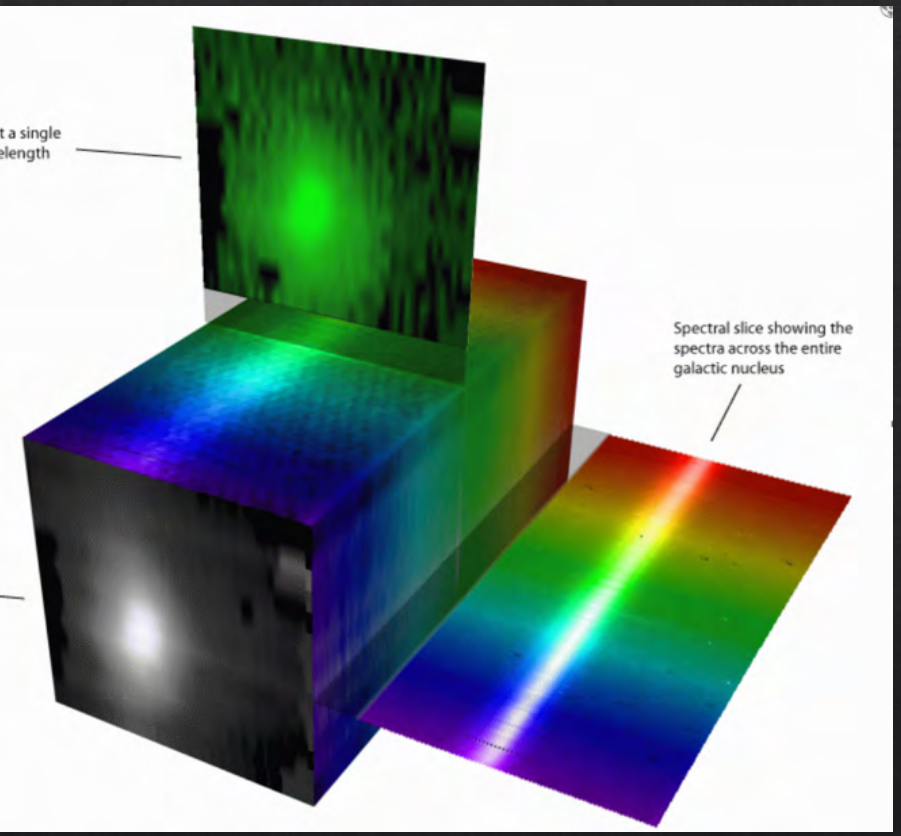
Survey Science Group Workshop

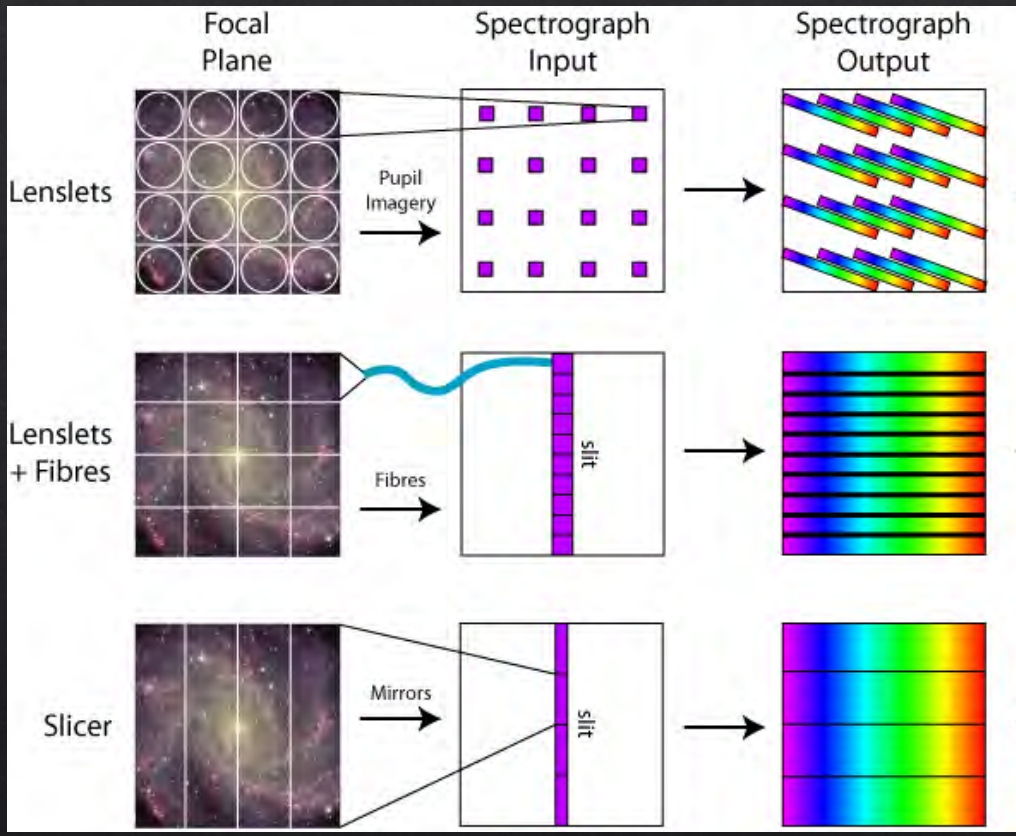
External galaxy researches using IFS data in Korea

Jong Chul Lee (KASI)

19.02.21. / Jeongseon

Concept of Integral Field Spectrograph





IFS instruments

GMOS (Gemini Multi-Object Spectrograph)

Format	rectangular IFU, hexagonal lenslets	
Wavelength (Å)	4000 — 11000	
Spectrograph resolution (R)	630 — 4300	
Simultaneous sky coverage	block of sky fibres separated by 1'	
Field of view	*Two-slit mode*	*One-slit mode*
"Object" field of view	5" x 7" (1000 lenslets)	5" x 3.5" (500 lenslets)
Nod & Shuffle FoV (GMOS-S only)	5" x 5" (700 lenslets)	5" x 2.5" (350 lenslets)
"Sky" field of view	5" x 3.5" (500 lenslets)	5" x 1.75" (250 lenslets)
Spatial element size	0.2''	

NIFS (Near-IR Integral Field Spectrograph)

Format	rectangular IFU, image slicer
Wavelength (μm)	0.94 — 2.40
Spectrograph resolution (R)	5000 — 6000
Simultaneous sky coverage	none
Field of view	3"x3"
Spatial element size	0.103"x0.04"
AO options	LGS/NGS with Altair

SparsePak (WIYN 3.5 m)

Format	sparsely packed rectangular IFU, red-sensitive fibres (no lenslets)
Wavelength (Å)	5000 — 9000
Spectrograph resolution (R)	5000 — 20000
Simultaneous sky coverage	7 fibres located ~65" from array centre along 2 sides
Field of view	72"x71.3"
Spatial element size	4.7"

VIMOS (Visual and IR Multi-Object Spectrograph)

Format	rectangular IFU, fibres + lenslets
Wavelength (Å)	4000 — 11500
Spectrograph resolution (R)	200 — 3000
Simultaneous sky coverage	none
Field of view	13"x13", 27"x27", 54"x54"
Spatial element size	0.33", 0.67''

muse

- Panoramic integral field unit on VLT
- 1x1 arcmin^2 Field of view in Wide Field Mode (WFM)
  - 7x7 arcsec^2 in NFM
- 0.2 arcsec sampling in WFM
  - 0.025 arcsec in NFM
- High image quality
- 4650-9300 A simultaneous wavelength range
- R = 1500-3500
- ~90000 spectra
- End-to-end throughput 0.35
- Advanced data reduction pipeline

IFS instruments

GMTIFS

single-object, AO-corrected, integral field spectrograph
spectral coverage: 1.22~2.46 micron
spectral resolution: R=3000/5000/10000
spaxel size: 6/12/25/50 mas
field of view: 0.54×0.27/1.08×0.54/2.25×1.13/4.5×2.25

EAGLE (E-ELT)	HARMONI (E-ELT)
AO-assisted, multi-IFS	single IFS
0.8~2.45 μm	0.47~2.45 μm
R=4000~10000	R=4000/10000/20000
1″.65×1″.65	10″×5″

WIFIS (Wide Integral Field Infrared Spectrograph; Dae-Sik Moon)

