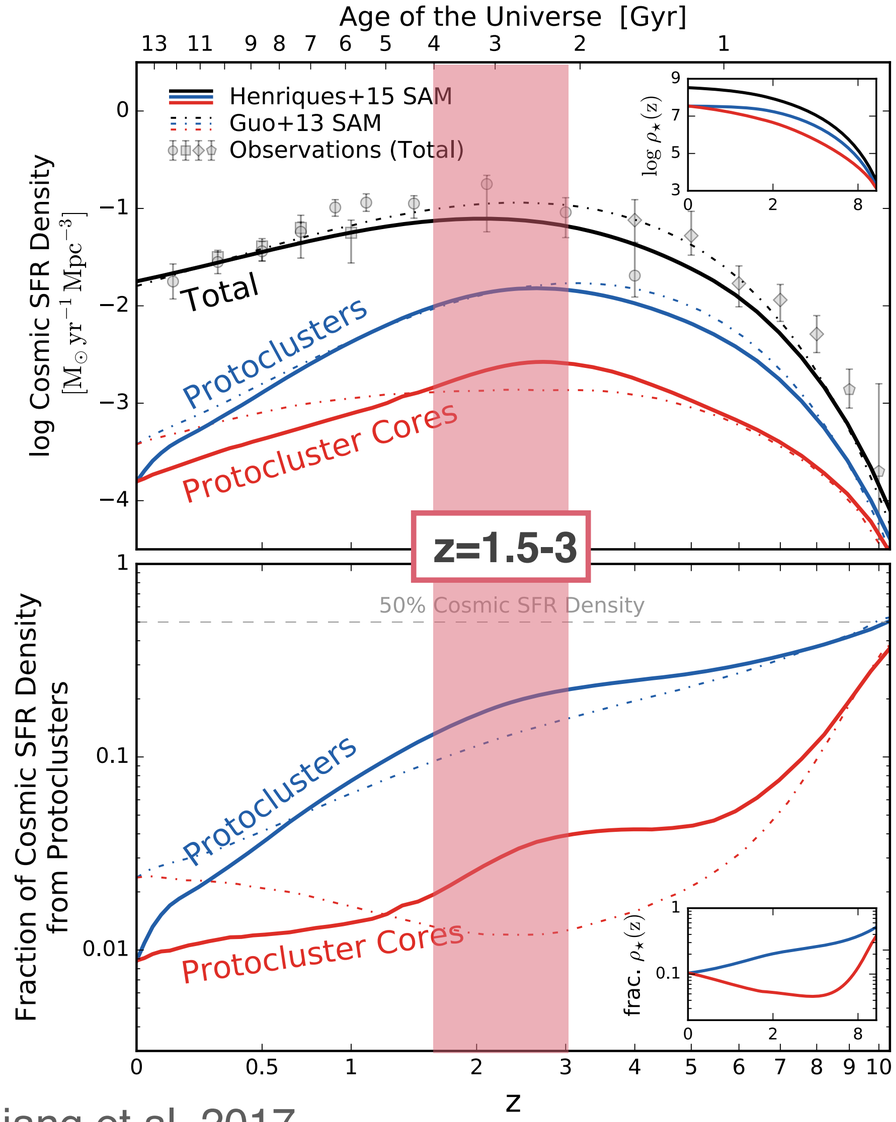
ALMA science IV:
ALMA+Subaru observations of high-redshift cluster galaxies

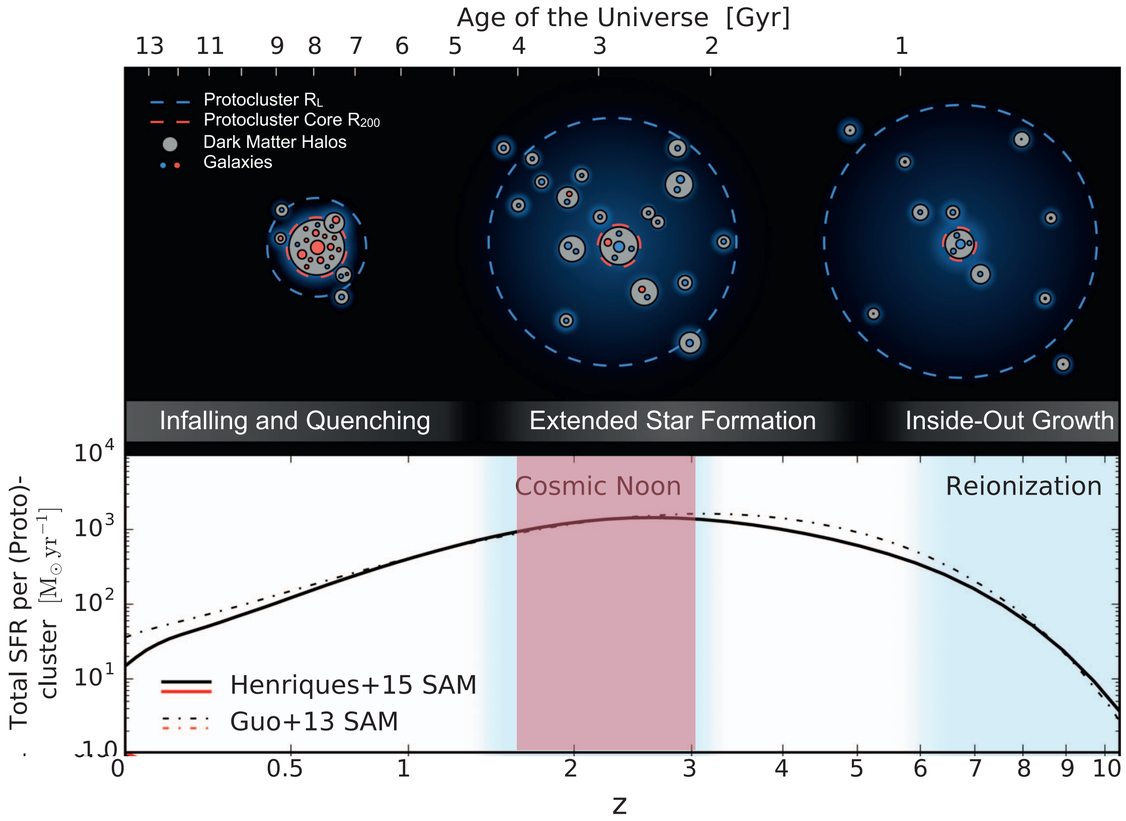
1. ALMA + Subaru/narrow-band synergy
2. ALMA + Subaru/medium-band synergy

