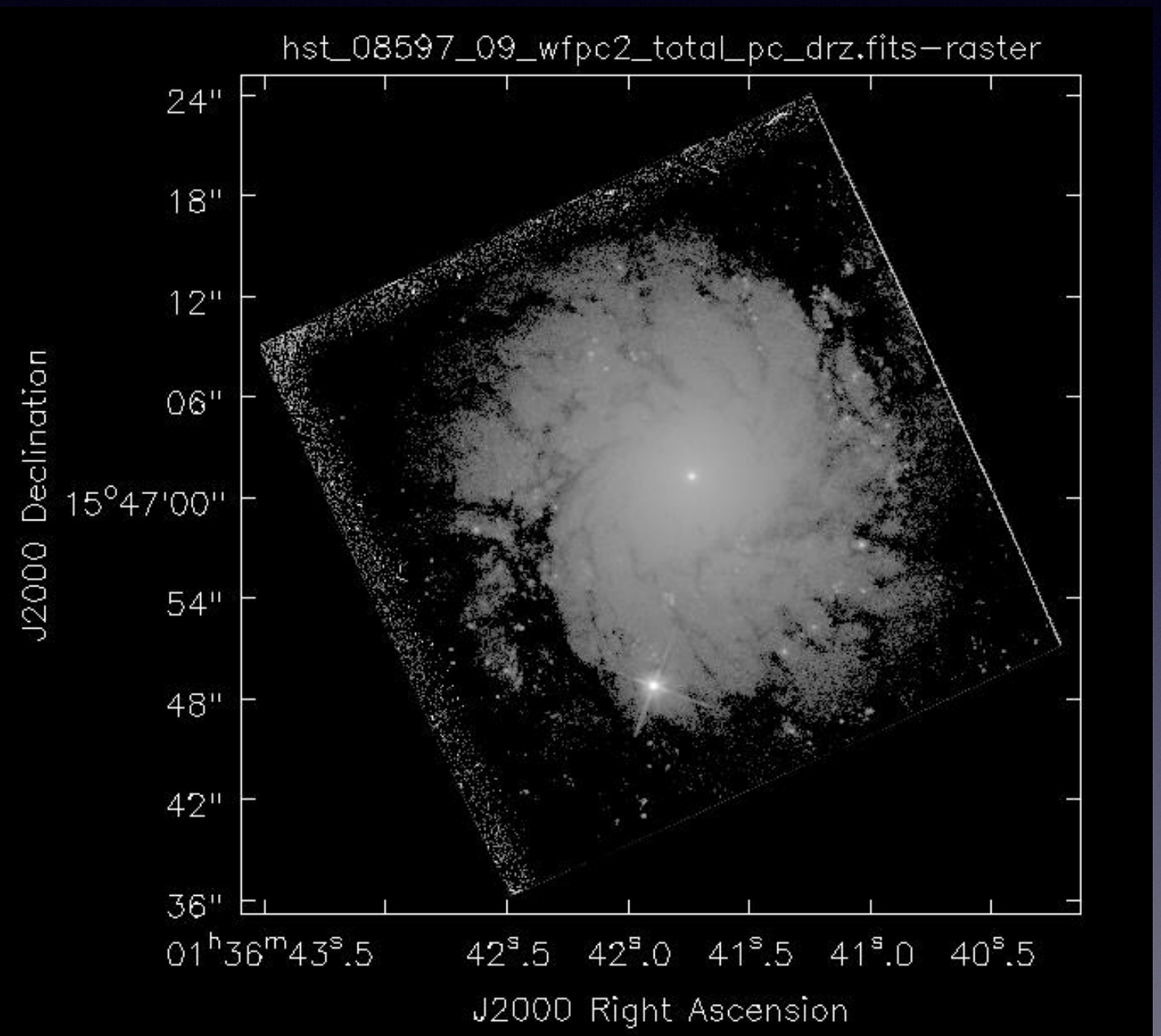
but it may 5 times less near active region such as AGN, starburst galaxy, etc.

Velocity dispersion

Does velocity dispersion of molecular cloud also affect SFR?

