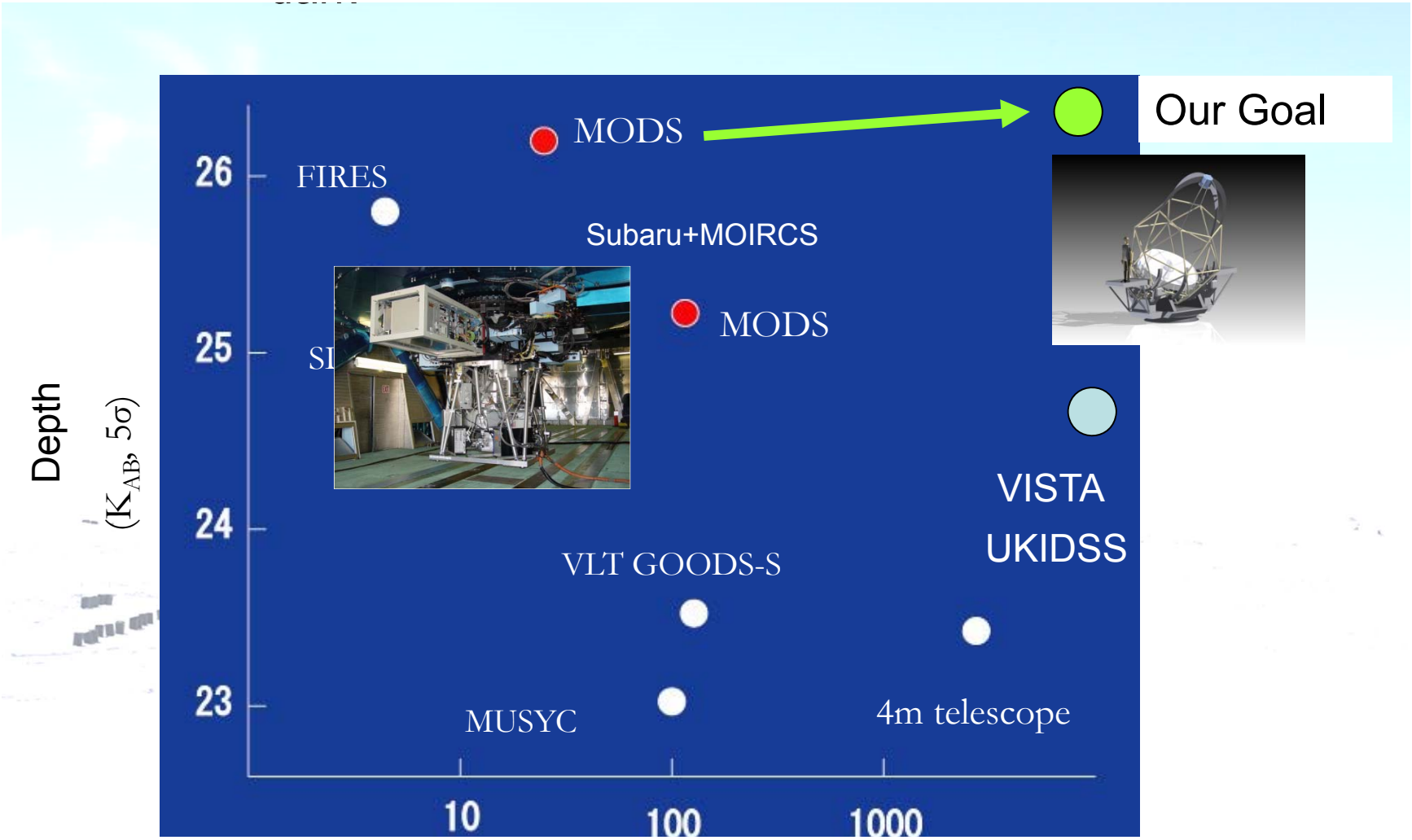
「銀河の広域探査」
@南極赤外線望遠鏡ワークショップ
2013/09/13

○森下 貴弘(M2)、小幡 朋和(M1)、
市川 隆（東北大学）
AND
南極コンソーシアム

南極望遠鏡　メインテーマ

- 銀河広域サーベイ
  - ✗ テラヘルツ銀河の広域探査と星生成活動
  - ✗ クラスターに存在する銀河（LBGs）調査
- 系外惑星
  - ✗ スーパーアースの水大気
  - ✗ 惑星大気
- 超新星
  - ✗ II型超新星探査

銀河広域サーベイ



市川（光天連シンポ2013）

Keywords

- Proto-Quasar / Proto-Cluster.
  - ✗ The formation of early-type galaxies (ex. Tamura+10).
  - ✗ (“Monolithic collapse” (Eggen et al. 1962)? / “(Major) Merger” (Searle & Zinn 1978)?)
  - ✗ 赤い銀河（Passive Galaxies or Dust-obscured Galaxies）の探査
- Search for over-densities near the SZ locations.
  - ✗ Red-sequence galaxies (ex. South Pole Telescope group).
- Search for SMGs.
- 重力レンズ
  - ✗ z>4のStarburst galaxies (Vieira+13)

Strazzullo+13

- z~2のcluster中心には、Passive compactだけでなく、Dusty-Red SFGsも存在する。
- （Tanaka+13でも）

IRAC/X-ray selected clusters; 10^{10}Msun/ UVJ-color

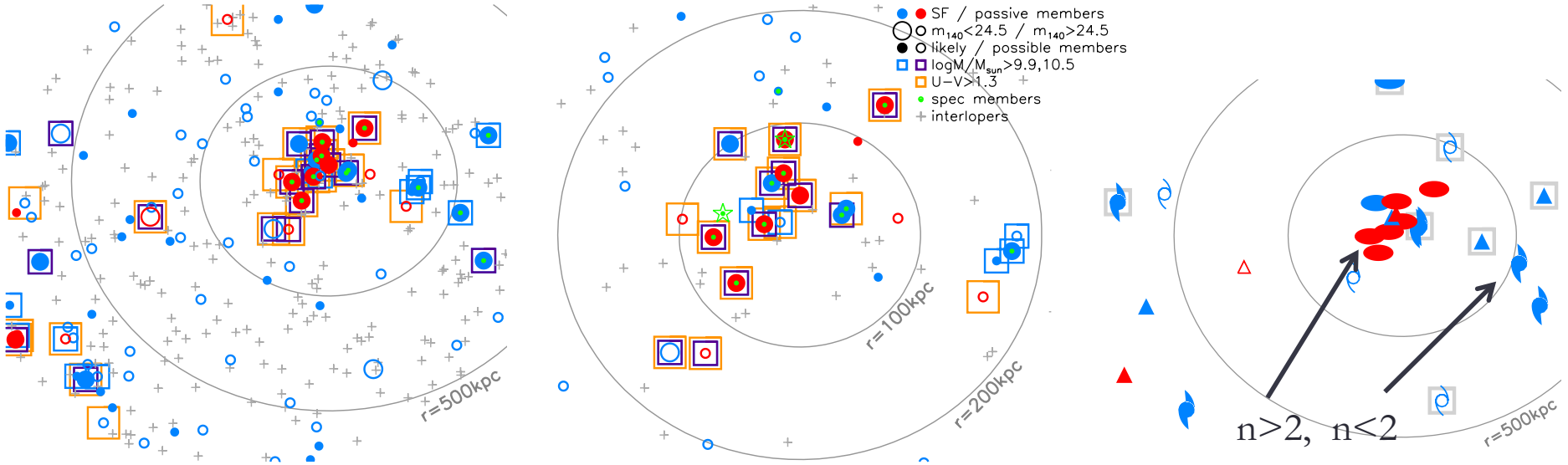
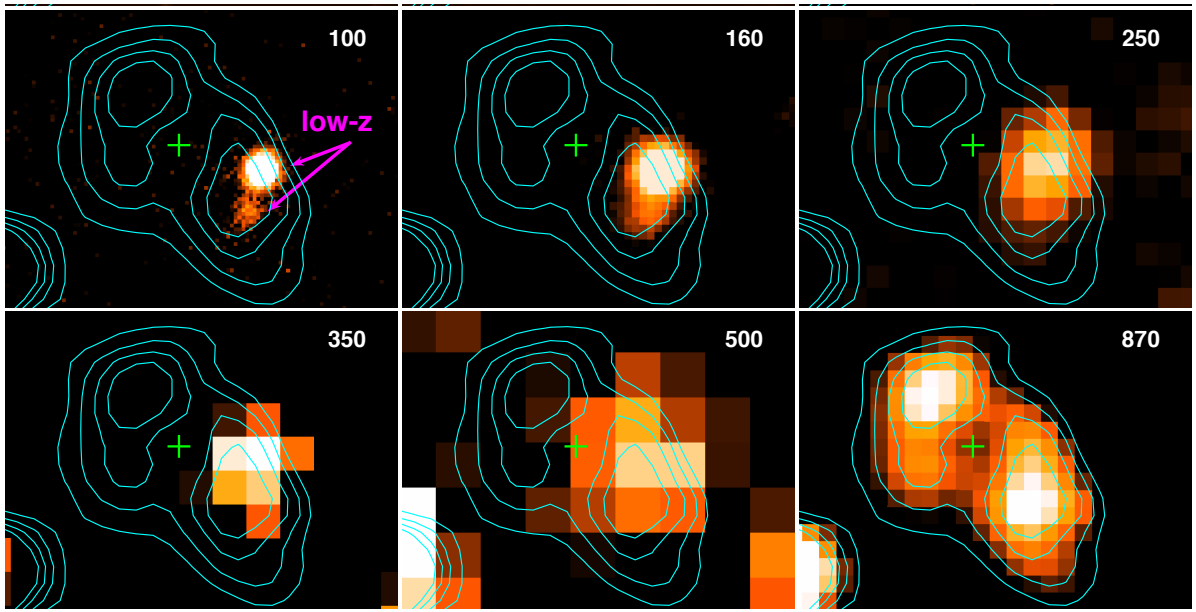