Ken-ichi Tadaki (NAOJ)

Why high-redshift cluster/protocluster?



Chiang et al. 2017



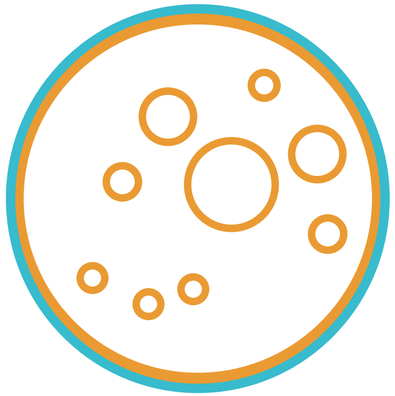
expected contribution to the cosmic star formation rate density

- **1% at z=0**
- **20% at z=2**

(Proto-)clusters are increasingly more important at higher redshift

Why Subaru?

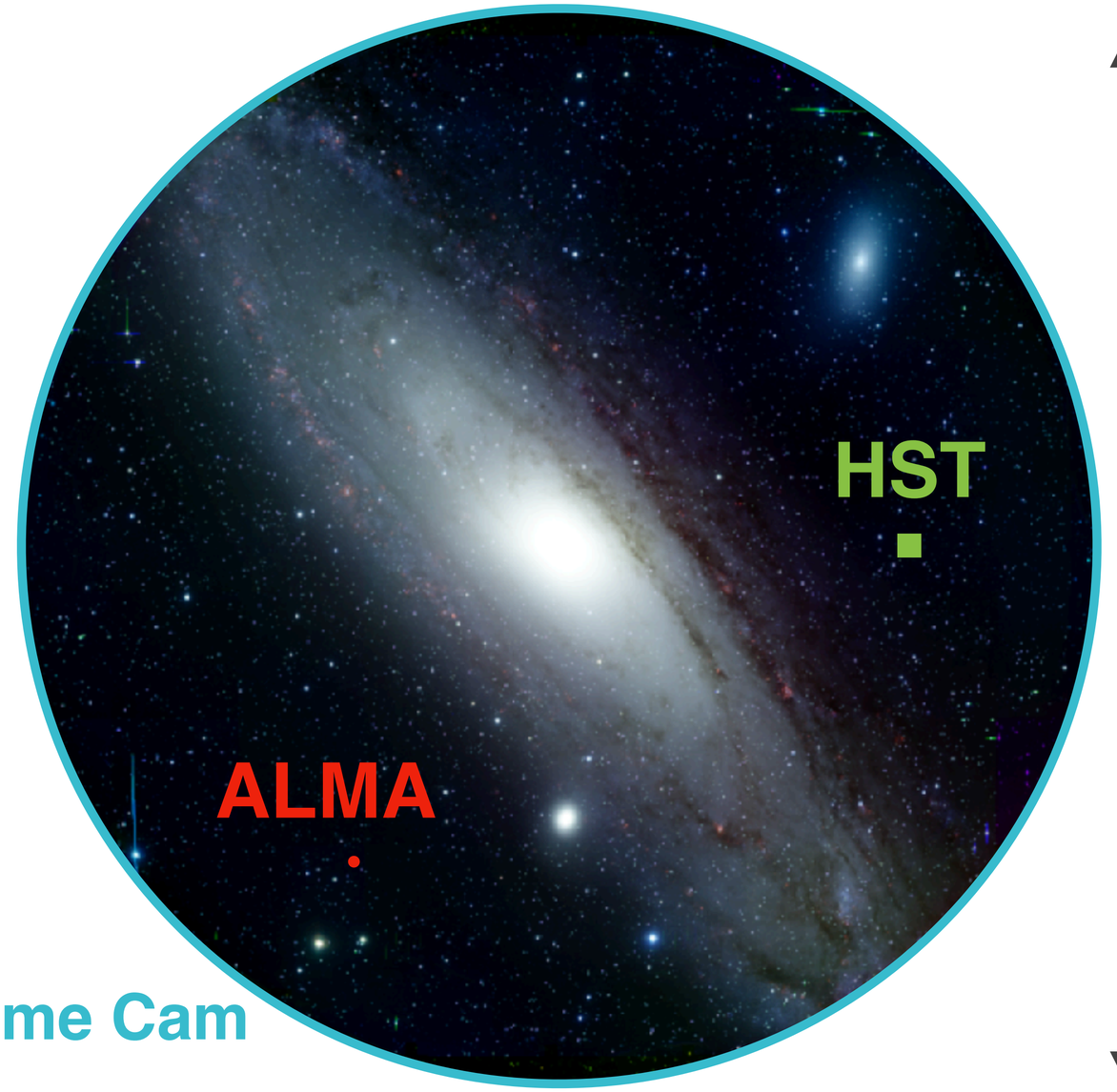
Moon



Subaru/Suprime-Cam

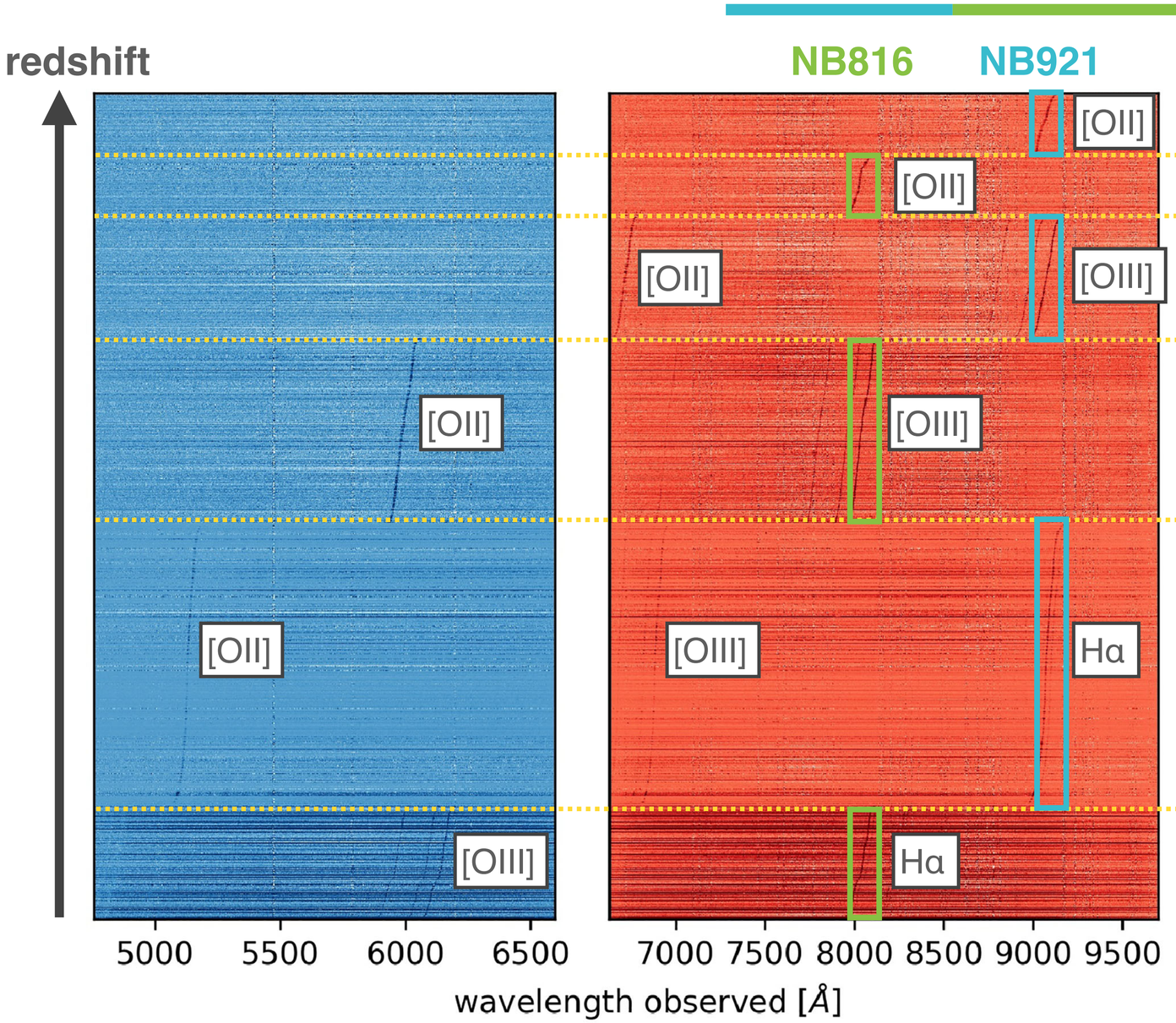
Sun

Subaru/Hyper Suprime Cam