we might expect that higher velocity dispersion implies lower SFR…

M74/NGC628



RA. $01^h36^m41.8^s$

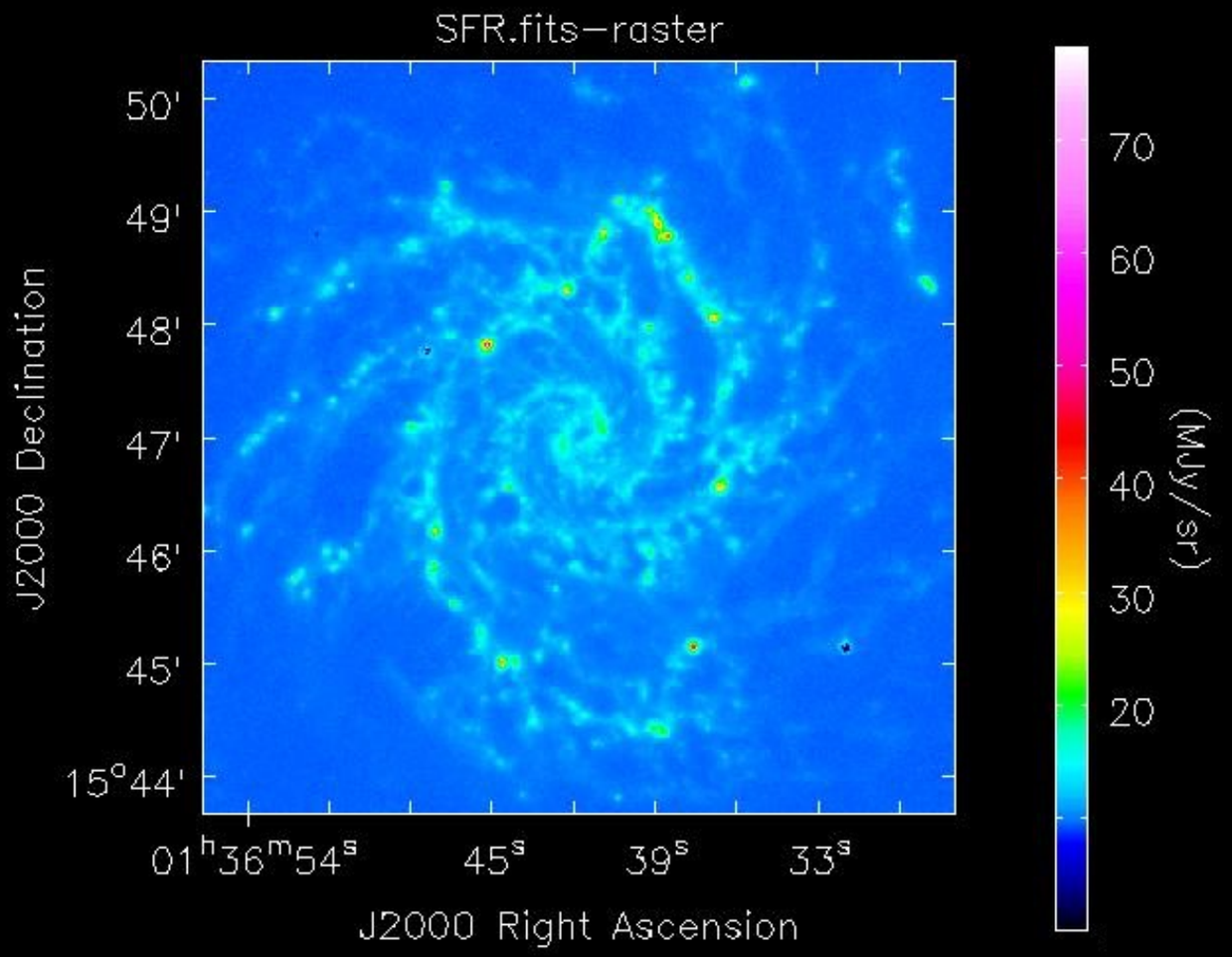
Dec. −15° 47′ 01″

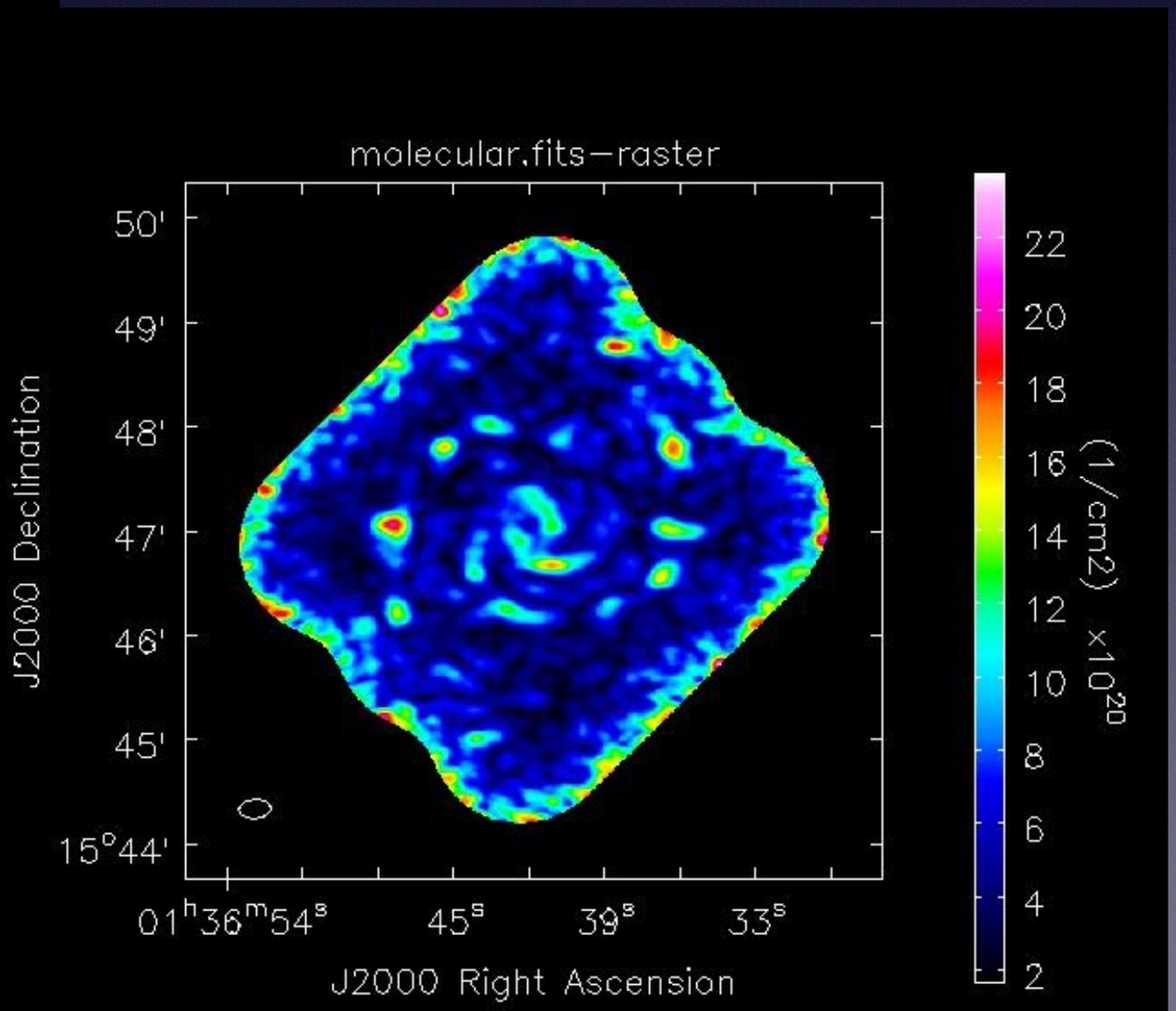
redshift ~657 km/s

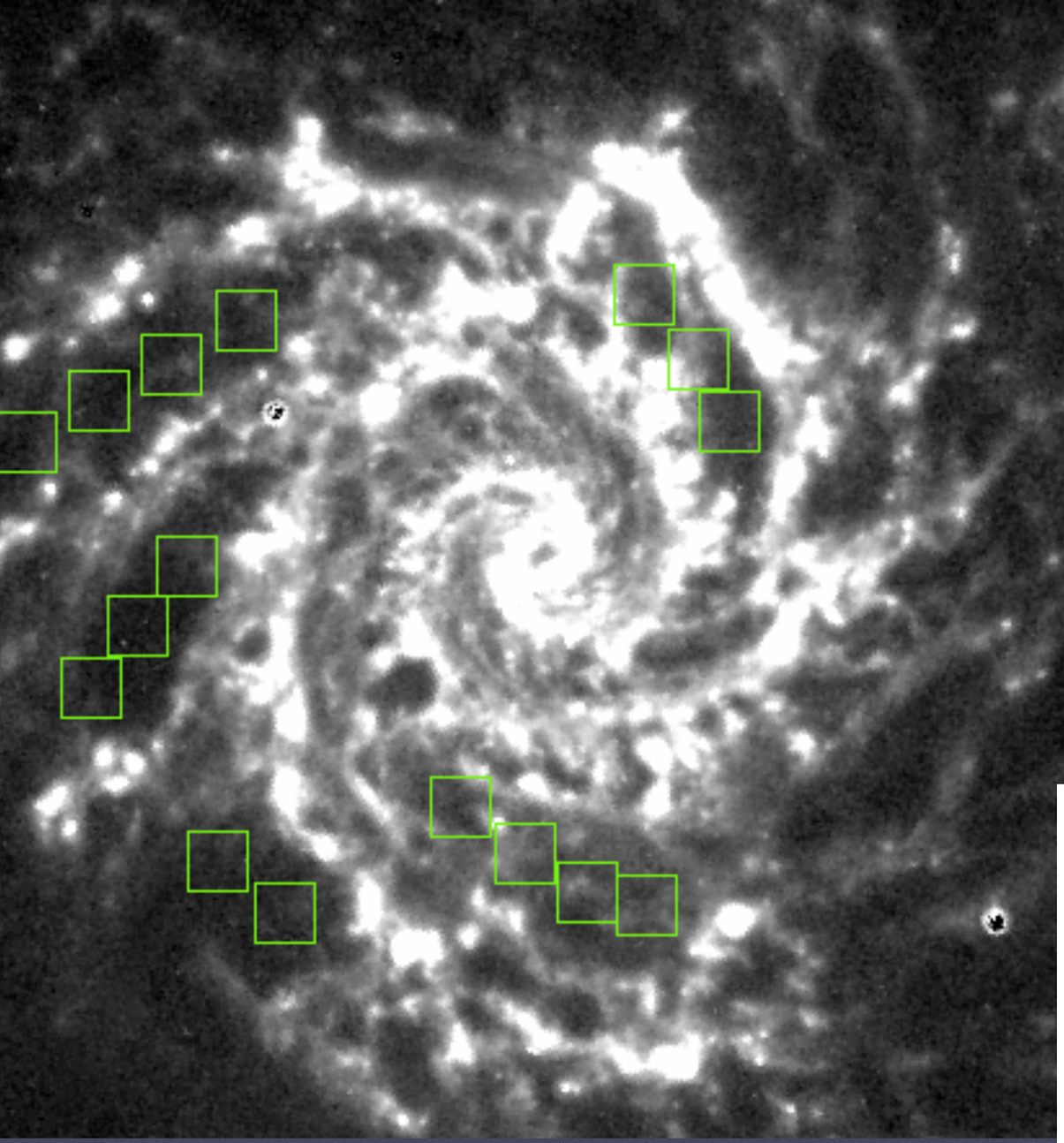
scale ~34.9 pc/arcsec

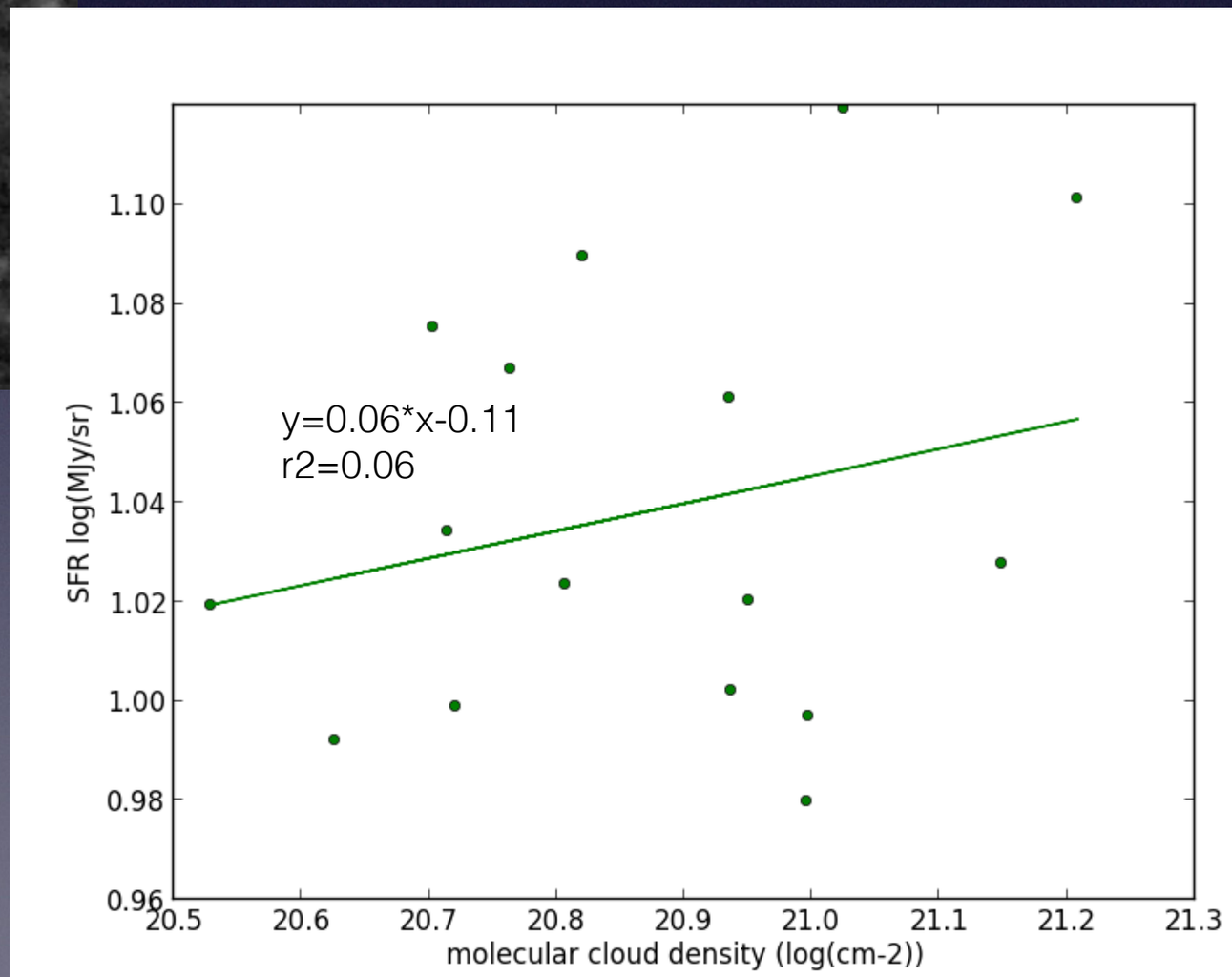
Gusev et al. 2014

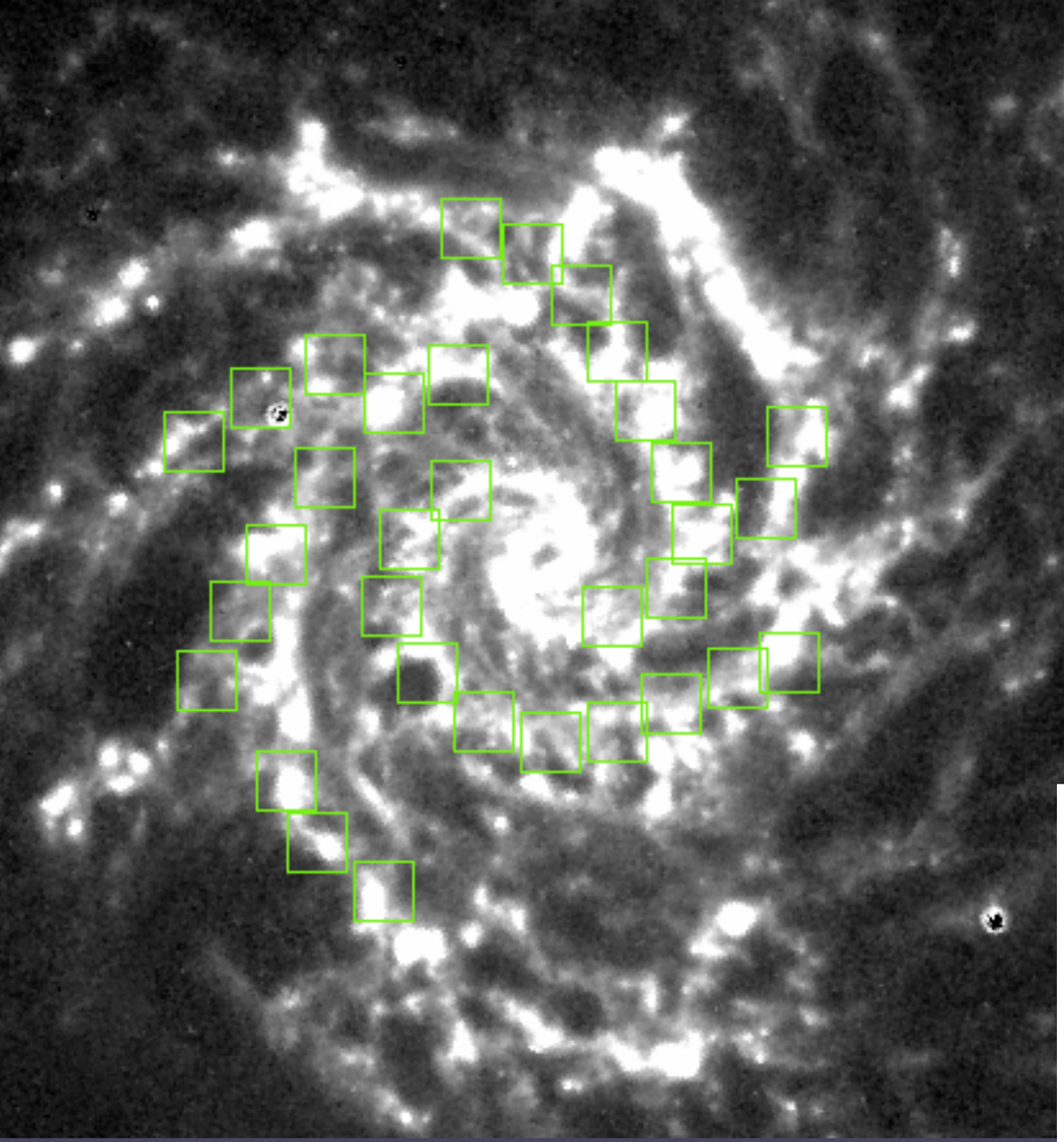
image by Hubble space telescope

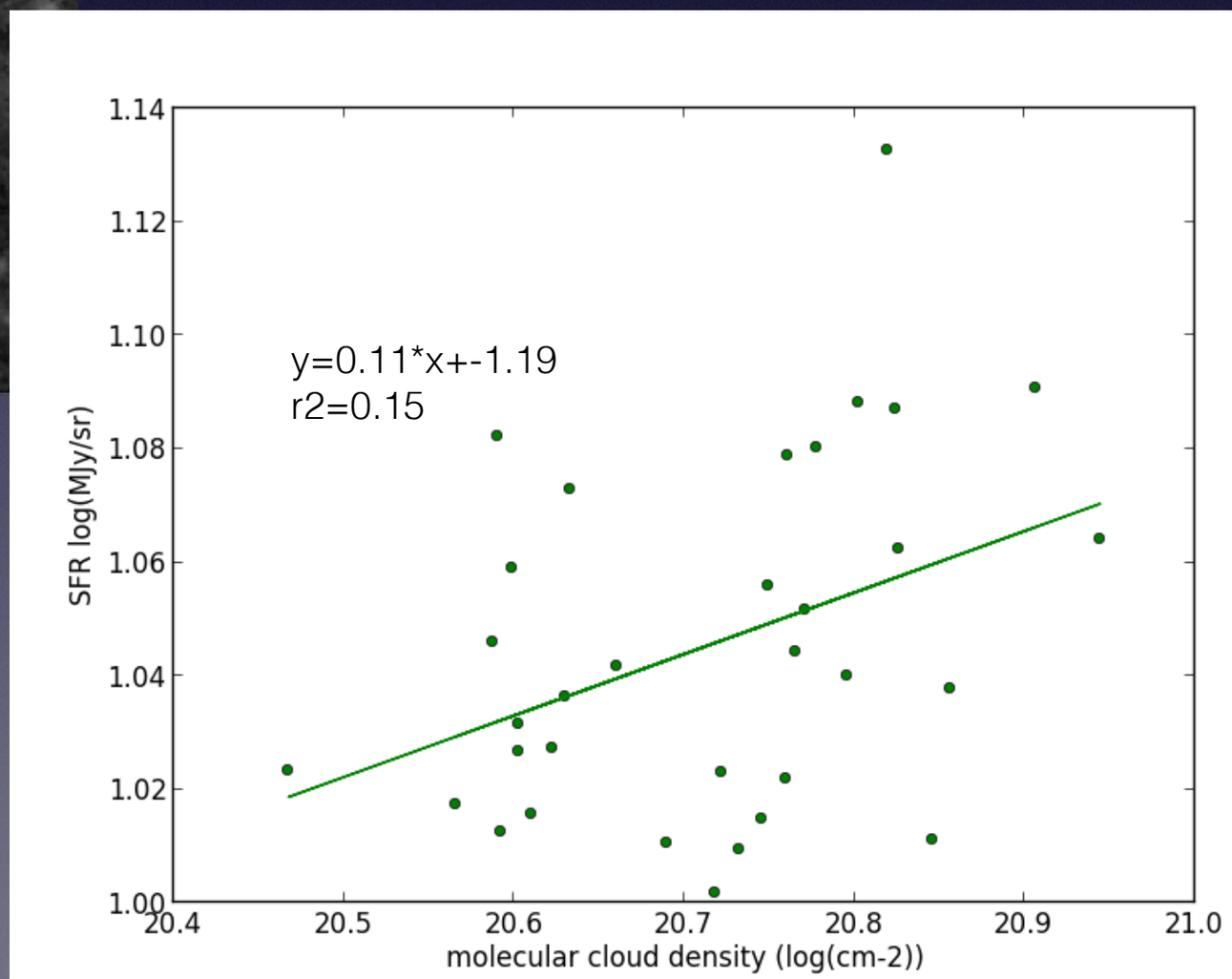

SFR.fits−raster
50'
49'
48'
47'
46'
45'
15°44'
J2000 Declination
01h36m54s
45s
39s
33s
J2000 Right Ascension
70
60
50
40
30
20
(MJy/sr)

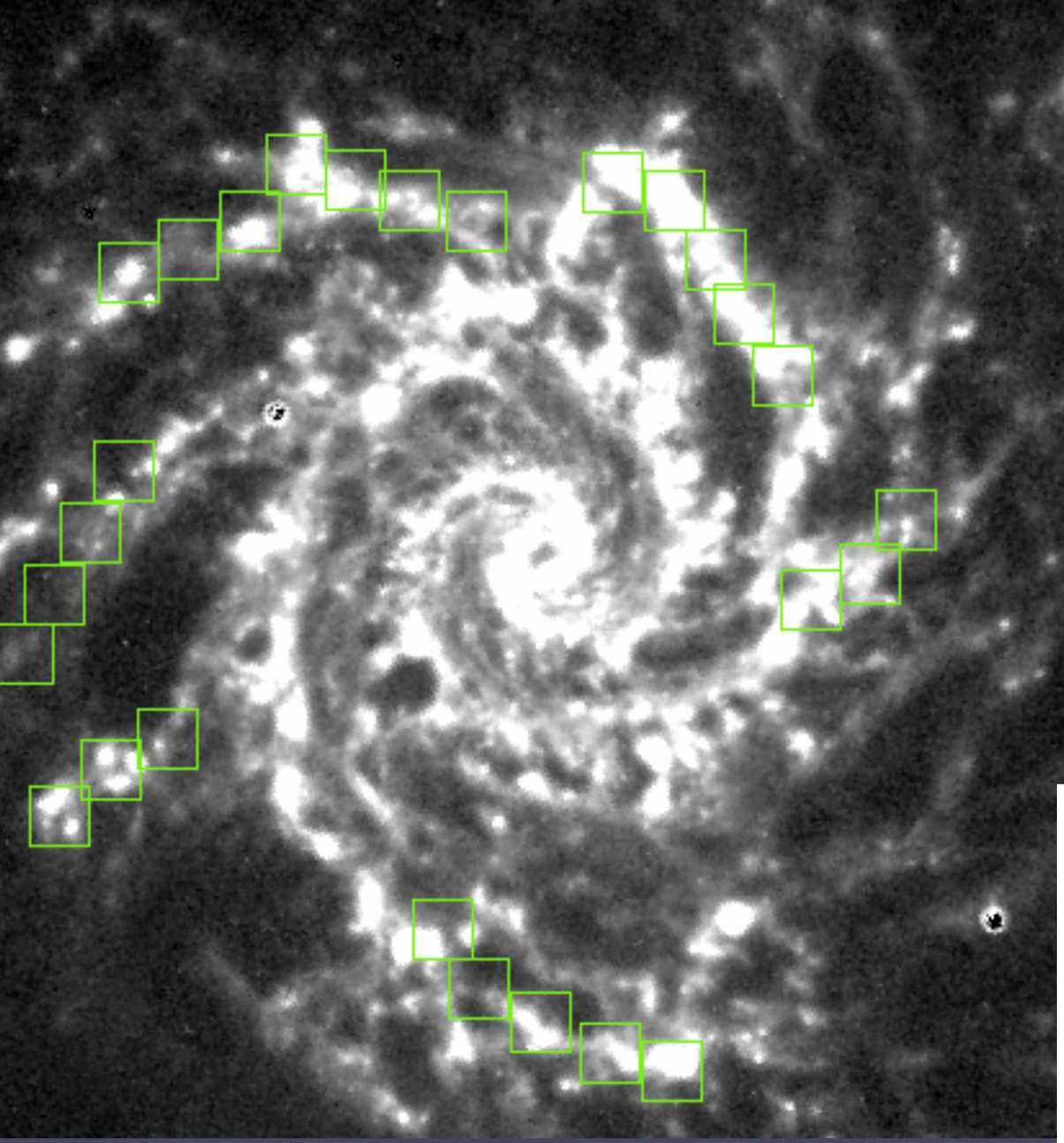

molecular.fits−raster
50'
49'
48'
47'
46'
45'
15°44'
J2000 Declination
01h36m54s
45s
39s
33s
J2000 Right Ascension
22
20
18
16
14
12
10
8
6
4
2
(1/cm2) ×10^20

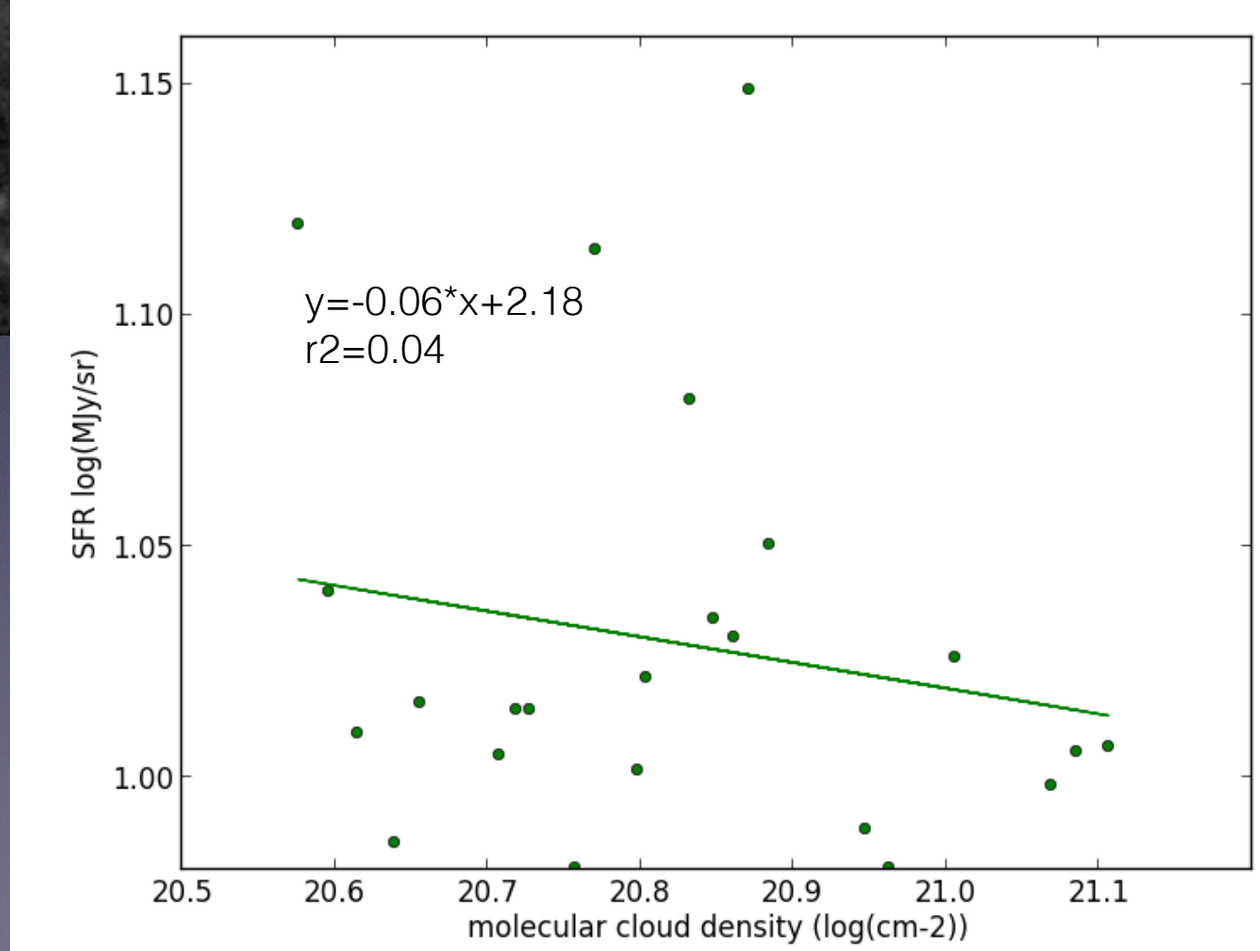


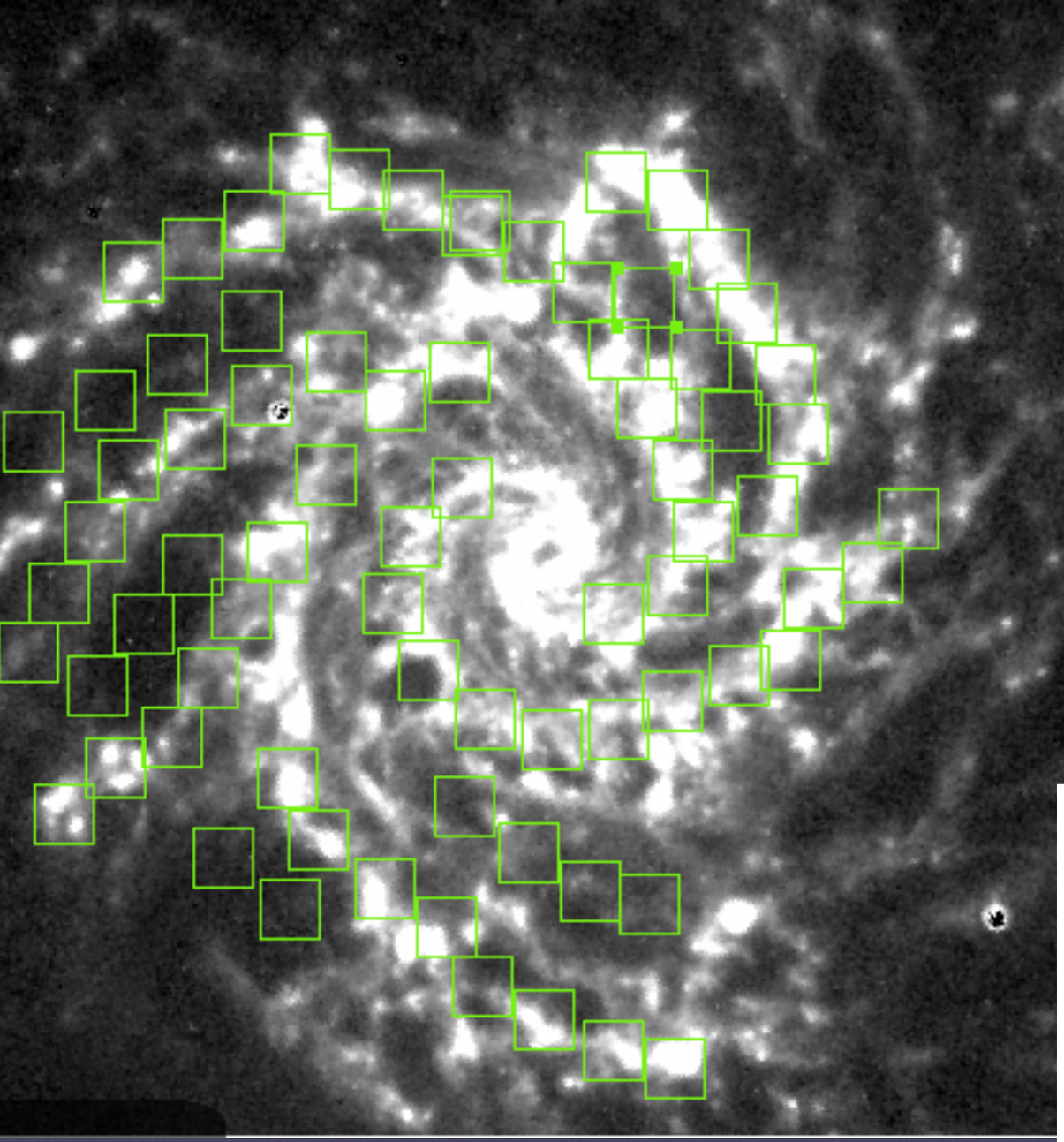

y=0.06*x-0.11
r2=0.06
SFR log(MJy/sr)
molecular cloud density (log(cm-2))
1.10
1.08
1.06
1.04
1.02
1.00
0.98
0.96
20.5
20.6
20.7
20.8
20.9
21.0
21.1
21.2
21.3

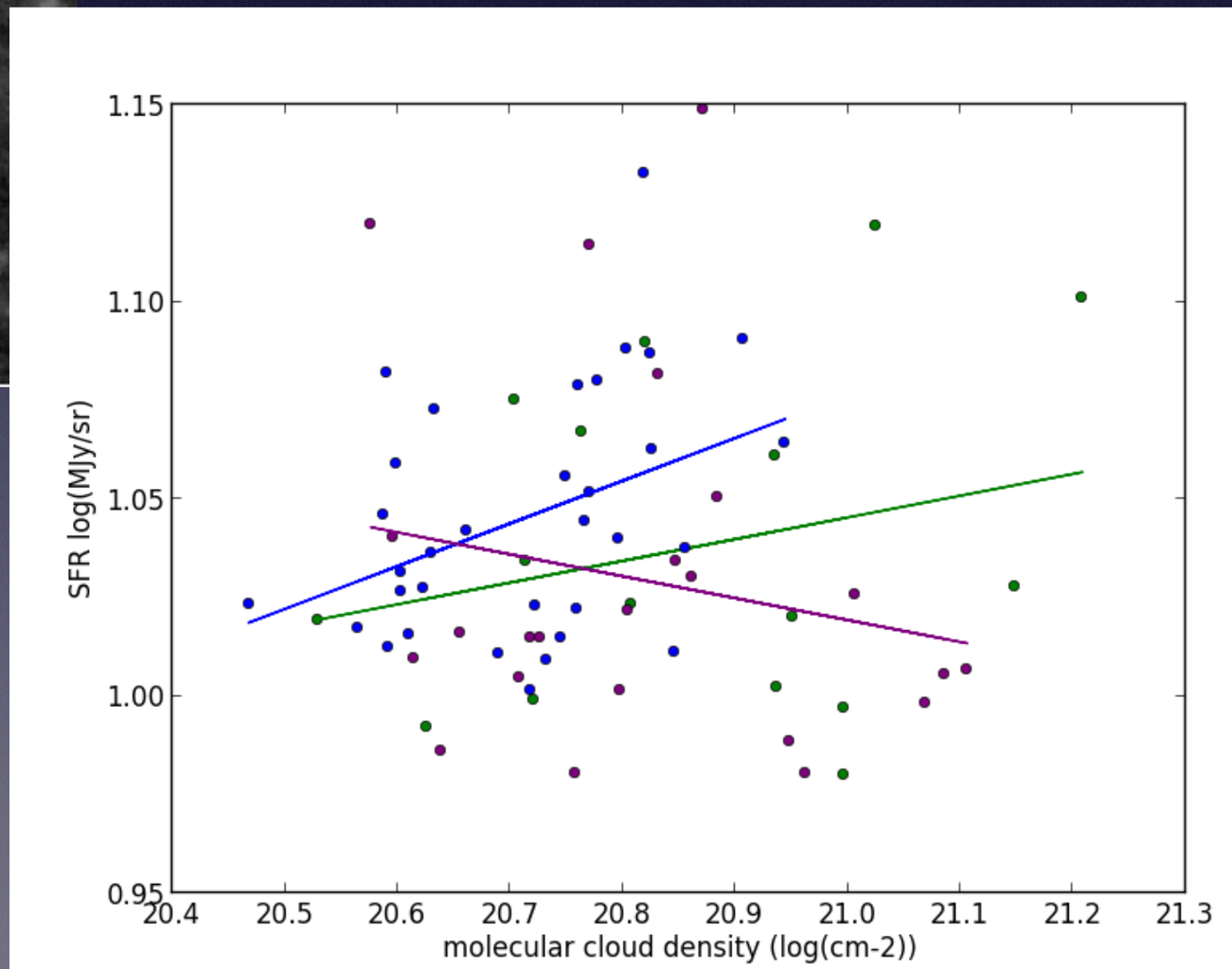



y=0.11*x+-1.19
r2=0.15
SFR log(MJy/sr)
molecular cloud density (log(cm-2))
1.14
1.12
1.10
1.08
1.06
1.04
1.02
1.00
20.4
20.5
20.6
20.7
20.8
20.9
21.0

