The gaseous disk orientations and origin: evolution of S0 galaxies

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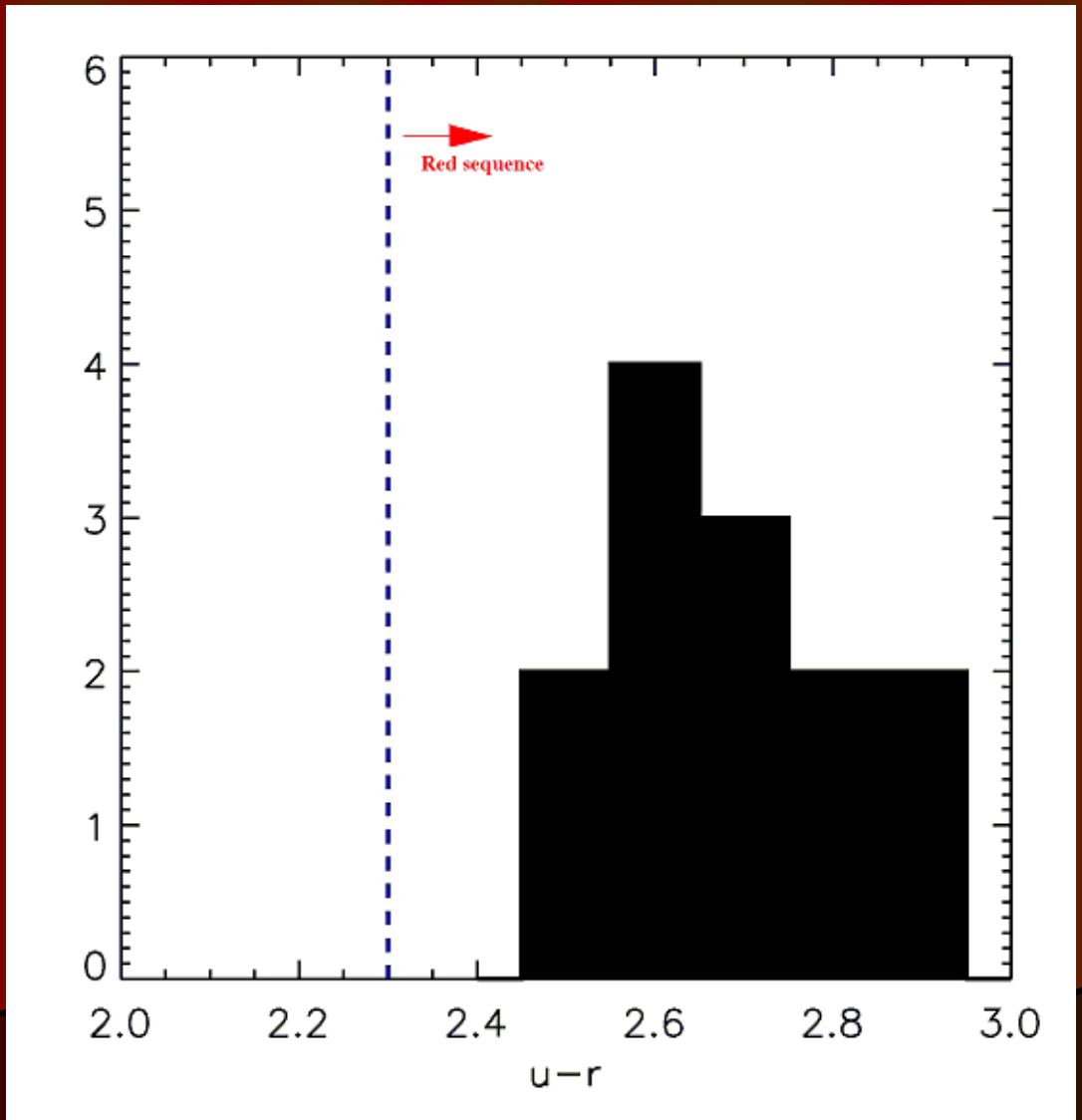
The Problem

- 40%-70% of field S0 galaxies possess HI reservoirs (Giovanardi et al. 1983; Sage & Welch 2006; Morganti et al. 2006; Serra et al. 2012).
- However, only in 50% of gas-rich S0s starforming regions are detected (Pogge & Eskridge 1987, 1993).
- Spirals are forming their stars also of accreted gas; what is the difference with lenticulars?

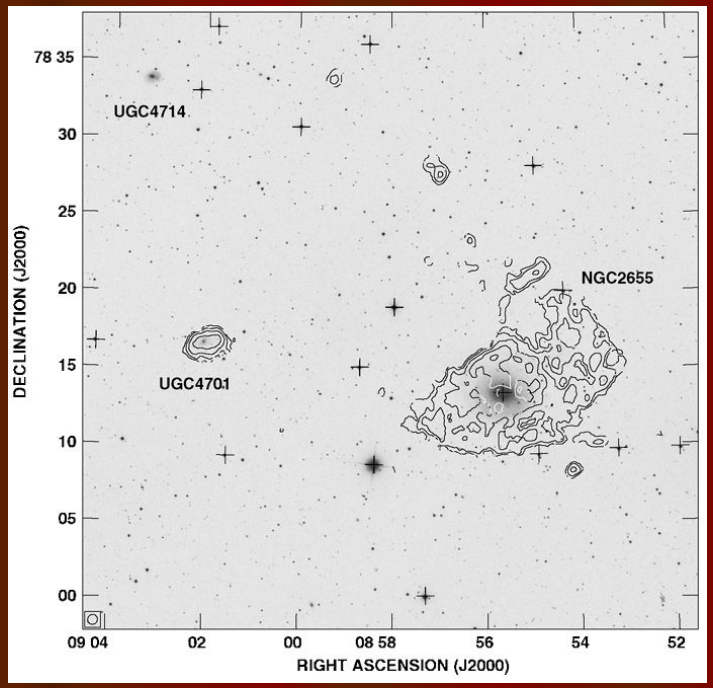
The part of our sample – just observed

Name	Type (NED[1])	M_{HI}, 10^8 $M_\odot$	M_{H_2}, 10^8 $M_\odot$ Young(2011)
I5285	S0/a[5]	37.5 (EDD)	
N774	S0		
N2551	SA(s)0/a	12 (EDD)	
N2655	SAB(s)0/a	11.4 (EDD)	1.3(Ueda14)
N2697	SA(s)0+:	5.8 (EDD)	1.8
N2787	SB(r)0+	9.8(Roberts)	0.18(Welch)
N2962	(R)SAB(rs)0+	11.0(EDD)	< 0.7
N3106	S0	108(Eder)	
N3166	SAB(rs)0/a	4.5(Roberts)	1.7(Wiklind)
N3182	SA(r)a?	0.08 **(Serral2)**	2.14
N3414	S0pec	1.9 **(Serral2)**	< 0.15
N3619	(R)SA(s)0+:	10.0 **(Serral2)**	1.9
N4026	S0	3.2 **(Serral2)**	0.88(Welch)
N4324	SA(r)0+	16.8 **(EDD)**	0.5
N7280	SAB(r)0+	0.83 **(Serral2)**	< 0.3
U9519	S0:	18.6 **(Serral2)**	5.9
U12840	(R)SAB(s)0[0]	50.5(ALFA)	6.2(AMIGA)

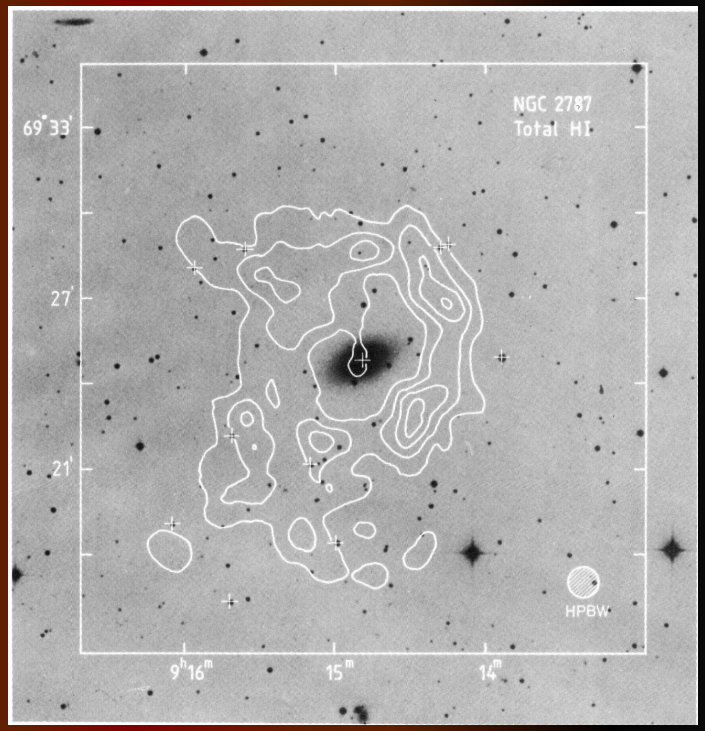
Only red sequence!



