

The VLA-COSMOS 3 GHz Large Survey:  
Cosmic evolution of AGN  
with higher radiative luminosity  
in the COSMOS field

**Lana Ceraj**  
University of Zagreb



# AGN dichotomy

different modes of accretion

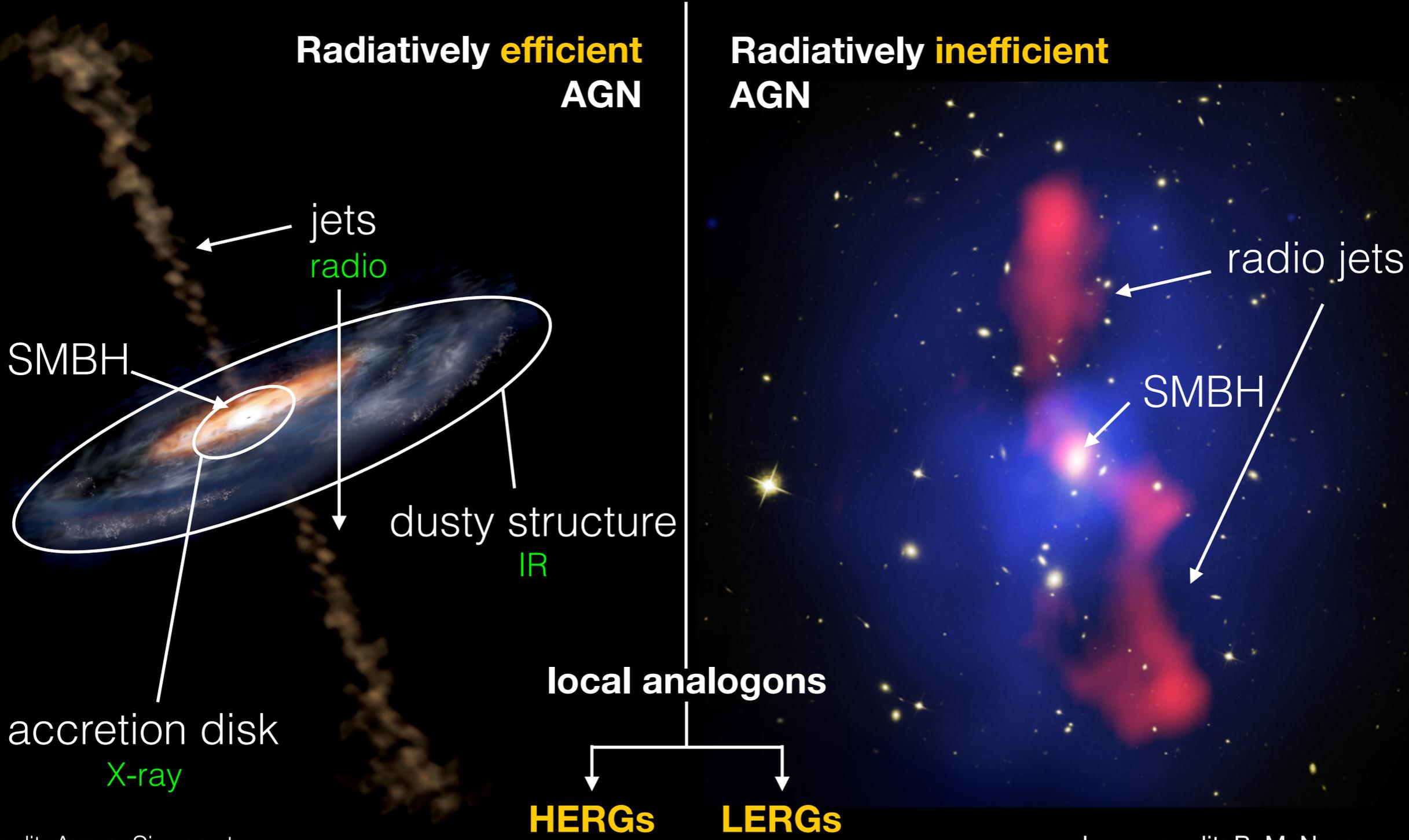
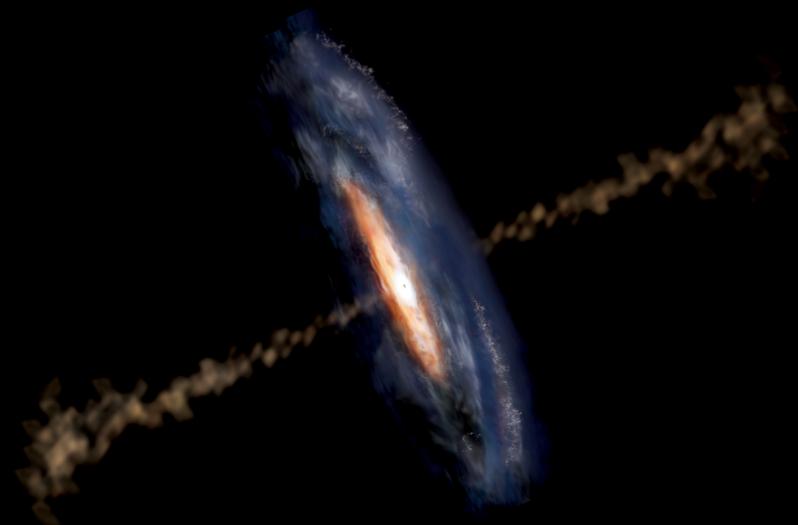


