Digest of science cases presented at Subaru Next-Generation AO workshop

Shin Oya (Subaru)

Background

At Subaru Telescope

- LGSAO188: commissioning is finishing
- optical instruments (dark nights)

  huge projects for prime focus

  - HSC: Hyper Suprime Cam on-going
  - PFS: Prime Focus Spectrograph partial budget approved
- next Cs Infrared instruments (bright nights) w/ AO
  - discussed by internal committee
  - input from community, especially on science cases

    meeting was held in September, 2011

Current View

- Wide field AO is suitable for Subaru future plan
  - synergy with seeing-limited wide-field instruments
  - competitiveness among 8m-class telescopes
  - complementarity with 30m-class telescopes
- GLAO by deformable 2ndry is 1^{st} candidate
  - 10-15 arcmin FoV; 0.5 mag gain; 1000act ASM
  - deformable 2ndry: on-source high order / low emissivity
  - MOIRCS like wide-field IR instrument at Cassegrain
- Study is needed
  - technical feasibility, performance simulation, seeing data
  - instrument, time-line, budget plan, etc.
  - science cases

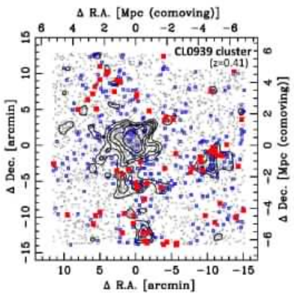
1.System Requirements from Science Cases

Science target	Refer to	AO type	Instrument	Obs. Mode	λ Range	λ Res	FoV	Sp. Res. ["] (Band)	Note
z ~ 7 LAE	Dr. Akiyama's talk	GLAO	NIR wide-field camera	narrow-band img.	1.0 - 1.8	N/A	> 100	0.2 (K)	
z ~ 2 galaxies	Dr. Iwata's poster	GLAO	NIR wide-field camera	broad-band img.	0.9 - 2.5	N/A	> 100	0.1 - 0.2 (K)	
		GLAO	NIR multi-IFU spec.	multi-obj. 2D spec.	0.9 - 2.5	N/A	> 100	0.2 (K)	
cluster environment galaxies 0.5 < z < 2.5	Sec.2	GLAO	NIR wide-field camera	multi-obj. 2D spec.	0.9 - 2.5	50 - 100	50 - 100	0.2 (K)	
		GLAO	NIR wide-field camera	broad-band img.	0.9 - 2.5	2000 - 3000	50 - 100	0.2 (K)	
		GLAO	NIR wide-field camera	narrow-band img.	0.9 - 2.5	N/A	50 - 100	0.2 (K)	
GC astrometry	Sec.3	GLAO	NIR wide-field camera	broad-band img.	K-band	5 - 10	100	0.15 - 0.2 (K)	
GC globular cluster	Sec.4	GLAO	NIR wide-field cam/spec	broad-band img. / spec.	0.9 - 2.5	50 - 100	100	0.2 (K), 0.4(J)	
z > 4 LBG outflow	Sec.5	MOAO	NIR multi-obj. spec.	multi-obj. spec.	1.1 - 2.5	> 2000	> 100	0.1 (K)	IFU preferable
z ~ 3 LAE outflow		GLAO	NIR camera	multi-obj. spec.	1.1 - 2.5	> 500	> 16	0.2 (K)	IFU preferable
exosolar planets	Sec.6	MCAO	NIR camera	broad-band img.	0.9 - 2.5	~ 2000	> 4	< 0.1 (K)	
		MOAO	NIR wide-field camera	multi-obj. spec.	0.9 - 2.5	> 2000	> 4	< 0.1 (K)	
nearby galaxies IMF	Sec.7	MCAO	NIR (5um-cut) camera	broad-band img.	0.9 - 2.5	> 2000	> 30	< 0.05 (K)	
SFR Jets	Sec.7	GLAO / MCAO	Opt. Fabry-Perot / IFU	narrow-band img.	2 - 5	~ 300	100 / a few	0.2 / 0.06 (K)	survey / individual
ULIRG / dual AGN	Sec.7	ASM	NIR multi-obj. spec.	K & L img.	0.6 - 1	~ 50	1	0.1 - 0.2 (K, L)	
z > 4 LAB	Sec.7	Optical AO	NIR multi-obj. spec.	multi-obj. spec.	[FeII] & H2	5 - 10	a few - 30	0.1 - 0.3 (opt)	

