alma summer school _group 5

Kennicutt-Schmidt Law in NGC 1808 and NGC 4321

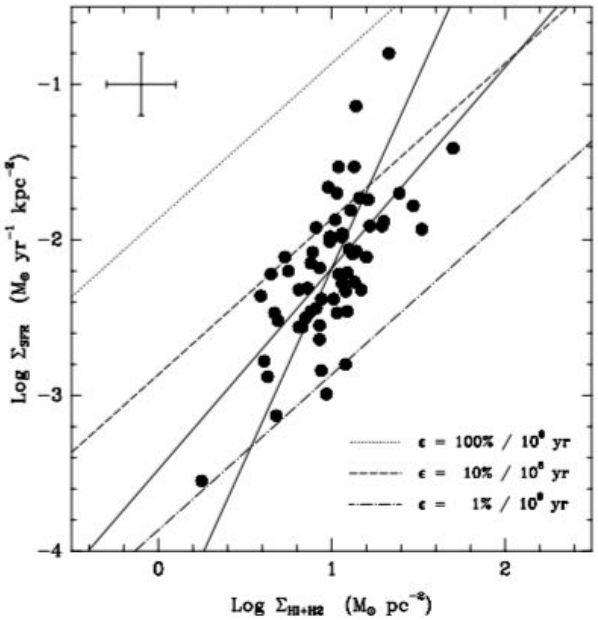
Taehwa Yoo, Bohyun Ryu, Eunhee Ko, Kijeong Yim

Kennicutt-Schmidt law

$$\Sigma_{SFR} \propto \Sigma_{gas}{}^{n}$$

Star Formation Rate per unit area

Surface gas density



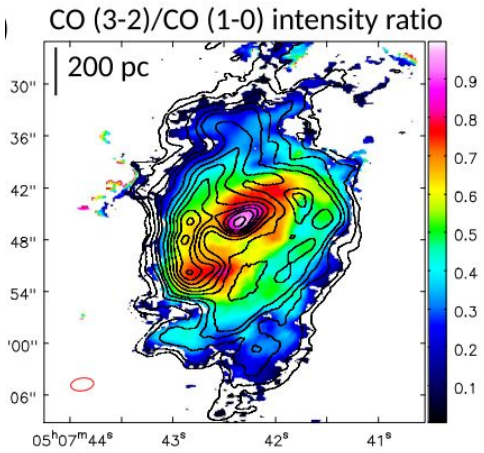
RC Kennicutt Jr. (1998)

- Empirical relation between **star formation rate** and **gas density**

Targets

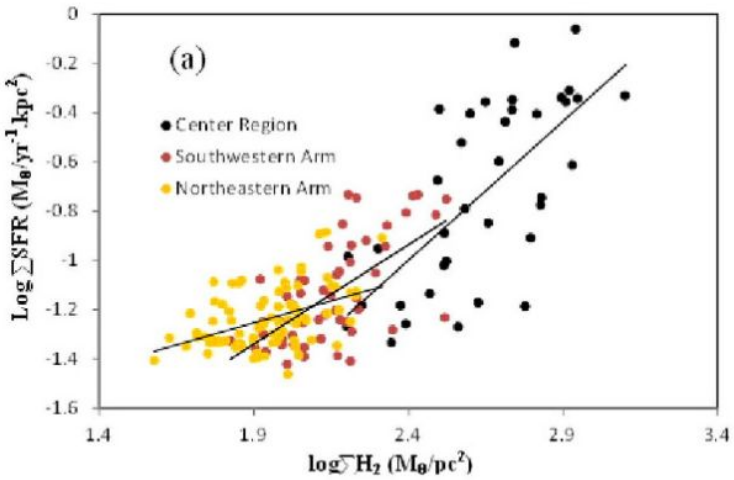
Target	NGC1808	NGC4321
Coord.	05:05:58.59-37:30:46.98	12:20:22.98+16:05:57.96
Redshift	0.003343	0.005251
Type	(R)SAB(s)a	SAB C
Activity	Seyfert 2, Starburst	Starburst

Previous studies



Salak et al. 2017

∑CO(1-0), ∑CO(3-2)



Azeez et al. 2016

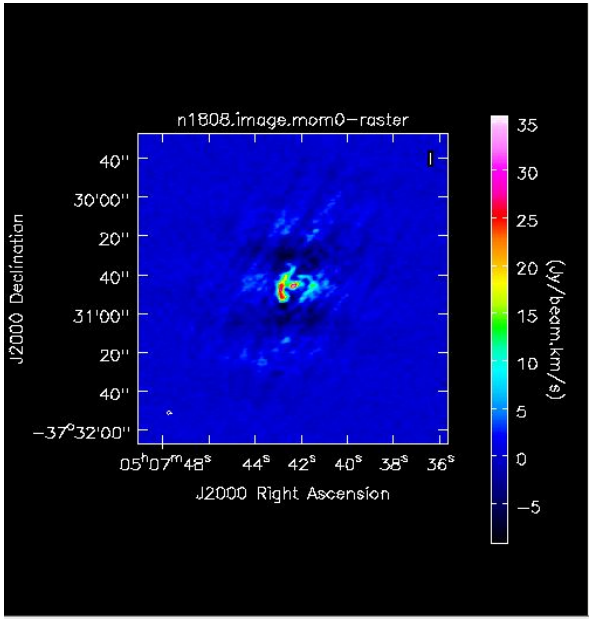
∑H2 (n ~ 1.13)

