The Co-evolution of AGNs and Galaxies

---- viewed from the 2D and mid-IR spectroscopy

Lei Hao

Shanghai Astronomical Observatory

Outline

- My personal science interests
  - 2D spectroscopy：（SDSS MaNGA，VENGA，CHILI）
    - AGN inflow and Galactic outflows
    - CHILI
    - Low Surface Brightness Galaxies
  - Infrared properties of AGNs and galaxies
  - AGNs at 2<z<4 in HETDEX
- Subaru Connections (me personally)
- Possible Collaborations in China (incomplete)
  - Chinese facilities

- 2D Spectroscopy
  - AGN inflows and galactic outflows
  - CHIna Lijiang IFUs
  - Low Surface Brightness Galaxies

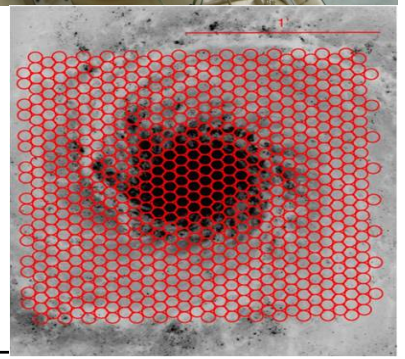
VENGA and MaNGA

- **VENGA**
  - VIRUS-P Exploration of Nearby Galaxies
  - 30 disk galaxies
  - Deep integration, wide FOV: 1.7'x1.7'
- **MaNGA**
  - IFU observations of ~10,000 galaxies, part of SDSS-IV
  - FOV: <32"