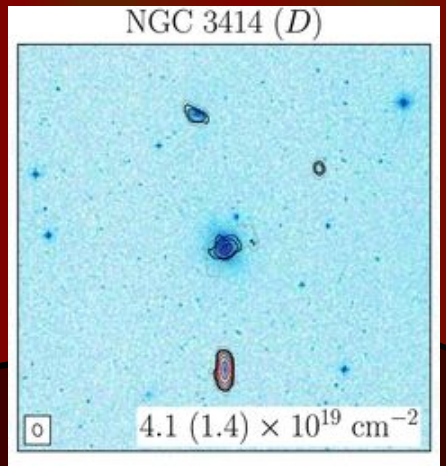
Some have extended HI disks



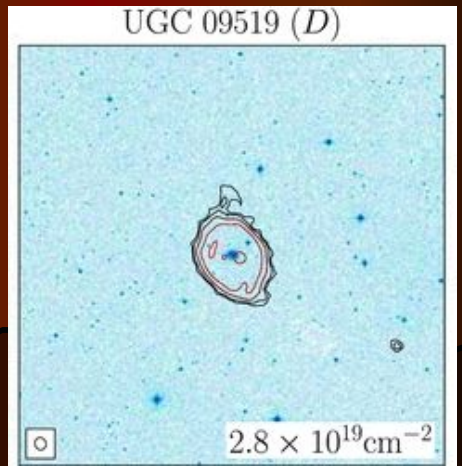
Sparke et al. 2008



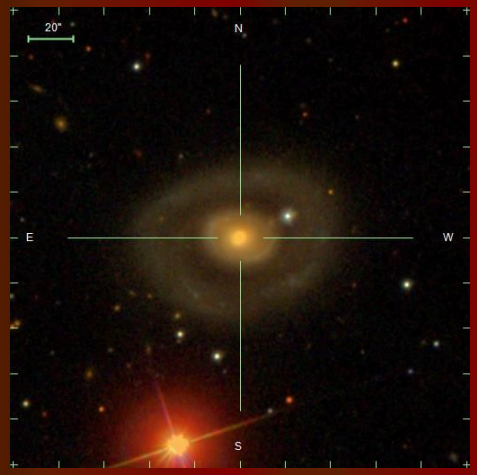
Shostak 1987



Serra et al. 2012

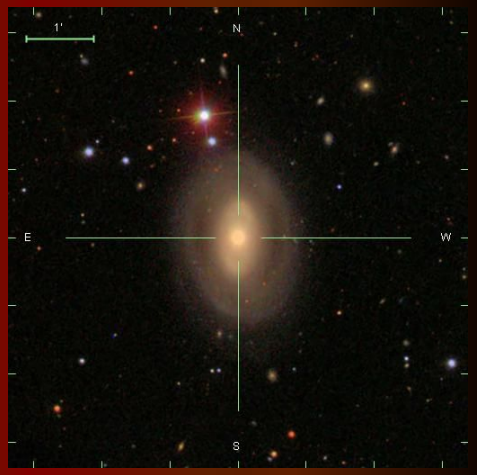


Some have blue (starforming?) rings

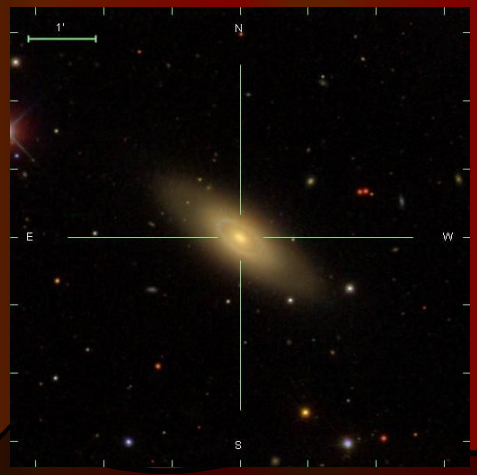


IC 5285

NGC 2962



SDSS



NGC 4324

UGC 12840

Observations: SAO RAS 6-m telescope

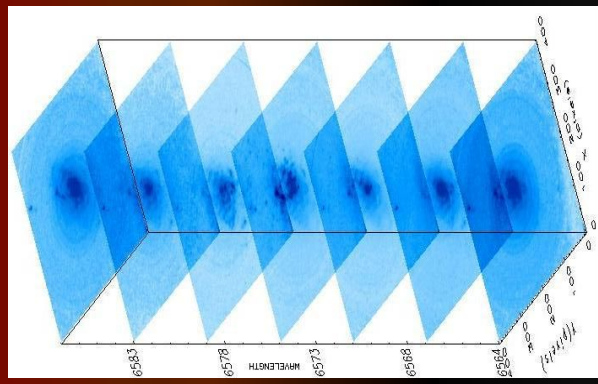
Multi-mode SCORPIO-2 focal reducer with a scanning Fabry-Perot interferometer (Afanasiev & Moiseev 11)

Emission lines : [NII]6583, [OIII]5007, Ha

Field of view: 6.1 x 6.1 arcmin

Spatial sampling: 0.70 arcsec/px

Vel. Resolution (FWHM): 70-120 km/s

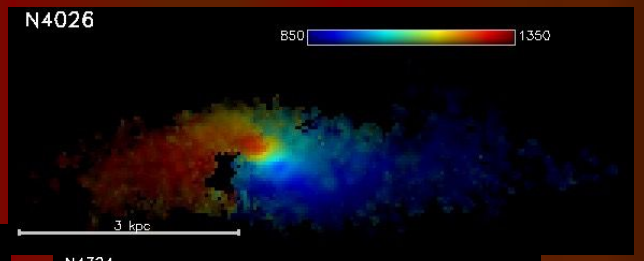


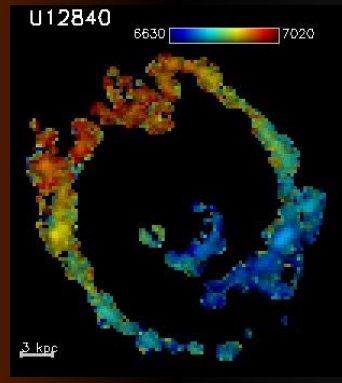
Additional data:
Long-slit spectroscopy (6-m BTA, 10-m SALT): stellar kinematics, age/metallicity

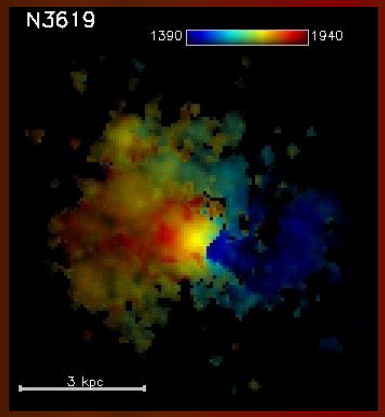
Available IFU maps: ATLAS3D, CALIFA, MPFS/6-m telescope