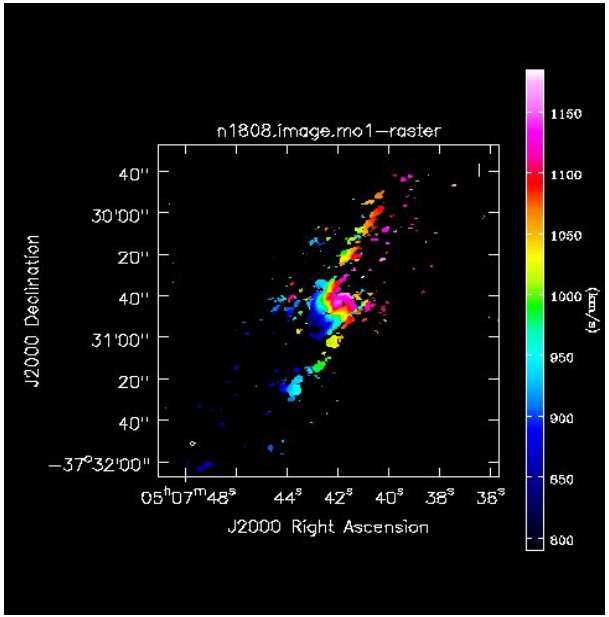
CO(1-0) as a molecular gas tracer

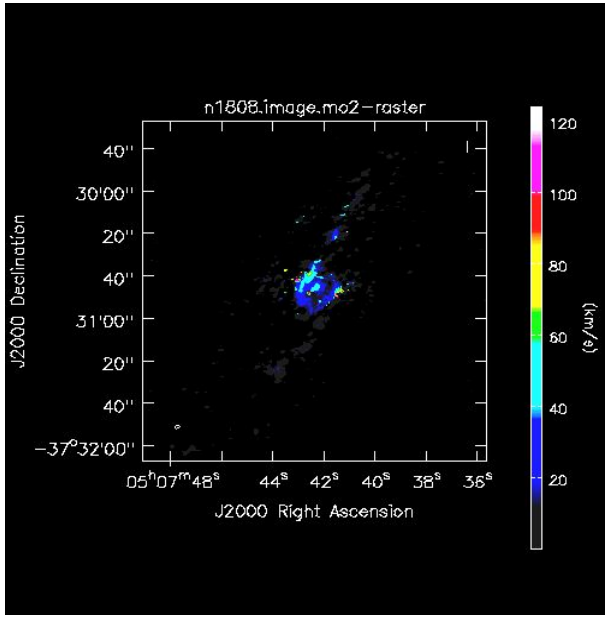
ALMA 12m array

Target	NGC1808	NGC4321
# of antennas	27	42
Angular Resolution	2.5’’ x 1.3’’	1.2’’ x 0.7’’
Total time	46 min	33 min

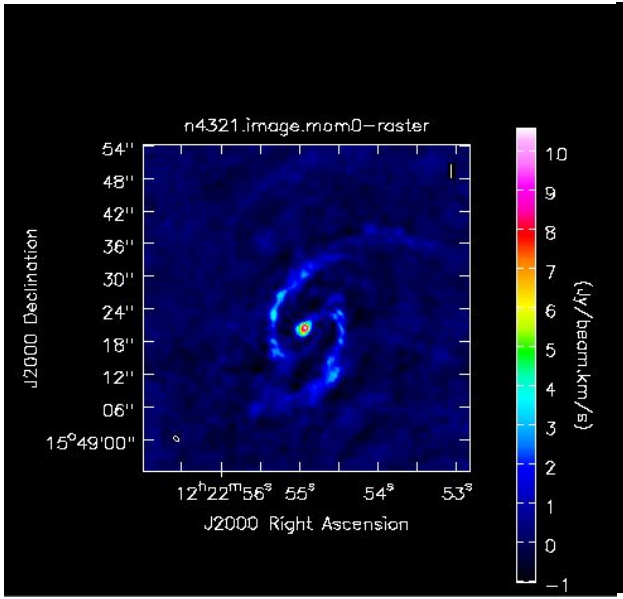
ngc 1808 moments map

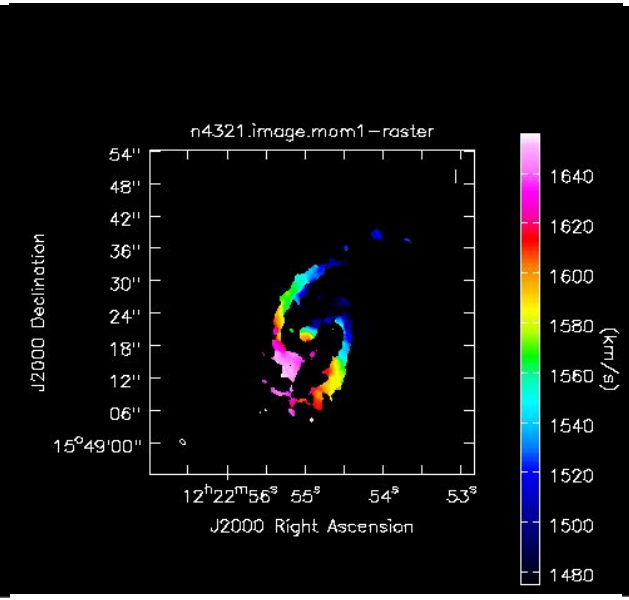


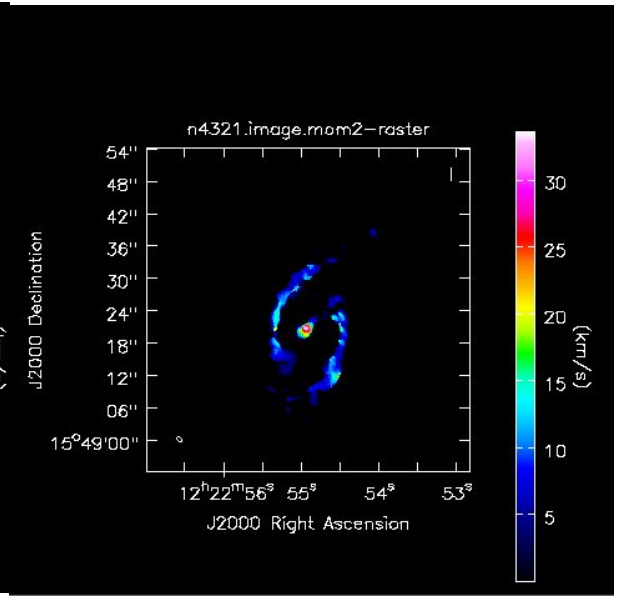




ngc 4321 moments map







CO data ,IR, uv데이터를 이용하여 K_S LAW 확인하기

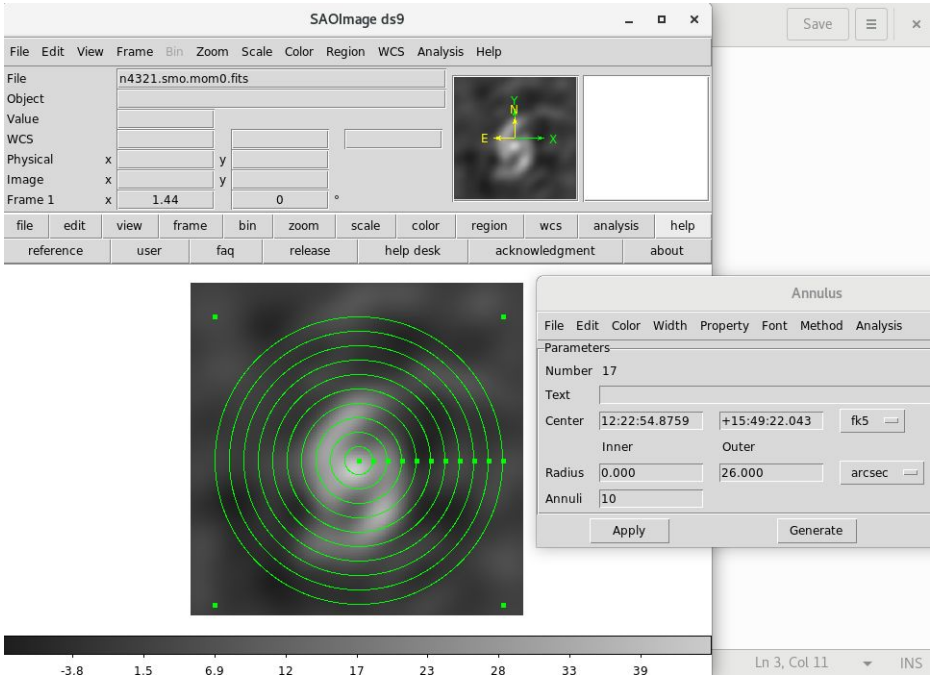
1. 'importfits'를 이용하여 IR , UV data의 형식을 casa로 바꿔준다.

