# Status of Low-z Science Study of ULTIMATE Subaru

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# Team Members

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* T. Takeuchi (Nagoya U.)
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# ZOOM Meetings

* 3 ZOOM Meetings so far
  * 2017/10/12
  * 2017/12/8
  * 2018/1/12
* Geological distance is a problem
  * Esp. timezone
  * Welcome new members from anywhere!

# Basic Survey Strategy

* Advantage of ULTIMATE
  * High spatial resolution with wide FoV
* Probe internal physical structure of nearby galaxies
  * Multiple emission line diagnosis may be the key

# Emission Lines in the NIR

* HI Lines (Br-G, Br-D, Pa-A, Pa-B) : HII region
* H2 Lines : Warm molecular gas (PDR, SNR, etc)
  * Rotation-vibration lines
* [FeII] : SNR, PDR
* (CO absorption) Evolved stars

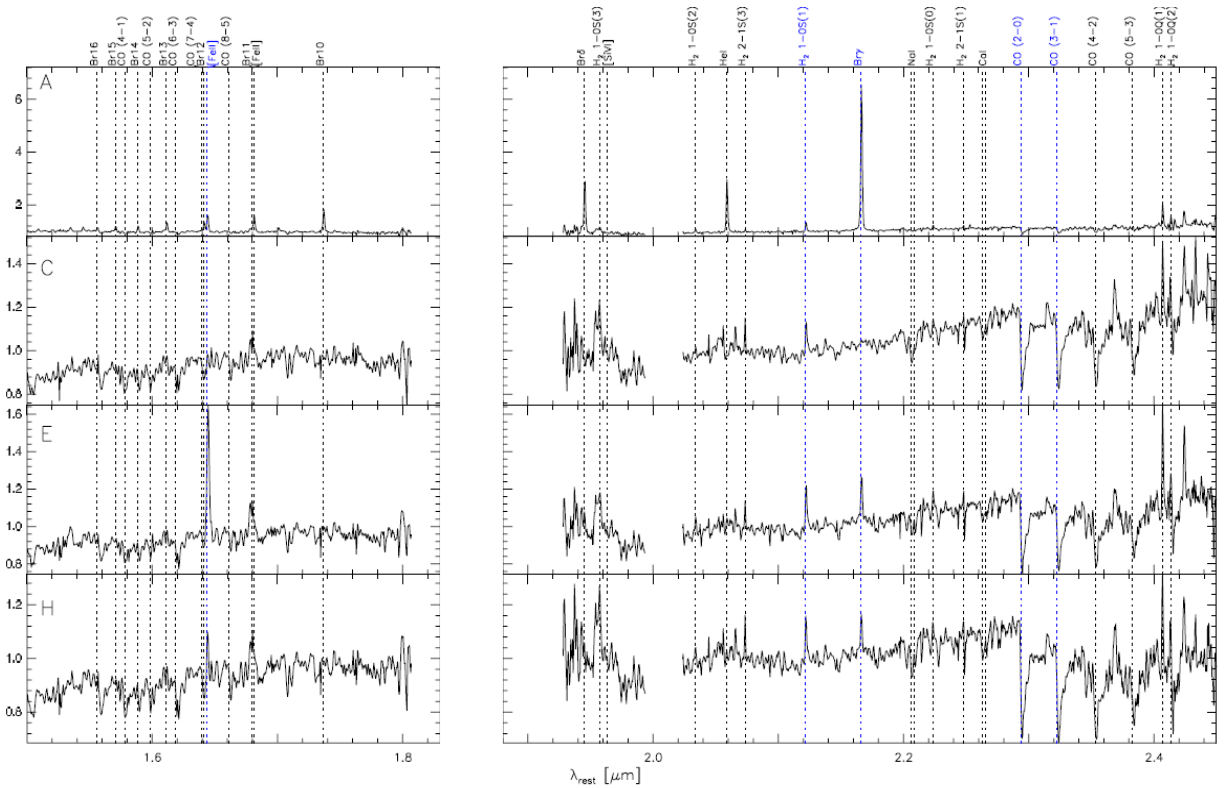


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**Figure 3.** Normalized $H+K$ spectra of the apertures A, C, E, and H (see Figure 4 for reference). Aperture A is located at the maximum of the Br$\gamma$ emission, aperture

