High-Resolution Multiwavelenght Diagnostics of AGN and Host galaxies

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OUTLINE

- THE ISM OF GALAXIES AND AGN HOSTS ALONG COSMIC TIME: DISKS, CLUMPS, OUTFLOWS/INFLOWS, PERTURBATIONS
- THE NEED OF AO FOR RELIABLE OVERVIEW OF GAS DISTRIBUTION AND KINEMATICS
- THE SYNERGY WITH MULTI-WAVELENGTH OBSERVATIONS TO PROBE BARYON MASS BUDGET AND PHYSICAL PROCESSES
- PERSPECTIVES FOR FUTURE AO-ASSISTED INSTRUMENTS

Disk and bulge build-up

Main scenario of bulge formation at high z:

- gas-rich turbulent disks, kpc-scale clumps form via violent disk instabilities clumps migrate inward on timescales of < 1Gyr and form bulge

Genzel+2008, Dekel+2009, Dekel & Burkert 2014

- galactic winds from SF regions and AGN appear and impact the surrounding ISM and the build-up of M*

Veilleux+2005, Fiore+2017

Signatures of the physical processes at play appear at scales of <1 kpc and 10-1000 km/s

Requirements:

- high quality resolved kinematics traced through multiple gas phases
- multiwavelenght observations

- separate different components in space and velocity: bulges, disks, clumps, outflows, inflows, perturbations/mergers
- separate narrow from broad components of emission lines: potential well vs. outflows/perturbations
- pinpoint launch sites of galactic winds
- multiple gas phases to achieve full census of baryons in galaxies and identify sources of heating

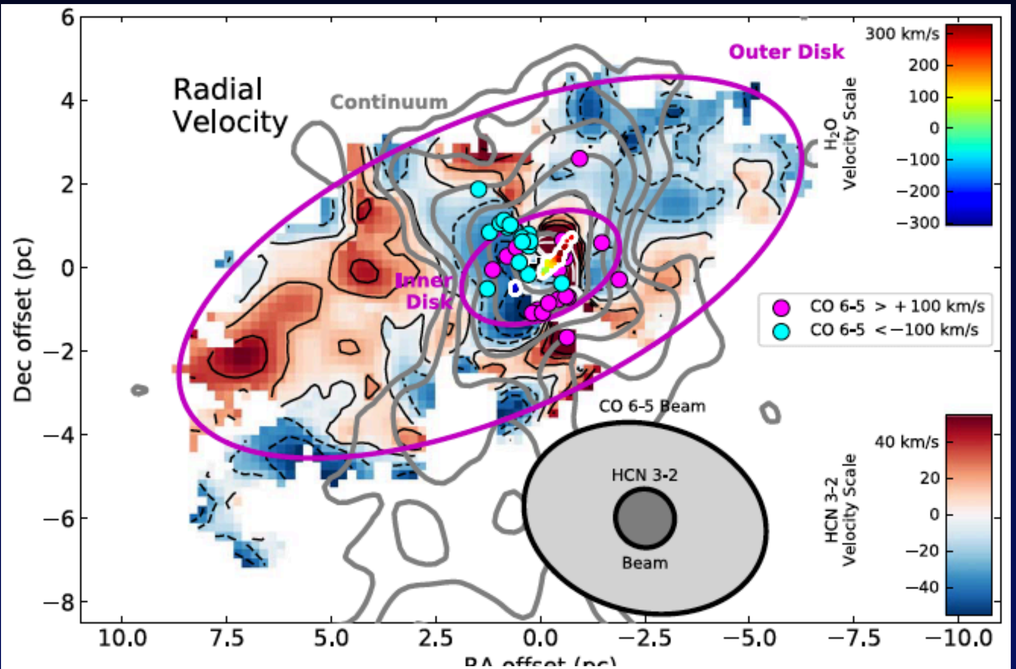
Detailed ISM study of local galaxies

In the local universe physical scales of:

- 100s pc = average distance between giant molecular clouds
- <1-10 pc = AGN torus, jet, nulcear winds

routinely reached

- ★ withouth AO / with ground layer correction (e.g. SINFONI/VLT)
- ★ opt/nir interferometry , mas (Gravity/VLT)
- ★ with ALMA long baselines <1 pc



NGC1068, ALMA, Impellizzeri+2019

Detailed ISM study of local galaxies

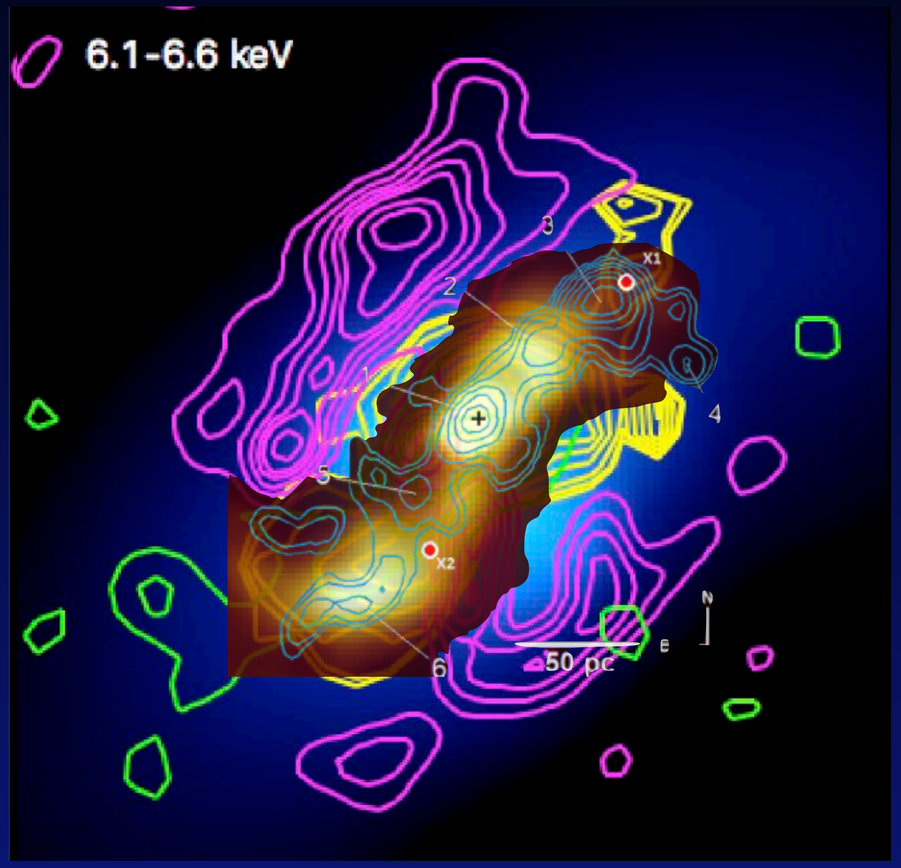
AO important to track ISM - AGN interplay
inflows/outflows
down to nuclear scales