HSC project (http://anela.mtk.nao.ac.jp/michitaro/m31-halpha/)

Emission-line galaxies identified by narrow-band observations

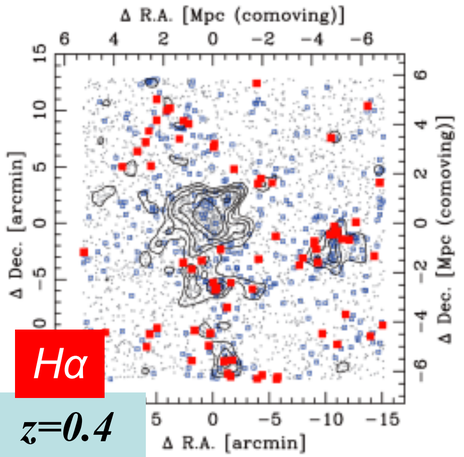


Filter	Line	Redshift	Redshift range	$N_{emitter}$
NB921	[OII]	1.471	1.453-1.489	14586
NB816	[OII]	1.193	1.178-1.208	15301
NB921	[OIII]	0.840	0.826-0.853	14647
NB816	[OIII]	0.633	0.621-0.644	10323
NB921	Hα	0.404	0.393-0.414	8532
NB816	Hα	0.246	0.237-0.254	5400