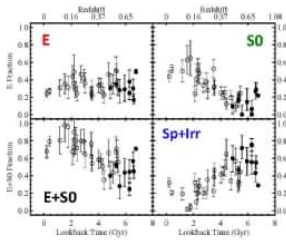
Note: biased to the wide-field science cases

2. Environment Effect on Galaxy Evolution in Clusters

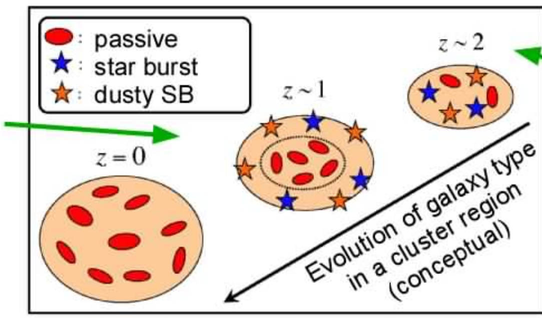
presented by Dr. Yusei Koyama



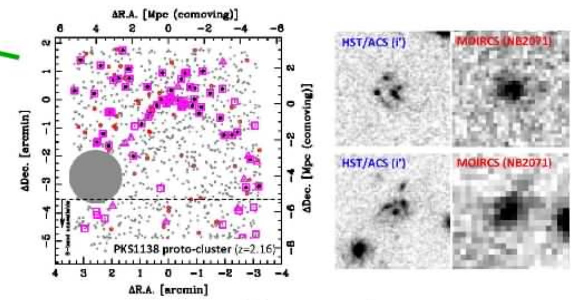
Koyama+11,ApJ,734,66



Desai+07,ApJ,660,1151



What happened in each galaxy?

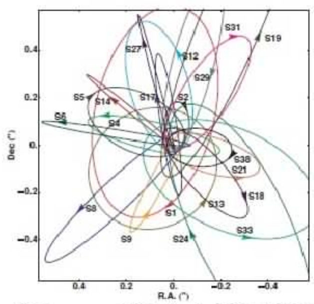


Koyama+, in prep.

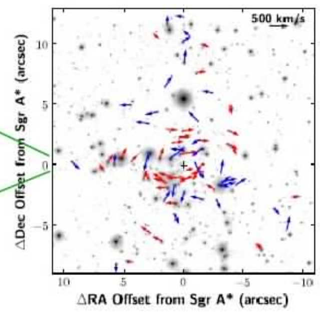
The evolution history of galaxies in the cluster and in the outskirt has been revealed as shown in the center panel. The segregation of the galaxy type found at z ~ 1, suggests the environment affects the evolution of the galaxies. However, the physical process happened in each galaxy at each environment at each evolution stage is still unknown due to the limited spatial resolution. Wide-field (>10') moderate resolution of GLAO is suitable with the following observations modes: (1) broad-band imaging: the rest-frame optical morphology of z~2 galaxies (the directly compared with z~0 galaxies). (2) narrow-band imaging: the star formation history is traced by Hα emission as a common measure between z~0.5 and z~2.5 where environment effect was notable. (3) IFU: the AGN activity, the distribution of metallicity (by [NII]/Hα), dust extinction (w/ Hβ, [OIII] in addition), and also dynamics can be determined (disk-rotation, random motion, sign of merger).