Inner 200 pc
of nearby Seyfert ESO428-G14
feruglio, fabbiano+2019

AO in optical range (e.g. MUSE,MAVIS)
for warm ionised gas
[OIII], Ha distributions
outflows/inflows

ALMA CO

SINFONI-AO H2



[SiVI] SINFONI-AO (May+18)

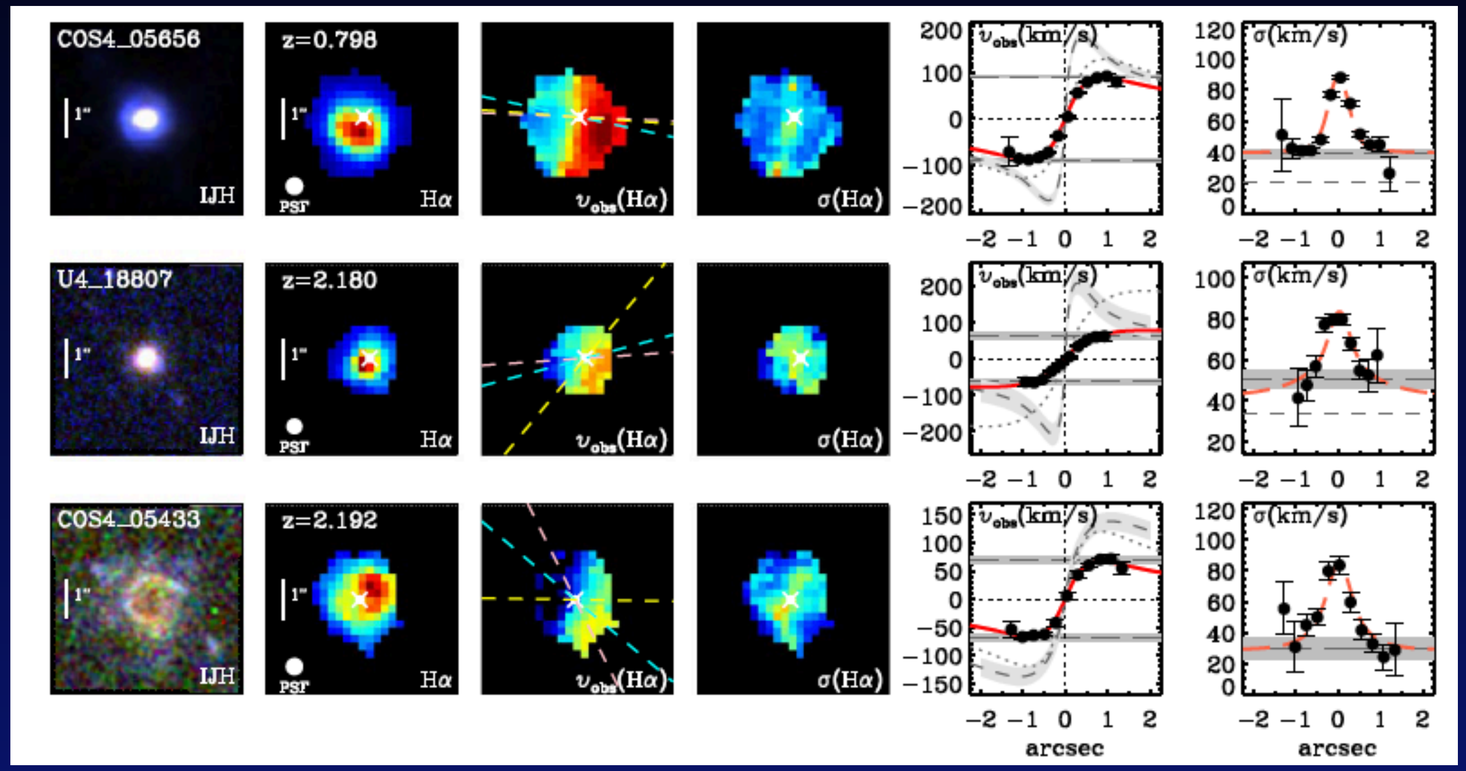
z=1-3 galaxies without AO

The KMOS^{3D} survey, Wisnioski+2019

Multi-IFU, large FOV —-> enables large samples: 700 galaxies and AGN hosts mapped at z=0.6-2.7

Seeing-limited : enables recovering global properties: Ha velocity fields, rotation/angular momentum of disks, detection of outflows, metallicity scaling relations

Best resolution achieved
0.5” seeing = 4 kpc at z~2



Not enough to isolate star-forming clumps, locate outflows, identify origin of the velocity dispersion