2.'immath'를 이용하여 background값을 처리해준다.

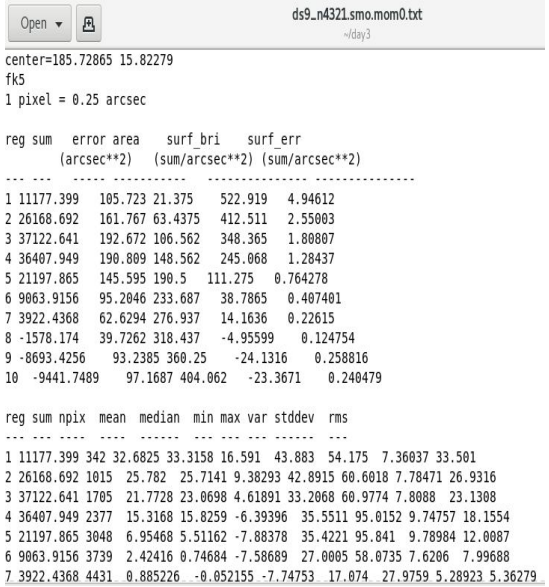
3. 'imsmooth'를 이용하여 uv, CO 이미지의 resolution을 가장 낮은 값(IR이미지의 값 5.9arcsec)에 맞춰준다.

4. 'exportfits'를 이용하여 fit파일로 바꿔준다.

5. ds9를 이용해 처리한 파일을 열고, region_ annulus 를 이용하여 radius 값에 따른 데이터 값을 얻는다.



▸ds9_annulus




```
center=185.72865 15.82279
fk5
1 pixel = 0.25 arcsec

reg sum   error area    surf_bri    surf_err
        (arcsec**2)   (sum/arcsec**2) (sum/arcsec**2)
--- ---   ----- -----------   -------------- --------------
1 11177.399   105.723 21.375    522.919   4.94612
2 26168.692   161.767 63.4375   412.511   2.55003
3 37122.641   192.672 106.562   348.365   1.80807
4 36407.949   190.809 148.562   245.068   1.28437
5 21197.865   145.595 190.5   111.275   0.764278
6 9063.9156   95.2046 233.687   38.7865   0.407401
7 3922.4368   62.6294 276.937   14.1636   0.22615
8 -1578.174   39.7262 318.437   -4.95599    0.124754
9 -8693.4256    93.2385 360.25    -24.1316    0.258816
10  -9441.7489    97.1687 404.062   -23.3671    0.240479

reg sum npix  mean  median  min max var stddev  rms
--- --- ----  ----  ------  --- --- --- ------  ---
1 11177.399 342 32.6825 33.3158 16.591  43.883  54.175  7.36037 33.501
2 26168.692 1015  25.782  25.7141 9.38293 42.8915 60.6018 7.78471 26.9316
3 37122.641 1705  21.7728 23.0698 4.61891 33.2068 60.9774 7.8088  23.1308
4 36407.949 2377  15.3168 15.8259 -6.39396  35.5511 95.0152 9.74757 18.1554
5 21197.865 3048  6.95468 5.51162 -7.88378  35.4221 95.841  9.78984 12.0087
6 9063.9156 3739  2.42416 0.74684 -7.58689  27.0005 58.0735 7.6206  7.99688
7 3922.4368 4431  0.885226  -0.052155 -7.74753  17.074  27.9759 5.28923 5.36279
```

▸얻은 data 값

6.얻은 데이터 값을 변환한다.

FUV: counts s−1 pixel−1, where 1 count s−1 (cps) is 108 μJy (equivalent to 1.4 × 10−15 erg s−1 cm−2 Å−1)
Ifuv=2.04*fuv [MJy/Sr]

sfr[Msun/yr/kpc^2]=0.081 *Ifuv[MJy/Sr] + 0.0032*I24[MJy/Sr]

beam=5.9*5.9*1.133 #ac^2

Jy/ac^2 x Km/s

cf1co=1./0.0096 #Jy/ac^2 -> K

cf2co=2.e20*8e-21*2. #K km/s -> mol/cm^2 -> Msun/pc^2

▶factor값

→

n1808data.csv

fuv	fuv_err	co	co_err	radius	distance	meav/beam	
0.0120671	0.00317212	116.327	24.6635	3	156	2.949487737	0.
0.0119517	0.0102298	95.9413	41.4136	6	312	2.432605396	1.
0.0122869	0.0162949	55.2848	31.8454	9	468	1.401754018	0.
0.00707156	0.00705119	18.2435	25.6434	12	624	0.462566554	0.
0.00591538	0.00528061	-1.60624	27.9903	15	780	-0.040726445	0.
0.0054386	0.00406782	-11.1486	27.7742	18	936	-0.282674349	0.
0.00555333	0.00361696	-12.6632	24.9898	21	1092	-0.321077249	0.
0.00559964	0.00391556	-9.62908	17.8131	24	1248	-0.244146702	0.
0.00490375	0.00390569	-5.54933	11.4958	27	1404	-0.140704057	0.
0.00378352	0.00266556	-1.95673	10.468	30	1560	-0.049613169	0.