Hayashi et al. 2020

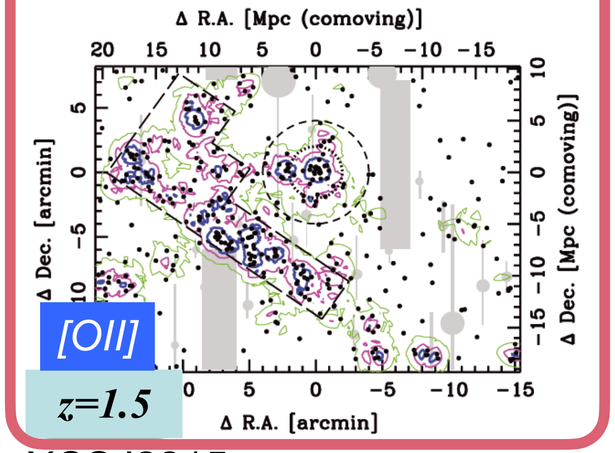
MAHALO-Subaru project (PI: Kodama)

MApping HAlpha and Lines of Oxygen with Subaru

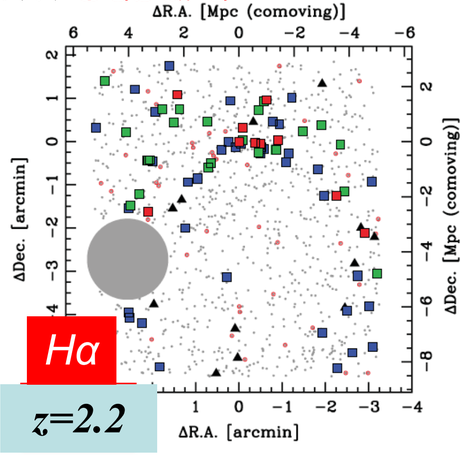


CL0939 *(Koyama+11)*

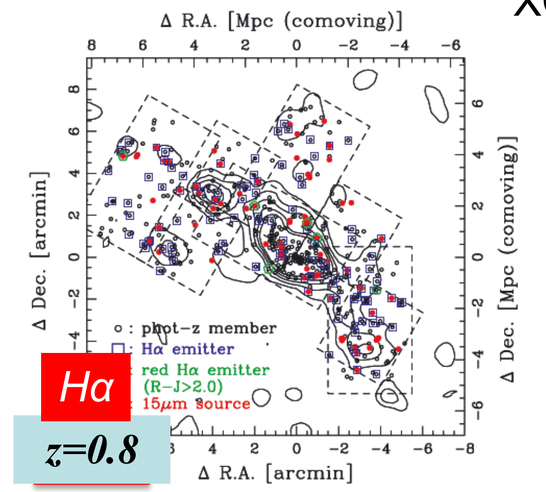
(Hayashi+10, 11)



