Archival science w/ Euclid — the external perspective

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Archival science

— Wide range of galaxy evolution studies. From grism (~30million galaxies) constraints on redshift, SFR(Halpha), extinction (Balmer decrement). From imaging (~1.5billion galaxies) photometry out to H-band, size, merger-status, and environment. *Combined with other wide area photometric and spectroscopic studies from helps with photo-z's and stellar population properties constraints!*

— BH-galaxy co-evolution studies. *Want cross-match with all-sky radio and X-ray surveys*

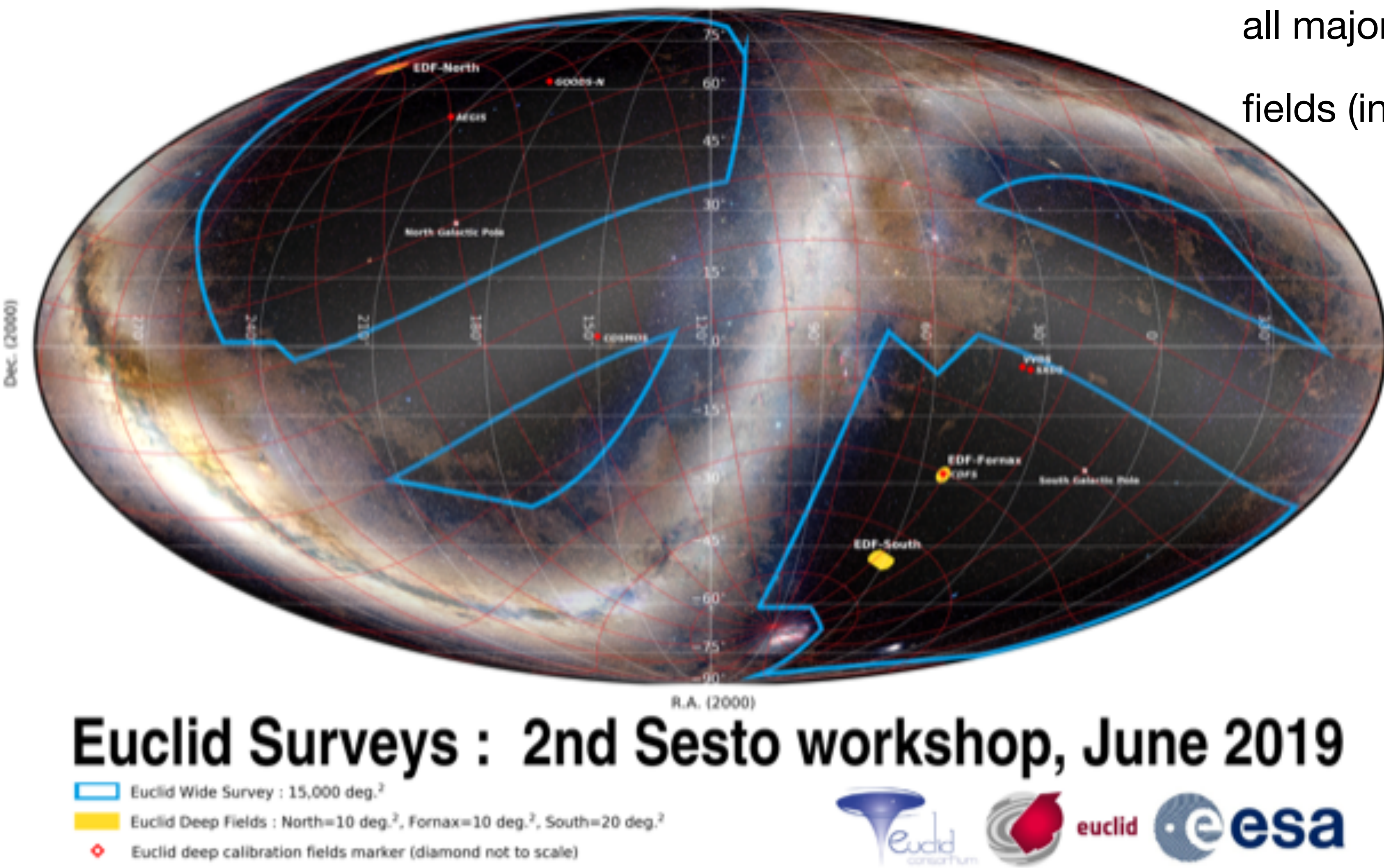
— High-z studies: LBGs, LAEs but also dusty high-z galaxies thanks to synergy with upcoming wide area (sub)mm surveys (LMT/Toltec).

