Maximizing the Scientific Potential of Multi-band Extragalactic Surveys using Forced Photometry

Kristina Nyland

Postdoc at NRAO

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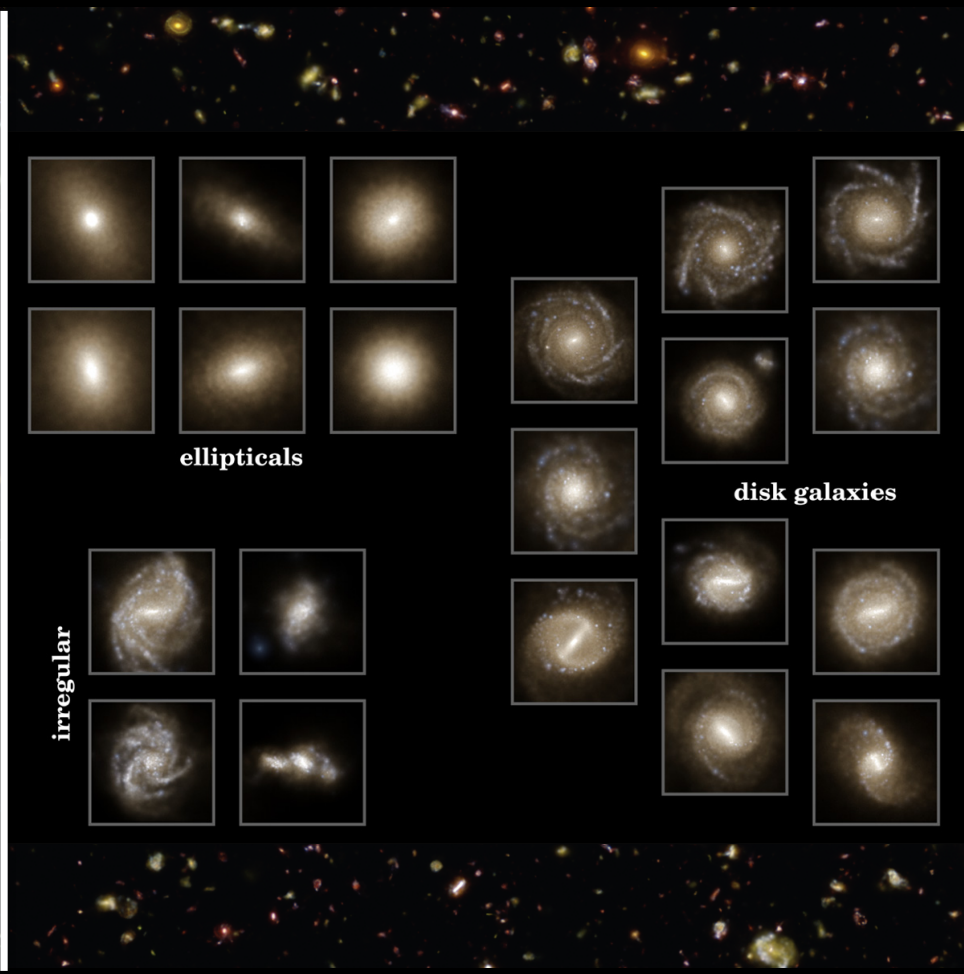
Collaborators: Mark Lacy
SERVS/Deepdrill team

Galaxy Evolution

- How is star formation quenched" in massive galaxies?
- What is the role of AGN feedback in galaxy evolution?
- How did the first galaxies form at high redshift?

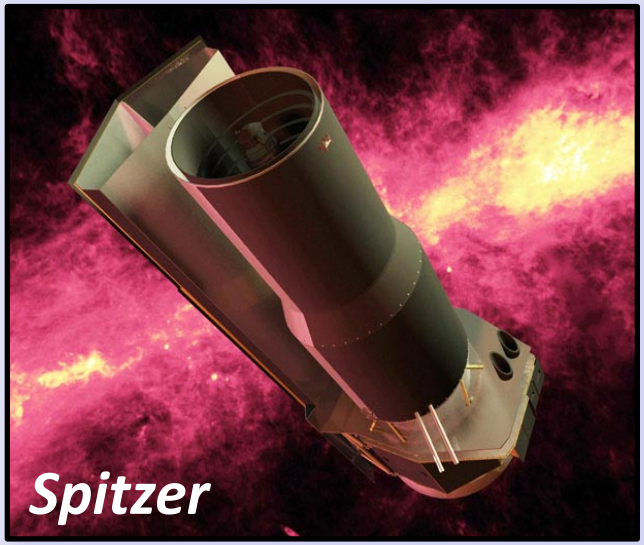
Credit: NASA/ESA, STScI, MAST, Illingworth et al. 2013
http://archive.stsci.edu/prepds/xdf/

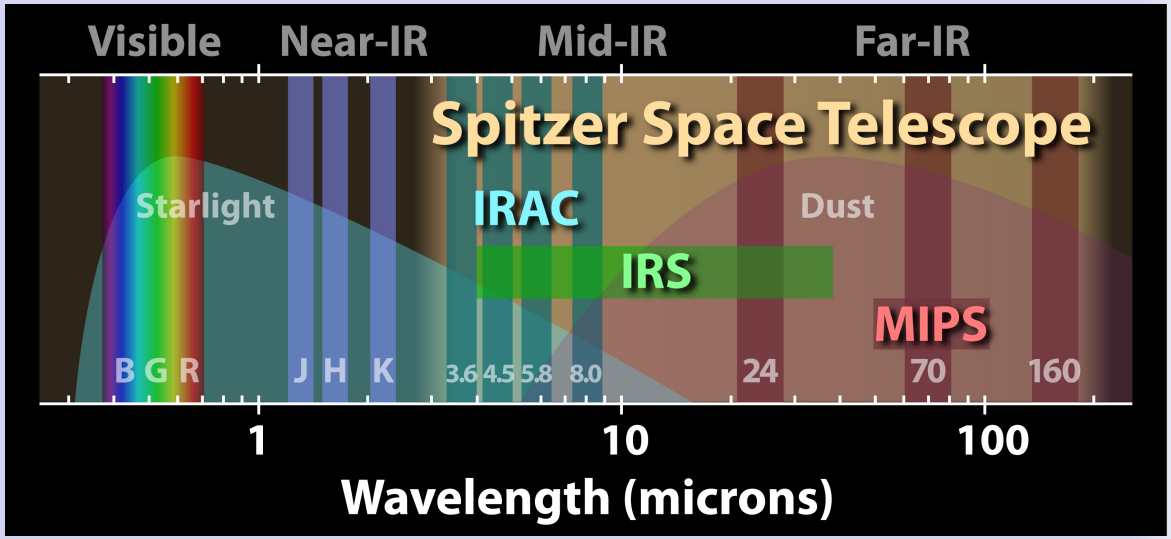


HST Observations

Illustris Simulations

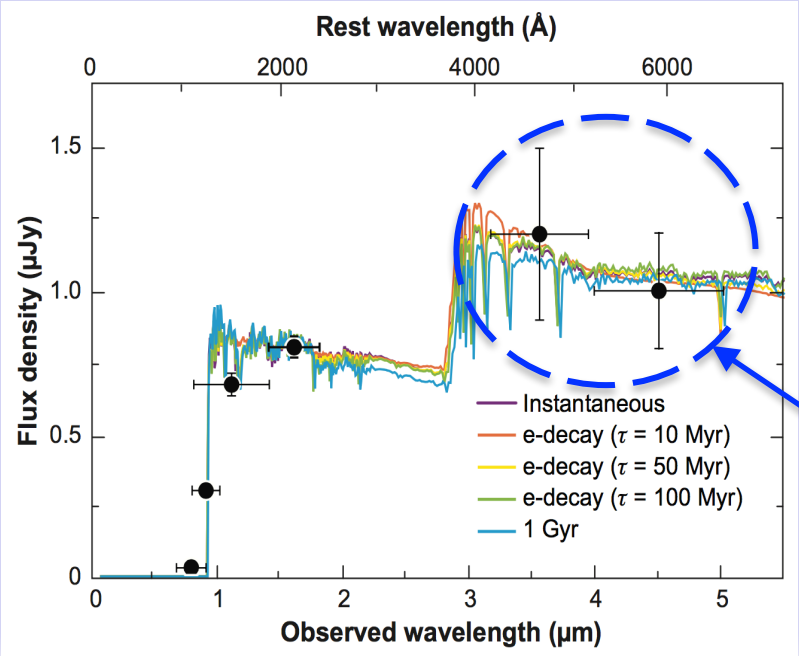
Galaxy Evolution Science with *Spitzer*





Sample z = 7 galaxy SED

Soifer et al. 2008



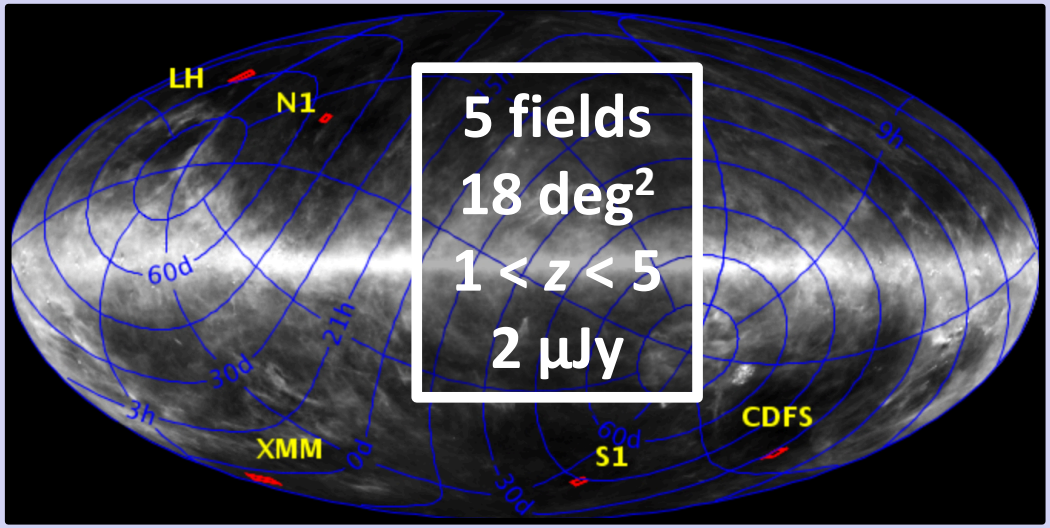
IRAC samples rest frame optical light for 4 < z < 10 galaxies