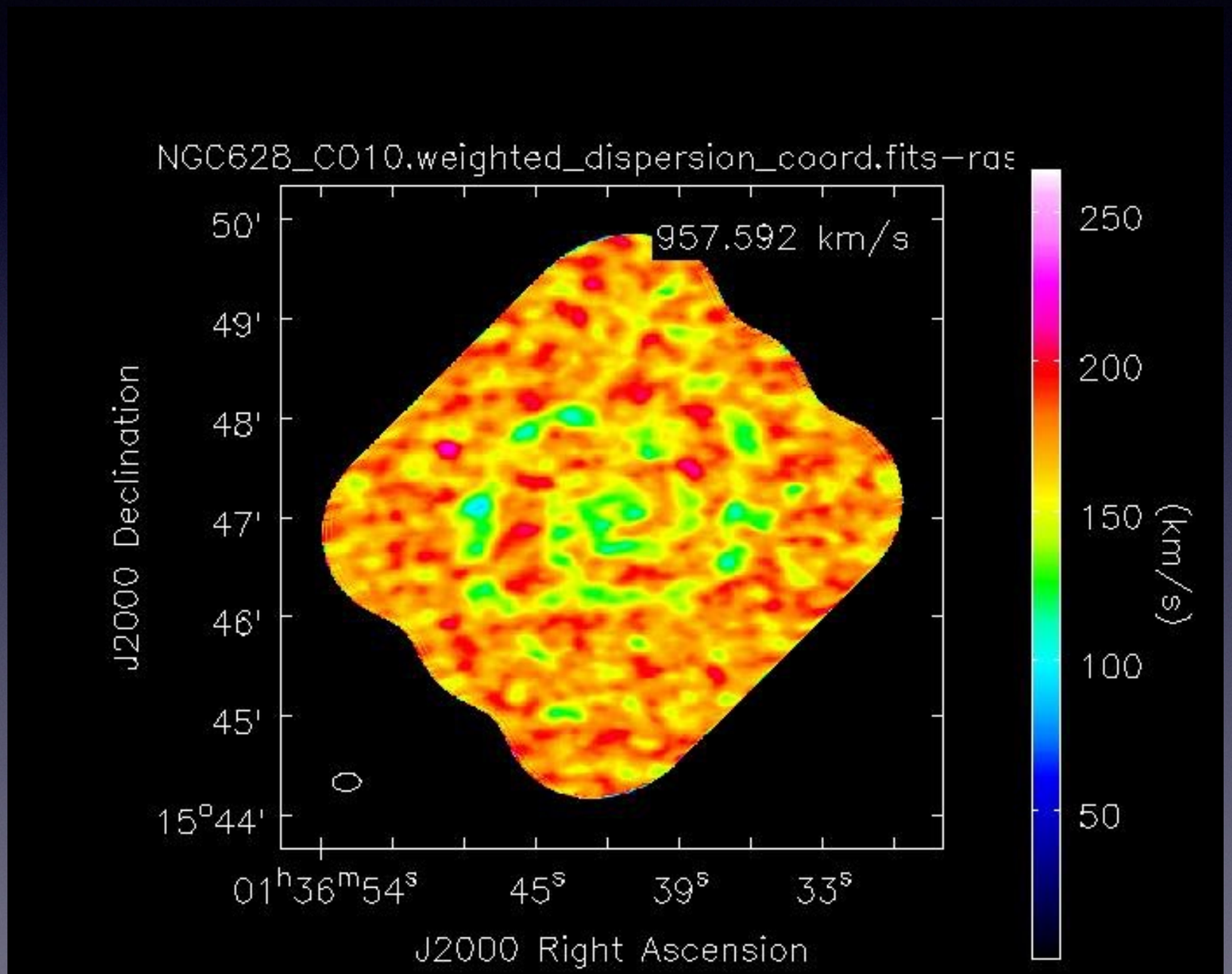


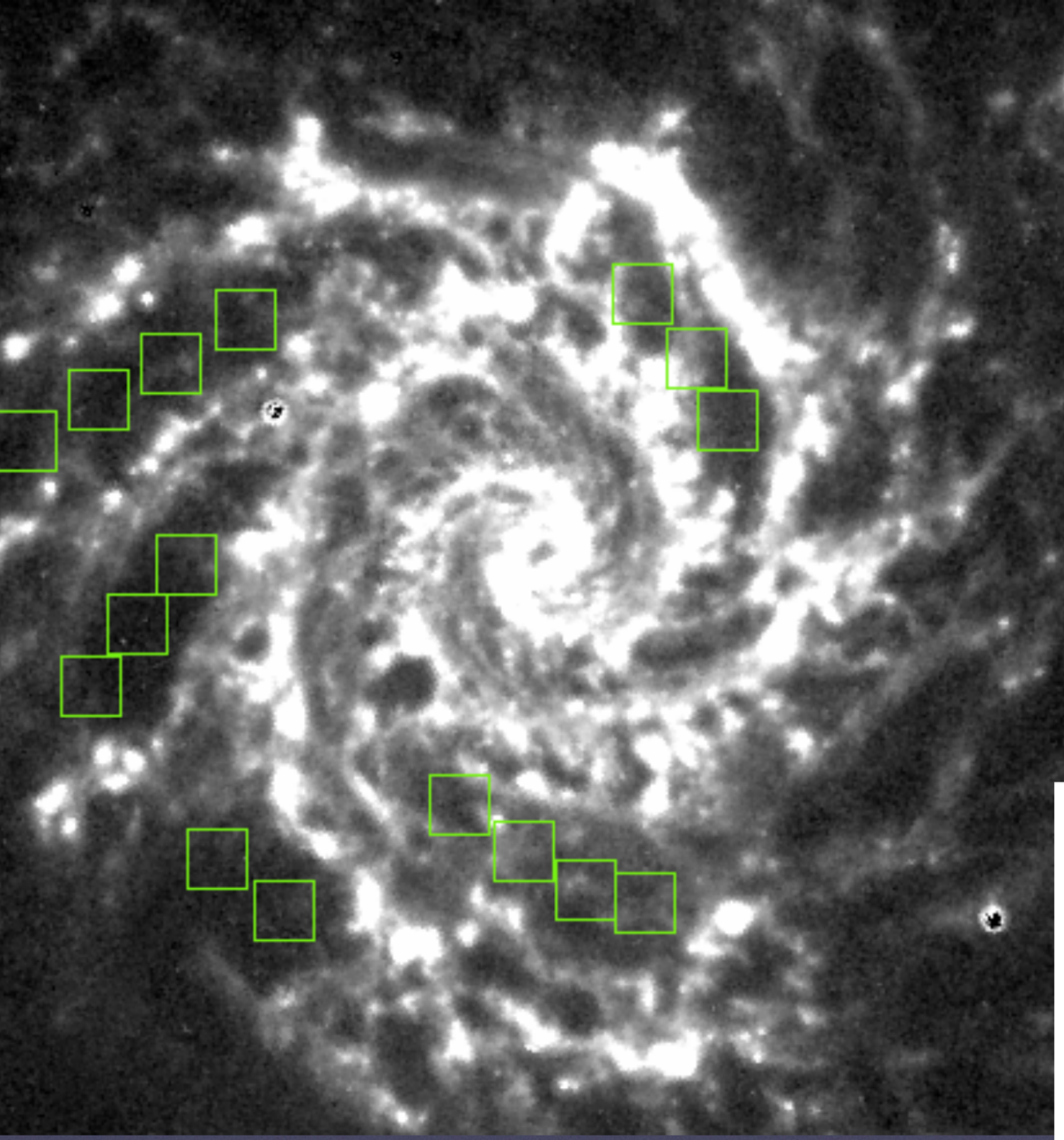

y=-0.06*x+2.18
r2=0.04
SFR log(MJy/sr)
molecular cloud density (log(cm-2))
1.15
1.10
1.05
1.00
20.5
20.6
20.7
20.8
20.9
21.0
21.1

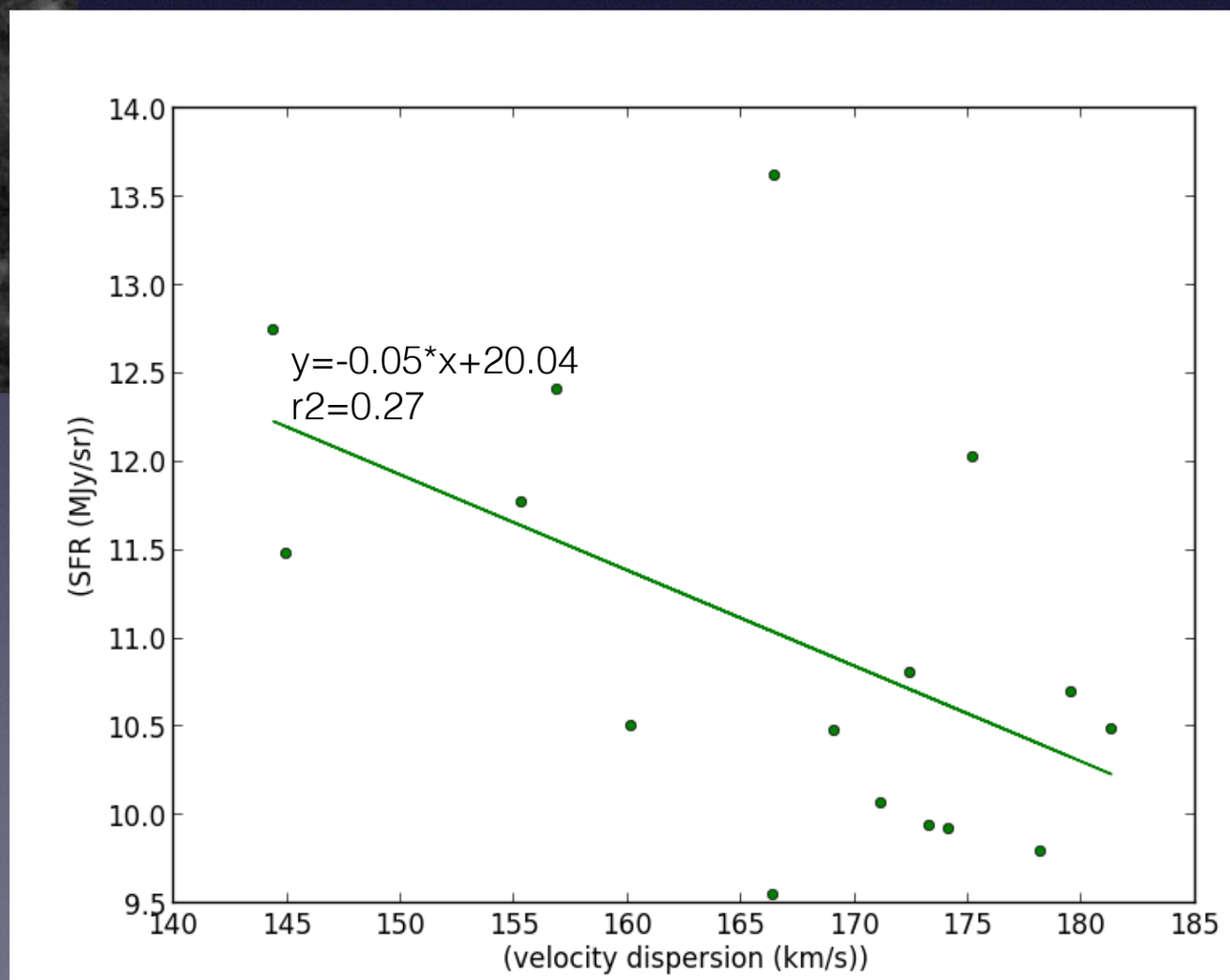


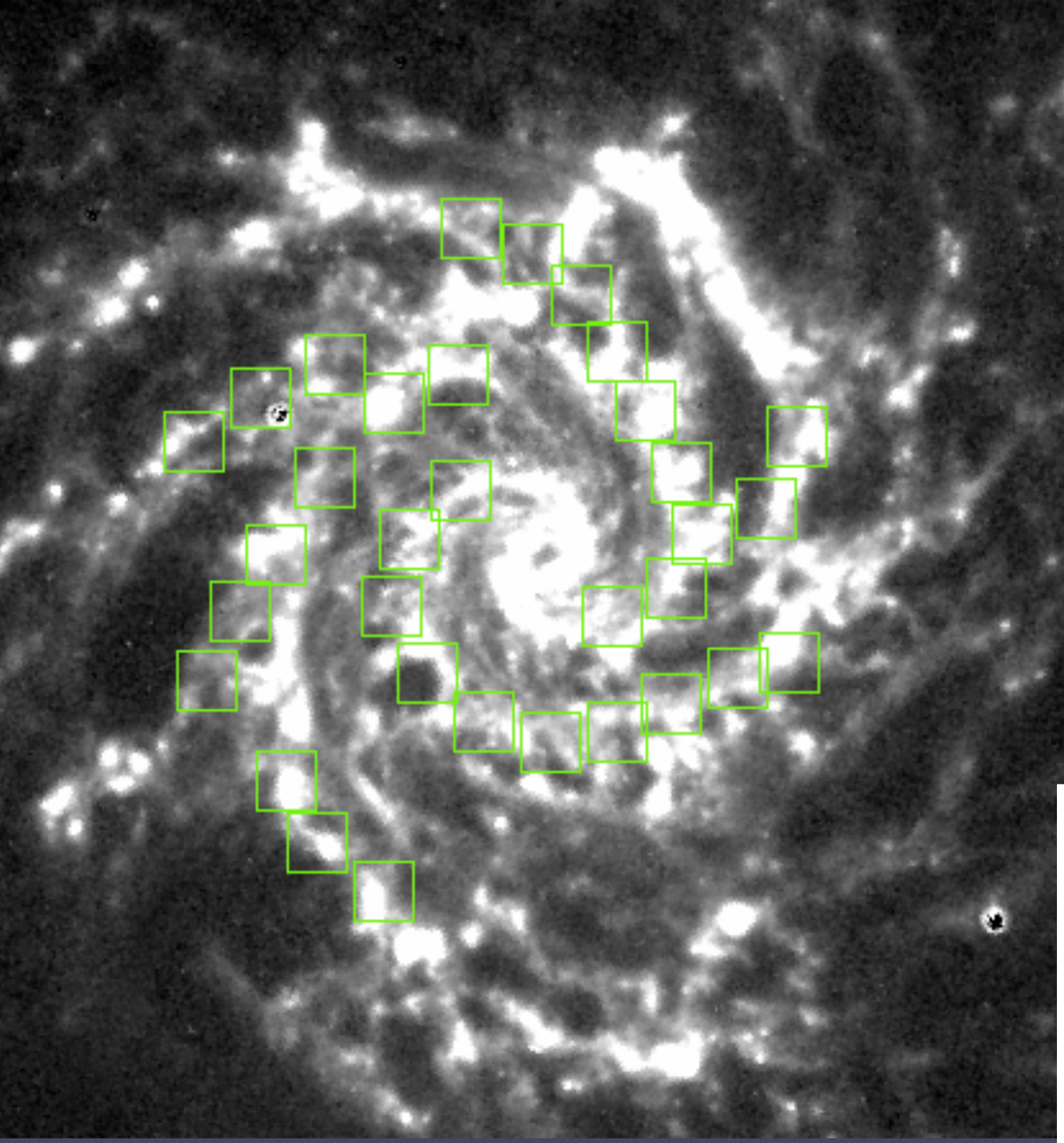

1.15
1.10
1.05
1.00
0.95
SFR log(MJy/sr)
20.4
20.5
20.6
20.7
20.8
20.9
21.0
21.1
21.2
21.3
molecular cloud density (log(cm-2))