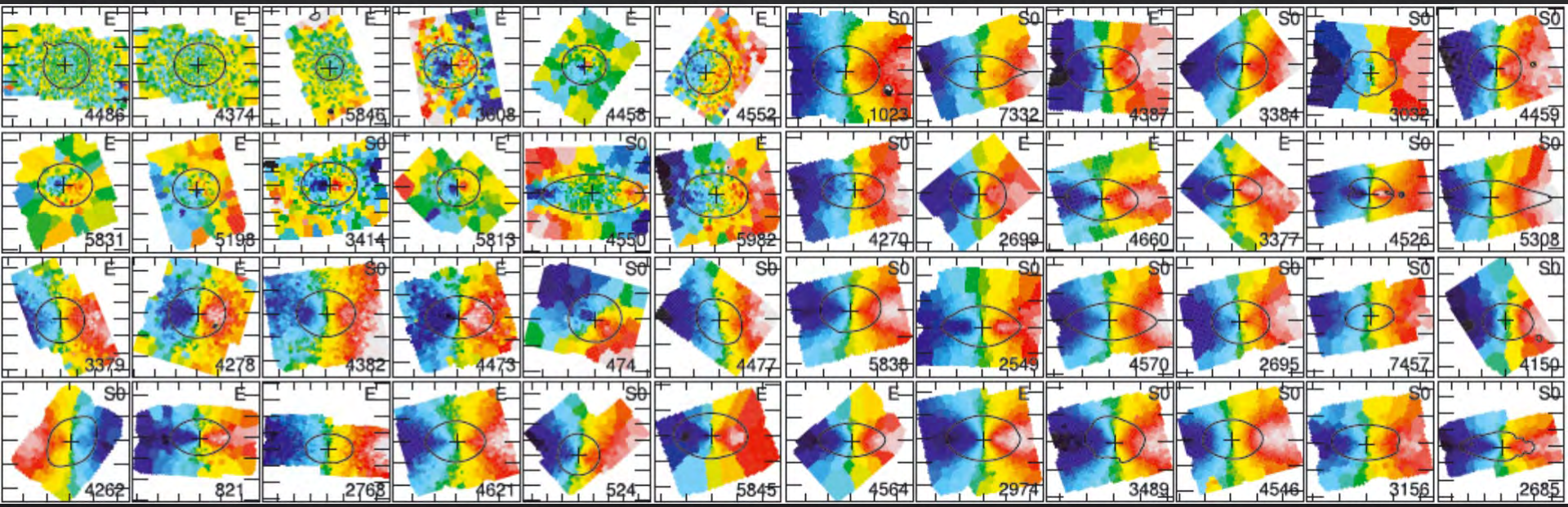
Telescope	Steward 2.3-meter Bok Telescope
Location	Kitt Peak, USA
Field-of-View	$50 \times 20''$
Number of Slices	18
Slice Scale	$1.1''$
Spaxel Scale (2 pixel sampling)	$\sim 1.1 \times 1.1''$
Operating Modes	$0.9 - 1.35\mu m$ (zJ) & $1.5 - 1.7\mu m$ (H_{short})
Spectral Resolving Power (R)	2,500 (zJ) & 3,000 (H_{short})

IFS surveys

Spectrographic Areal Unit for Research on Optical Nebulae

SAURON

72 early types
4.2m WHT
4800~5380 Å (3.6 Å)
33″×41″ (0″.94)



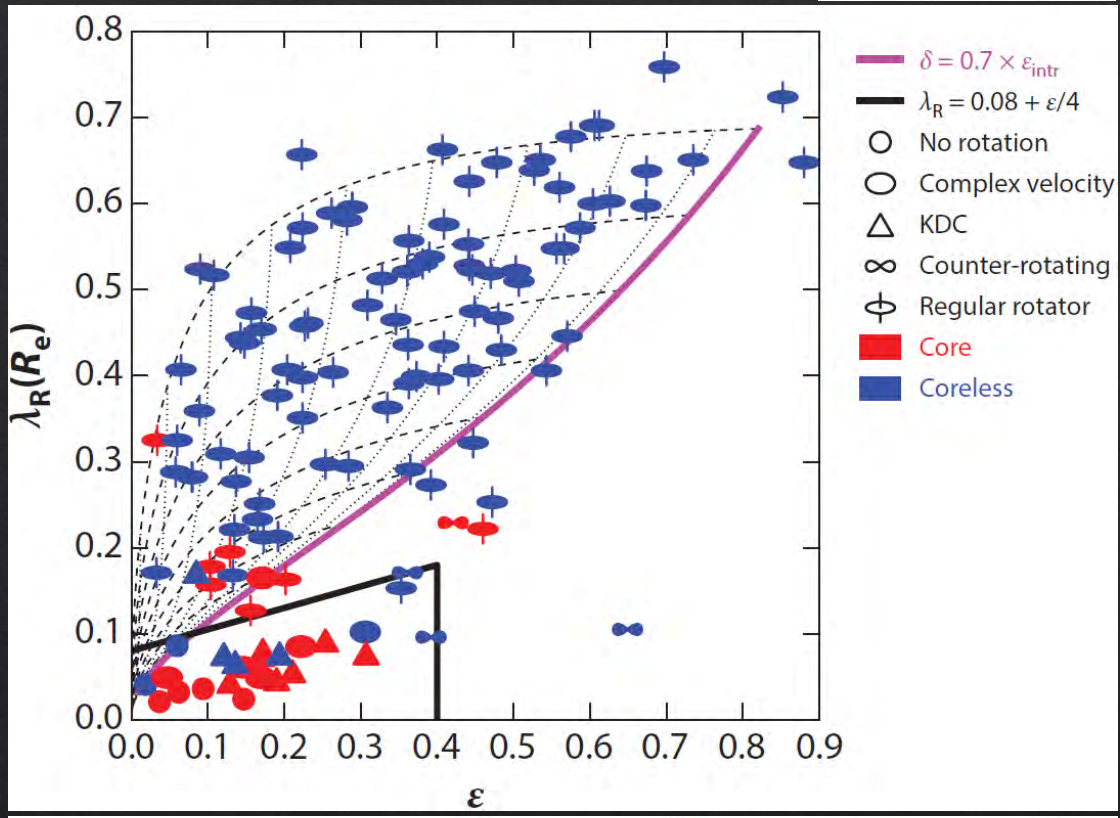
Emsellem+04

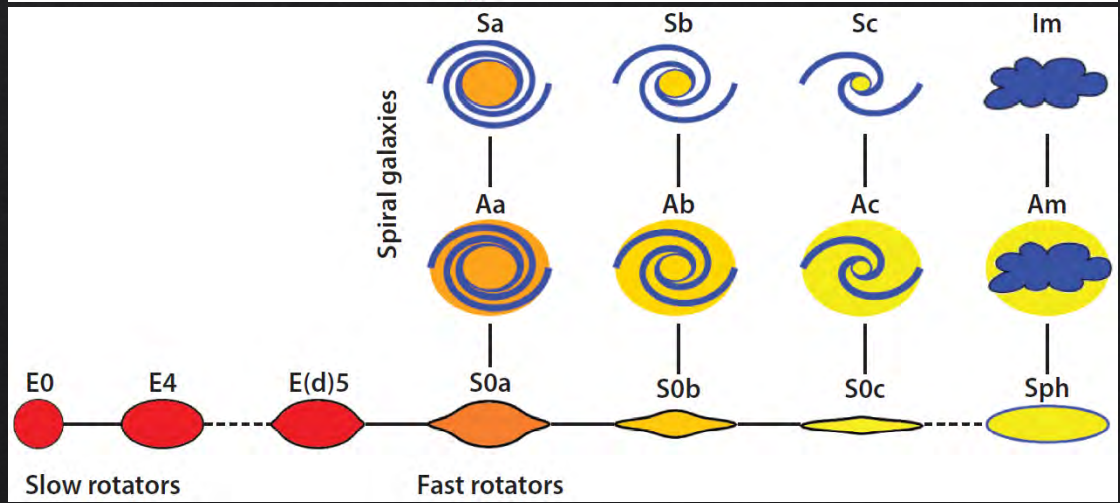
IFS surveys



260 early types
4.2m WHT
4800~5380 Å (3.6 Å)
33″×41″ (0″.94)

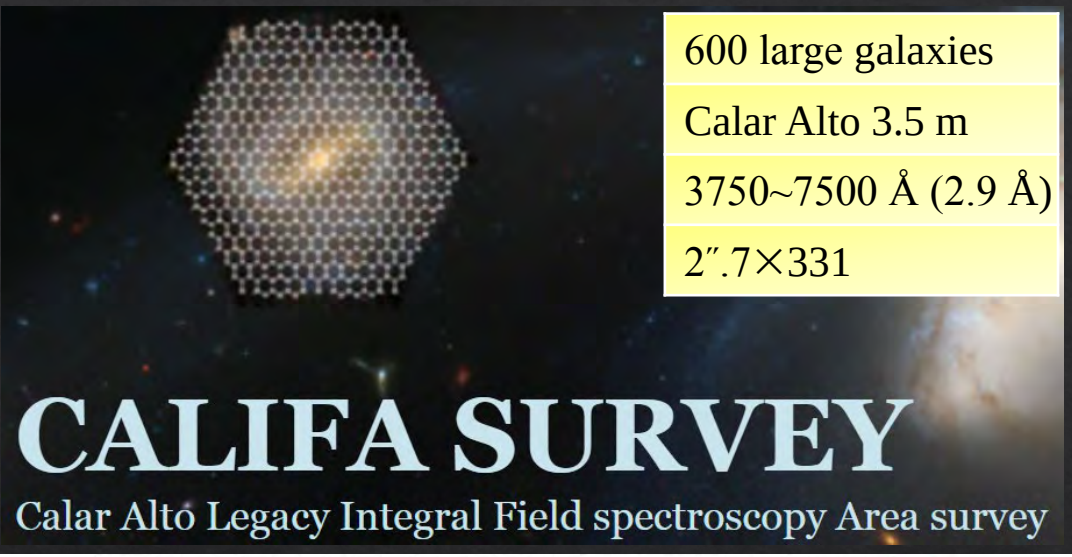
$$\lambda_R = \frac{\langle R|V|\rangle}{\langle R\sqrt{V^2+\sigma^2}\rangle}$$