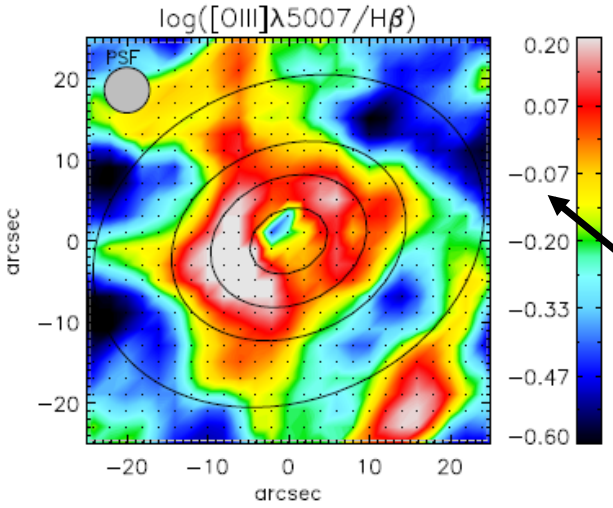
2.7 m
Harlan J. Smith
Telescope

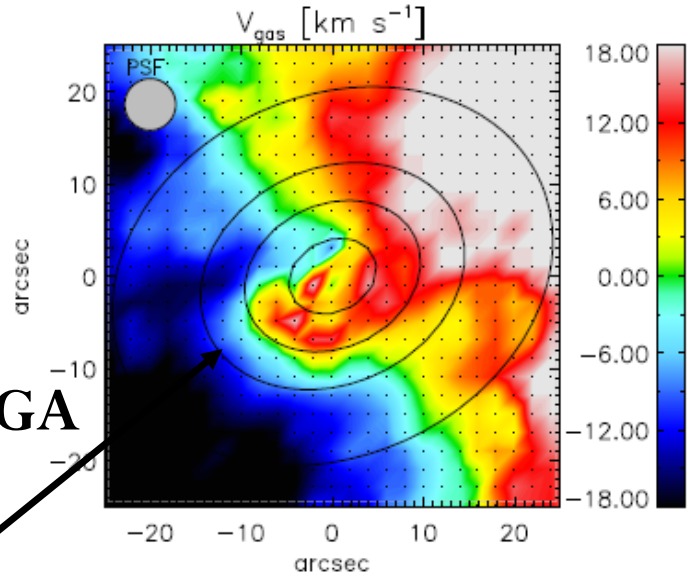
VIRUS-P

246 fibers
in one pointing
of VIRUS-P

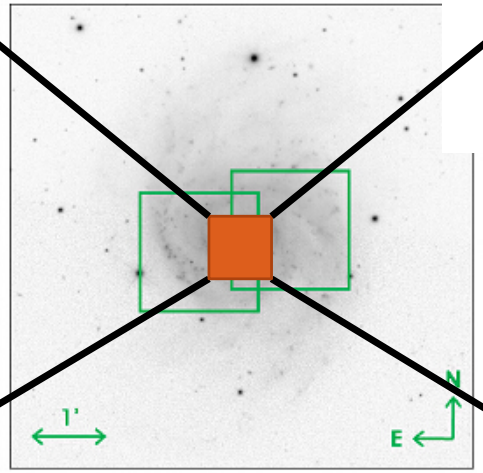


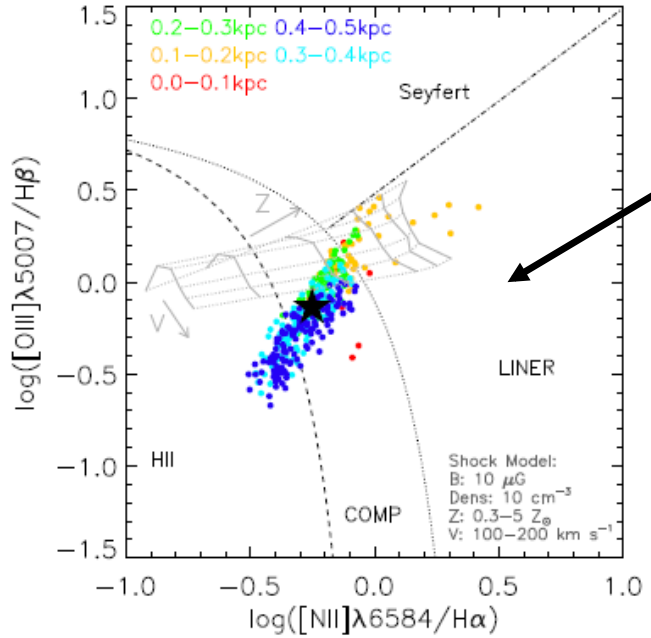
Gas inflow in AGNs

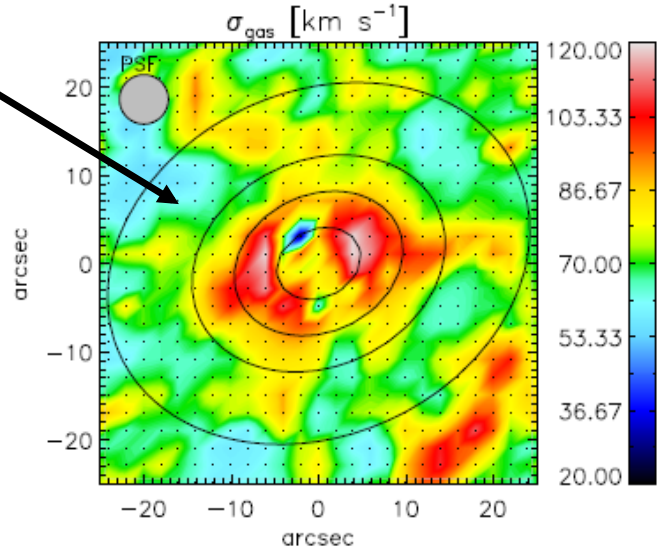




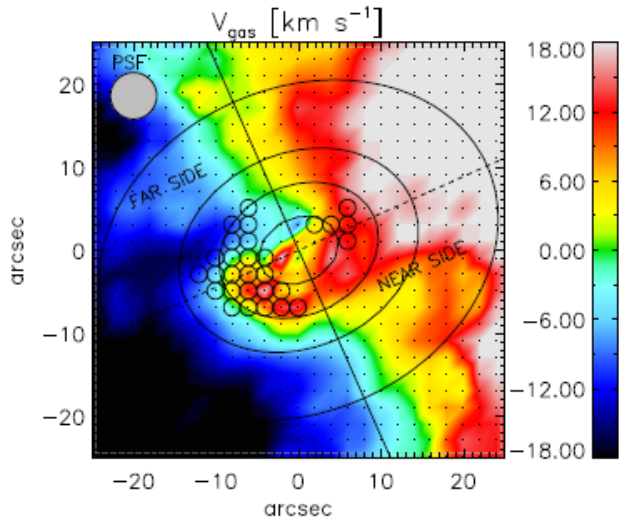
NGC1042 with VENGA

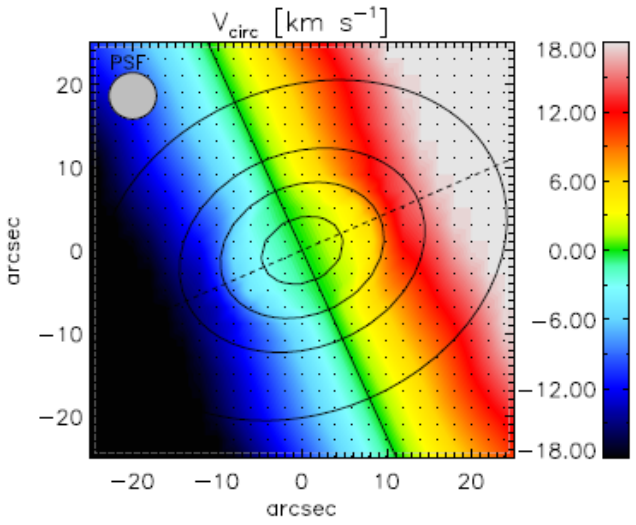


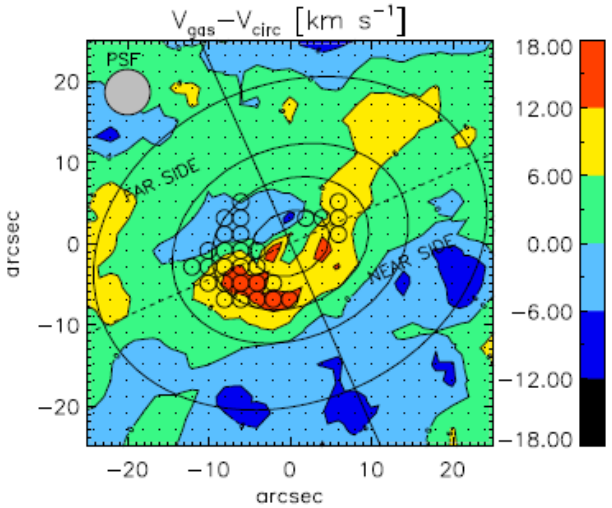


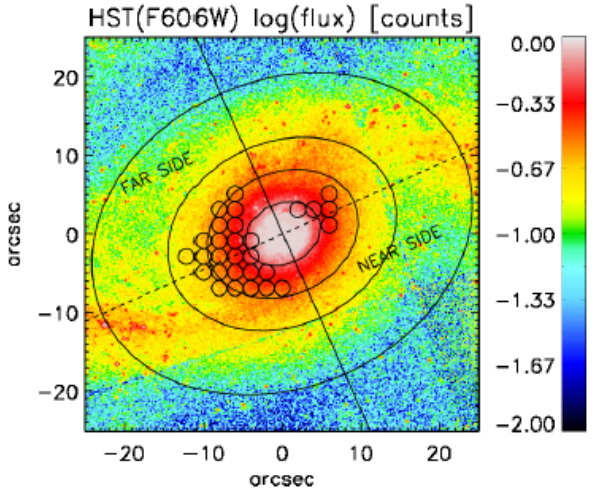


Luo et al. 2016









The residual velocity is ~ 20 km s^{-1}

The deprojected gas inflow velocity is ~ 32 km s^{-1}

The mass inflow rate at gas inflow region:

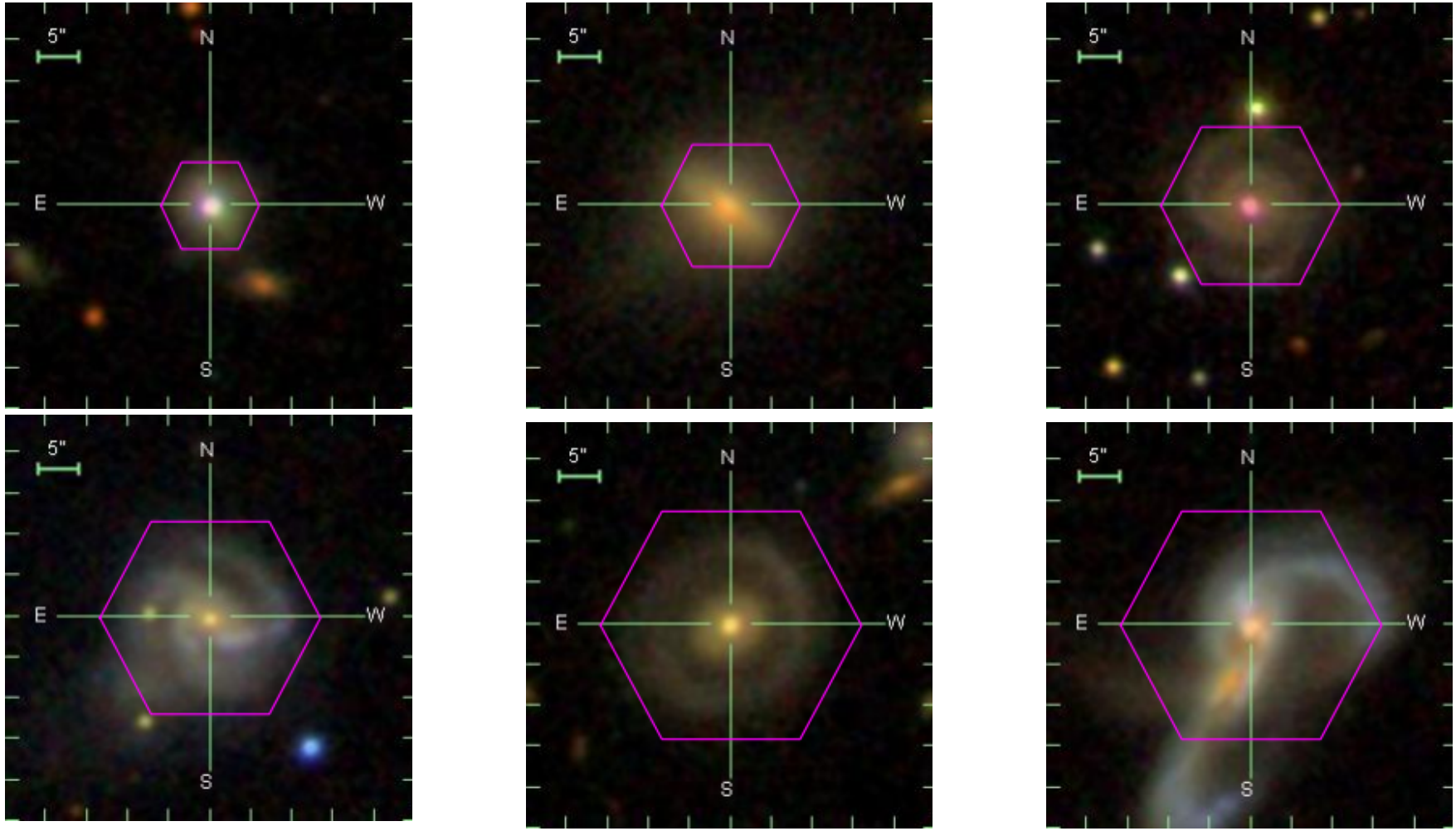
$$\dot{M}_{in} = 2\pi n_e m_p f V_{in} r h \quad \sim 1.1\times 10^{-3}\ \mathrm{M_\odot\ yr^{-1}}$$

The mass accretion rate at the last stable orbit of the BH and the star formation rate in the NSC:

Luo et al. 2016

$$\dot{M} = \frac{L_{bol}}{c^2\eta} \quad \sim 1.4 \times 10^{-5}\ \mathrm{M_\odot\ yr^{-1}} \qquad M_{SR} \sim 7.94 \times 10^{-5}\ \mathrm{M_\odot\ yr^{-1}}$$

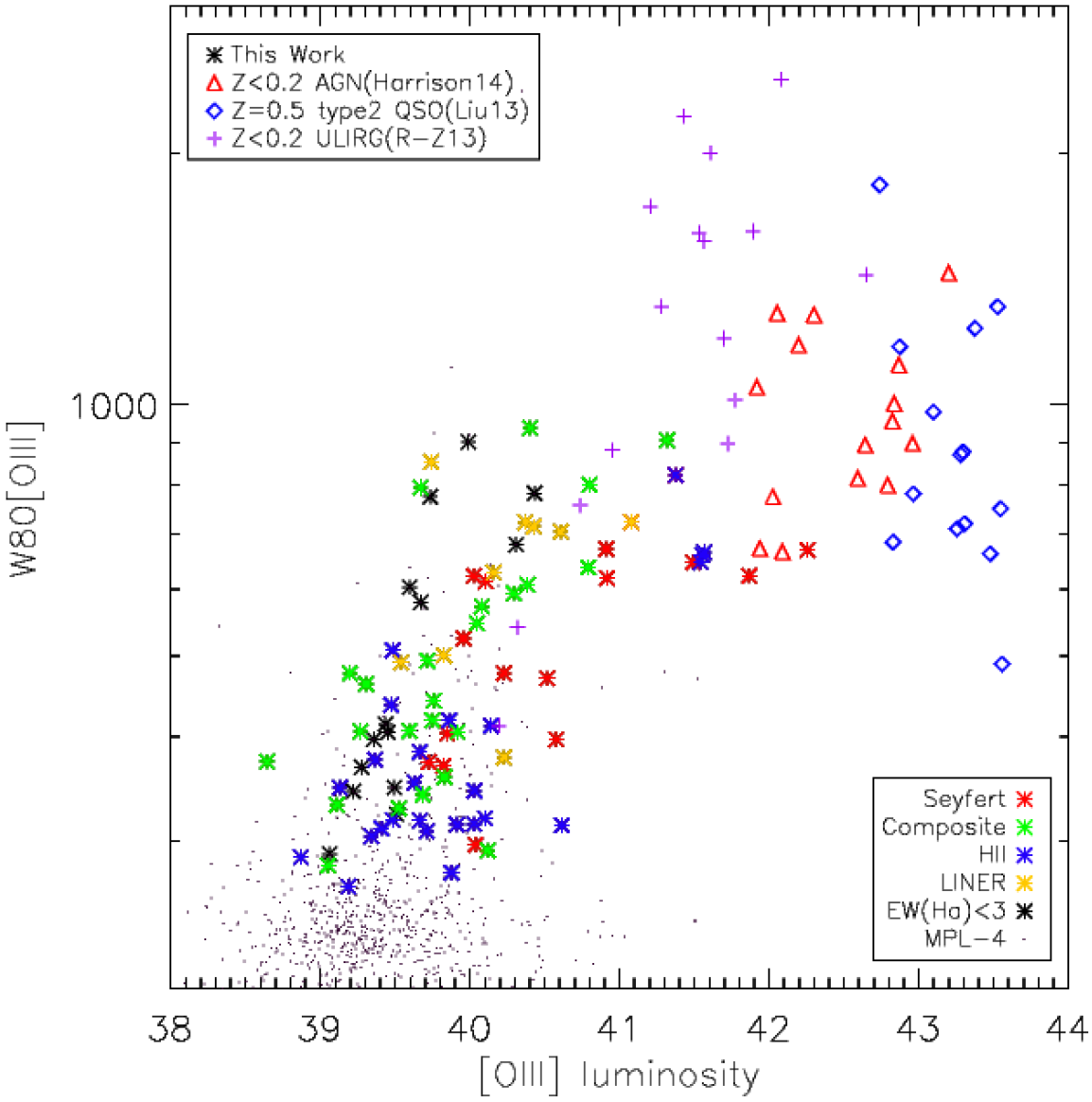
Outflows in galaxies (with MaNGA)



Find sources with extended regions of broad [OIII] lines

Quantify the outflow frequencies; their strengths and other properties

Outflows in galaxies (with MaNGA)