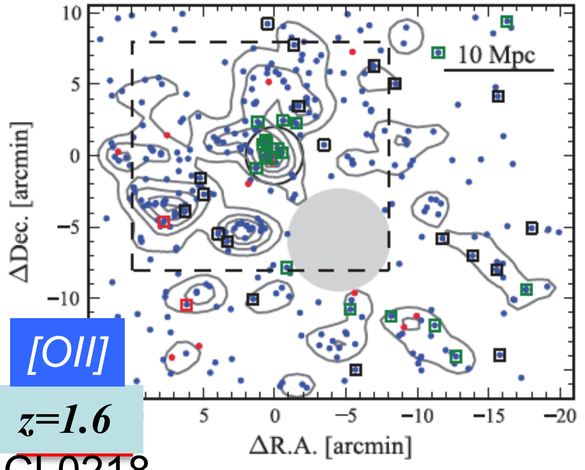
XCSJ2215 *(Tadaki+12)*



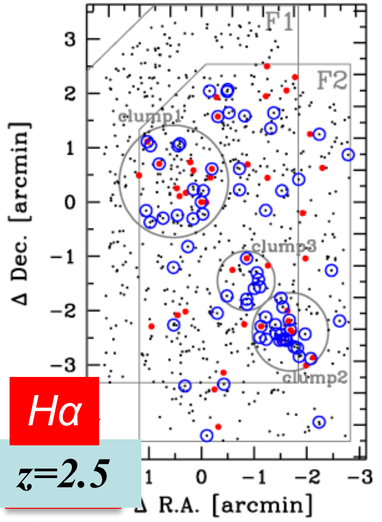
PKS1138 *(Koyama+13)*



RXJ1716 *(Koyama+10)*