From Extragalactic Surveys to Science

Spitzer Extragalactic Representative Volume Survey

P.I. – Mark Lacy

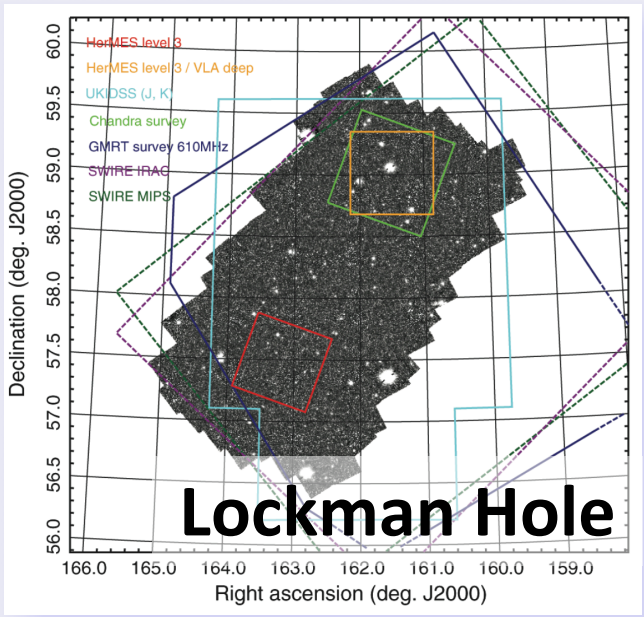
Mauduit et al. 2012

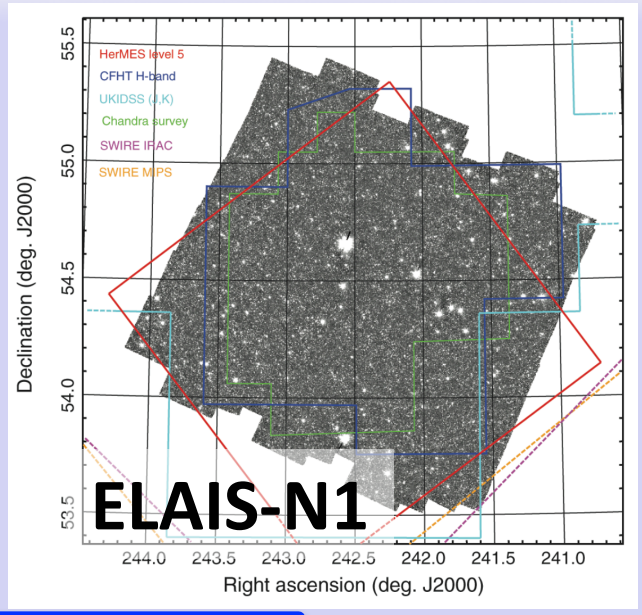


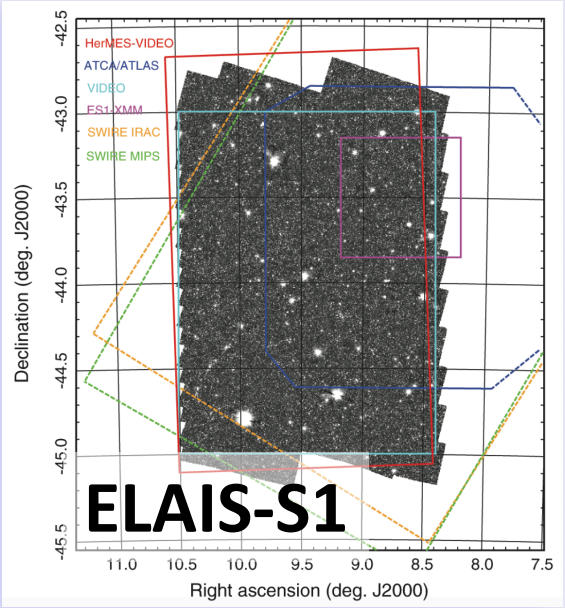
Post-cryogenic IRAC 3.6 + 4.5µm

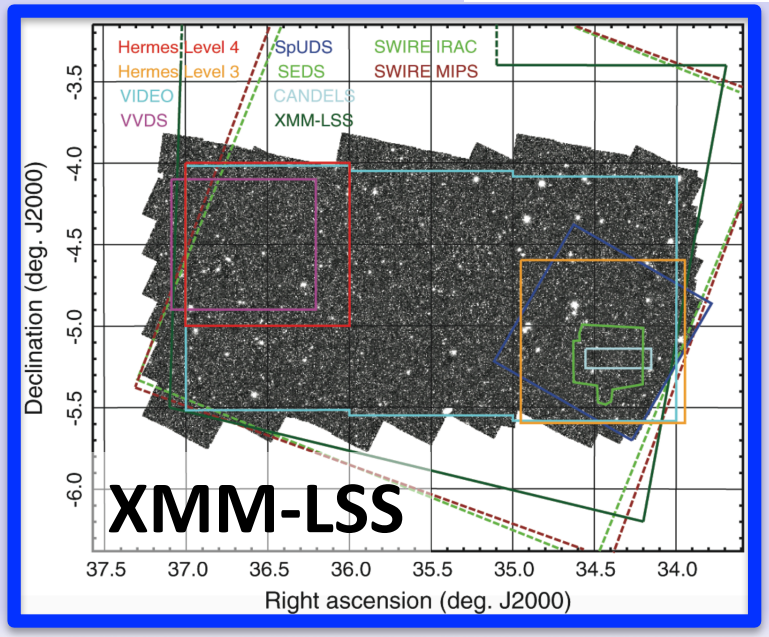
- Stellar mass assembly
- Obscured star formation
- Role of AGNs in galaxy evolution

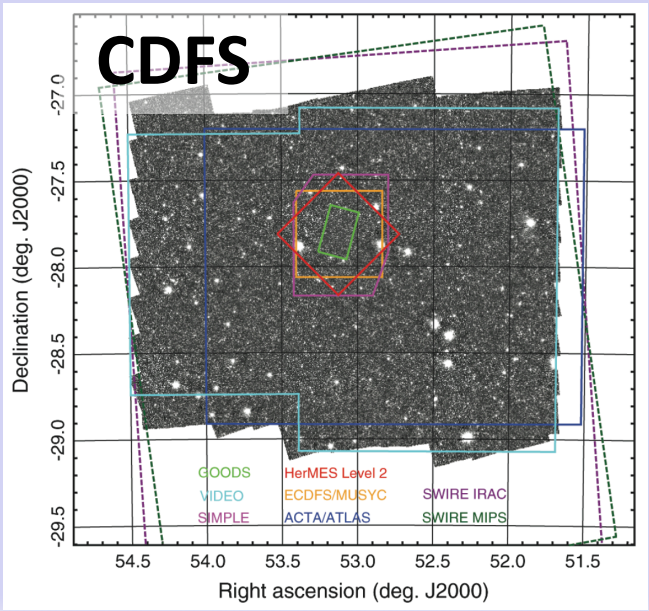
SERVS Fields











Multi-band Data in XMM-LSS

VIDEO

Bands: Ks, H, J, Y, Z

(Jarvis et al. 2013)

θ ≈ 0.8”

CFHTLS-D1

Bands: I, R, G, Z, U

(Gwyn et al. 2008; 2012)

θ ≈ 0.8”

SERVS

Bands: 3.6, 4.5 μm

(Mauduit et al. 2012)

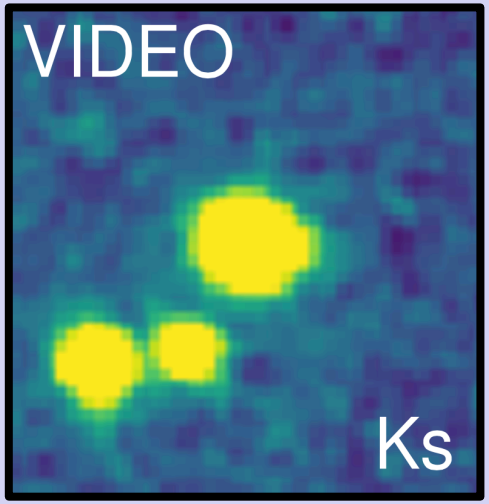
θ ≈ 2.0”

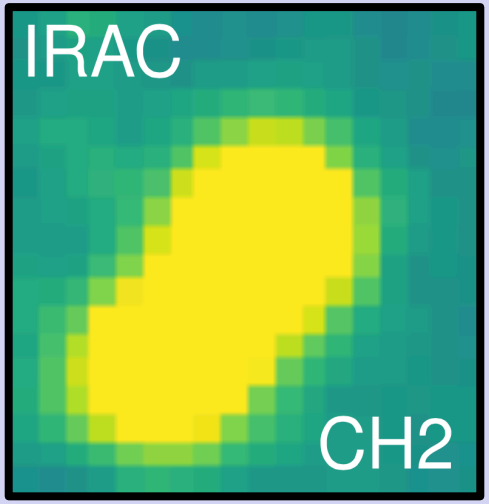
<u>Goal</u>: Construct a catalog of robust multi-band photometry across 12 NIR and optical bands with different resolutions!