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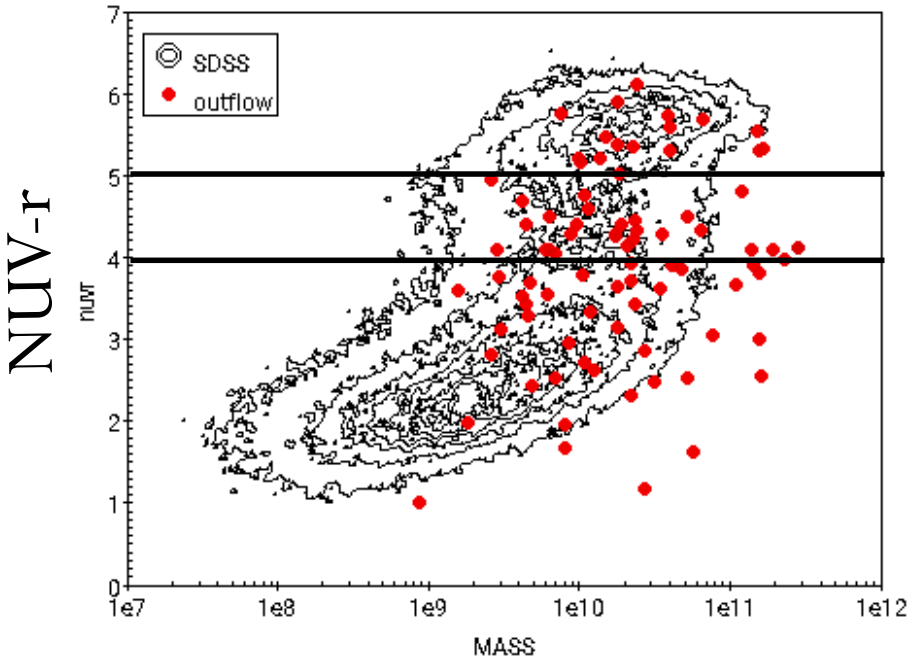
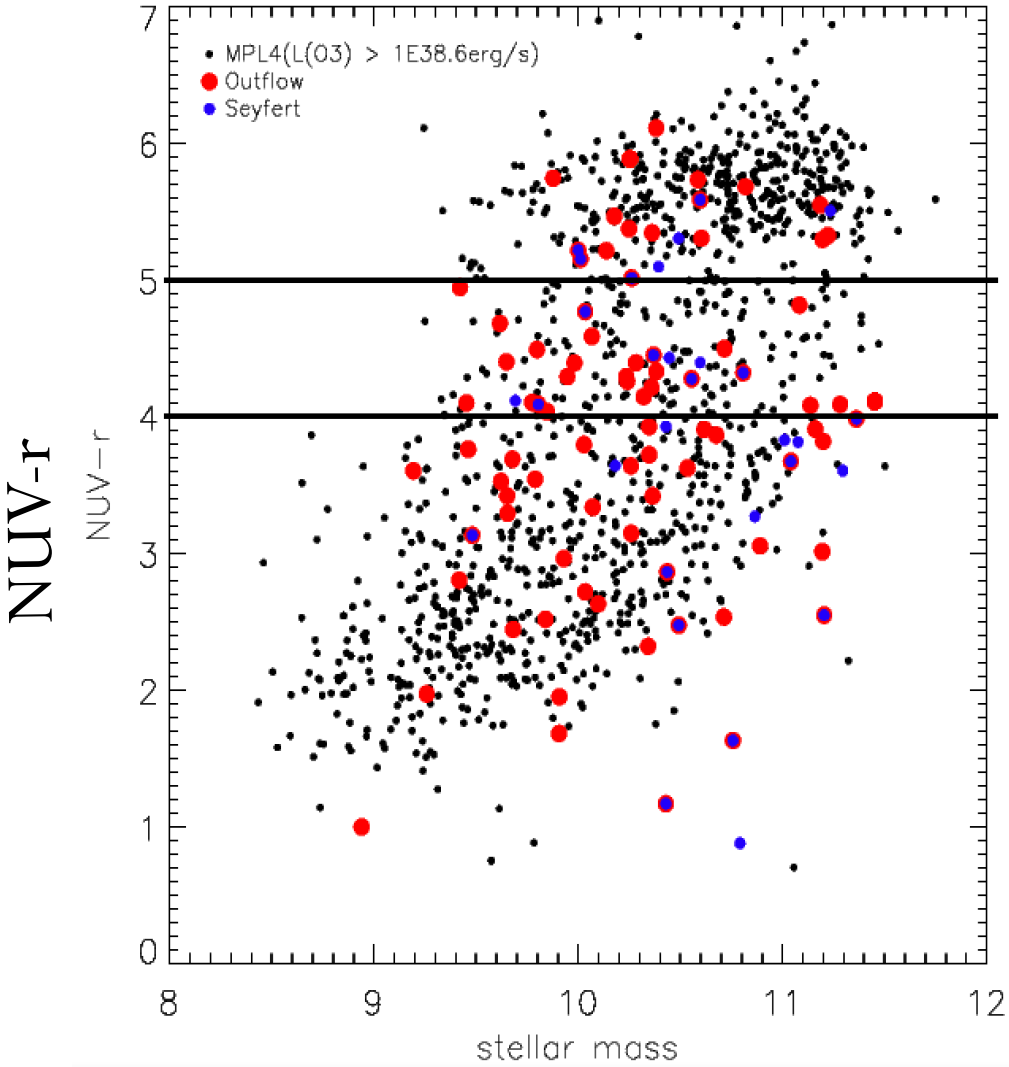
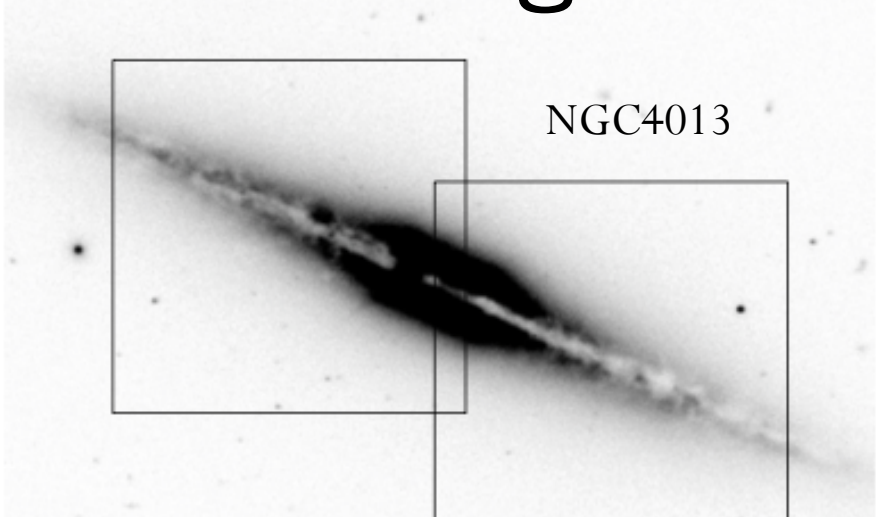