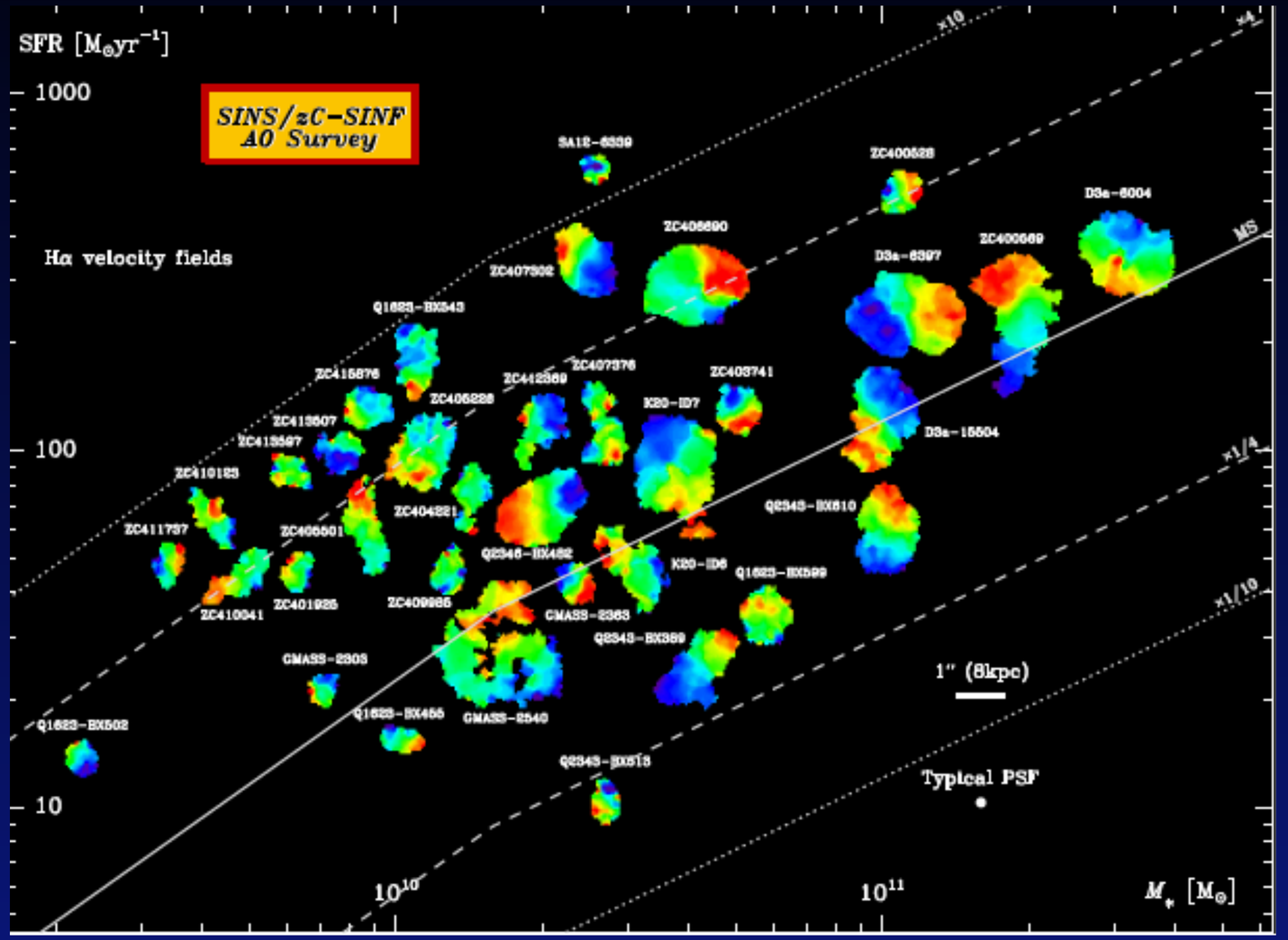
z=1-3 galaxies with AO

SINS/zC-SINF
Forster-Schreiber+2009, 2019

SINFONI/VLT program
100 massive galaxies seing limited
35 AO-Assisted
z=1-3

Best example of high quality AO data
to achieve
reliable overview of kpc scale kinematics
emission line properties

- Quantify fraction/structure of disks/mergers
- Investigate dynamical processes driving galaxy evolution
- Origin of high gas turbulence
- Map galactic winds
- Growth of bulges and SMBH
- Rotation curves for baryon/DM disentangling



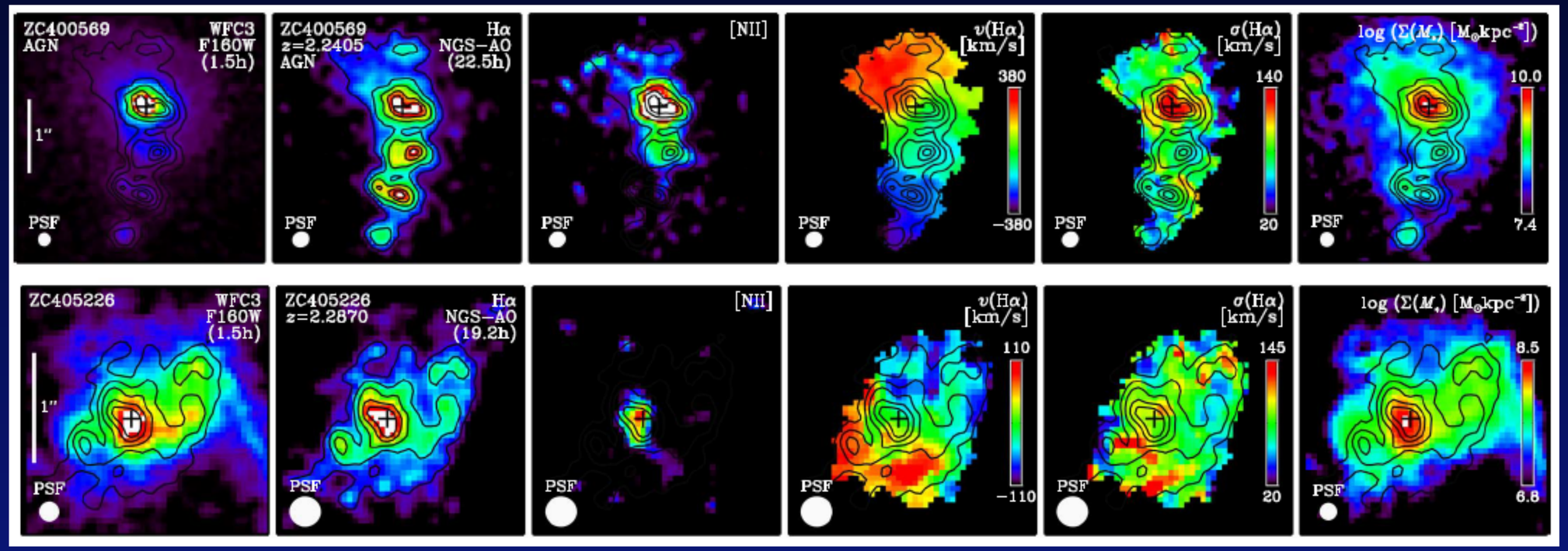
z=1-3 galaxies with SINFONI-AO

With SINFONI/VLT + AO MACAO NGS/LGS PSF of 0.1" is reached

- The low surface brightness emission is recovered with long instegrations
- The clumpy structure of disks emerges
- kinematic complexity
- resolve Regions with high velocity dispersion (around AGN and Star-Forming clumps)