Traditional Positional Cross-Matching

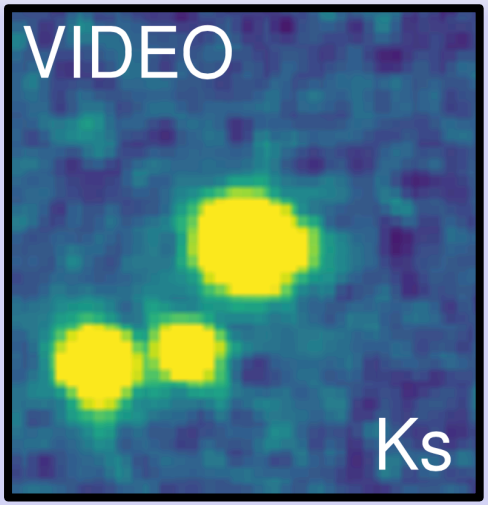
VIDEO

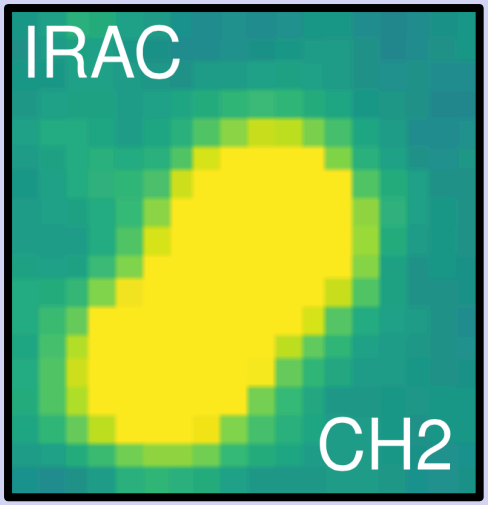
SERVS

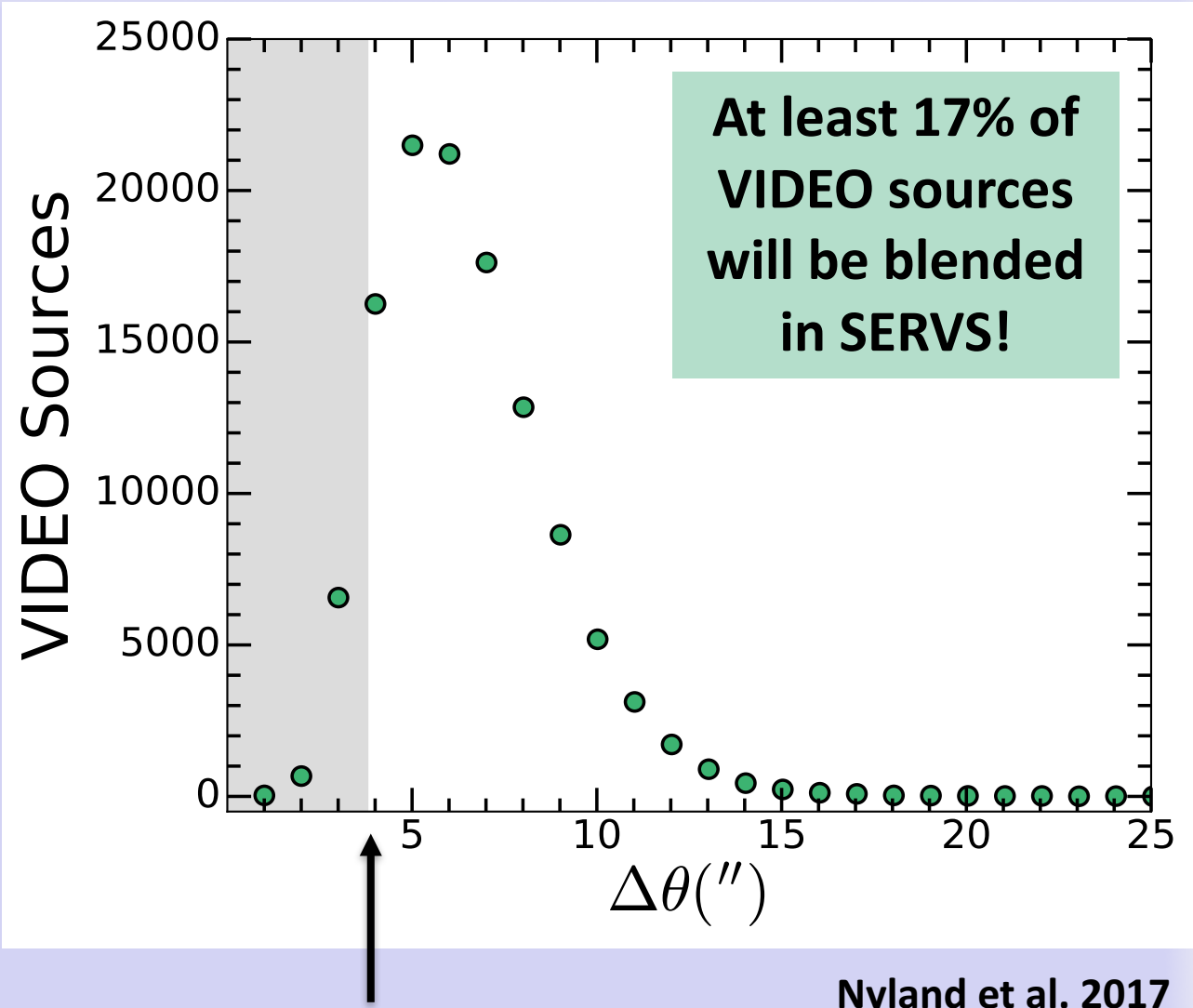




VIDEO Sources Blended in SERVS







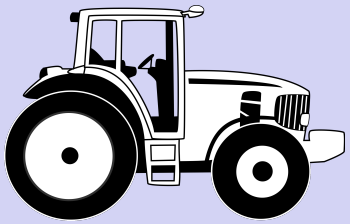
Nyland et al. 2017

Forced Photometry with *The Tractor*

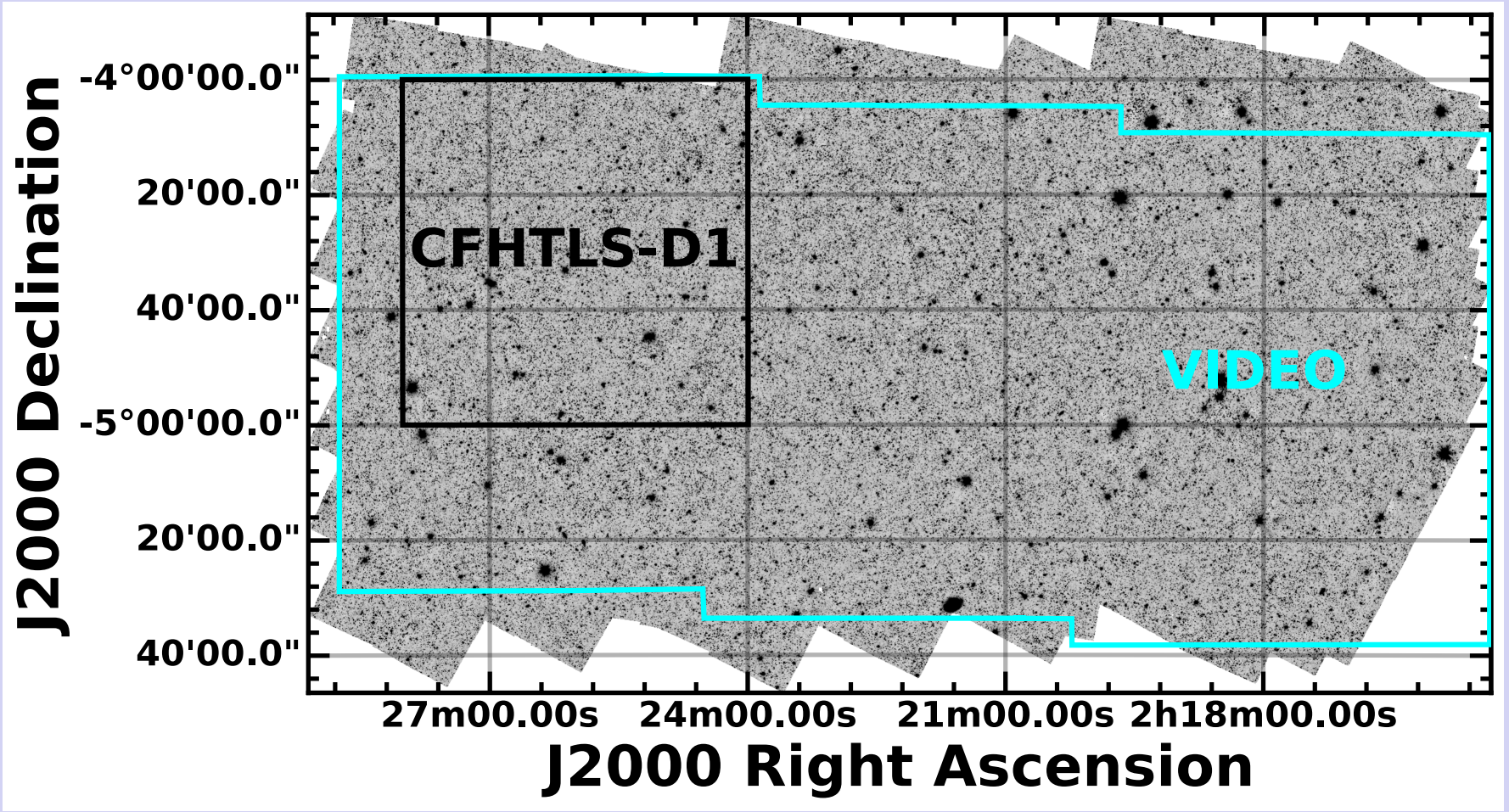
***The Tractor* Optimizes the likelihood for the source properties given:**

1. Source position