Figure 4. Left: the distribution of galaxies brighter than $m_{140} = 25.7$ in the studied field. Interlopers are plotted as gray crosses, while passive and star-forming candidate members are highlighted in red and blue, respectively. Filled and empty circles show likely and possible candidates, and spectroscopically-confirmed members are marked with a small green point in the center. Large and small circles show sources brighter than $m_{140} = 24.5$ and $m_{140} = 25.7$, respectively. Yellow squares mark candidate members with rest-frame $U - V > 1.3$, while blue and purple squares show the *mass-complete* samples of members more massive than $\log M/M_{\odot} = 9.9$ and 10.4, respectively. Solid gray circles show clustercentric radii of 250 and 500 kpc (proper) at the cluster redshift. North is up, east to the left. Right: a close-up of the left-hand panel in the cluster center. Symbols are the same, gray circles mark clustercentric radii of 100 and 200 kpc (proper) at the cluster redshift. Two AGNs spectroscopically confirmed to belong to the cluster (Gobat et al. 2013) are marked by green stars.

(A color version of this figure is available in the online journal.)

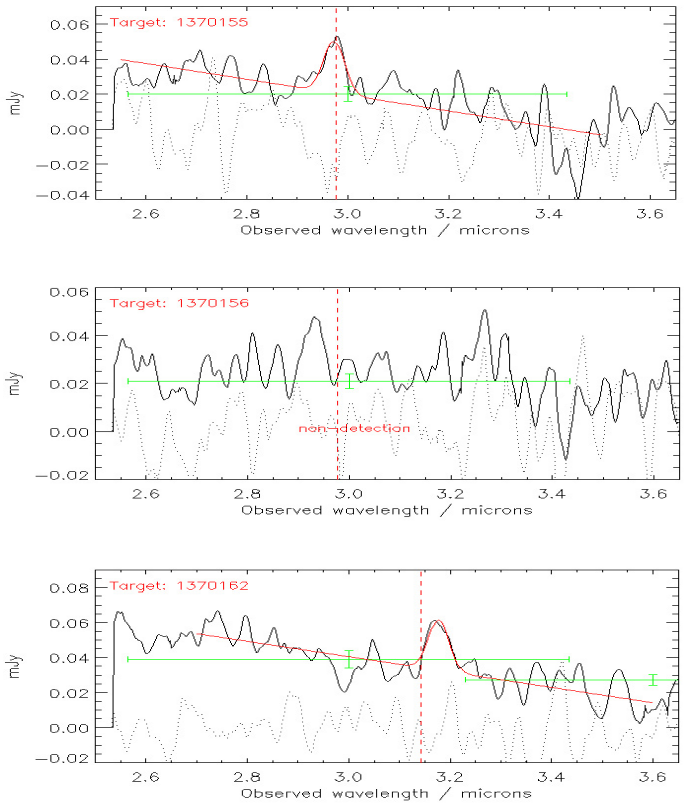
Boone+13 : Herschel Normal SFGs

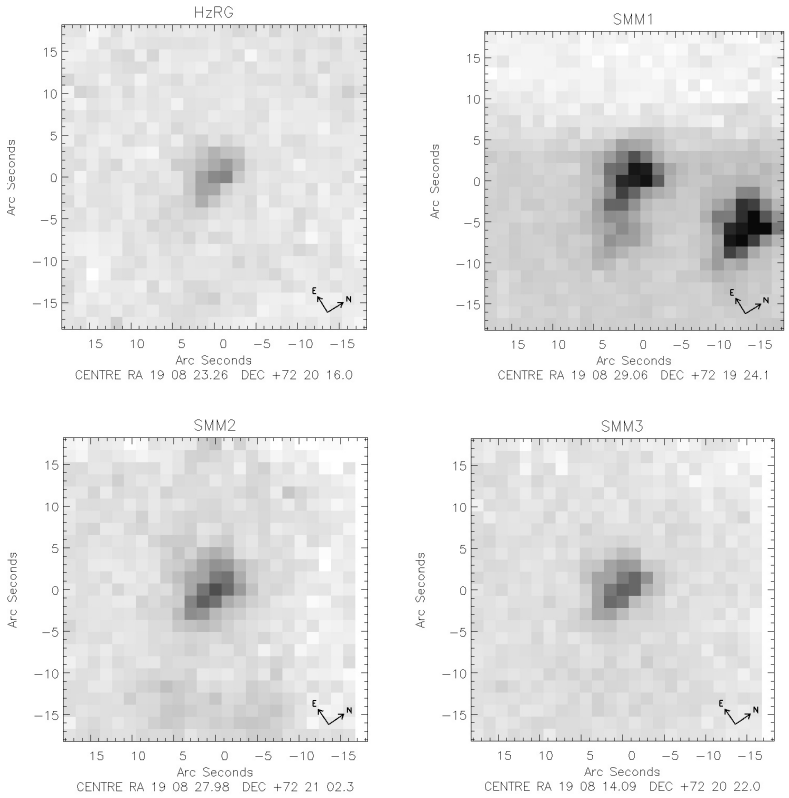
- Herschel lensing galaxy + 870 μm APEX/LABOCA follow up
  - ✗ Drop out (Flux Ratio $S_{870}/S_{500} > 0.5$) : $z > 4.0$
- VLT/FORS spectroscopy
  - ✗ A 'normal' dusty galaxy at z~6.107 ?
  - ✗ $L_{FIR} \sim 5 - 15 \times 10^{11}\ L_{\odot}$ (SFR ~ 80 – 260 $M_{\odot}$ yr^{-1})



Sedgwick+13 : AKARI Spectroscopy

- SMGのうち、Redshiftが既知の明るい天体。(z~3.5-4.0)
- AGN Binary at z>3.5?
  - ✗ PSF FWHM=4.7”





High+10

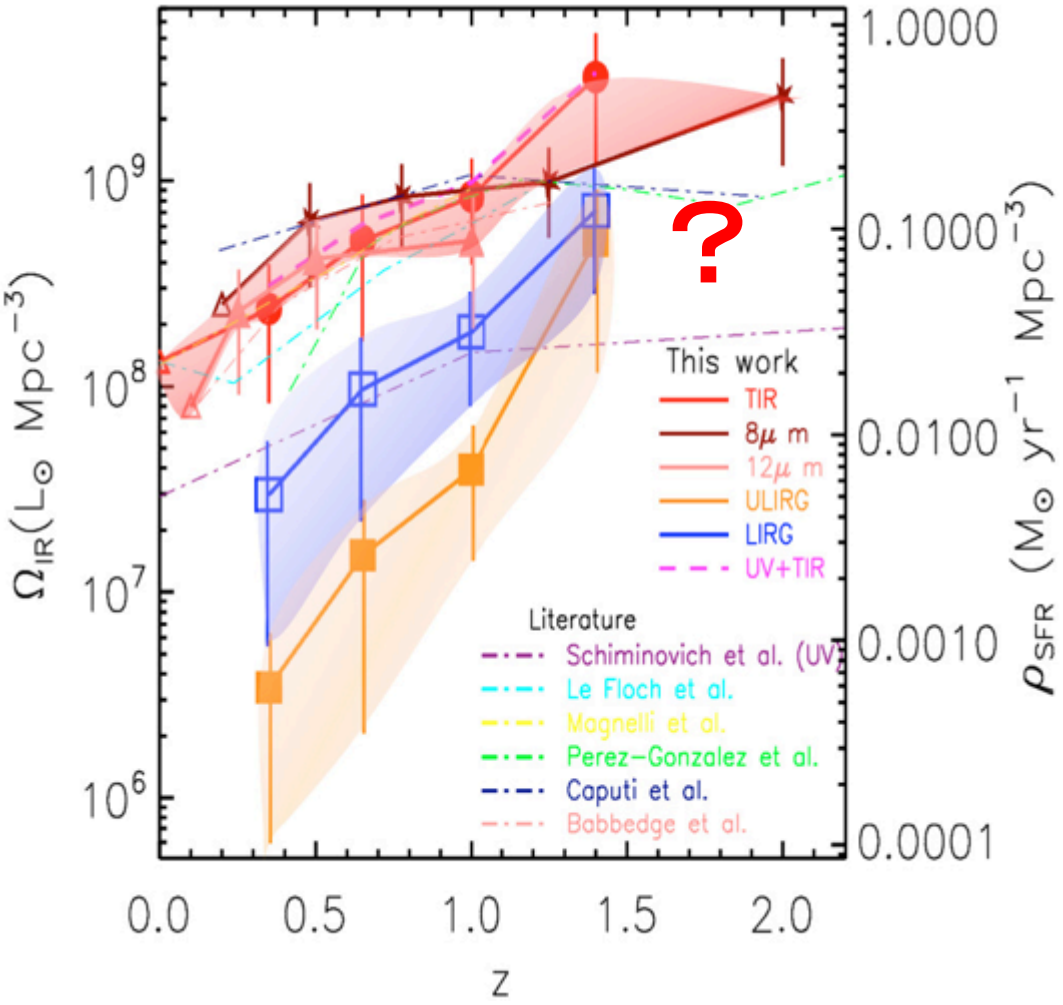
- South Pole Telescope (SPT) : SZ survey
  - ✗ 21 galaxies were detected in a 178 deg^2
  - ✗ $0.15 < z < 1.0$
  - ✗ The Blanco Cosmology Survey date (BCS; Ngeow et al. 2006)
    + 可視光(grizバンド)follow up 観測
  - ✗ → Cluster mass, radius, redshift