SINS/zC-SINF

Ha and [NII]
- clumpy structure
- velocity and σ_{vel}
- M* density distrib



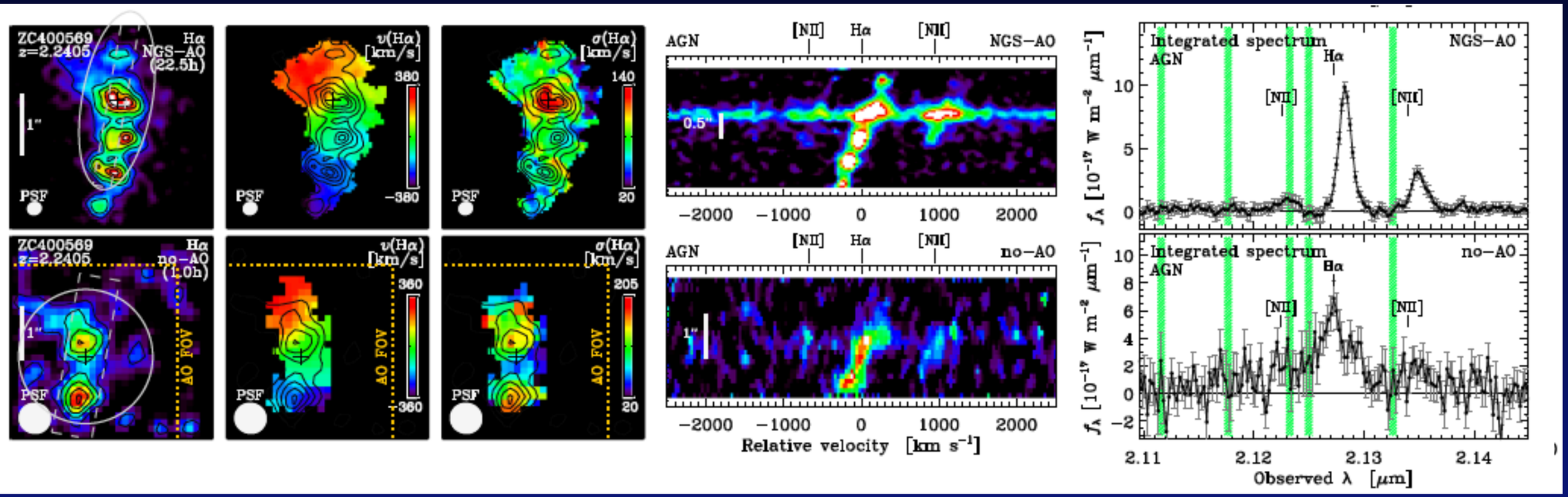
FORSTER-SCHREIBER+ 2019

z=1-3 GALAXIES WITH SINFONI-AO

AO SUPPORTED BY LONG (STILL FEASIBLE) INTEGRATIONS ALLOWS TO GAIN IN IMAGE QUALITY, x10 IN RESOLUTION AND IN SURFACE BRIGHTNESS SENSITIVITY

AO NGS/ LGS

seeing-limited

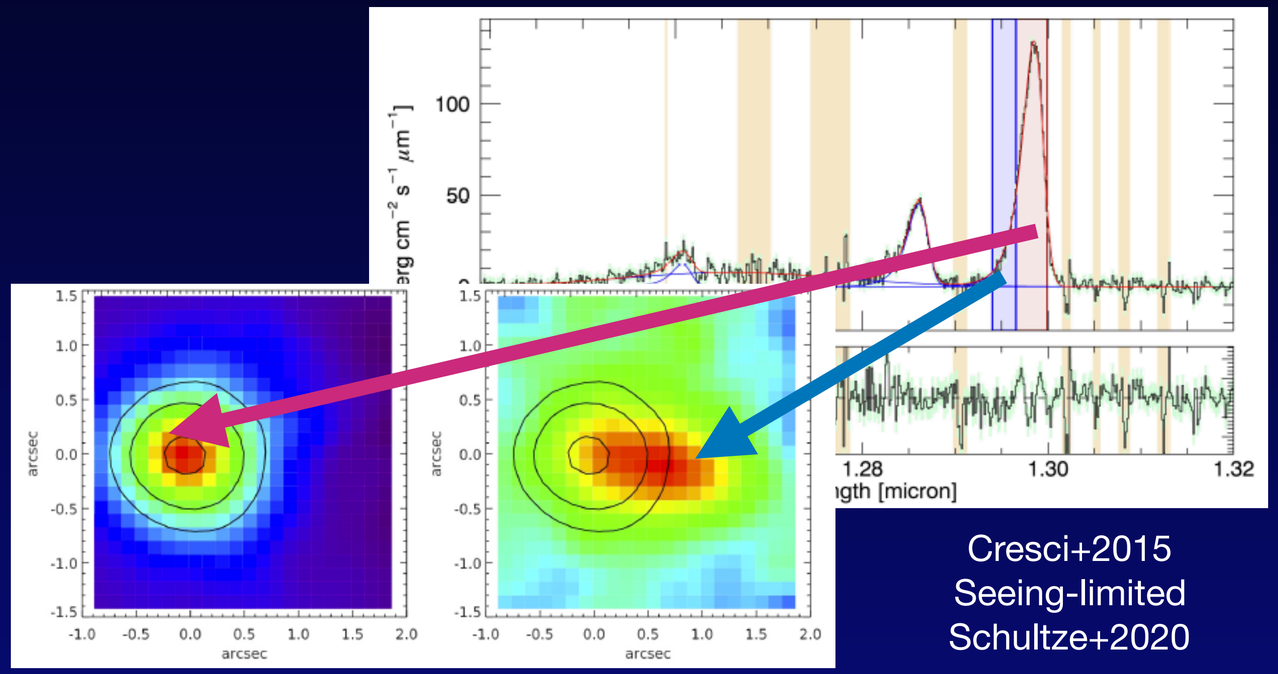


Forster-Schreiber+2019

HIGH-z LUMINOUS AGN HOSTS

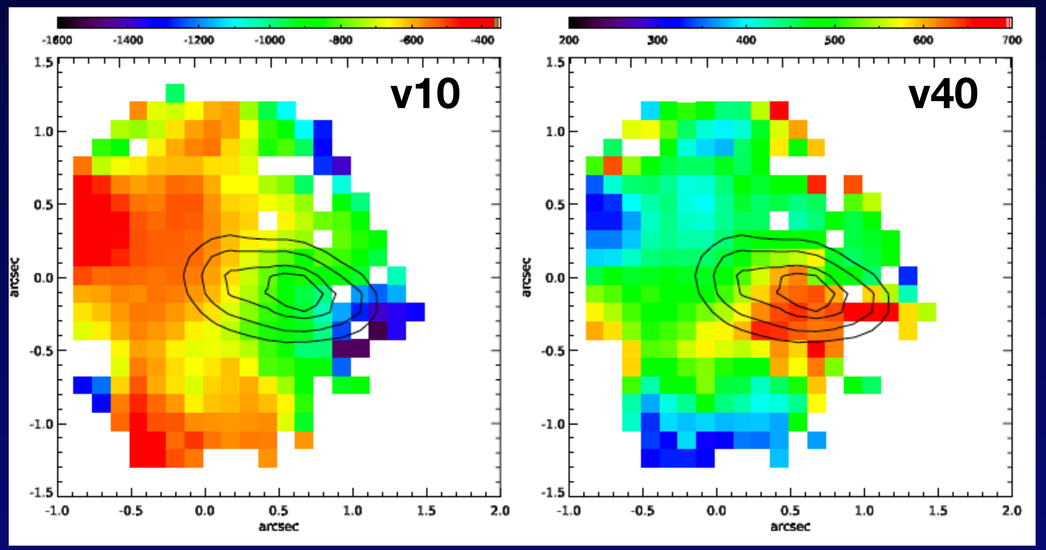
FOR GALAXIES WITH LUMINOUS AGN, POINT SOURCE TO BE SUBTRACTED

- PSF NOT WELL DEFINED, VARIES IN FOV
- EXTRA-EFFORT IN DATA ANALYSIS PACKAGES TO ANALYSE AGN COMPARED TO SF GALAXIES WITHOUT BRIGHT NUCLEUS



Cresci+2015
Seeing-limited
Schultze+2020

QSO HOST AT z=1.5
SKEWED [OIII] PROFILES = OUTFLOW
LOCATION OF SF VS OUTFLOW
HIGH VELOCITY DISPERSION AT OUTFLOW, SF CANNOT OCCUR THERE