3. Astrometry at the Galactic Center

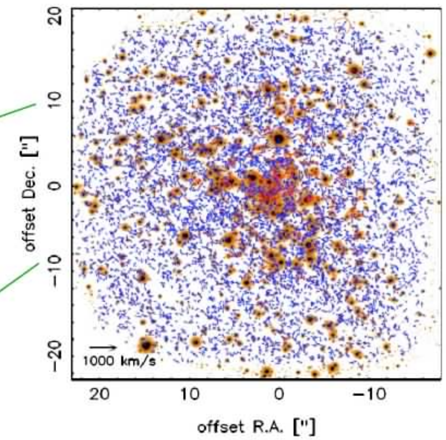
presented by Dr. Shogo Nishiyama



Gillessen+09,ApJ,692,1075
(1" = 0.04pc; 26 stars)



Lu+09,ApJ,690,1463
(20" = 0.8pc; 200 stars)



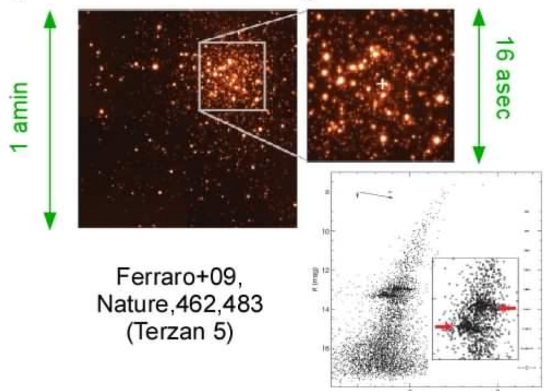
Schodel+09,ApJ,502,91
(40" = 1.6pc; 6000 stars)

Wider FoV

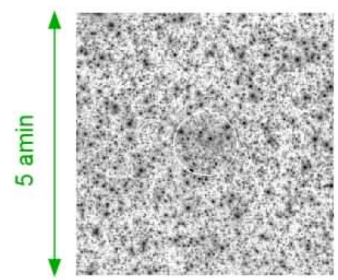
The orbit of S2 (<0.2") determines the mass of the SMBH at the GC as 3x10^5 Msun at 0.01pc. Within 0.04pc (1"), the orbits of 26 young stars (6-400Myr) are determined. At 20" (0.8pc) scale, a disk of young (~6Myr) early type stars are found, even under the strong tidal force by the SMBH. Wider-field observations are proposed for: (1) Nuclear Star Cluster (NSC): known to co-evolve with SMBH and bulge. The observed range is limited at 1/6 of the half-light radius of the Galactic NSC (5pc). Better accuracy (<1/100 FWHM) by AO extends the detectable range. (2) Hidden Cluster / Remnants: can be only identified by astrometry at the GC to know if the young cluster was born in the gas disk surrounding SMBH or formed outside and then fell to the center. (3) Hyper Velocity Stars (HVSs): moving at ~1000km/s (> escape velocity of the galaxy). The three-body interaction including a BH generates HVS. Some HVSs also come form outer disk. Astrometric survey is a key to understand the origin. The (relative) astrometric accuracy should be a few mas.

4. Galactic Archaeology

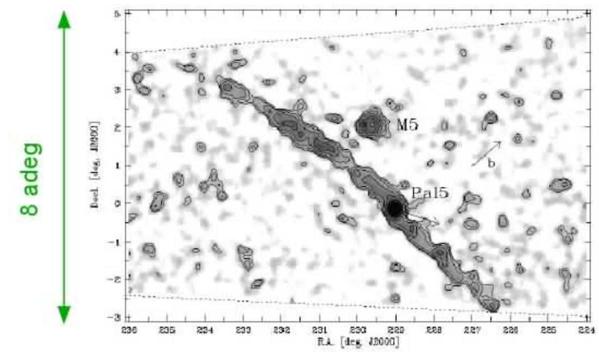
presented by Prof. Masahi Chiba



Ferraro+09,
Nature,462,483
(Terzan 5)



Moni Bidin+11,A&A,535,A33
Bulge Globular Cluster
Candidate (VVV CL003)