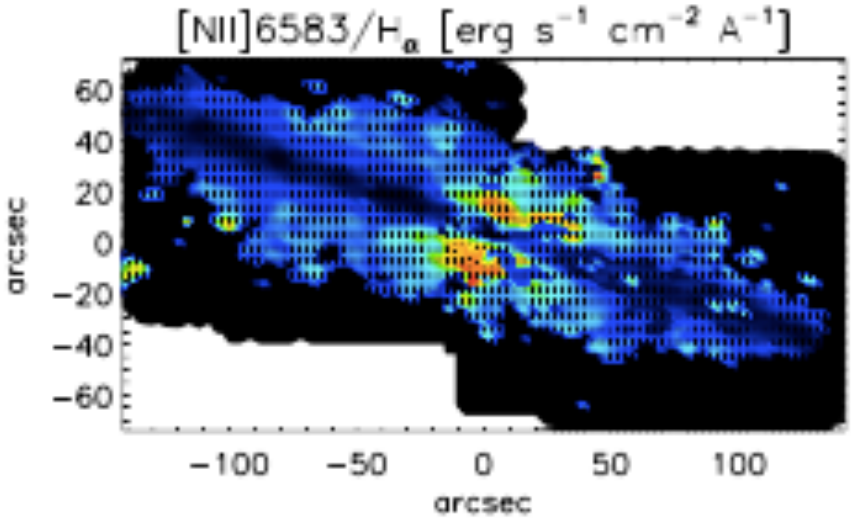
Stellar Mass

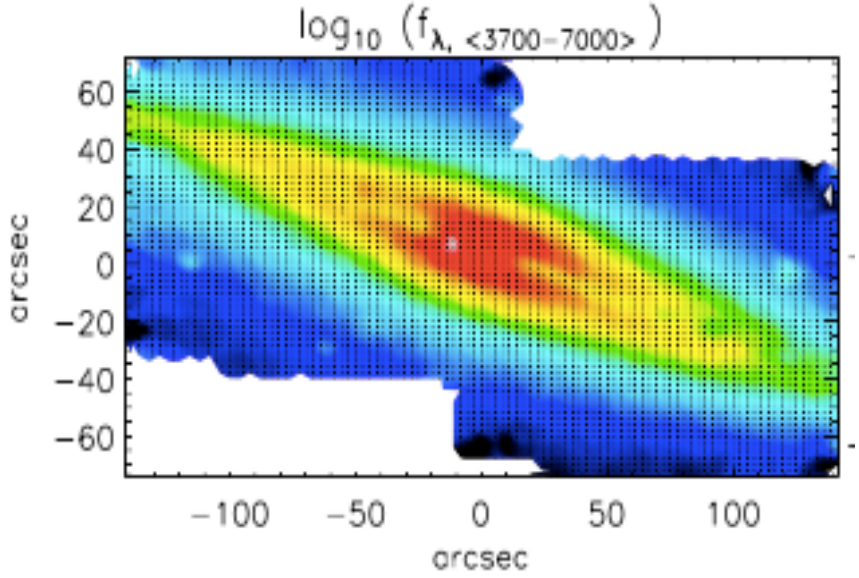


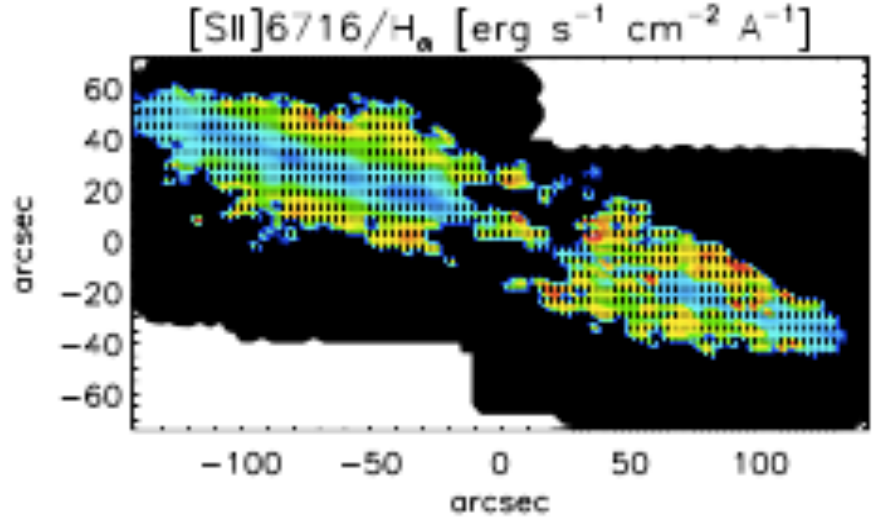
Stellar Mass

Outflows in galaxies (with VENGA)









CHILI: CHIna Lijiang IFU

- HETDEX collaboration, copy of a VIRUS unit, ~2xVIRUS-P
- 494 fibers, each fiber 3.2 arcsec
  - VIRUS-P: 246 fibers, each 4.2”
  - MaNGA: 17x19-127 fibers, each 2”
- The total field of view is 71”x65”
  - Almost 100% filling factor
    - VIRUS-P: 100”x100”, at 1/3 filling
    - MaNGA: <32”, at 60% filling
- R=900 (~VIRUS-P) and R~2000 (~MaNGA),
- Spectral coverage: 360-720nm
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- Red and blue are not observed simultaneously
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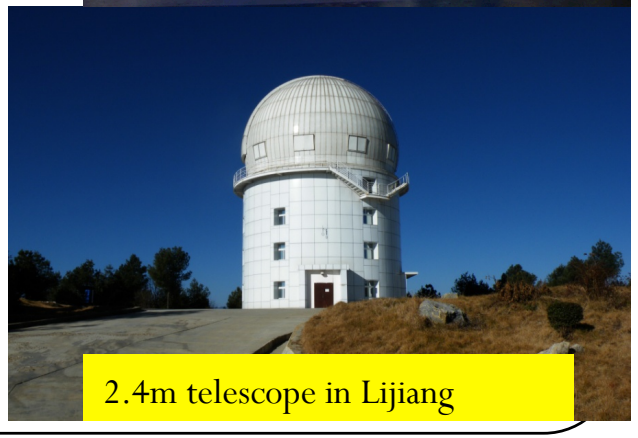

2.4m telescope in Lijiang

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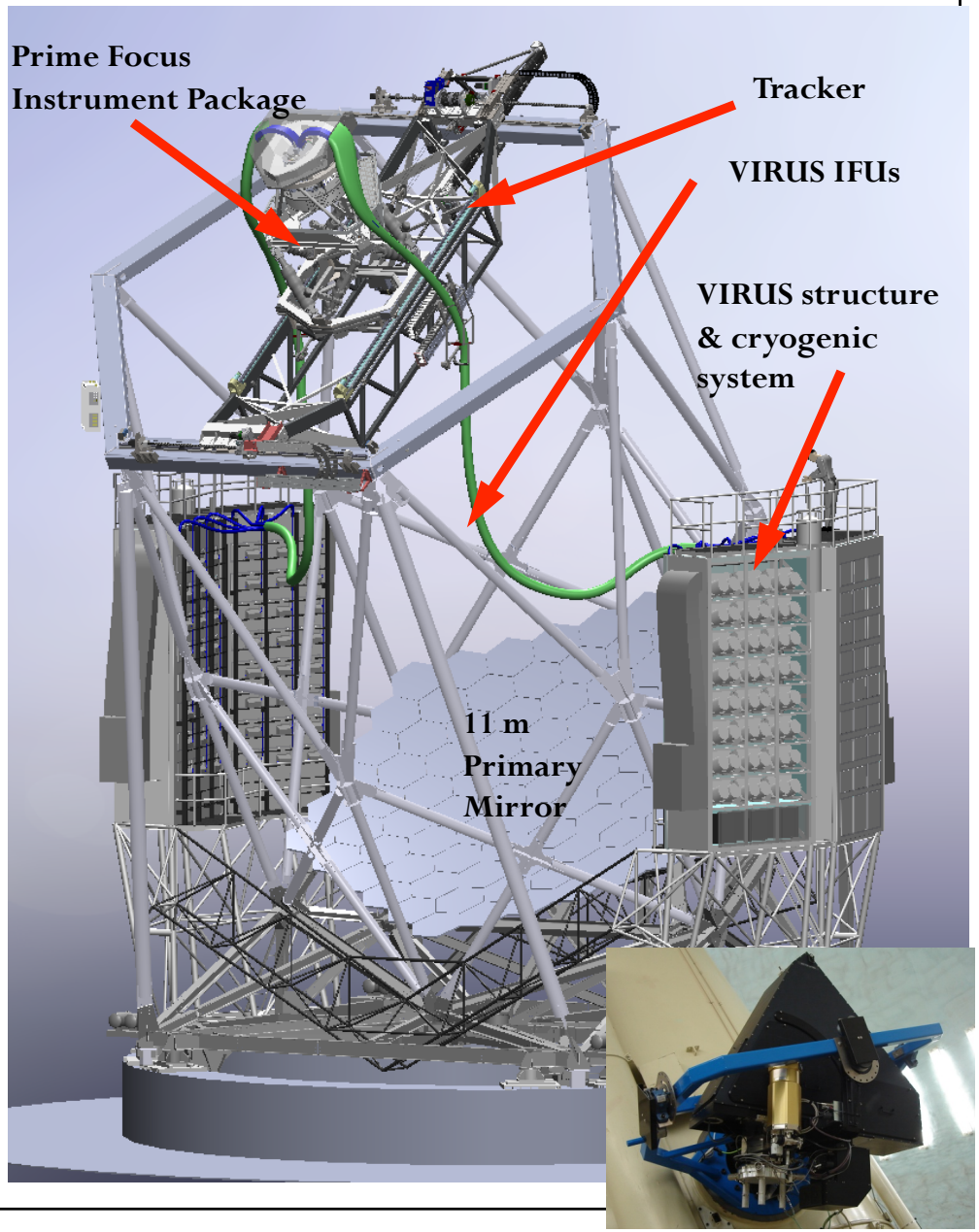

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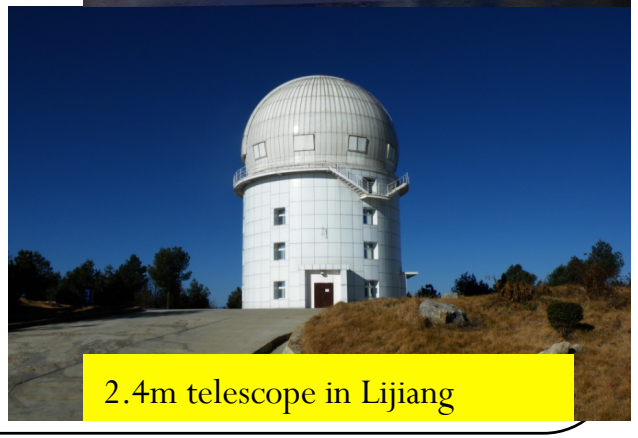

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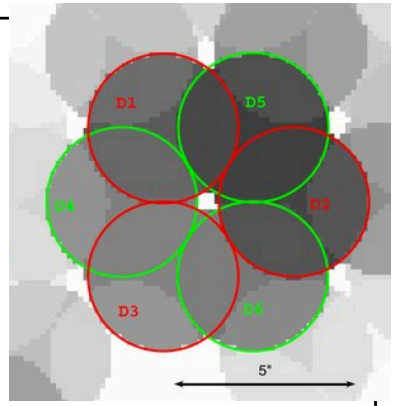
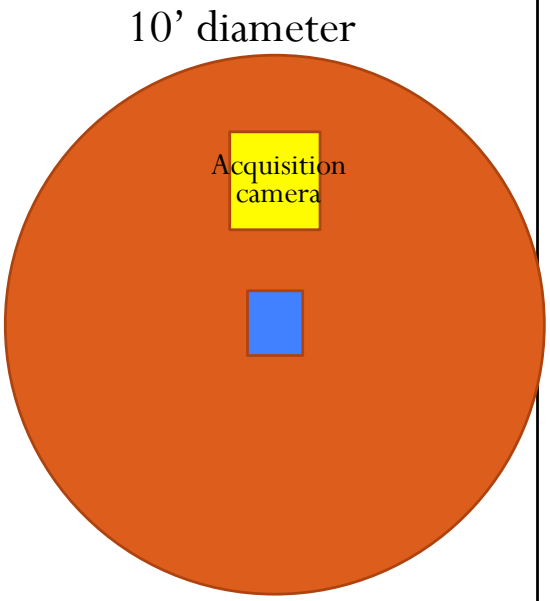
The characteristics of CHILI