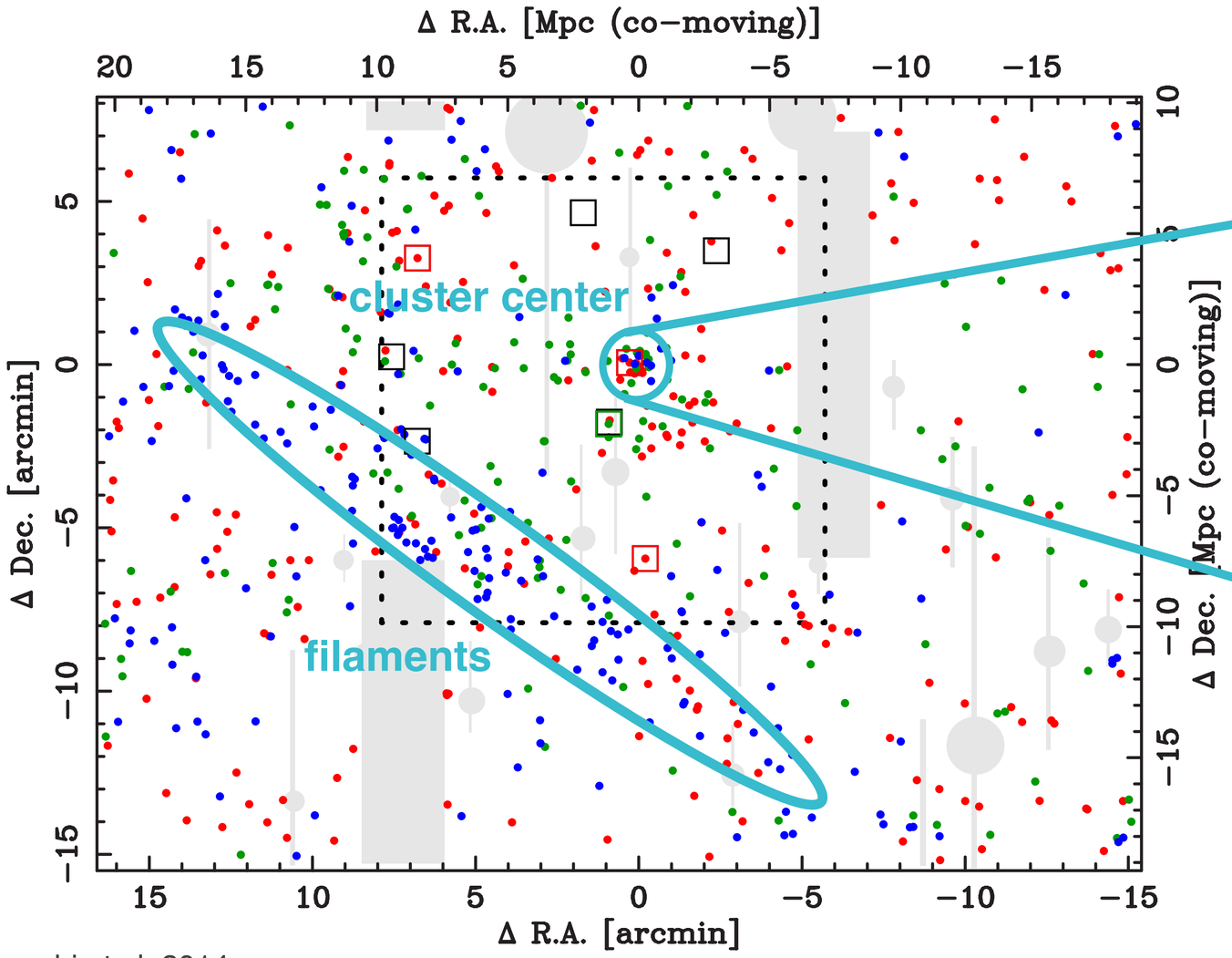
CL0218



USS1558 *(Hayashi+12)*

XCS2215 cluster at z=1.46

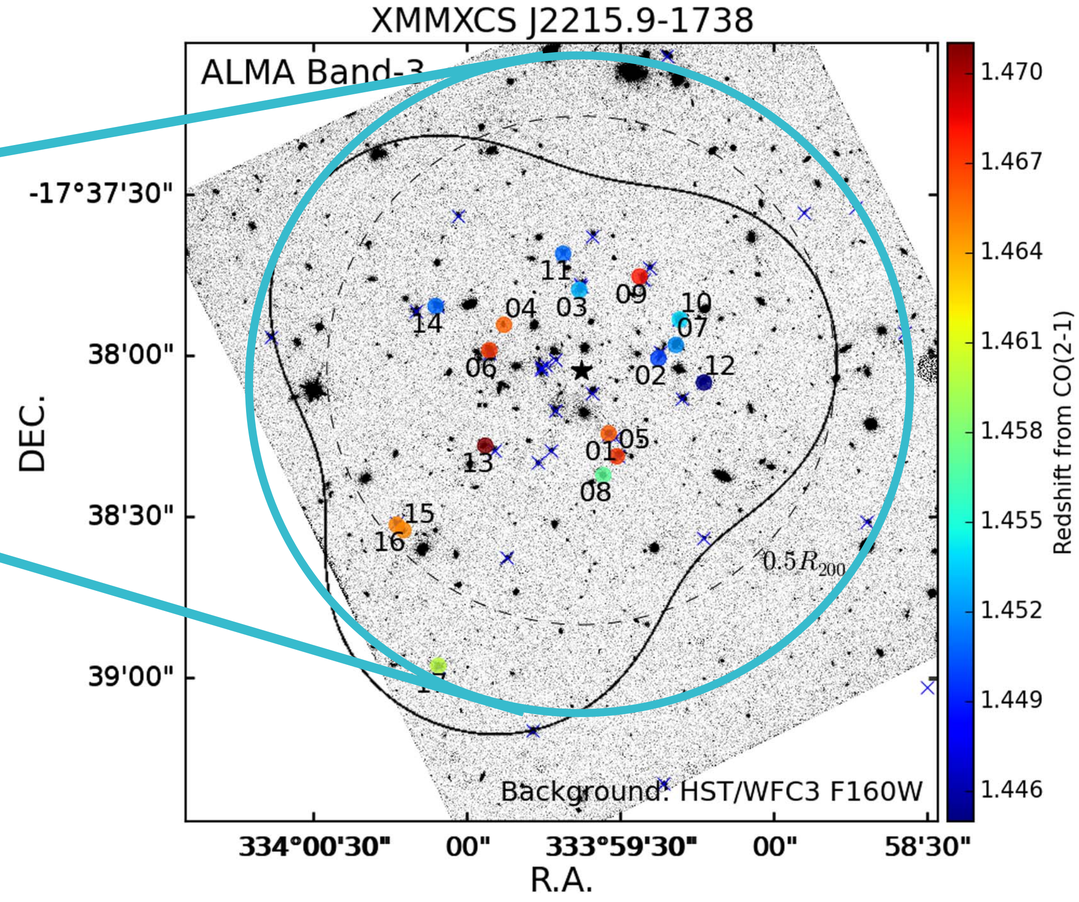
NB912 [OII], NB912+NB921 [OII], NB921 [OII]