Reichardt+13

- South Pole Telescope (SPT) : SZ survey
  - ✗ 158 galaxy clusters were detected in a 720 deg^2
  - ✗ 135 were first identified as clusters
  - ✗ $0.55 < z < 1.37$

by Obata

THz銀河の赤外線 follow up観測



- Goto+ 10

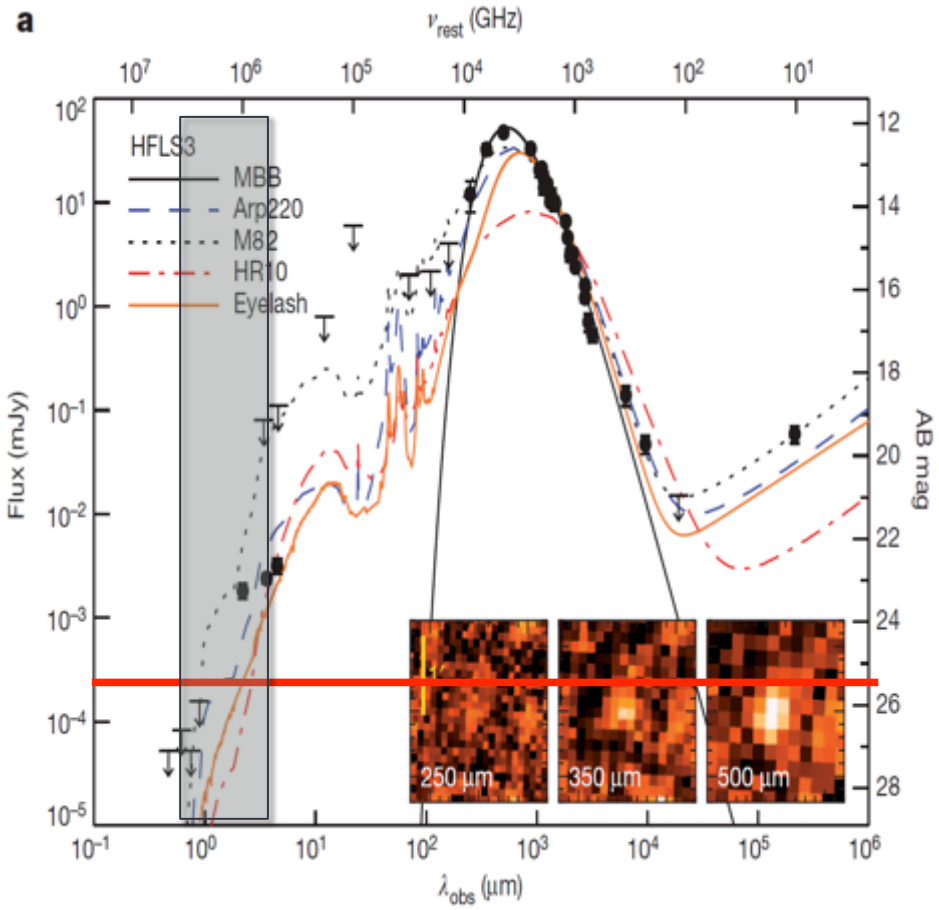
High-zになるにつれ、
赤外線光度が支配的になる。

High-zで赤外線で輝くTHz銀河
→ 遠方銀河の赤外線寄与

by Obata

THz銀河の赤外線 follow up観測

●Riechers+ 13



z=6.34のdust Massive Galaxy
南極赤外線望遠鏡の感度なら観測可能！

他にも…
BHの有無 (Johnson+ 13)
Galactic wind (Veilleux+ 05)
銀河進化史においても重要！

by Obata

SZ effect survey:Galaxy cluster survey

- SZ effect
  - ✗ Galaxy clusterのhot gasによってCMBが逆コンプトン散乱
  - ✗ CMBのズレを観測することで、Galaxy clusterを検出できる

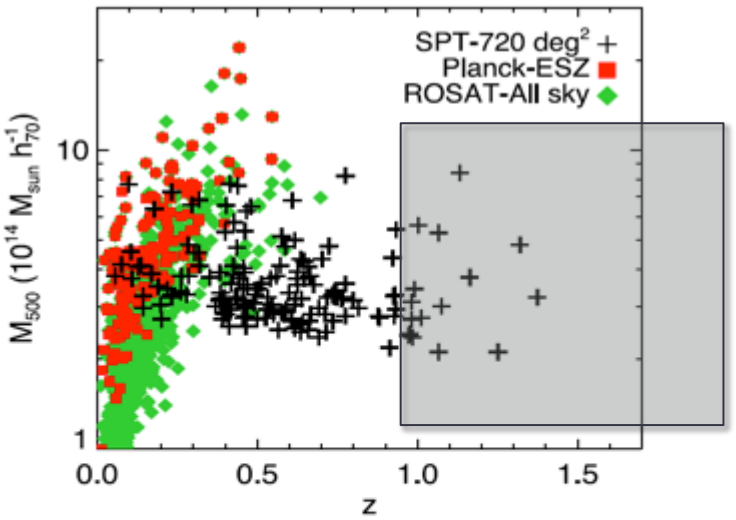


Figure 4. Mass estimates vs. redshift for three cluster samples: (1) optically confirmed SZ-selected galaxy clusters from the SPT survey, (2) SZ-selected galaxy clusters from the *Planck* survey (Planck Collaboration et al. 2011), and (3) X-ray-selected galaxy clusters from the *ROSAT* all-sky survey (Piffaretti et al. 2011). High-resolution SZ surveys, such as that performed with the SPT, uniquely have a nearly redshift independent selection function. The redshift-dependent selection in the *Planck* survey is due to beam dilution; the redshift dependence of the *ROSAT* catalog is due to cosmological dimming.

(A color version of this figure is available in the online journal.)

Reichardt+13

- 赤外線・可視光によるfollow up
  - ✗ 1m Swope telescope
  - ✗ 4m Blanco telescope
  - ✗ Spitzer/IRAC 3.6,4.5μm etc.
- Follow upできなかった天体
  - ✗ Follow up観測限界？
  - ✗ SPTのfalse detection

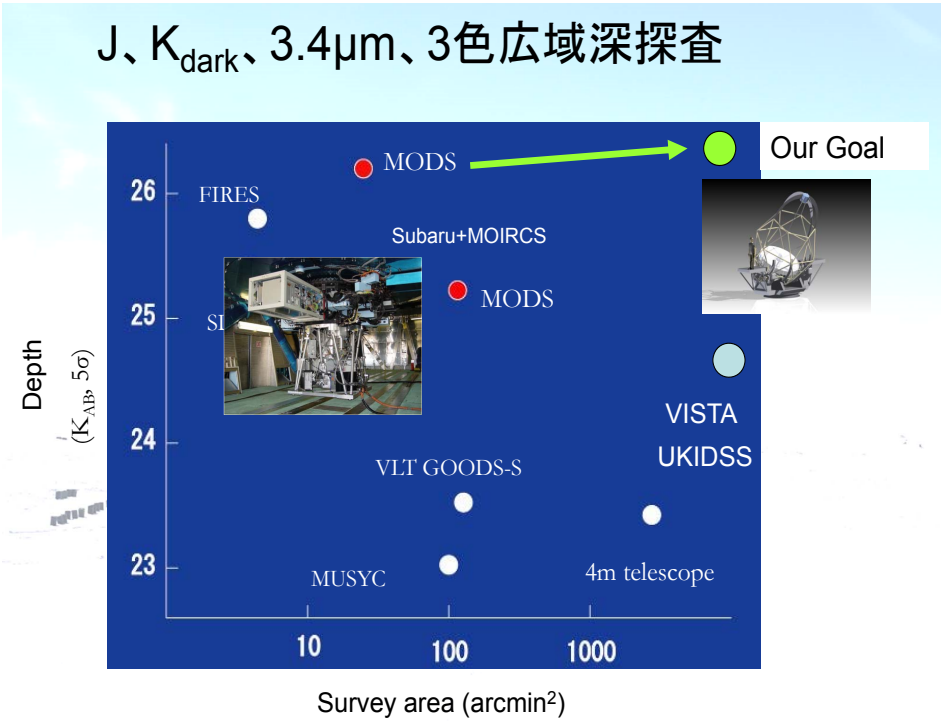
by Obata

SZ effect survey:Galaxy cluster survey

Reichardt+13

●赤外線・可視光によるfollow up
- ✗ 1m Swope telescope
- ✗ 4m Blanco telescope
- ✗ Spitzer/IRAC 3.6,4.5μm etc.