— Time-domain astronomy (find transients and study their hosts)

— ???? *Discuss!*

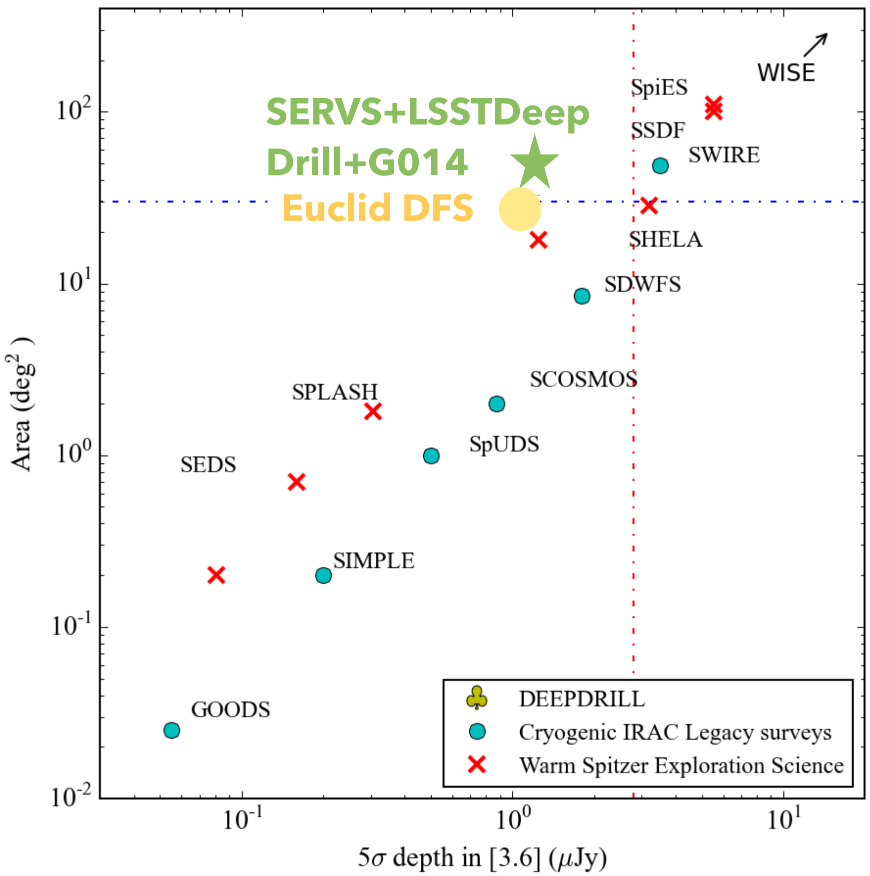
Galaxy evolution archival science considerations

- Lots of options within Euclid deep fields, but Euclid-wide also increases bang of many other existing datasets in other fields!
- In conjunction with ancillary data can have significantly improved redshifts (photometric+grism) and derived stellar population parameters over significant cosmic volume
- Want to facilitate archival science with Euclid by facilitating the rapid inclusion of Euclid redshifts and photometry into NED (e.g. . bulk of WISE sources in NED currently, no other info).



Excellent coverage of all major extragalactic fields (including COSMOS)

Provide critical near-IR photometry+grisms to other wide area surveys e.g. the Spitzer surveys of the LSST DeepDrill fields (Lacy et al. 2020 in prep.) and of the HSC-Deep fields



1) deep enough to reach massive galaxies at z~6

2) wide enough to study all environments and rare objects.

SERVS+Spitzer-LSSTDeepDrill (PI Mark Lacy)

SpitzerG014 (PI Sajina)

Euclid DeepFields (PI Capak/ Scarlatta)

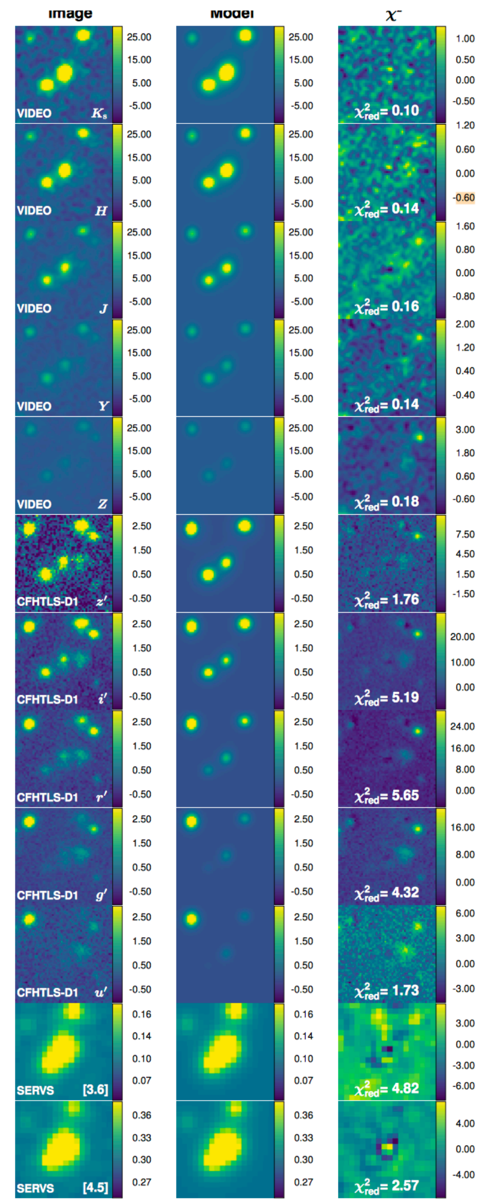
Using Euclid images as priors can greatly improve existing lower-resolution data (e.g. Spitzer IRAC data)