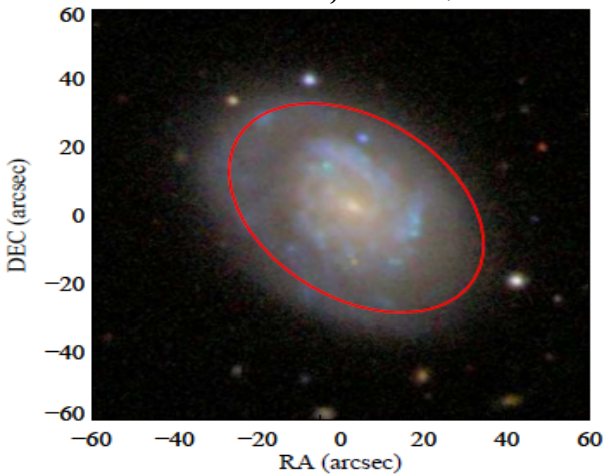
- Big Field of View
  - microlense（~100% filling）： 71”x65”
    - SAURON: 33”x44”， WiFeS: 38”x25”
  - 3 observations： >VIRUS-P by 33%

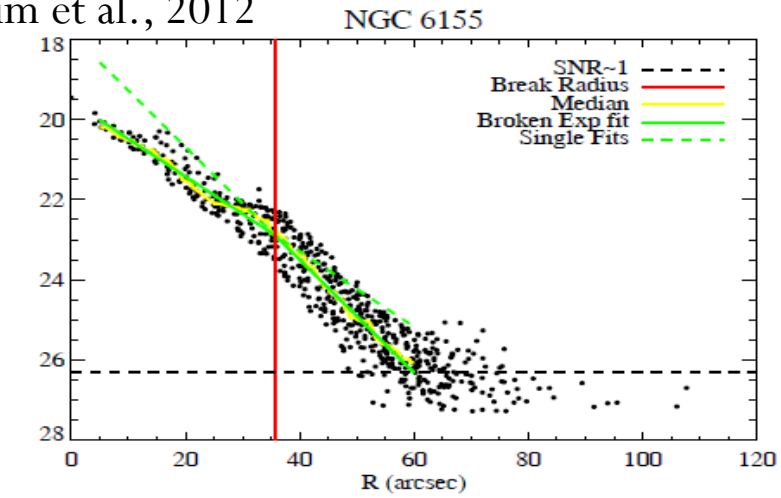


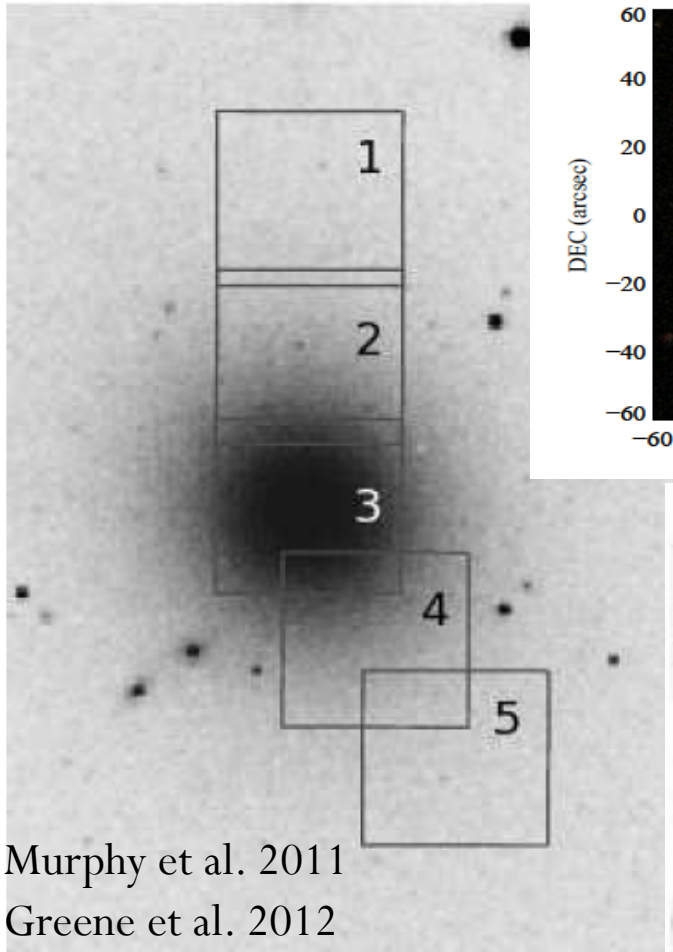
- Sensitive to low-surface brightness regions：
  - 100% filling+fat fibers: f = $\Sigma \bullet A$
  - Avoid Dither
- Deep exposure

Sciences Cases done by VIRUS-P

Yoachim et al., 2010； Yoachim et al., 2012



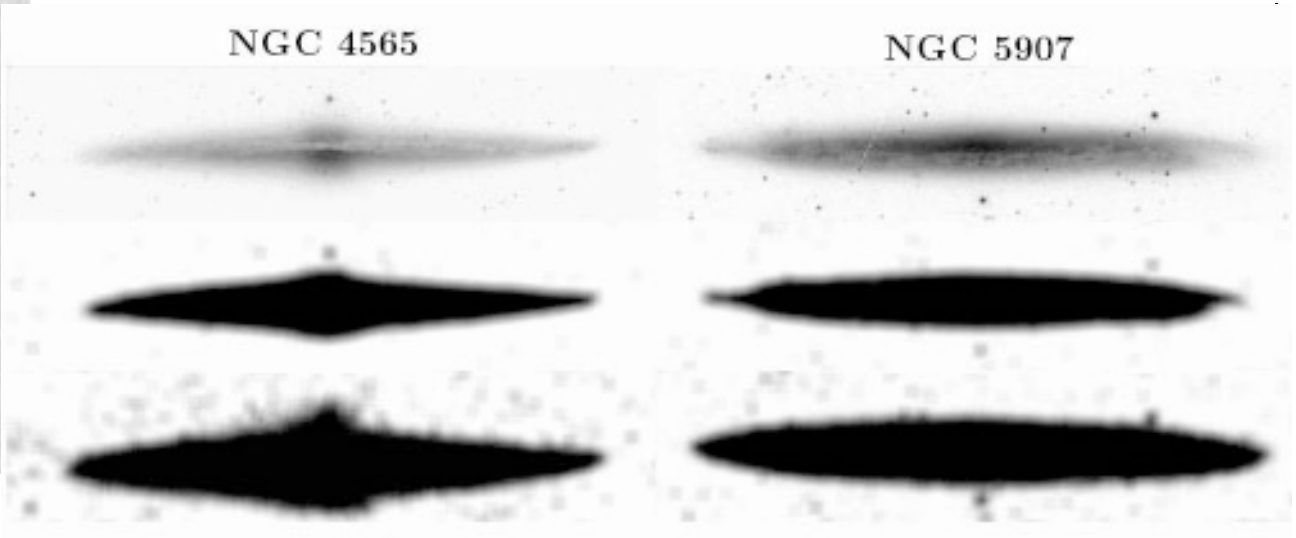




Murphy et al. 2011

Greene et al. 2012

Raskutti et al., 2014



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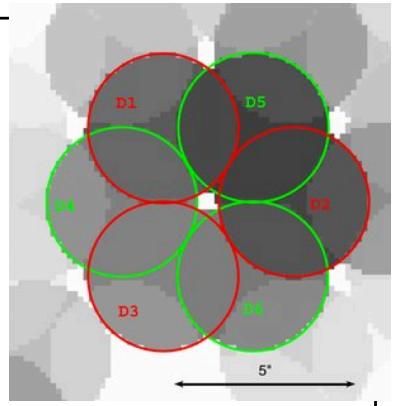

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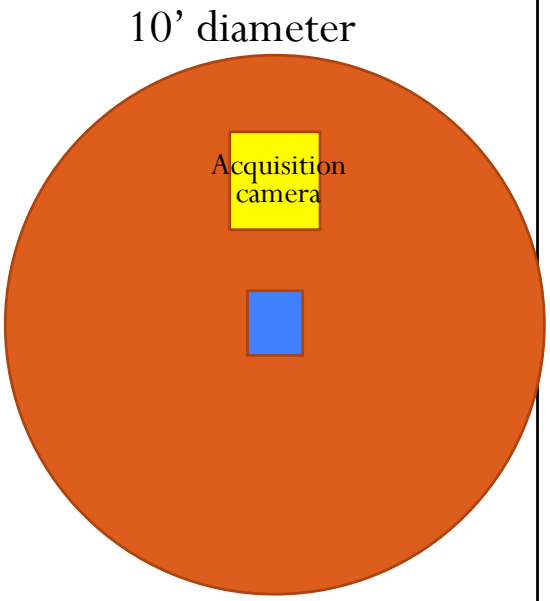

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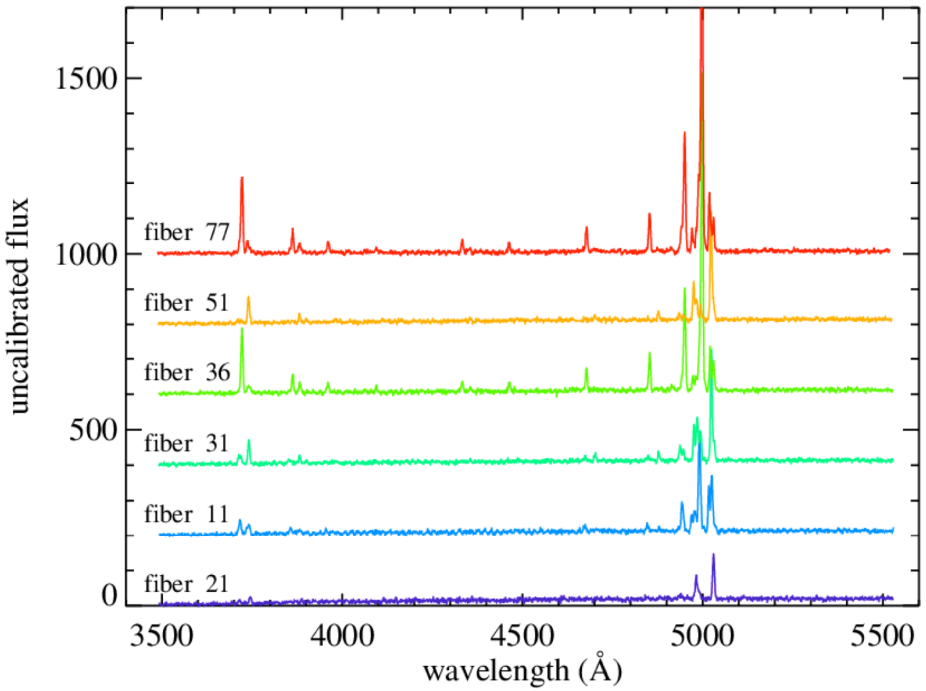
  - Avoid Dither
- Deep exposure