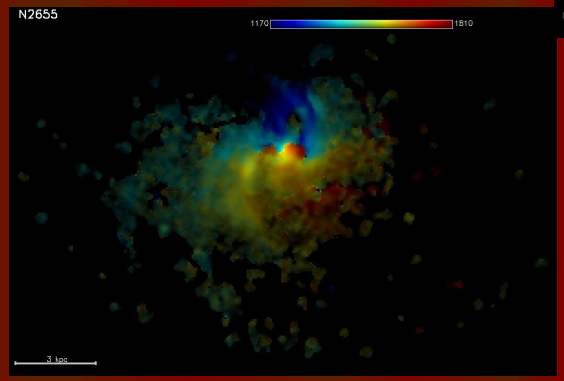
http//:www.sao.ru

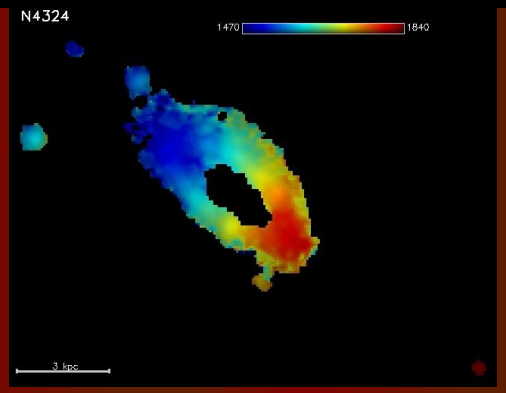
Now:17 galaxies

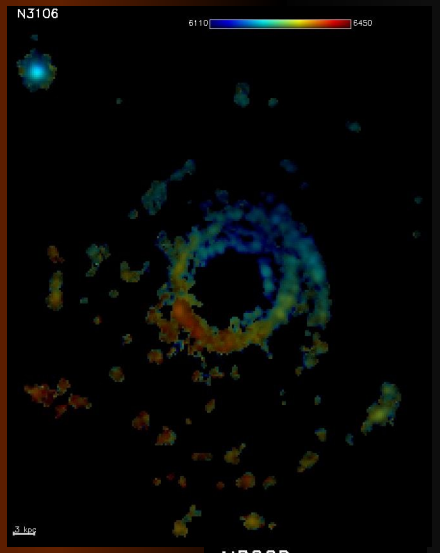


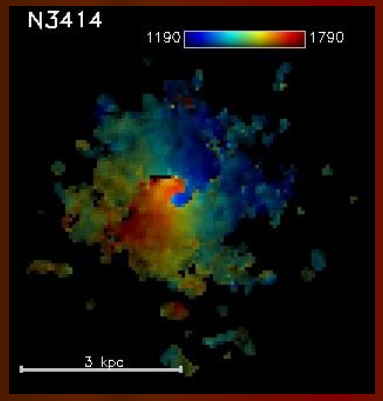


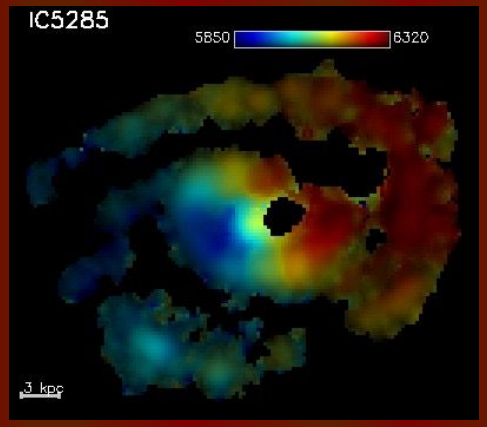


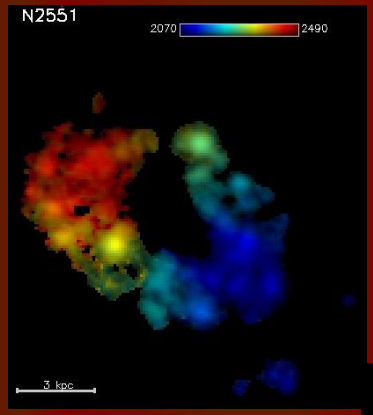


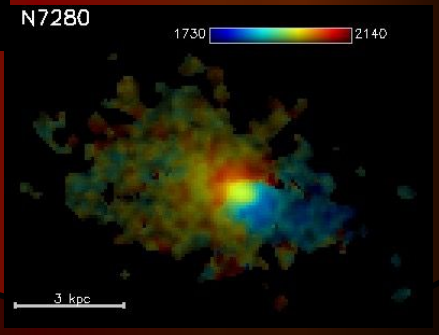


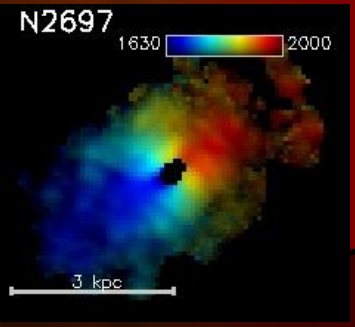


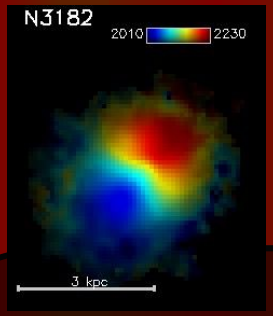


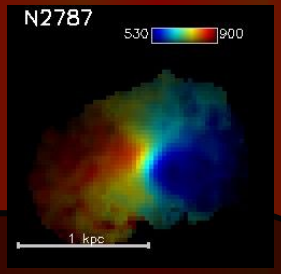


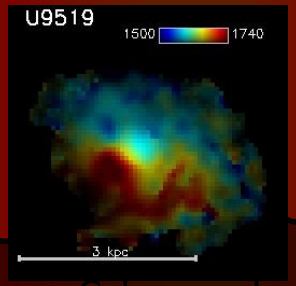










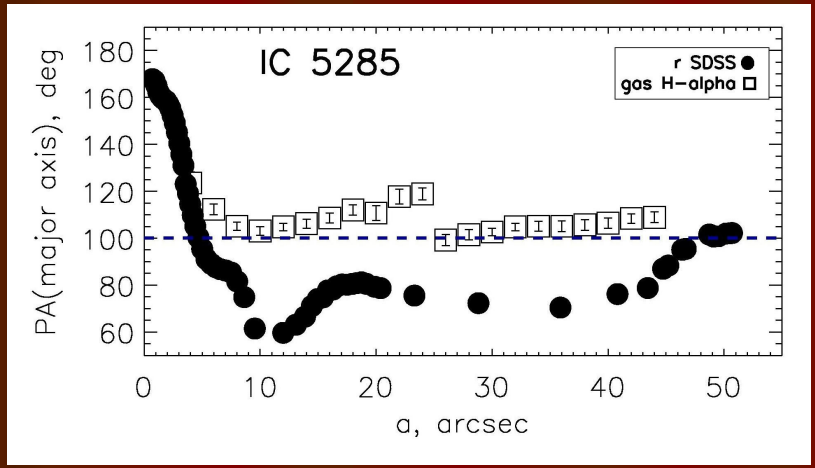


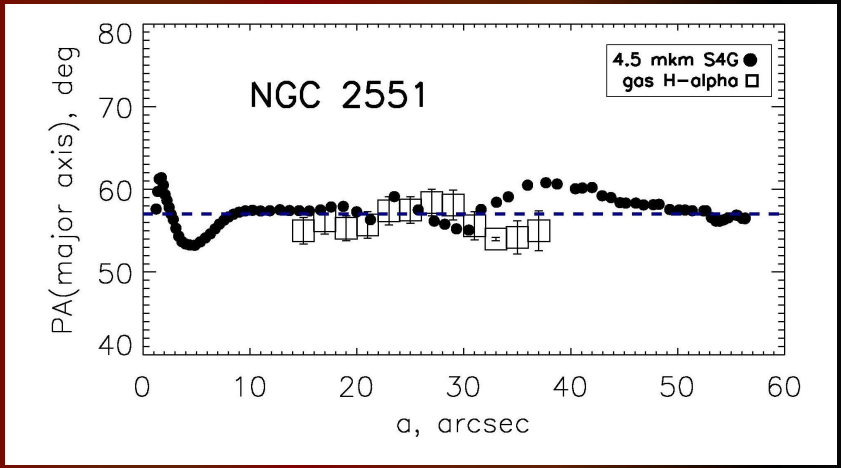
Color = velocity, intensity = emission-line brightness

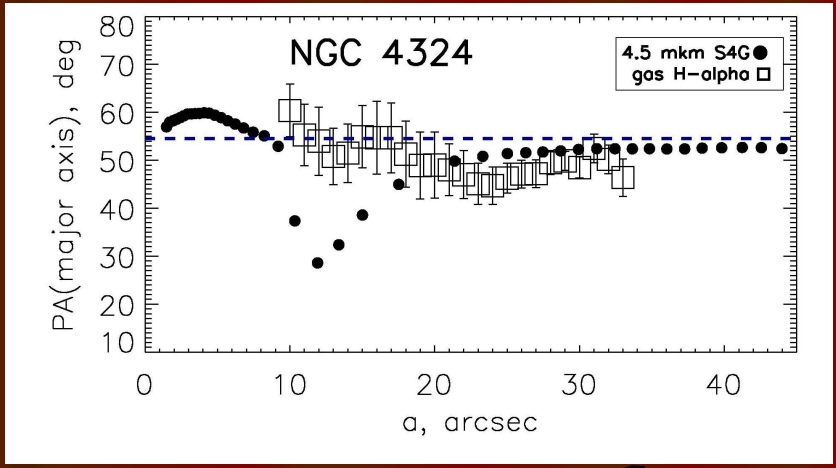
Comparison of the gas rotation-plane lines of nodes with continuum isophote major axes:

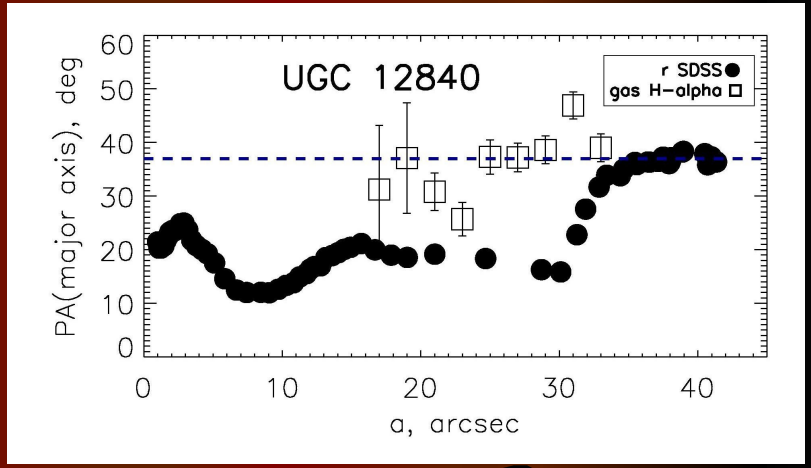
- 4 cases of fully consistent gas rotation plane orientations with respect to the stellar disks – ‘SF DISKs’;
- 5 cases of completely different gas rotation plane and stellar disk orientations – ‘WARPs’;
- The others have PARTLY coincident PA(gas kinematical major axis) and the PAs of the isophote major axes - `RINGs’.

`SF DISKS':



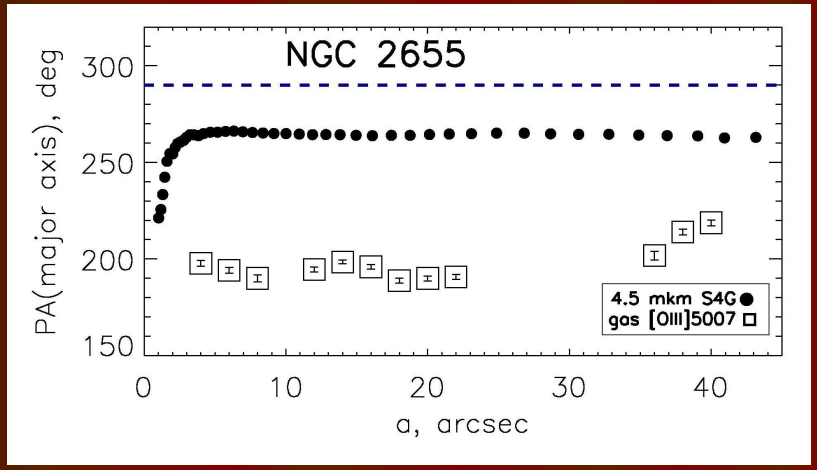


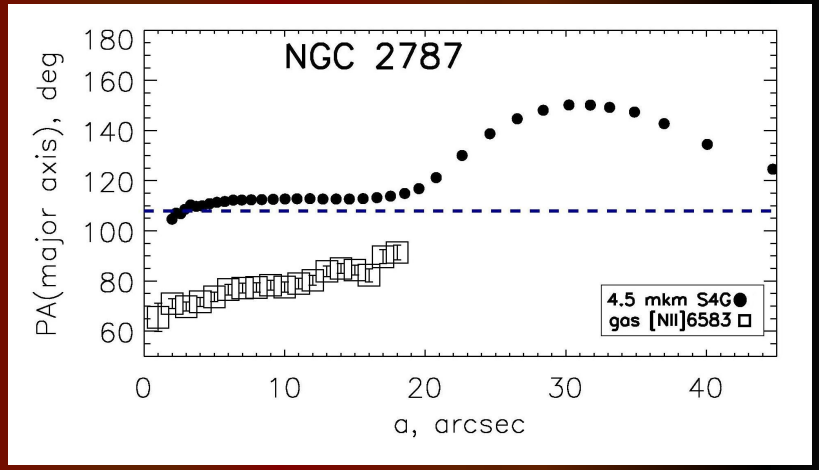


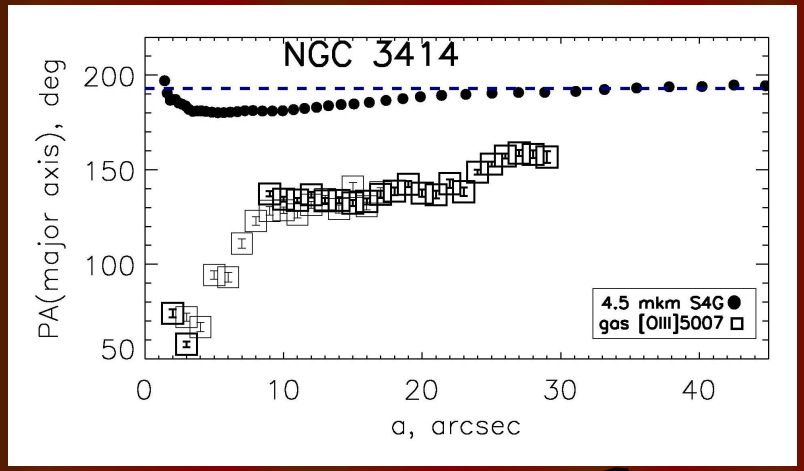


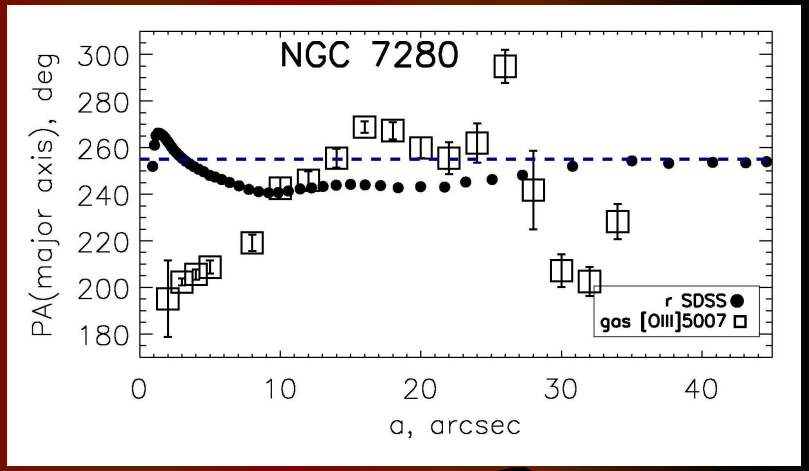
Blue dashed line – the orientations of the outer isophotes – stellar disks line of nodes

