Extended nebular emission and gas excitation mechanisms in ETG galaxies

Jean Michel Gomes

Institute of Astrophysics and Space Sciences
www.iastro.pt

ia
instituto de astrofísica e ciências do espaço

CALIFA Survey

Team

P. Papaderos
J.M. Vílchez
C. Kehrig
J. Iglesias-Páramo
I. Breda
M. Lehnert
S.F. Sánchez
B. Ziegler
and the CALIFA collaboration

FCT
Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

Centro de Astrofísica da Universidade do Porto

ia instituto de astrofísica e ciências do espaço

SEL GIFS

POPH QUALIFICAR É CRESCER.

QREN QUADRO DE REFERÊNCIA ESTRATÉGICO NACIONAL PORTUGAL 2007.2013

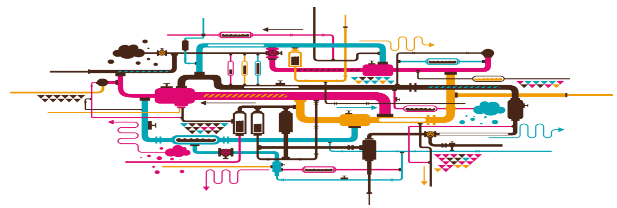
GOVERNO DA REPÚBLICA PORTUGUESA

UNIÃO EUROPEIA Fundo Social Europeu

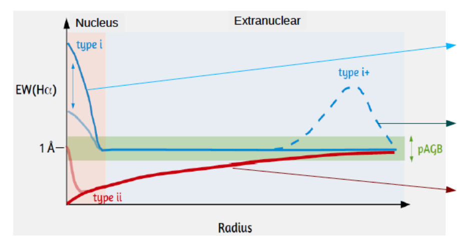
HEADLINES

1. Overview — **Motivation**

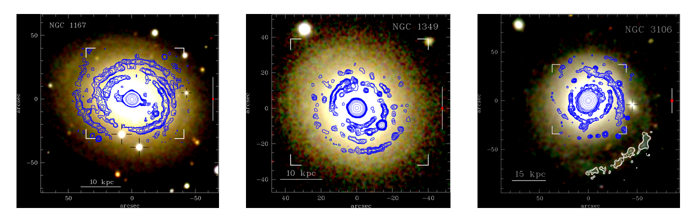
2. Porto3D



3. IFU analysis of 32 ETGs
   * Type i, i+ & ii



4. Spiral-like features in ETGs?



5. Final remarks

1. Overview

- Early-type galaxies (ETGs)

Past	Now
Devoid of dust and gas	**Gas 60-80% of ETGs**
Metal-rich stellar populations	**α -enhancement**
Formed coevally	**Residual SF, Mergers…**
Circularly-symmetric features	**Spiral or bar-like patterns**

1. Overview

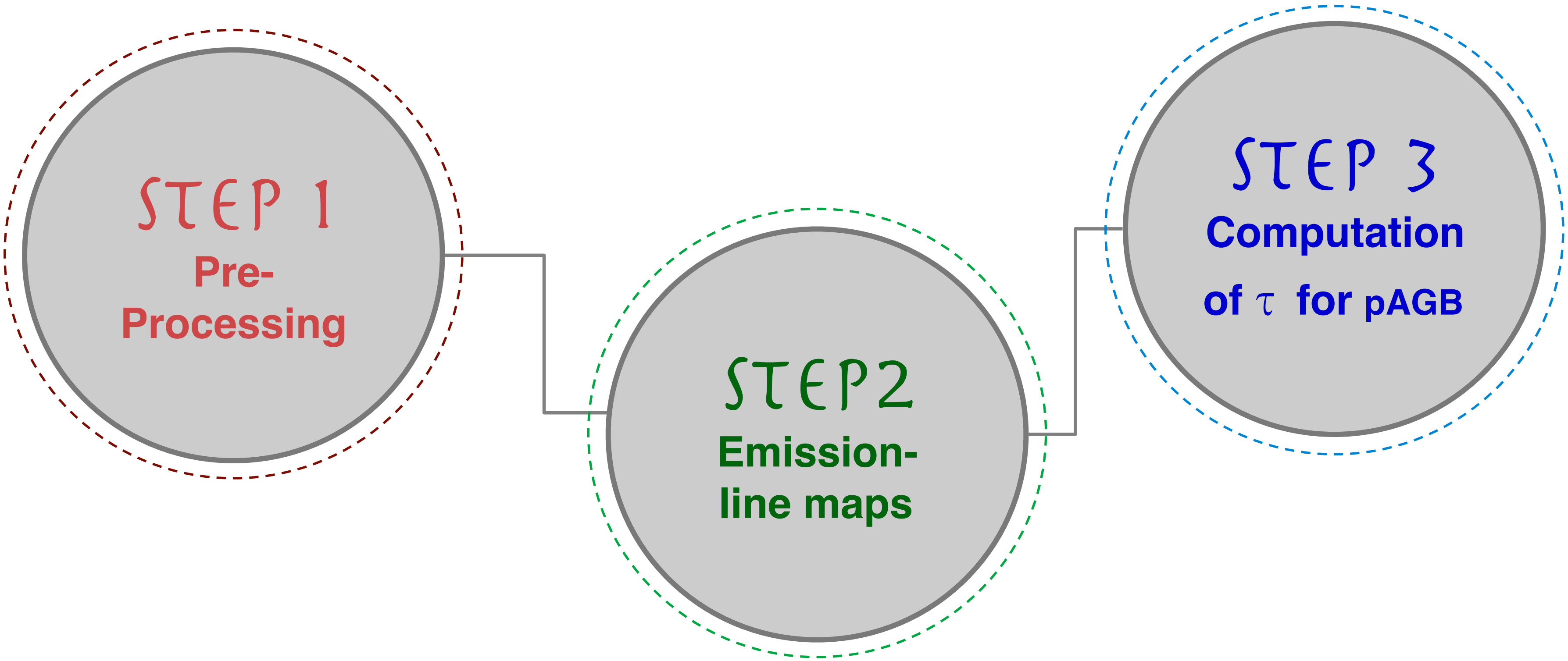
*What is the nature of the warm interstellar medium in ETGs? AGN? Post-AGB stars? Residual SF? Shocks?

*Faint Nebular Emission - EW(Hα) <~ 3Å - Usually compatible with LINER line-ratios in standard diagnostic diagrams

*This project mainly focus on the Post-AGB component for the ionization mechanism in ETGs

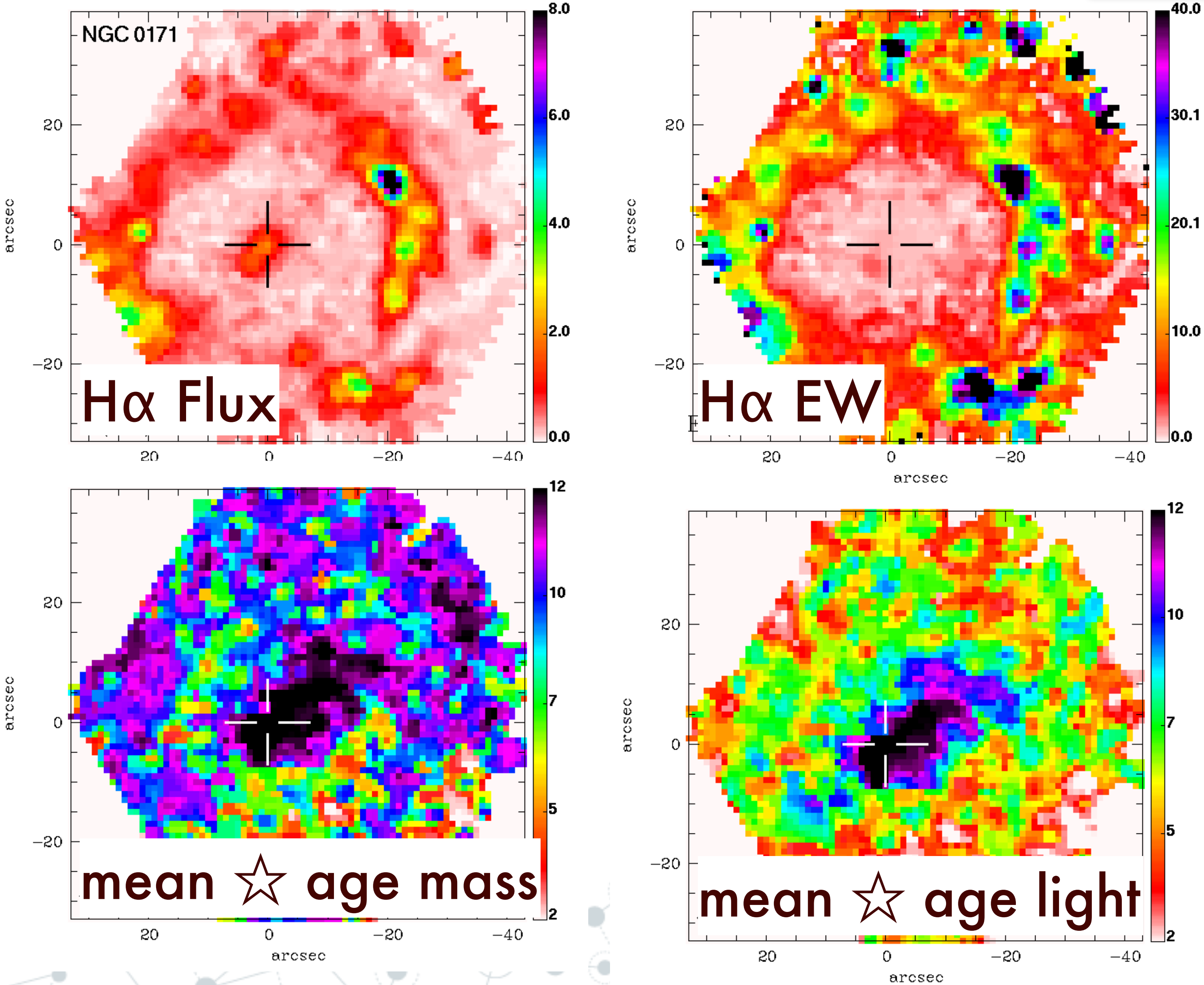
2. Porto3D – IFU Pipeline

Gomes et al. 2016a



- MODULAR structure
- STARLIGHT spectral synthesis code
- ESO-MIDAS + Fortran standalone routines