2. Surface brightness model
3. PSF, noise, and WCS info
4. Multi-band images

http://thetractor.org
(Lang et al. 2016)



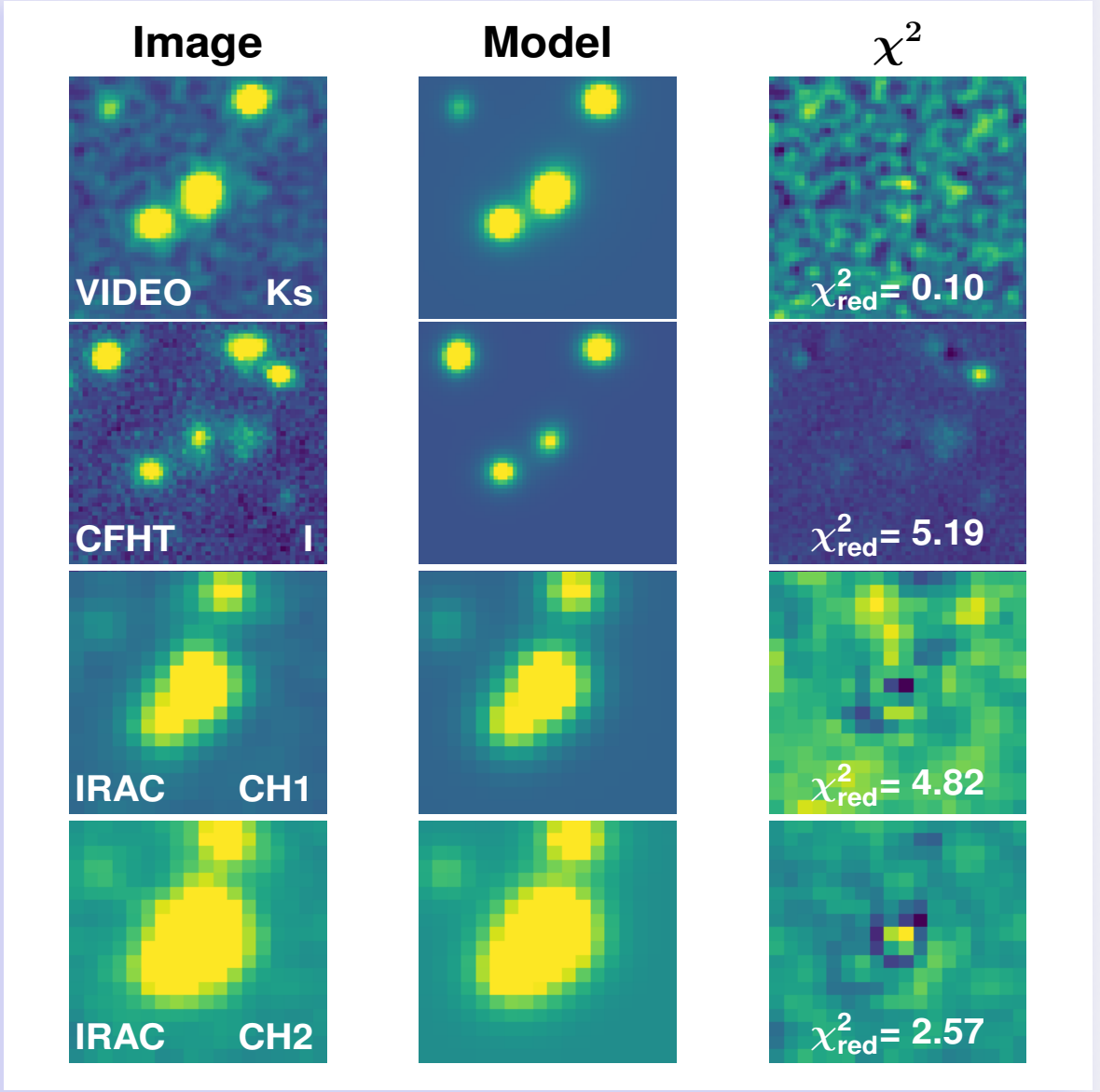
XMM-LSS Square Degree Test Field



Input catalog: 117,281 sources selected from the VIDEO source catalog located in the deg^2 CFHTLS-D1 test field

“Forced Photometry” with *The Tractor*

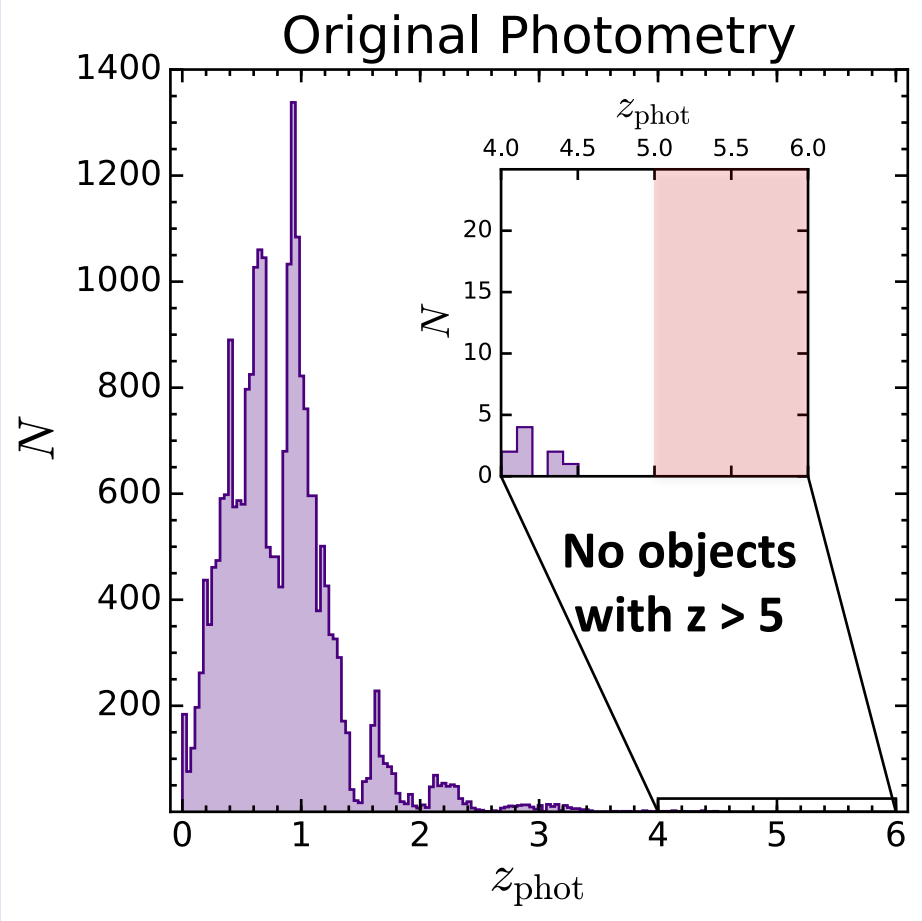
Source fitting using our parallelized Python implementation