`WARPs':



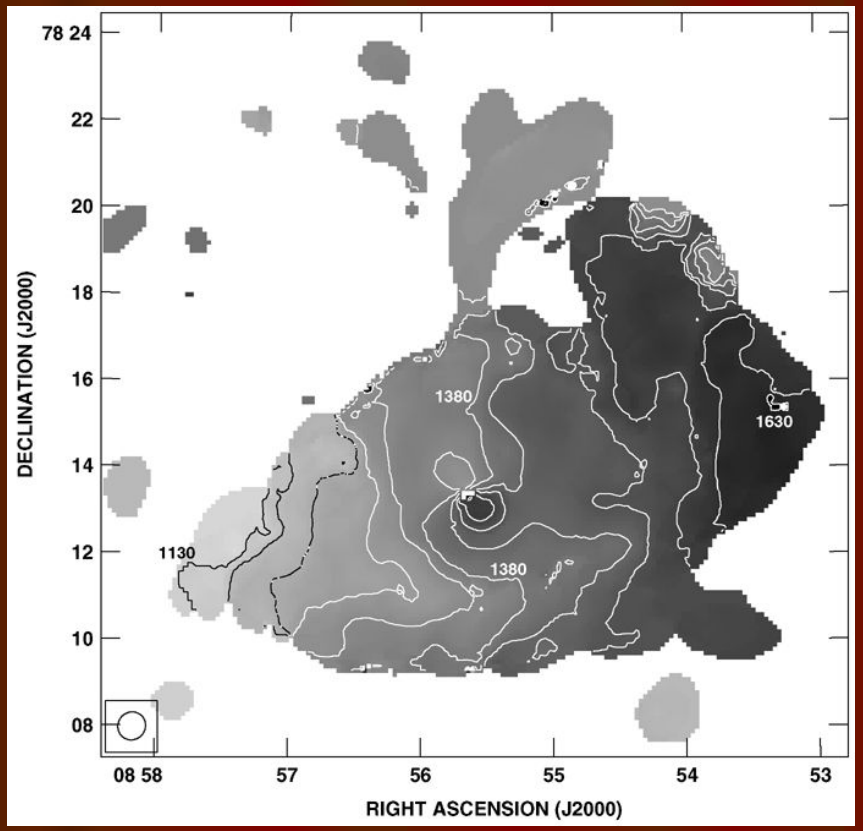




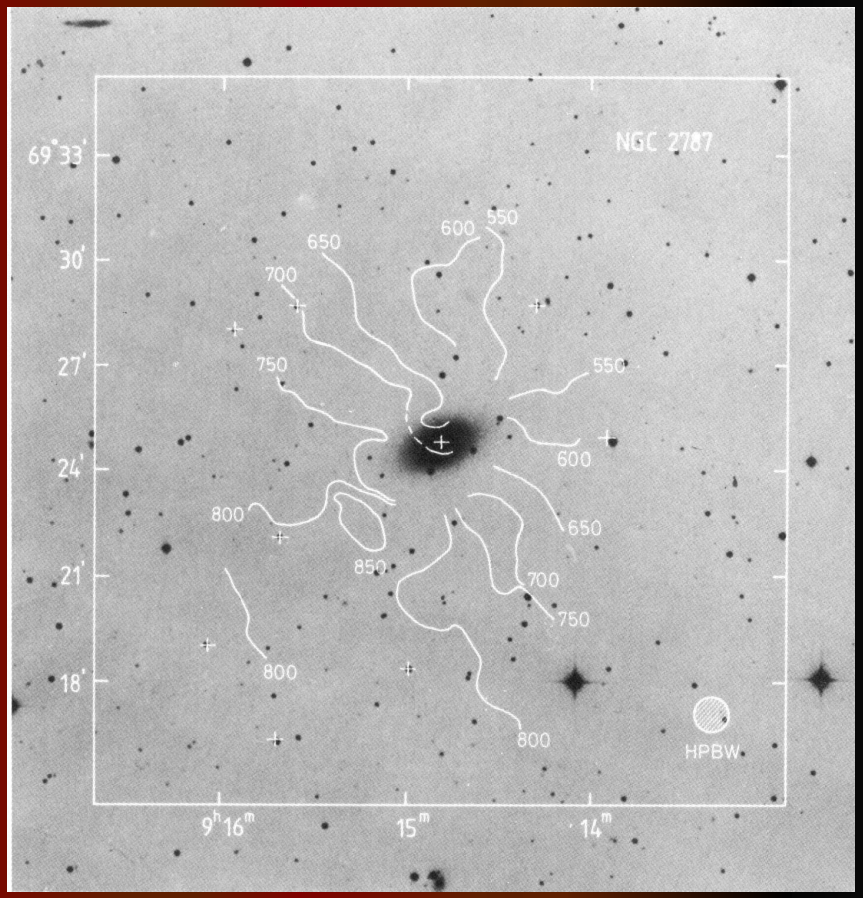


Blue dashed line – the orientations of the outer isophotes – stellar disks line of nodes

Outer HI of the `warped' ionized-gas disks lies closer to the galactic planes:

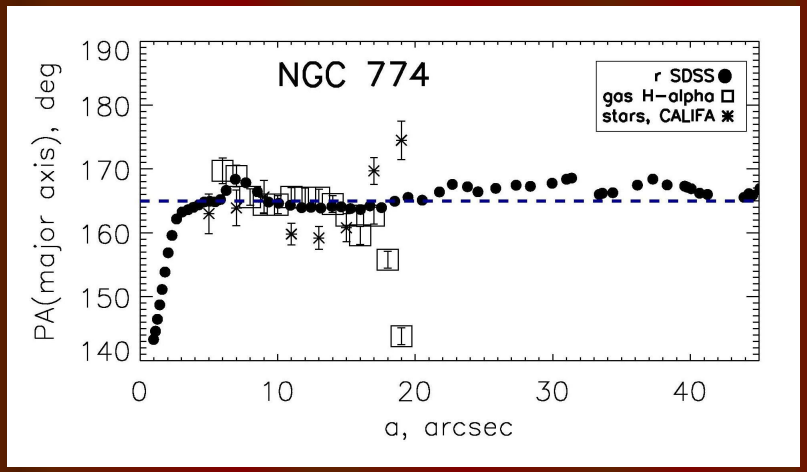


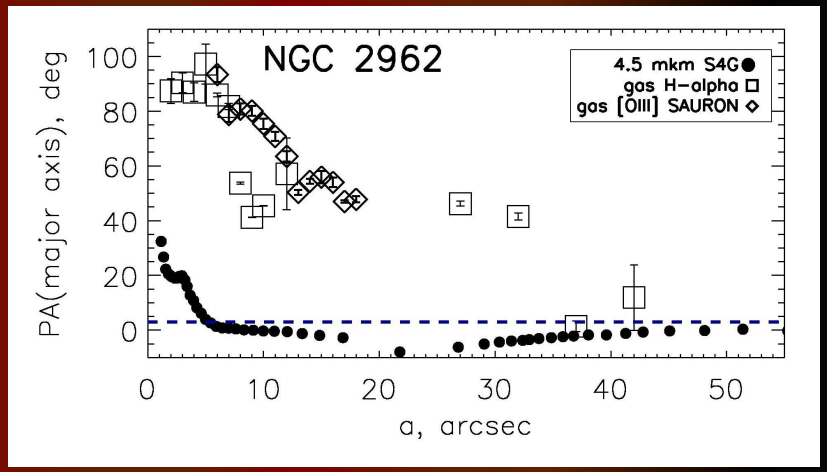
NGC 2655, Sparke et al. 2008

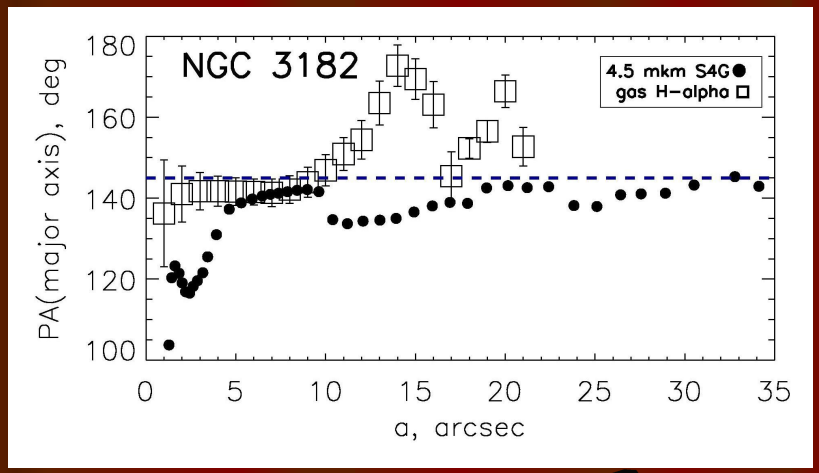


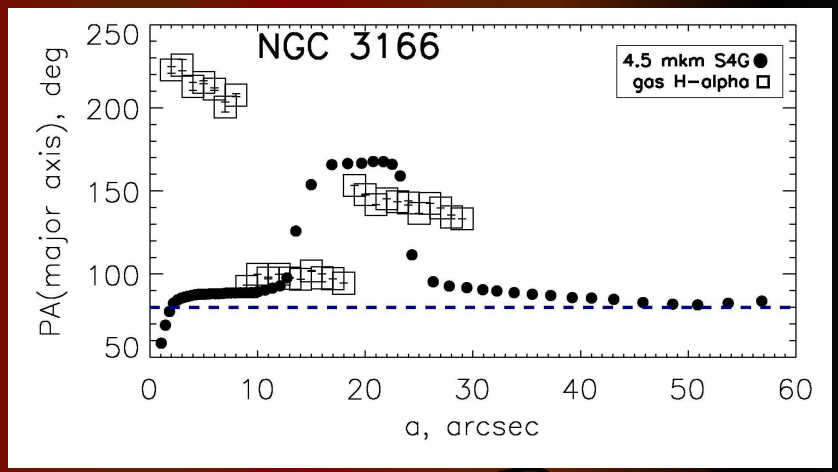
NGC 2787, Shostak 1987

`RINGs':