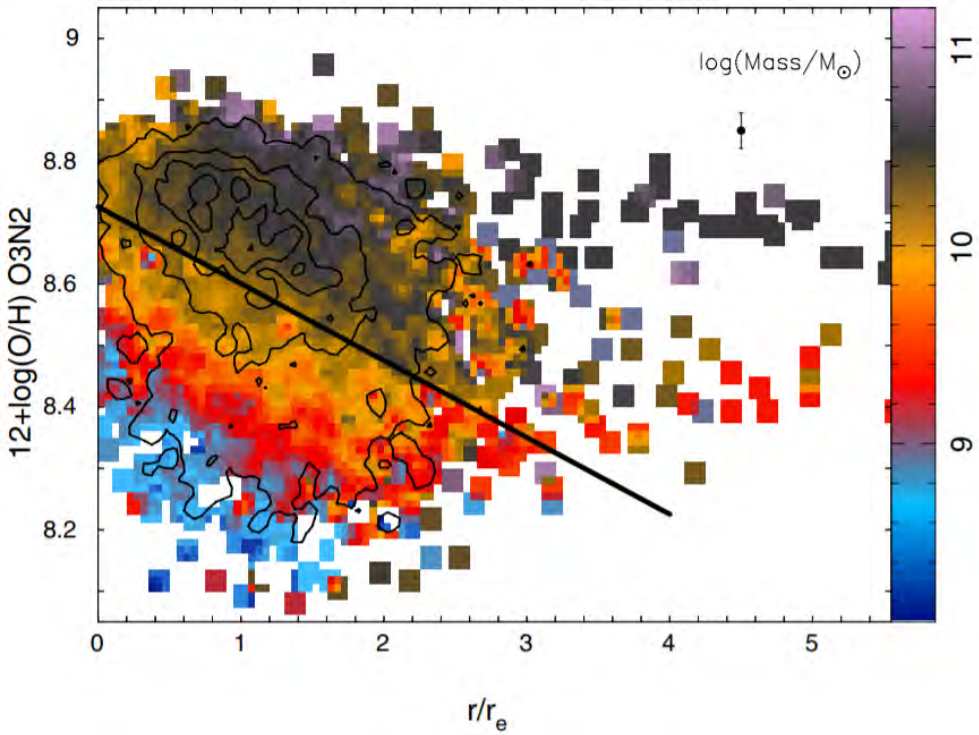
Cappellari+11

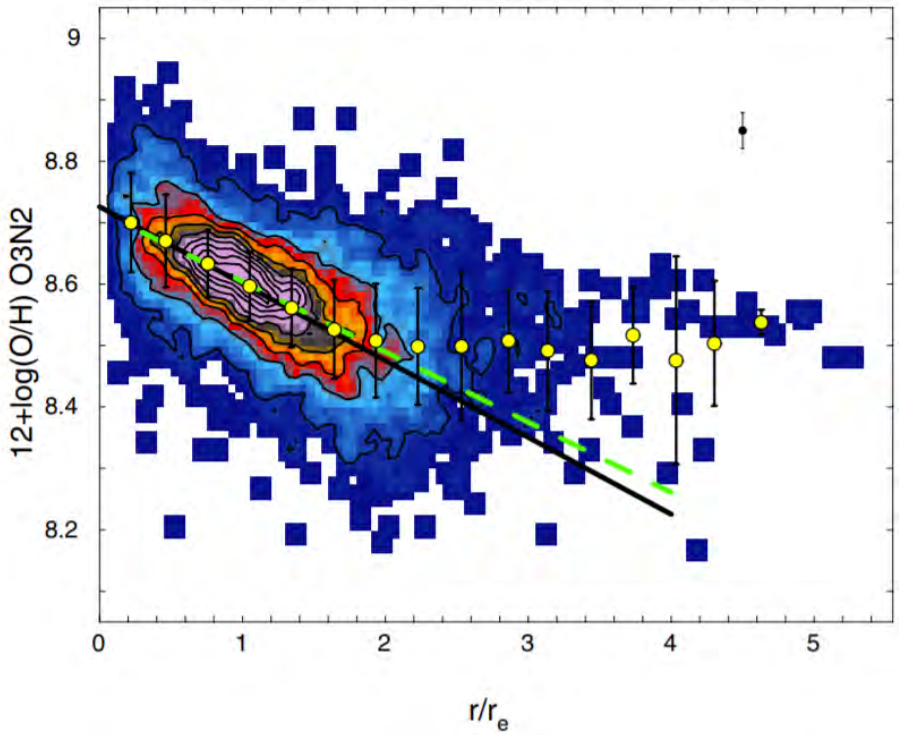
IFS surveys



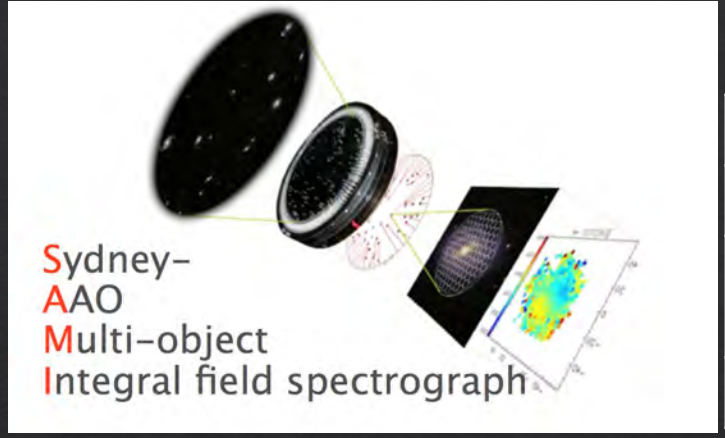
600 large galaxies
Calar Alto 3.5 m
3750~7500 Å (2.9 Å)
2″.7×331