# Science Cases

* Resolved SF, KS-law using Br-G and Pa-B
* Ram-Pressure Stripping in Local Galaxy Clusters
* Intragroup Starburst in  Compact Groups of Galaxies
* Formation and Evolution of Stellar Clusters
* ANU, Taiwan proposals !!
  * Nearby AGN ionization

# NIR Narrow-band Imaging of Nearby Galaxies (Koda)

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**Table 3**
Integrated Fluxes of the $H_2$ Lines for the Optical Nucleus and the Inner arc

| Line | λ ($\mu$m) | Flux ($10^{-15}$ erg s$^{-1}$ cm$^{-2}$) | |
|---|---|---|---|
| | | Optical Nucleus | Inner Arc |
| 1–0S(3) | 1.958 | $4.24 \pm 0.73$ | $1.19 \pm 0.20$ |
| 1–0S(2) | 2.034 | $0.50 \pm 0.27$ | $0.43 \pm 0.06$ |
| 2–1S(3) | 2.073 | $1.30 \pm 0.19$ | $0.23 \pm 0.05$ |
| 1–0S(1) | 2.122 | $1.85 \pm 0.26$ | $1.24 \pm 0.15$ |
| 1–0S(0) | 2.223 | $0.73 \pm 0.14$ | $0.44 \pm 0.05$ |
| 2–1S(1) | 2.248 | $0.55 \pm 0.19$ | $0.34 \pm 0.07$ |

* Overall understanding of ISM physics in galaxies
  * Obscured regions
  * NIR emission line is crucial
* NBFs imaging
  * 4 NBF x redshift bins
  * SFR indicator : Pa-B/Br-G
    * Extinction correction as well
  * Shock and PDR: H2 rot-vib lines
    * Multiple line diagnosis

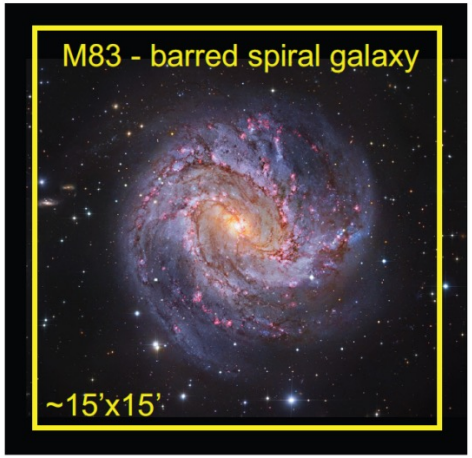
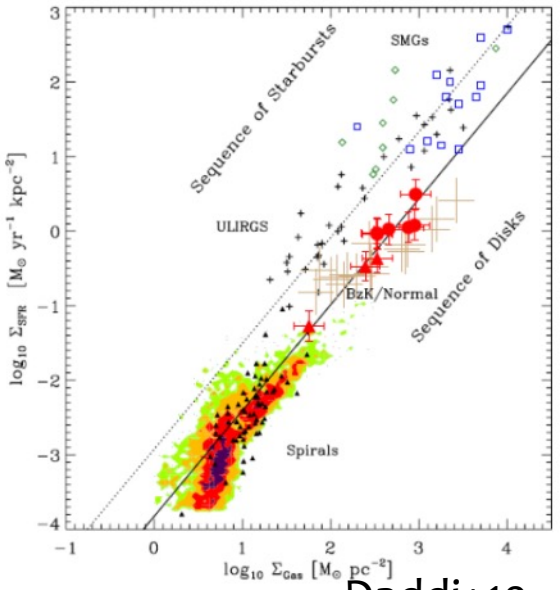



Figure 1: The barred-spiral galaxy M83 (composite image of Subaru, HST, and ESO telescopes; Processing & Copyright Robert Gendler). The box indicates a 15'×15' region.