- Here show example of this method where used VISTA VIDEO Ks data as priors for IRAC data.
- Code is parallelized and can process 10^6 galaxies through 13 bands in a few days.
- **Such forced photometry leads to effectively deeper data** (by up to 0.5mag)
- This more reliable photometry (less blending issues) leads to significantly **improved photometric redshifts**

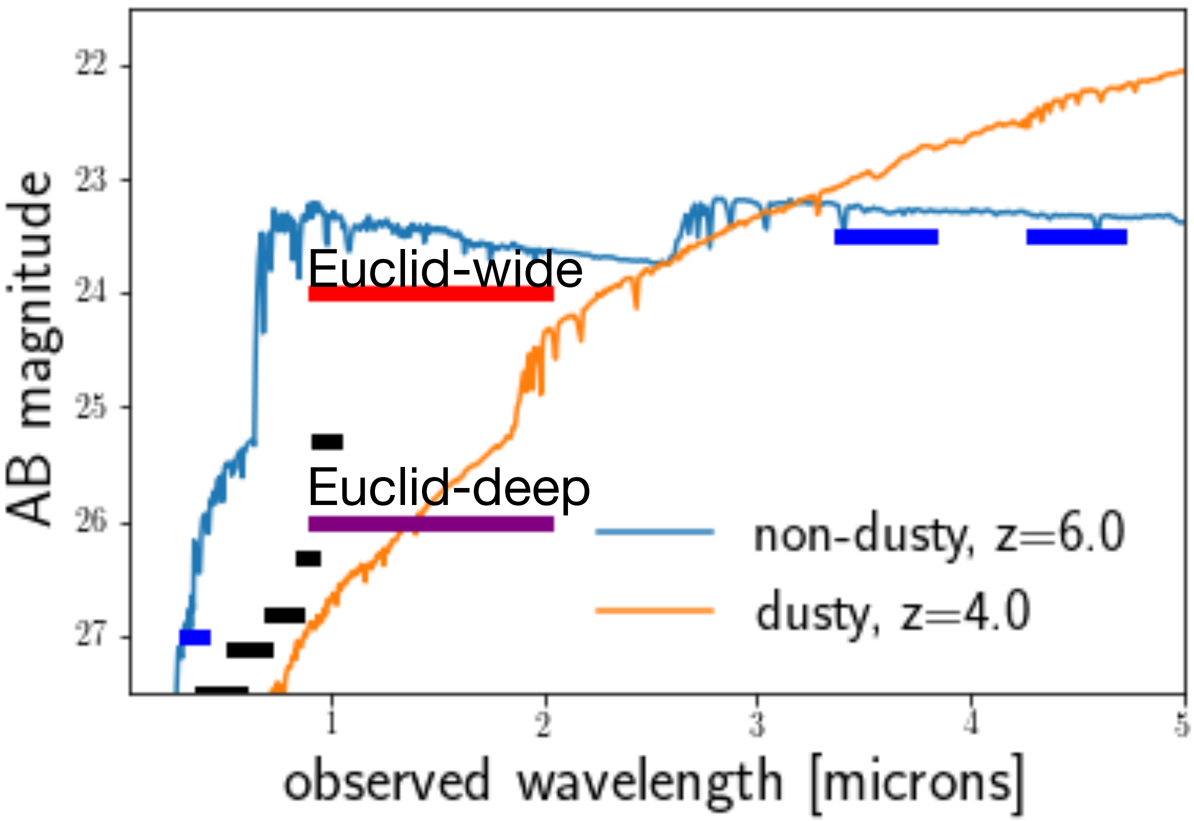
Nyland, Lacy, AS et al. +17

(on results for 1sq.deg in XMM-LSS)