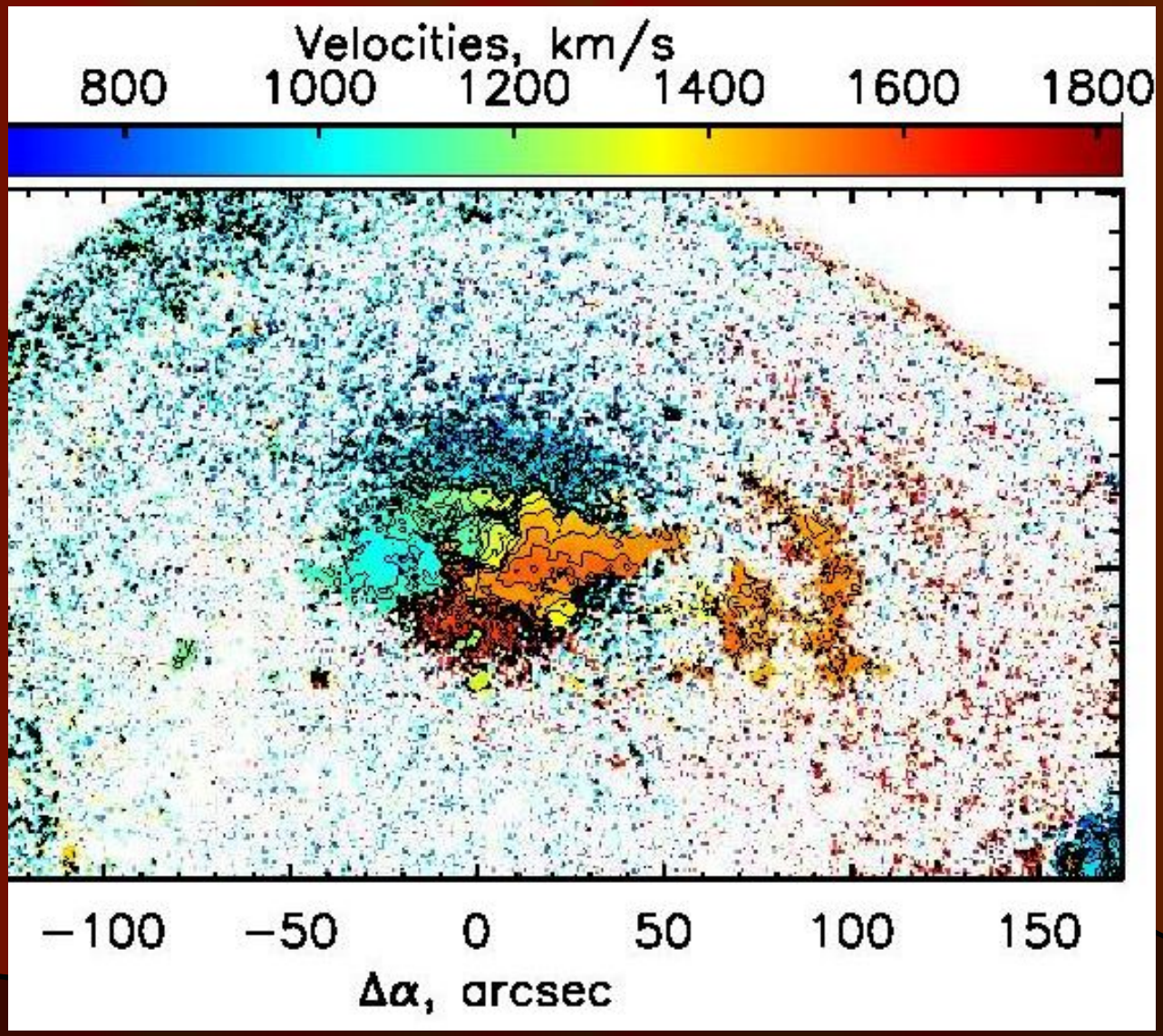




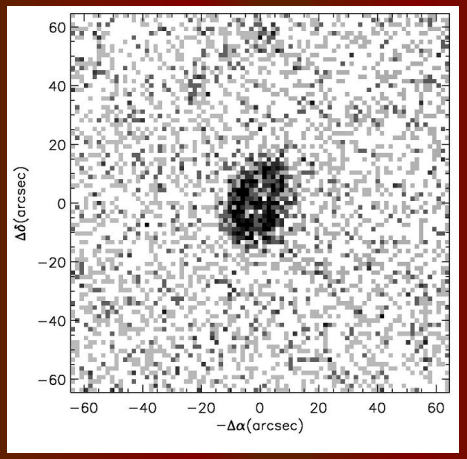


Blue dashed line – the orientations of the outer isophotes – stellar disks line of nodes

NGC 3166

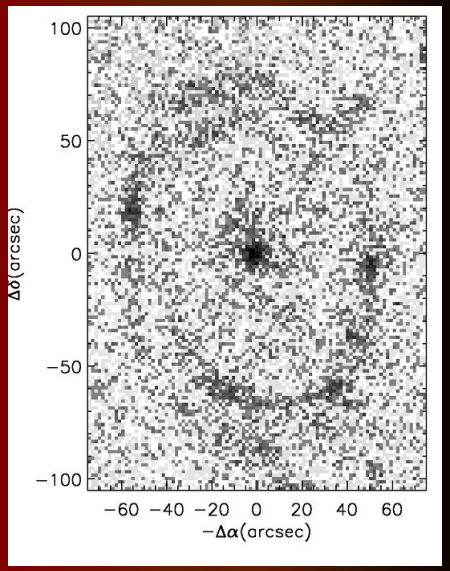

Velocities, km/s
800
1000
1200
1400
1600
1800
−100
−50
0
50
100
150
Δα, arcsec

`RINGs' are indeed starforming rings!