Sánchez+14

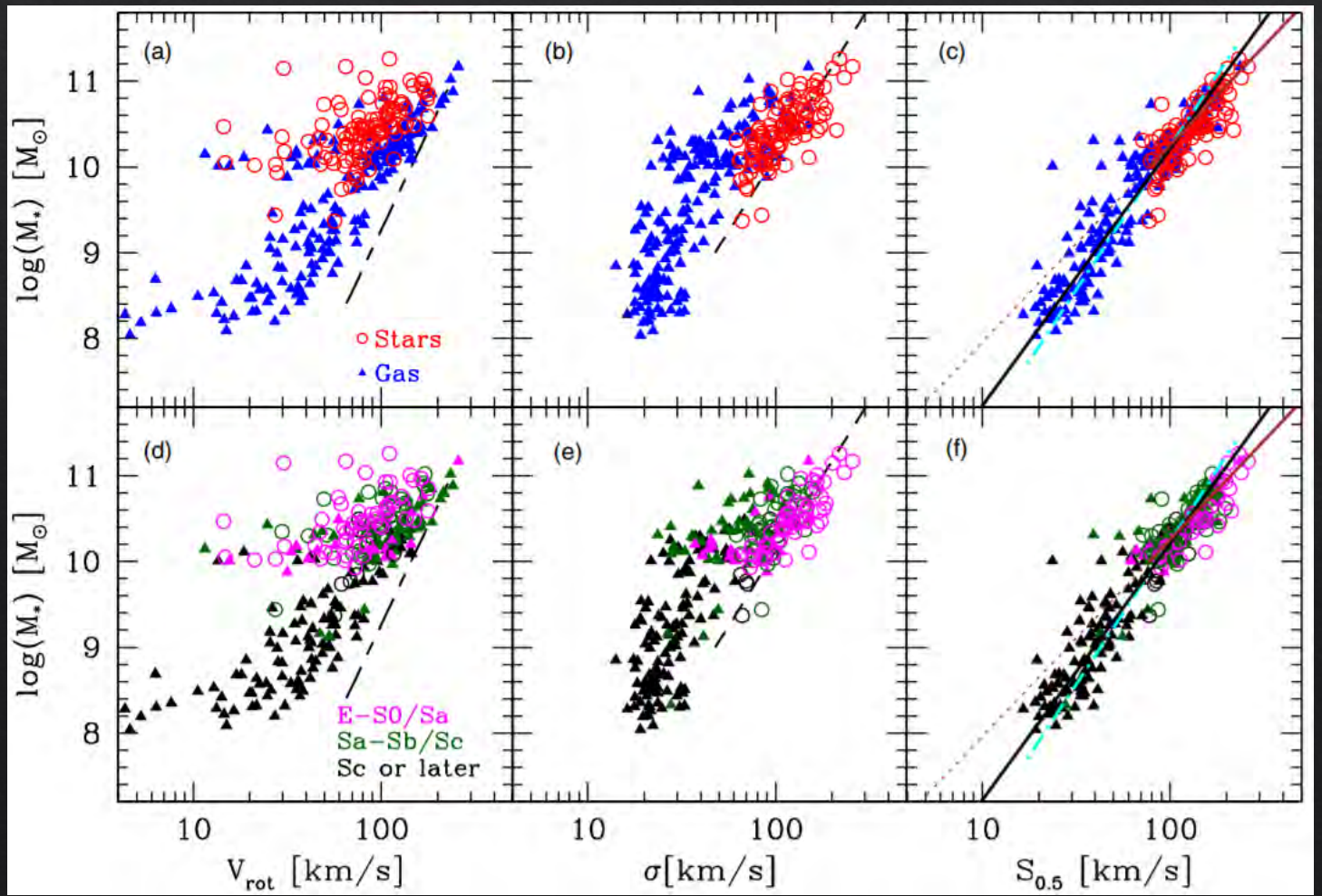




IFS surveys



3400 galaxies
3.5 m AAT
3700~5700 Å (2.8 Å) 6250~7350 Å (1.6 Å)
1″.6×61

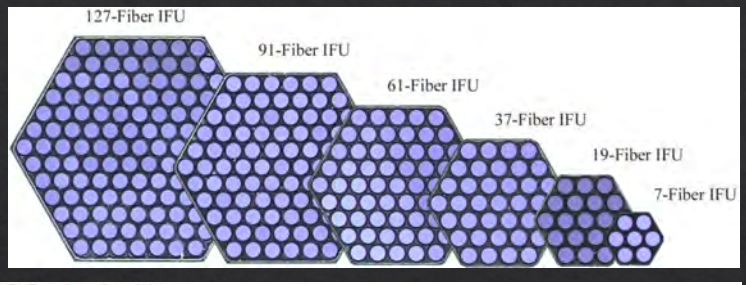


Cortese+14

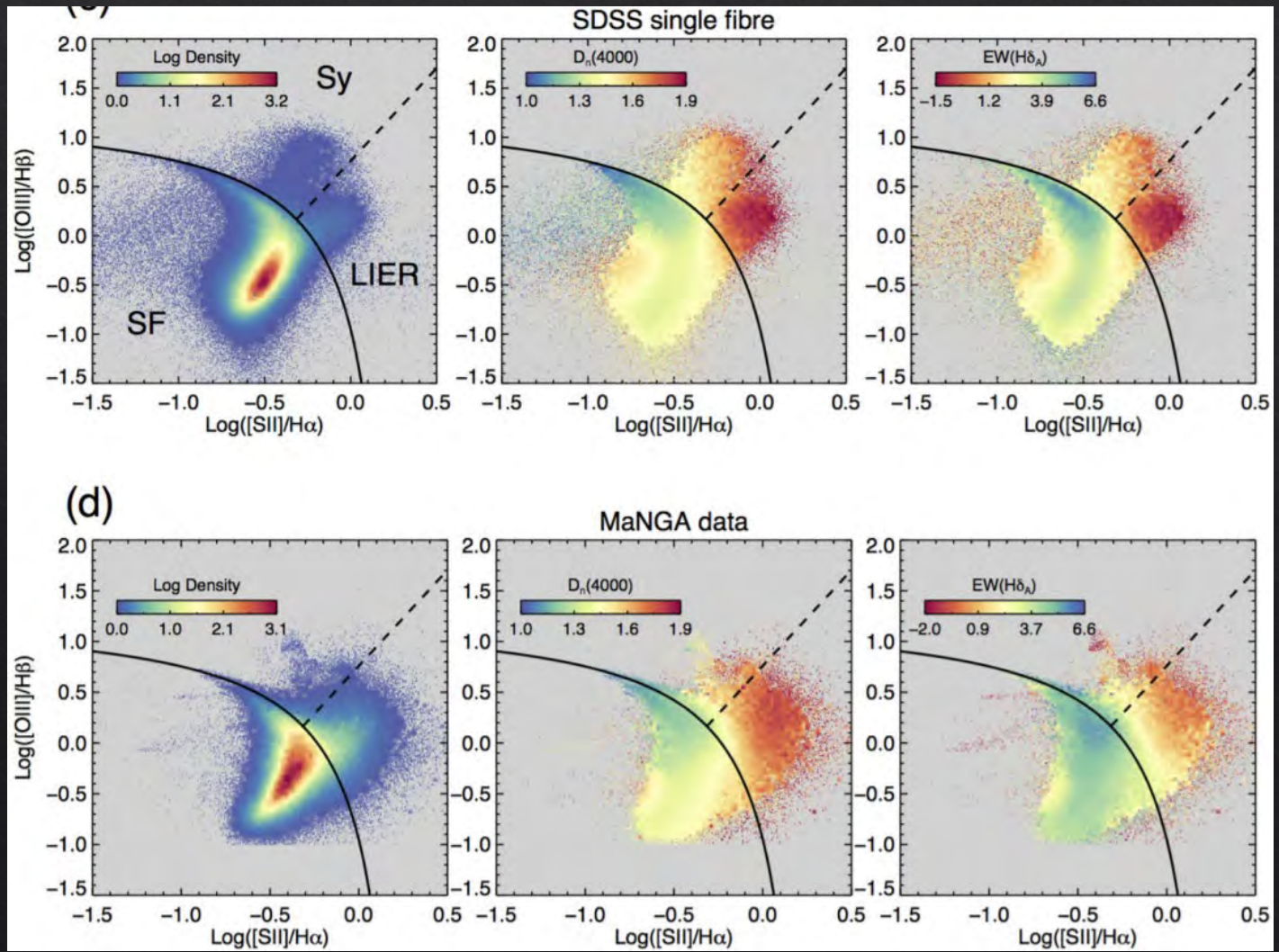
$$S_K = \sqrt{K V_{\rm rot}^2 + \sigma^2}$$

IFS surveys

Mapping Nearby Galaxies at APO (MaNGA)



- 10,000 galaxies
- 2.5 m Apache Point
- 3600~10300 Å (2.3 Å)
- 2″×127



Belfiore+16

IFS surveys

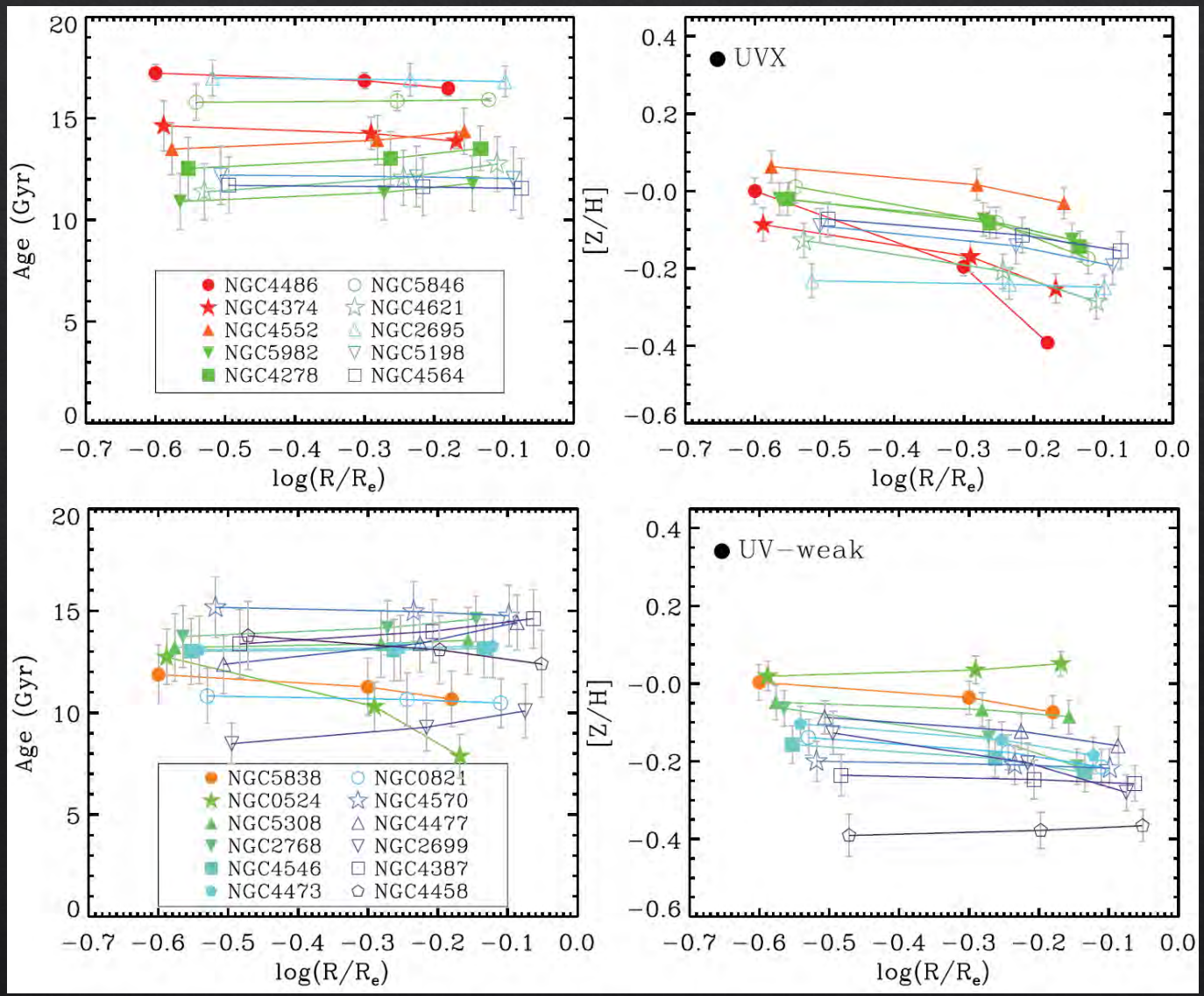
Bundy+15

Specification	MaNGA	SAMI	CALIFA	ATLAS^{3D}
Sample size	10,000	3400	600	260
Selection	$M_* > 10^9\ M_\odot$	$M_* > 10^{8.2}\ M_\odot$	$45'' < D_{25} < 80''$	$M_* \gtrsim 10^{9.8}\ M_\odot$[a] E/S0
Redshift	0.01–0.15	0.004–0.095	0.005–0.03	$z \lesssim 0.01$
Radial coverage	1.5 R_e(P+) 2.5 R_e(S)	1.1–2.9 R_e	1.8–3.7 R_e	0.6–1.5 R_e
S/N[b] at 1R_e (per spatial sample)	14–35	12–28	10–50	15
λ range (nm)	360–1030	370–570 (580V) 625–735 (1000R)	375–750 (V500) 370–475 (V1200)	480–538
$\sigma_{instrument}$ (km s^{-1})	50–80	75 28	85 150	98
Angular sampling[c] (diameter)	2″	1.″6	2.″7	0.″8
Angular FWHM (reconstructed)	2.″5	2.″1[d]	2.″5	1.″5
Spatial FWHM (physical)	1.3–4.5 kpc (P+) 2.2–5.1 kpc (S)	1.1–2.3 kpc	0.8–1.0 kpc	0.15 kpc
Spatial FWHM (in R_e)	0.2–0.6 (P+) 0.3–0.9 (S)	0.3–0.8	0.2	0.09