(using Tractor, Lang et al. 2016)



NISP photometry+IRAC great for redder high-z galaxies (quiescent or dusty)



Optical depths: HSC-Deep

IRAC depths: Spitzer DeepDrill

+Spitzer HSCDeep

Used CSP Maraston2005 models

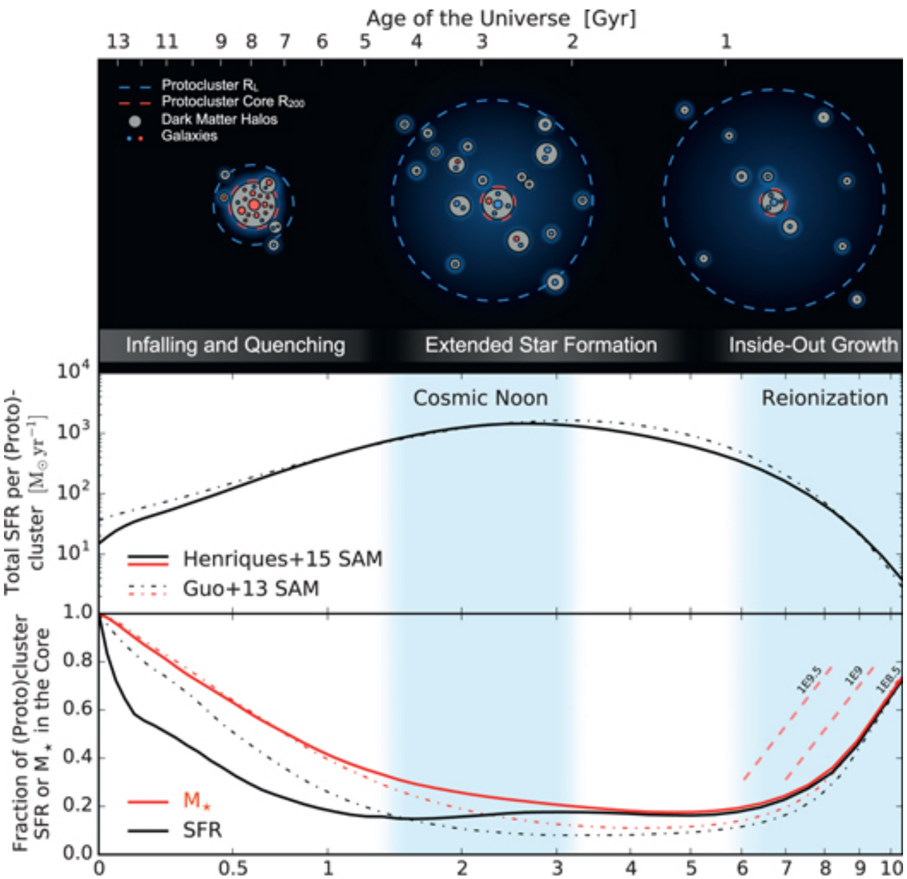
With log(Mstar)~11 for non-dusty

log(Mstar)~11.6, and Av~2 for dusty

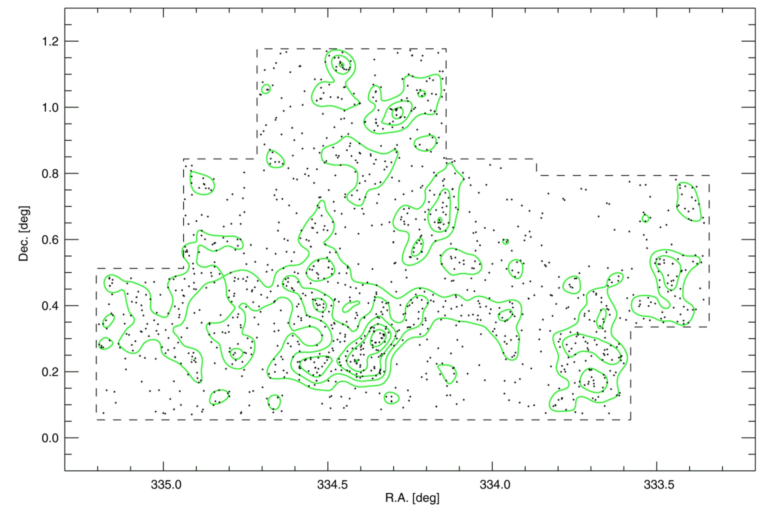
Role of environment in galaxy/BH evolution

- *Euclid will sample a huge cosmic volume enabling all types of "role of environment" studies as well as rare populations studies*.
- Combined with ancillary ground-based and other space-based data will have redshifts and derived stellar population parameters for the 1.5 billion galaxies in its imaging sample + 30million grism spectra.
- It will be able for example to find large samples of high-z (proto-)clusters as well as sample the cosmic web at later epochs.