Hayashi et al. 2014

efficient observations of CO(2-1) line emission

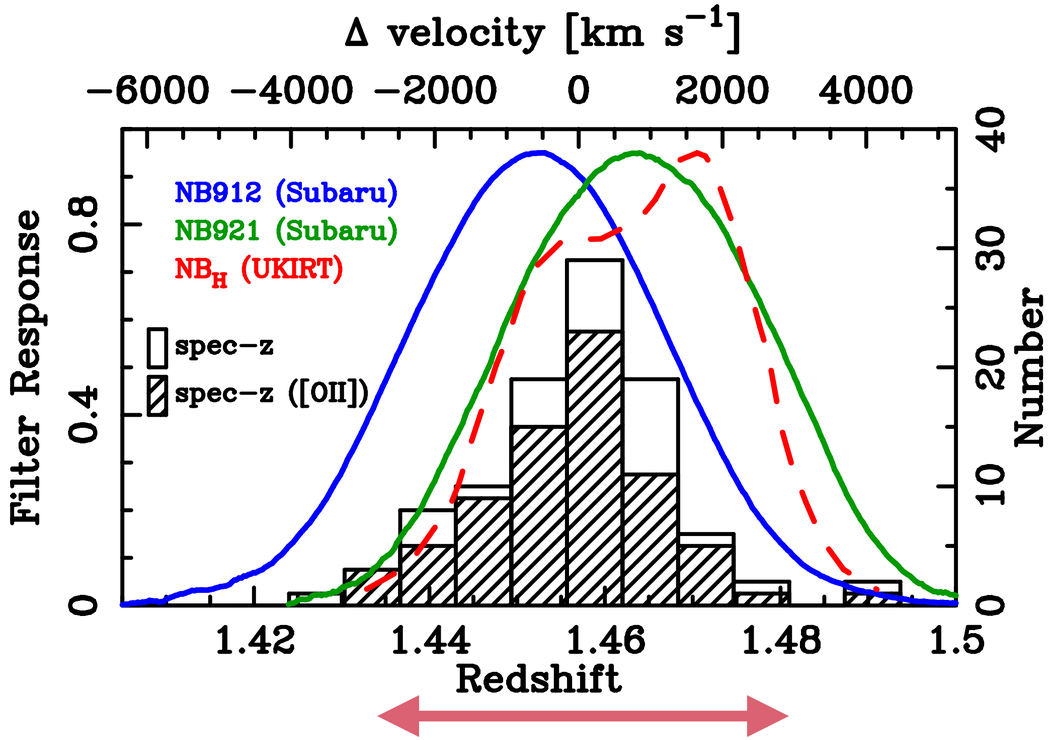
3 pointings: ~50 galaxies



17 CO emitters are detected

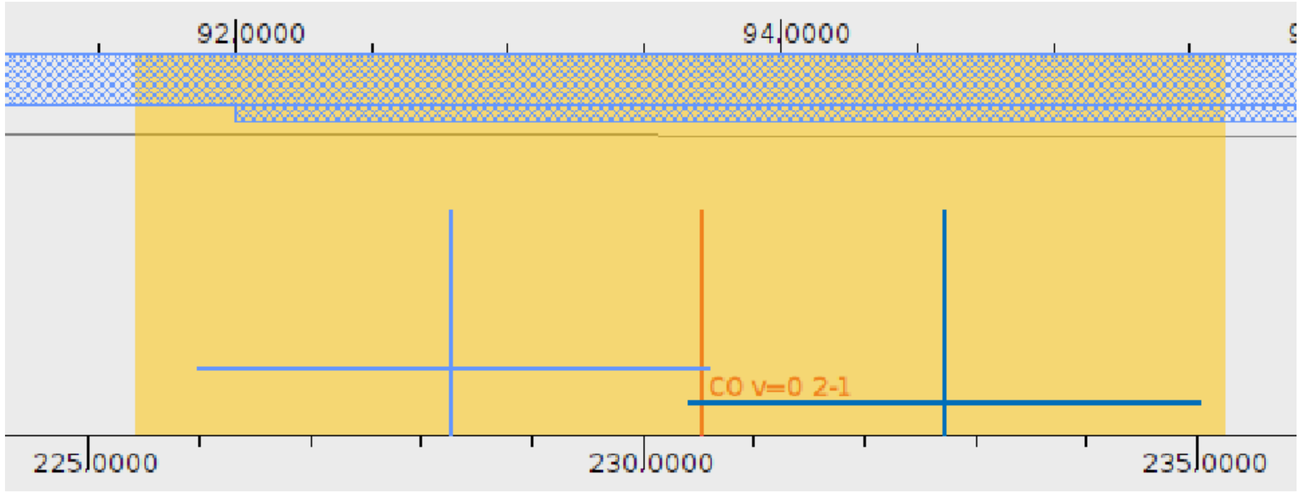
Hayashi et al. 2017

Subaru -> ALMA



NB surveys covers **Δv=±2000 km s^{-1}**

ALMA/Band-3 spectral setups



2 spectral windows covers **Δv=±6000 km s^{-1}**

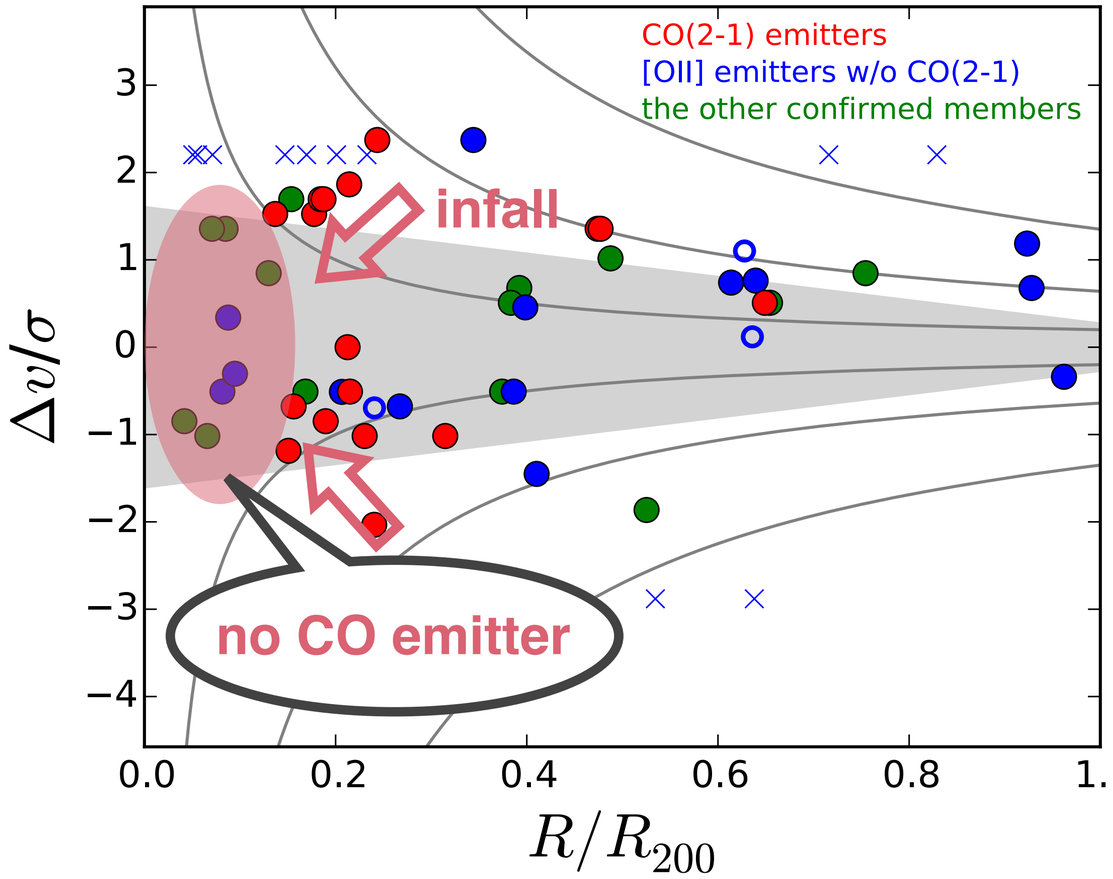
Normal case: photo-z selection => spectroscopic confirmation => CO line observations