Korean researchers

Hyunjin Jeong (KASI), 2012, SAURON

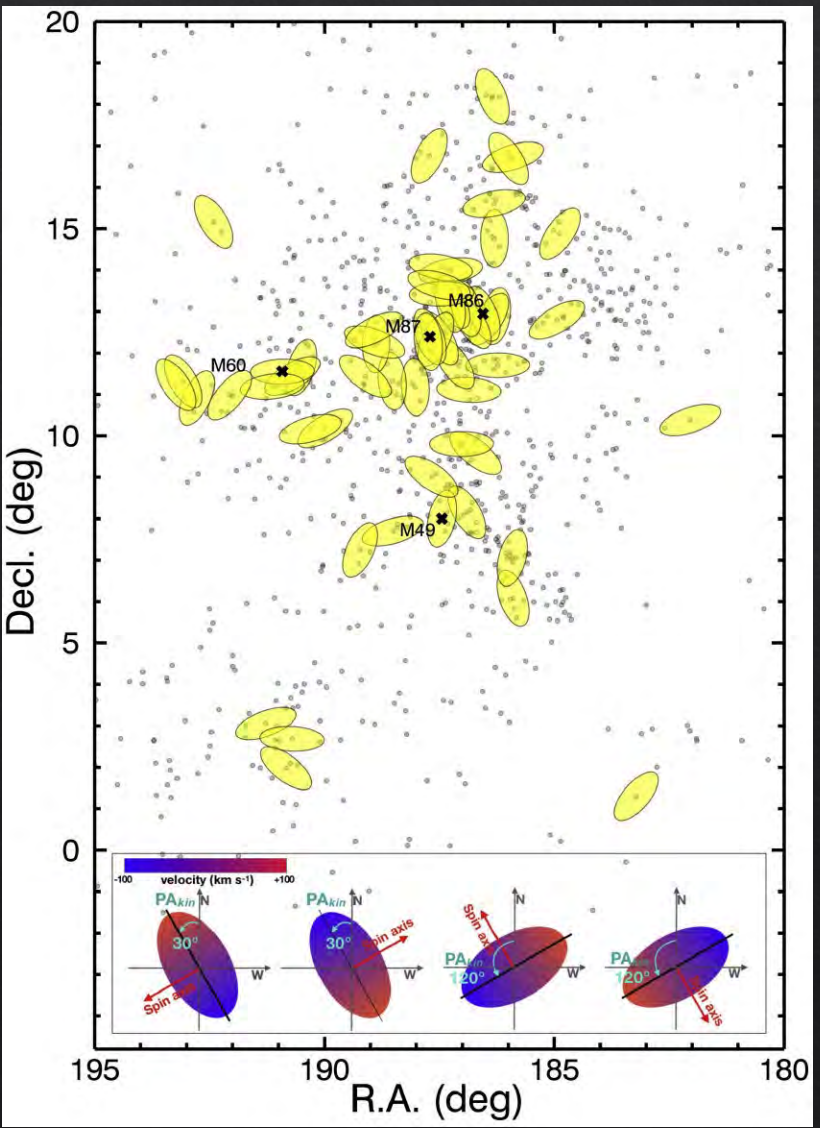
: UV color, age, and metallicity gradients in early-type galaxies

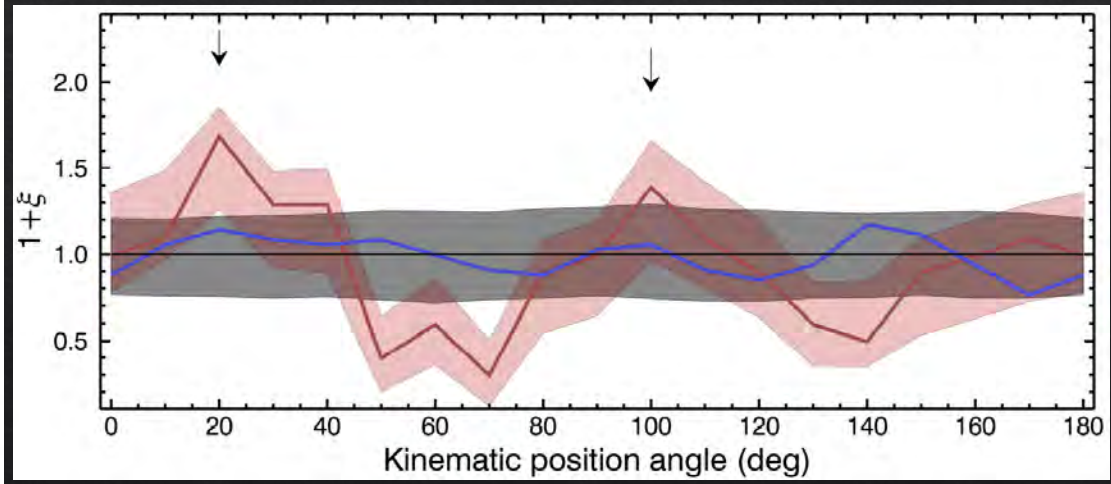


Korean researchers

Hyunjin Jeong (KASI), 2019, SAMI

: Spin axis alignment in clusters (pilot study for Virgo with Suk Kim)