Role of environment, including assembly of proto-clusters on 10s of Mpc scales is a big open question in galaxy assembly out to cosmic noon, and quenching later on.



Chiang et al. 2017



Protocluster at z=3.09 (SSA22 region)

6x overdensity in LAEs up to 60Mpc in scale.

Yamada et al. 2012, AJ, 143, 4

BH-galaxy co-evolution science considerations

Cross-match Euclid sources with:

— radio surveys such as VLASS https://science.nrao.edu/vlass

— X-ray surveys such as eROSITA https://www.mpe.mpg.de/eROSITA

— Spitzer and WISE to select obscured AGN

Cross-match with Euclid will address the common dearth of reliable optical/near-IR counterparts in these surveys and so lead to greater science return from these past or ongoing surveys as well.

Associating host galaxies and their redshifts, stellar masses, host DM halos etc with BH activity of different modes will allow for key advances in our understanding of BH-galaxy co-evolution.

Synergy with upcoming ground-based highly multiplexed spectroscopic surveys

WAVES - https://wavesurvey.org/project/survey-design/waves-deep/

WAVES-Deep in particular is very complementary to Euclid Deep fields

Aims ~1m spectra out to z~0.8, including a catalog of ~40,000 groups for environment studie

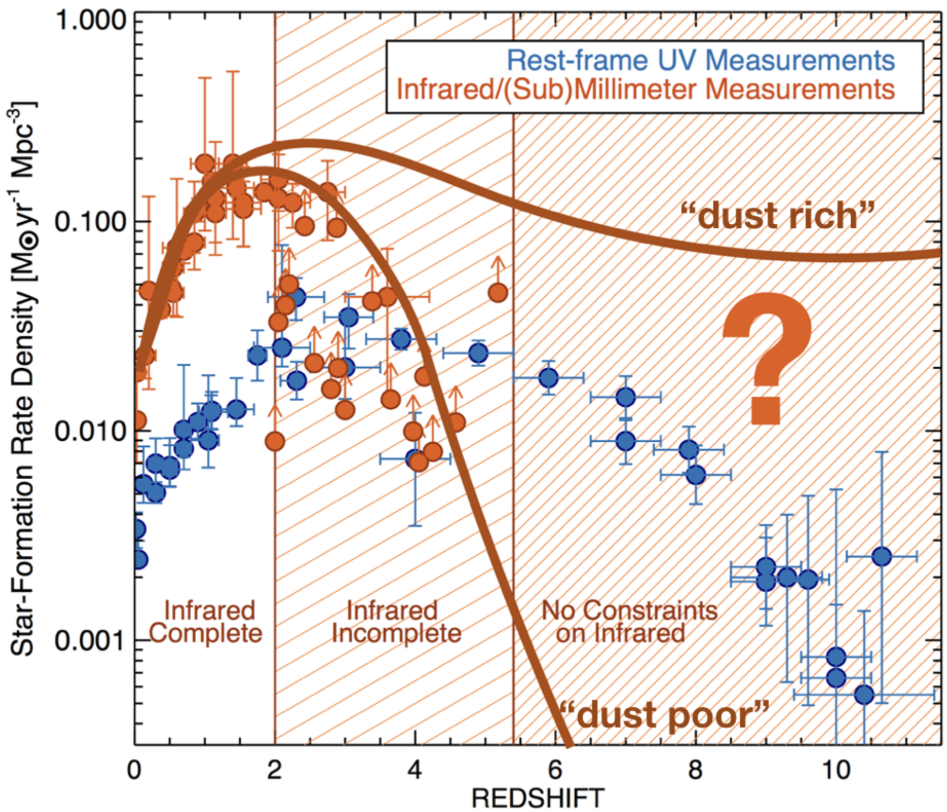
Prime Focus Spectrograph (PFS) Survey - https://pfs.ipmu.jp/research/index.html

Includes a wider (cosmology) component and a deeper up to 15sq.deg. (galaxy evolution) component with targets within respectively HSC-Wide and HSC-Deep (which includes the Euclid calibation field, COSMOS).

PFS spectral range 0.38-1.3um w/ R~3000, Euclid grism 0.9-1.8um

Euclid grism extends coverage (in key redshift ranges adds Halpha, Balmer decrement). Ground-based spectra great for calibrating photo-z's, providing more detailed information on overlap galaxies, and testing reliability of grism spectra in assigning redshift or finding AGN (e.g. see Bridge et al. 2019).