Ex.: Porto3D - NGC 171



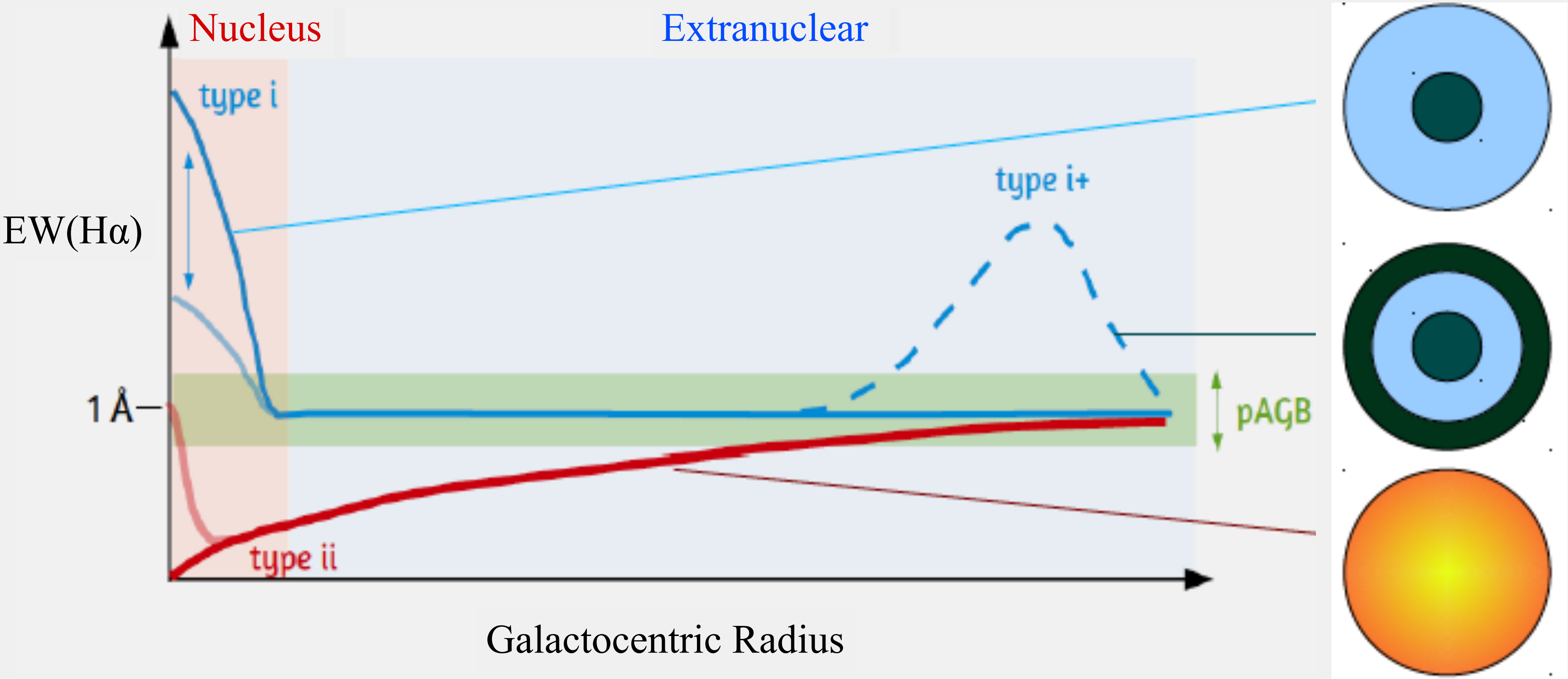
3. IFU analysis of 32 ETGs

Gomes et al. 2016a

Table 1. General properties of the sample ETGs.

Name (1)	Morph. (2)	Type (3)	α(J2000) (4)	δ(J2000) (5)	D (6)	m_g (7)	m_r (8)	r_p (9)	$f_{H\alpha}$ (10)	$L_{H\alpha}$ (11)	$\mathcal{M}_\star$(e/p) (12)	$<\tau>$ (13)
UGC 05771	S0/a	i	10:37:19.33	+43:35:15.31	106.4	14.15	13.23	7.3	251	34.0	11.560/11.398	0.69
NGC 4003	SB0	i	11:57:59.03	+23:07:29.63	96.6	14.06	13.21	9.6	455	50.8	11.378/11.218	0.57
UGC 08234	S0/a	i	13:08:46.50	+62:16:18.10	116.1	13.51	12.82	5.2	99	15.9	11.270/11.131	1.09
NGC 5966	E	i	15:35:52.10	+39:46:08.05	69.0	13.32	12.52	9.4	206	117.2	11.311/11.155	1.26
UGC 10205	Sa	i	16:06:40.18	+30:05:56.65	97.6	14.06	13.16	12.2	561	63.9	11.375/11.221	0.20
NGC 6081	S0	i	16:12:56.85	+09:52:01.57	79.6	13.79	12.86	8.2	249	18.9	11.493/11.331	1.07
NGC 6146	E?	i	16:25:10.32	+40:53:34.31	127.4	13.31	12.49	7.2	180	34.9	11.880/11.720	1.86
UGC 10695	E	i	17:05:05.57	+43:02:35.35	120.1	14.07	13.19	10.7	274	47.3	11.493/11.335	0.90
UGC 10905	S0/a	i	17:34:06.43	+25:20:38.29	114.1	13.95	13.03	7.1	217	33.8	11.641/11.487	0.98
NGC 6762	S0/a	i	19:05:37.09	+63:56:02.79	44.9	14.02	13.19	5.8	236	56.7	11.678/11.524	0.77
NGC 7025	Sa	i	21:07:47.33	+16:20:09.22	70.7	13.15	12.20	9.2	604	36.1	11.655/11.496	1.67
NGC 1167	SA0	i+	03:01:42.33	+35:12:20.21	66.2	13.23	12.19	13.6	827	43.3	11.572/11.410	0.87
NGC 1349	S0	i+	03:31:27.51	+04:22:51.24	87.7	14.16	13.09	11.7	467	42.9	11.341/11.183	0.89
NGC 3106	S0	i+	10:04:05.25	+31:11:07.65	90.1	13.50	12.69	11.0	651	63	11.474/11.314	0.60
UGC 0029	E	ii	00:04:33.74	+28:18:06.20	118.5	14.35	13.44	8.9	33	5.6	11.362/11.203	4.98
NGC 2918	E	ii	09:35:44.04	+31:42:19.67	98.1	13.42	12.56	8.3	60	6.9	11.501/10.340	4.87
NGC 3300	SAB(r)0	ii	10:36:38.44	+14:10:15.97	48.0	13.25	12.45	10.9	39	1.1	11.012/10.858	19.8
NGC 3615	E	ii	11:18:06.65	+23:23:50.36	98.3	13.35	12.50	6.9	35	4.0	11.690/11.523	10.8
NGC 4816	S0	ii	12:56:12.14	+27:44:43.71	102.6	13.74	12.91	12.7	35	4.4	11.530/11.367	18.6
NGC 6125	E	ii	16:19:11.53	+57:59:02.89	72.2	12.96	12.13	9.1	52	3.2	11.600/11.437	23.4
NGC 6150	E?	ii	16:25:49.96	+40:29:19.41	126.0	13.95	13.12	7.6	20	3.8	11.660/11.496	10.9
NGC 6173	E	ii	16:29:44.87	+40:48:41.96	126.9	13.18	12.33	11.0	45	8.6	12.161/11.999	15.6
UGC 10693	E	ii	17:04:53.01	+41:51:55.76	120.5	13.54	12.70	9.3	34	5.9	11.731/11.572	11.7
NGC 6338	S0	ii	17:15:22.97	+57:24:40.28	117.5	13.47	12.56	11.3	178	29.4	11.870/11.707	2.21
NGC 6411	E	ii	17:35:32.84	+60:48:48.26	57.6	12.93	12.09	11.3	97	3.9	11.363/11.203	8.62
NGC 6427	S0	ii	17:43:38.59	+25:29:38.18	51.3	13.53	12.71	4.9	68	2.1	11.141/10.985	7.60
NGC 6515	E	ii	17:57:25.19	+50:43:41.24	99.0	13.69	12.87	9.2	87	10.2	11.474/11.316	2.46
NGC 7194	E	ii	22:03:30.93	+12:38:12.41	110.7	13.77	12.87	6.6	30	4.4	11.698/11.536	12.9
NGC 7236	SA0	ii	22:14:44.98	+13:50:47.46	108.2	14.57	13.72	3.4	35	5.0	11.565/11.403	8.16
UGC 11958	SA0	ii	22:14:46.88	+13:50:27.13	108.3	14.27	13.35	14.2	153	21.4	11.776/11.612	2.67
NGC 7436B	E	ii	22:57:57.54	+26:09:00.01	100.6	13.75	12.80	10.0	94	11.4	11.867/11.708	6.87
NGC 7550	SA0	ii	23:15:16.07	+18:57:41.22	69.2	13.27	12.29	11.6	267	15.3	11.555/11.394	3.02
IC 0540	S	—	09:30:10.33	+07:54:09.90	31.9	14.47	13.61	8.9	401	4.9	10.152/10.004	0.36
UGC 8778	S?	—	13:52:06.66	+38:04:01.27	52.6	14.28	13.56	9.6	590	19.6	10.590/10.439	0.31
IC 0944	Sa	—	13:51:30.86	+14:05:31.95	104.8	13.77	12.89	10.6	530	70	11.556/10.439	0.58
IC 1683	S?	—	01:22:38.92	+34:26:13.65	65.4	14.30	13.47	9.2	1703	87	10.924/10.772	0.18
NGC 4470	Sa?	—	12:29:37.77	+07:49:27.12	38.4	13.05	12.57	13.3	8372	147	10.231/10.108	0.03