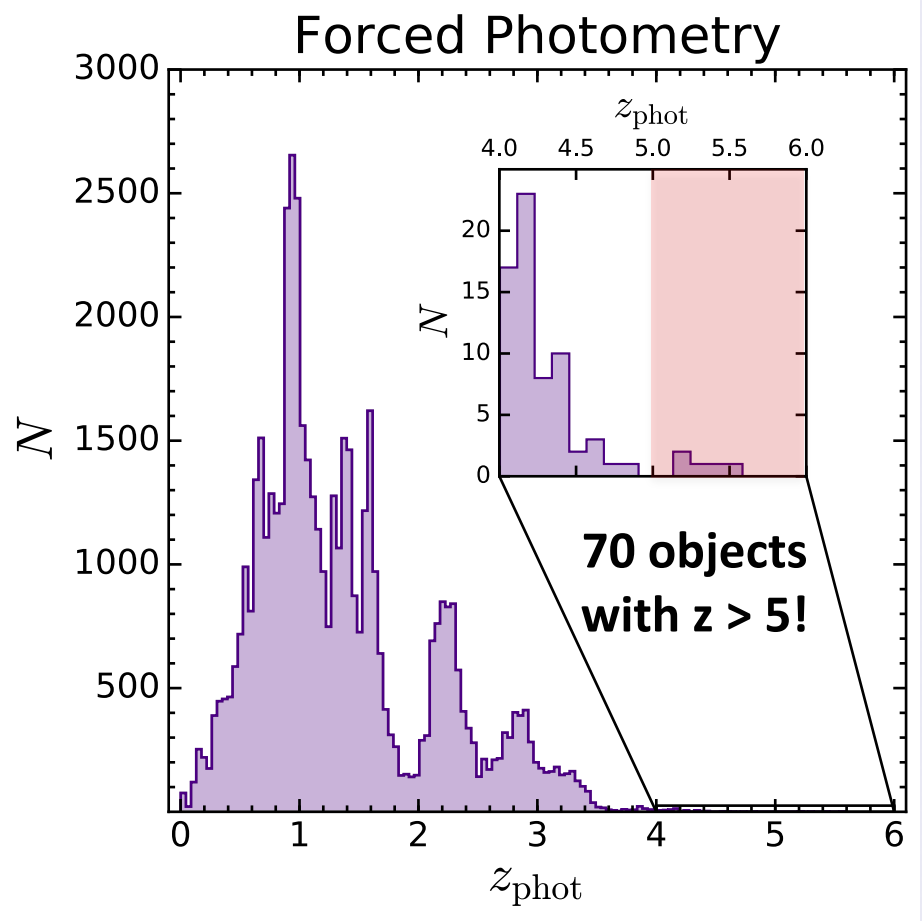


Nyland et al. 2017

Improved Photometric Redshifts

Nyland et al. 2017; Pforr et al., in prep.

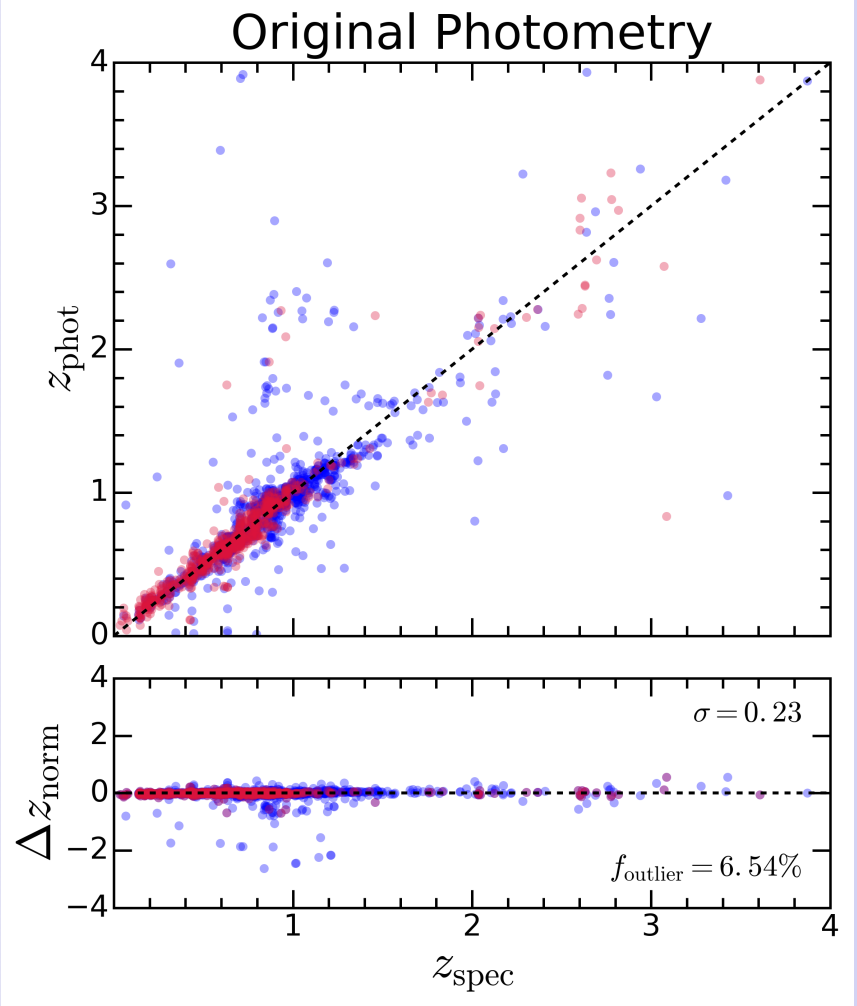


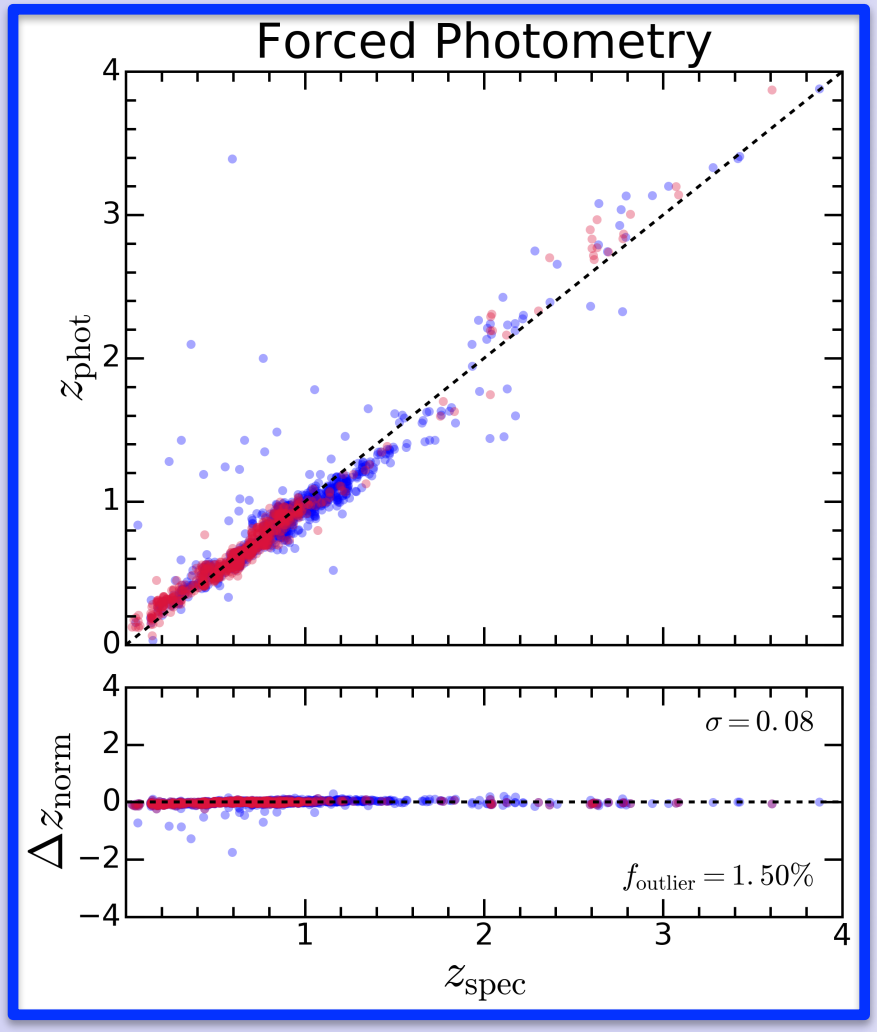


Tractor yields accurate photometric redshifts for 2X more sources and identifies more candidate high-z objects!

Improved Photometric Redshifts

Nyland et al. 2017; Pforr et al., in prep.