Past cosmic noon our census of SF (and AGN) activity is incomplete



Euclid already aims to study the high-z Universe through LBG and LAE selected sources.

The synergy with the planned LMT/Toltec survey (covers 2/3 Euclid DFs) will help tackle the high-z dusty galaxies. The Toltec survey will detecting all ULIRGs out to whatever redshift they exist in these fields. Euclid+Spitzer will provide the optical/near-IR counterpart.

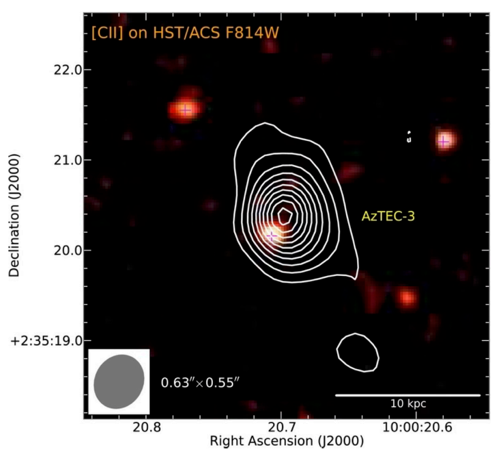
(from Astro2020 Taking Census of Massive, Star-Forming Galaxies formed <1 Gyr After the Big Bang by C. Casey)

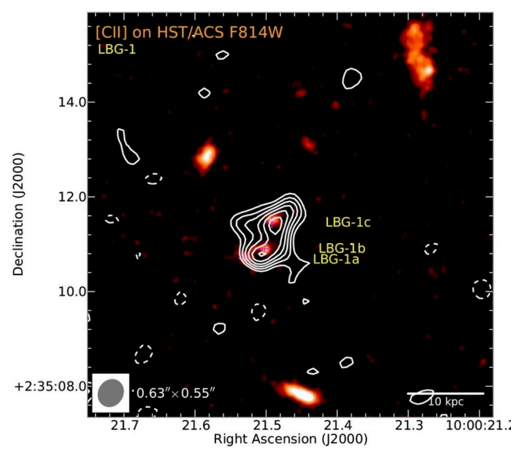
Morphologies of stars and dust

There are multiple follow-up studies possible for high-z dusty galaxies

E.g. follow them up with ALMA and compare their stellar (in Euclid VIS) and dust (in ALMA) morphologies (e.g. Riechers et al. 2014, Jin et al. 2019).

VIS res 0.1”/pixel





e.g. Riechers et al. 2014

z~5 SMGs

Time domain science

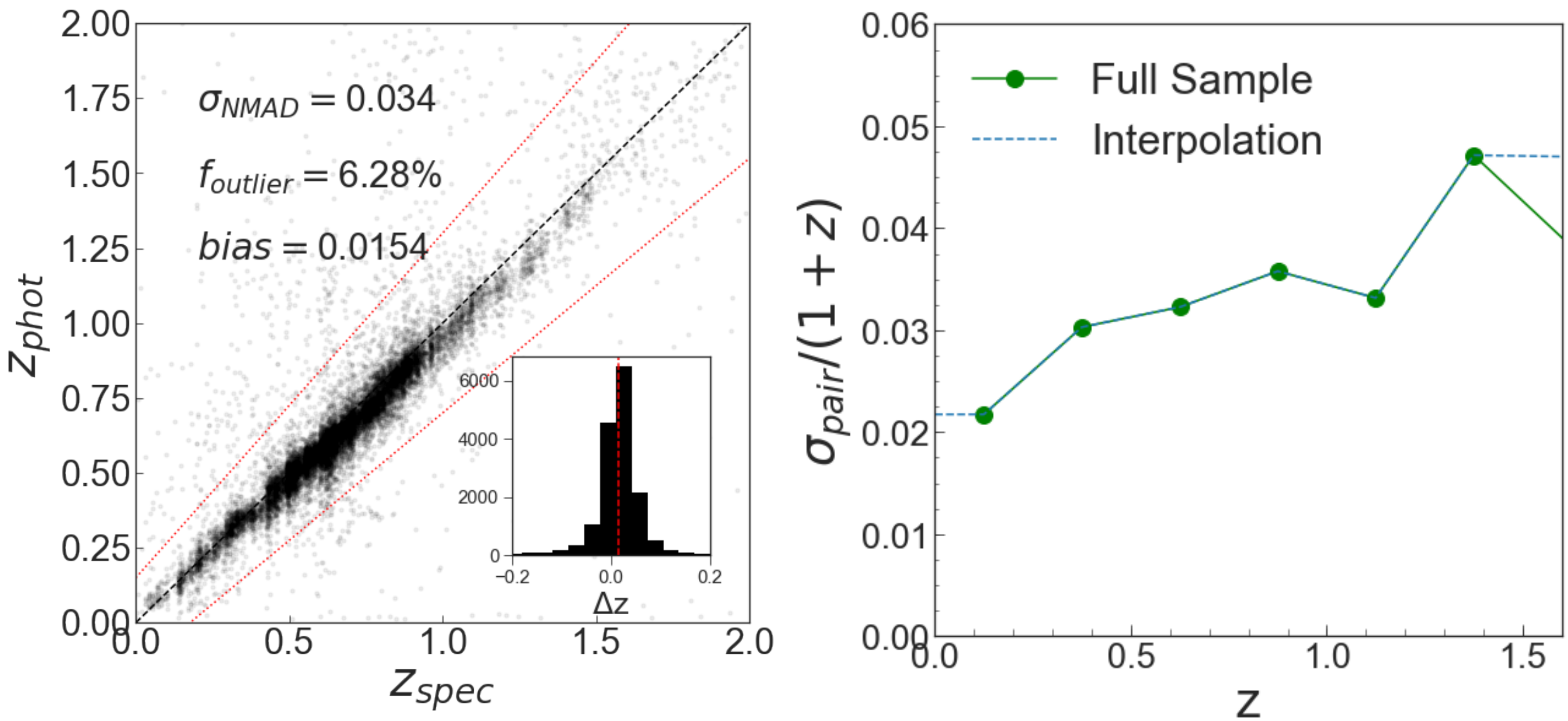
- Find transients in multi-epoch data
- Support TDA science by supporting rapid host galaxy ID— as in through the new NED GW follow-up tool — https://ned.ipac.caltech.edu/uri/NED::GWFoverview/