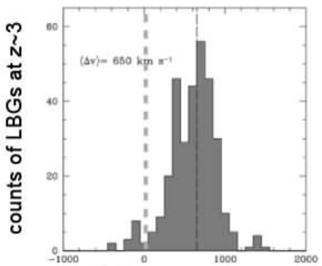


Odenkirchen+03,AJ,126,2385
Tidal Tail (Pal 5)

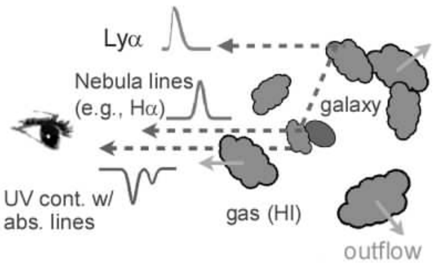
The stellar population of the globular clusters in the bulge shows a variety of properties than those in the halo. VLT/MAD found that Terzan 5 has two populations: old lower-metalicity ([Fe/H]=-0.2 & 12Gyr) and young high-metacity ([Fe/H]=+0.3 & 6Gyr), possibly the remnant of a dwarf galaxy forming the bulge. On the other hand, HP1 has only one population: quite-old low-metalicity ([Fe/H]=-1.0 & 13.7Gyr), possibly the fossil of the primordial galaxy. It is still unknown that these varieties are universal for bulge globular clusters, or just the feature of a given cluster. The sample of the bulge globular clusters are still limited, especially toward the galactic center. The physical properties of candidates found by surveys of 2MASS, Spitzer/IRAC, VVV, are yet to be determined by follow-up imaging with wide-field AO. The bulge globular clusters probably has the stream structures due to the tidal force of the bulge and dark halo. The wide-field multi-objects spectroscopy embosses the stream structure, by which the gravitational potential at the bulge and possible perturbation from dark subhalos are determined.

5. Outflow from High-z Galaxies

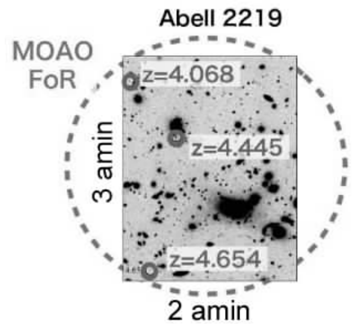
presented by Takatoshi Shibuya



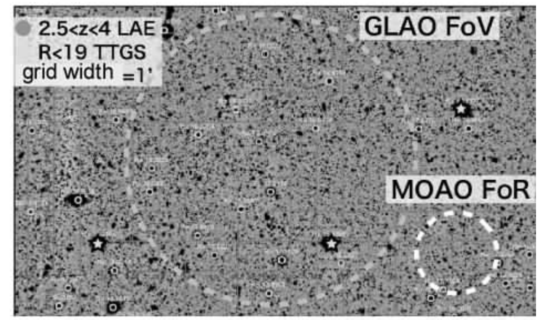
velocity difference (emi - abs) [km/s]



Relation between the emission lines and the absorption lines from the galactic outflow



Frye+02,ApJ,568,558
z ~ 4 galaxies magnified by gravitational lens of the cluster