→ 5σ point-source limiting magnitude
< 25mag (in griz band)



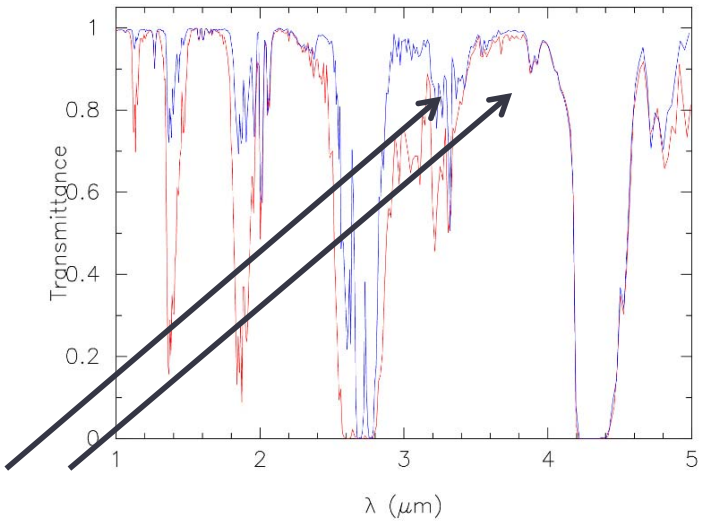
南極赤外線望遠鏡
5σ point-source limiting magnitude
> 26mag
=> High-z Galaxy clusters

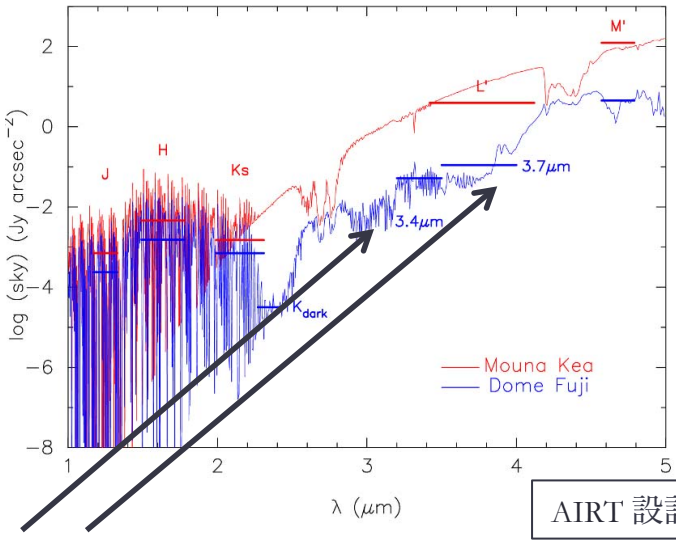
静止系での可視光の輝線を観測
→ 輝線強度診断でAGN確認？

by Obata

Our Contribution?

- 2 - 5 umでの高い透過率、空の暗さ（他のサイトでは困難な3.4um)
- 0”.2 (@optical) という優れたシーイング条件





AIRT 設計まとめより

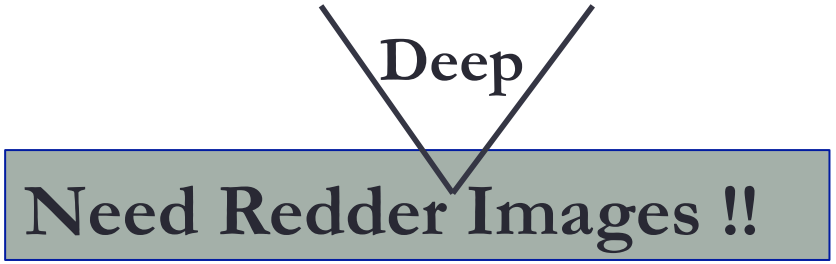
✗ A, L’-band Survey for Higher Redshift (3<z<6) galaxies.
これまでよりもhigh-zでの「普通な銀河」のサーベイ

✗ Internal Morphology with Highly Resolved Imaging.
高い空間分解能を活かした詳細な銀河内部の調査

Survey for galaxies at z>3.

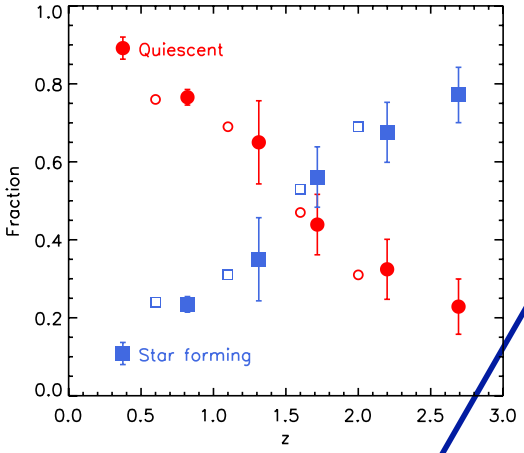
- MOIRCS Deep Survey (MODS; Kajisawa+09)
  - ✗ J, H, K_S-band deep survey @ Subaru/MOIRCS
  - ✗ Massive (>$10^9 M_{sun}$) galaxies at z<3.
- CANDELS H_{160}-band (FWHM~0".18, m_H~25 mag)

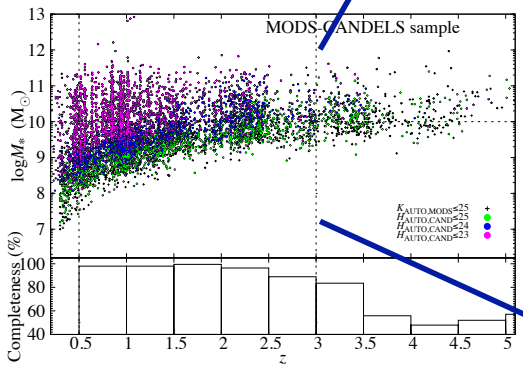
- ->激進化期の銀河の形態調査

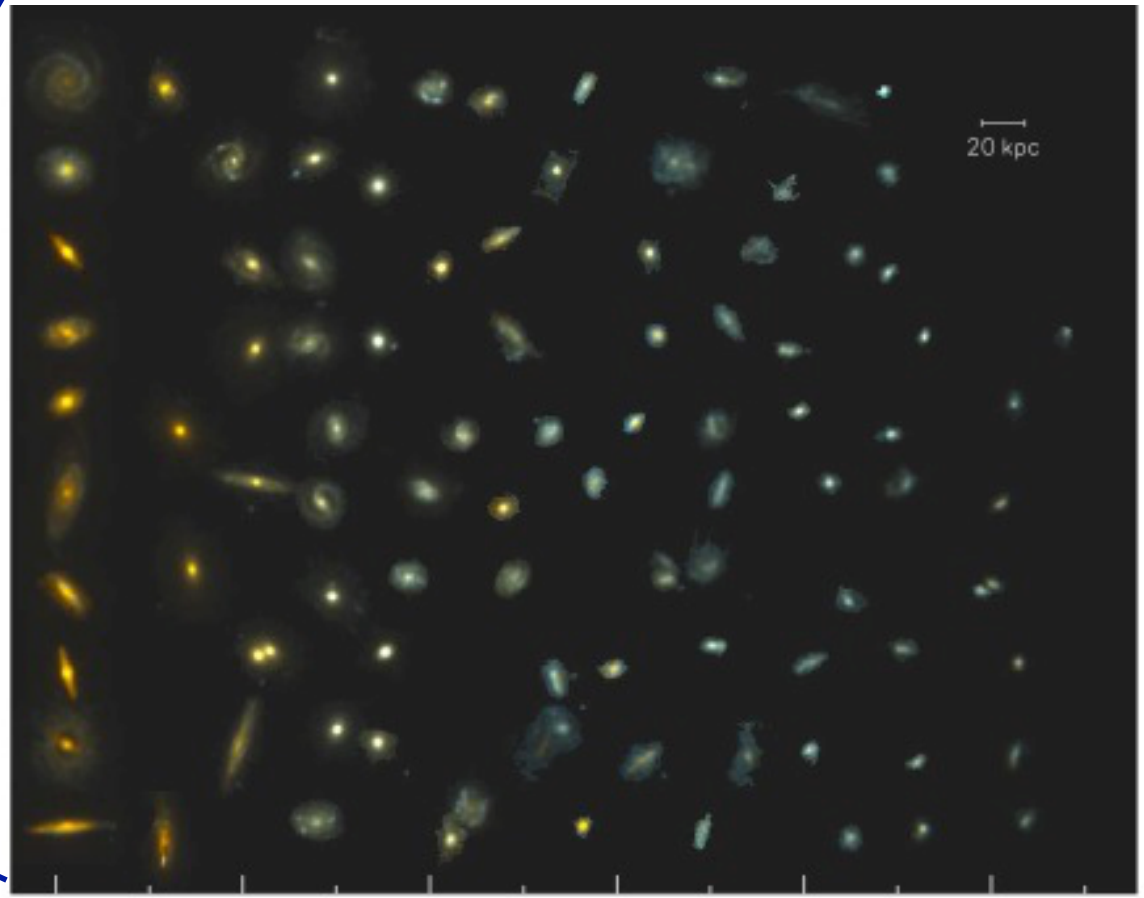


Survey for galaxies at z>3.