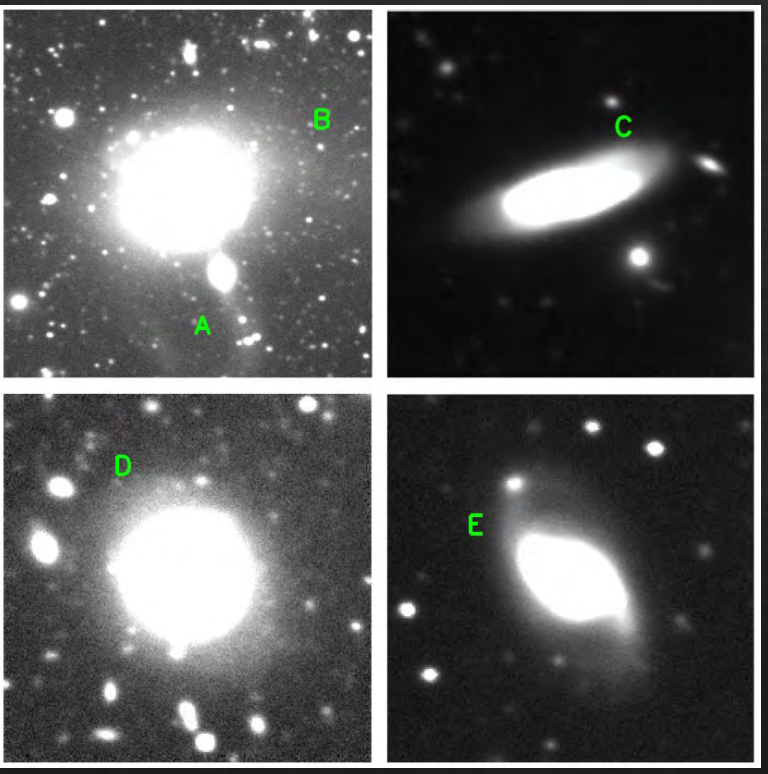


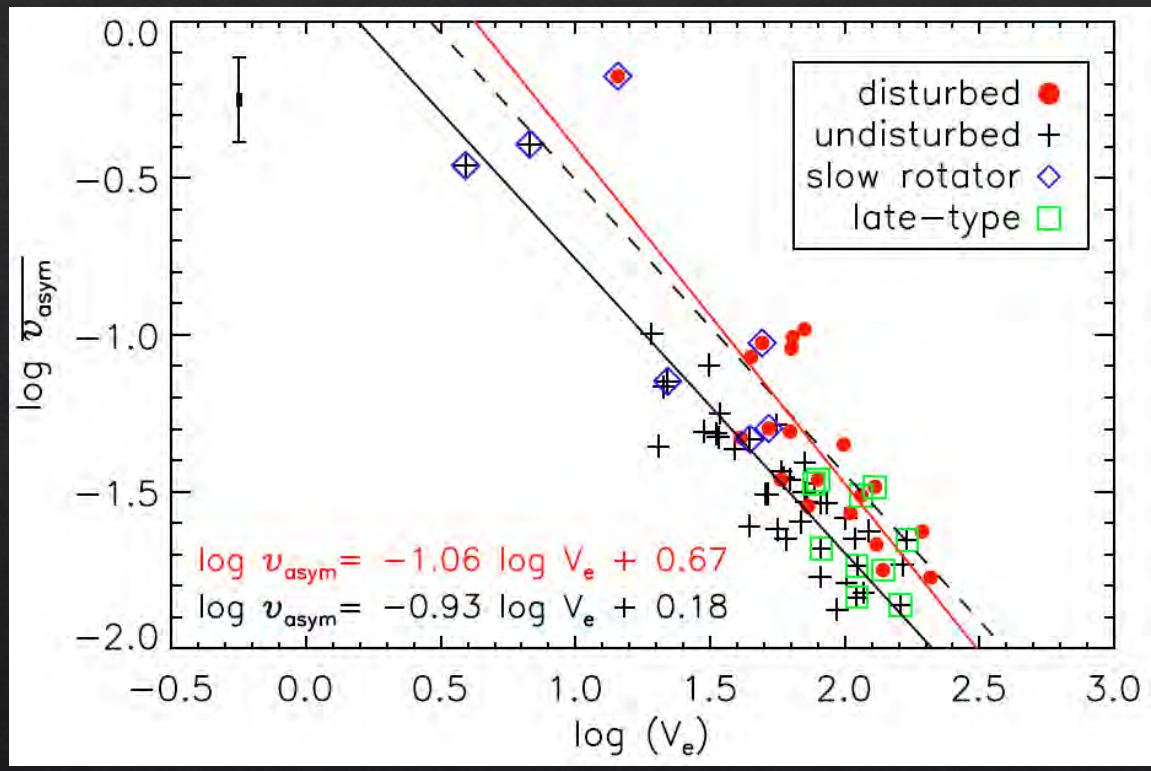


Korean researchers

Sree Oh (Yonsei; ANU), 2016, SAMI

: Galaxy interactions and kinematic anomalies

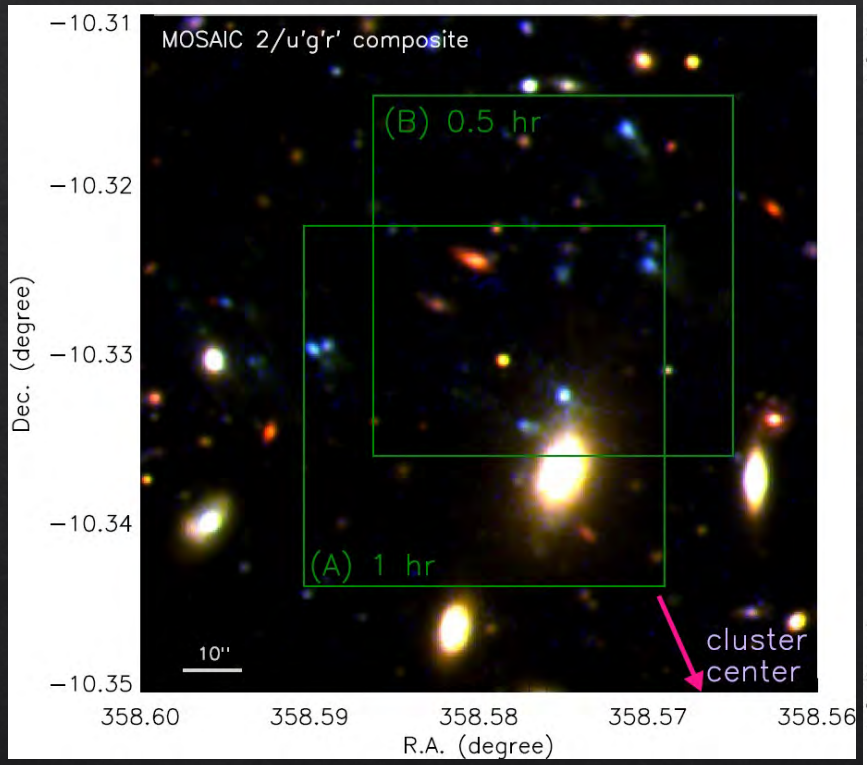


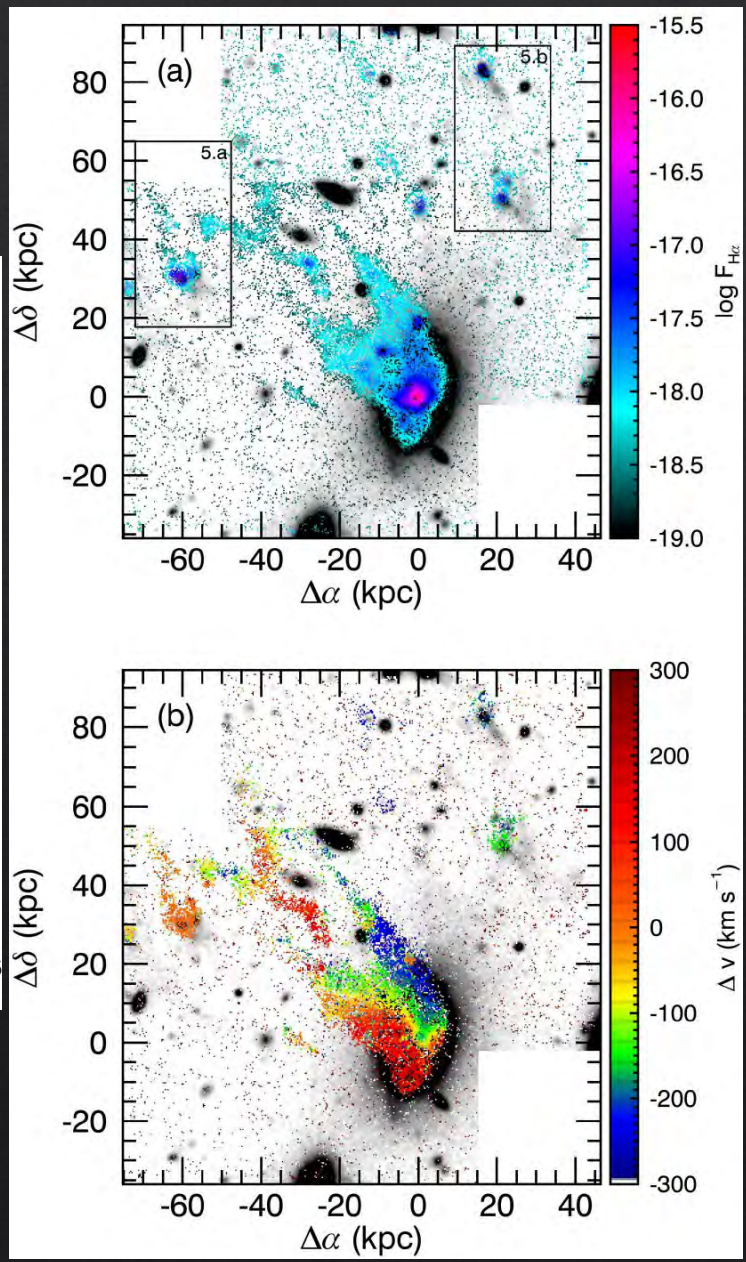


Korean researchers

Yun-Kyeong Sheen (KASI), 2017, MUSE

: Ram-pressure stripped gas
around an elliptical galaxy