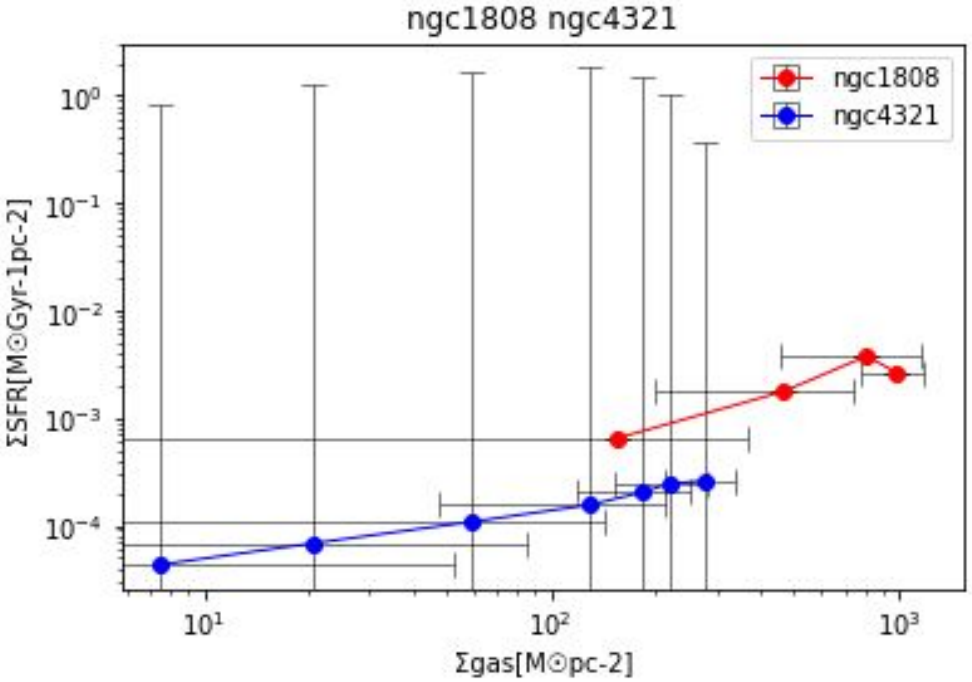
▶ngc1808값

n4321data.csv

fuv	fuv_err	co	co_err	radius	distance	meav/beam	
0.0207066	0.00852525	32.6825	7.36037	2.6	215.54	0.828669466	
0.0258149	0.0226118	25.782	7.78471	5.2	431.08	0.653706301	
0.0261914	0.0299688	21.7728	7.8088	7.8	646.62	0.552052461	
0.0278856	0.0353483	15.3168	9.74757	10.4	862.16	0.388359657	
0.0387385	0.0511131	6.95468	9.78984	13	1077.7	0.176336907	
0.0454302	0.0648576	2.42416	7.6206	15.6	1293.24	0.061464924	
0.0471614	0.0724718	0.885226	5.28923	18.2	1508.78	0.022445032	
0.0353902	0.0576346	-0.30975	3.33029	20.8	1724.32	-0.007853756	
0.021864	0.0328538	-1.50823	3.02405	23.4	1939.86	-0.038241388	
0.0110979	0.0127164	-1.46044	3.40757	26	2155.4	-0.037029665	

▶ngc4302값

7. gas의 density에 따른 SFR(Star Formation Rate)를 plot한다.



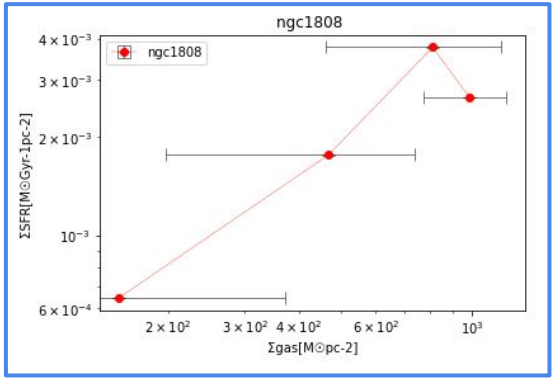
	den
4	983.1629
3	810.8687
5	467.2515
3	154.1889
9	-13.5755
5	-94.2248
9	-107.026
5	-81.3823
3	-46.9014
9	-16.5377

▶ngc1808
밀도 값

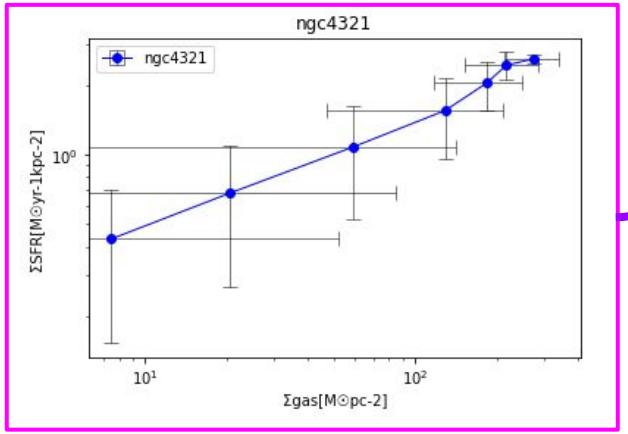
	den
	276.2232
	217.9022
	184.0175
	129.4533
	58.77899
	20.48831
	7.48168
	-2.61792
	-12.7471
	-12.3432

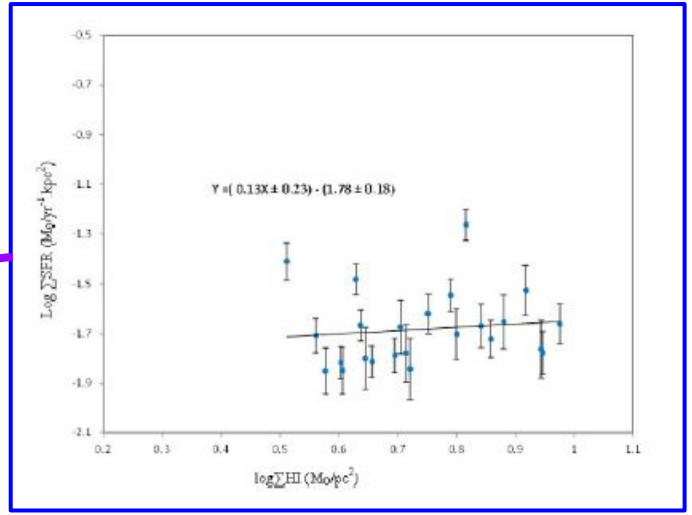
▶ngc4321
밀도 값

결과 비교하기



▶ngc1808값

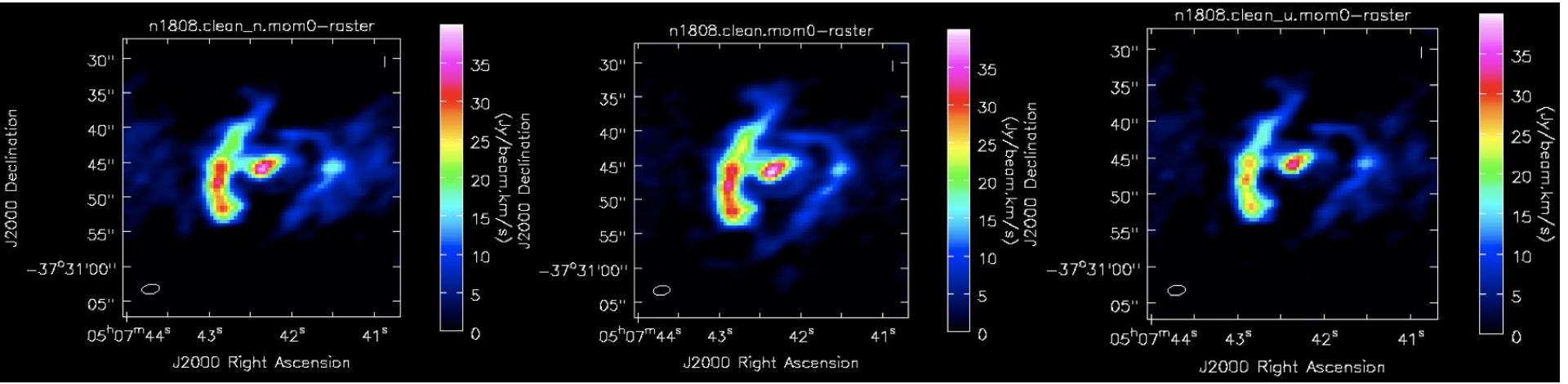




▶ngc4302값

Azeez, J et al.(2016)

mom-0 map with different weightings (uniform, natural, briggs)



natural
(2.59” X 1.39”)