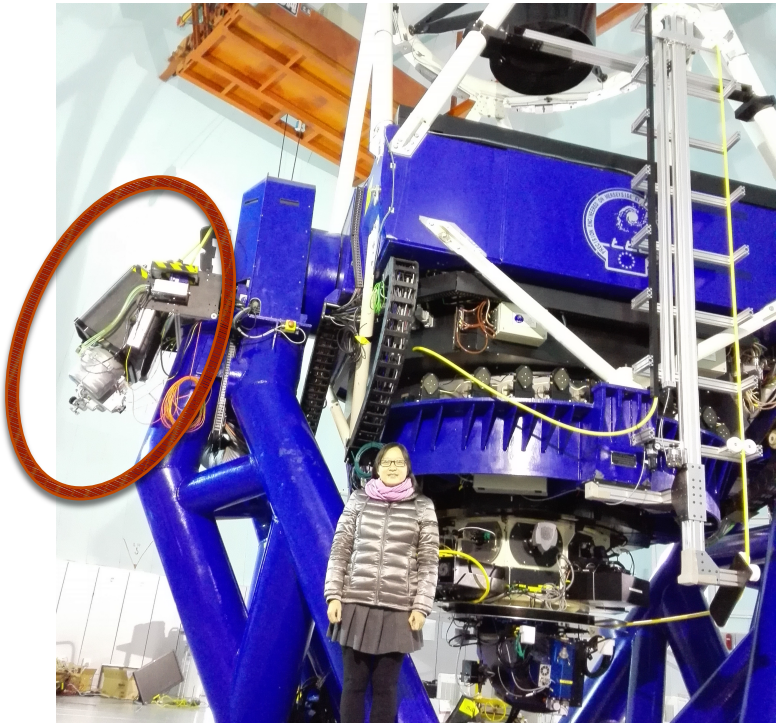
CHILI Sciences

- Break radius of the disk galaxies
- Kinematics of bars and non-axisymmetric structures
- The outer region of the Elliptical galaxies: dark matter and the evolution (e.g., metallicity distribution)
- Bulge (including psudobulge) formation and AGN fueling and feedback at galactic scale
- Large-scale outflow (e.g. super winds)
- Detection of the "cold flows" of galaxies
- The diffused ionized gas of the edge-on galaxies

CHILI Status and Timeline

- Hardware ready by August, 2016
- Now in commissioning,
- Hopefully real observation in September, 2017





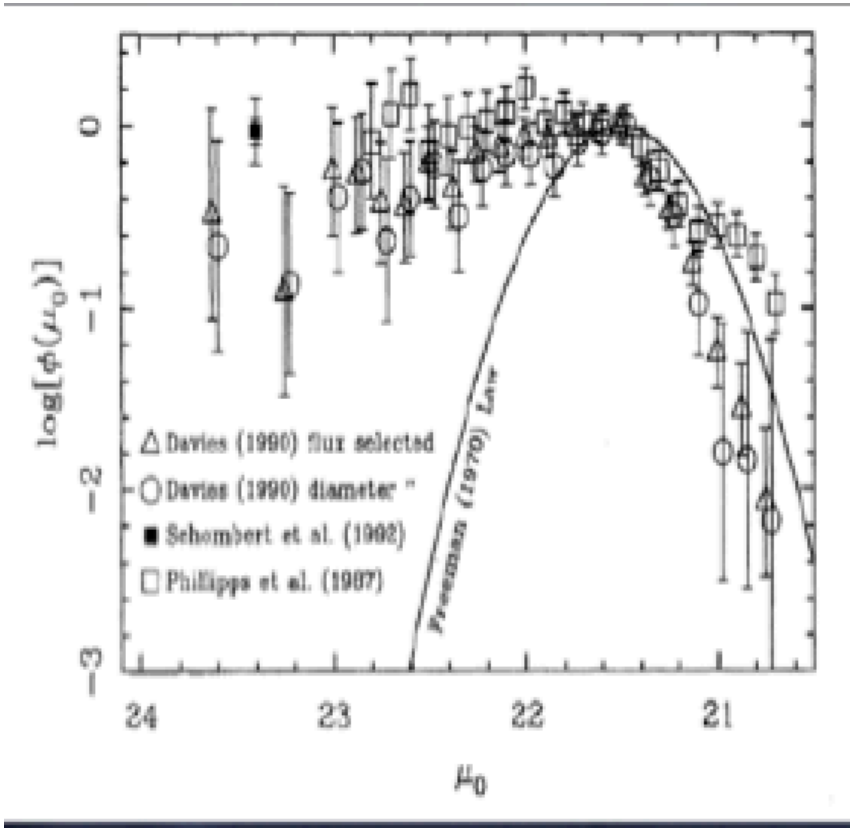
20mins on Crab Nebular, blue

Low-surface Brightness galaxies

- μ_0>22.5mag/arcsec^2
- Are they a physically-disctinct class of galaxies
- Low starformation rate

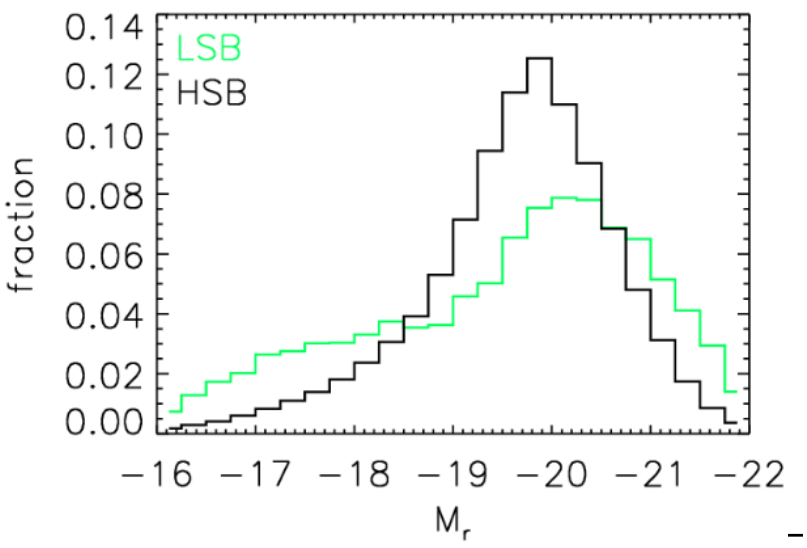
A series of investigations:

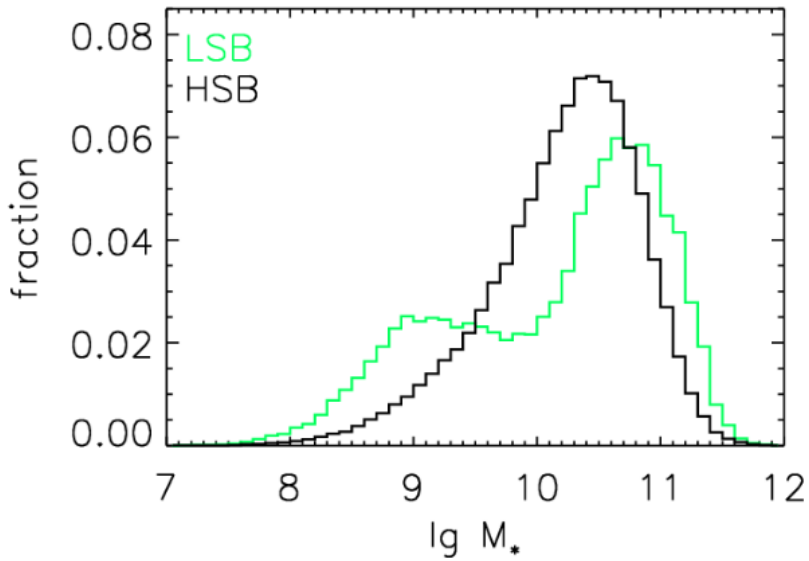
1. Selecting: image decompositions
2. Using Σ_* to select LSBs using the MaNGA data
3. Structural properties of LSBs using the MaNGA data
4. Giant LSBs,
5. Environments of the LSBs