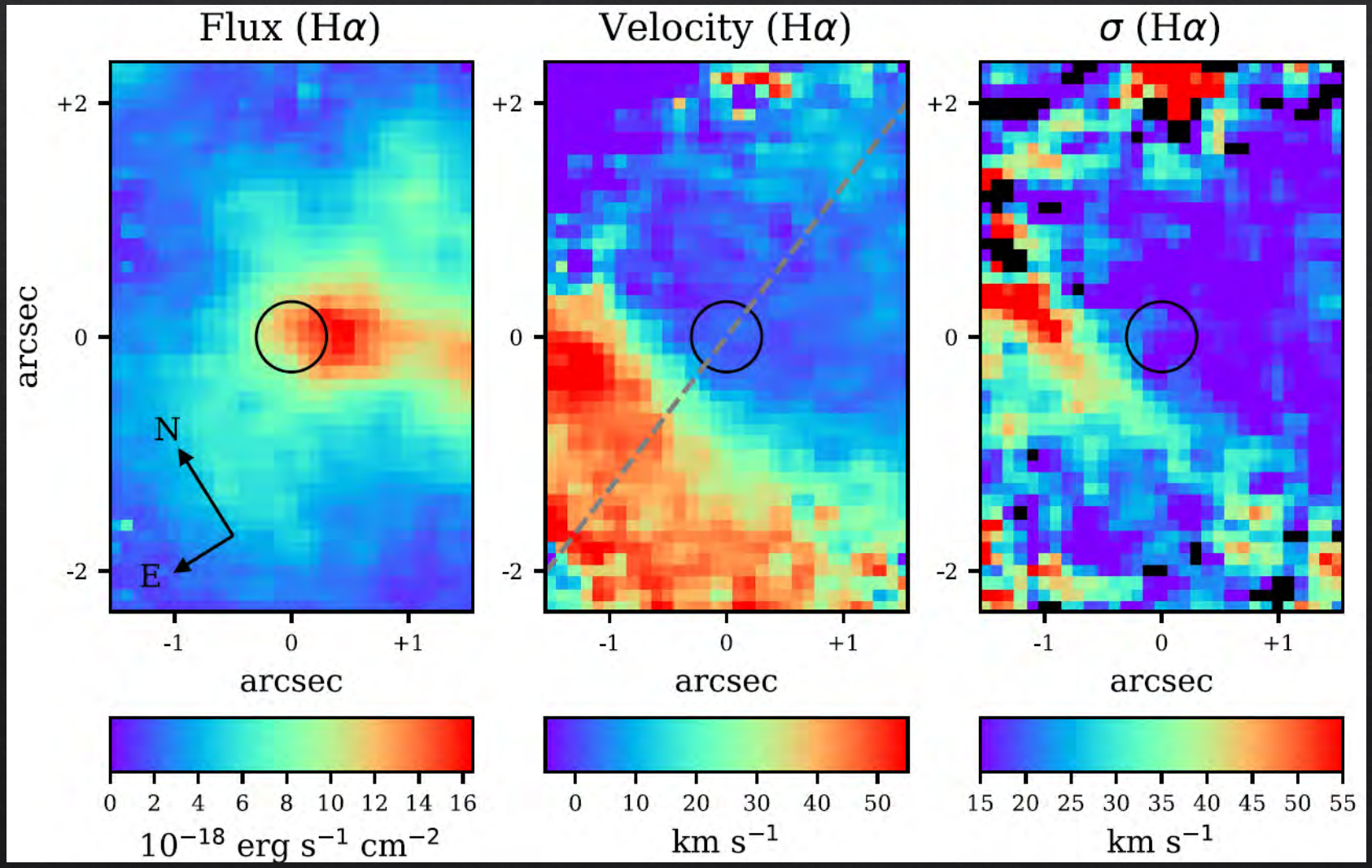




Korean researchers

Minjin Kim (KASI; KNU), 2017, GMOS

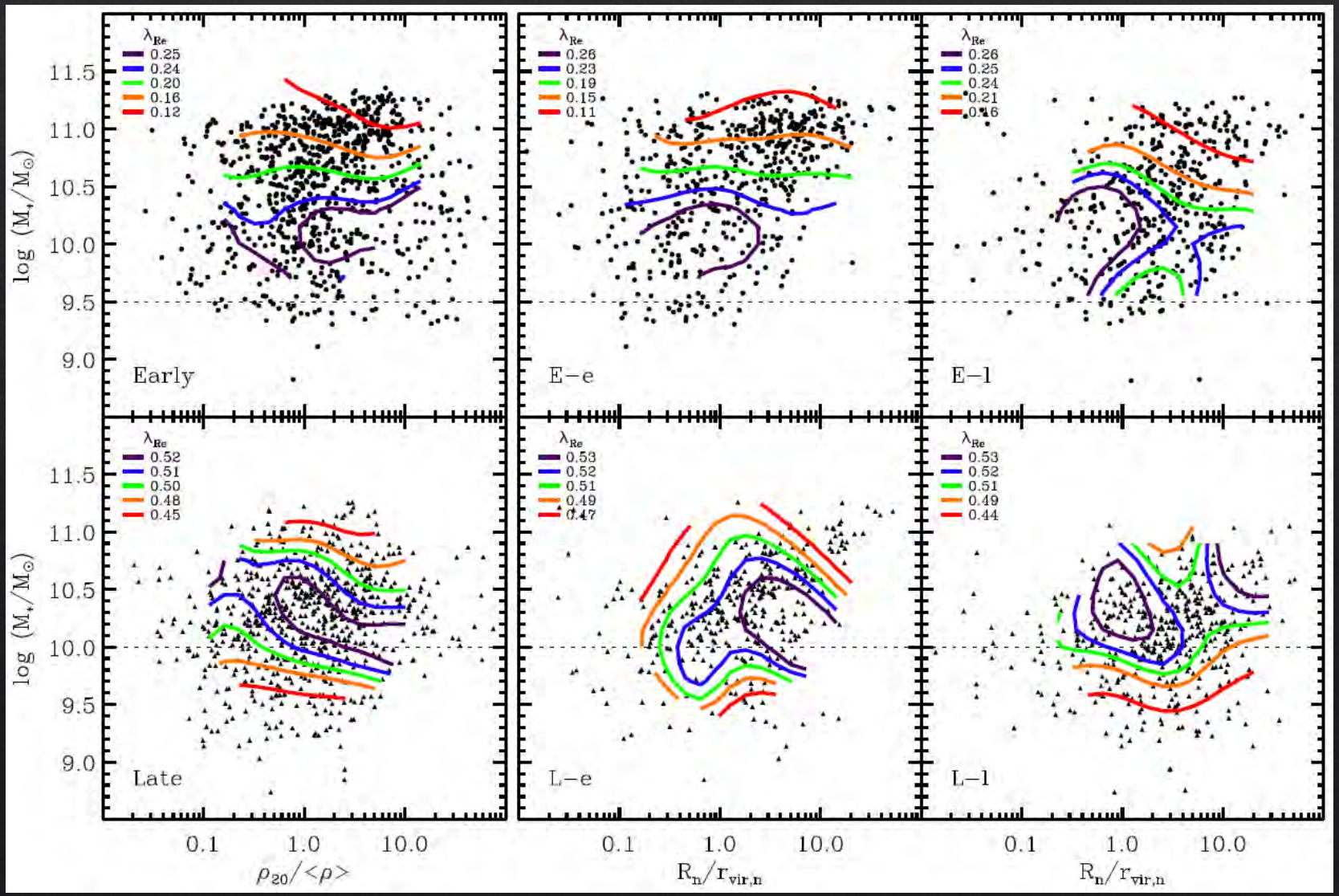
: ULX source as a candidate of IMBH (& tidal disruption events)



Korean researchers

Jong Chul Lee (KASI), 2018, MaNGA

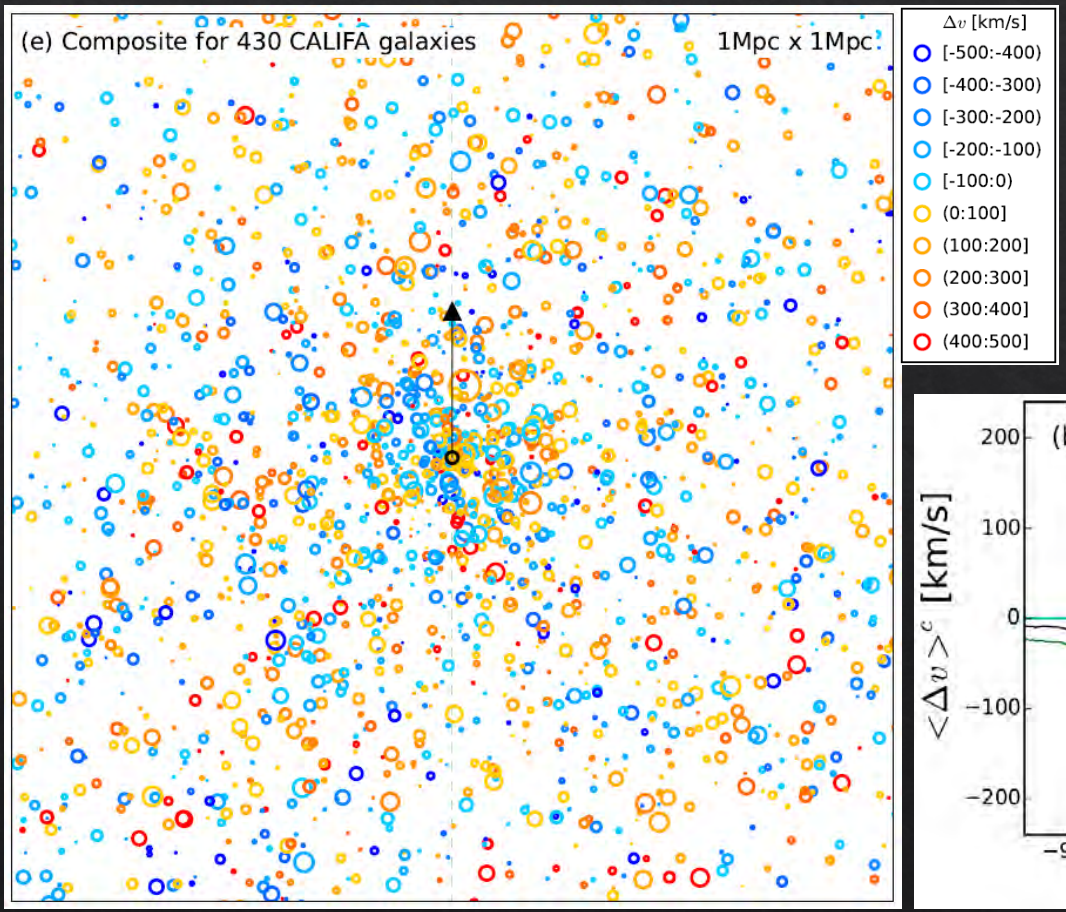
: Environmental effects on galaxy spin (& star/gas/dust distribution)