Type i, i+ and ii

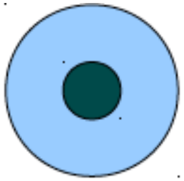


Tentative classification scheme based on distinct EW zones

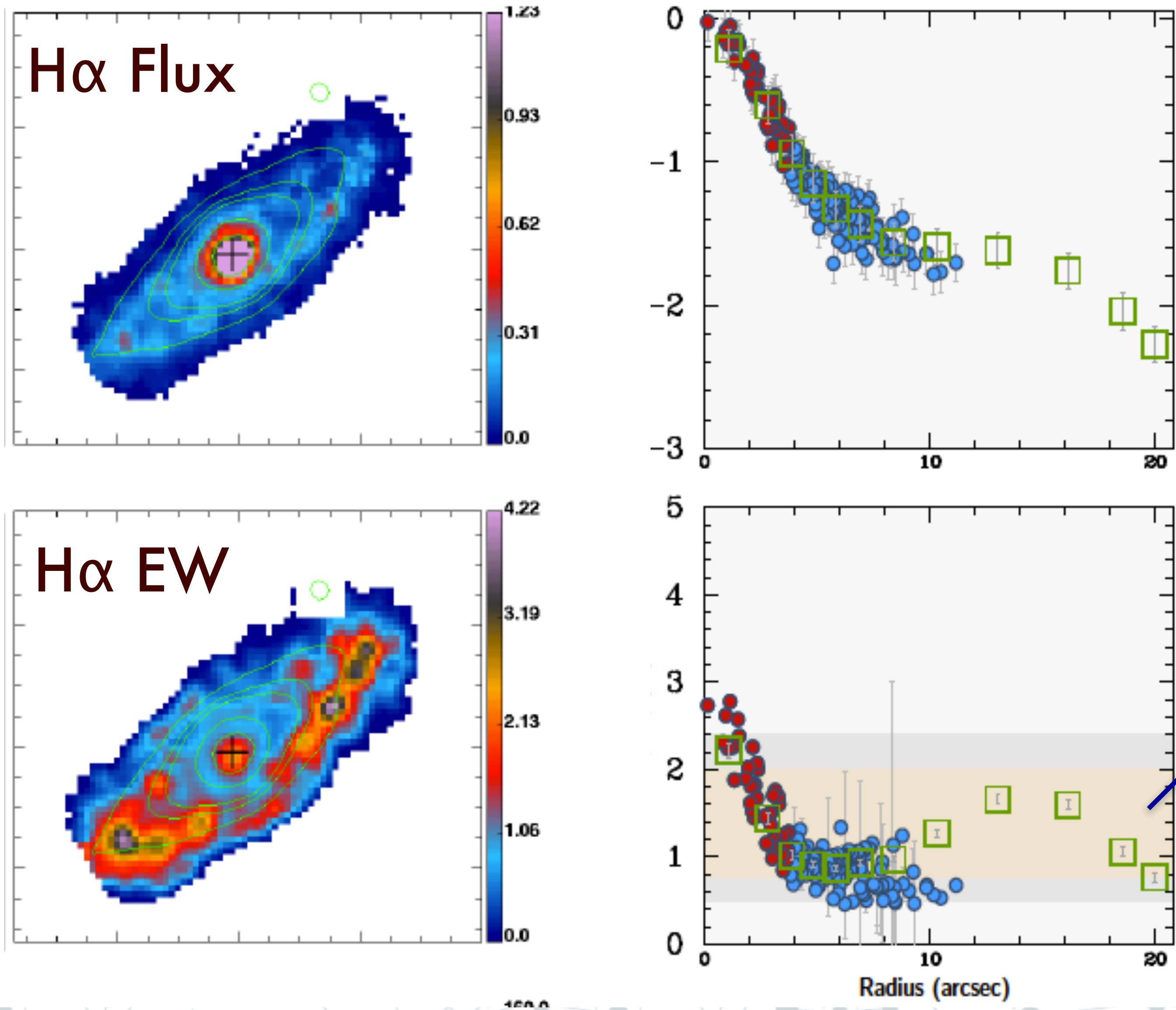
Type i ➡ 64% S0's : radially constant <EW(Hα)> ~ 1Å

Type i+ ➡ 100% S0's : ~10% of all ETGs in our sample

Type ii ➡ 78% E's : very low (< 0.5 Å) EW(Hα) with positive radial gradients



Type i

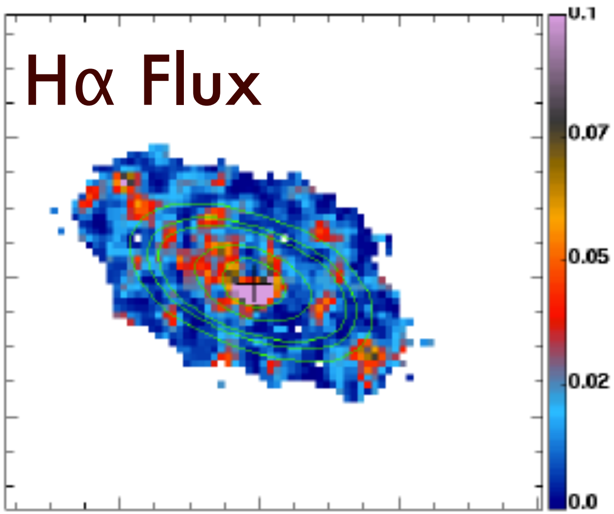


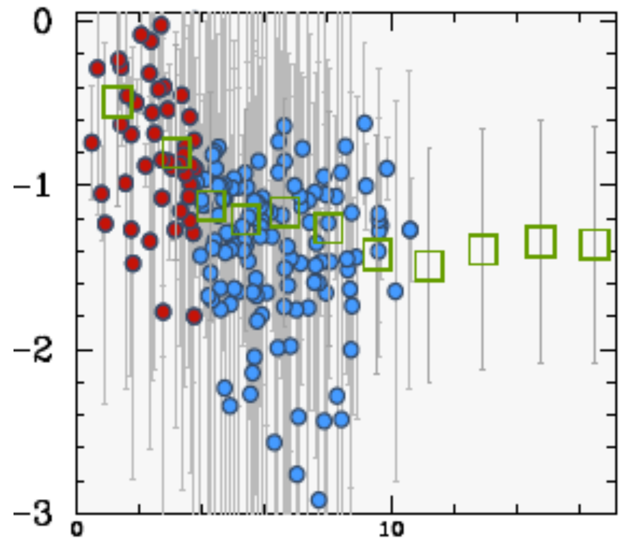
NGC 6081

Morphology NED: S0
ETG type i
$\langle \tau(\mathrm{H}\alpha)_e \rangle = 1.07$
$D = 79.6$ Mpc | $M_r = -21.64$ mag
$\mathrm{L(H}\alpha) = 18.9 \times 10^{39}$ erg s^{-1}
$\log M_\star = 11.331$ [$M_\odot$]