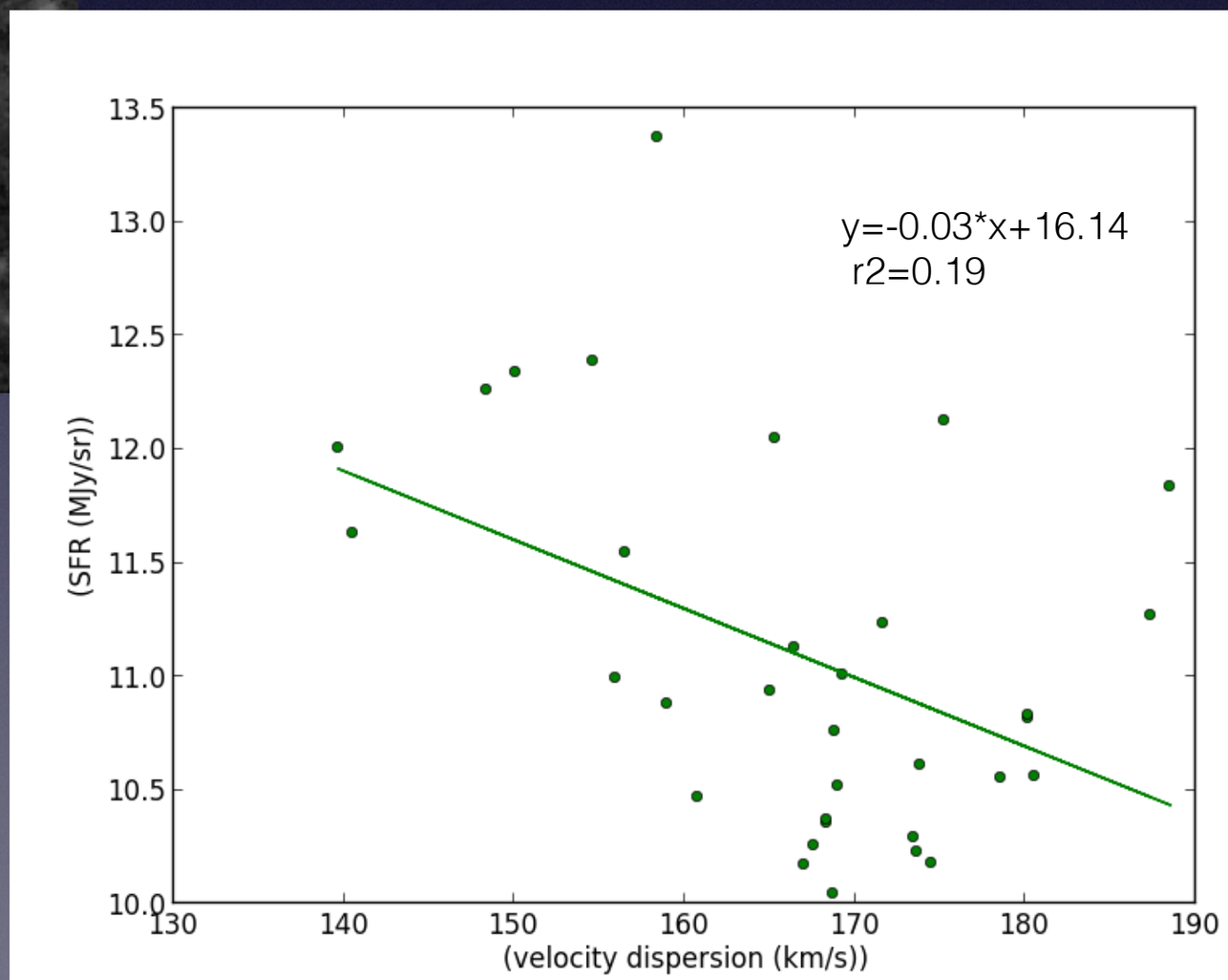
Velocity dispersion

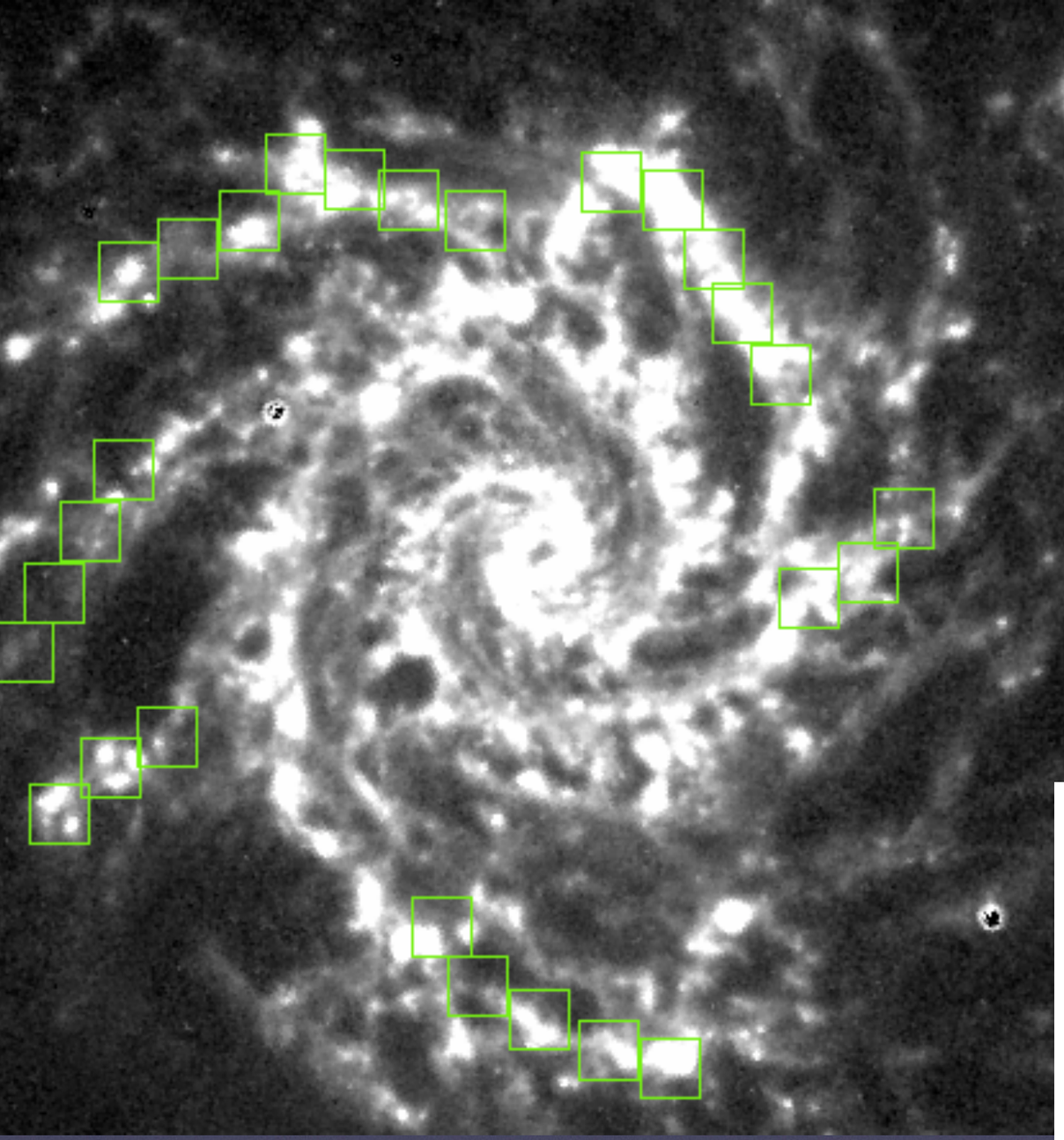


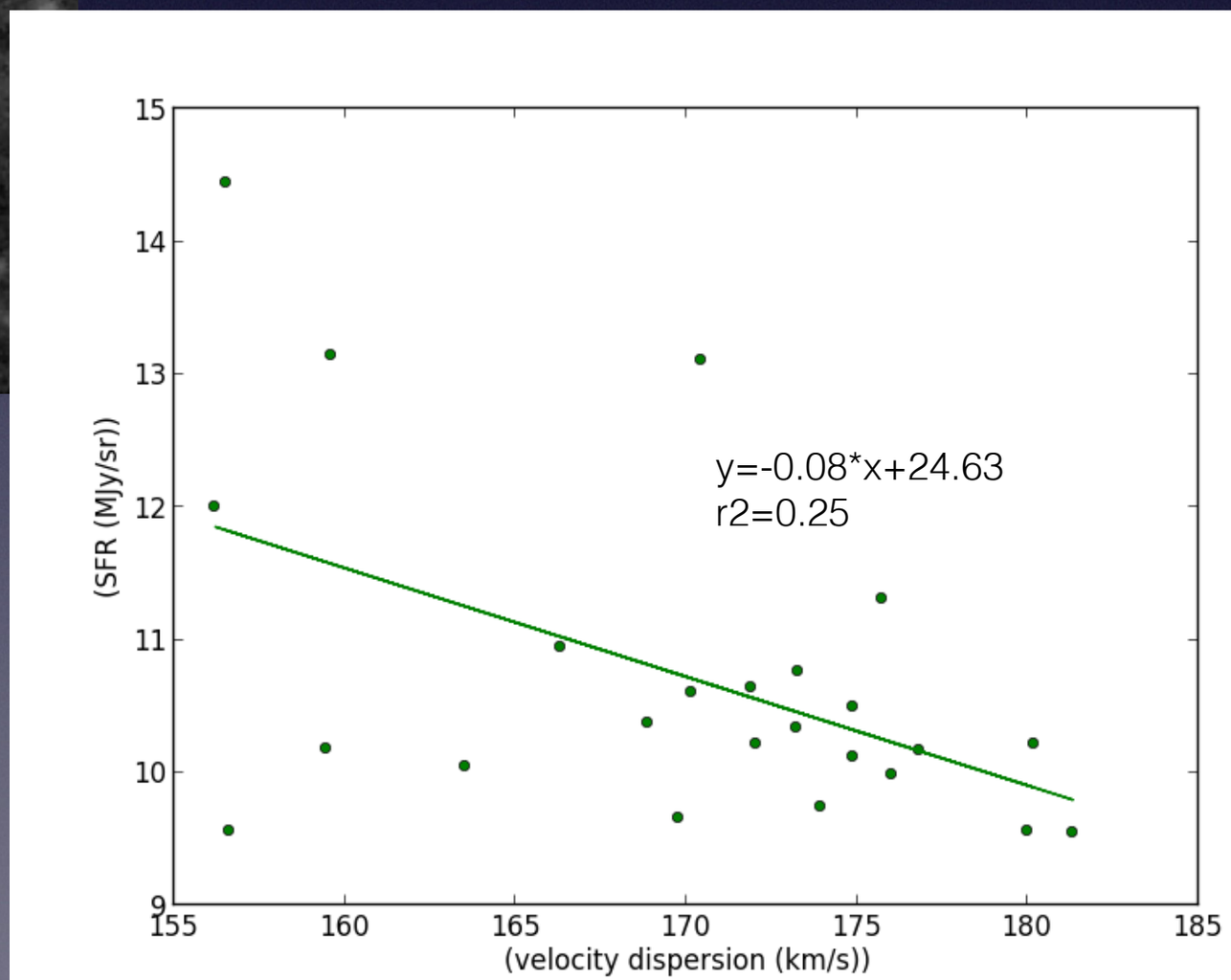


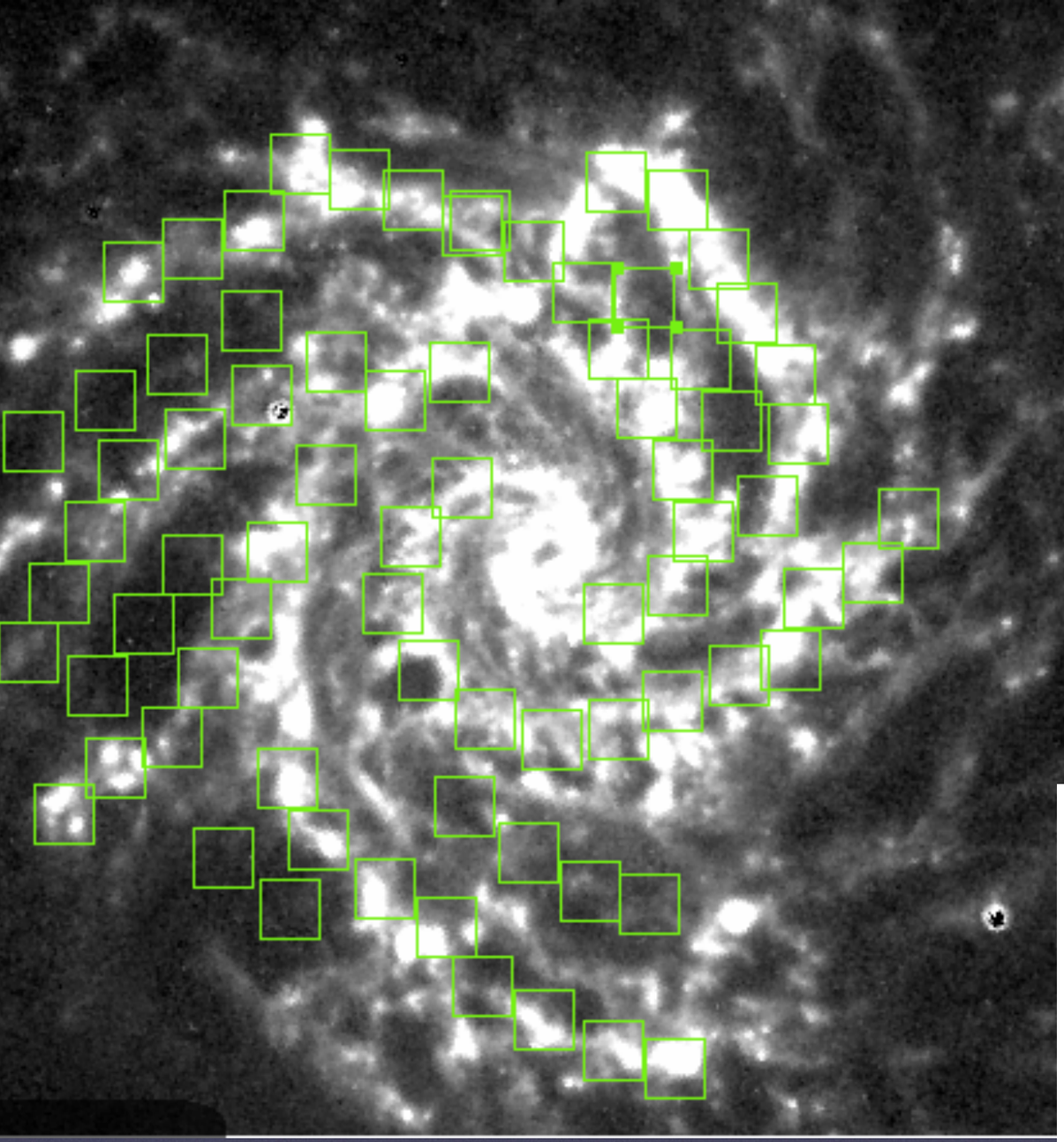

y=-0.05*x+20.04
r2=0.27
(SFR (MJy/sr))
(velocity dispersion (km/s))
14.0
13.5
13.0
12.5
12.0
11.5
11.0
10.5
10.0
9.5
140
145
150
155
160
165
170
175
180
185




y=-0.03*x+16.14
r2=0.19
(SFR (MJy/sr))
(velocity dispersion (km/s))
13.5
13.0
12.5
12.0
11.5
11.0
10.5
10.0
130
140
150
160
170
180
190

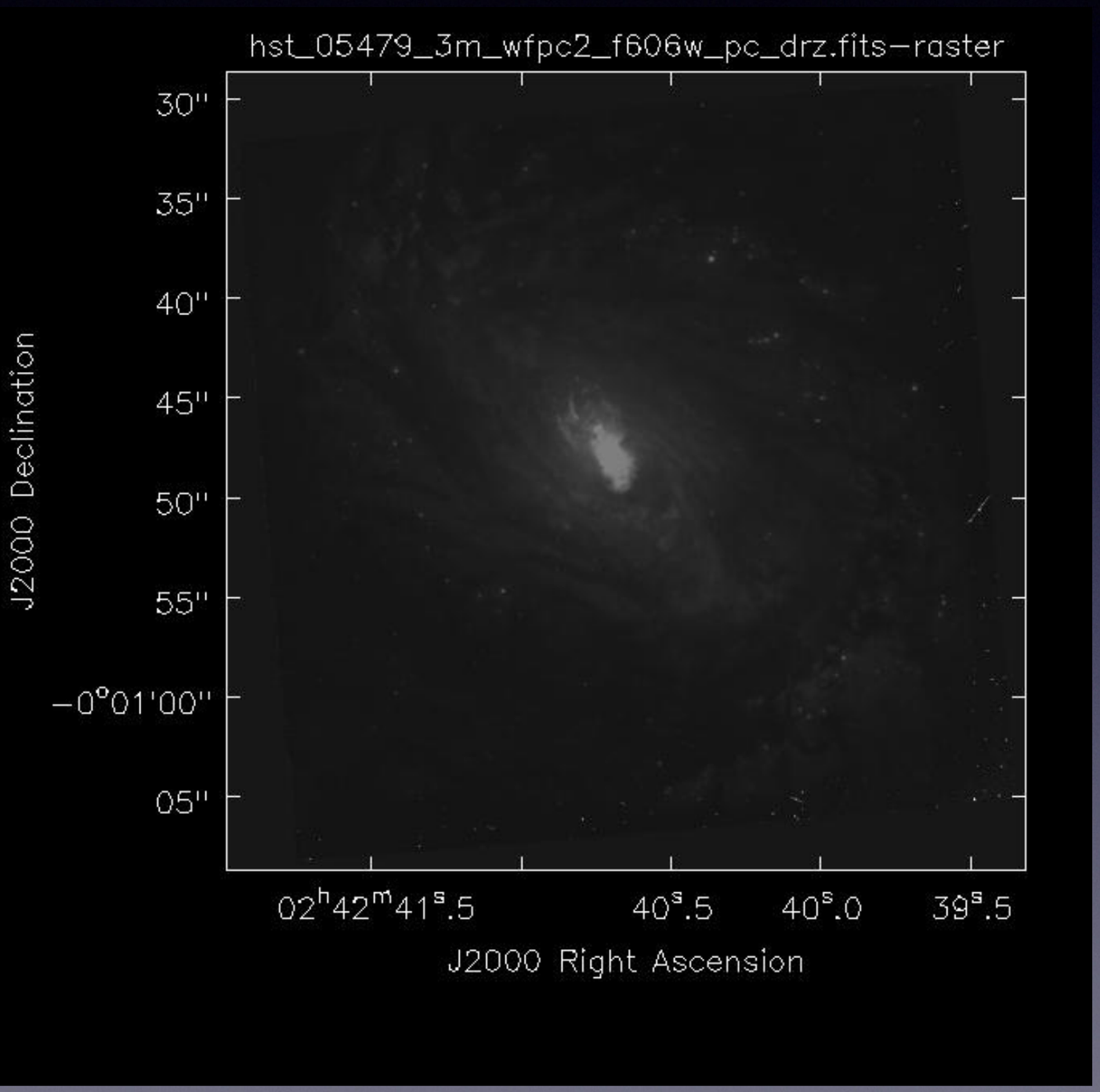



15
14
13
12
11
10
9
155
160
165
170
175
180
185
(SFR (MJy/sr))
(velocity dispersion (km/s))
y=-0.08*x+24.63
r2=0.25



15
14
13
12
11
10
9
(SFR (MJy/sr))
130
140
150
160
170
180
190
(velocity dispersion (km/s))