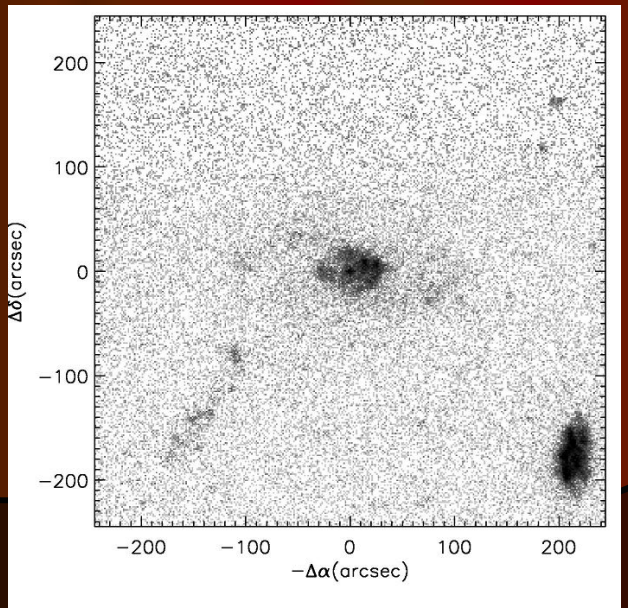


NGC 774

NGC 2962

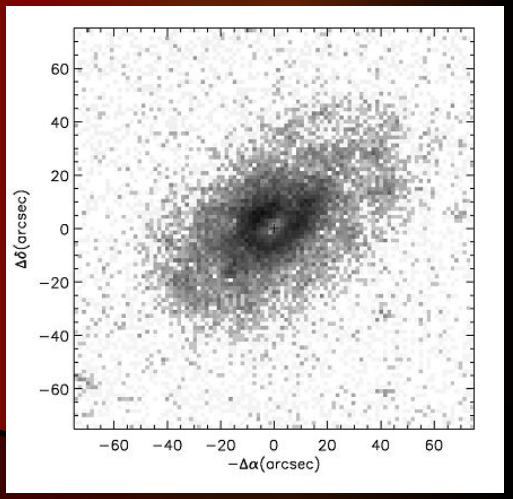


GALEX/FUV

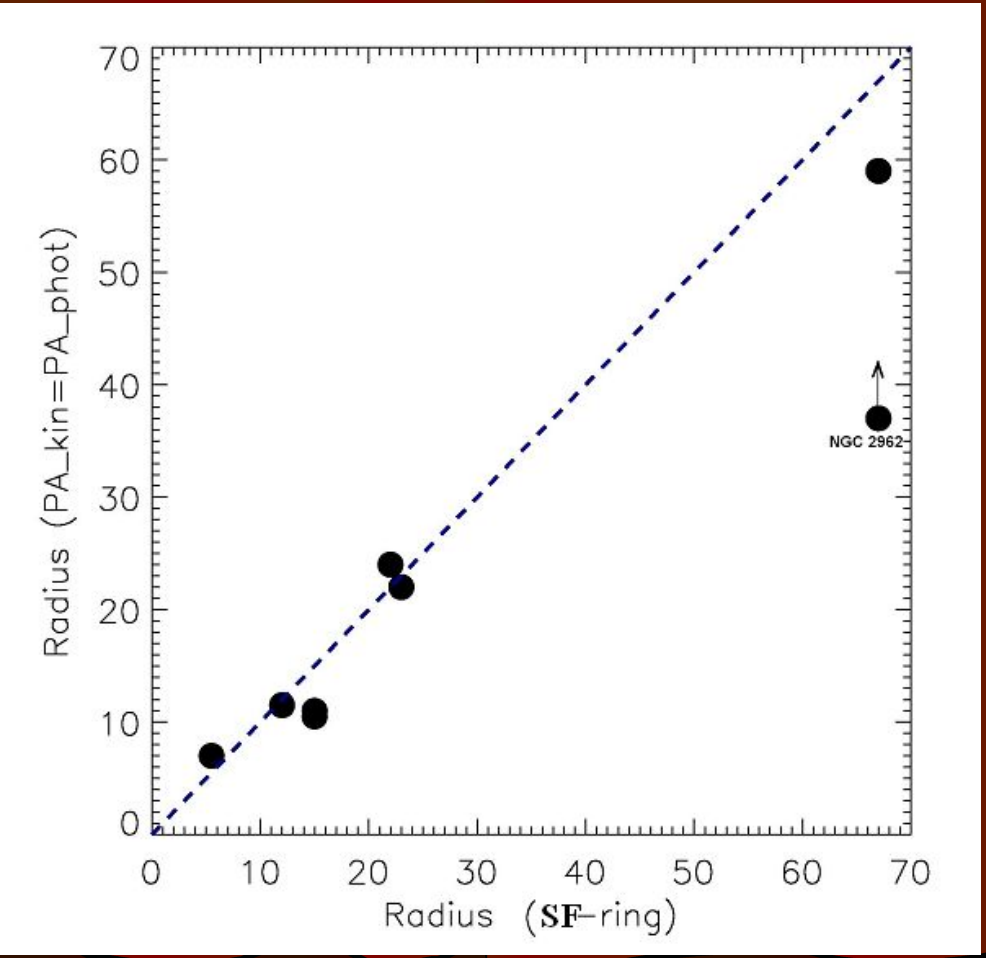


NGC 3166

NGC 2697

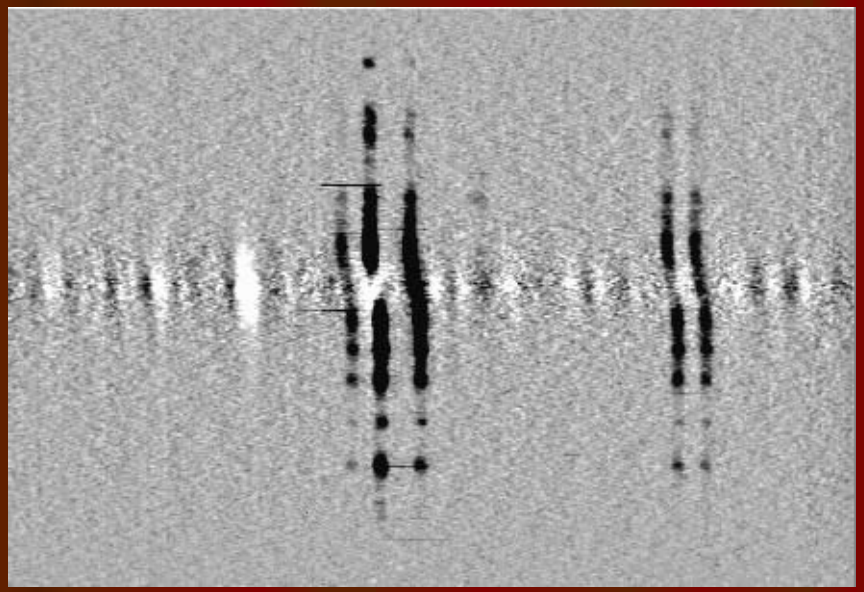


Their radii are just the radii of PA coincidence!



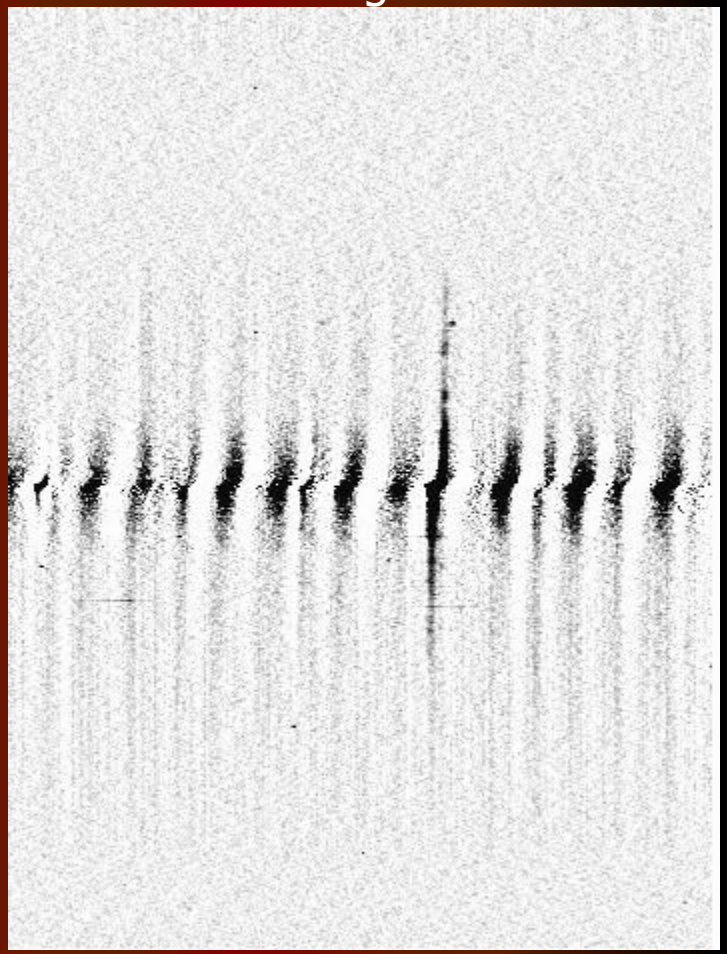
By integrating along the slit…

NGC 2697 red



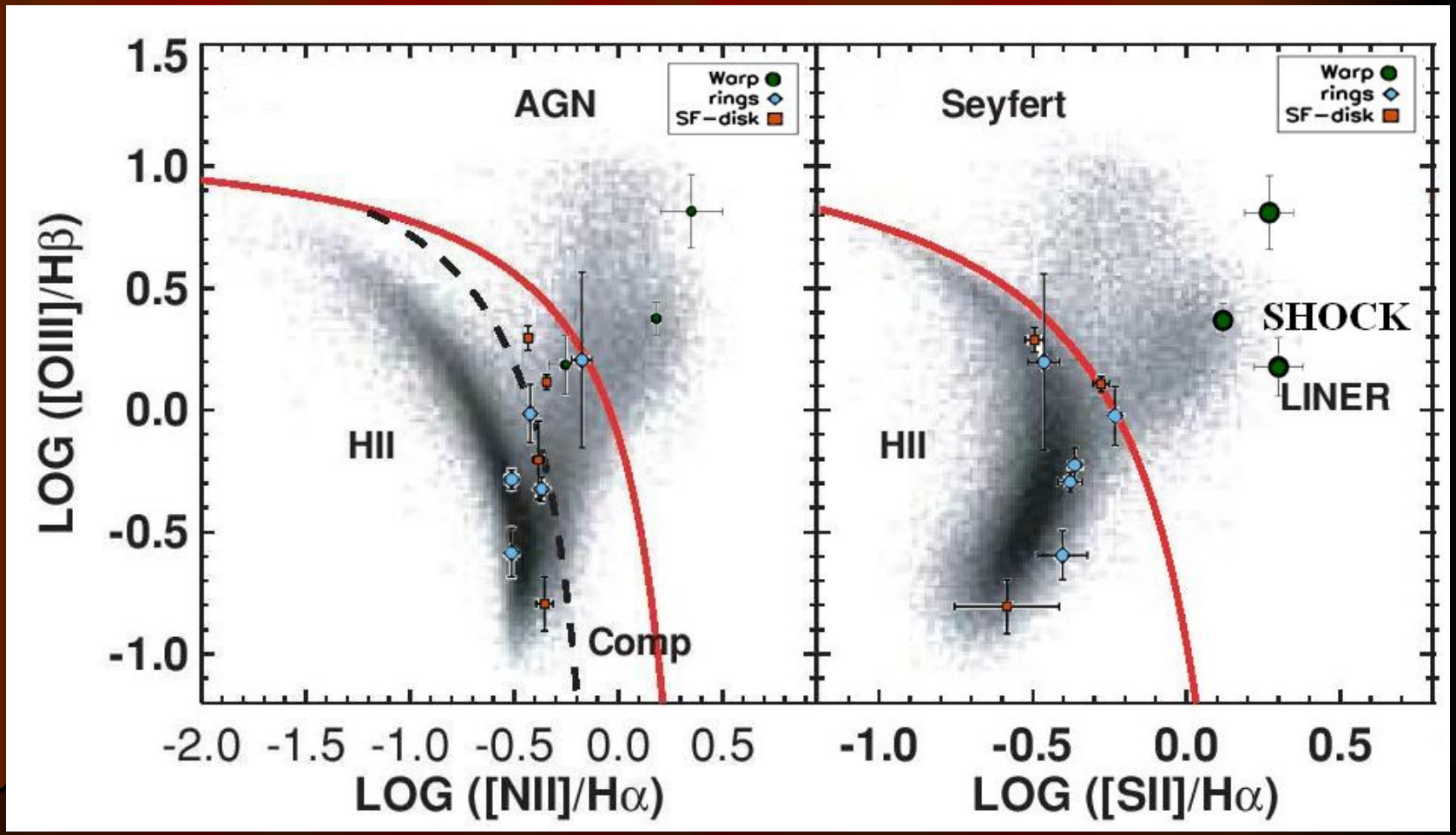
… spectra at the radii of starforming rings…

NGC 2787 green

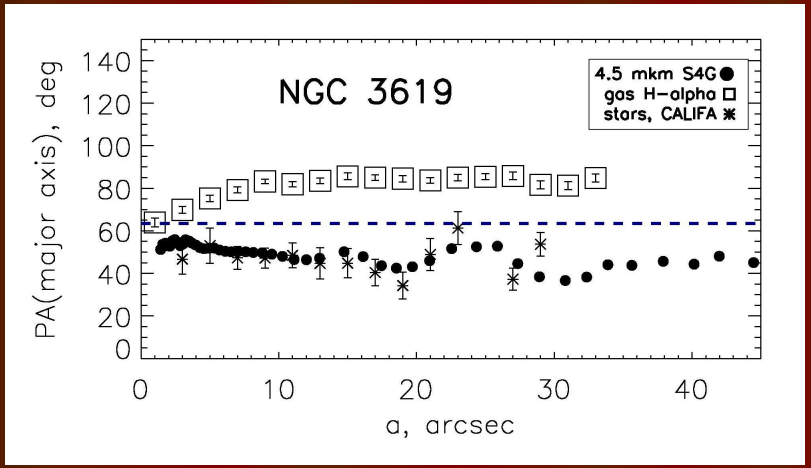


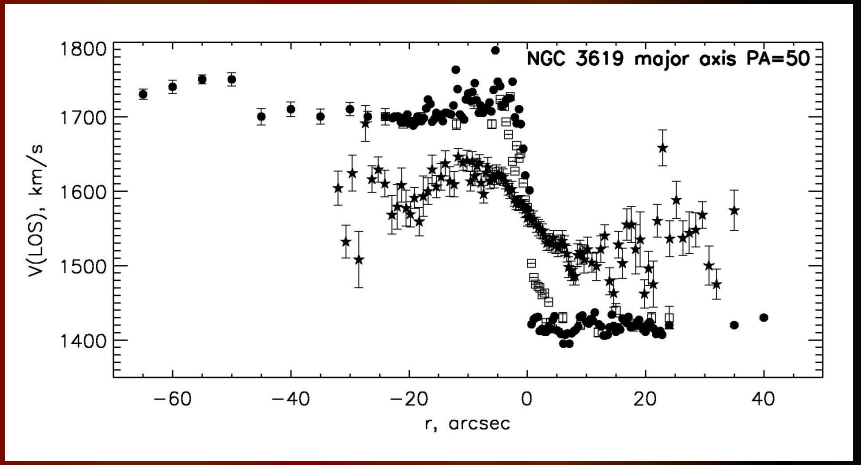
… or, in the absence of star formation, some radial range of gas emission…