pAGB consistent

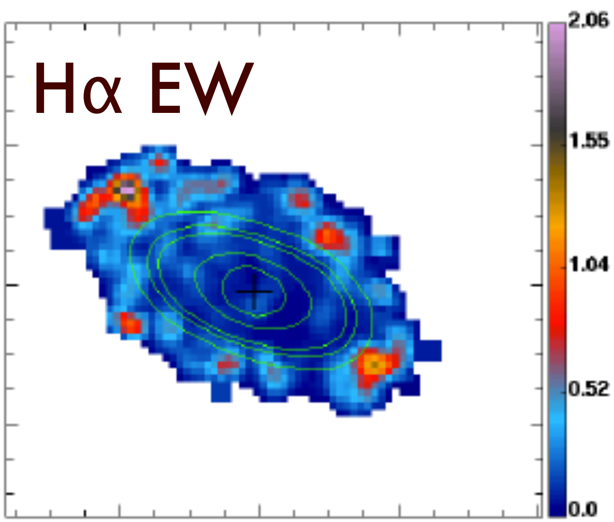
Type ii

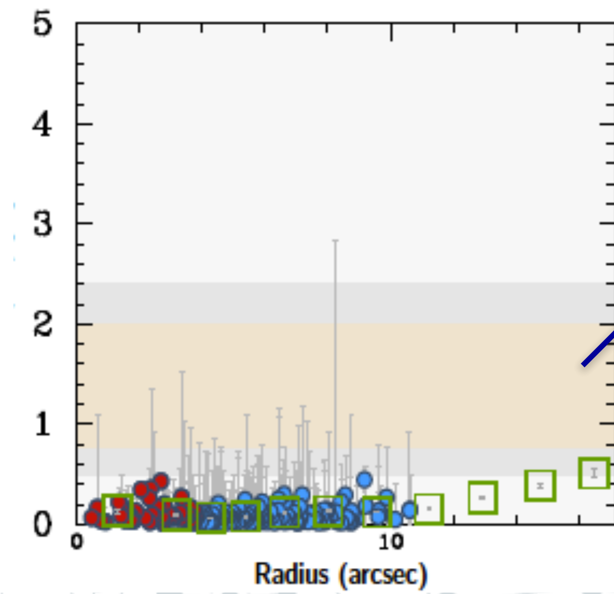




NGC 6150

Morphology NED: E?
ETG type ii
$\langle \tau(\mathrm{H}\alpha)_e \rangle = 10.9$
$D = 126.0$ Mpc | $M_r = -22.38$ mag
$L(\mathrm{H}\alpha) = 3.8 \times 10^{39}$ erg s^{-1}
$\log M_\star = 11.496$ [$M_\odot$]

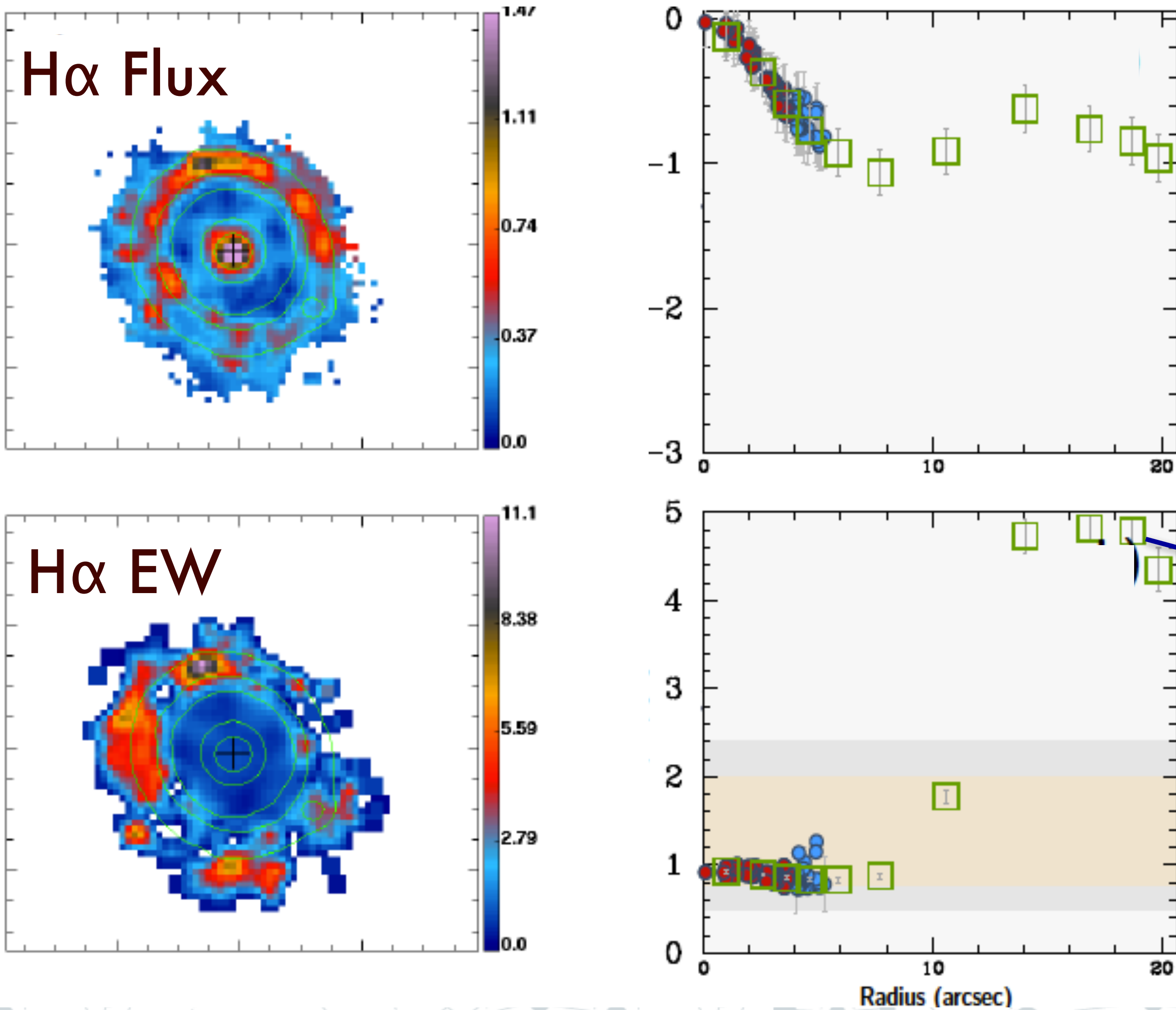




Bellow threshold of pAGB photoionization

Gas-devoid system with EW(Hα) < 0.5

Subclass Type i+

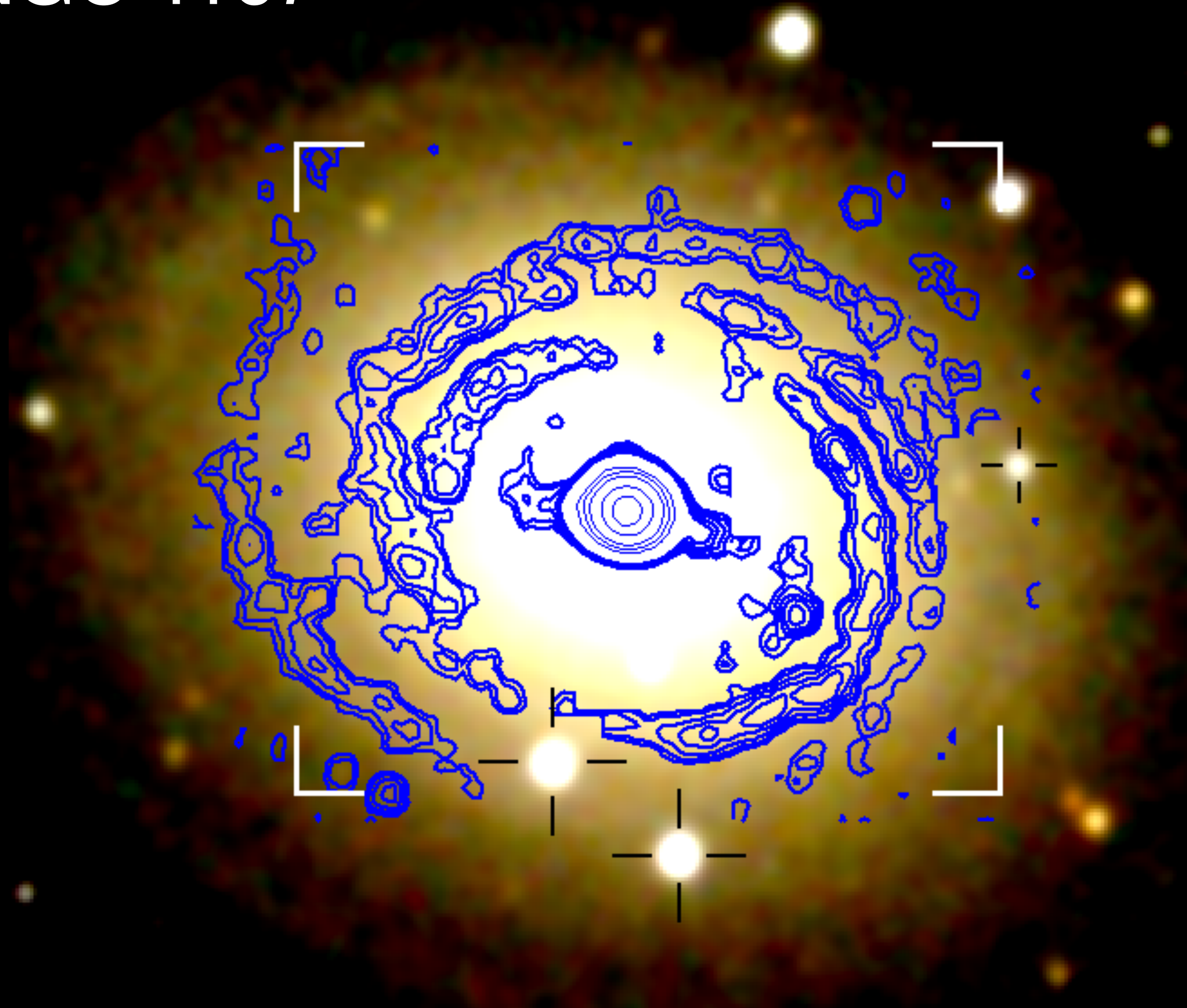


NGC 1349

Morphology NED: S0
ETG type i+
$\langle \tau(\mathrm{H}\alpha)_e \rangle = 0.89$
$D = 87.7$ Mpc | $M_r = -21.62$ mag
$L(\mathrm{H}\alpha) = 42.9 \times 10^{39}$ erg s^{-1}
log $M_\star = 11.183$ [$M_\odot$]