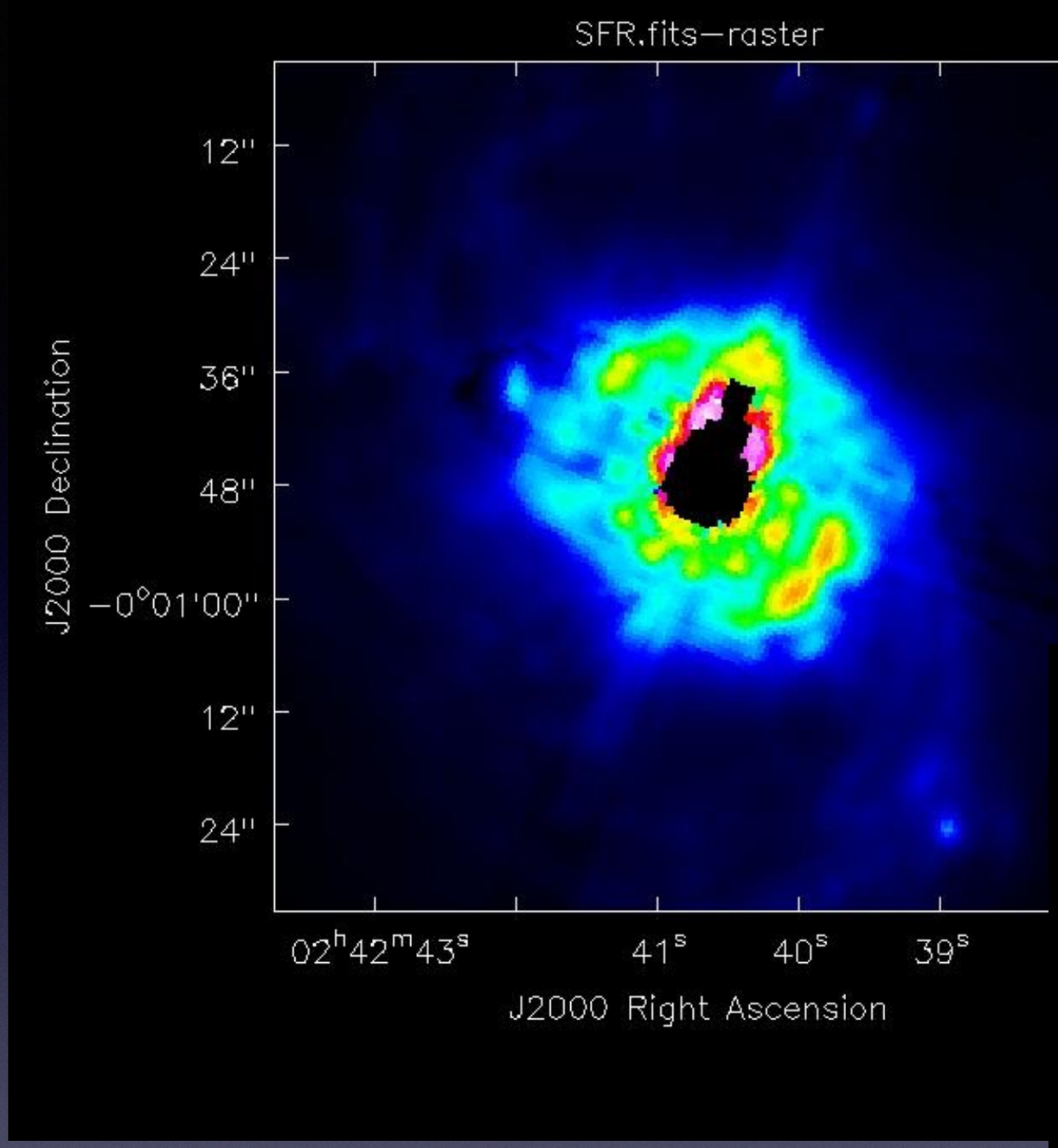
NGC1068/M77

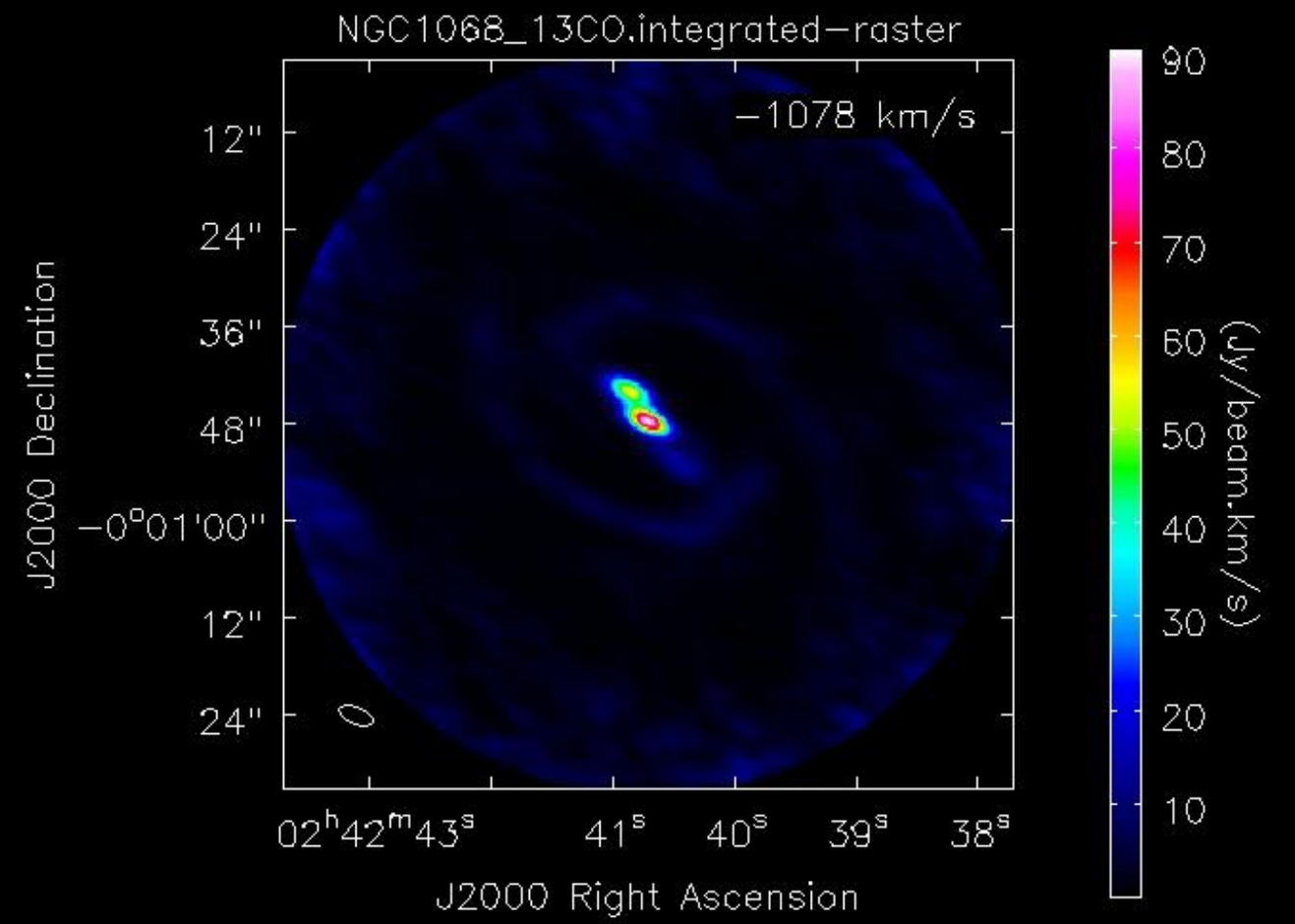


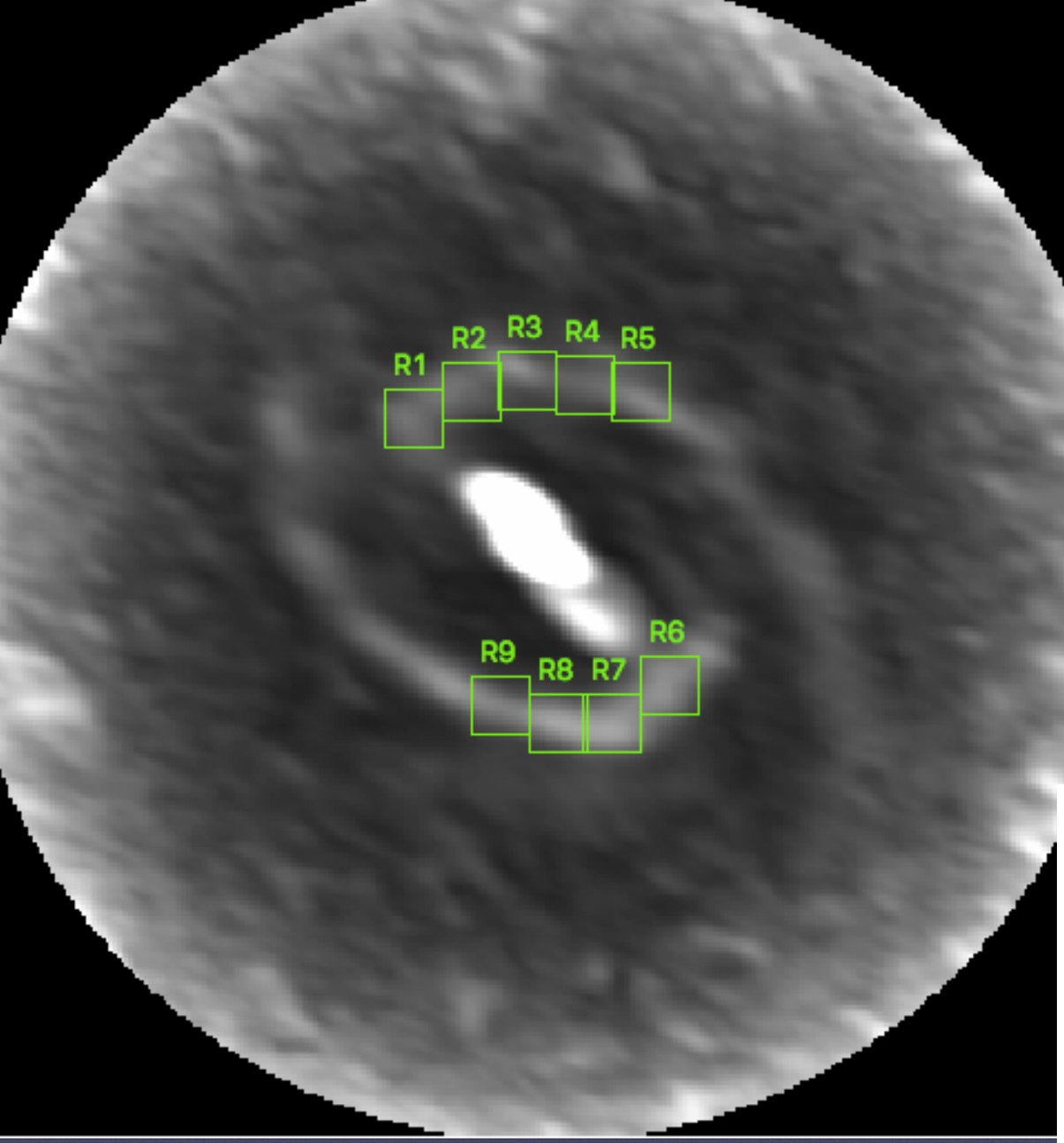
RA.	$2^h42^m40.7^s$
Dec.	−00° 00′ 48″
redshift	1137±3 km/s
scale	~72 pc/arcsec

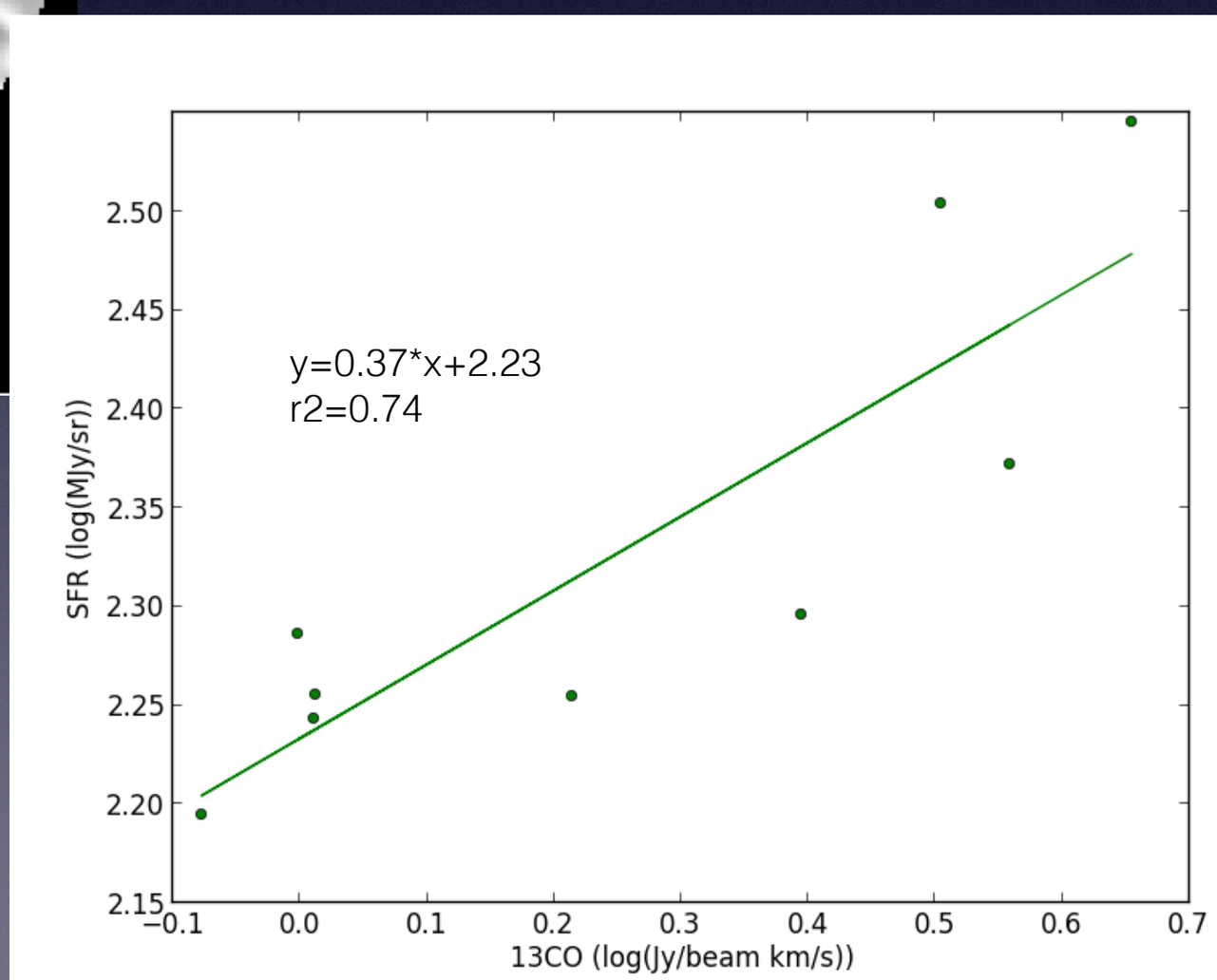
Bland-Hawthorn et al. 1997

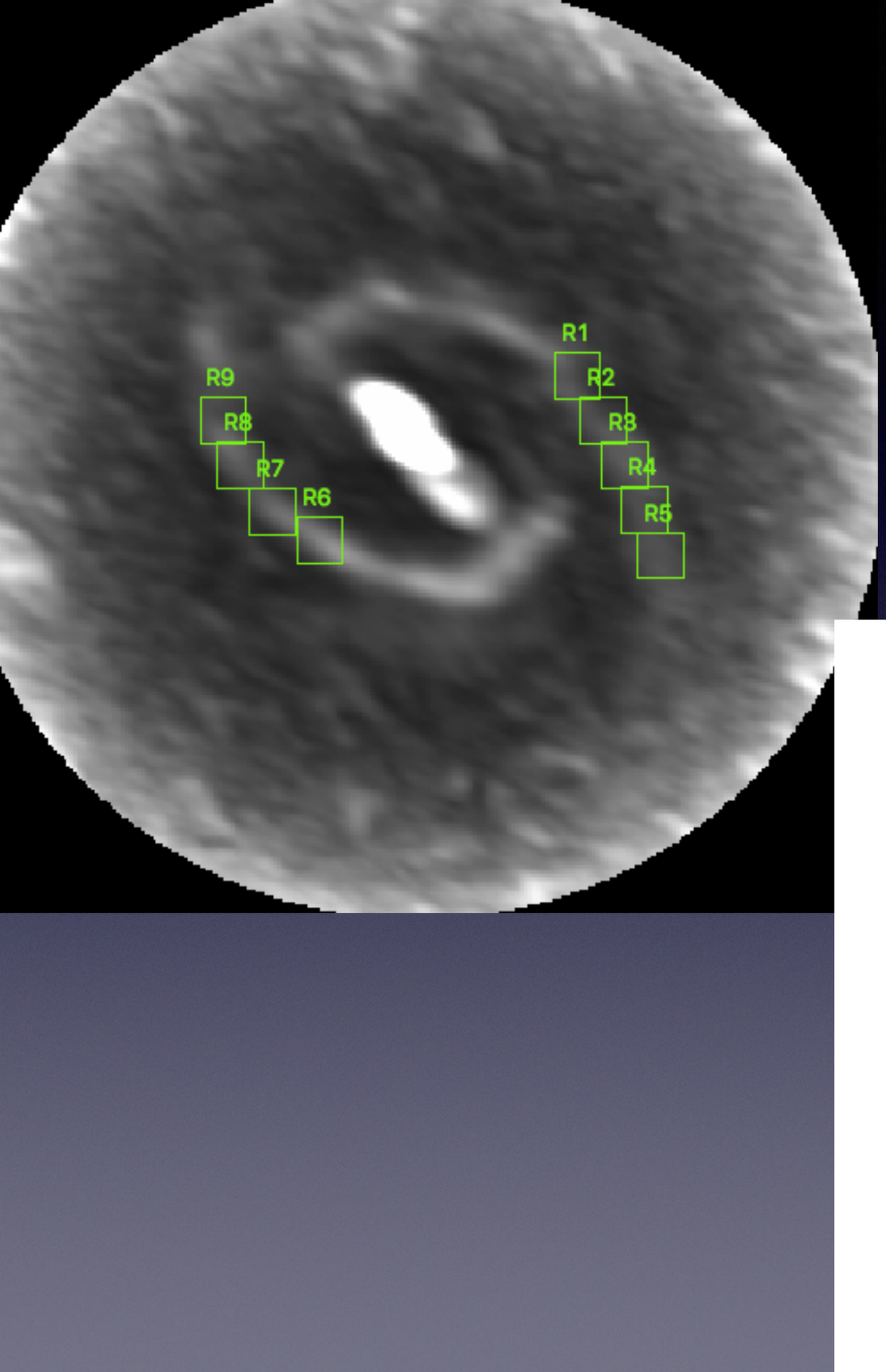
image by Hubble space telescope

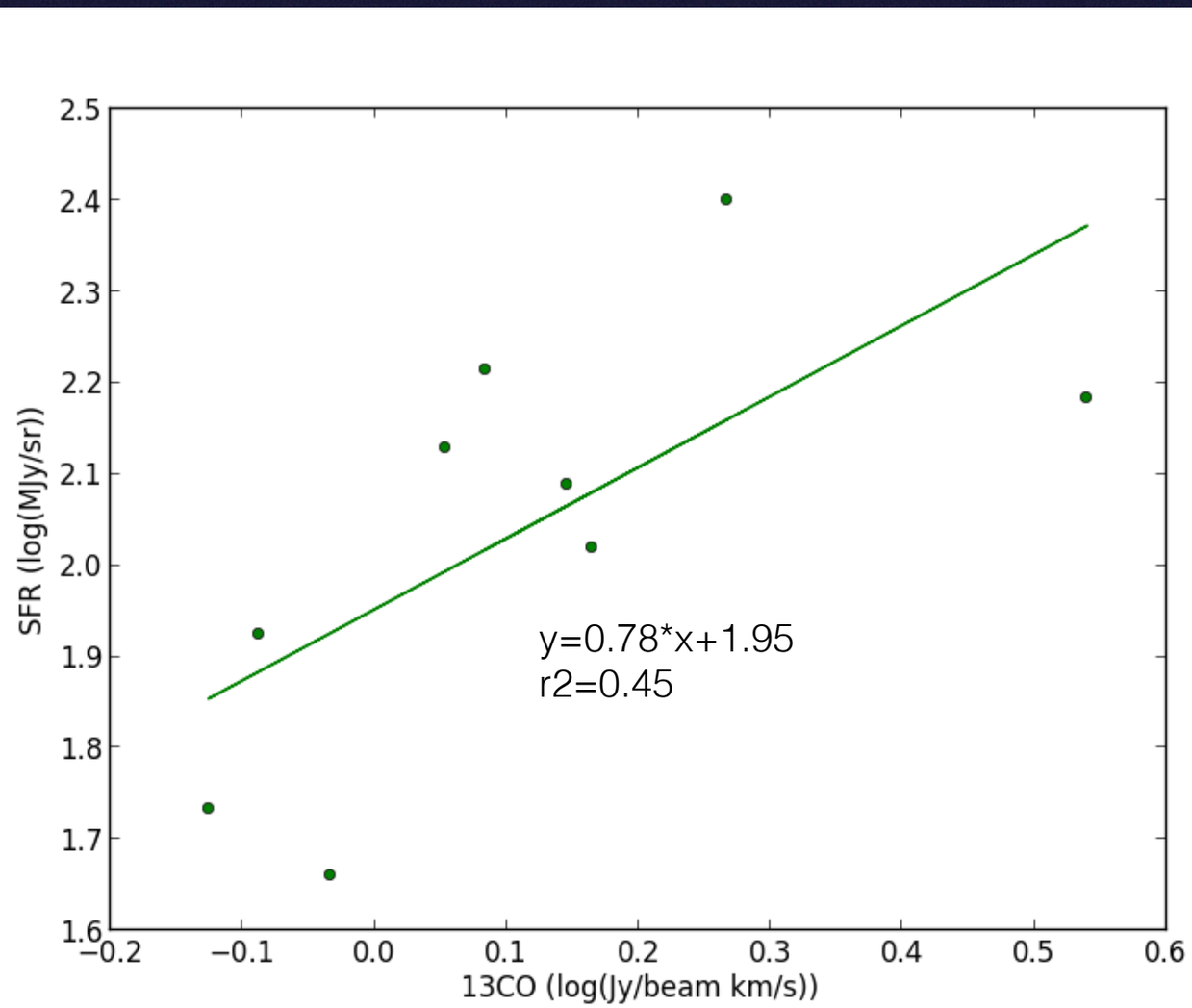

SFR.fits−raster
12''
24''
36''
48''
−0°01'00''
12''
24''
J2000 Declination
02h42m43s
41s
40s
39s
J2000 Right Ascension