Image credit: Aurore Simonnet

Image credit: B. McNamara+ 2005



# Outline

- VLA-COSMOS 3 GHz Large Project
- Radio (3 GHz) luminosity decomposition
- AGN luminosity functions
- Cosmic evolution of higher radiative luminosity AGN

# The VLA – COSMOS 3 GHz Large Project

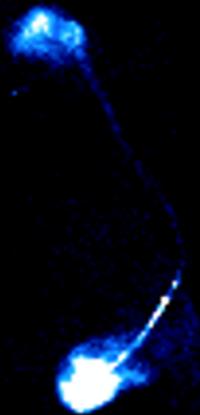
## Radio data

Smolcic et al. 2017, A&A, 602, A1

- 400 h of observations with VLA
- ~11,000 radio sources detected
- ~2.3  $\mu\text{Jy}$ , 0.75'' resolution
- ~2.5 times more sensitive than the previous survey (at 1.4 GHz; Schinnerer et al., 2007)



**Vernesa Smolčić (PI)**  
Assoc. Prof. at Uni. Zagreb



# The VLA – COSMOS 3 GHz Large Project

## Multi-wavelength data



**Chandra**  
**X-ray observatory**

Image credit: NASA



Image credit: NASA, ESA, Z. Levay



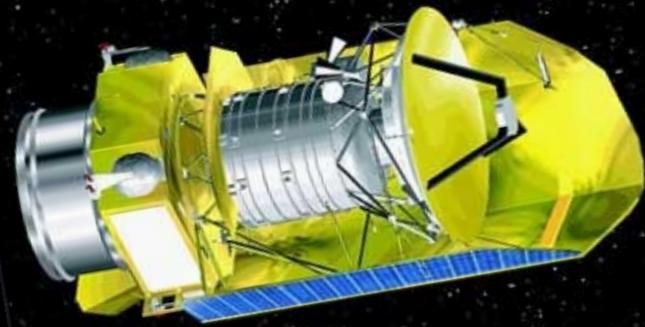
**Spitzer**  
**Infrared Array Camera (IRAC)**