# HII Mapping Survey of Local Galaxies (Kaneko)

* Star-Formation – GMC relation
  * What makes the difference of observed Disk/Starburst?
* More accurate understanding of K-S law
  * GMC scale resolution (fewx10pc)
  * Extinction free SFR probe
    => Hydrogen Recombination Lines
* NBF imaging of Nearby Galaxies
  * 2 NBFs x redshift bins
  * Pa-B
  * Br-G
  * Seeing 0.2” ⇔ 50pc @ z=0.01

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# Formation and Evolution of Stellar Clusters (Kim)

* Stellar Clusters : Probe of SFH, dynamics and structure
* Demographic census of SC in galaxies
  * High spatial resolution is required to avoid contamination from surroundings
* Broad-band Imaging of nearby galaxies
  * CC diagram => age, mass
* Additional Br-G/Pa-B NB imaging => more precise age/mass estimate

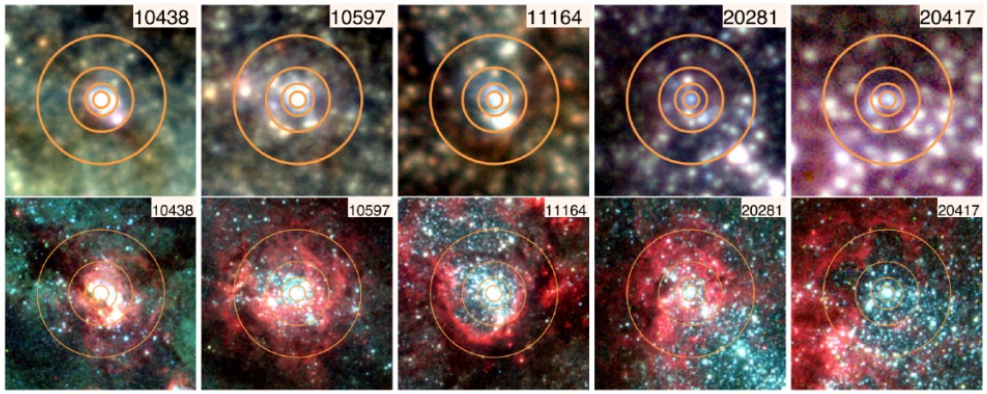
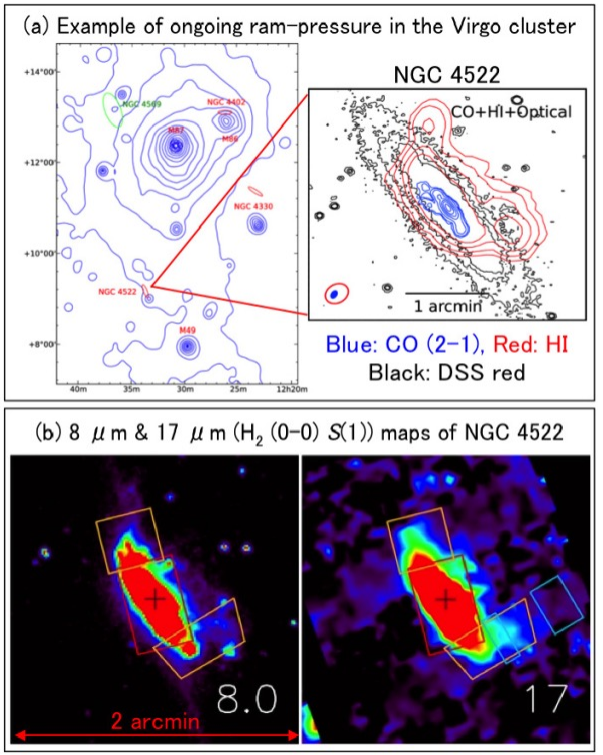



Figure 1: Figure 5 of Bastian et al. (2014). False colour composite images of a sample of clusters used in their work. Upper panels: VLT J-, H-, K-band composites. Bottom panels: HST/WFC3 B-, V-, Hα-band composites. The apertures used (11, 22, 44, 87 pc) are shown. In most of the NIR images, a source with a brightness similar to or larger than the central source is contained within the 44 pc aperture.