- A (L')-band deep survey ?
- Finding the "normal" galaxies at z~3 to z~5-6.







Detection Limit

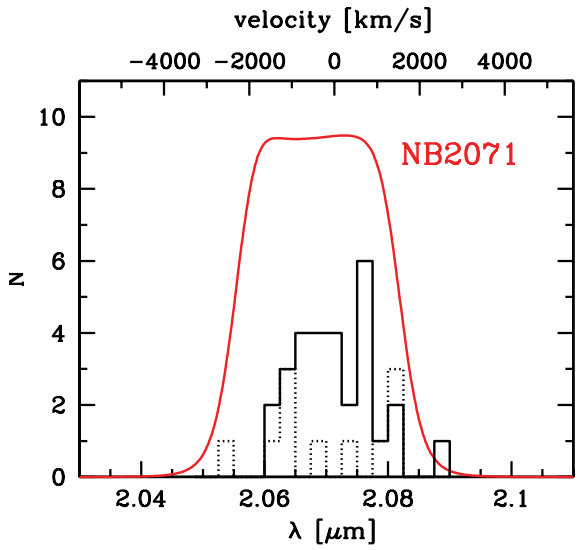
- 10 hr :
  - ✗ 20.9 mag (3.4um)
  - ✗ 20.4 mag (L')
- 30 hr :
  - ✗ 22.1 mag (3.4um)
  - ✗ 21.6 mag (L')
- 100 hr ? :
  - ✗ 23.4 mag (3.4um)
  - ✗ 22.9 mag (L')

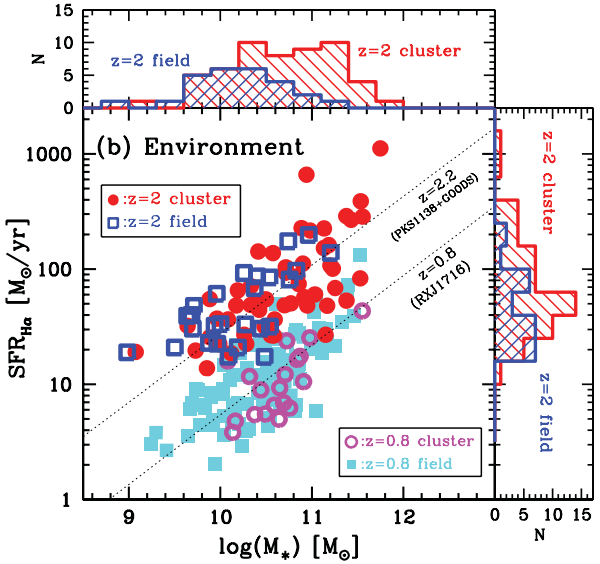
要検討

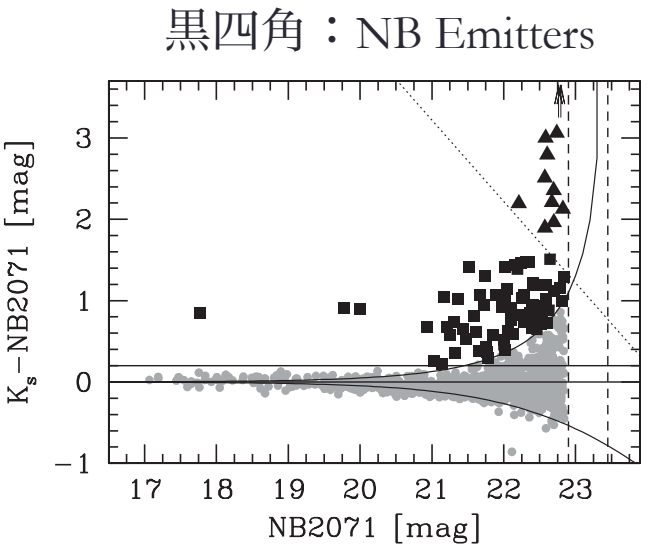
点源検出限界 S/N=5, 1 時間積分				
band	λ_{eff} (μm)	Δλ (μm)	2.5m mag (μJy)	Subaru mag (μJy)
V	0.56	0.083	25.9 (0.16)*	26.0 (0.14)
J	1.25	0.16	24.0 (0.40)**	23.2 (0.84)
H	1.64	0.29	22.5 (0.99)**	22.1 (1.43)
Ks	2.15	0.32		22.1 (0.93)
Kdark	2.36	0.18	22.5 (0.54)	
3.4μm	3.35	0.3	18.4 (13.2)	
L'	3.78	0.5	17.9 (12)	17.6 (14)
M'	4.78	0.22	14.8 (140)	14.9 (50)
*オーロラの影響は含めない, **OH 夜光はマウナケアの 1/3 を仮定				

H α (6563Å) from high-z galaxies

- Koyama+13, Hayashi+13 (MOIRCS)
  - ✗ z~2.16 proto-cluster detected by H α .
  - ✗ Stellar mass-SFR relation : 環境依存性はあるか？
  - ✗ K-bandが地上の限界…