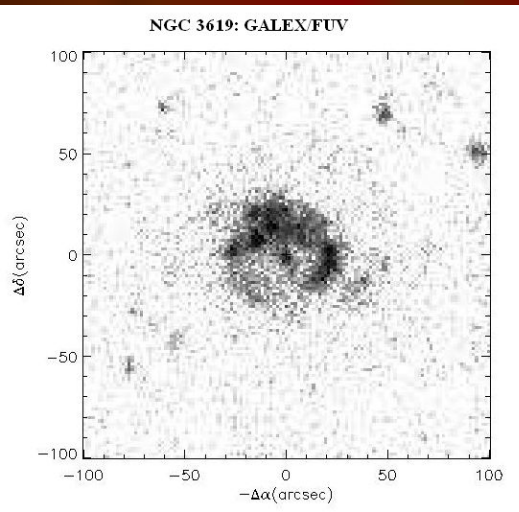
We plot the line ratios onto BPT-diagrams to look at gas excitation in S0 gaseous disks of three types

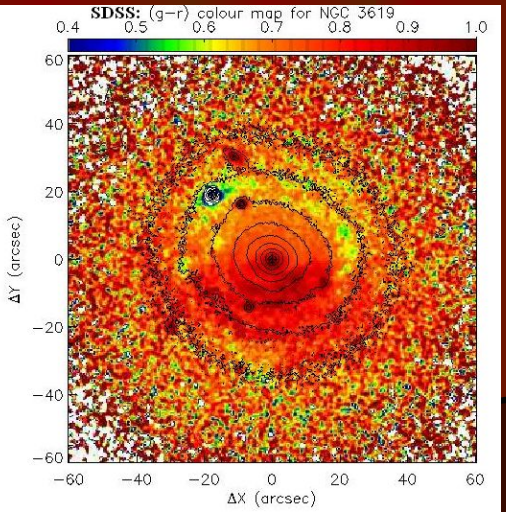


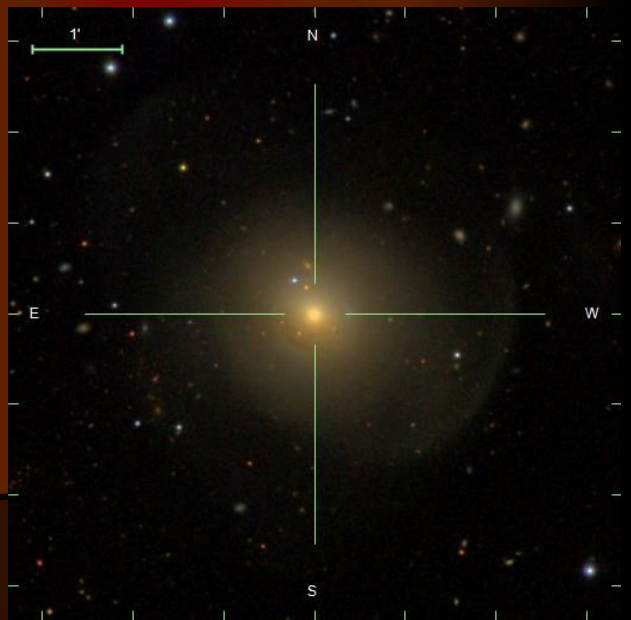
Only one exception: NGC 3619



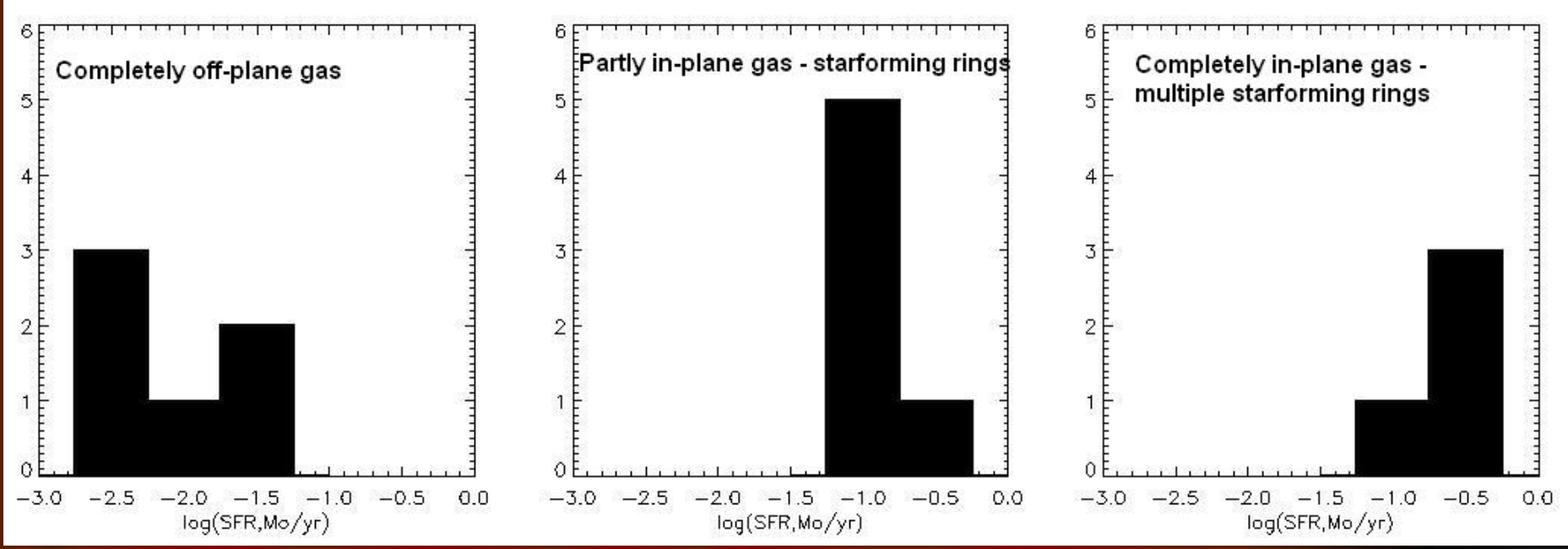




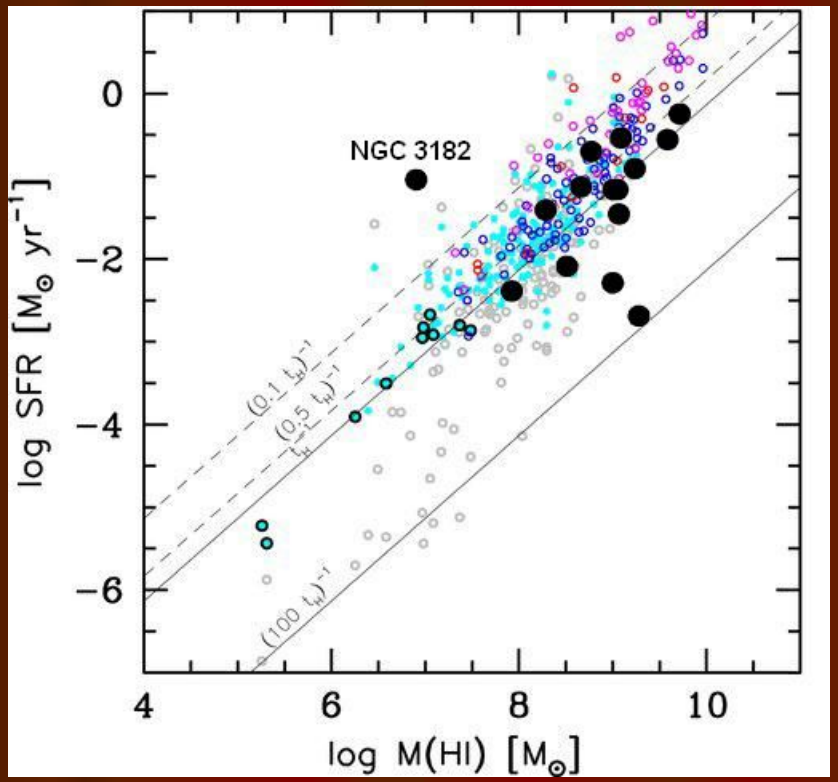




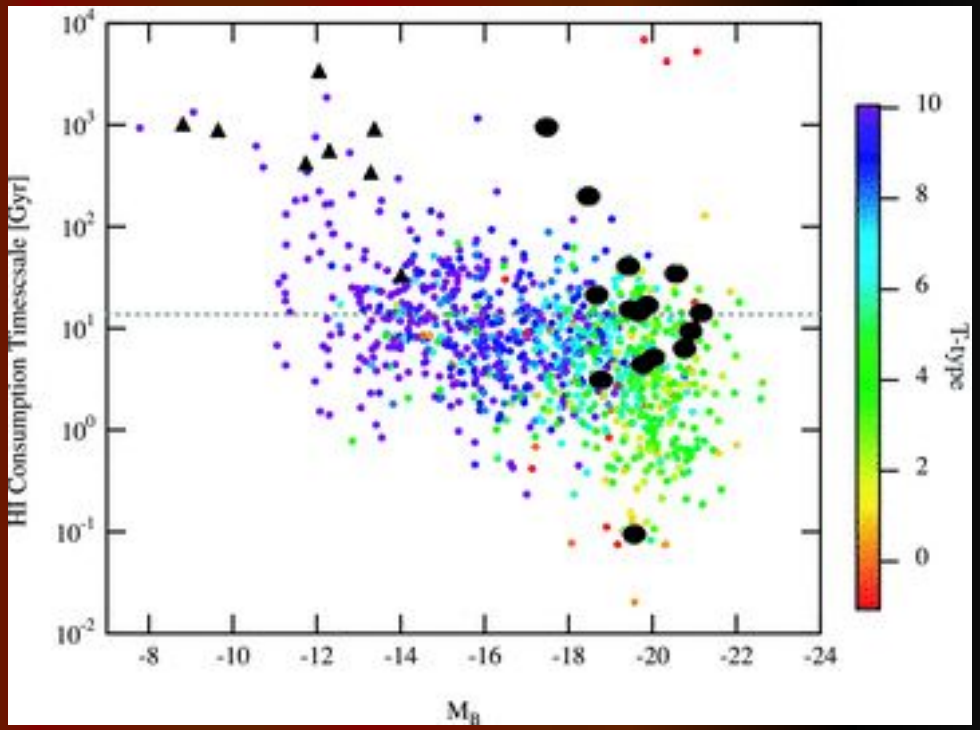
Star formation rates (from the integrated FUV-magnitudes):