Narrow-band: NB emitter selection => CO line observations

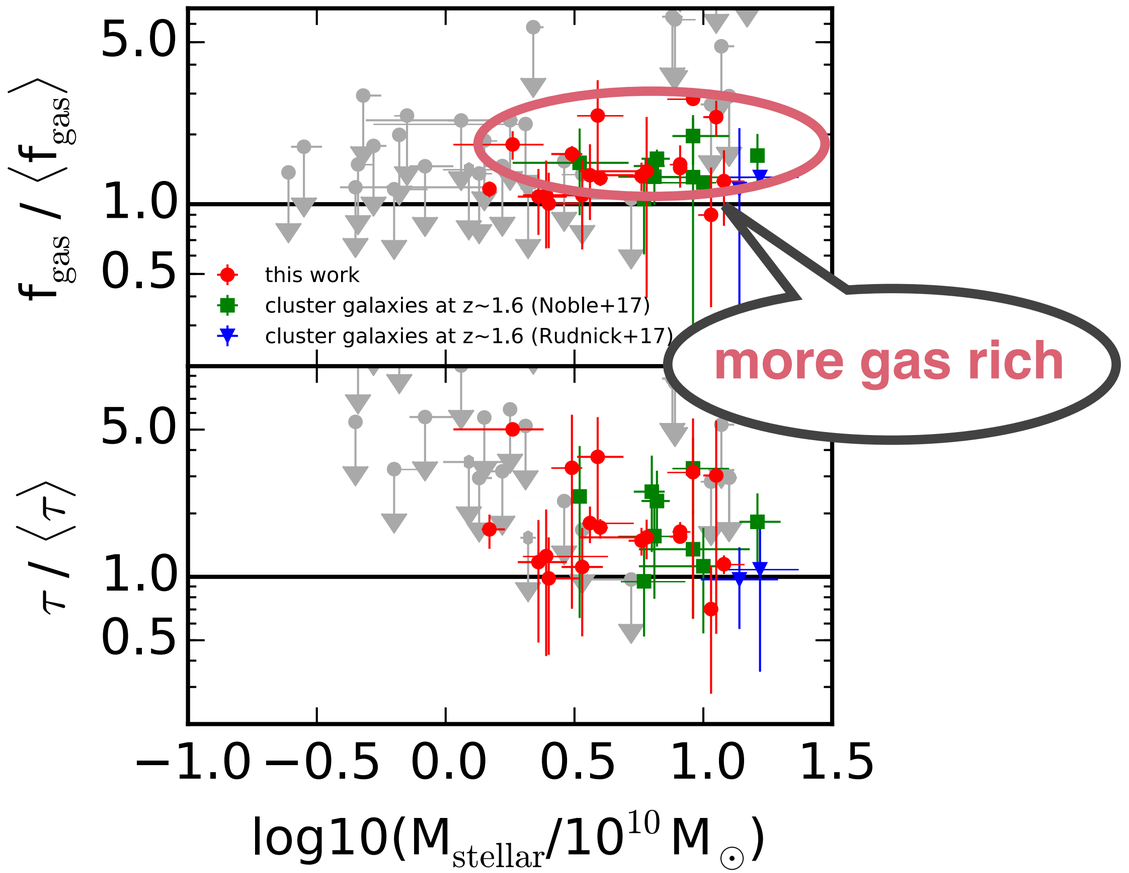
Hayashi et al. 2014

Subaru -> ALMA

Phase-space diagram of cluster galxaies



Gas fraction and gas depletion timescale



CO emitters could have entered the cluster more recently than other quiescent and less massive [OII] emitters

Cluster galaxies could be more gas rich due to efficient accretion of gas

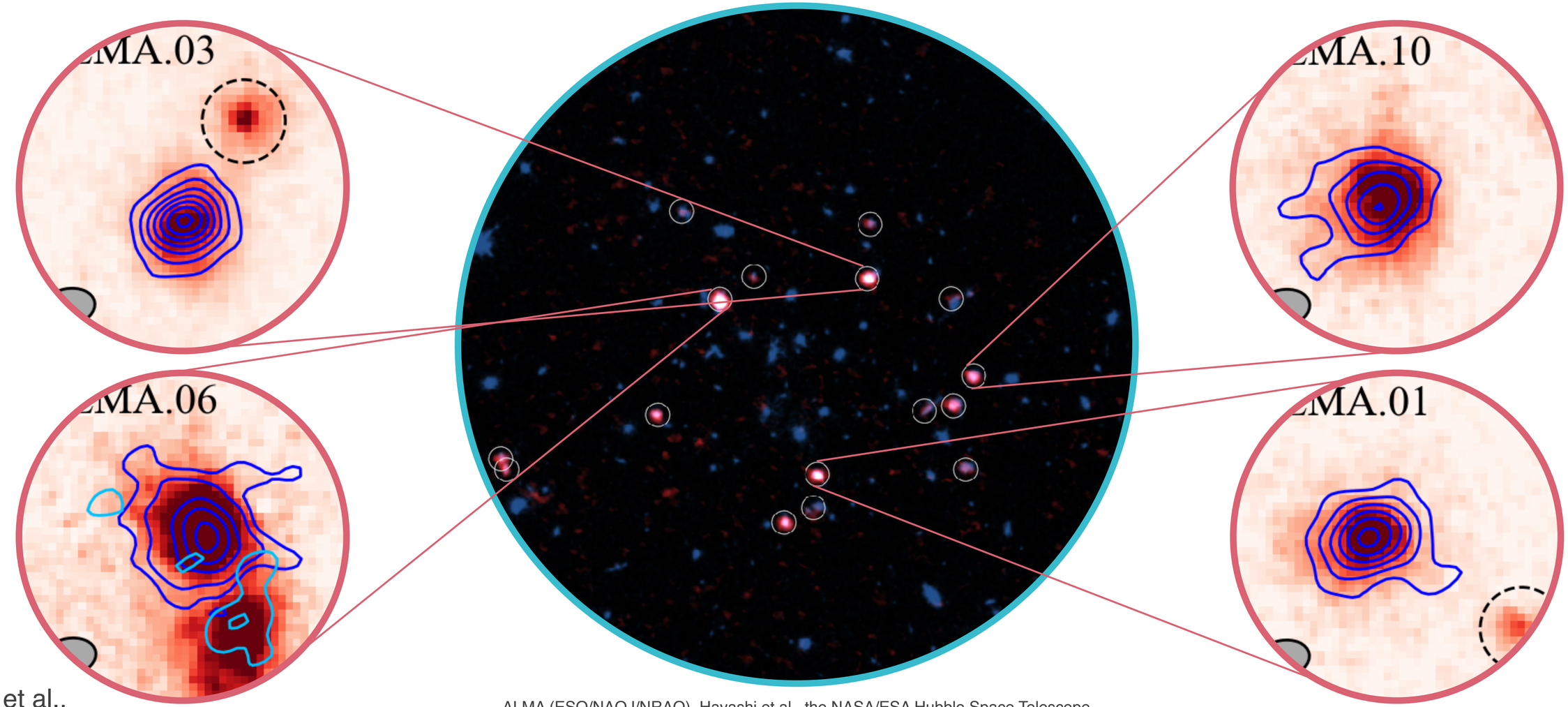
Hayashi et al. 2017

Hayashi et al. 2018

Summary: ALMA + Subaru synergy

Subaru
wide-field of view + unique filter set

ALMA
spatially-resolved observations



Ikeda et al.,

ALMA (ESO/NAOJ/NRAO), Hayashi et al., the NASA/ESA Hubble Space Telescope