Way above the threshold for pAGB photoionization in the outskirts

NGC 1167



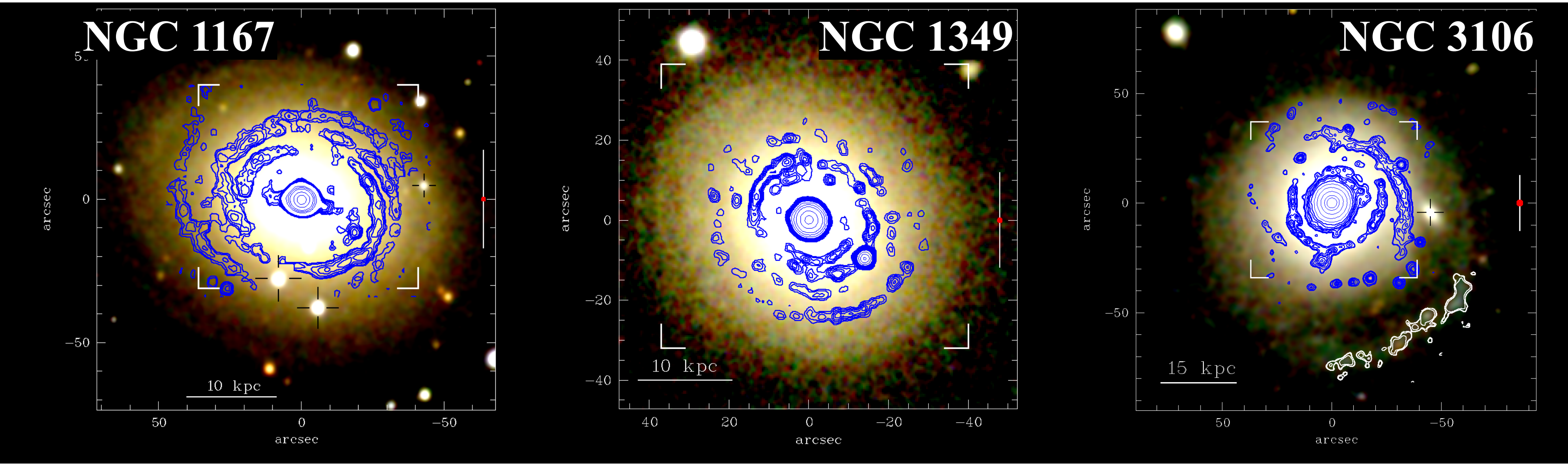
instituto de astrofísica
e ciências do espaço

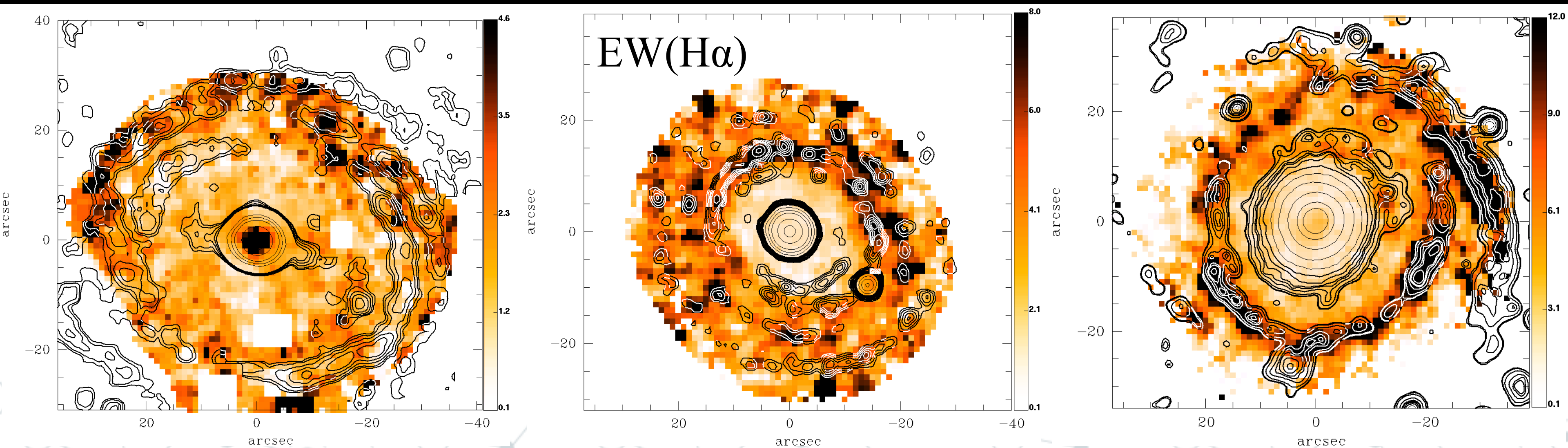
4. Spiral-like features in ETGs?