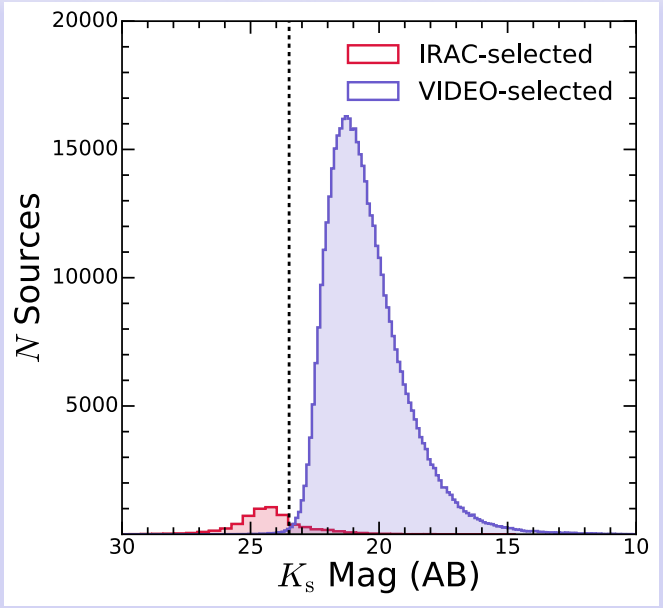
Spectroscopic redshifts from VVDS and VUDS (Le Fevre et al. 2013; 2015)

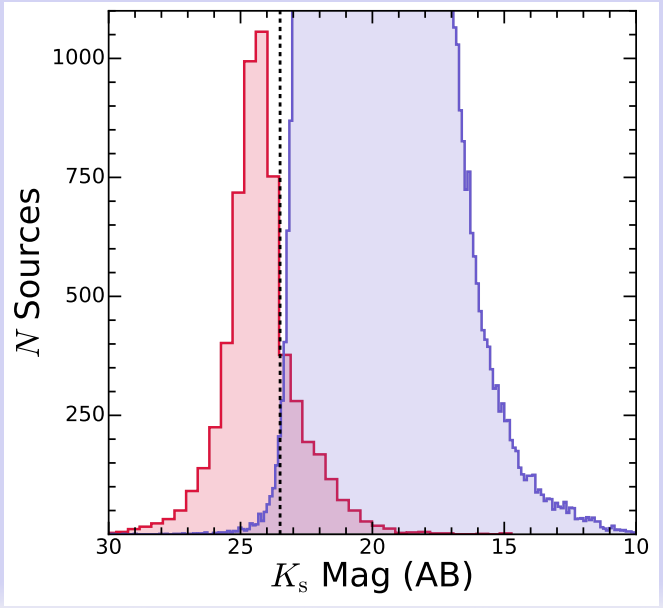
***Significantly* more accurate photometric redshifts!**

IRAC-Selected Photometry

- **8,441 sources detected in at least one SERVS band but not in VIDEO**
- **Increased fraction of objects with multi-band detections**
- **0% to 67% improvement in detection rate at *K*s-band**

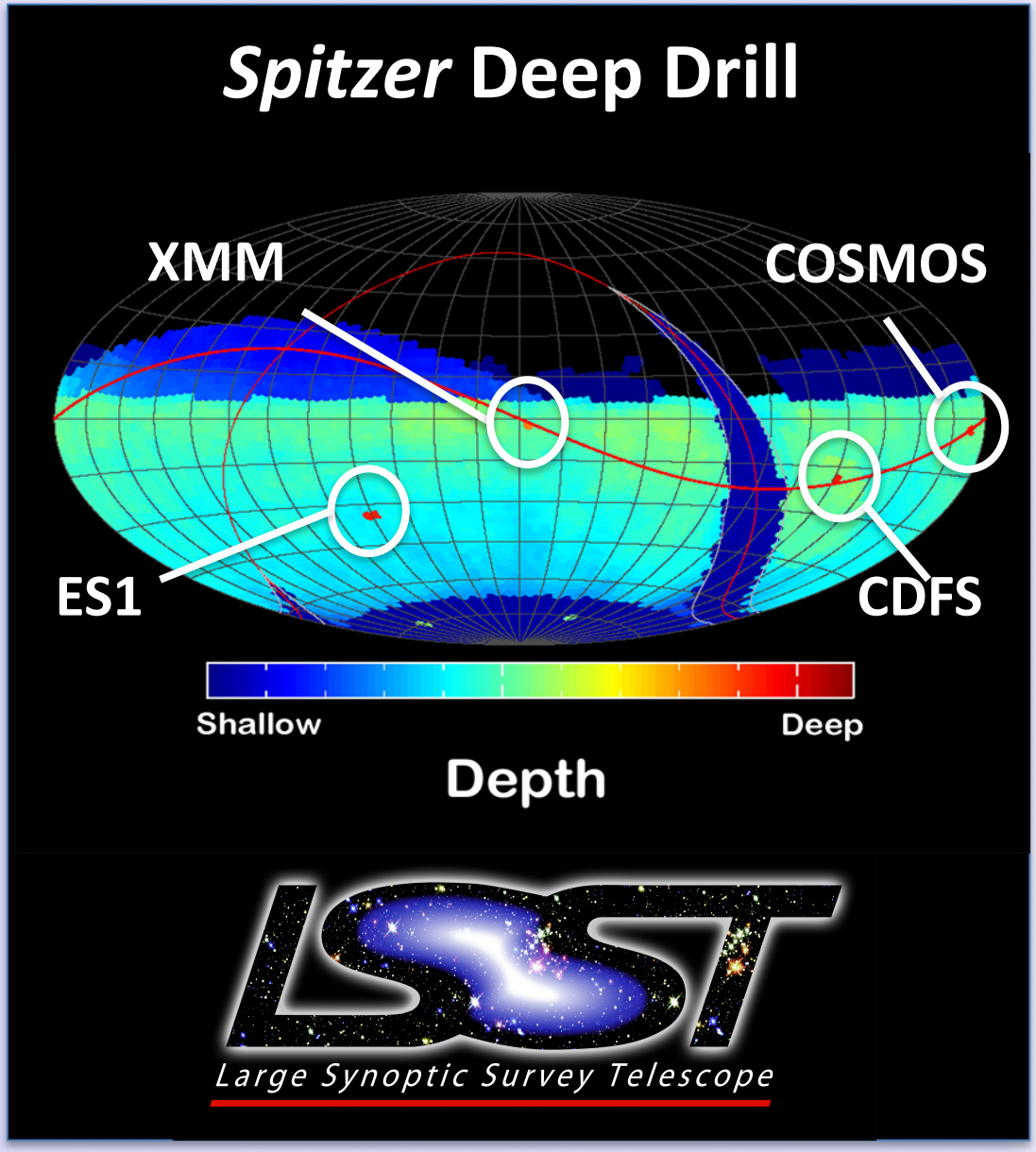
Provide constraints on properties of rare "extremely red objects"





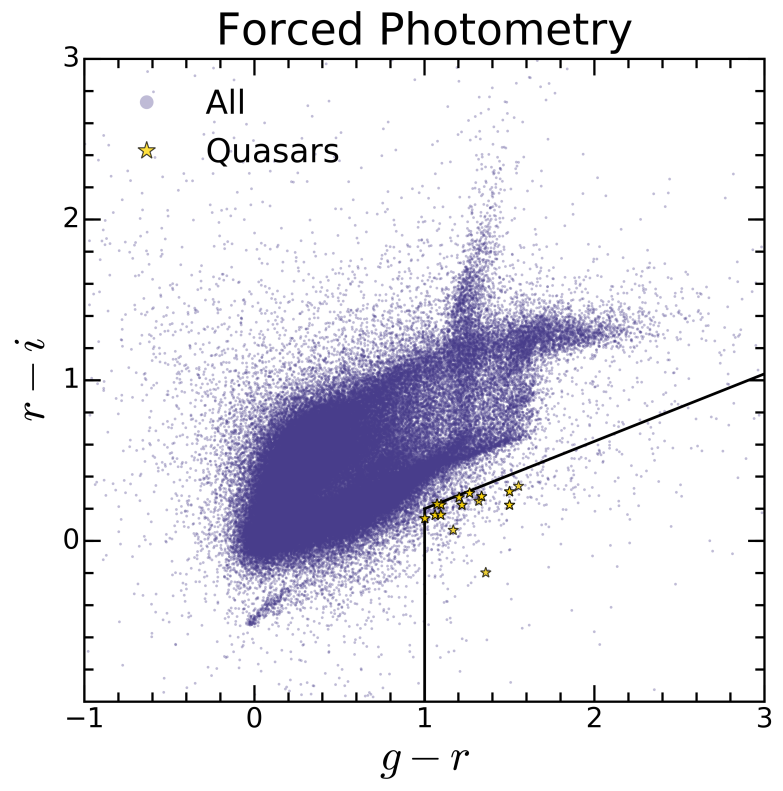
Upcoming *Tractor* Applications

- *Tractor* photometry for all 5 SERVS fields (in progress now!)
- Incorporation of new optical survey data from Hyper Suprime Cam and PanSTARRs
- Future application to *Spitzer* Deep Drill survey of pre-defined LSST deep-drilling fields