Wish list

Tools that would facilitate archival research

- Rapid inclusion in NED will support a wide range of extragalactic research
- This will also directly support TDA in providing most probable host galaxies.
- Data volume huge — need platforms for science close to data see Desai et al. Astro2020 white paper.
- Simulations are increasingly key in interpreting our complex datasets. Simulated data products to help interpret Euclid data would also be useful.
- ????? *Discuss!*

Improved photometry=improved photo-zs

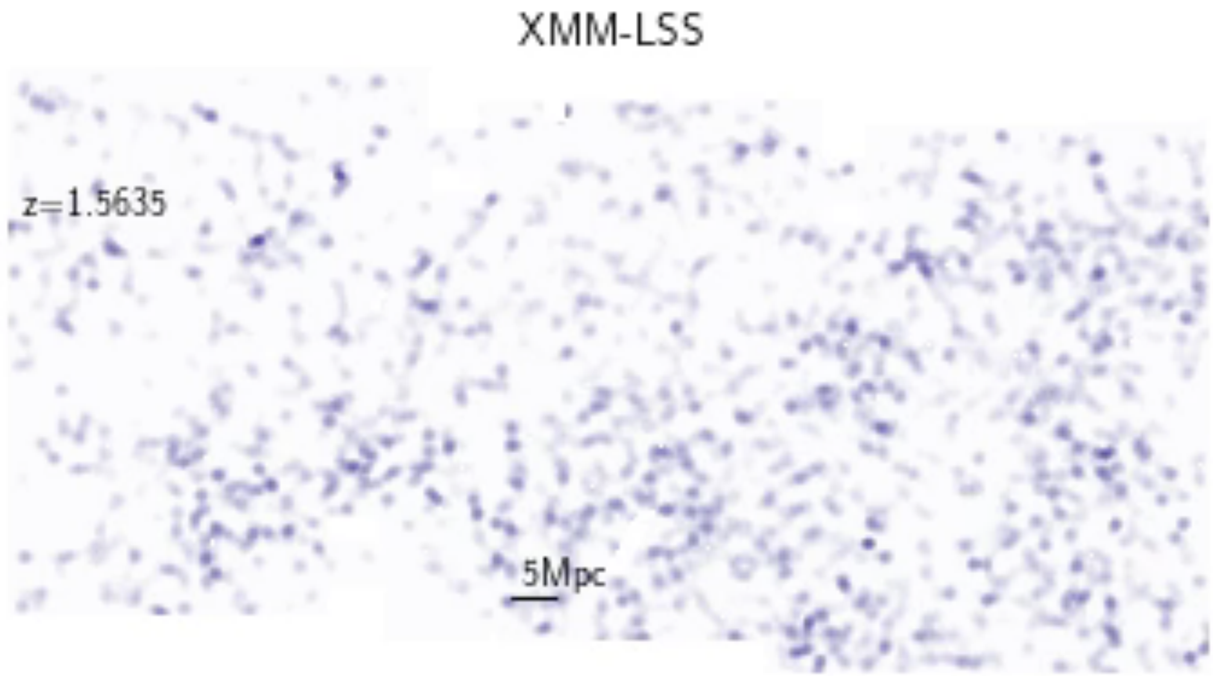


This is a factor of 2-3 better than prior to Tractoring

Krefting, AS et al. 2020, ApJ,

Galaxy evolution in the context of environment

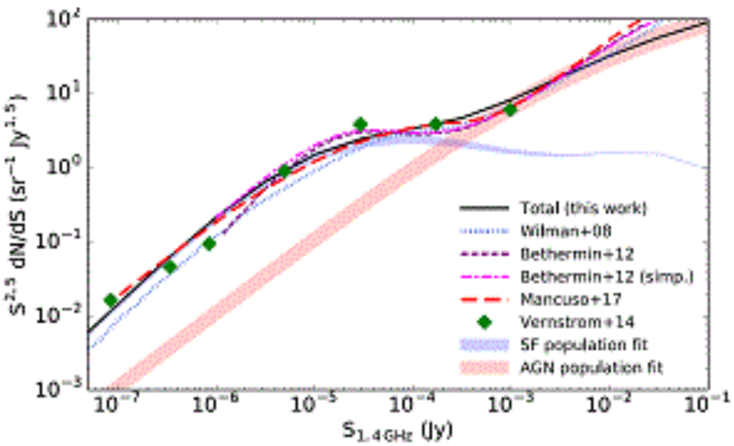
- -Clustering
- -Cosmic web



Can be much finer with Euclid's grism redshifts

BH-galaxy co-evolution science considerations

E.g. in the EUCLID-wide expect >2million radio sources (VLASS depth ~70uJy)



(at 70uJy galaxies dominate, low radio-based SFR vs. Halpha SFR may indicate very recent bursts).

(from Novak et al. 2018 A&A)

High-z dusty galaxies

Large Millimeter Telescope (LMT)

Planned Toltec Legacy survey includes two of Euclid's Deep fields at NEP and CDFS.

Detect ULIRGS out to highest redshift exist and with angular resolution of 5" (comparable to Spitzer MIPS).

Biases in galaxy evolution studies

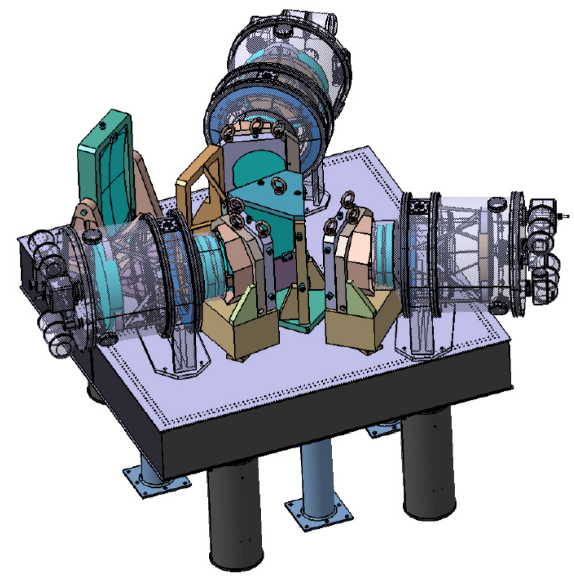