Type i+ examples

SDSS images

Gomes et al. 2016b

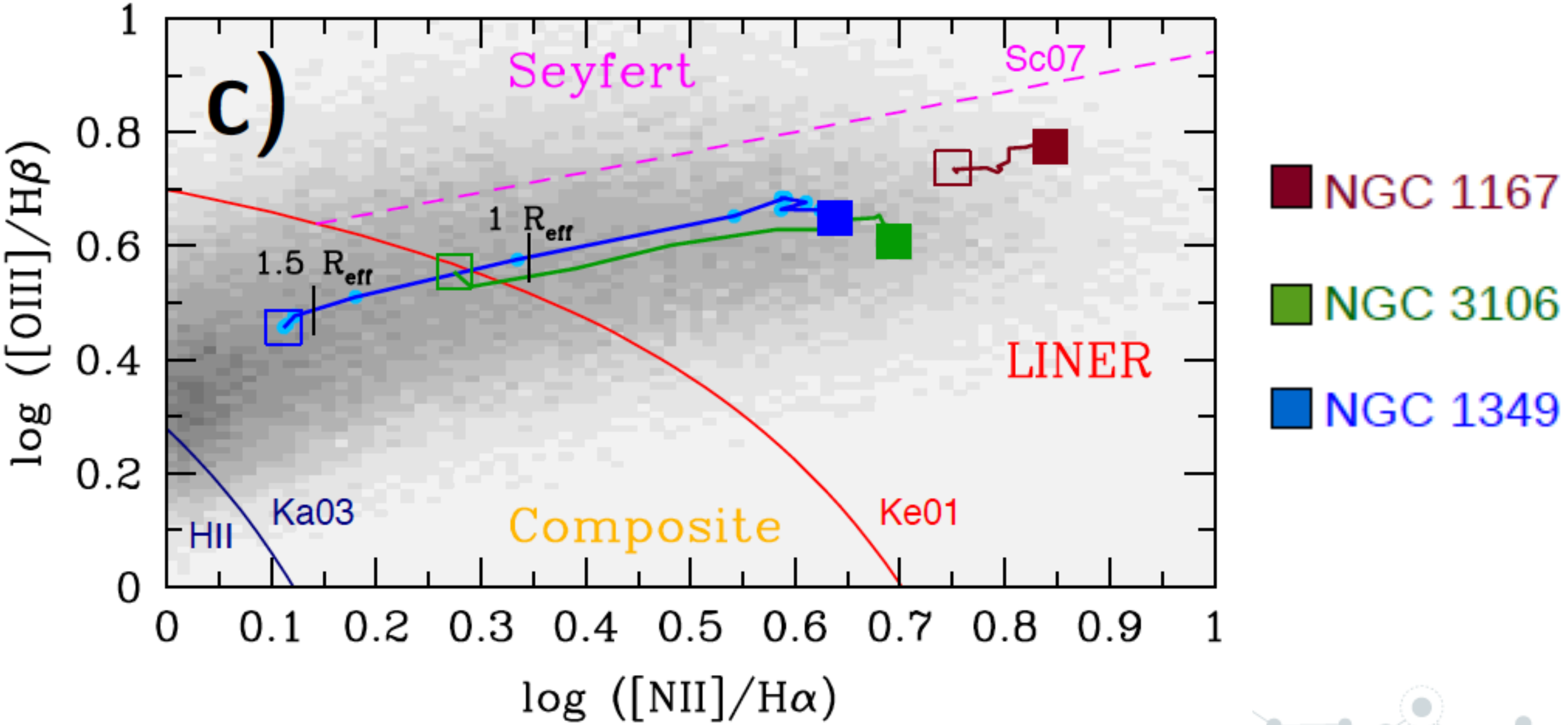




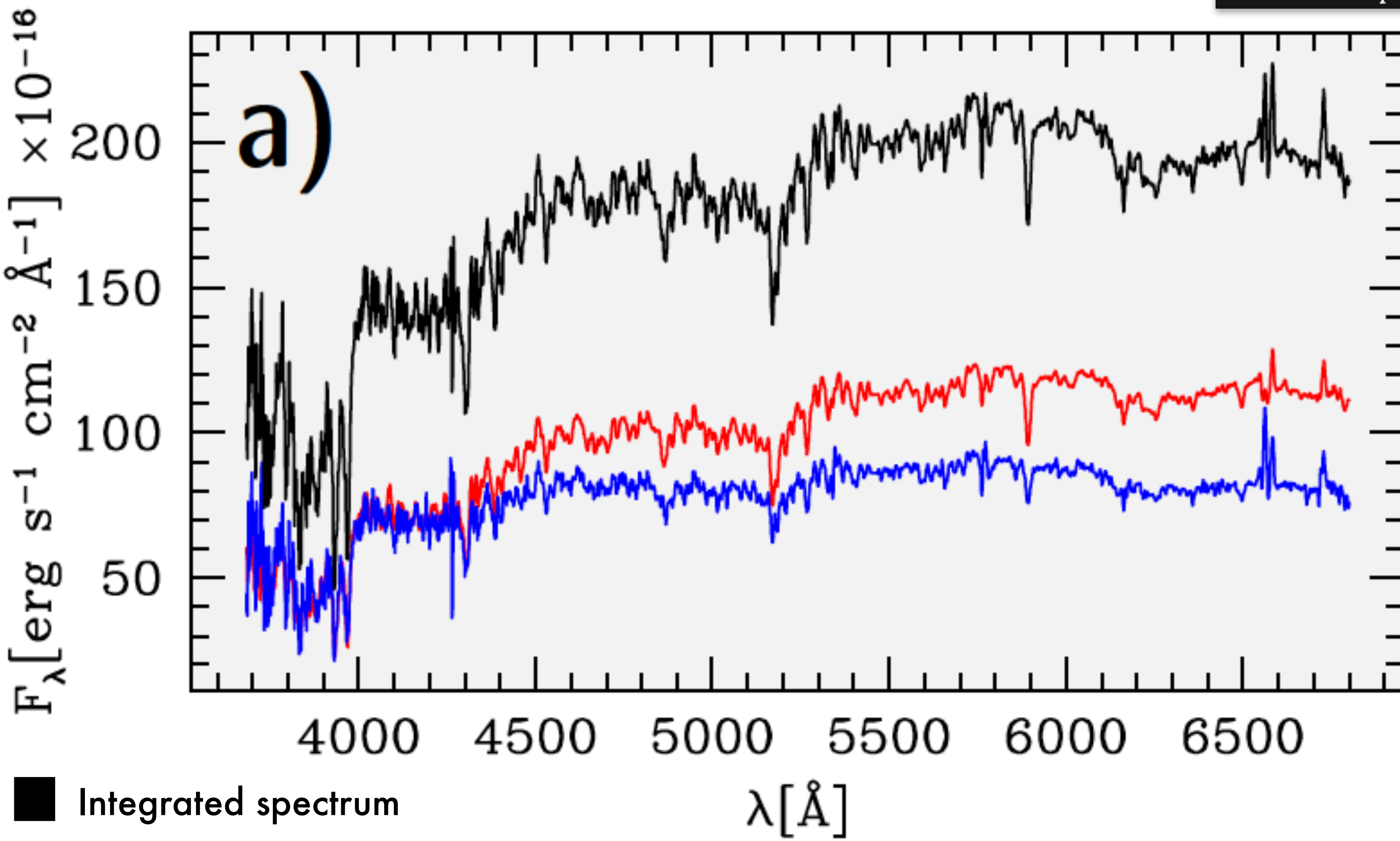
SSFR ~ 10^{-12} yr^{-1} & SFR ~ 0.1-0.3 $M_{\odot}$ yr^{-1} - S0