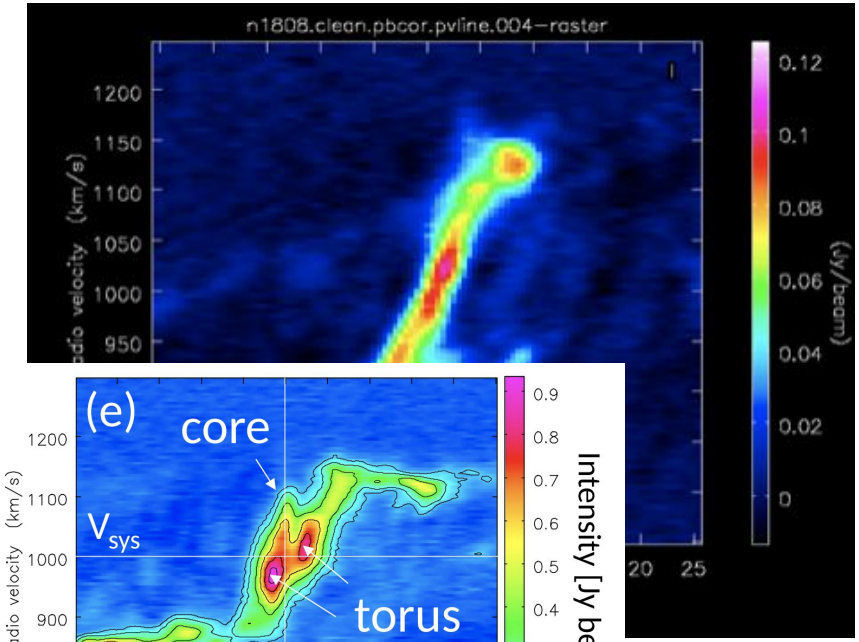
low resolution, high sensitivity

briggs
(2.53” X 1.37”)

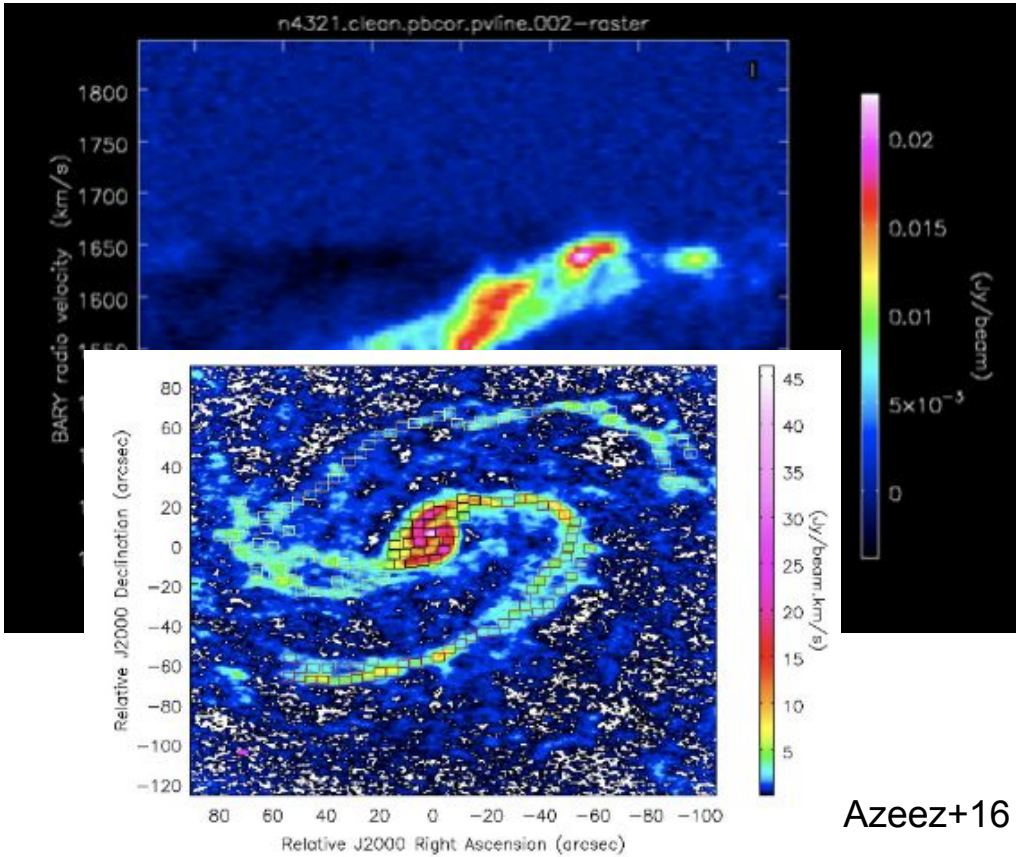
uniform
(2.48” X 1.37”)

high resolution, low sensitivity

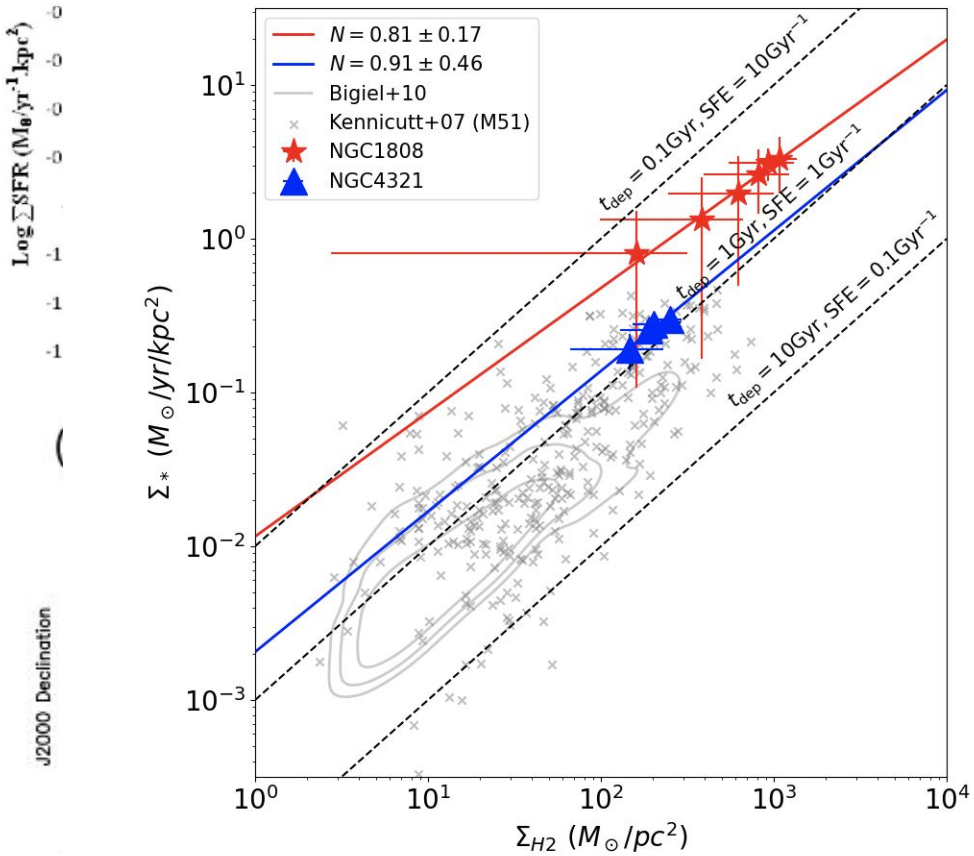
Position-velocity diagram (PVD)