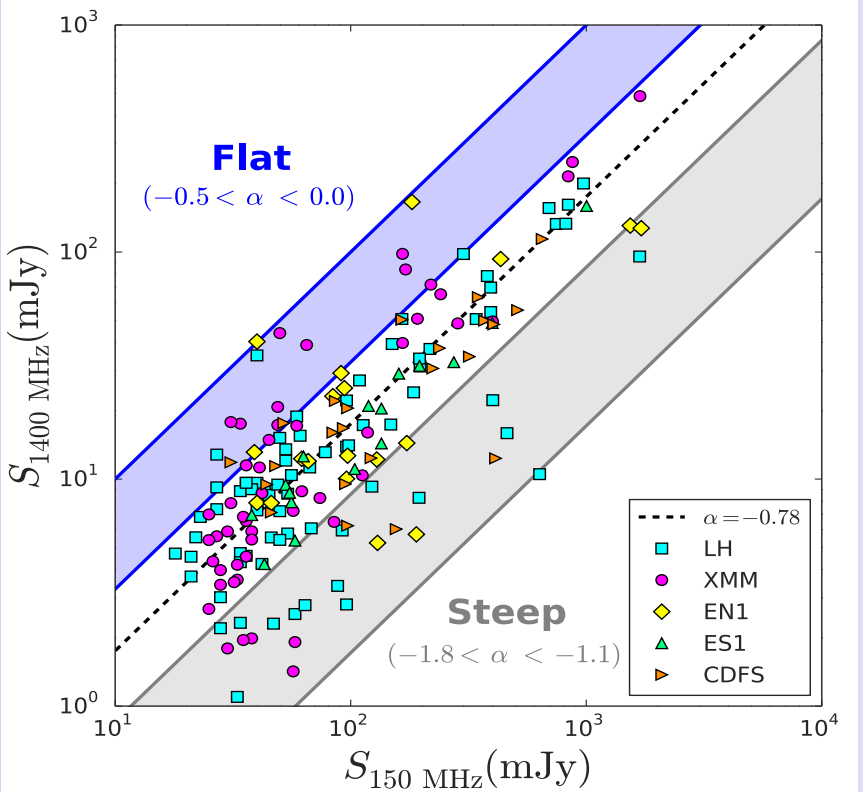
Future Science Applications

★ **Selection of NIR/optical quasar candidates**



Type I quasar selection (3.7 < z < 4.7) in the deg² XMM-LSS test field

★ **Cosmic evolution of radio AGNs and their host galaxies**

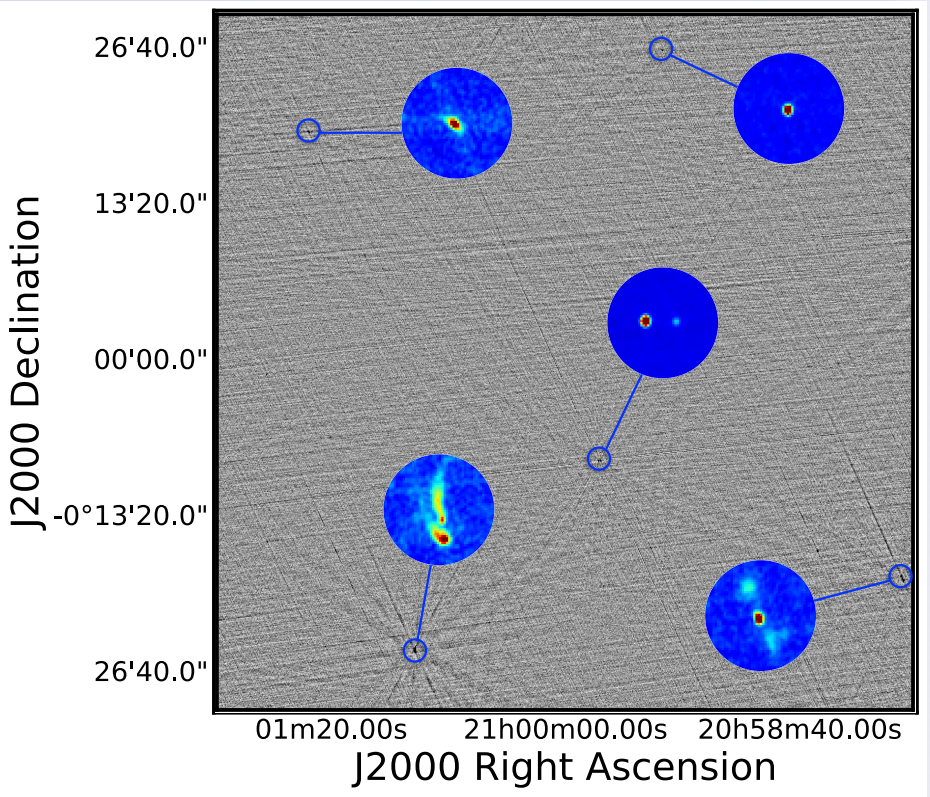


Radio spectral indices for SERVS sources in existing 150 and 1400 MHz surveys

Synergy with VLASS

VLA SKY SURVEY

Highest resolution “all sky” radio continuum survey ever performed



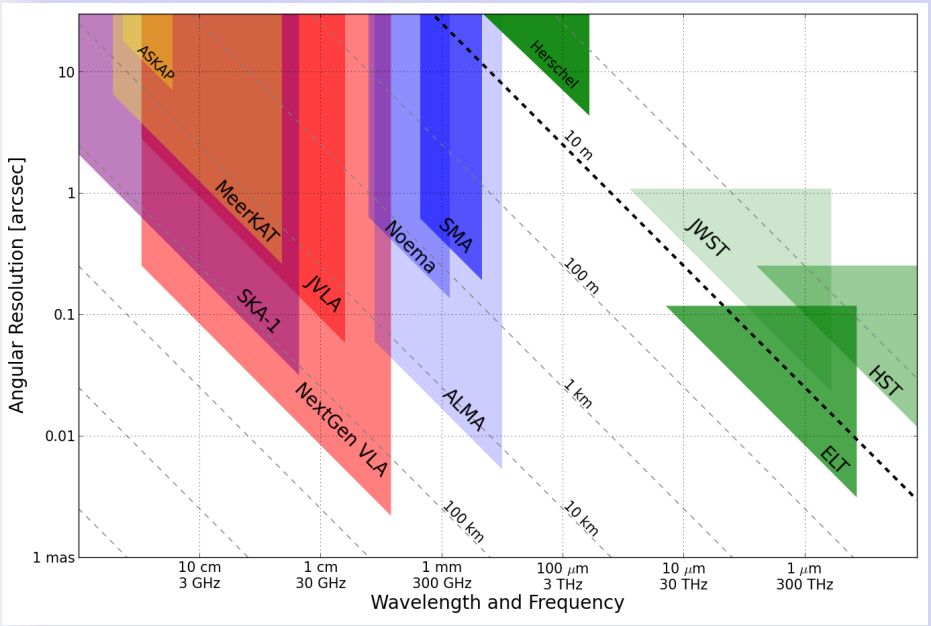
Sample pilot VLASS “quick look” deg² test image