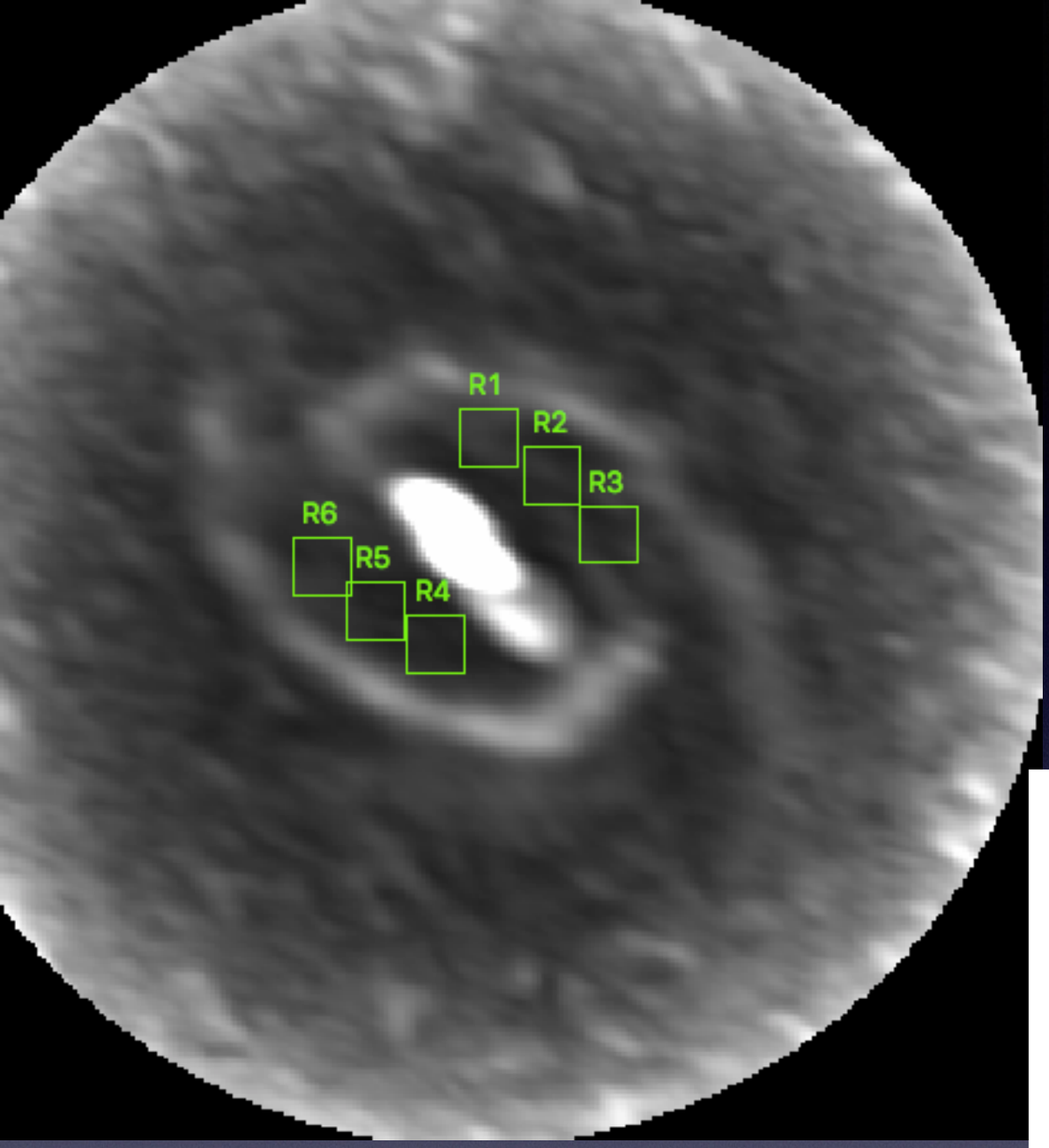

NGC1068_13CO.integrated−raster
−1078 km/s
12''
24''
36''
48''
−0°01'00''
12''
24''
J2000 Declination
02h42m43s
41s
40s
39s
38s
J2000 Right Ascension
90
80
70
60
50
40
30
20
10
(Jy/beam.km/s)

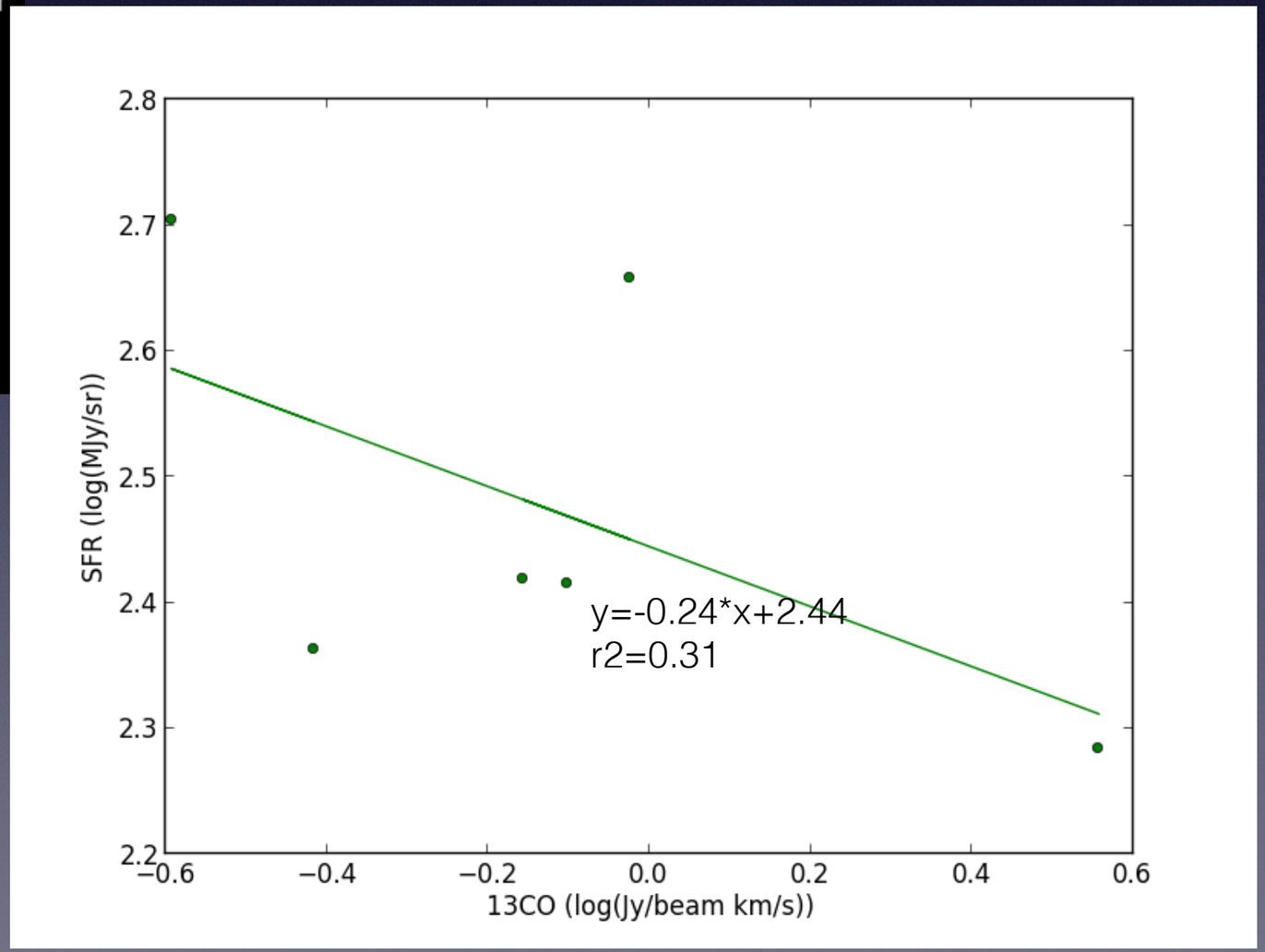

R1
R2
R3
R4
R5
R6
R7
R8
R9

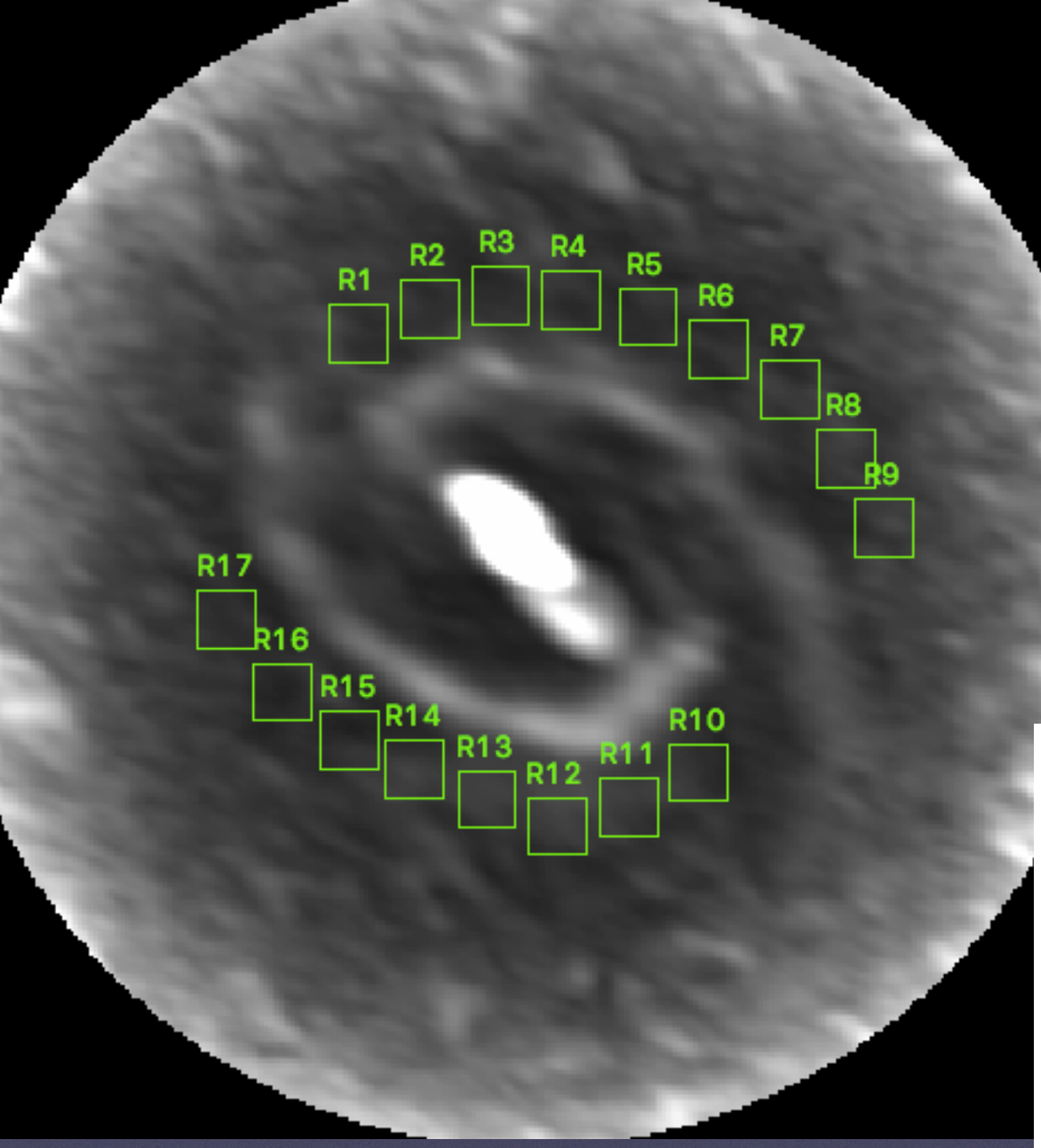

y=0.37*x+2.23
r2=0.74
SFR (log(MJy/sr))
13CO (log(Jy/beam km/s))
2.50
2.45
2.40
2.35
2.30
2.25
2.20
2.15
−0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

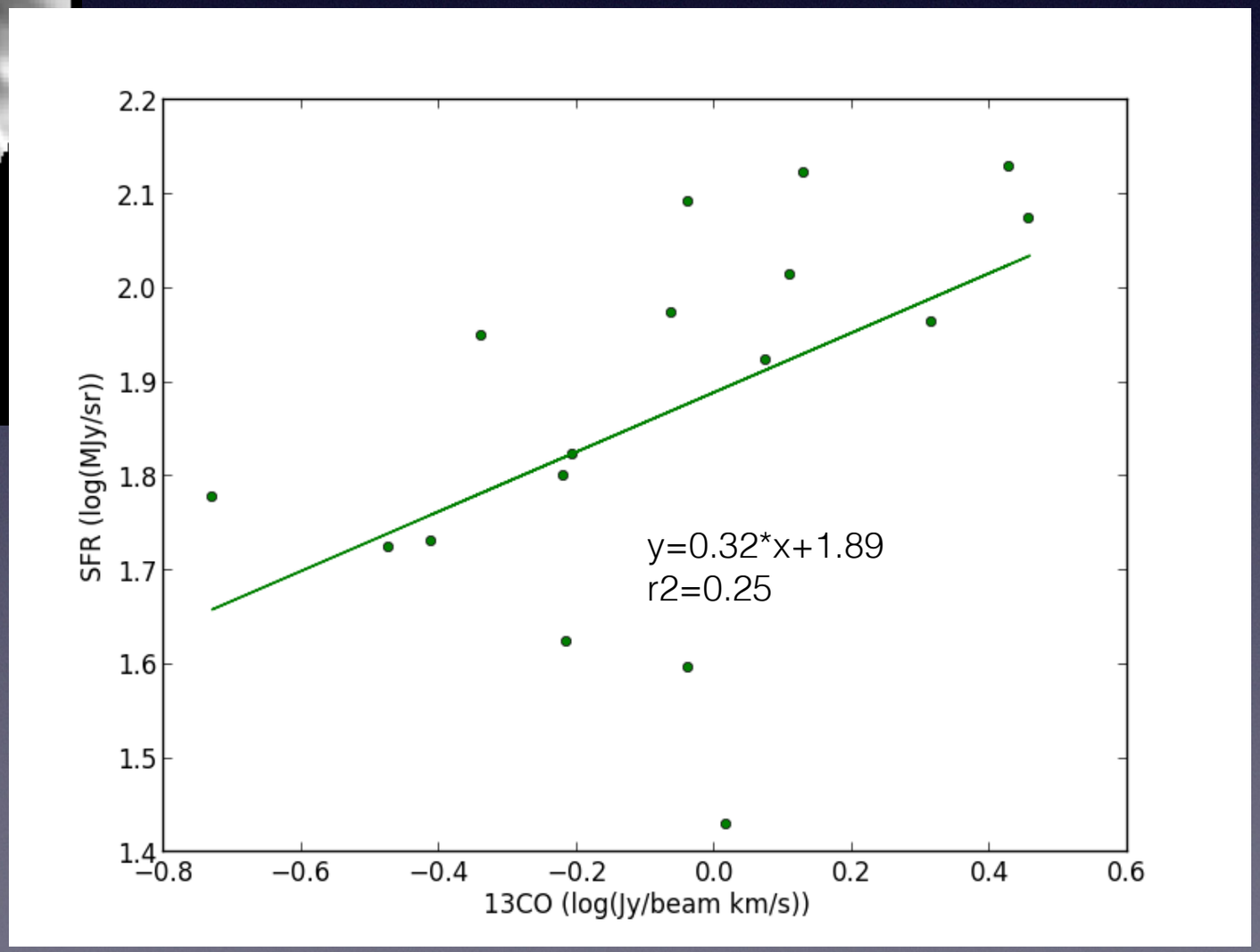

R1
R2
R3
R4
R5
R6
R7
R8
R9

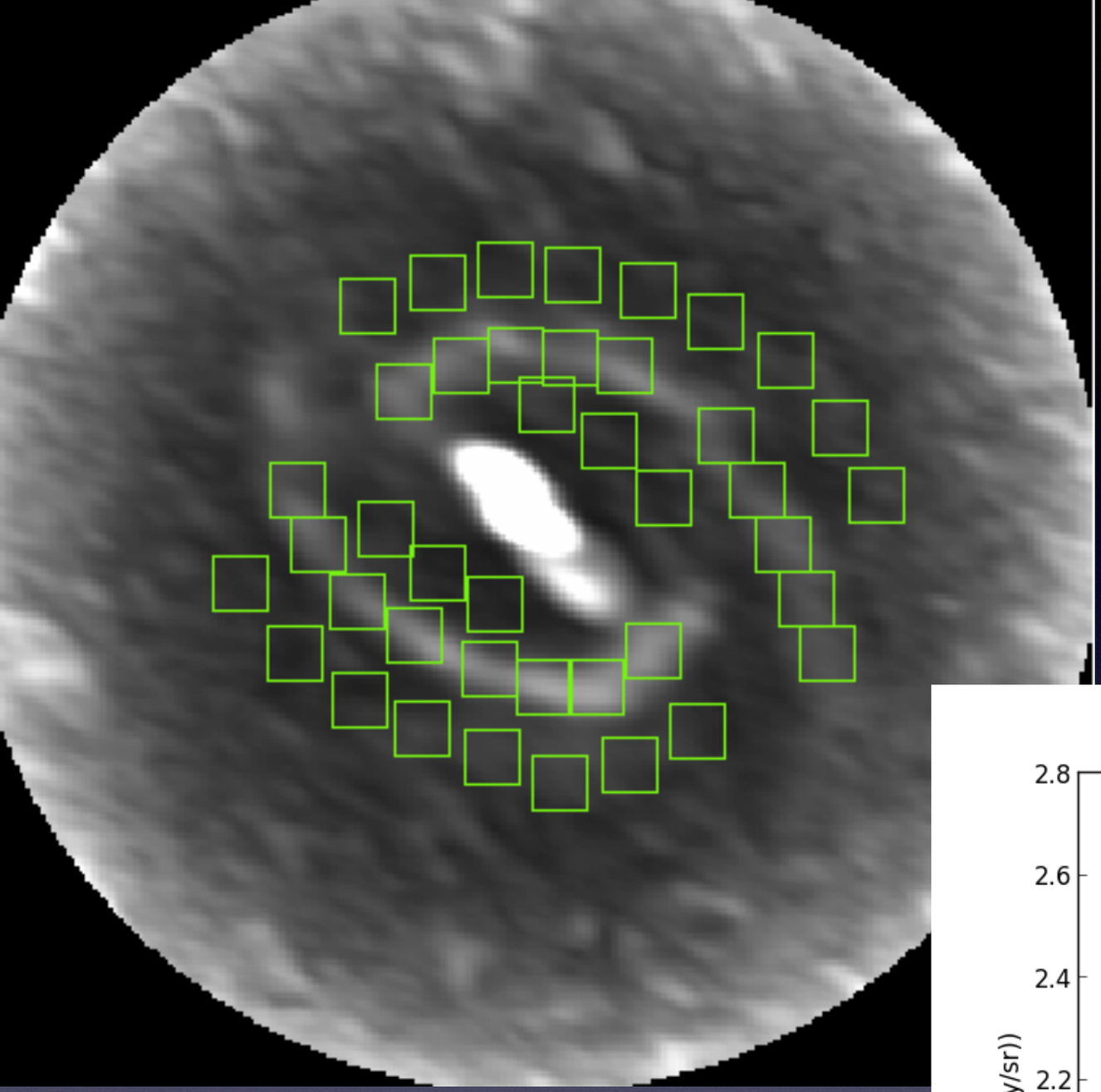

SFR (log(MJy/sr))
13CO (log(Jy/beam km/s))
y=0.78*x+1.95
r2=0.45
2.5
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
−0.2
−0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6

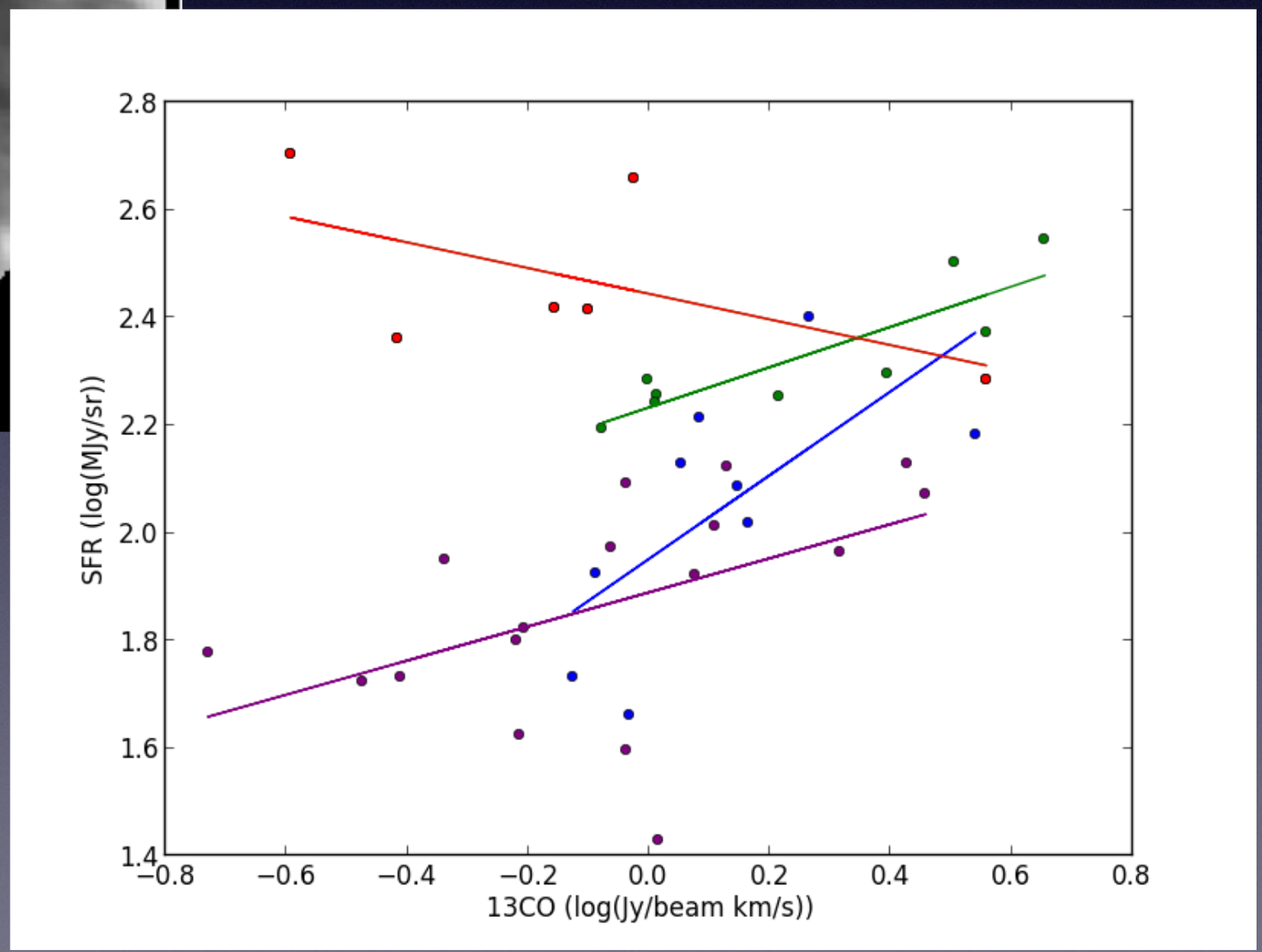

R1
R2
R3
R4
R5
R6


SFR (log(MJy/sr))
13CO (log(Jy/beam km/s))
y=-0.24*x+2.44
r2=0.31
2.8
2.7
2.6
2.5
2.4
2.3
2.2
−0.6
−0.4
−0.2
0.0
0.2
0.4
0.6