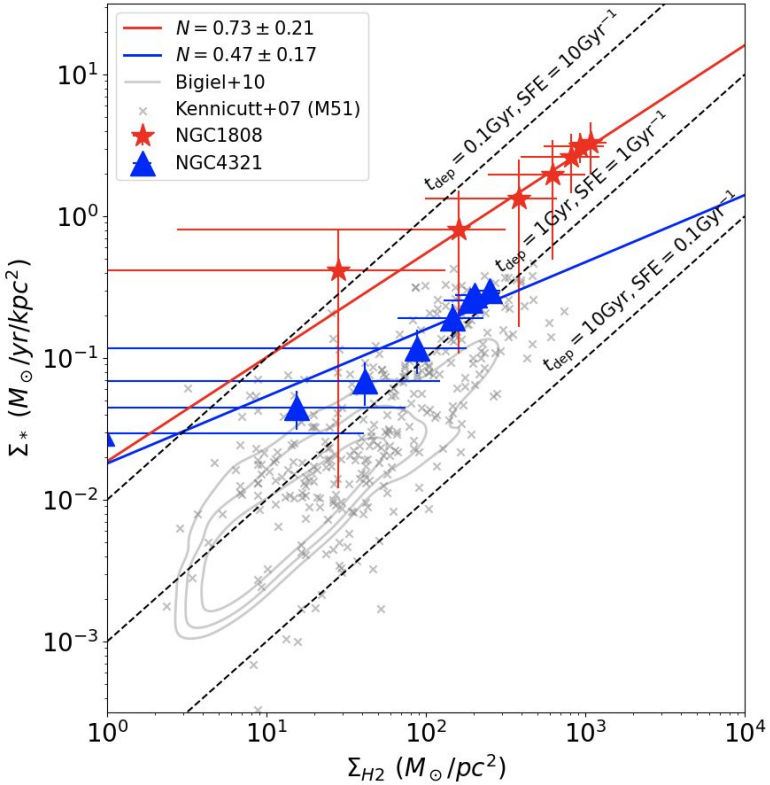


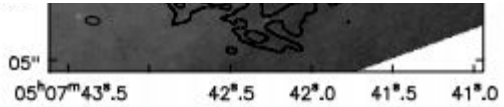
Salak+17



Azeez+16

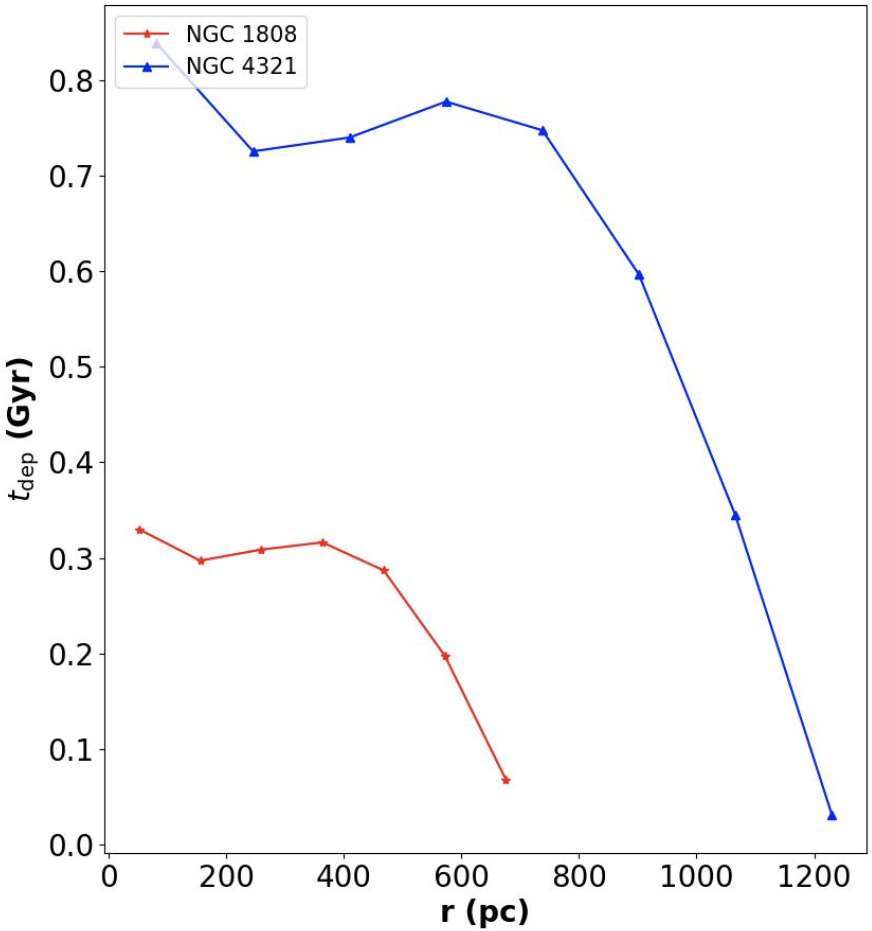

$N = 0.81 \pm 0.17$
$N = 0.91 \pm 0.46$
Bigiel+10
Kennicutt+07 (M51)
NGC1808
NGC4321
$t_{dep} = 0.1$Gyr, SFE = 10Gyr^{-1}
$t_{dep} = 1$Gyr, SFE = 1Gyr^{-1}
$t_{dep} = 10$Gyr, SFE = 0.1Gyr^{-1}
Σ_* ($M_\odot$/yr/kpc^2)
Σ_{H2} ($M_\odot$/pc^2)


$N = 0.73 \pm 0.21$
$N = 0.47 \pm 0.17$
Bigiel+10
Kennicutt+07 (M51)
NGC1808
NGC4321
$t_{dep} = 0.1$Gyr, SFE = 10Gyr^{-1}
$t_{dep} = 1$Gyr, SFE = 1Gyr^{-1}
$t_{dep} = 10$Gyr, SFE = 0.1Gyr^{-1}
Σ_* ($M_\odot$/yr/kpc^2)
Σ_{H2} ($M_\odot$/pc^2)