Observational evidence
Aperture Effects

Gomes et al. 2016c



NGC 1349

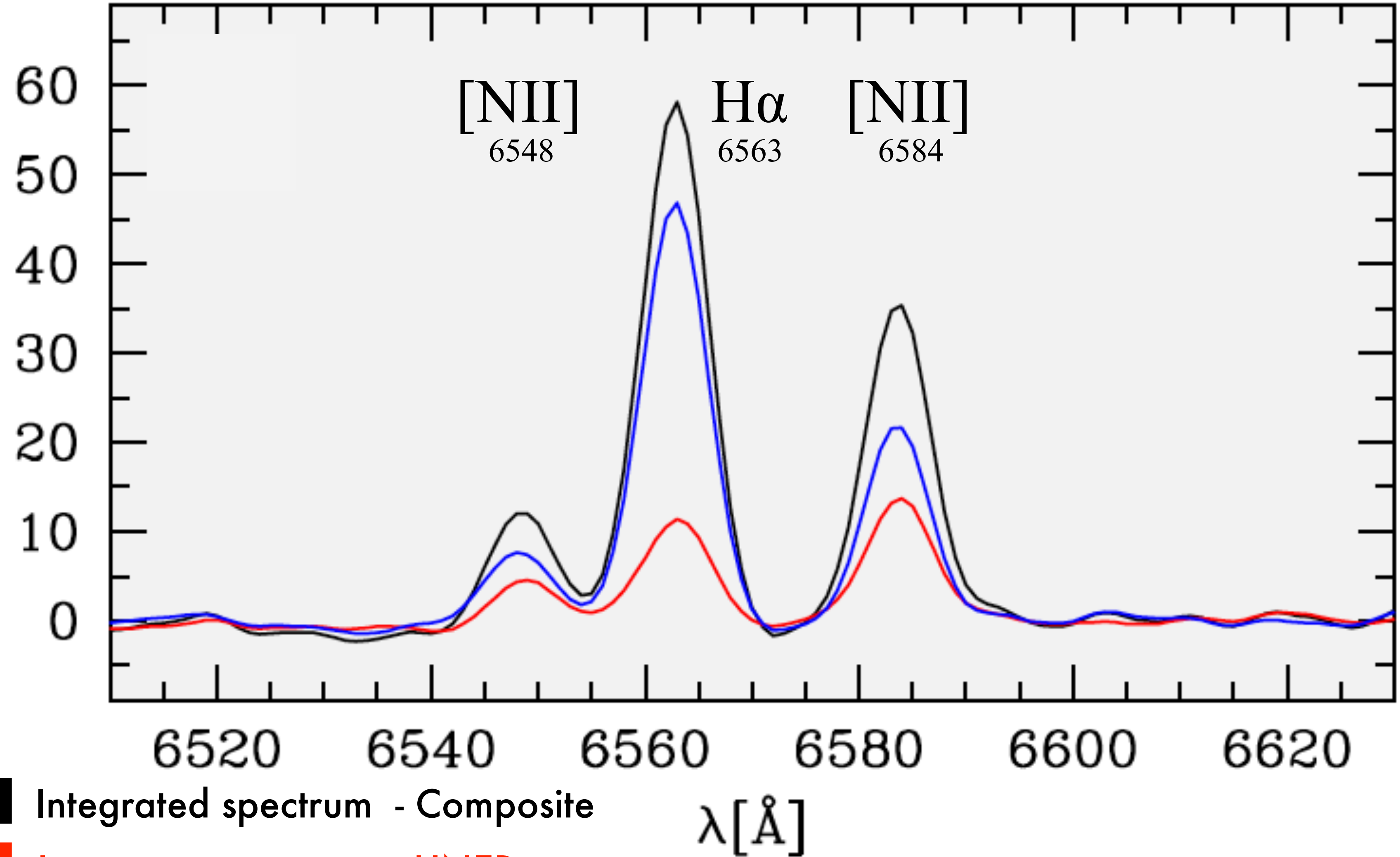


Integrated spectrum

Inner zone spectrum

Outer zone spectrum

NGC 1349

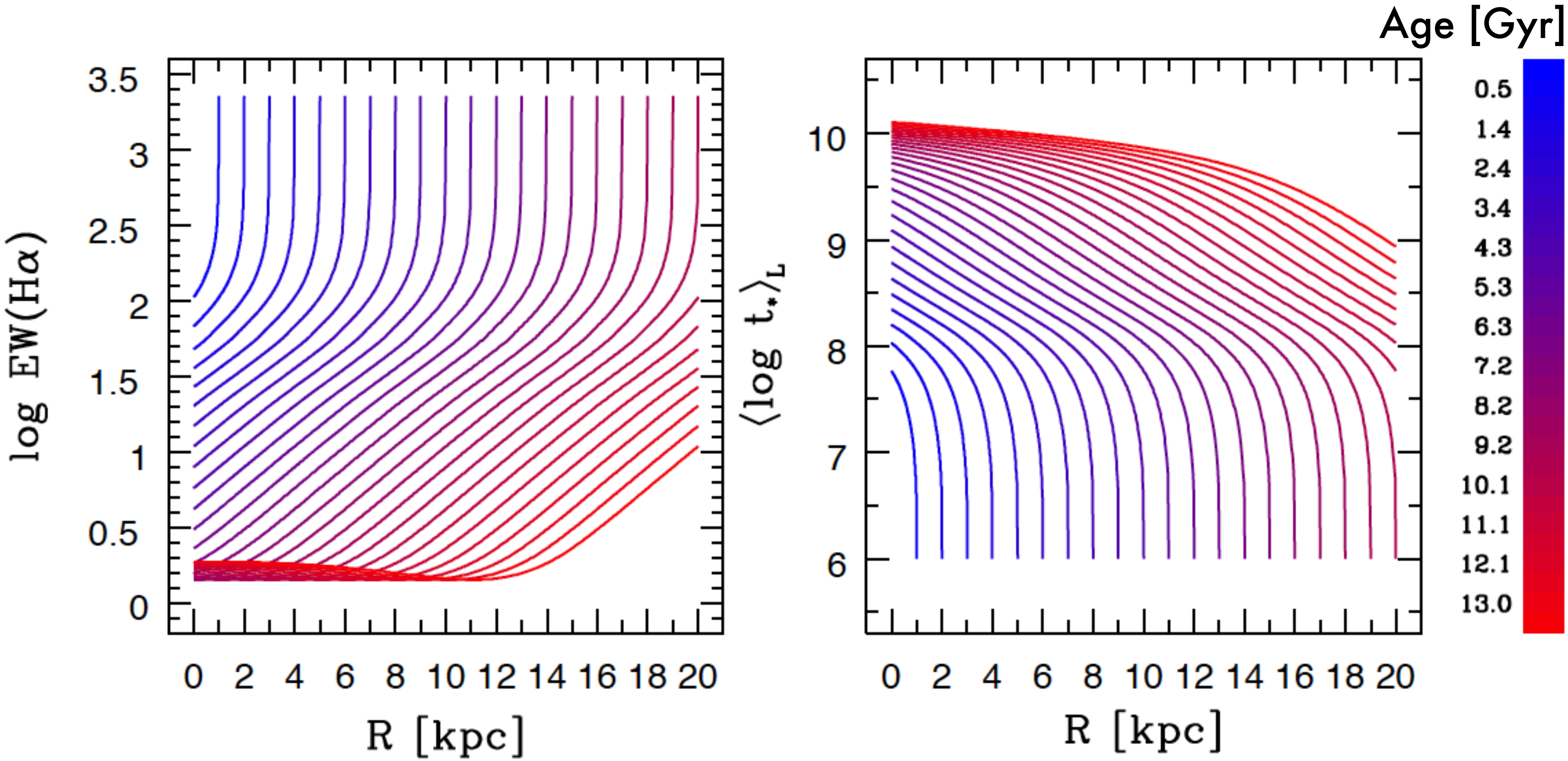


Integrated spectrum - Composite

Inner zone spectrum - LINER

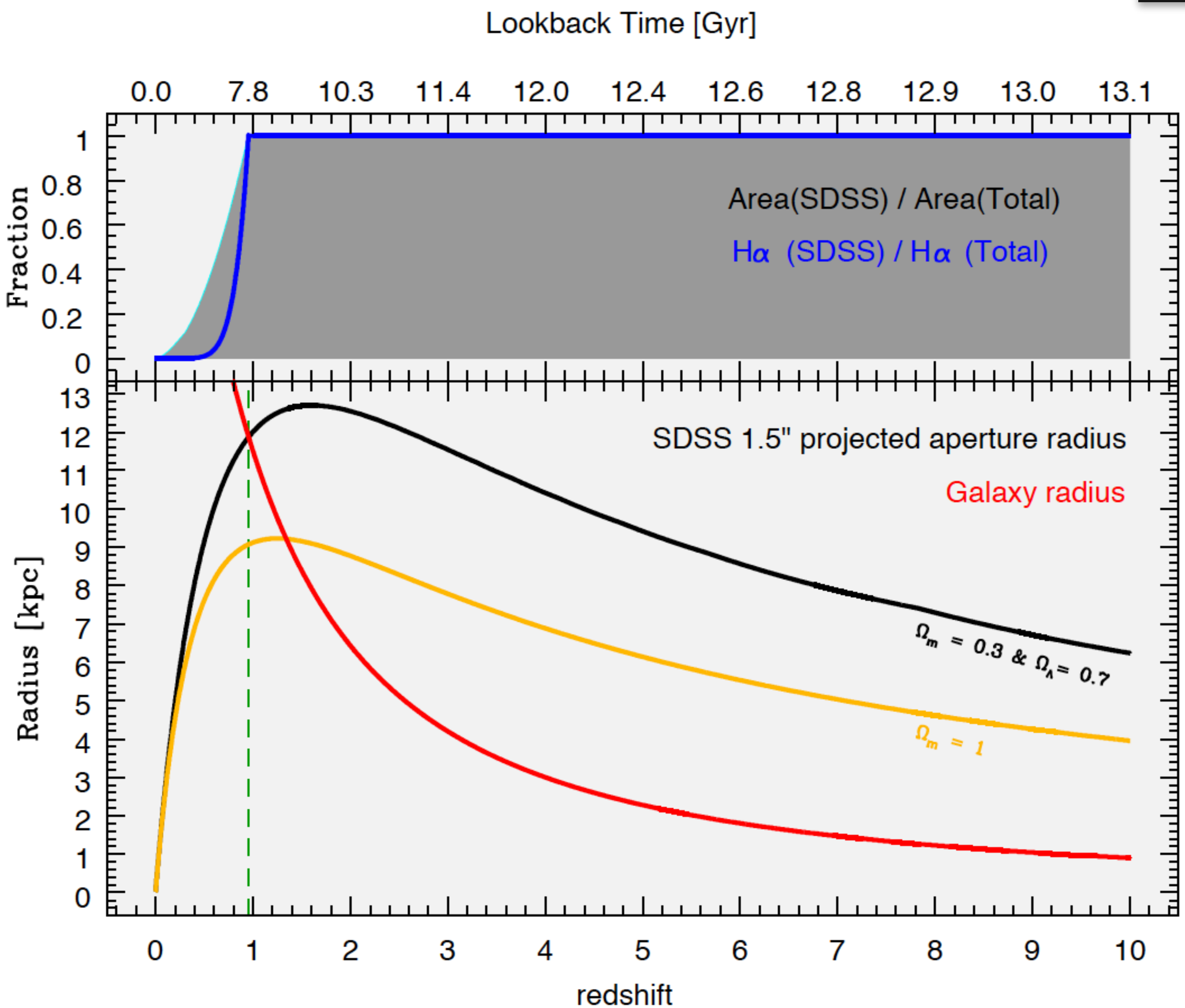
Outer zone spectrum - SF/HII

Simple 1D model: Inside-out growth



SFR $\propto e^{-t/\tau}$ with τ = 1Gyr wave outwardly propagating

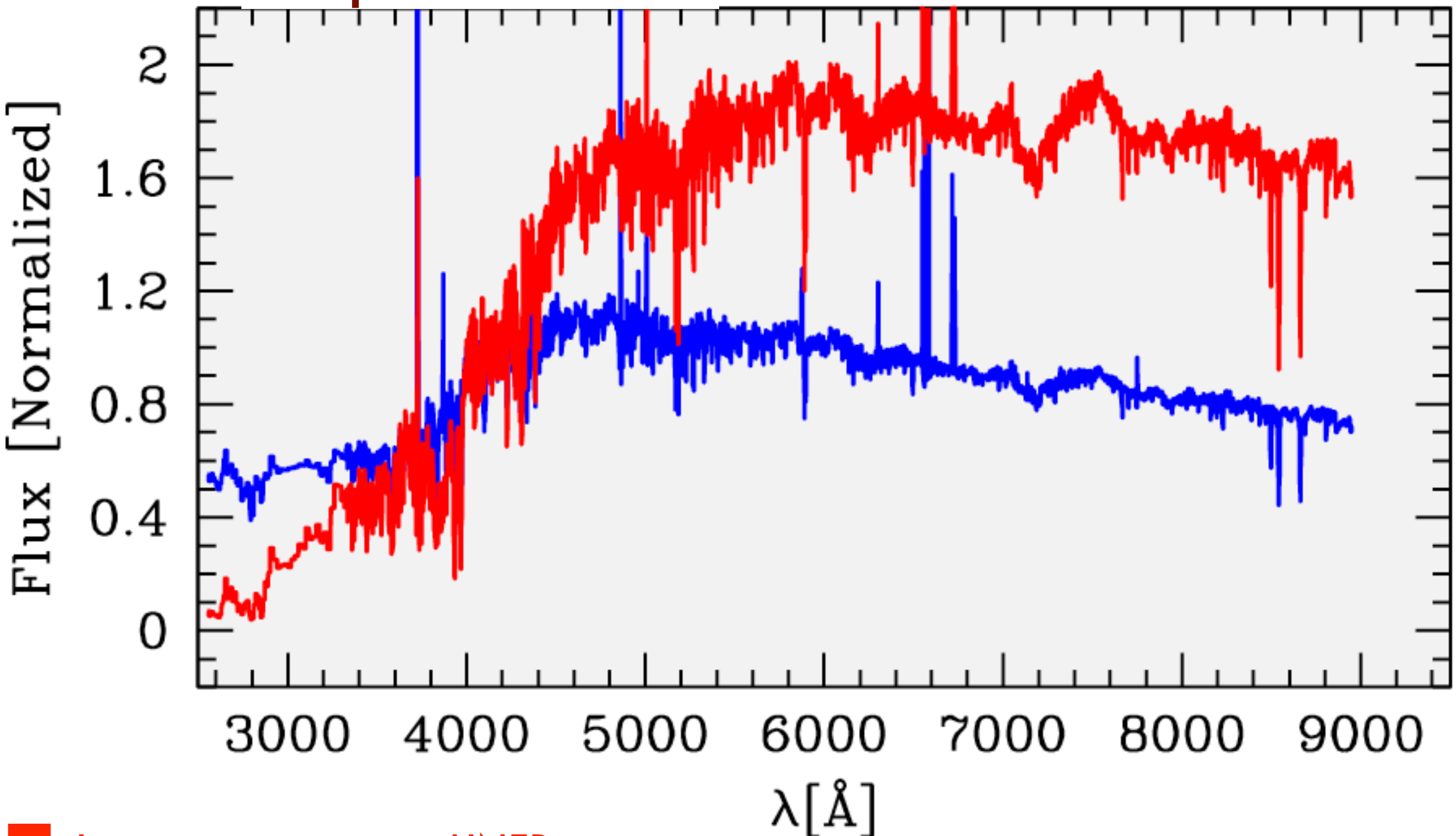
Simulation: Aperture Effects



Friedmann-Robertson-Walker cosmology

Simulation: Aperture Effects

Snapshot z = 0.1

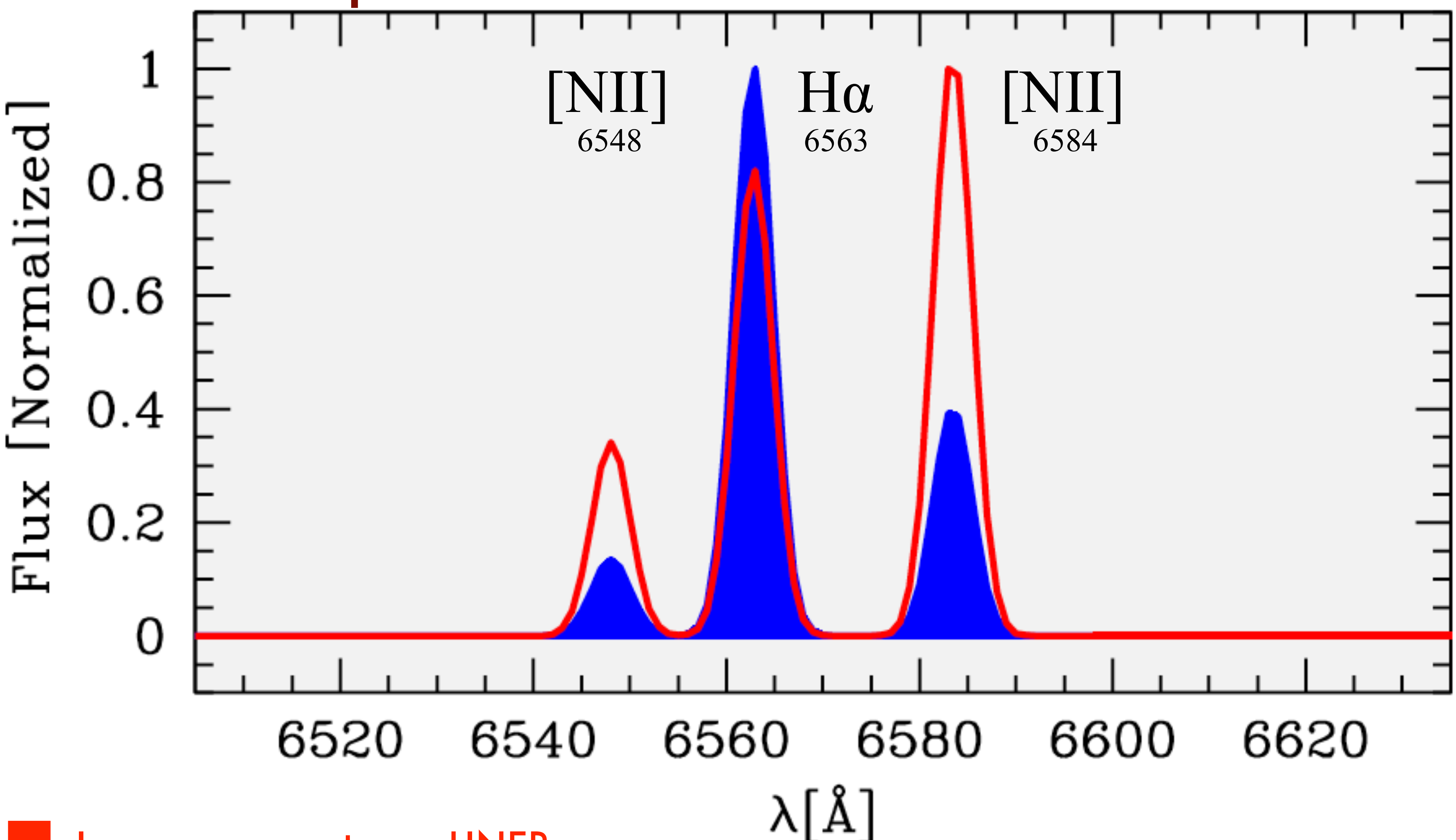


Inner zone spectrum - LINER

Integrated spectrum - SF/HII

Simulation: Aperture Effects

Snapshot z = 0.1

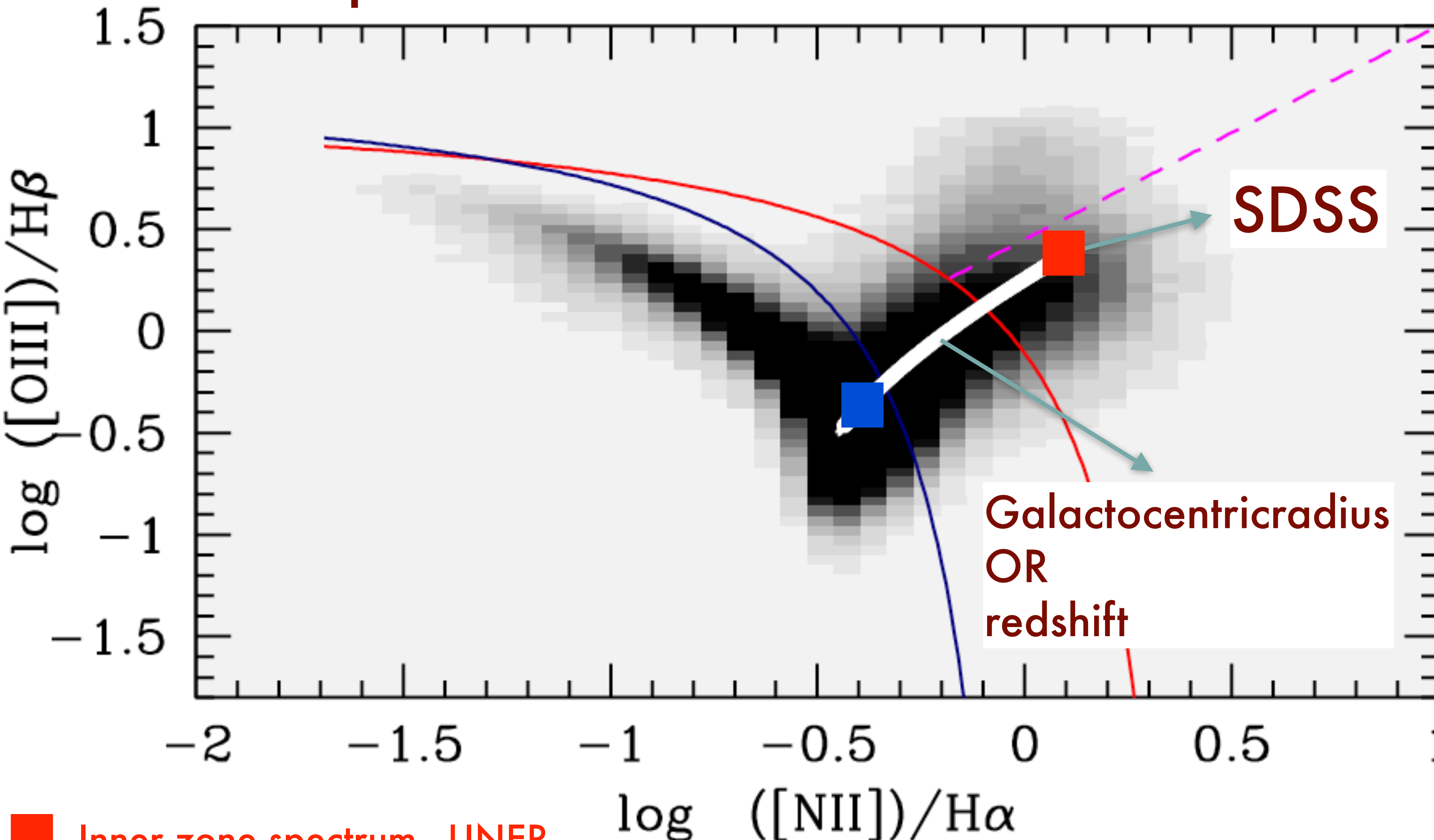


Inner zone spectrum - LINER

Integrated spectrum - SF/HII

Simulation: Aperture Effects

Snapshot z = 0.1



Inner zone spectrum - LINER

Integrated spectrum - SF/HII

5 . Final Remarks

1) Faint spiral-like star-forming features detected in the outskirts of local ETGs (~10% of the sample).

2) Empirical assessment of aperture effects using CALIFA IFS data for type i+ & theoretical study based on a simple inside-out galaxy growth model.

3) Interesting to note that the *right-wing* distribution for individual galaxies from SDSS is consistent with (yet no proof for) a pure aperture effect, and naturally reproducible in an inside-out galaxy growth scenario.

4) Steeper decline of the SFR density: Hα luminosity within the SDSS fiber is reduced by 50% at z~0.86, reaching only 0.1% of its integral value at z=0.1.

5) These affect studies of both type i+ ETGs and their morphological analogs (e.g., SF-quiescent bulges within star-forming disks).