- Given our fantastic datasets — at hand and upcoming in 2020s, we should not neglect improving the means of turning observed photometry to basic stellar population properties (e.g. stellar mass, star-formation rate, dust attenuation level etc).
- Key biases — star-formation history treatment (e.g. Leja et al. 2019) which may not be simple in form, and dust attenuation curve which may be variable (e.g. Kriek & Conroy 2013, Narayanan et al. 2018, Roebuck et al. 2019)
- The more extensive photometric coverage from UV through far-IR, the more sophisticated models we can fit (Euclid fills in in particular the critical large area deep near-IR)
- Multiple constraints on SFH (e.g. SFR indicators sensitive to different timescales) and dust (e.g. Balmer decrement and far-IR emission).

Prime Focus Spectrograph (PFS) Survey - https://pfs.ipmu.jp/research/index.html

Includes a wider (cosmology) component and a deeper up to 15sq.deg. (galaxy evolution) component.

Spectral range 0.38-1.3um w/ R~3000

PFS galaxy evolution survey will be taken in the HSC-Deep footprint but limited by spotty and not too deep near-IR coverage. Euclid photometry can eventually help improve Spitzer coverage in these fields and lead to better photo-z's and stellar population parameters.



The PFS spectra are much more information rich so help with e.g. calibrate methods of selecting AGN in the grism (e.g. as in Bridge et al. 2019)