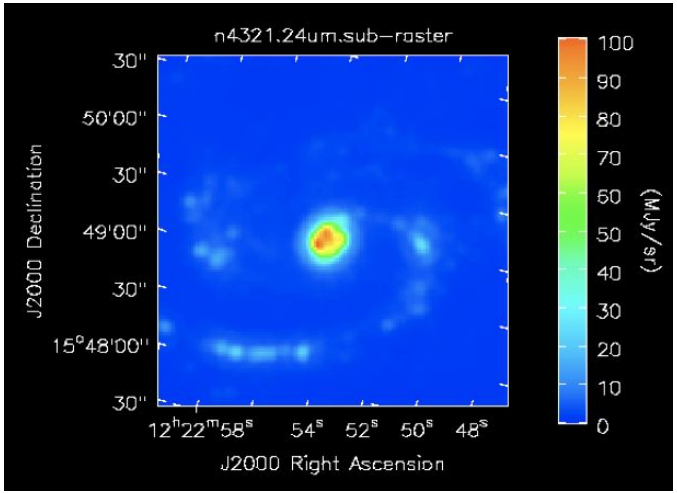

05"
05h07m43s.5
42s.5
42s.0
41s.5
41s.0

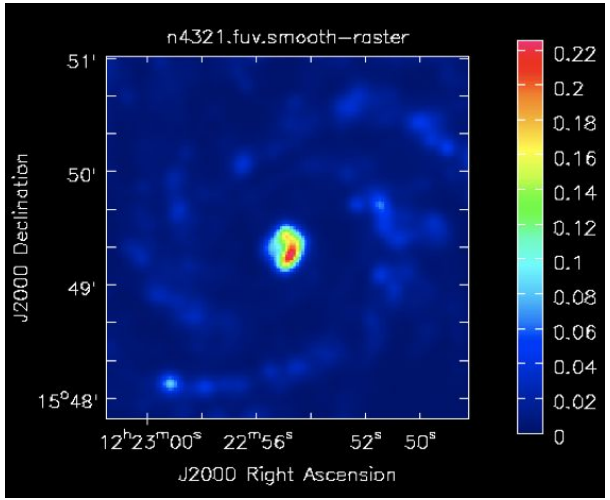
Salek+17

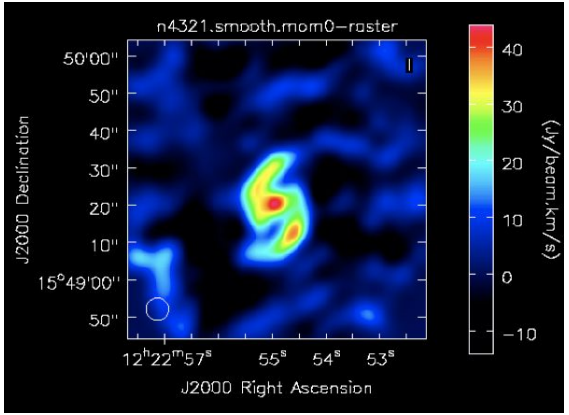
Gas depletion time

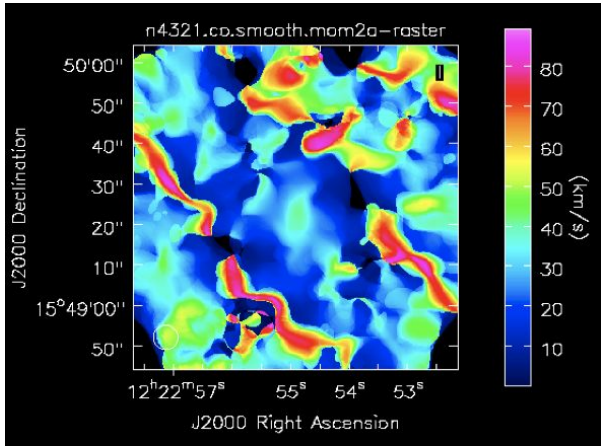


Discussion


n4321.24um.sub−raster
J2000 Declination
J2000 Right Ascension
(MJy/sr)


n4321.fuv.smooth−raster
J2000 Declination
J2000 Right Ascension

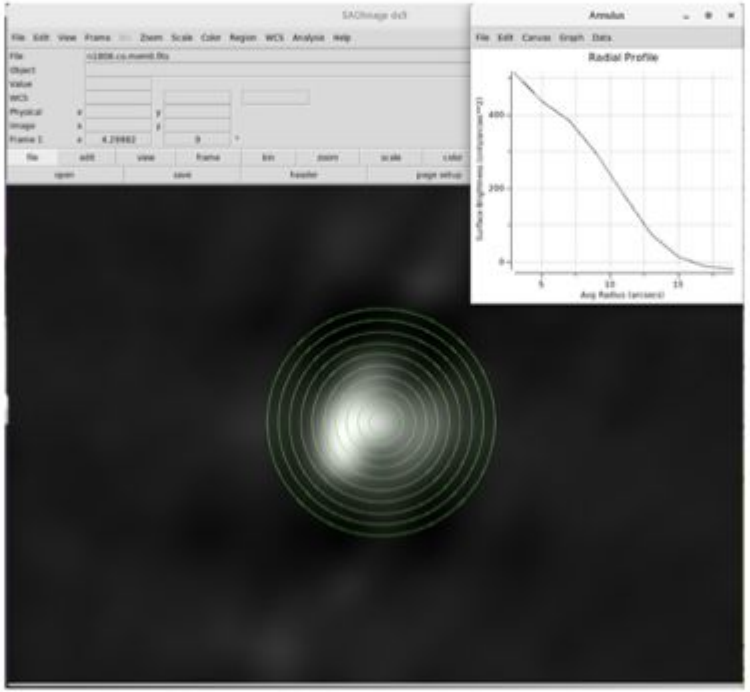

n4321.smooth.mom0−raster
J2000 Declination
J2000 Right Ascension
(Jy/beam.km/s)