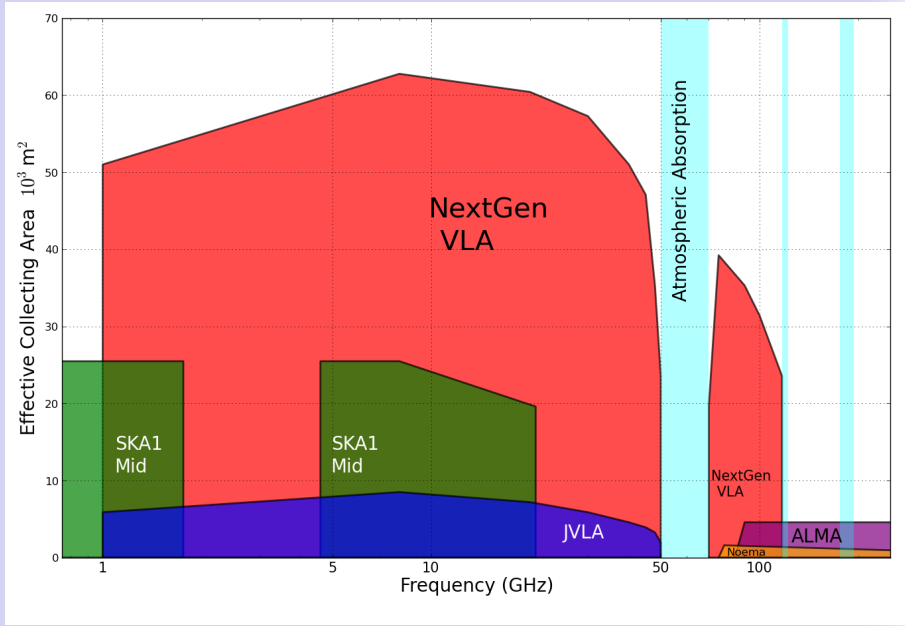
Next Generation VLA

ngVLA = 

✖ 10

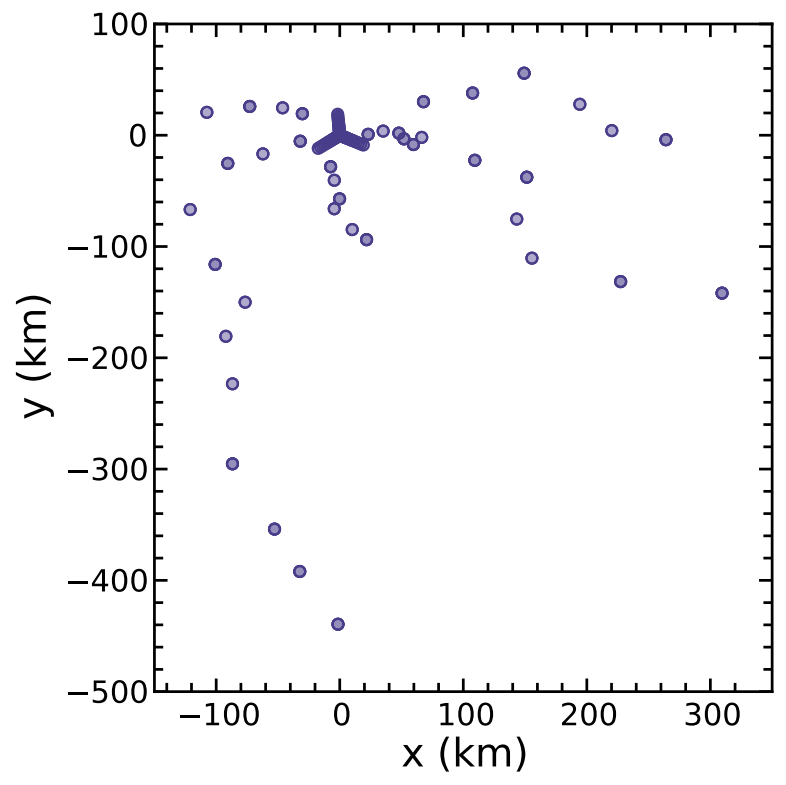
- **300 x 18m dishes**
- **300 km baselines**
- **1-115 GHz**





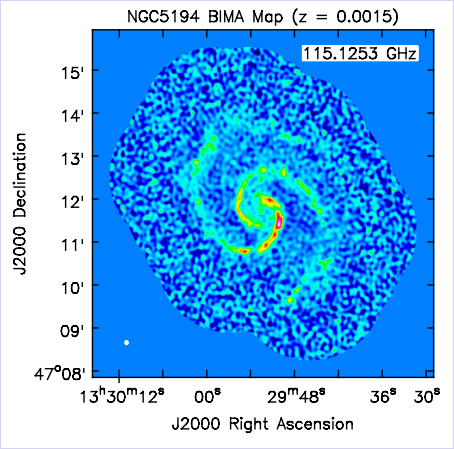
Galaxy Evolution and the ngVLA

ngVLA Simulations



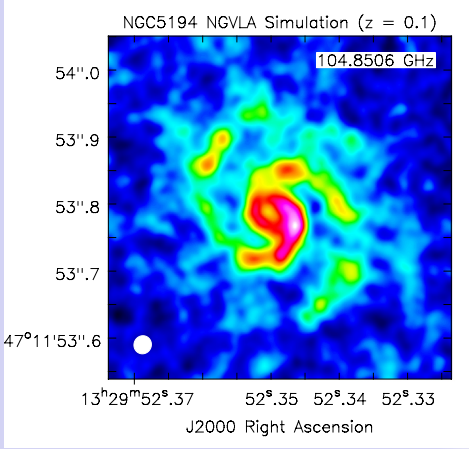
“Southwest” Array

VLA

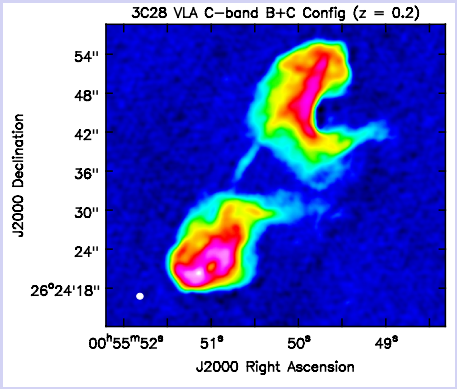


CO(1-0) at z = 0

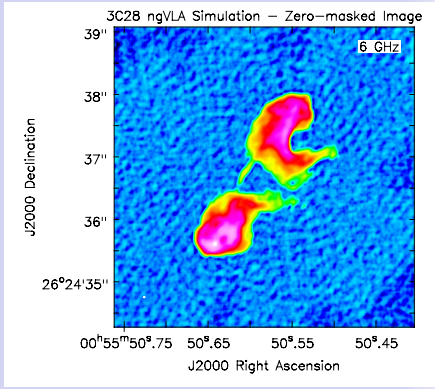
ngVLA



CO(1-0) at z = 0.1



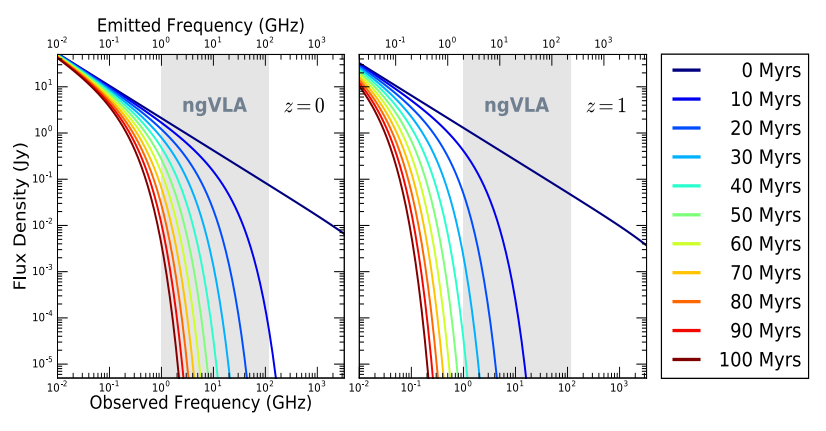
Continuum at z = 0.2



Continuum at z = 1.0

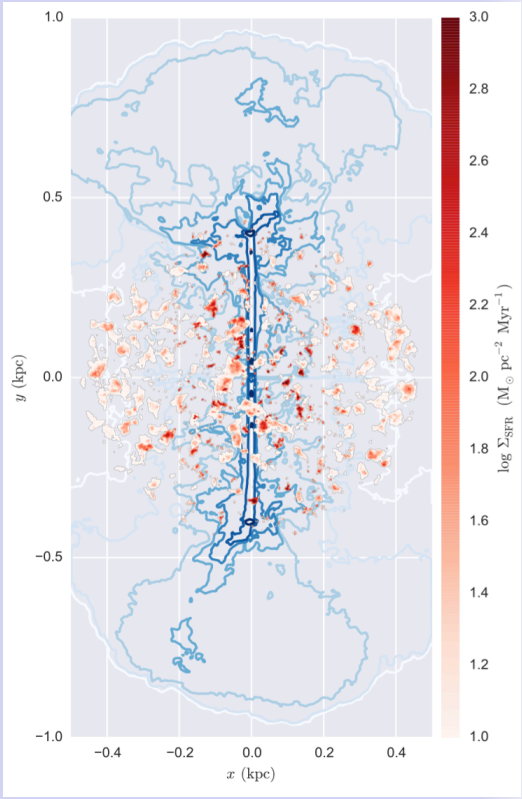
Future AGN Studies with the ngVLA

Nyland et al., in prep.

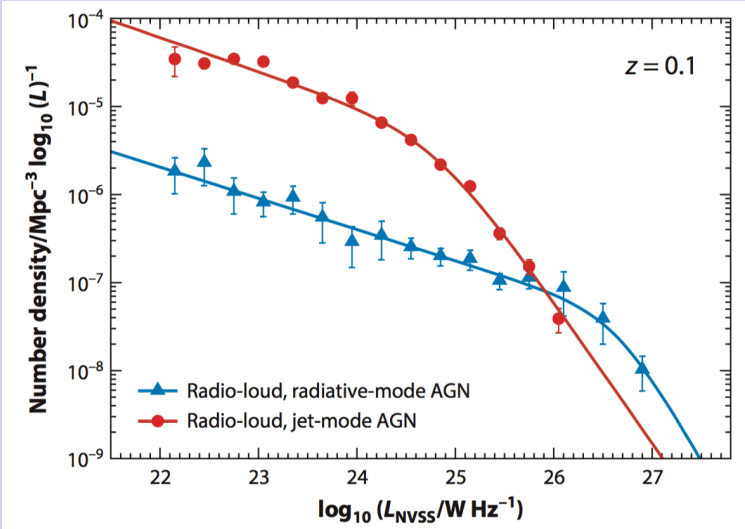


Survey spectral ages to constrain radio source life cycles & evolutionary impact

Wagner 2016



Space density of radio AGNs with different cold gas distributions and properties as a function of redshift



Heckman & Best 2014

Direct imaging of radio jets interacting with cold gas (HI and CO) – address key jet physics questions!

Summary

★ **New Tractor forced photometry over 1 deg^2 of SERVS:**

- **Accurate source cross-matching**
- **De-blended IRAC photometry**
- **Better sensitivity to faint sources**
- **Significantly more accurate z_{phot}**

Nyland et al. 2017 (submitted to ApJ)

★ **SERVS + radio (including VLASS) data will provide new insights into cosmic evolution of radio AGNs and black hole-galaxy co-evolution**

★ **Next generation telescopes such as the ngVLA will provide further advances in our understanding of galaxy evolution and AGNs!**