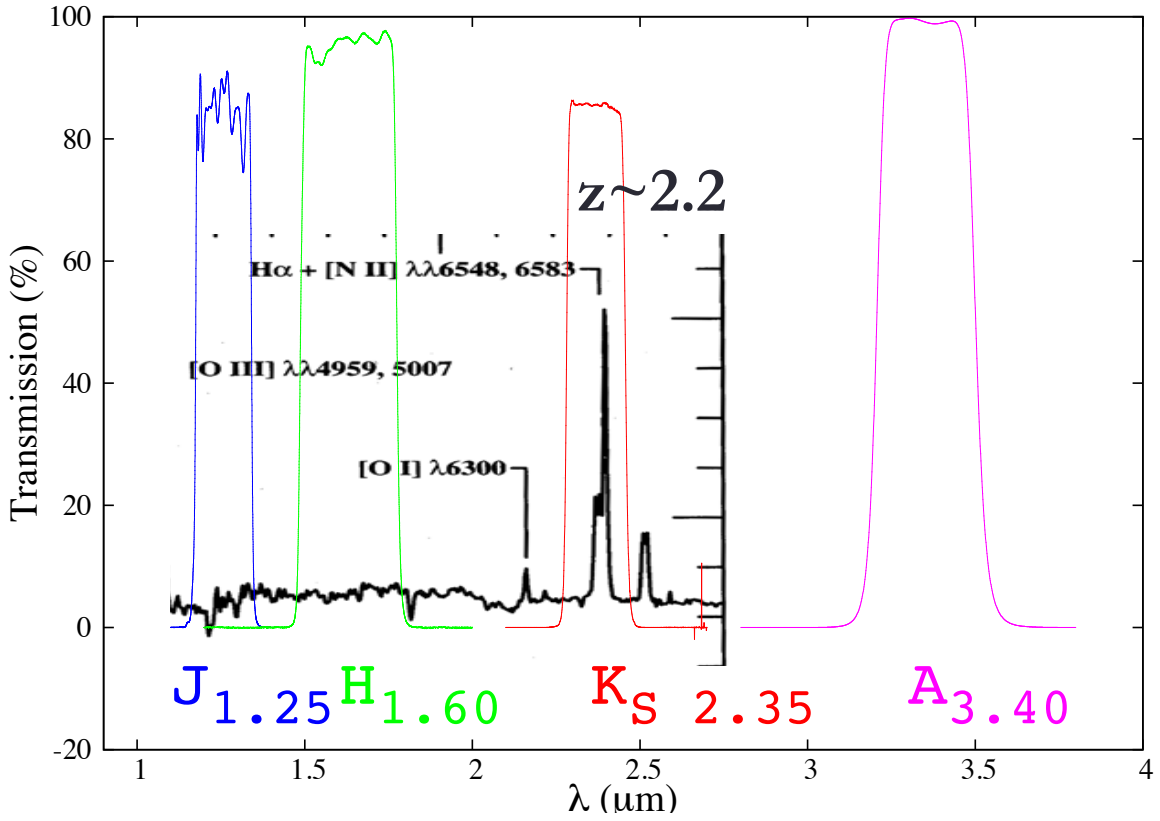




Koyama+13

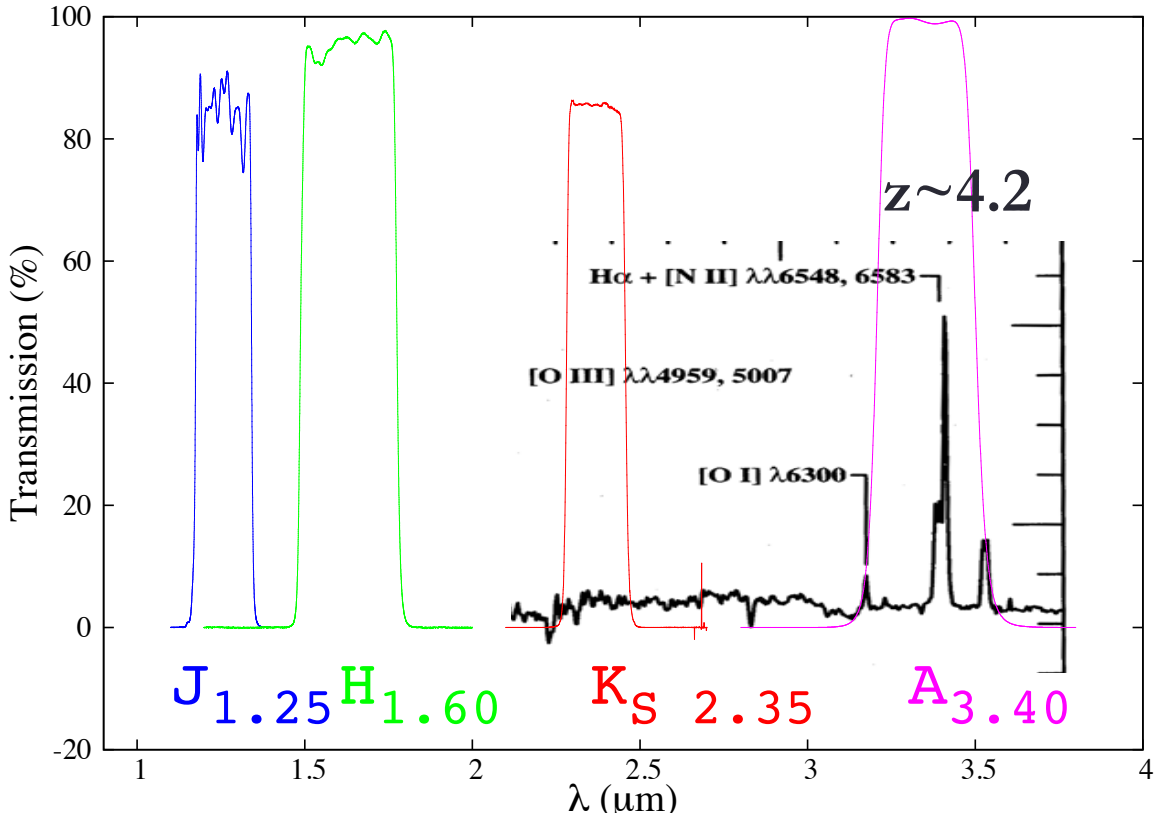
H α from z~4.2 (?) starburst galaxies

- A, L' - 狭帯域フィルター + 三色カメラ
  - ✗ K, A-drop H α Emitter candidates



H α from z~4.2 (?) starburst galaxies

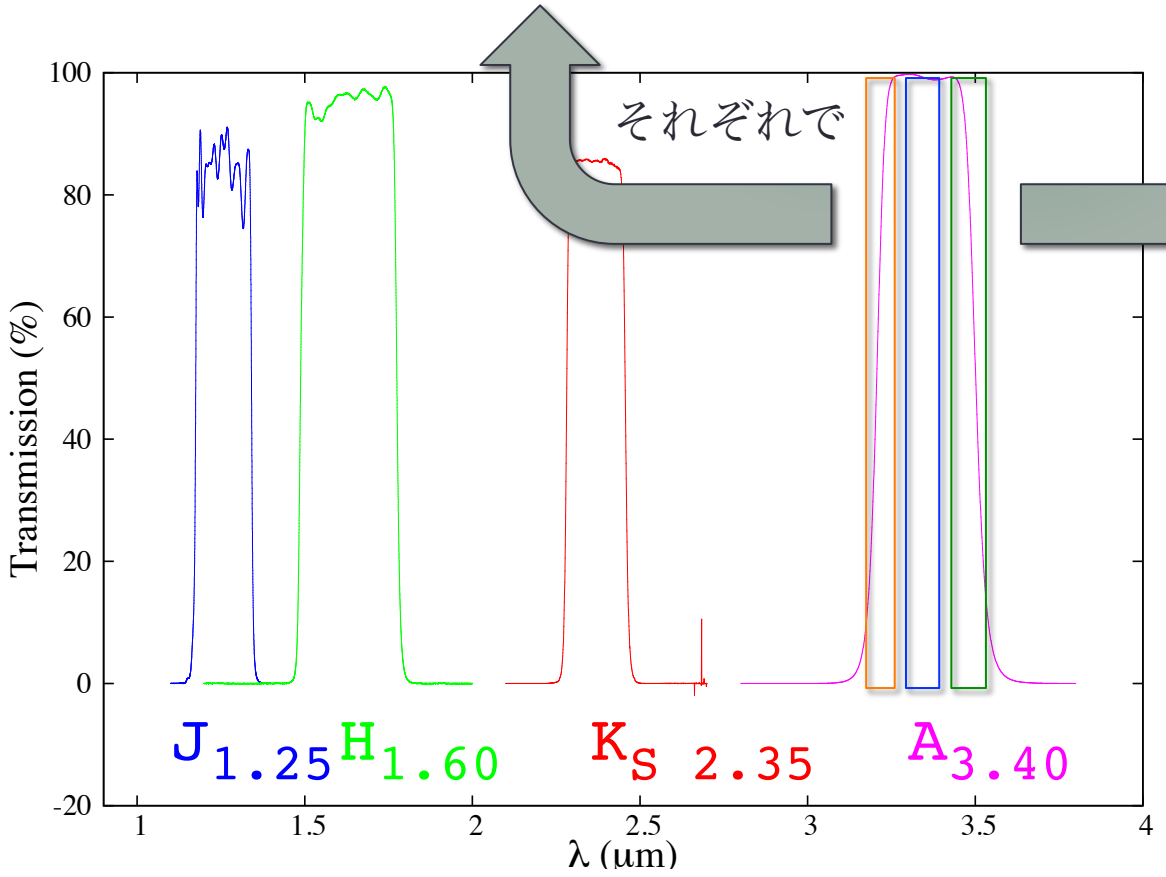
- A, L' - 狭帯域フィルター + 三色カメラ
  - ✗ K, A-drop H α Emitter candidates



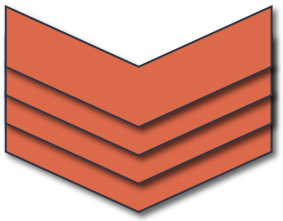
H α from z~4.2 (?) starburst galaxies

- A, L' - 狭帯域フィルター + 三色カメラ
  - ✗ K, A-drop H α Emitter candidates

Single Deep A-band image



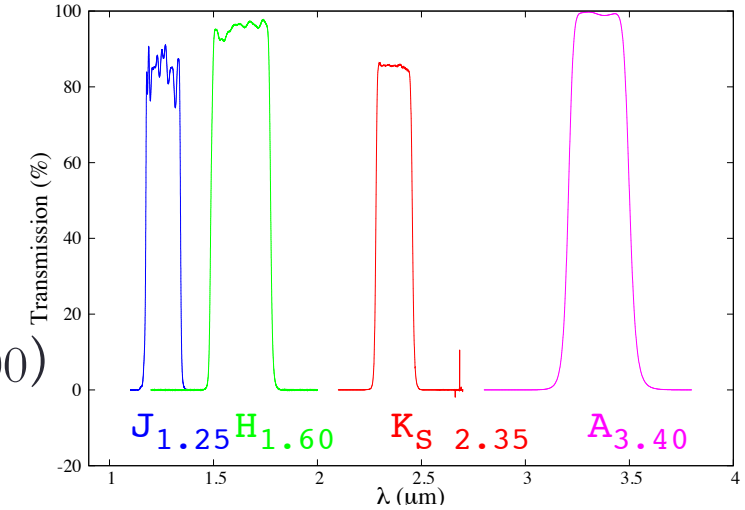
ex) $m_{3.6}$~20-22 mag
at z~2.1-2.5 (Mancini+11)