Image credit: NASA

### **COSMOS2015 catalog**

Laigle et al. 2016

- 30 band photometry
- over half a million sources over 2 deg<sup>2</sup>



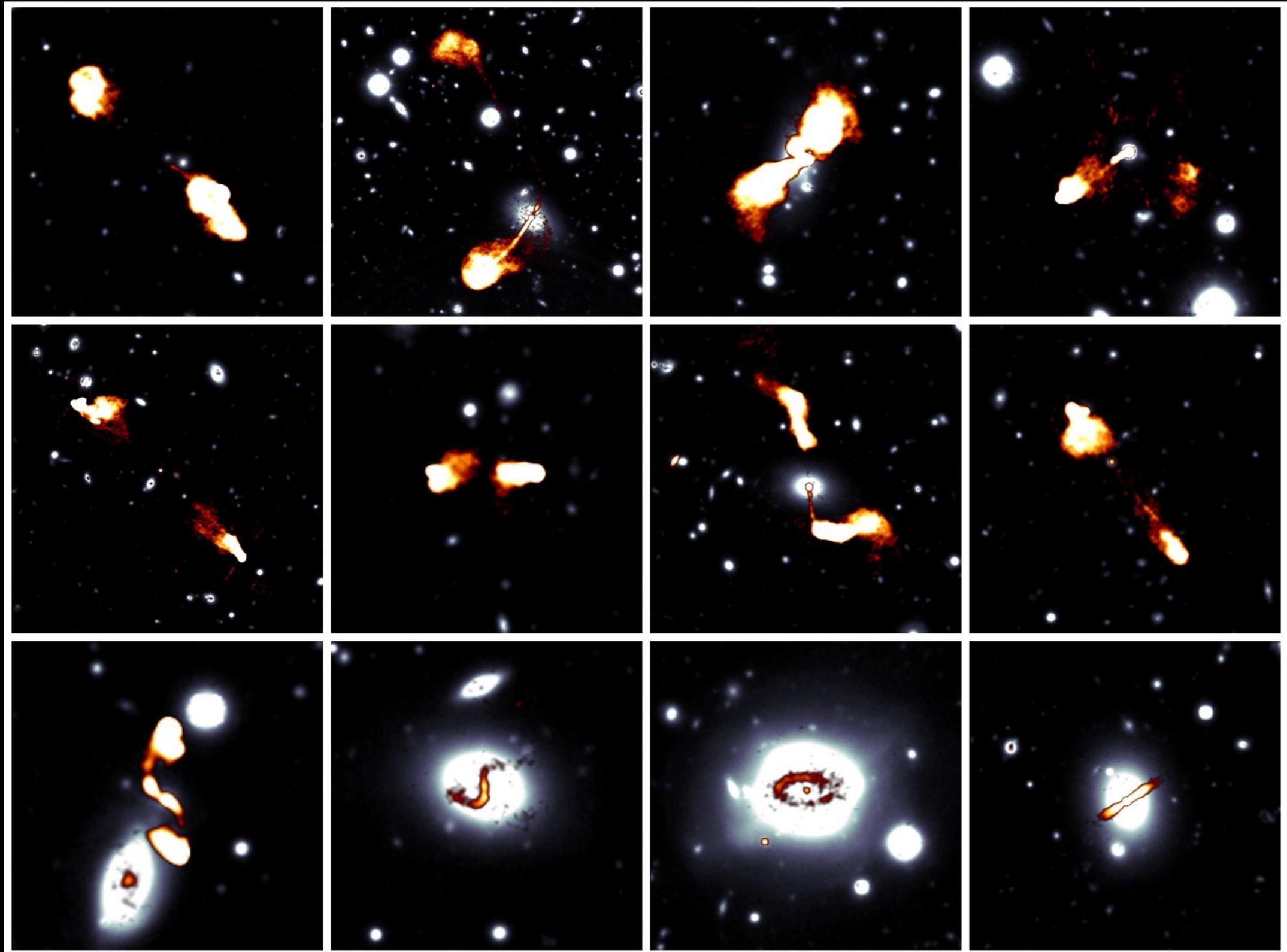
**Herschel**  
**Infrared telescope**

Image credit: NASA



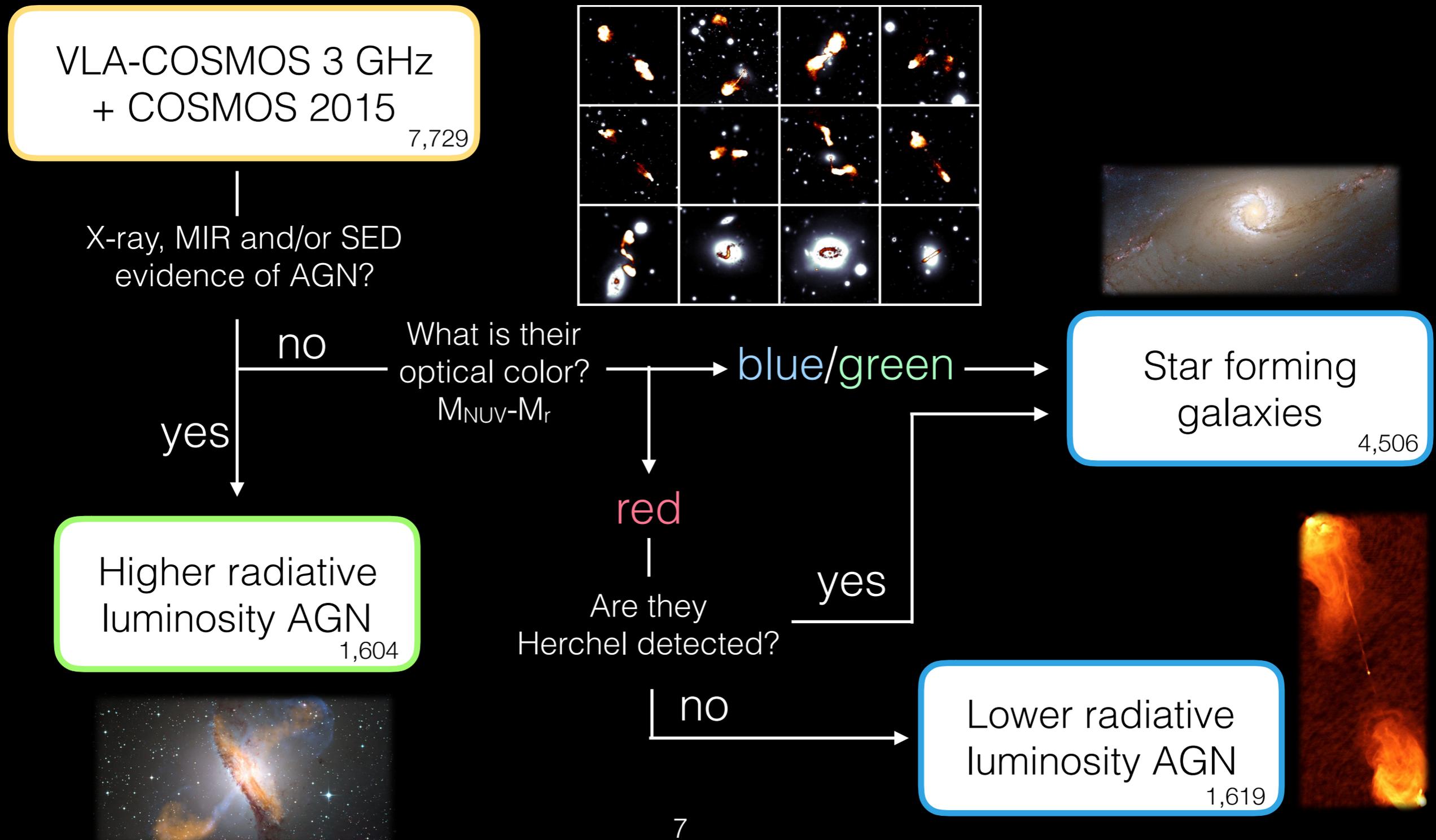
Image courtesy of NRAO/AUI and NRAO/AUI Photographer: Bob Tetro

# The VLA – COSMOS 3 GHz Large Project



# The VLA – COSMOS 3 GHz Large Project

## Classification of sources





# The VLA – COSMOS 3 GHz Large Project

## A&A special edition & press release

**Astronomy & Astrophysics**  
**The VLA-COSMOS 3 GHz Large Project**

13th June 2017

- Radio data and counterpart matching (Smolcic+ 17a, 17b)
- SFGs  
Infrared-radio correlation (Delhaize+ 2017)  
Cosmic star-formation rate history (Novak+ 2017)
- AGN  
Multi-wavelength properties, host galaxies (Delvecchio+17)  
Cosmic evolution of radio AGN (Smolcic+ 17c)
- Sub-millimeter galaxies (Miettinen+ 2015a, 2015b, 2017)

The screenshot shows the COSMOS website header with the logo and a navigation menu: Home, For the Public, For Astronomers, For Reviewers, Publications, News, Internal. Below the menu is a news article titled 'The VLA-COSMOS 3 GHz Large Project - Deep space studies with a new radio sky survey' dated June 13, 2017. The article features a video player with a play button and the text 'The VLA-COSMOS 3 GHz Large Project'. Below the video is a short paragraph: 'An international team of astronomers has conducted a powerful new survey of the sky at radio wavelengths. This has provided some of the most advanced data with which to examine the life-cycle of galaxies over the past 13 billion years of the universe's history.'