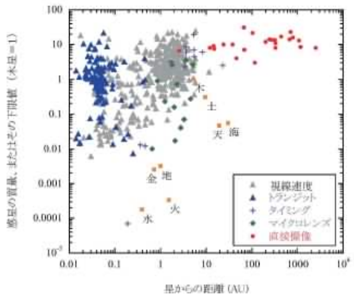


Distribution of z ~ 3 LAE in Subaru Deep Field

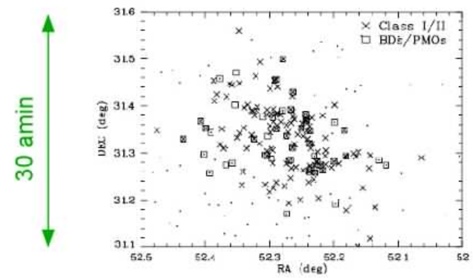
The outflow from a galaxy is a key activity to understand the history of the universe: the star formation is determined by the balance between the inflow and outflow of the galaxy; the metalicity of the intergalacitc medium is increased; the escape fraction of Lyα photon in the early universe may be affected, and so on. The absorption lines by neutral hydrogen-gas cloud in front of the galaxy have been used as the reference of the systematic velocity. However, because the cloud itself is expected to move toward us, the measured velocity could be biased. The nebular lines like Hα are better as the reference for correct measurement. The researches using a nebular line have been done toward more than 100 LBGs at z~3, while only little for LBGs at z>4 or LAEs at z~3. Efficient observations using wide-field AO with assist of gravitational-lensing by a cluster of galaxies increase the statistical samples to trace the evolution of the galactic outflow, For detection of faint nebular line from z>4 LBGs ([OII] & Hβ), the better correction by MOAO is necessary, while for rather bright z~3 LAE ([OIII]), the wider FoV of GLAO is advantageous.

6. Exosolar Planet

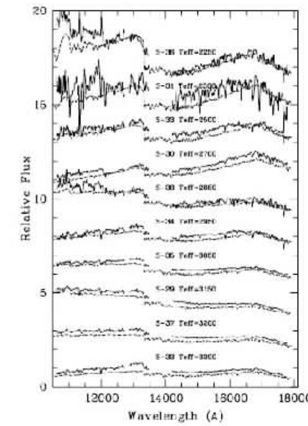
presented by Dr. Misato Fukagawa



Exosolar Planets
Aug, 2011; increasing



Sholz+12,ApJ,744,6
Spatial distribution of brawn dwarfs and planetary mass objects in NGC1333



Sholz+12,ApJ,744,6
Spectra of young very low-mass objects (brown dwarf) in NGC1333

Of course the direct imaging of terrestrial planets by ExAO is the most exciting topic. There are still parameter spaces left for the wide-field AO with diffraction-limited resolution (MCAO). To date, most of planets are found by transit or Doppler method. These methods tend to find short-period planets close to the central star. In addition the transit is biased to the large planets and the Doppler to the heavy planets. On the other hand, the low-mass planets (1~5Mj) at the large orbit (>5AU) or floating planets are not investigated well yet; e.g., the differences between orbiting planets and floating planets are unknown and the IMF is not determined for the mass less than 6 Mj. These planets can be found more efficiently by the assist of wide-field AO. The spectroscopy to examine the planet atmosphere is also possible down to 2 Mj, which is more efficiently performed if MOAO is used. The wide-field monitoring of M stars at NIR to find planets by transit or microlensing is also interesting, though the program need to occupy the telescope time.

7. Other science cases

Growth of SMBH in ANG by Galaxy Merger *presented by Dr. Masatoshi Imanishi*

The mass accretion process to the central SMBH in the merger galaxies is important for galaxy evolution. As the surroundings of SMBH are small and buried in dust, the high spatial-resolution at long wavelengths are essential. Thermal background reduction by adaptive 2ndary mirror (ASM) is advantageous.

Surveys of Jets in Star Formation *presented by Dr. Tae-soo Pyo*

The long and sharp outflow is the record of mass-loss history. [FeII] emission traces partially ionized atomic jet (J-shock) and H2 emission does molecular gas flow (C-shock). Because massive star forming region is far from us, AO is needed. GLAO is suitable for survey and MCAO for details.

IMF in Near-by Galaxies *presented by Dr. Chikako Yasui*

The IMF is one of basic parameters in the history of the universe. The IMF of young cluster in a near-by galaxies (one and maby two more dwarf irregulars are reachable at < 1 Mpc) are determined by resolving each star using AO, to examine the universality or dependency on the environment. MCAO is suitable.

Evolution of Internal Structure in Primordial Galaxies *presented by Dr. Tomoki Saito*

The Lyα blobs are the probe of interaction between galaxies and intergalactic medium: the cold accretion gas releasing the potential energy and the shock of galactic wind. The sample is limited to the bright blobs at $z\sim3$ (incl. both inflow-like and outflow-like). The velocity maps for $z>4$ LABs by optical Fabry-Perot, are desired.