Low-surface Brightness galaxies

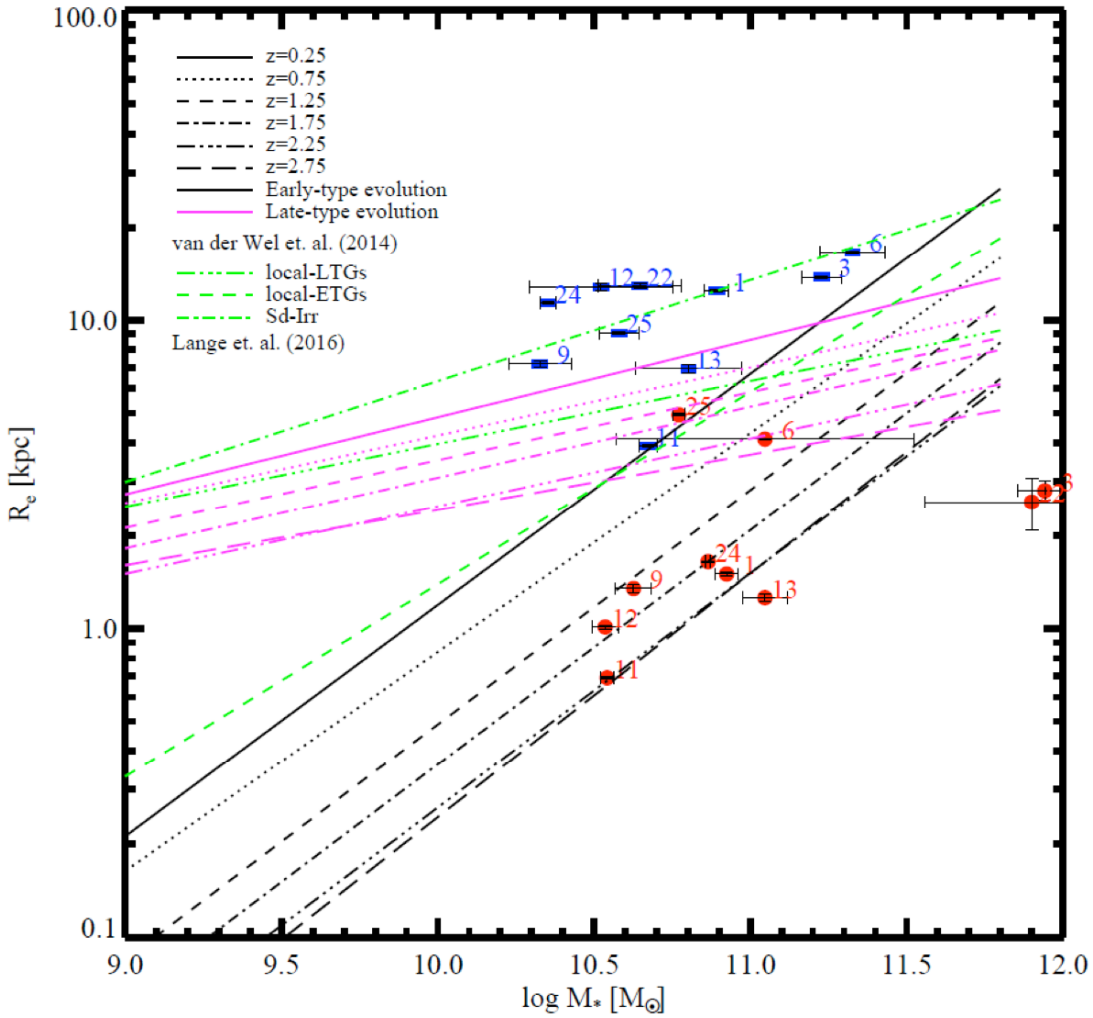
- LSB identification:
  - Previous: assume exponential disk model for the whole galaxy, fails for galaxies with bulges.
  - $\mu_0(B) > 22.5$ mag/arcsec^2, where $\mu_0(B)$ is from Simard et al. 2011.
    - $p_{ps}<0.4$: (devecular + exponential) fit
    - $p_{ps}\geq 0.4$: pure sersic fit





Low-surface Brightness galaxies

- Giant Low-surface Brightness Galaxies (GLSBs)



HSC deep images of LSBs

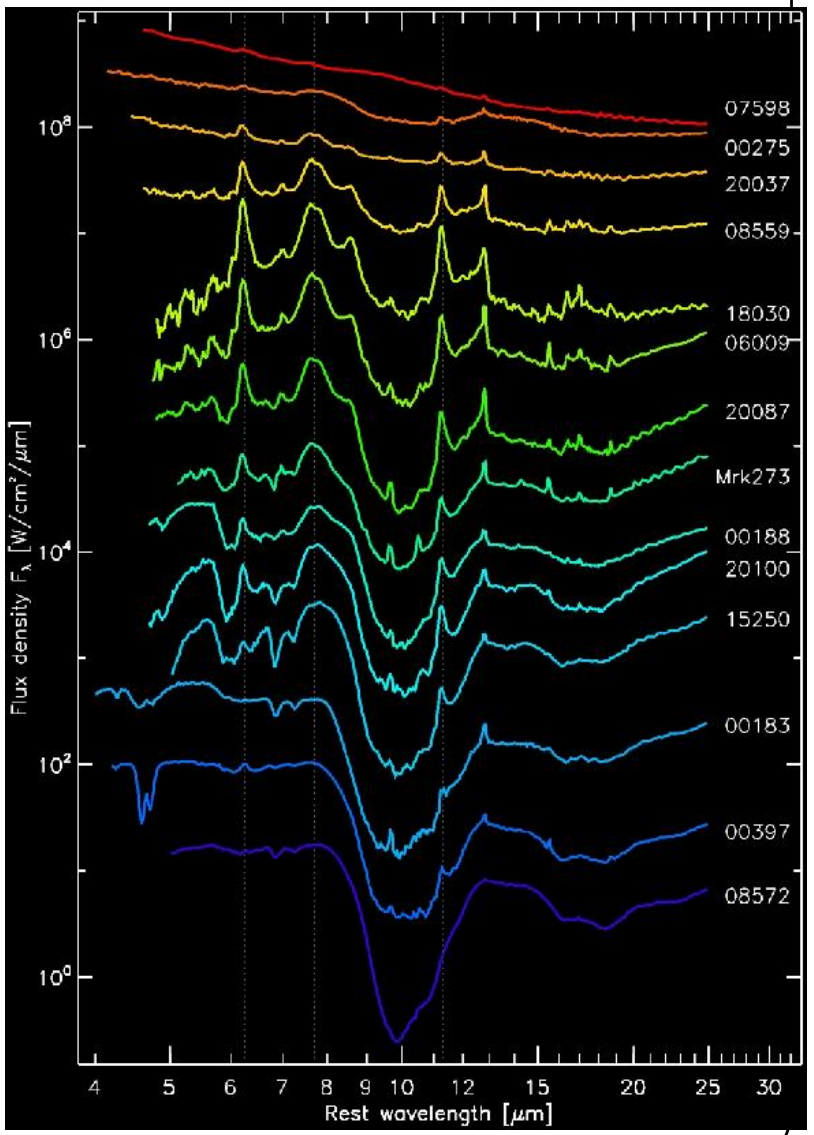
Sathuram et al., in prep.

- Infrared studies of AGN and galaxies
- AGNs at $2<z<4$ (HETDEX)

Infrared Spectra: Spitzer (and JWST)

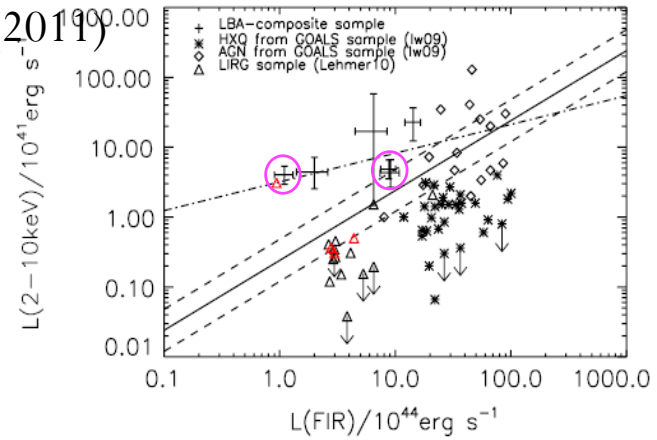
- A sample (600 galaxies) with uniform mid-IR spectra (from Spitzer) and optical spectra (from SDSS)
  - AGN torus, Starbursts
  - Molecular emissions
    - Dust: silicates and PAHs
    - Gas:
      - H2 emission, other molecules
  - Atomic emissions of gas
    - [NeII], [NeIII], [SIII], [SIV], [NeV], [OIV], etc.
  - Diagnositc power

Lyu, Hao & Li, 2014; Xie, Hao, & Li, 2014; Xie, Li, Hao & Nikutta 2015; Xie et al., 2016

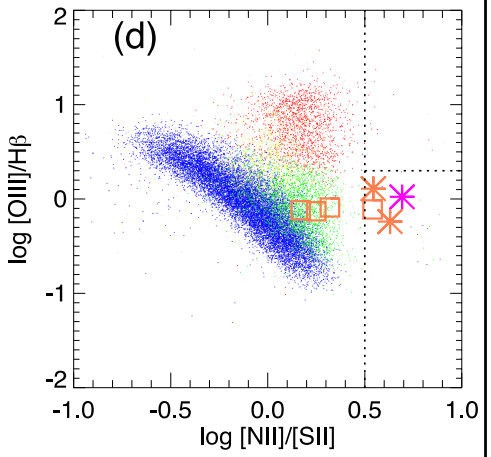


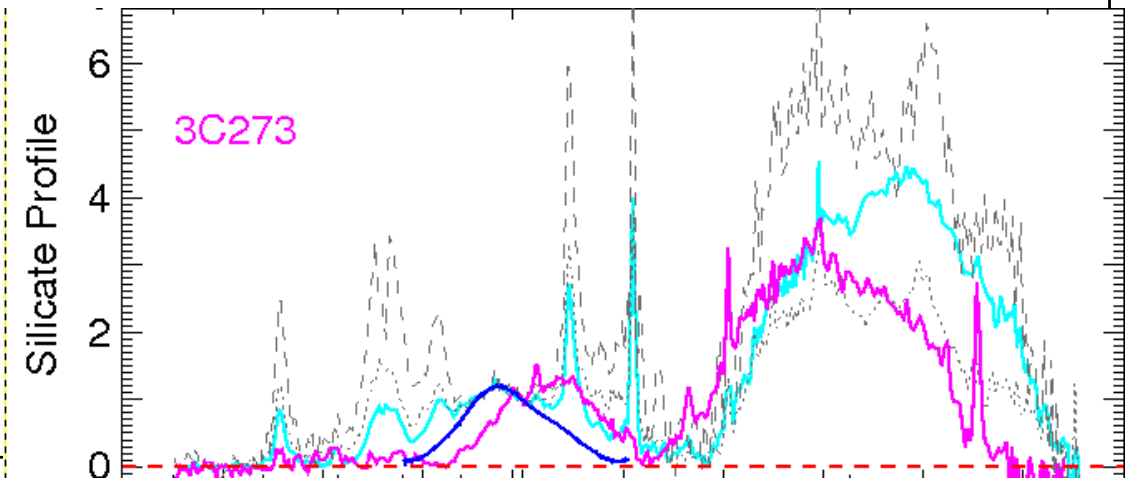
A Tale of 3 galaxies

Jia et al. (2011)



- No evidence of AGN in almost all bands, except maybe in hard X-ray.
- Extreme starburst:
  - Lyman Break Analog (Heckman, 2005)
  - Compact in UV
  - Strong outflows seen in UV absorption spectra
  - WR signatures
- Silicate emission by starburst?
- Other unusual things:
  - Crystallized silicate
  - Strong [NII]/[SII]
- torus in forming?