m_A~22-24 mag at z~4.2

Hα from z~4.2 (?) starburst galaxies

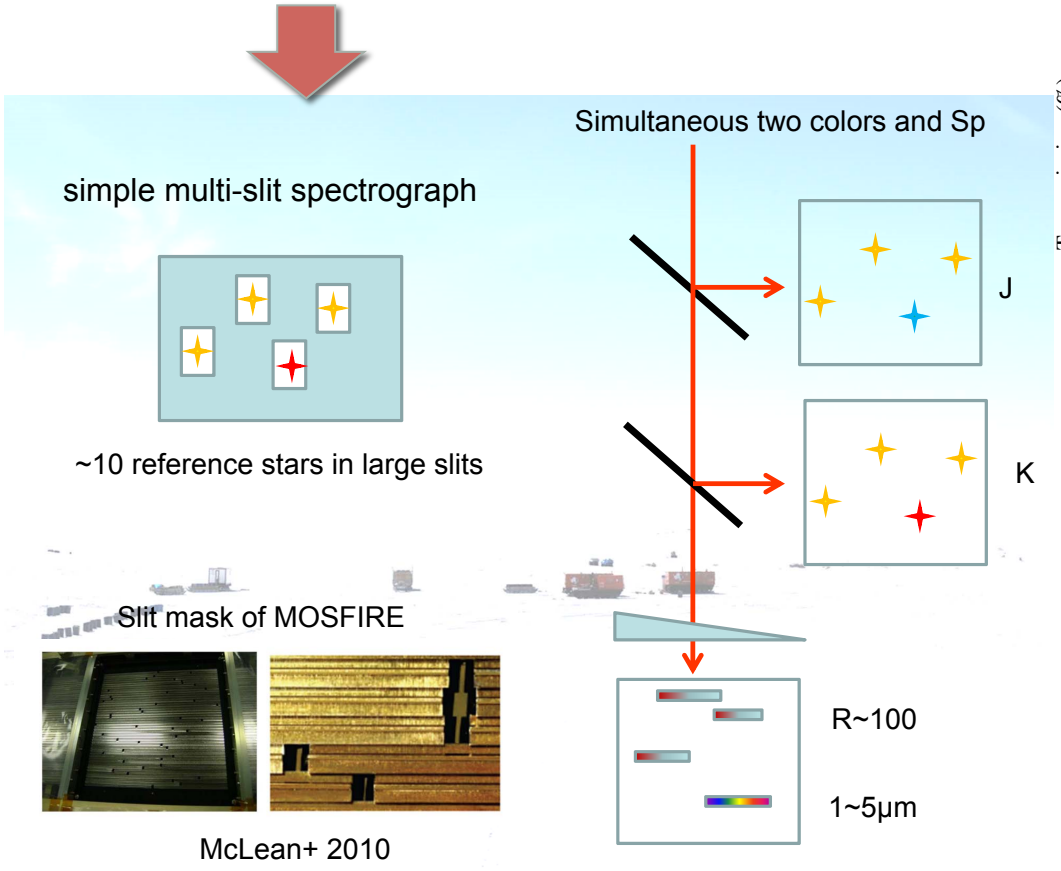
- A, L' - 狭帯域フィルター + 三色カメラ
  - ✗ K, A-drop Hα Emitter candidates

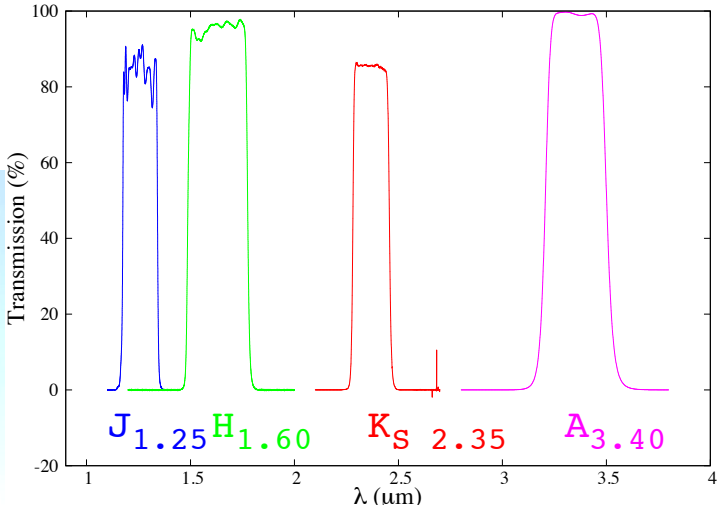


- Spectroscopy
  - ✗ Redshift
  - ✗ ダスト減光量（Hα-Hβ比; Calzetti+97,00）
  - ✗ SFR, Σ_{gas}

H α from z~4.2 (?) starburst galaxies

- A, L' - 狭帯域フィルター + 三色カメラ
  - ✗ K, A-drop H α Emitter candidates





or …IFU ?

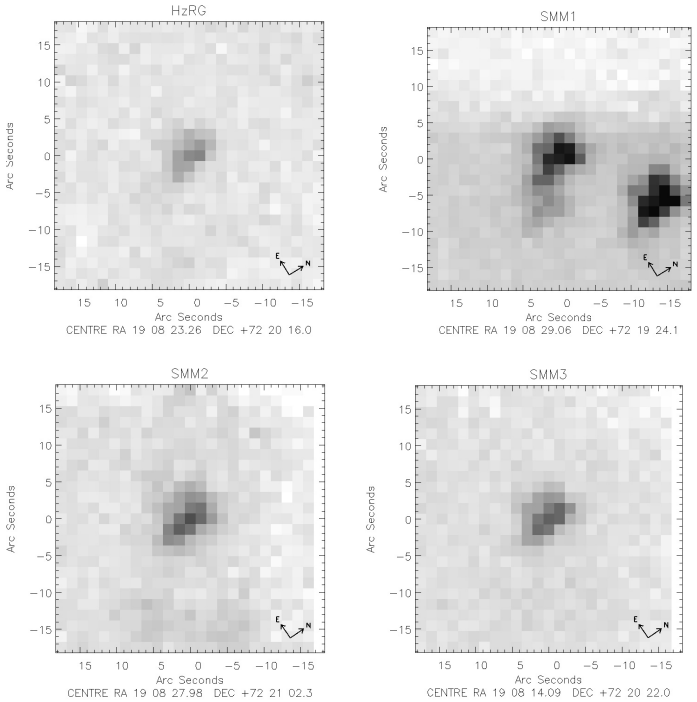
Hα from z~4.2 (?) starburst galaxies

- A, L' - 狭帯域フィルター + 三色カメラ
  - ✗ K, A-drop Hα Emitter candidates

- Spectroscopy
  - ✗ Redshift
  - ✗ ダスト減光量（Hα-Hβ比; Calzetti+97,00）
  - ✗ $SFR_{Nebular}$, Σ_{gas}, 星形成銀河の主系列

- **Hα clumpsの空間分解**
  - ✗ **A-band 回折限界**
  - ✗ **3.4um@2.5m=0.28"**

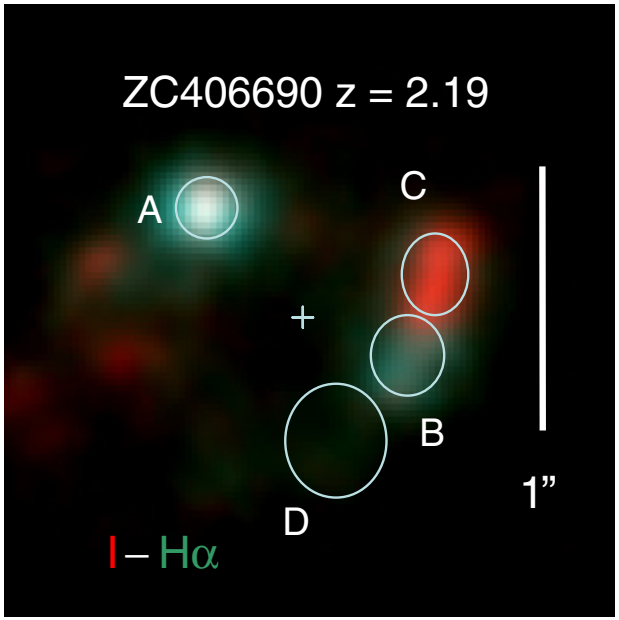
AGN Binary at z>3.5?
(PSF FWHM=4.7")

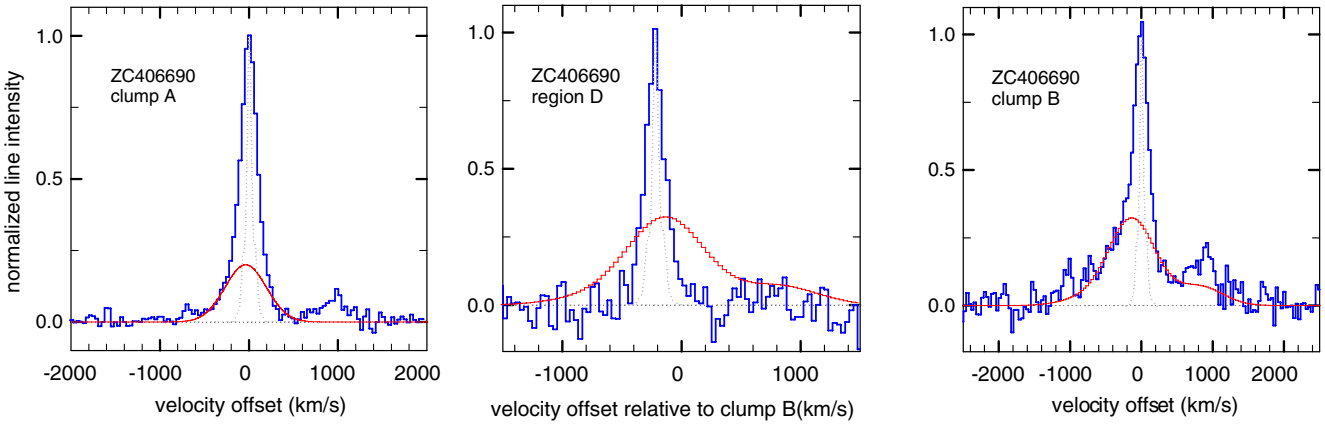


Sedgwick+13

Hα clumpの分解 (Max Planck Group)