# Ram Pressure Stripping in Local Galaxy Clusters (Ueda, Saito)

* Probe galaxy quenching mechanism in high density regions
* Wide field H2 observations of cluster galaxies
  * Use H2 as a shock indicator
  * Start with MOS spectroscopy (GLAO + MOIRCS)
  * Multi-object IFU at K-band desired



# Intragroup Starbursts in Compact Groups of Galaxies (Ueda, Saito)

* CGs (density between field and cluster) shows various environment effects
  * Morphology-density relation is not so clear
  * Important to understand IGM physics
* Targets : HCGs
  * z<0.06
  * D<20 arcmin
* Wide field Br-G NB Image
  * 1NBF x redshift bins
  * H2 lines may be taken by targeted spec.
  * Multi-object IFU at K-band desired

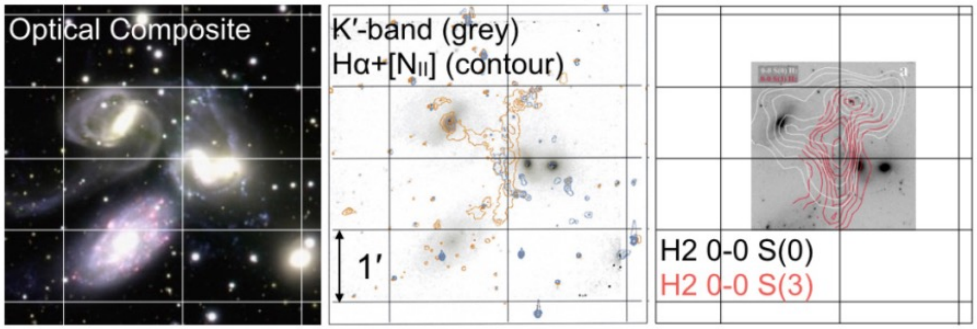



Figure 3: (a) Optical composite, (b) Hα+[N$_{II}$] narrow-band ($K'$-band image in grey scale), and (c) NIR pure-rotational H$_2$ images of the Stephan's Quintet (Xu et al. 1999, 2003; Appleton et al. 2017).

Stephan's Quintet shows strong shock in IGM

# Survey Targets

* Narrow-band Imaging Survey of Nearby Galaxies
  * NGC, UNGC catalog
    * 208 / 114 galaxies observable with Diameter > 5arcmin
    * Some of them are cluster galaxies
  * Nearby LIRGs
    * 153 U/LIRGS observable, which is also included in GOALS
  * Choose from SFR-M* parameter space
    * E.g.) 3 SFR, 3 M* bins
    * ~10 galaxies / bin => 100 galaxies in total

# NBF Observations

* BBF : JHKs
* Various NBFs
  * Br-G : 2.166μm
  * Pa-B : 1.282μm
  * H2(v=1-0)S(1) : 2.122μm
  * H2(v=1-0)S(3) : 1.958μm
  * ([Fe II] : 1.644μm, H2(v=2-1)S(1)..)
  * Several sets for different redshifts
* 30min/NBF, 30min/BBF
  * 3.5hr/galaxy => 2 galaxies/night
  * 100 galaxies / 50 nights

# Summary

* Emission-line imaging is crucial for nearby galaxy science
  * Br-G, Pa-B, H2(v=1-0)S(1), H2(v=1-0)S(3)
  * K-band MOS/Multi-IFS
  * May have good synergy with ALMA/EVLA
* Nearby Galaxy Survey
  * From NGC, UNGC catalog
  * 50nights / 100 galaxies