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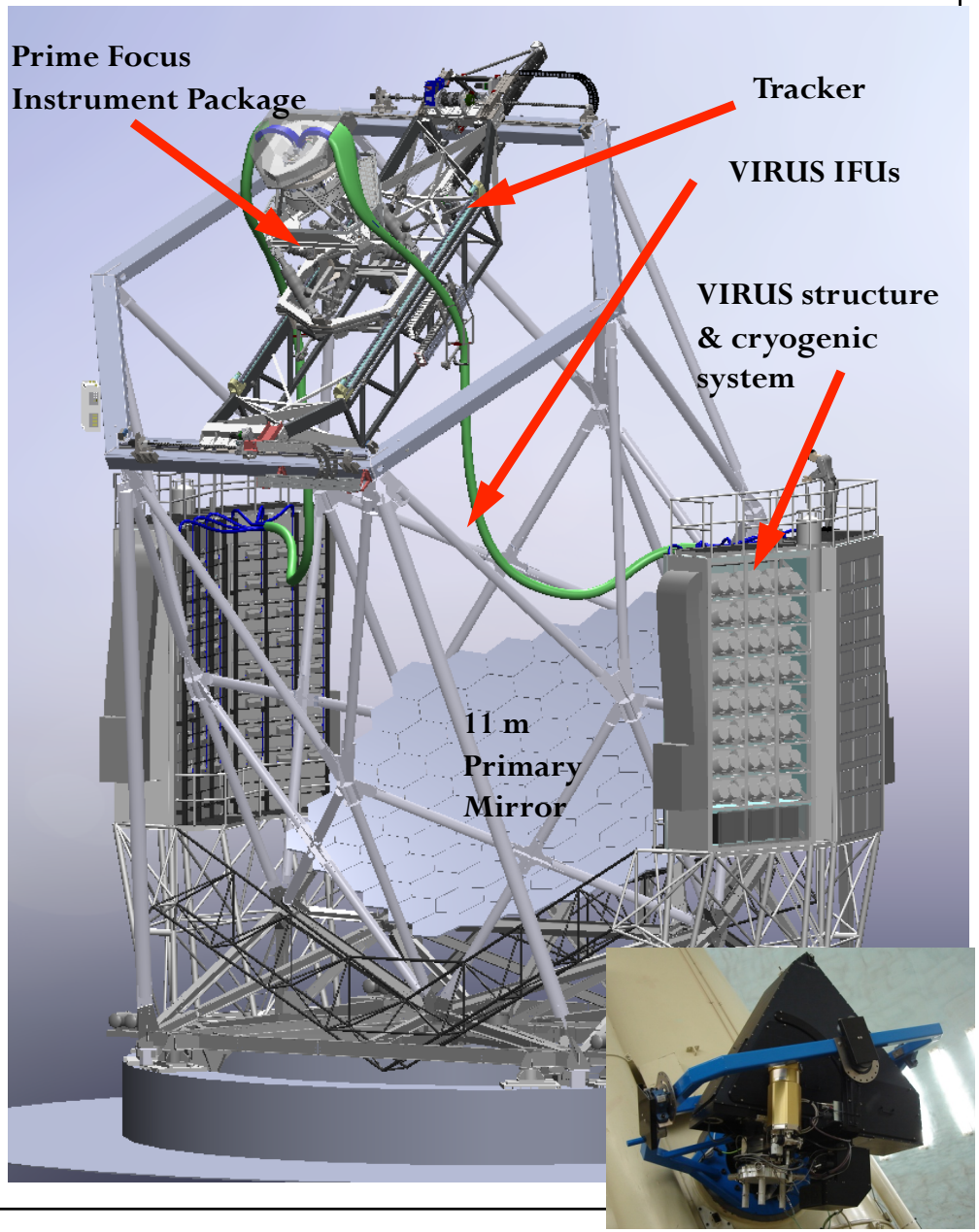
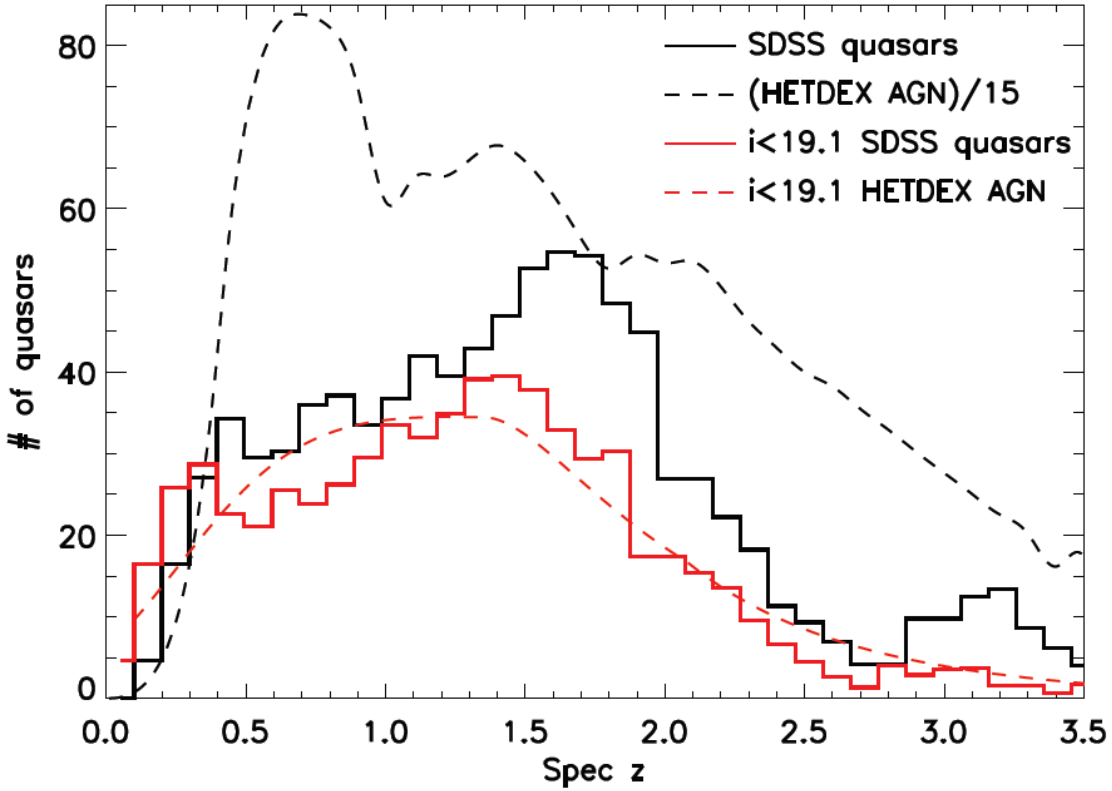


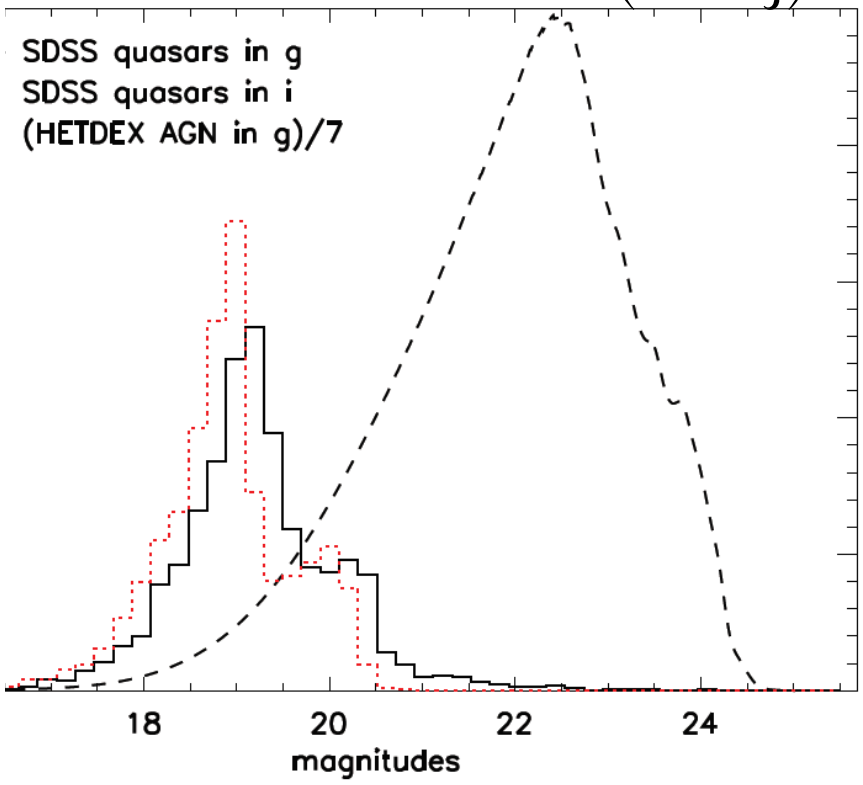
HETDEX

HSC images of HETDEX AGNs: host properties

- Largest lower-luminosity AGN sample at high-z
- >20,000 spectroscopically confirmed AGN at z~2-4, down to g~24mag

with Andreas Shultz (NAOJ)





Subaru Connections (me)

- HSC images:
  - LSBs
  - HETDEX AGNs
- IFU instrumentation developments:
  - CHILI
  - Possible developments on IFU instrumentation for the 4m telescopes in built
- Infrared properties of galaxies and AGNs

Subaru Connections (China, incomplete)

- PFS:
  - 6 institutes in China (10s people)
- 1 μ m Subaru HSC survey of a JWST field: time-domain observations looking for earliest BHs and earliest SNs. (by Lifan Wang, see the poster in the meeting.)
- A wide community on AGN sciences
- Facilities in China

Subaru Connections (China, incomplete)

- Facilities in China:
  - LAMOST (ref. the talk by Haining Li)
  - FAST
  - CSST (an imaging and slitless spectroscopic survey of 17500 square degrees)
  - Large Optical/Infrared Telescope (12m)