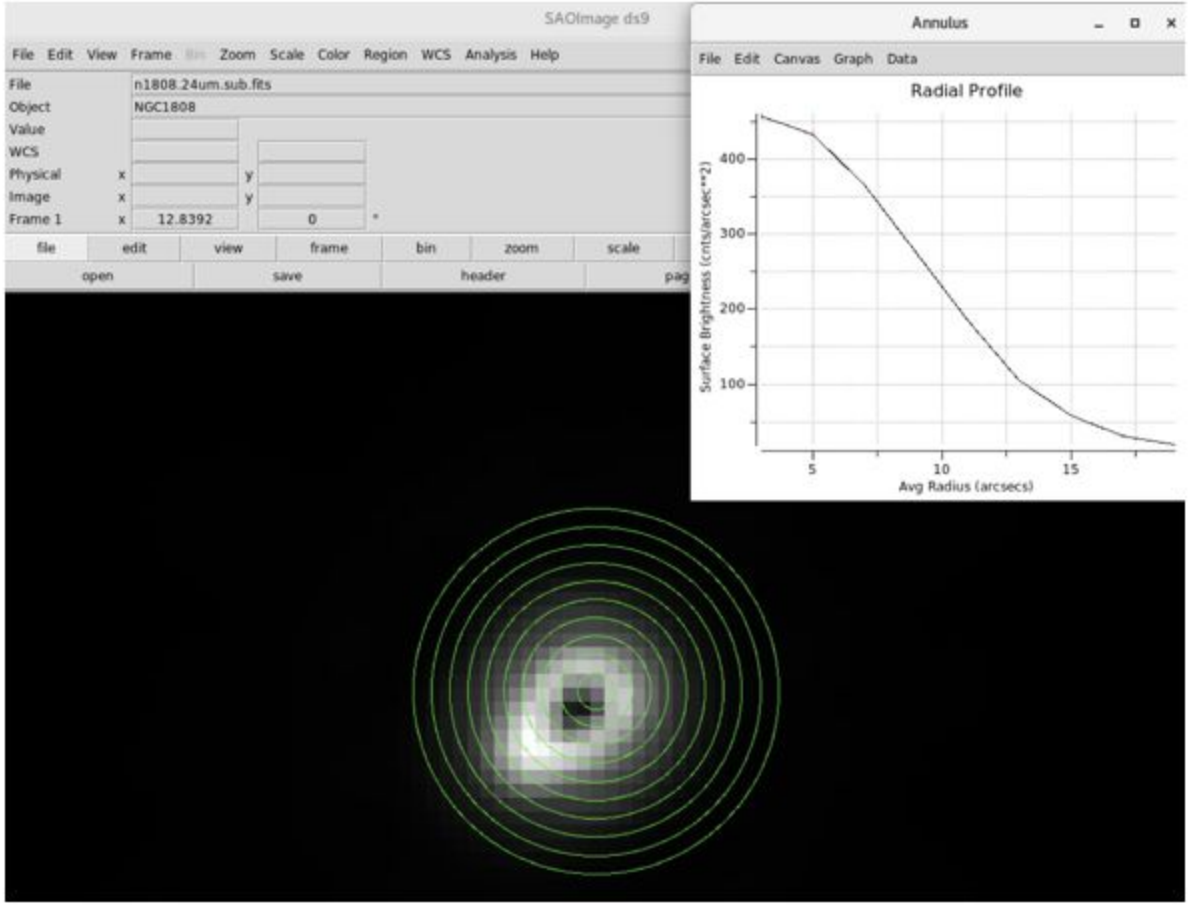

n4321.co.smooth.mom2a−raster
J2000 Declination
J2000 Right Ascension
(km/s)

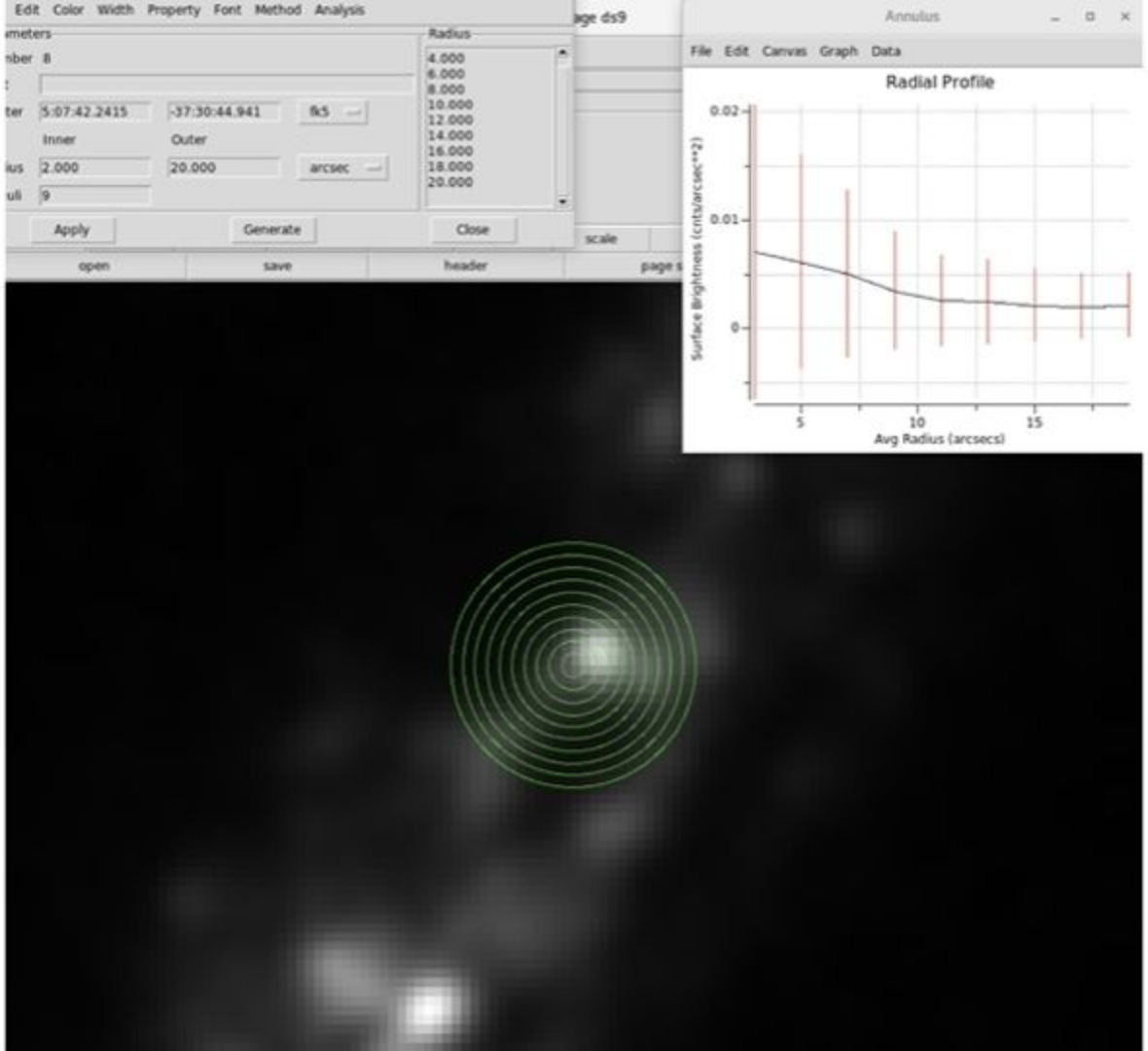
Conclusion

- Both NGC 1808 and NGC 4321 show non-linear KS relation, which is consistent with previous studies.

- Low N (N=0.73, 0.47, respectively) mainly results from lower N in outer region of galaxies.


SAOImage ds9
File Edit View Frame Bin Zoom Scale Color Region WCS Analysis Help
File
Object
Value
WCS
Physical
Image
Frame 1
file
edit
view
frame
bin
zoom
scale
color
open
save
header
page setup
Annulus
File Edit Canvas Graph Data
Radial Profile
400
200
0
5
10
15
Avg Radius (arcsecs)


SAOImage ds9
File Edit View Frame Bin Zoom Scale Color Region WCS Analysis Help
File n1808.24um.sub.fits
Object NGC1808
Value
WCS
Physical x y
Image x y
Frame 1 x 12.8392 0
file edit view frame bin zoom scale
open save header
Annulus
File Edit Canvas Graph Data
Radial Profile
Surface Brightness (cnts/arcsec**2)
400
300
200
100
5
10
15
Avg Radius (arcsecs)


Edit Color Width Property Font Method Analysis
Radius
4.000
6.000
8.000
10.000
12.000
14.000
16.000
18.000
20.000
5:07:42.2415
-37:30:44.941
fk5
Inner
Outer
2.000
20.000
arcsec
Apply
Generate
Close
open
save
header
scale
Annulus
File Edit Canvas Graph Data
Radial Profile
Surface Brightness (cnts/arcsec**2)
0.02
0.01
0
5
10
15
Avg Radius (arcsecs)