AO FOR BETTER MAPPING OF [OIII] AND Ha AND BETTER SUBTRACTION OF CENTRAL QSO

HIGH-z Luminous AGN hosts

FOR GALAXIES WITH LUMINOUS AGN, POINT SOURCE TO BE SUBTRACTED

+DIFFICULT PSF RECONSTRUCTION, VARIES IN FOV

+EXTRA-EFFORT IN DATA ANALYSIS PACKAGES TO ANALYSE AGN COMPARED TO SF GALAXIES WITHOUT BRIGHT NUCLEUS

SUPER Large Program @SINFONI

P.I. Mainieri

The SINFONI Survey for Unveiling the Physics and Effect of Radiative feedback

200 hours with SINFONI+AO

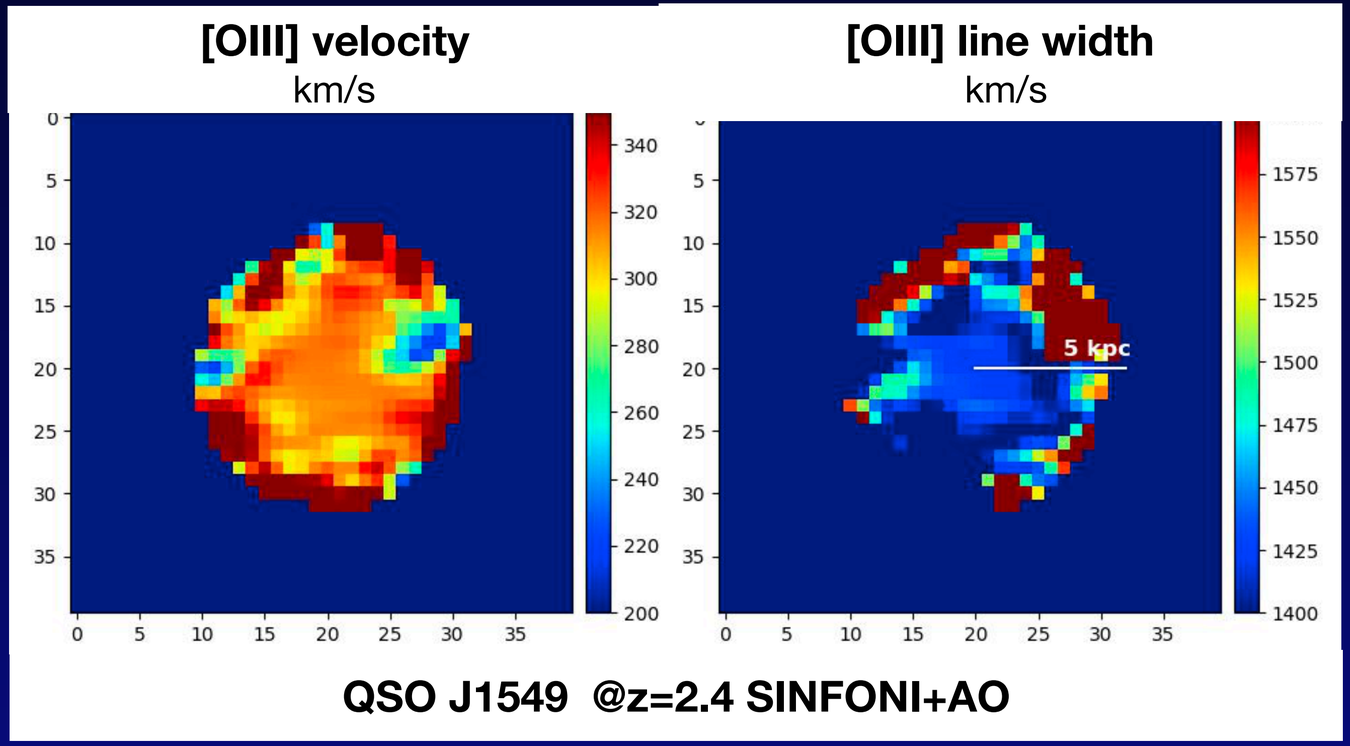
30 AGN z~2

GOAL: kpc resolution

+[OIII] and Ha kinematics

+isolate disks / outflows / perturbations

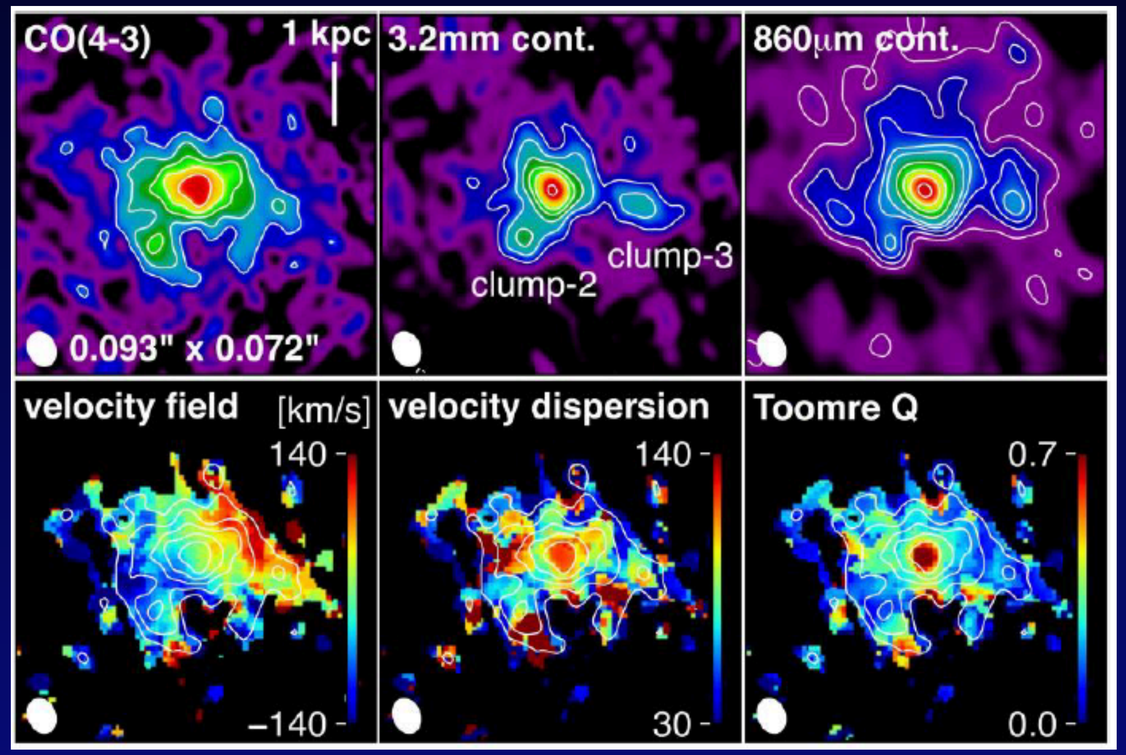
+outflow census and physical parameters (sizes, mass rates, mass loading)



MULTIPHASE DIAGNOSTICS AT HIGH RES

SYNERGY WITH ALMA (P. CILIEGI'S TALK YESTERDAY)

- COMBINE WARM GAS KINEMATICS WITH COLD MOLECULAR GAS
- DOMINANT AND UNOBSCURED ISM PHASE —> BARYONIC MASS BUDGET
- RELATION OF DIFFERENT GAS PHASES : COLD/WARM/HOT , IONISED/NEUTRAL/MOLECULAR