COSMOS web page: <http://cosmos.astro.caltech.edu/>

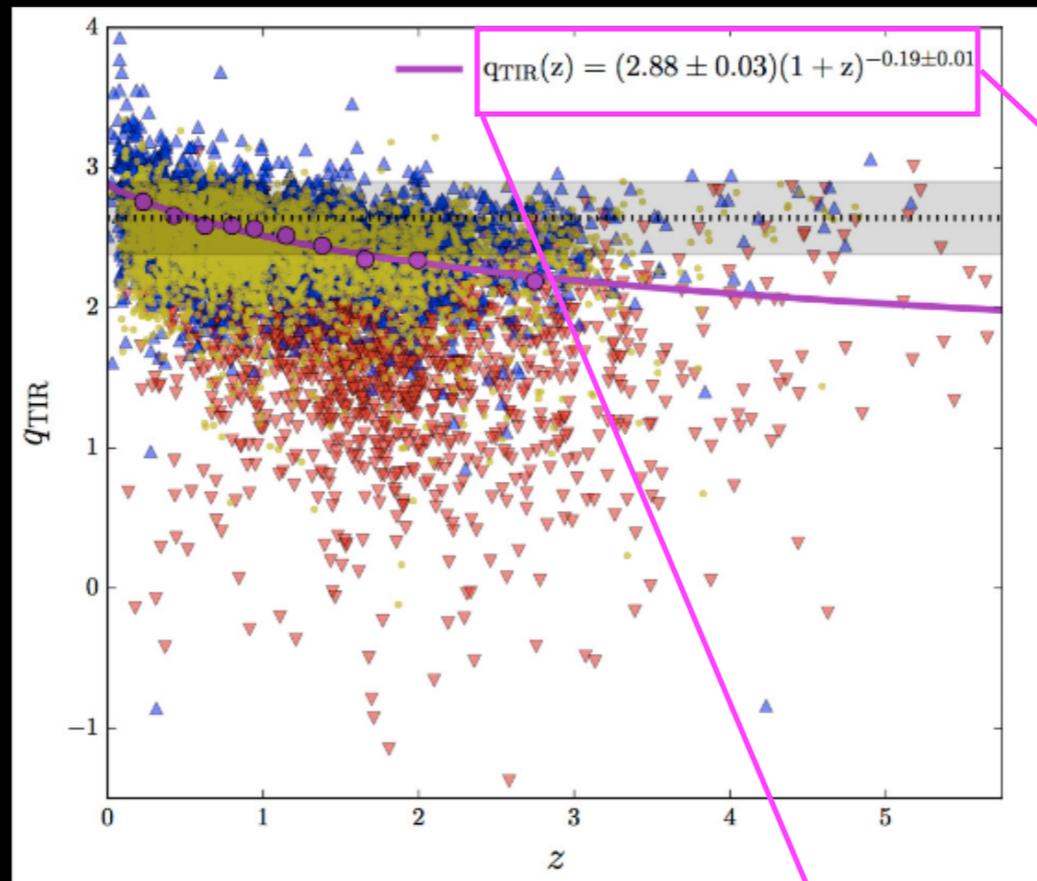
# The VLA – COSMOS 3 GHz Large Project

## Infrared-Radio Correlation (IRRC)

Delhaize et al., 2017, A&A, 602, A4



**Jacinta Delhaize**  
postdoc at Uni. Zagreb



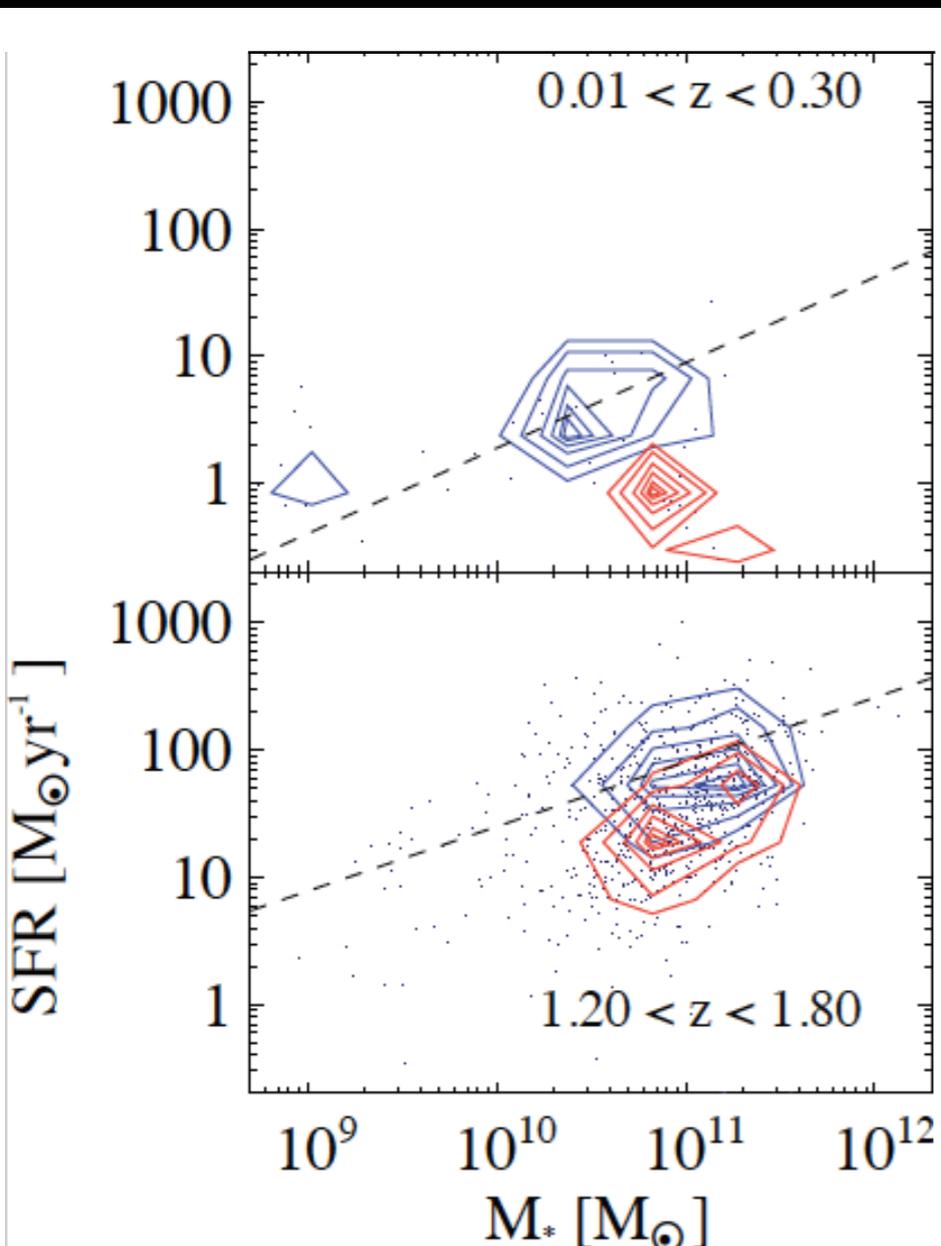
- derived from the sample of SFGs
- slightly **decreases** with redshift

$$q_{\text{TIR}}(z) = (2.88 \pm 0.03)(1 + z)^{-0.19 \pm 0.01}$$

# The VLA – COSMOS 3 GHz Large Project

## AGN and host properties

Delvecchio et al., 2017, A&A, 602, A3



- higher radiative luminosity AGN's hosts typically bluer than those of lower radiative luminosity AGN
- ongoing star formation contributes significantly to total radio light
- quantifying radio excess from IRRC due to AGN

--- Whitaker et al. (2012)