# Backup Slides

# H2 Line Diagnosis

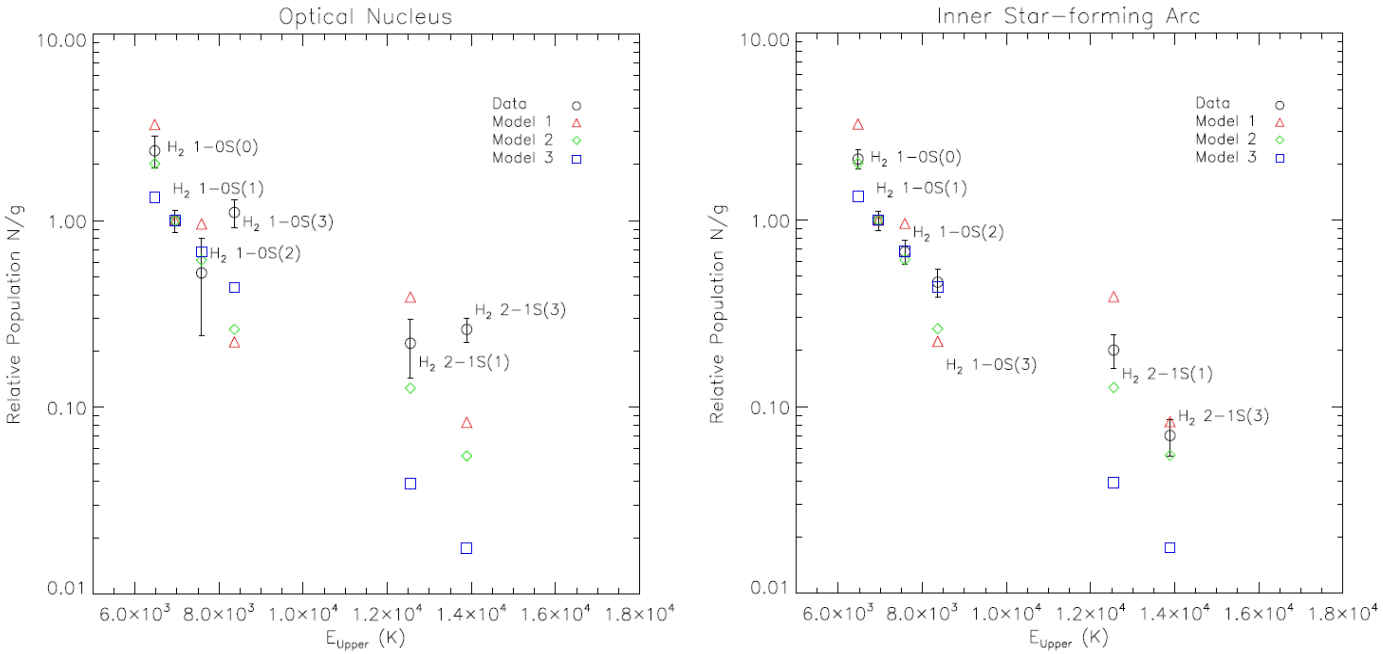



**Figure 8.** $H_2$ excitation diagrams relative to 1–0S(1) for the optical nucleus (left panel) and the inner star-forming arc (right panel). The lines from which the population

Model 1 : n_H=1e3 + UV fluorescence
Model 2 : n_H=1e4 + UV fluorescence
Model 3 : thermalized T=2000K

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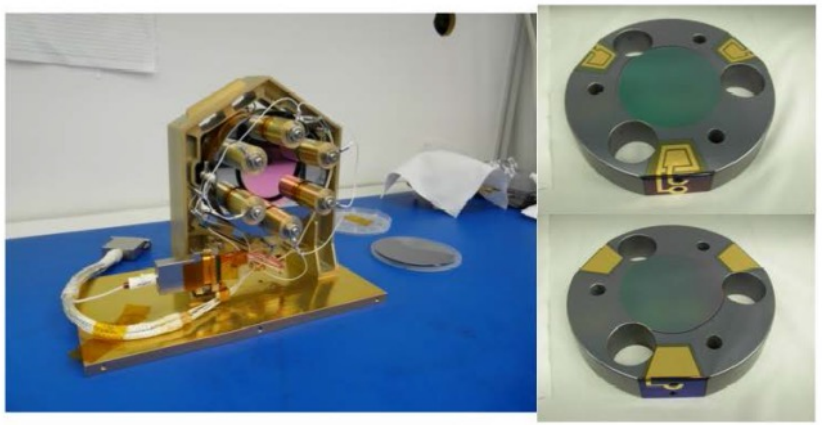
# NBF or Tunable Filter

* Current requests to NBFs
  * Br-G, Pa-B, H2(v=1-0)S(1) , H2(v=1-0)S(3), H2(v=2-1)S(1)
  * R=100 : Δz=0.01
  * 4~5 filters per redshift bin
* Fabry-Perot Tunable Filter?
  * Not a established technology
  * Wavelength calibration is critical, and challenging
  * Applying to KAKENHI for R&D (Takahashi et al.)



Ethalon of JWST/TFI
Doyon et al., ProcSPIE 7731, 77310F (2010)

# Emission-Line Sensitivity

* SFR density sensitivity of HAWK-I/VLT ETC (3600sec, 1arcsec^2 aperture):

  Br-G : ΣSFR=2e-7Msun/yr/pc^2 (5sigma)

  Pa-B : ΣSFR=3e-8Msun/yr/pc^2 (5sigma)

# Comparable with Pa-A obs by miniTAO 1m

* Komugi, Tateuchi, KM+12
  * 1.5hr exposure