Tadaki+2018

kpc resolution at z~4

LUMINOUS SMG AT z~4
VERY RARE OBJECT!
NOT REPRESENTATIVE OF MS POPULATION (<1 MJY)

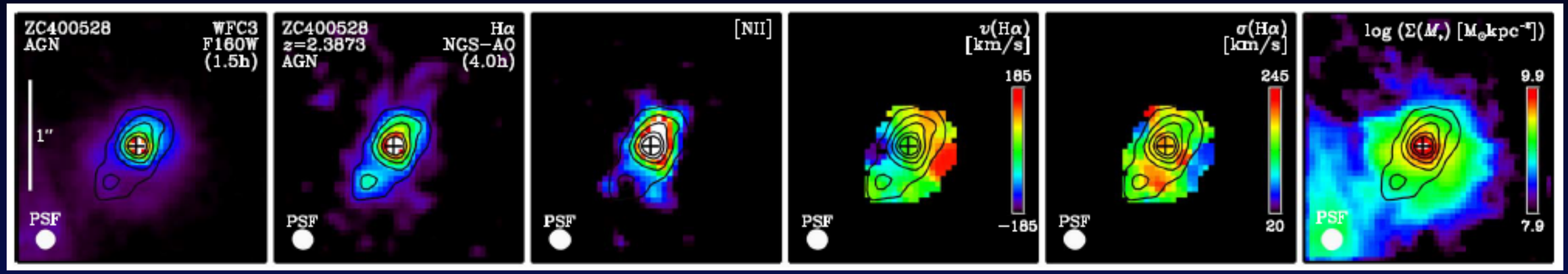
CO AND CONTINUUM MAP AT KPC RESOLUTION

SUPER-BRIGHT CO LINE (6MJY AT PEAK)
14 HOURS INTEGRATION WITH ALMA

SPECTRO-IMAGING
WITH COMPARABLE QUALITY TO SINFONI(ERIS)+AO
HARDLY FEASIBLE WITH ALMA
FOR MS GALAXIES AT z~2

MULTIPHASE DIAGNOSTICS AT HIGH RES

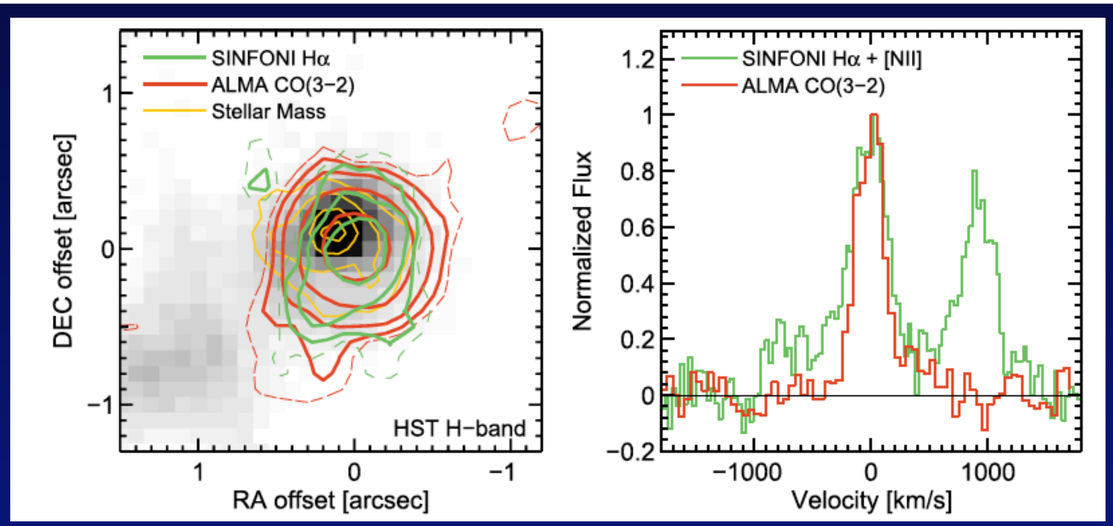
- WE NEED TO CONSTRAIN DIFFERENT GAS PHASES : COLD/WARM/HOT , IONISED/NEUTRAL/MOLECULAR
- FOR THESE TARGETS DIFFICULT TO REACH SIMILAR ANGULAR RESOLUTION / SENSITIVITY WITH ALMA



ALMA CO MAP
0.5” RESOLUTION = 4 KPC

CO PEAK 2 MJY FOR DISK
0.4 MJY FOR OUTFLOW
HERRERA-CAMUS+2019

IFS+AO on 8m(40m) beats ALMA



COMPARE
HA AND CO
LINE PROFILES

FUTURE: ERIS/VLT AND ELT

EXTEND DETAILED KINEMATIC STUDIES IN GALAXIES AND AGN USING

1- ERIS/VLT + SCAO

IFU SPIFFIER

UPGRADED VERSION OF SPIFFI/SINFONI

+HIGH RESOLUTION GRATING R=8000

DIFFRACTION LIMITED IMAGING WITH AO DSM + NGS/ 4 LGS

IFU	
Band	J,H,K
FOV	8”x8”, 3.2”3.2”, 0.8”x0.8”
Px scale	250,100,25 mas/spaxel

INDISPENSABLE INSTRUMENT

2- MAORY+MICADO

IN SINERGY WITH HARMONY (P. CILIEGI’S TALK)