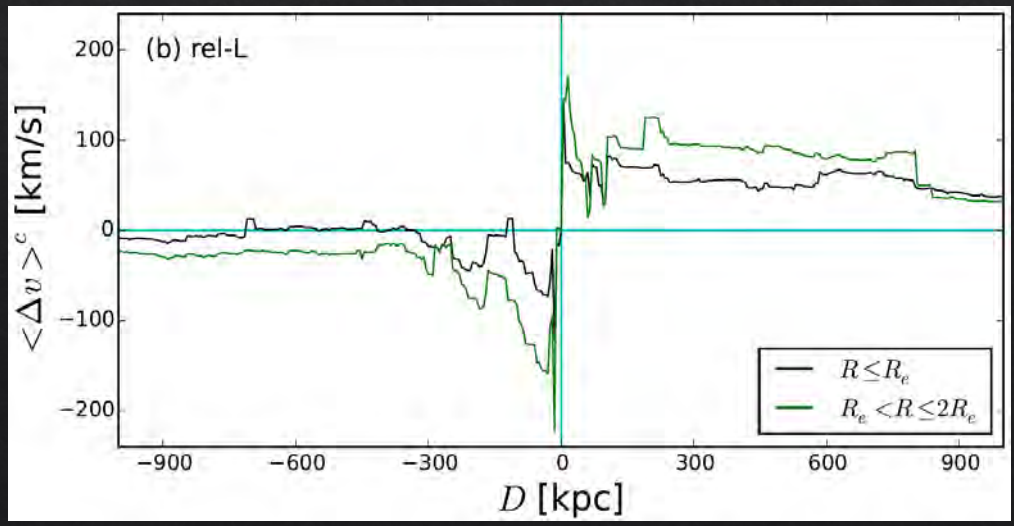


Korean researchers

Joon Hyeop Lee (KASI), 2019, CALIFA

: Galaxy rotation and the motion of neighbors





Korean researchers

정현진, 오슬희, 신윤경, 김민진, 이종철, 이준협

양유진: E+A galaxy
이광호: green valley galaxy
신민수: ISM absorption
우종학: AGN outflows
김도형: binary SMHM

황호성
김재우
심현진
고종완
김석

정하은: rotational curve, deconvolution effect
박민아: passive spirals, 3D decomposition
……

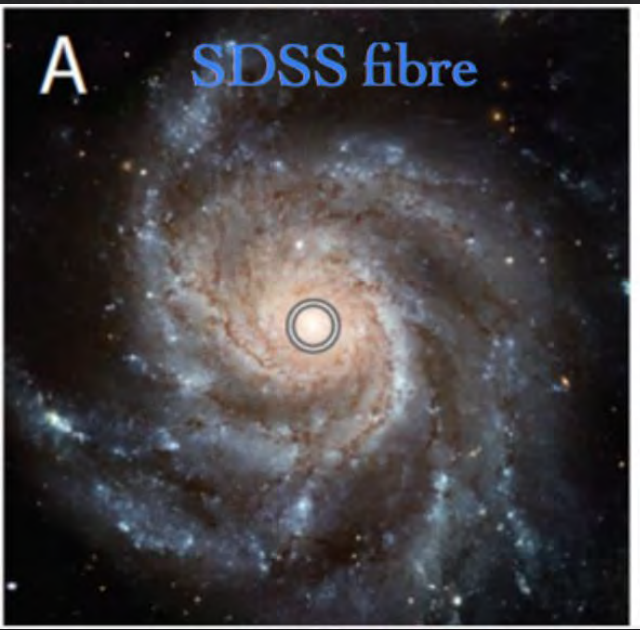
Hector project: beyond SAMI

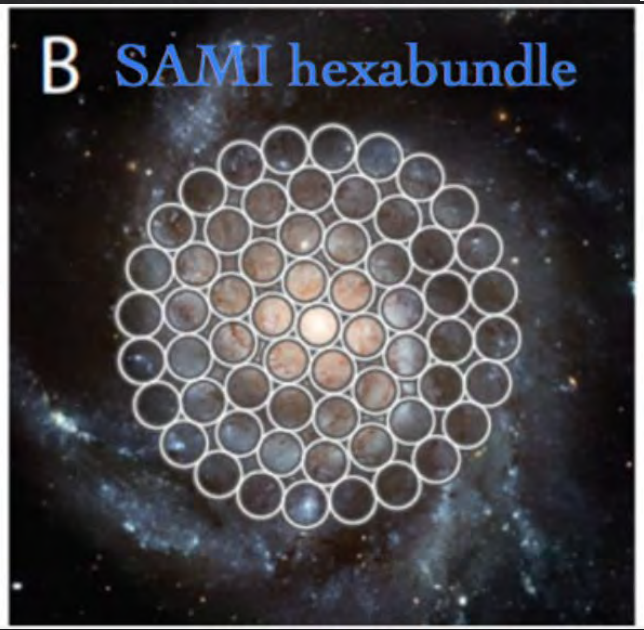
PI: **Joss Bland-Hawthorn**
Project Scientist: **Julia Bryant**
Project astronomer: **Scott Croom**
Project Leader: **Jon Lawrence**
Project Manager: **Julia Tims**
Instrument Scientist: **Will Saunders**

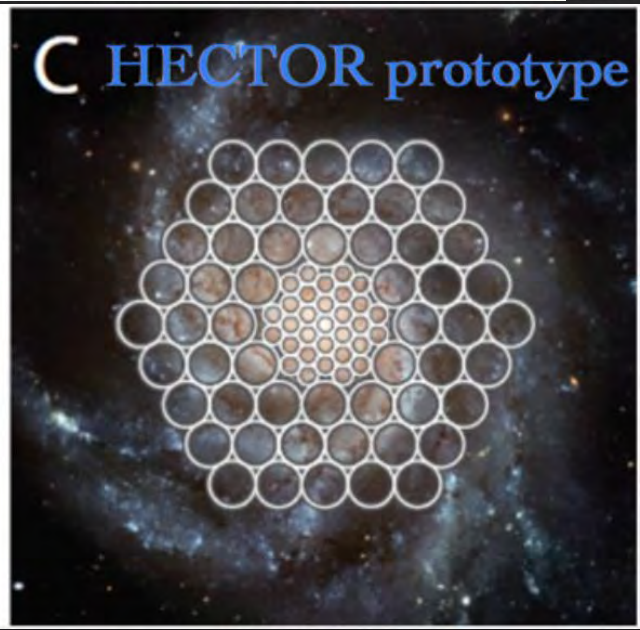
Hector: R_λ = 1.3Å

SAMI: blue: R_λ = 2.75Å (R~1800)
red: R_λ = 1.6Å (R~4300)

MANGA: blue: R_λ = 2.85Å
red: R_λ = 3.4Å







Hector project: beyond SAMI

	SAMI	Hector-I	Hector-2
Number of hexabundles	13	21	51
Field diameter (degrees)	1	2	2
Coverage diameter on each galaxy	15"	15-30"	15-30" (2R_e on 90% of galaxies)
Survey size by end of 2024	7,100	15,000	>30,000
Cost	$0	$3M	$15M

	SAMI	Hector 2df	Hector 3df
No. hexabundles	13	50	100
No. fibres	819	>3000	>7000
Top end	1 deg. field	2 deg. field	3 deg. field
spectrograph	AAOmega – flexible format	Dedicated fixed-format sectrographs	Dedicated fixed-format sectrographs
Nights x fields/night x objects/field x weather	181 x 2.1 x 12 x 0.75	~500 x 2.5 x 50 x 0.75	~500 x 2.5 x 100 x 0.75
Survey objects	3400 in 3 years	50,000 in <5 years	100,000 in <5 years
Density	15 objects/square degree	16 obj/sq. deg – could increase by 50%	14 obj/sq.deg. – could increase by 50%

International interested groups:

Hyunjin Jeong & Sukyoung Yi

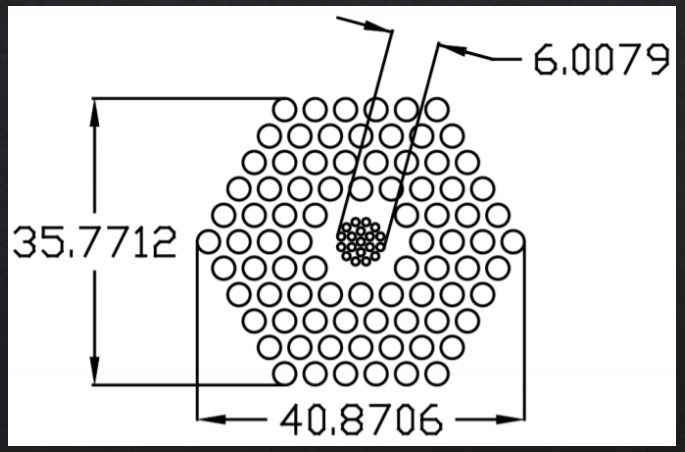
with

Joon Hyeop Lee

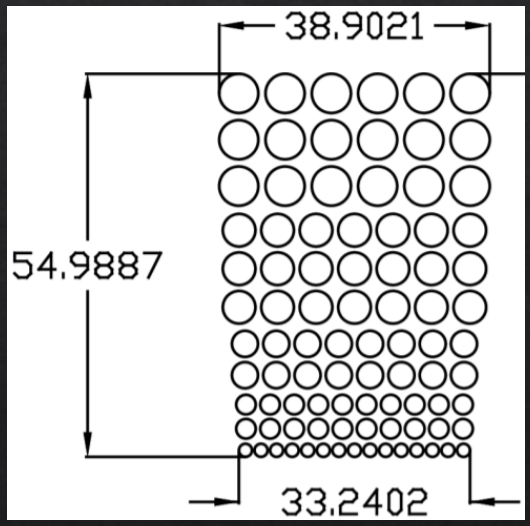
Jong Chul Lee

Discussion

- IFS is becoming more popular.
- MOS + IFS mode? pros and cons
- new IFS instrument?



HexPak



GradPak

- new IFS survey? Hector and …