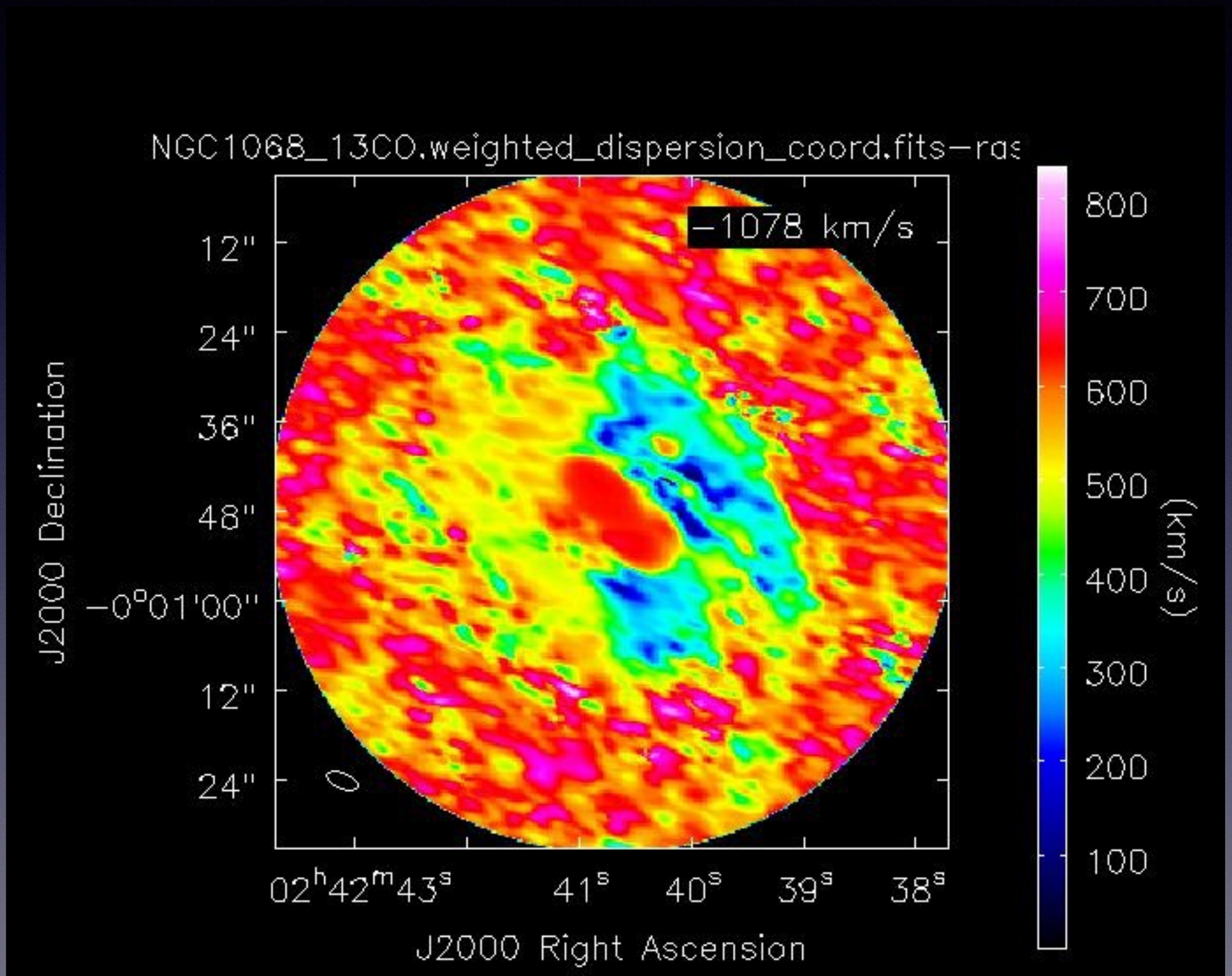

R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12
R13
R14
R15
R16
R17

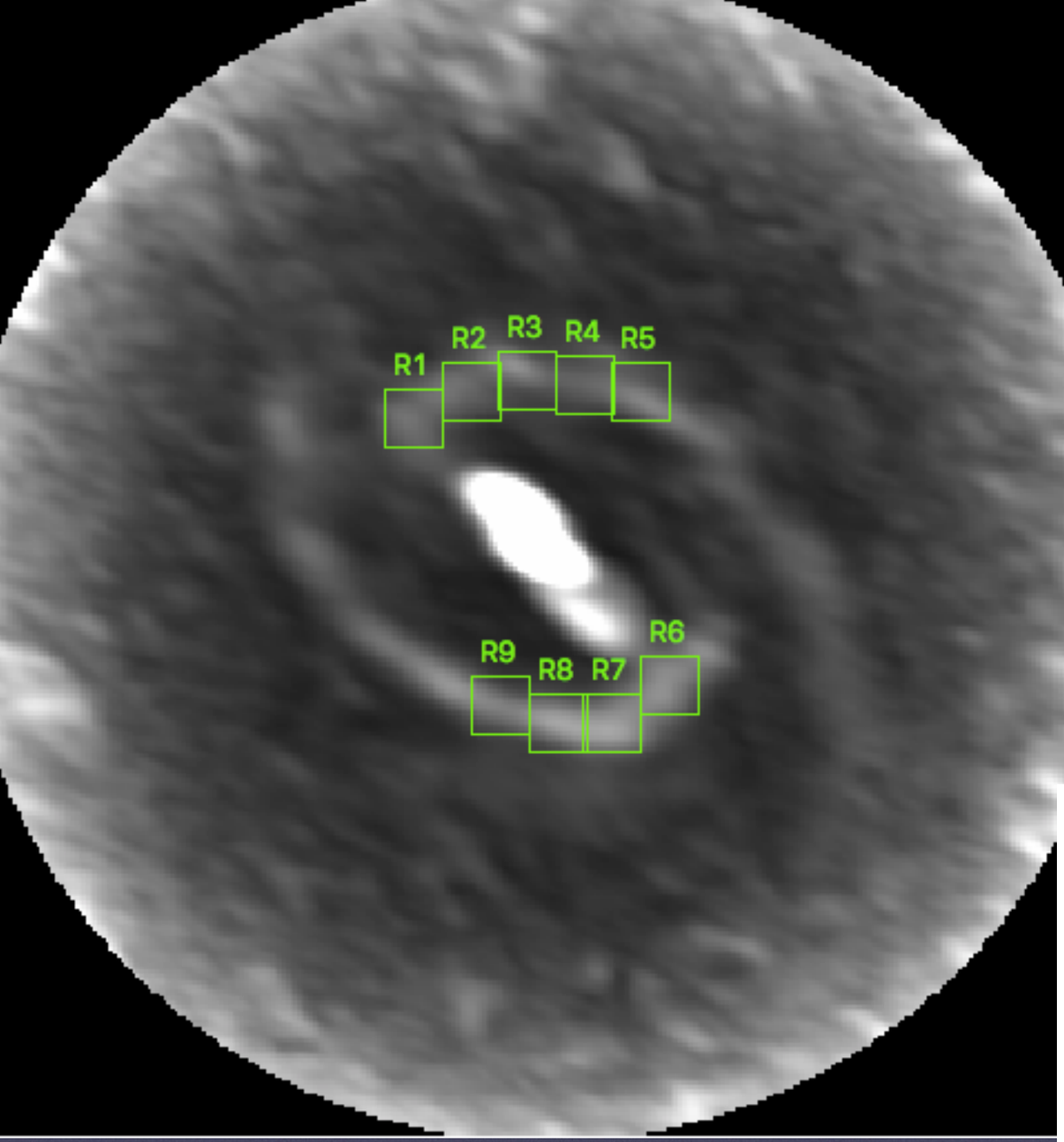

SFR (log(MJy/sr))
13CO (log(Jy/beam km/s))
y=0.32*x+1.89
r2=0.25
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
−0.8
−0.6
−0.4
−0.2
0.0
0.2
0.4
0.6

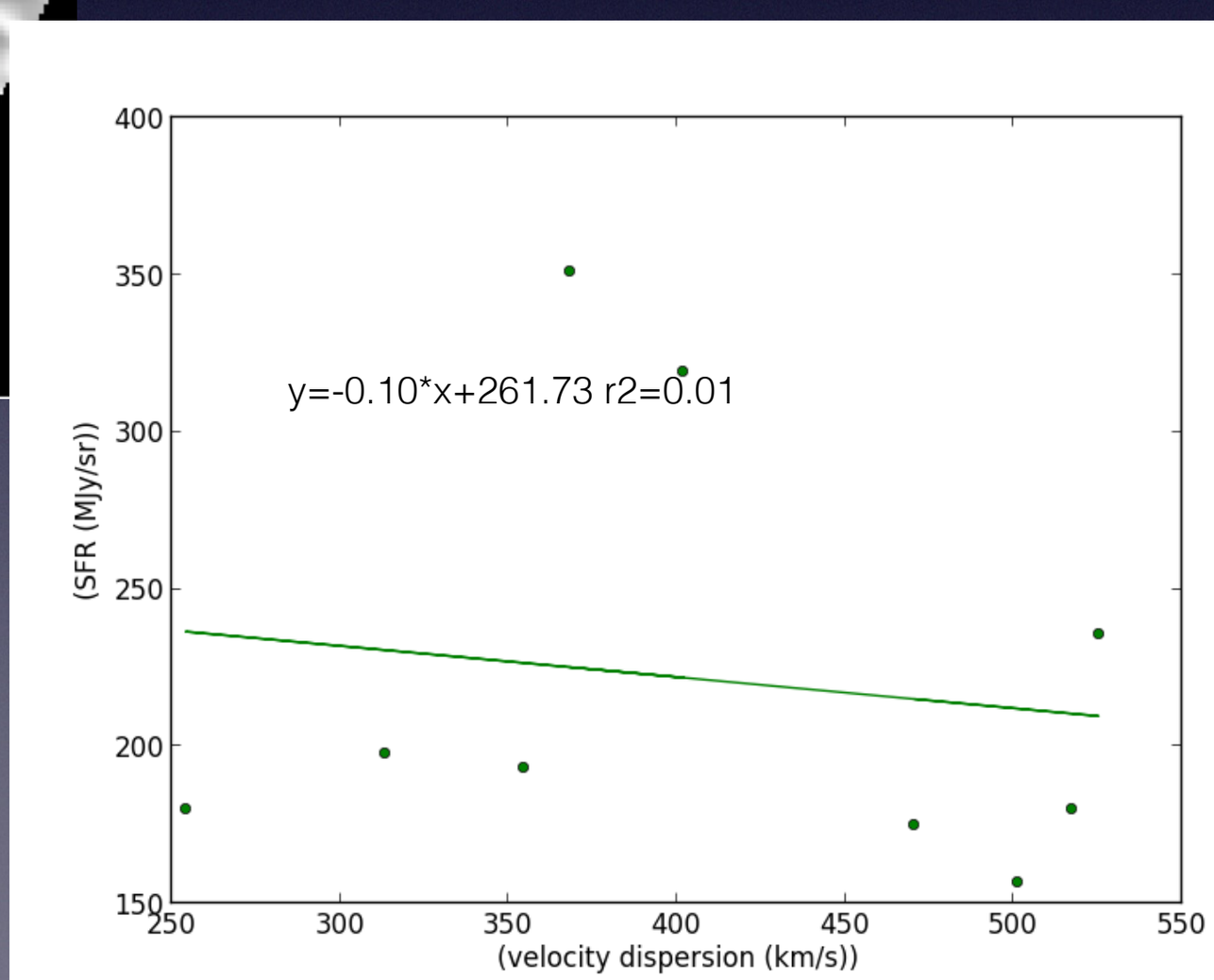


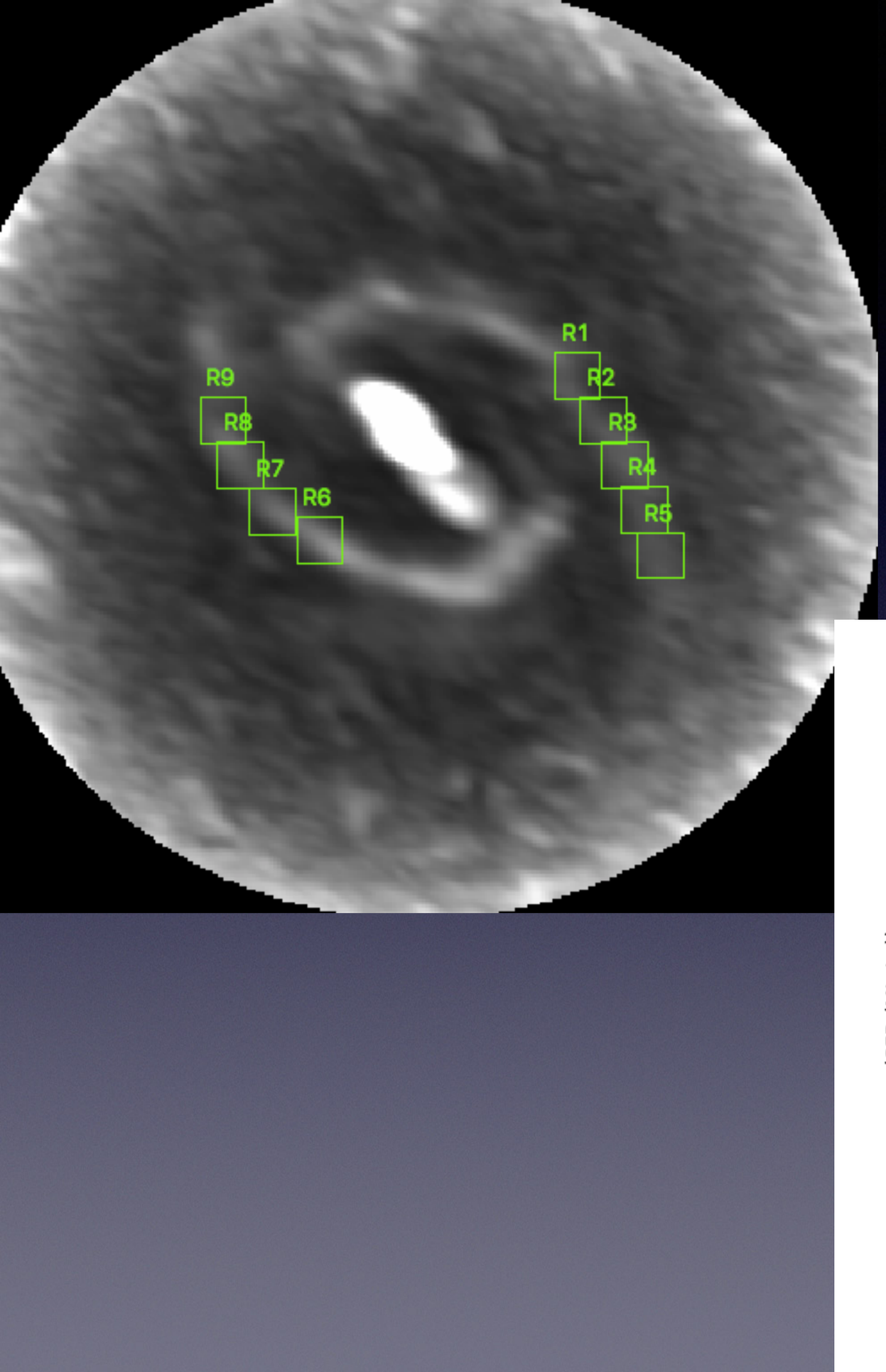

2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
SFR (log(MJy/sr))
−0.8
−0.6
−0.4
−0.2
0.0
0.2
0.4
0.6
0.8
13CO (log(Jy/beam km/s))