MAP GAS DISTRIBUTION IN DISKS AT HIGH Z: <1 KPC AT Z~2 TO 100 PC AT Z>1

LARGE FOV —> IDENTIFY BEST TARGETS FOR SPECTROSCOPIC FOLLOW-UP

LUCI+AO @ LBT

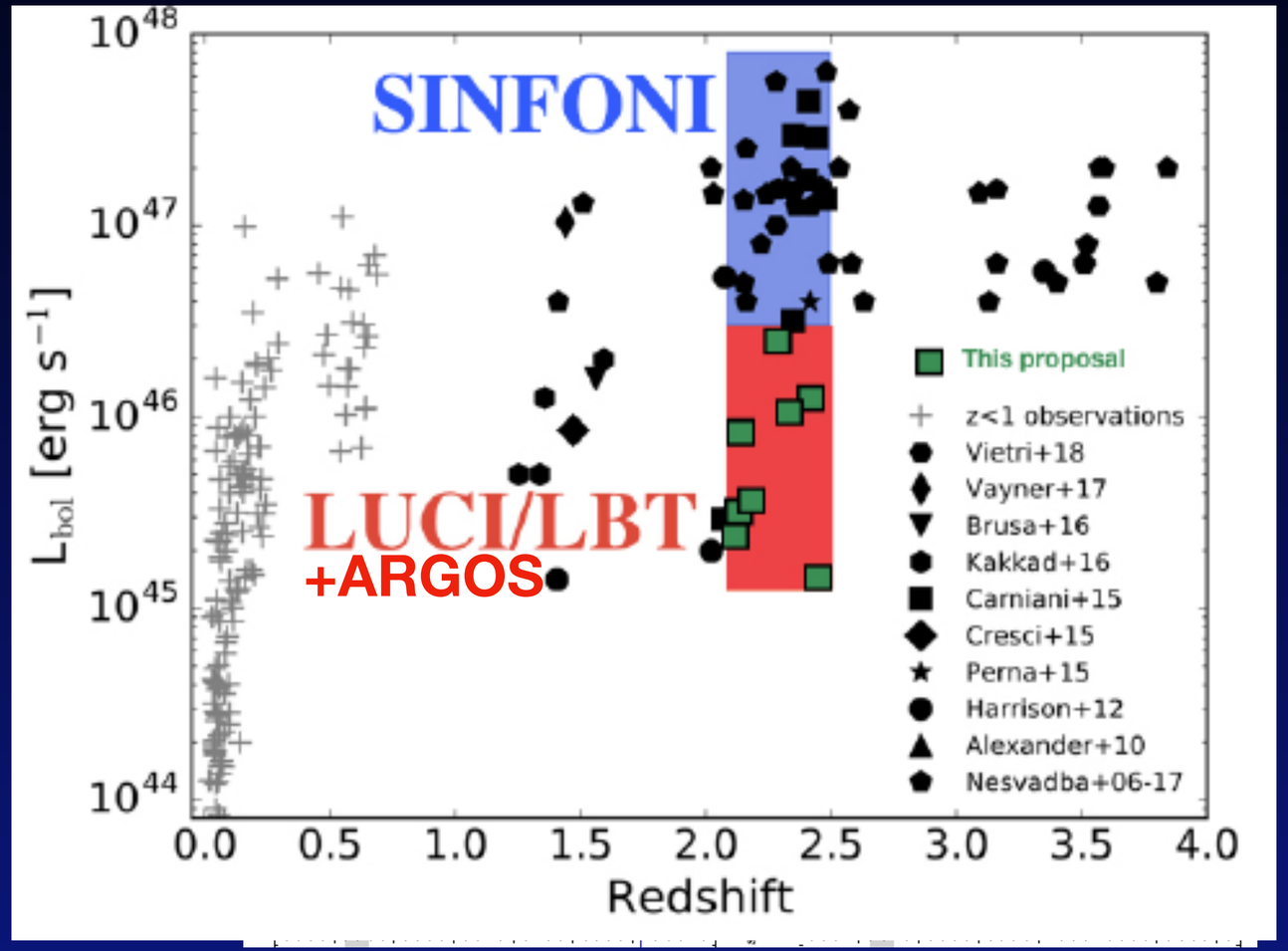
SLIT spectroscopy + AO to resolve emission along slit

LUCI SEEING-LIMITED: SIZE OF EMISSION ALONG THE SLIT (NEAR-SLIT SPECTROSCOPY) FOR HIGH Z AGN
ALLOWS EXPLORING SPATIAL DISTRIBUTION /SIZES, DERIVE DISK AND OUTFLOW SIZES, MASS RATES, LOADING FACTORS BISCHETTI+2017, A&A

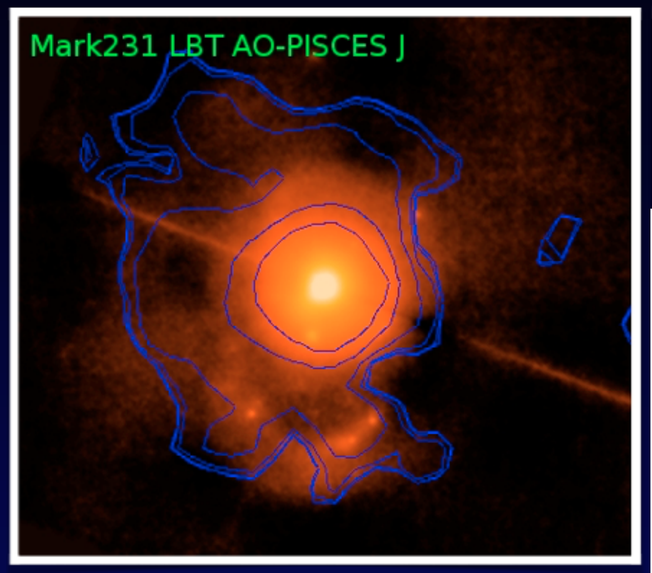
LUCI + SOUL ARGOS GLAO CORRECTION TO ENHANCE SENSITIVITY AND SPATIAL RESOLUTION IN A SAMPLE OF Z>2 QSO HOSTS