- Genzel+11：星形成銀河の面分光観測。
  - ex) CZ406690 (z=2.19)
  - $m_{3.6}$=20.93 mag
  - 10hr@VLT/SINFONI (K-band)+AO

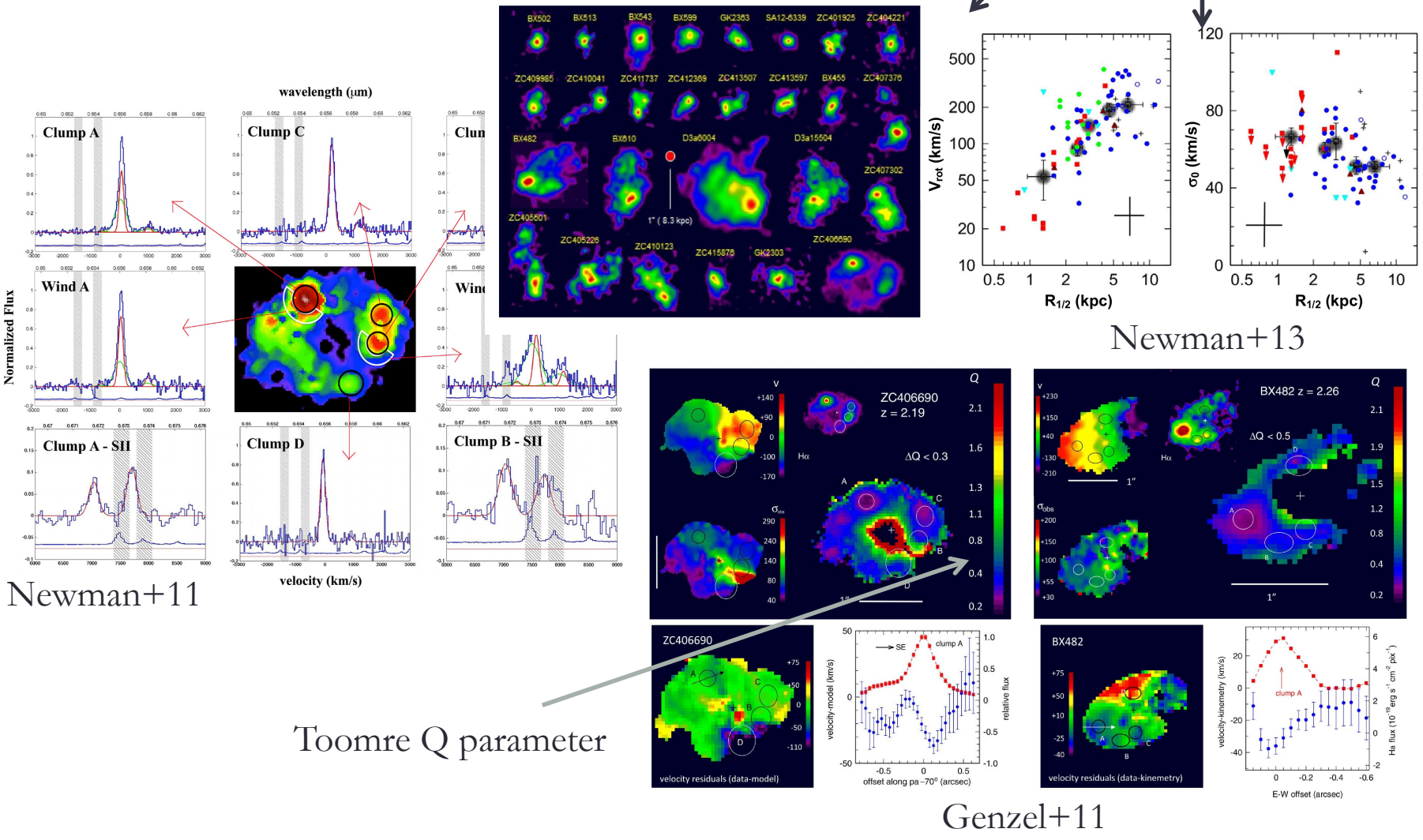




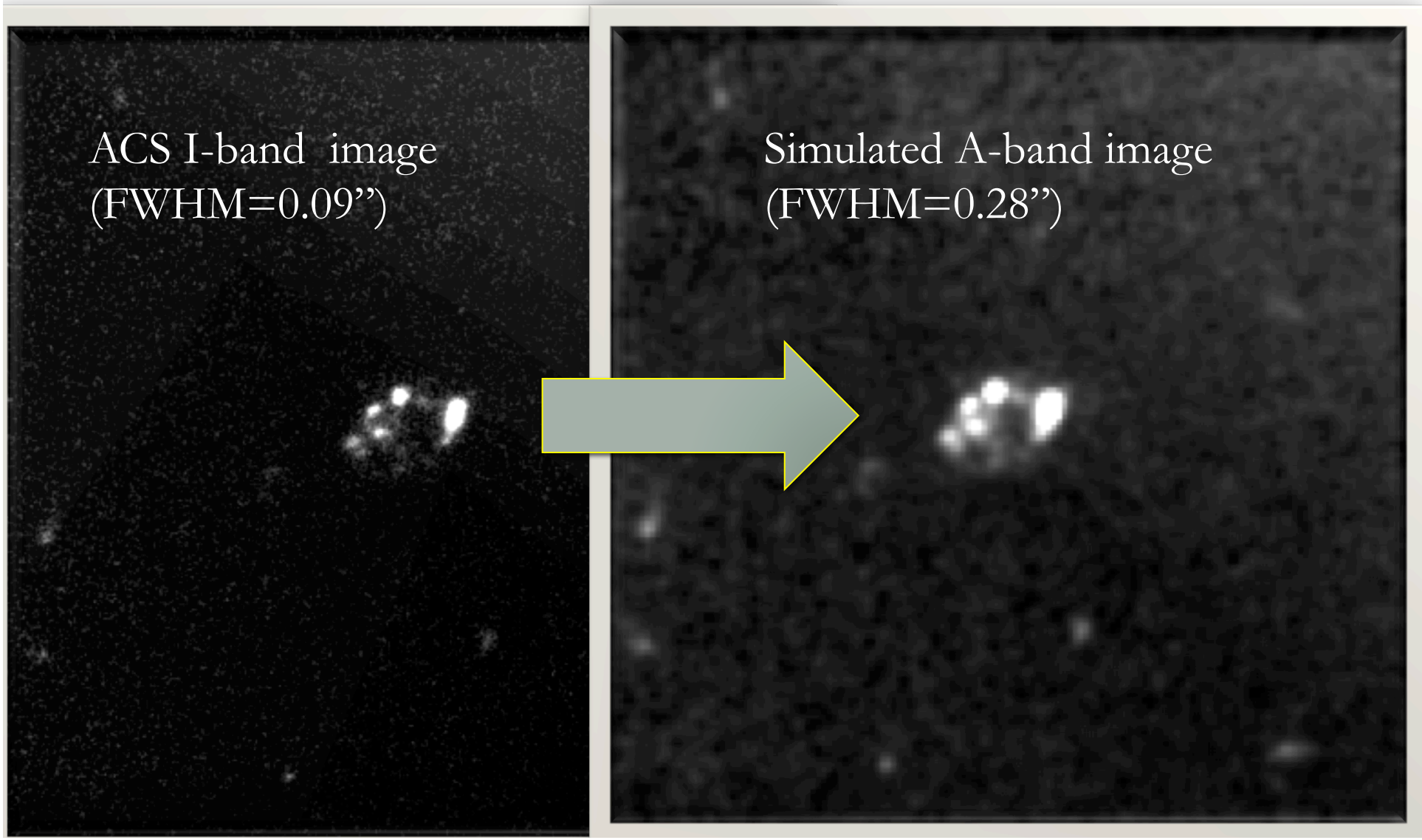
Genzel+11

Hα clumpの分解 (Max Planck Group)

回転速度　　速度分散



Hα clumpの分解 for higher z galaxies



まとめ（どんなことができる？）

- THz銀河のfollow up：Proto-cluster中の銀河を調査。
  - ✗ 銀河形成の初期段階を知る。
- 重力レンズ効果を利用したHighest Redshift Starburst galaxiesの探査。

- A, L'-bandでの深い観測（A~23.4 mag, L'~22.9 mag）
  - ✗ z~5-6までの Massive ($10^{10}M_{sun}$) 銀河カタログ。
  - ✗ Red Sequenceの起源。

- K, A, L'-bandでの高い透過率・空間分解能を活かし、
  - ✗ Hα candidatesの検出（K,A-drop）
  - ✗ 空間分解
  - ✗ 星形成のモードがlow-z側（z~1-2）とどのように違うのか。