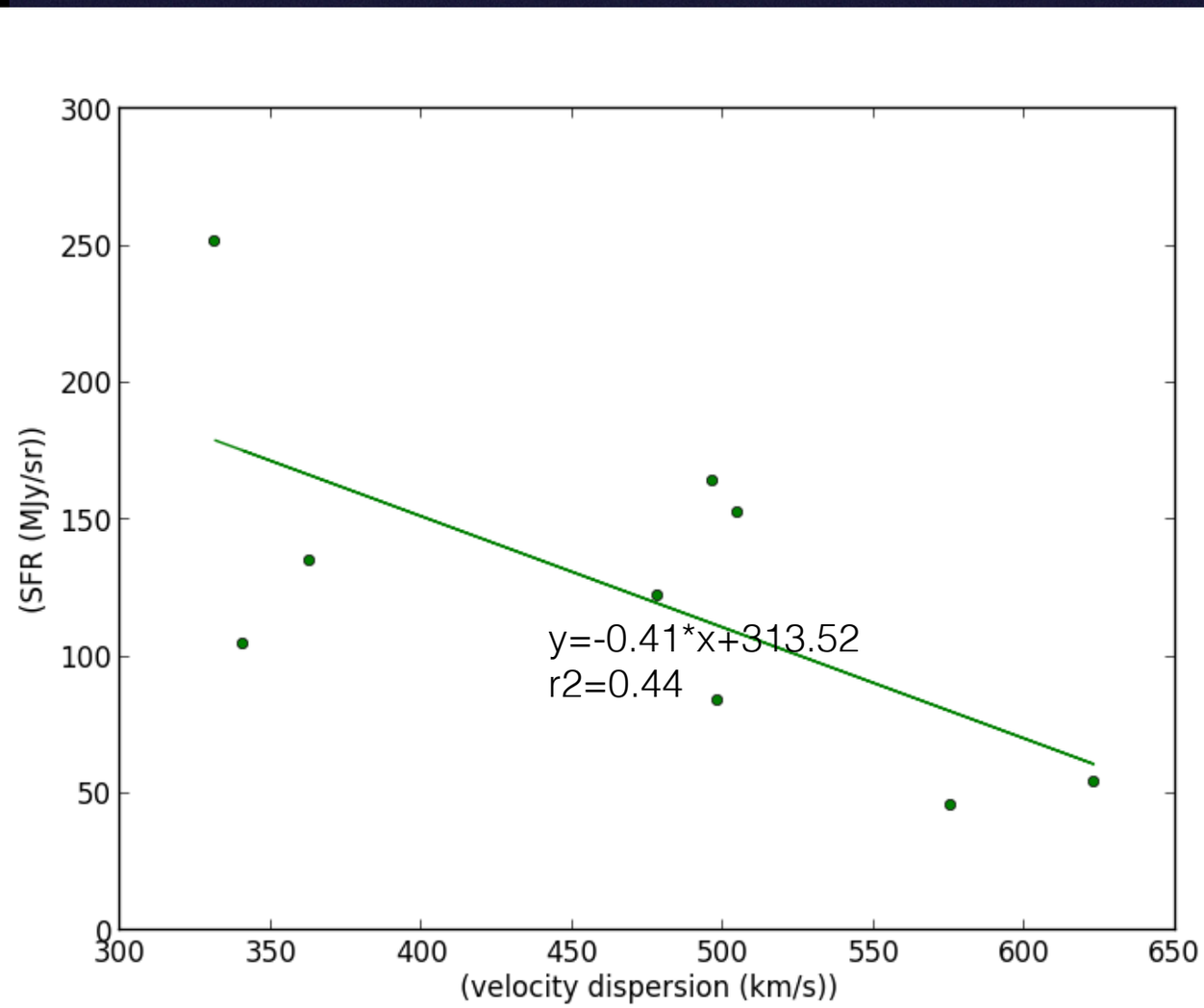
Velocity dispersion

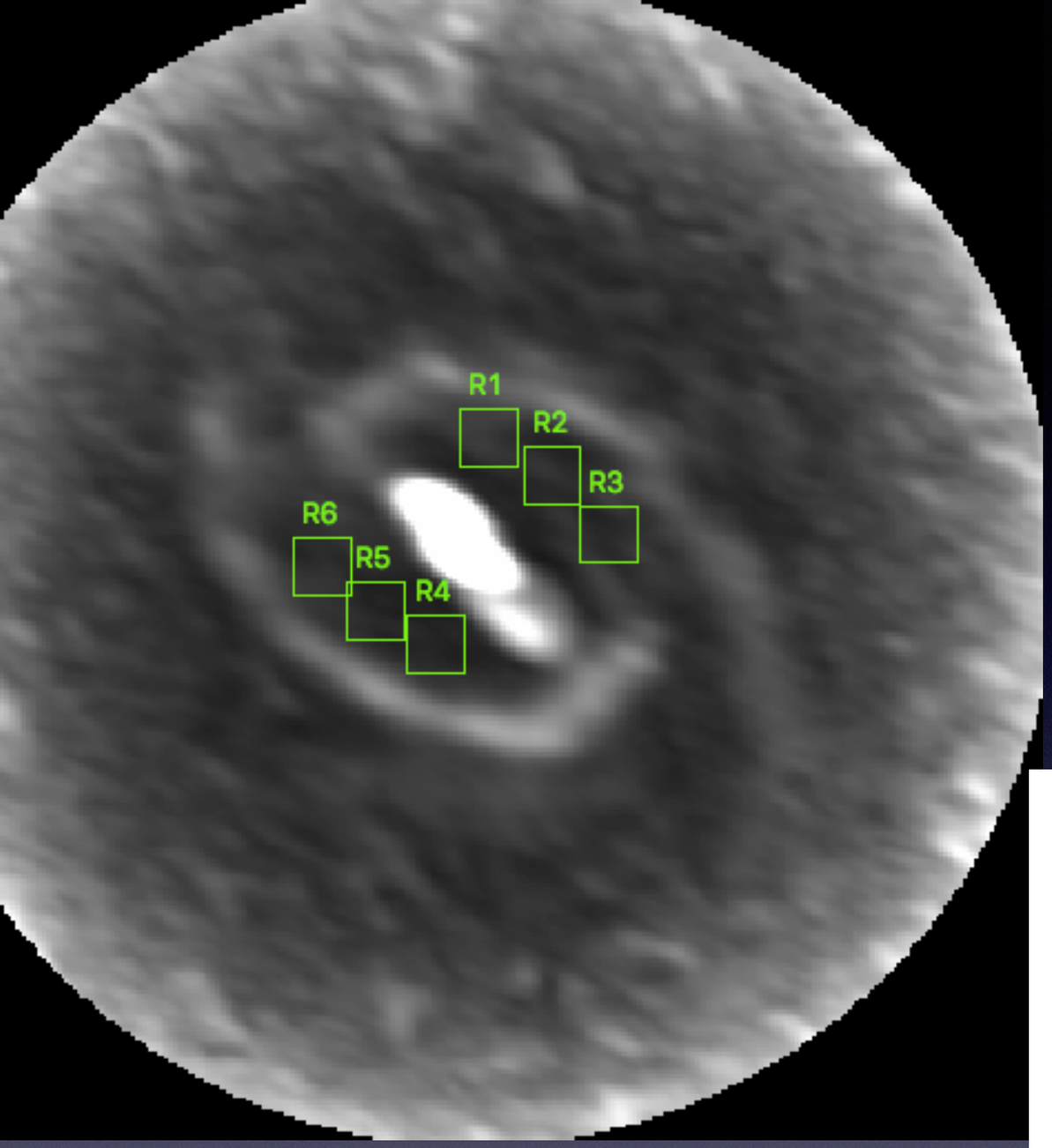


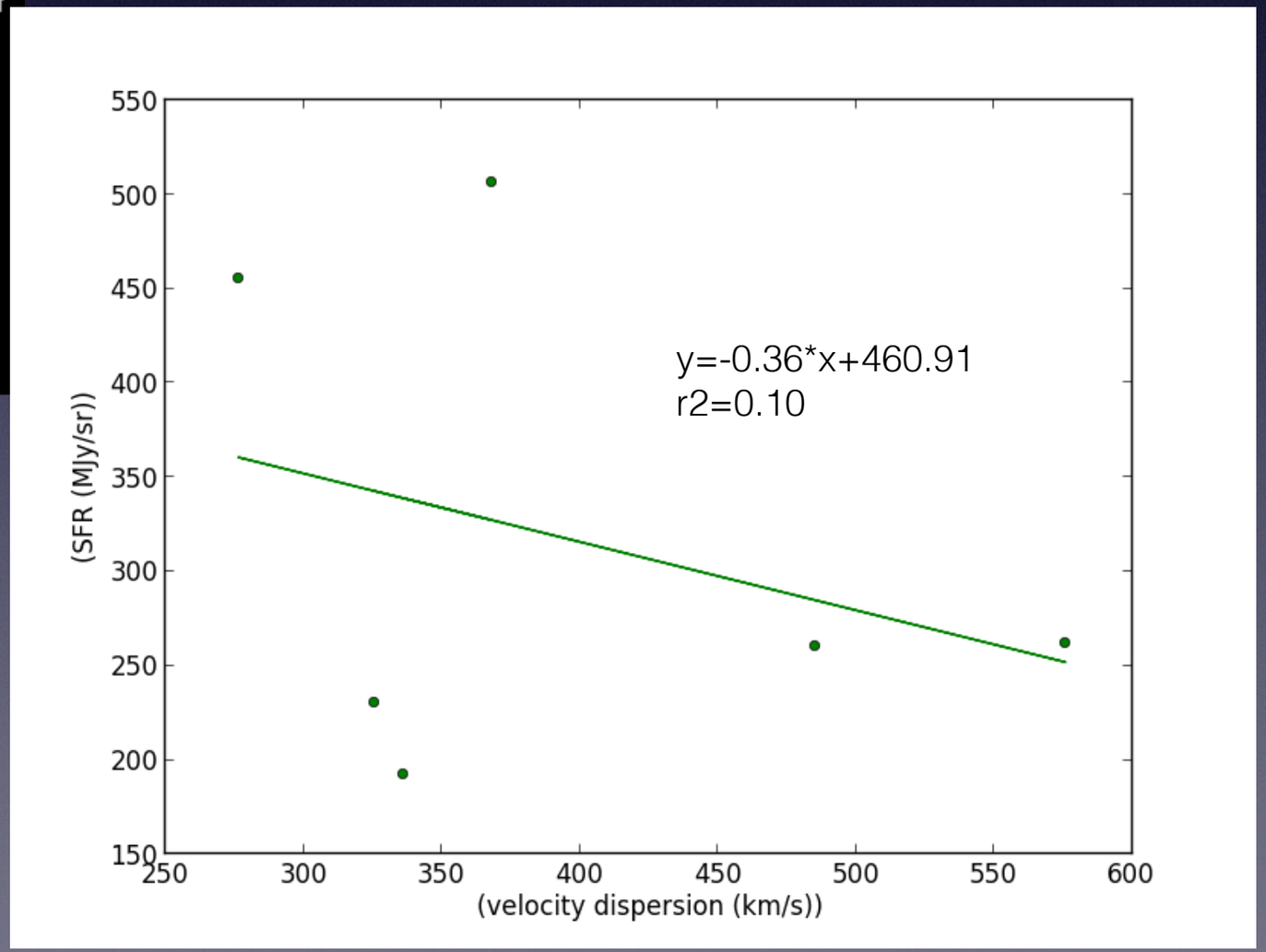

R1
R2
R3
R4
R5
R6
R7
R8
R9

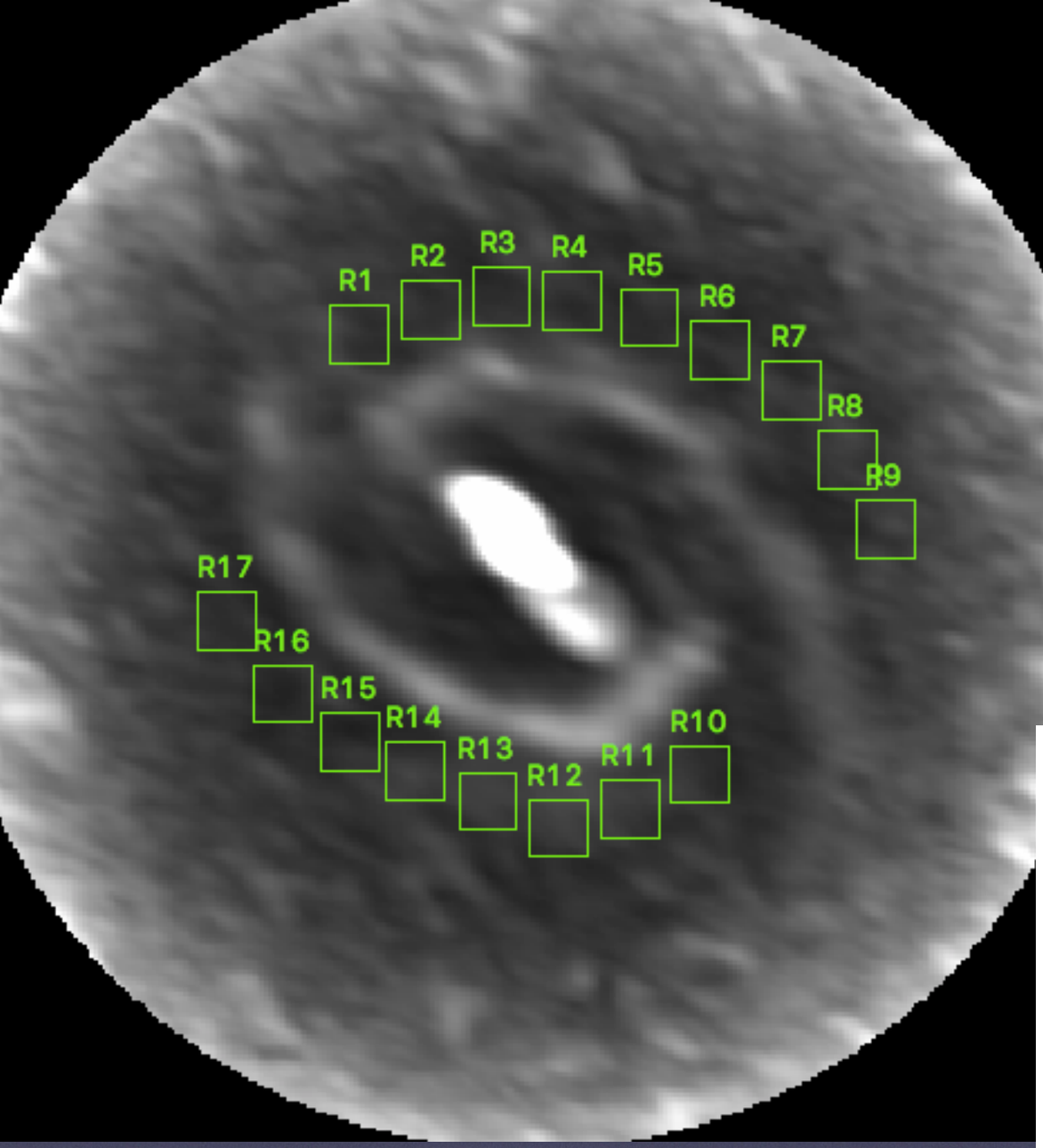

y=-0.10*x+261.73 r2=0.01
(SFR (MJy/sr))
(velocity dispersion (km/s))
400
350
300
250
200
150
250
300
350
400
450
500
550

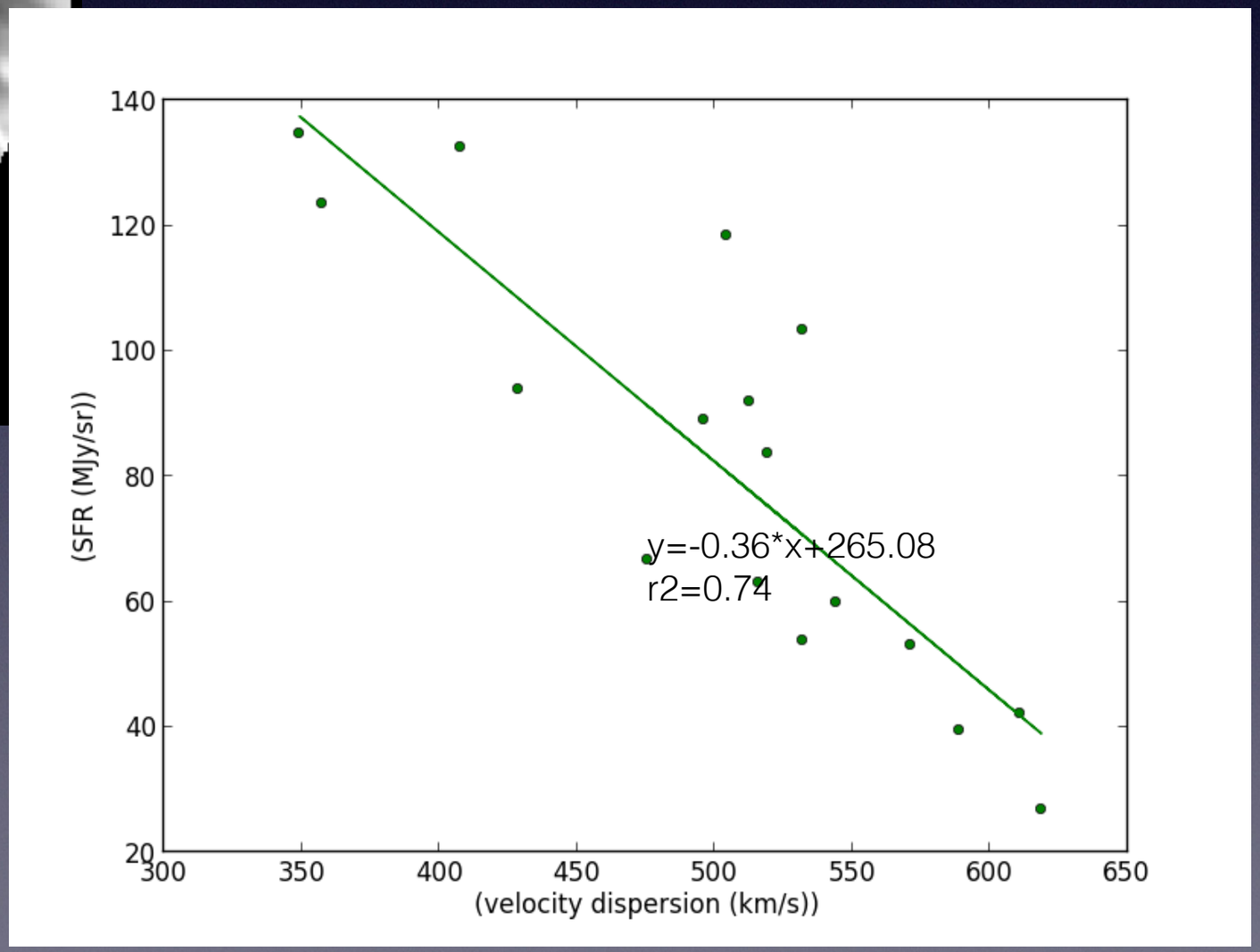

R1
R2
R3
R4
R5
R6
R7
R8
R9

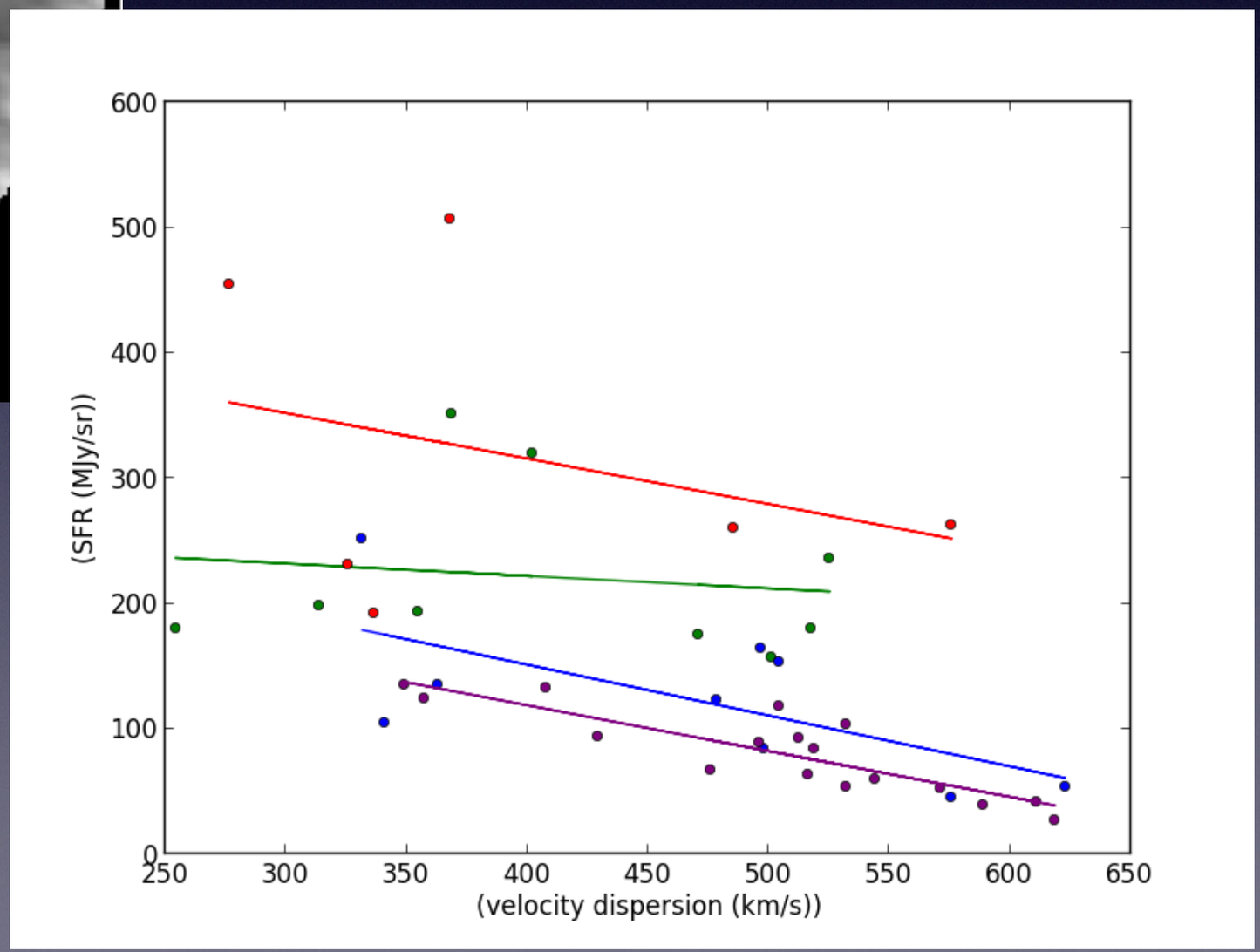

300
250
200
150
100
50
0
(SFR (MJy/sr))
300
350
400
450
500
550
600
650
(velocity dispersion (km/s))
y=-0.41*x+313.52
r2=0.44


R1
R2
R3
R4
R5
R6


y=-0.36*x+460.91
r2=0.10
(SFR (MJy/sr))
(velocity dispersion (km/s))
550
500
450
400
350
300
250
200
150
250
300
350
400
450
500
550
600


R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12
R13
R14
R15
R16
R17


140
120
100
80
60
40
20
300
350
400
450
500
550
600
650
(SFR (MJy/sr))
(velocity dispersion (km/s))
y=-0.36*x+265.08
r2=0.74


600
500
400
300
200
100
0
250
300
350
400
450
500
550
600
650
(SFR (MJy/sr))
(velocity dispersion (km/s))

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Thank you for listening!