— lower radiative luminosity AGN  
— higher radiative luminosity AGN

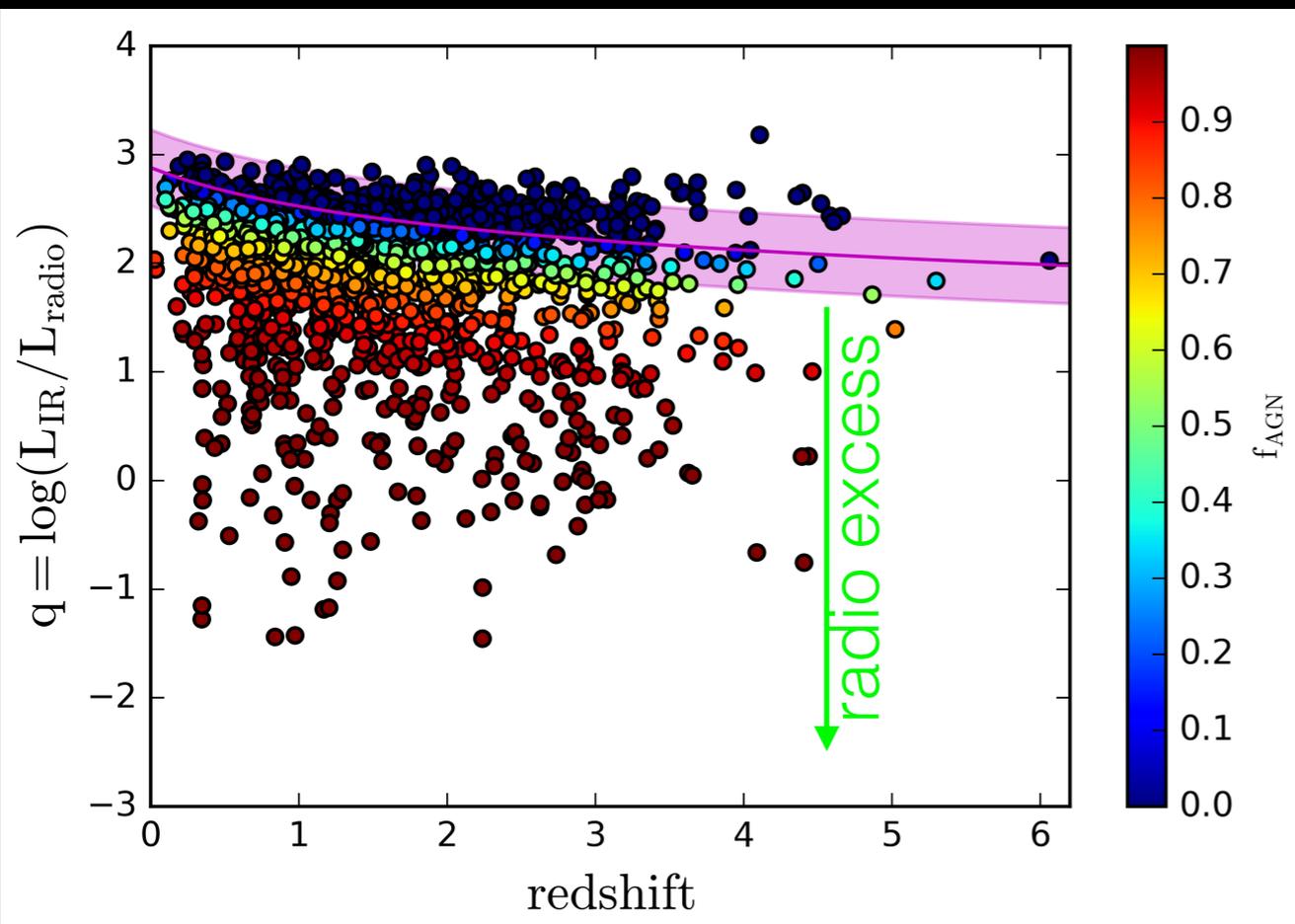


**Ivan Delvecchio**  
postdoc at Uni. Zagreb

# VLA – COSMOS 3 GHz Large Project

## Radio emission in higher radiative luminosity AGN

AGN fraction for every galaxy!