ON-GOING PROJECT IT-2019B-035

TODAY LUCI THE ONLY AO-ASSISTED NIR SPECTROGRAPH ACCESSIBLE TO US



LBT-AO TO MAP QSO HOST GALAXIES



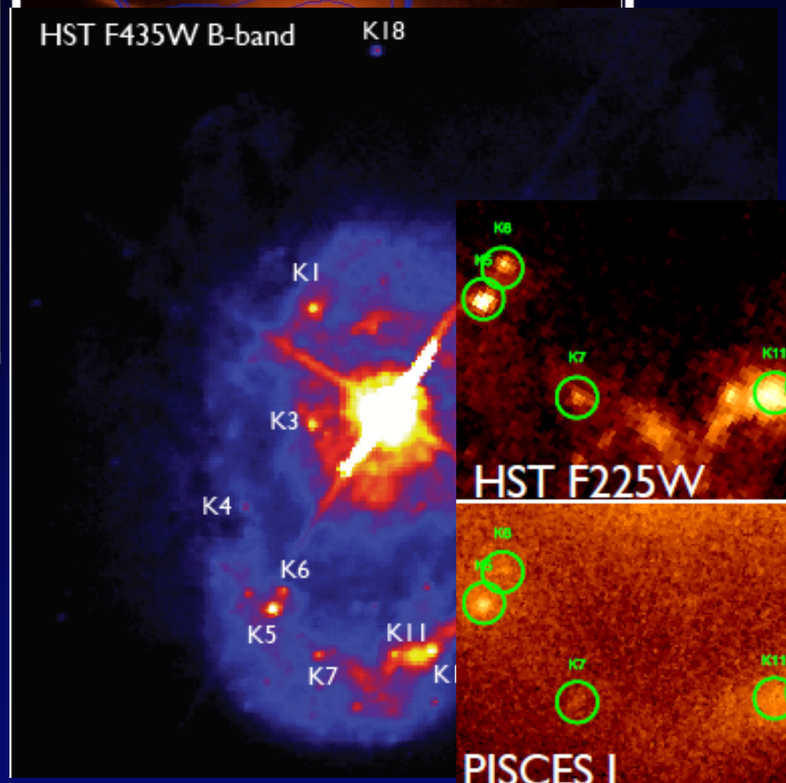
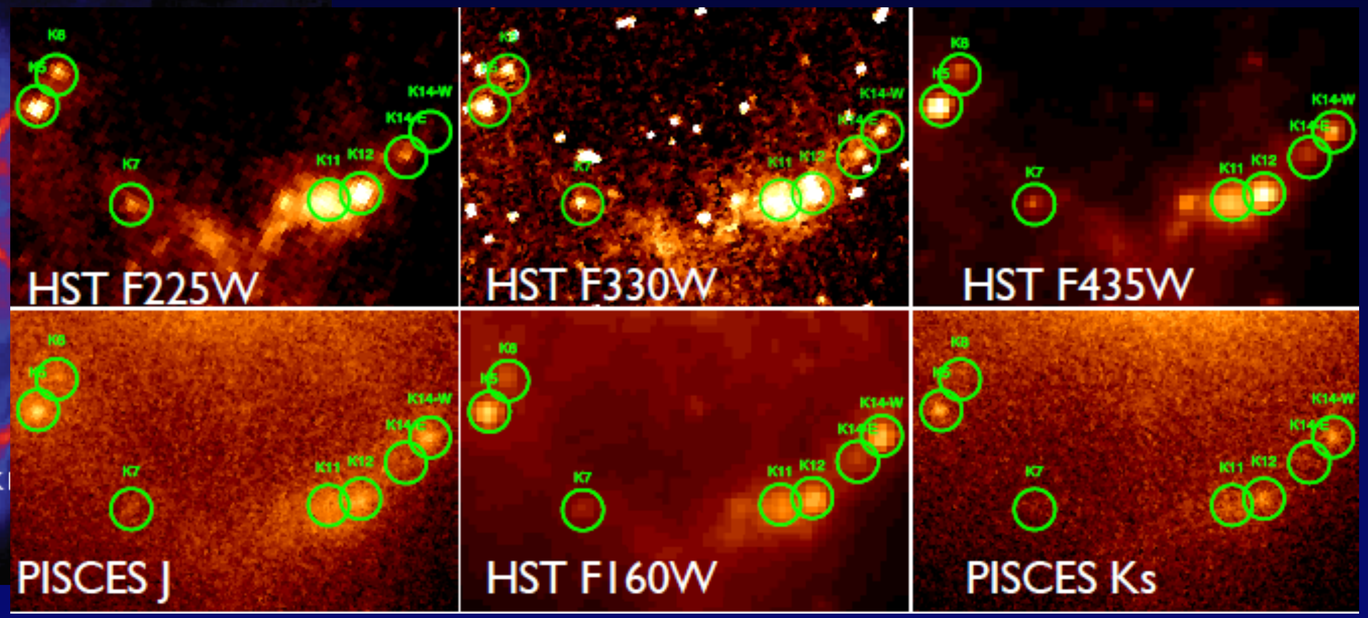


IMAGE OF THE HOST GALAXY OF QSO MRK231
WITH LBT AO
YEAR 2012

IMAGE QUALITY SIMILAR TO HST

Probe clump colors, ages, gradients location with respect to outflows



credits Angela Bongiorno, V. Testa

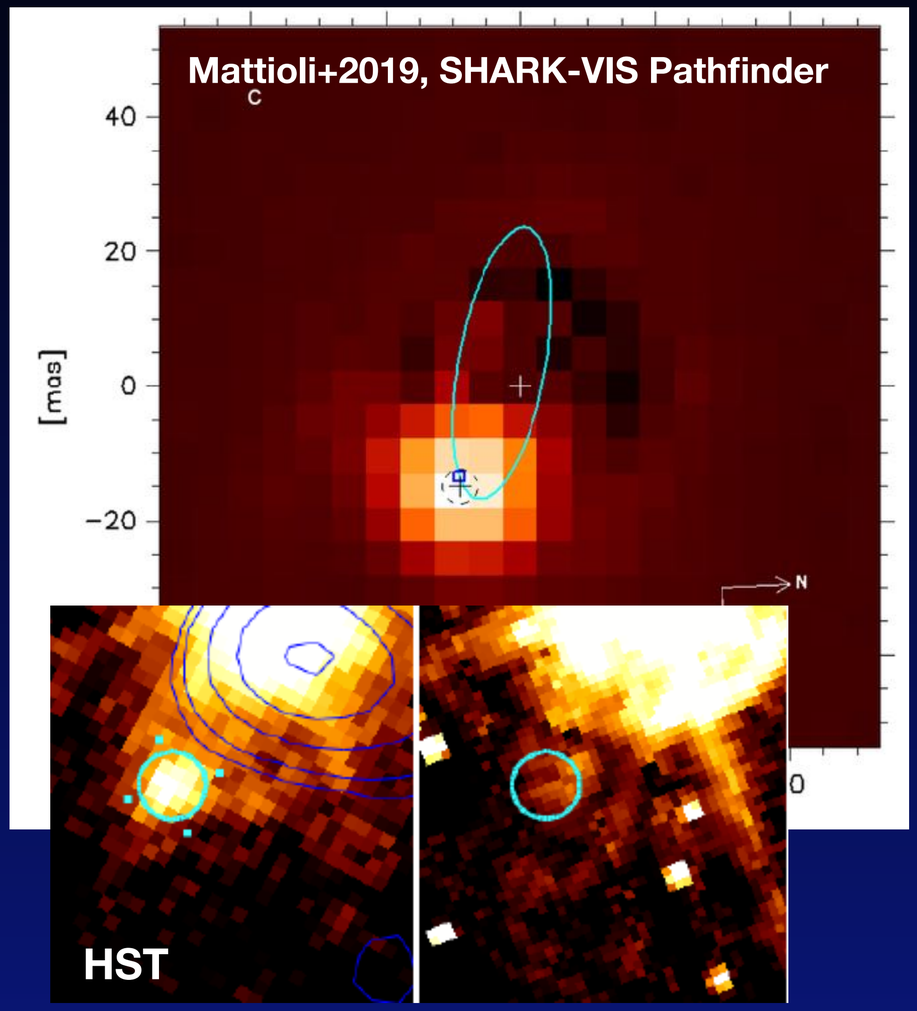
FUTURE:SHARK-NIR/VIS+SOUL

will approach Diffraction limit
contrast enhancement
SRH ~ 70% at mag 13.5

Extragalactic application on AGN/QSOs:
SHARK-NIR + SOUL will enable

- imaging of host galaxies of few 10-100 luminous AGN/QSOs
- map morphology of host galaxy/mergers & environment
- probe the stellar mass of hosts
- competitive with HST imaging
- interesting to have a slit / IFU

R=700 a bit low



micado as well, Portaluri's talk earlier

Conclusions

- opt/nir spectro-imaging with AO best (only) option to map with sub-kpc resolution galaxy/agn kinematics at z~2 and beyond
- mapping with ALMA limited: opt/nir imagers with large fov, mavis, micado, strategic to select best candidates for spectro follow-up
- Improve reliability of AO isntruments
- effort in data analysis sw to make easier and enhance impact of the intruments (dedicated workshops, schools,...)

e.g. MUSE without AO data analysis straightforward
with AO challenging even for experts