Scaling relations: Star formation is normal for their HI content

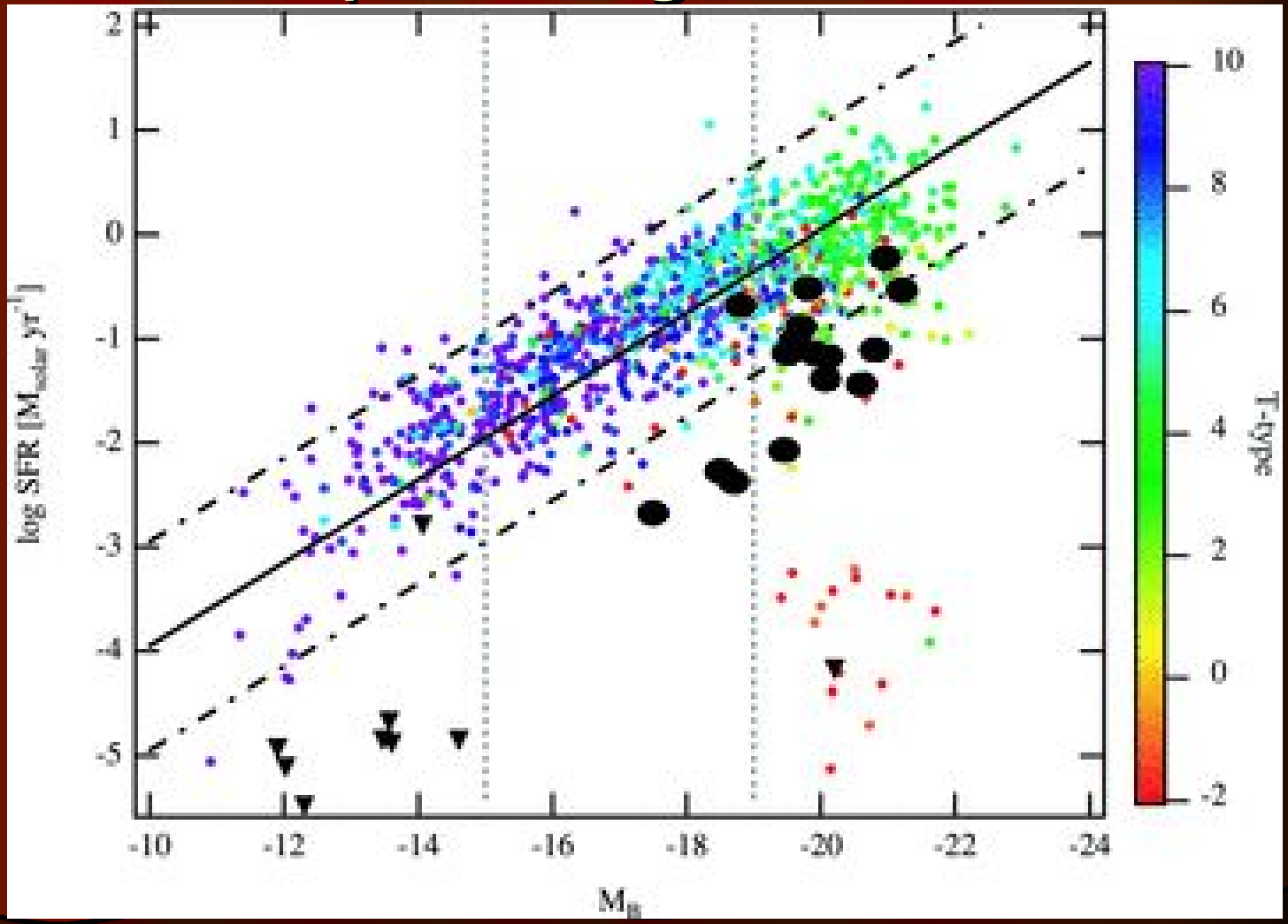


Adopted from Lee et al. 2011



Adopted from Bothwell et al. 2009

Scaling relations: however the `main sequence' goes above



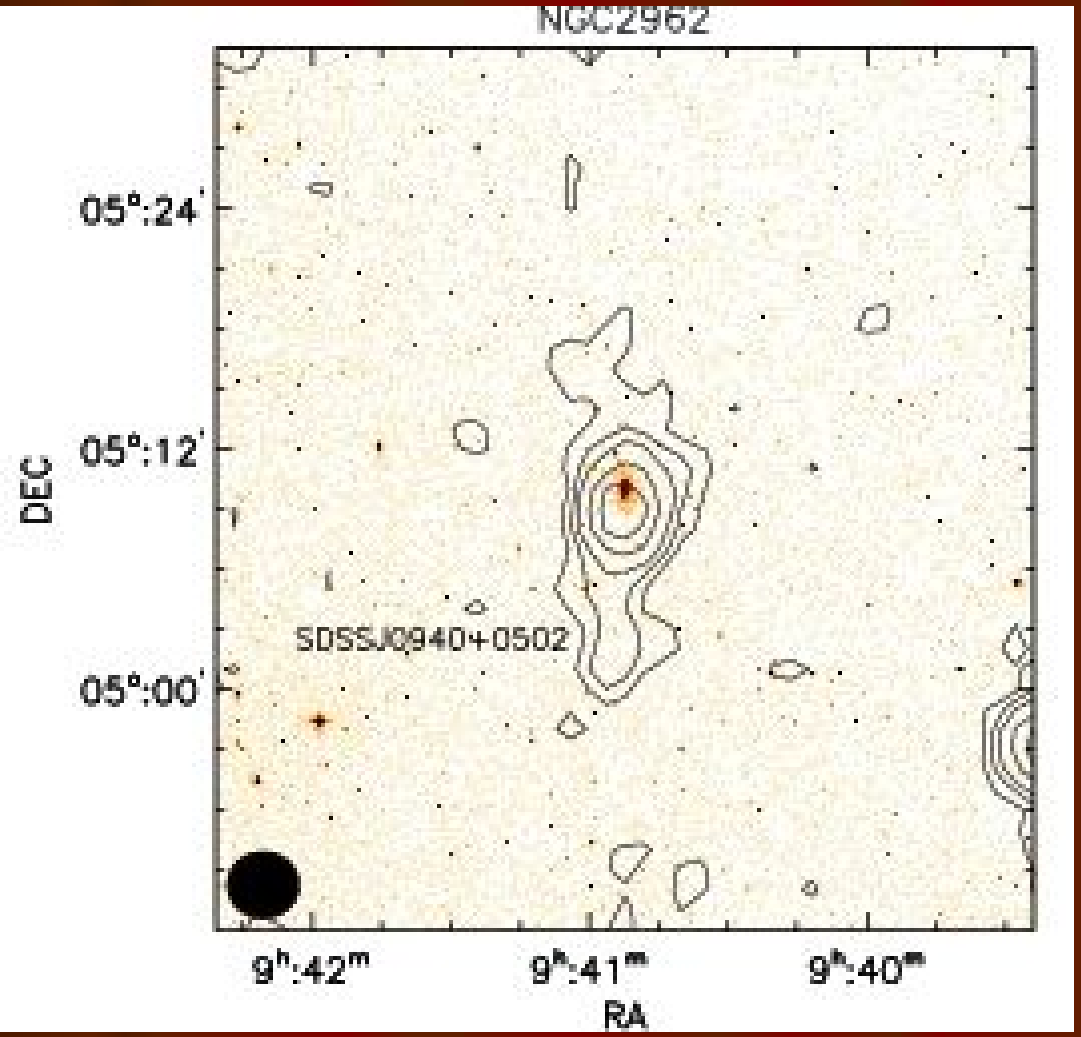
Adopted from Bothwell et al. 2009

Conclusions

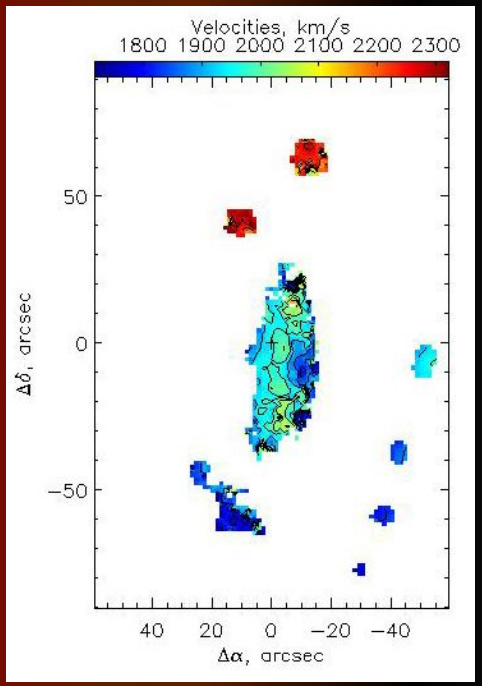
- Lenticulars in the field accrete the outer cold gas just as spirals.
- BUT
- From inclined orbits – in such cases there are shocks and there is no star formation;
- If in plane, then in less abundant and/or in intermittent regime – so star formation is weak and confined to rings, no inflow (`spiralling') to the centers.

NGC 2962

Ionized gas, Full field, SCORPIO2/FP



HI, Grossi et al. 2009



Center, SAURON