$0 \leq f_{AGN} < 0.3$   
( $34 \pm 1$ )%

$0.3 \leq f_{AGN} < 0.7$   
( $23 \pm 1$ )%

$0.7 \leq f_{AGN} \leq 1$   
( $43 \pm 1$ )%

- using radio excess from the IRRC to estimate AGN fractions

from SED fitting  
after removing AGN component  
(Delvecchio et al. 2017)

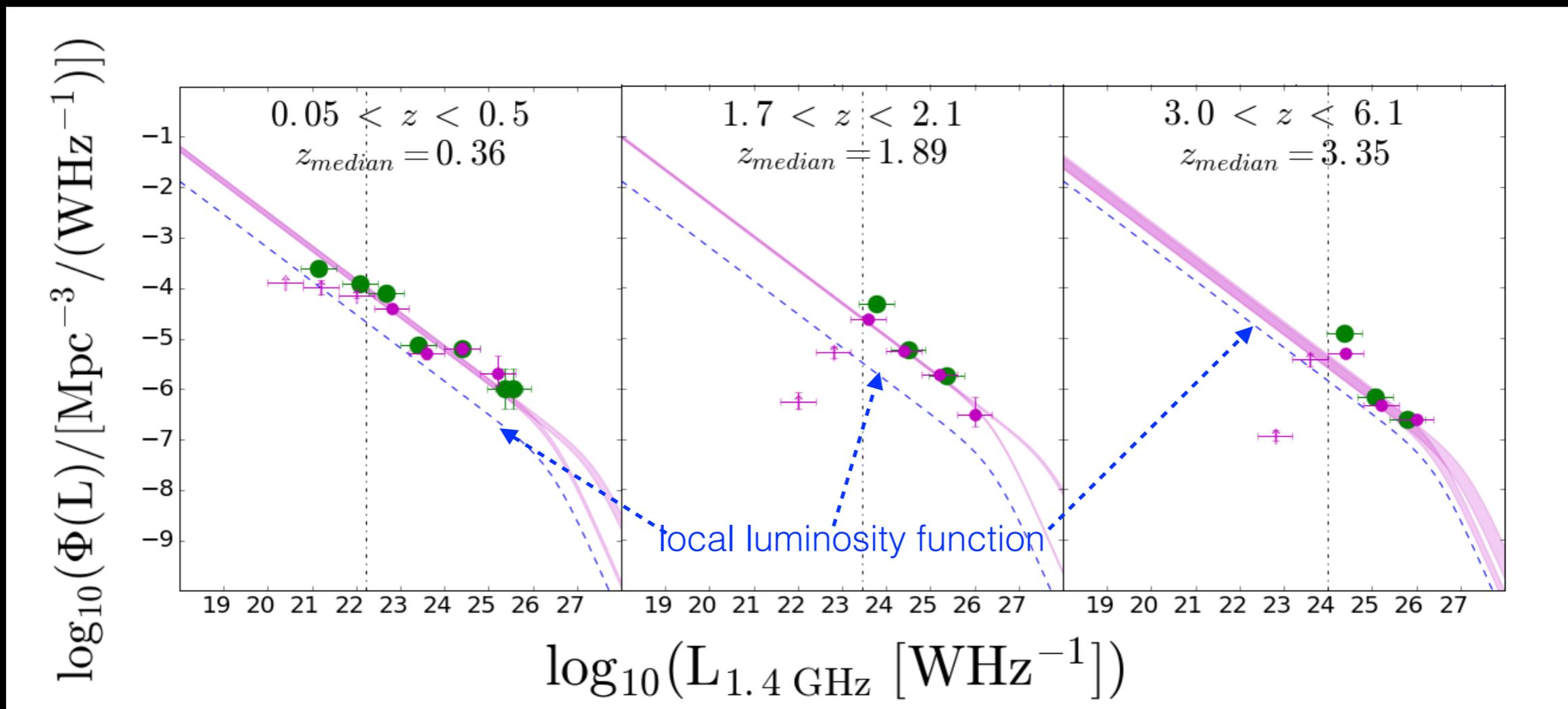
$$L_{IR} \rightarrow L_{radio}(SF) \rightarrow L_{radio}(AGN)$$

using z dependent IRRC  $q(z)$   
(Delhaize et al. 2017)

# VLA – COSMOS 3 GHz Large Project

## AGN luminosity functions

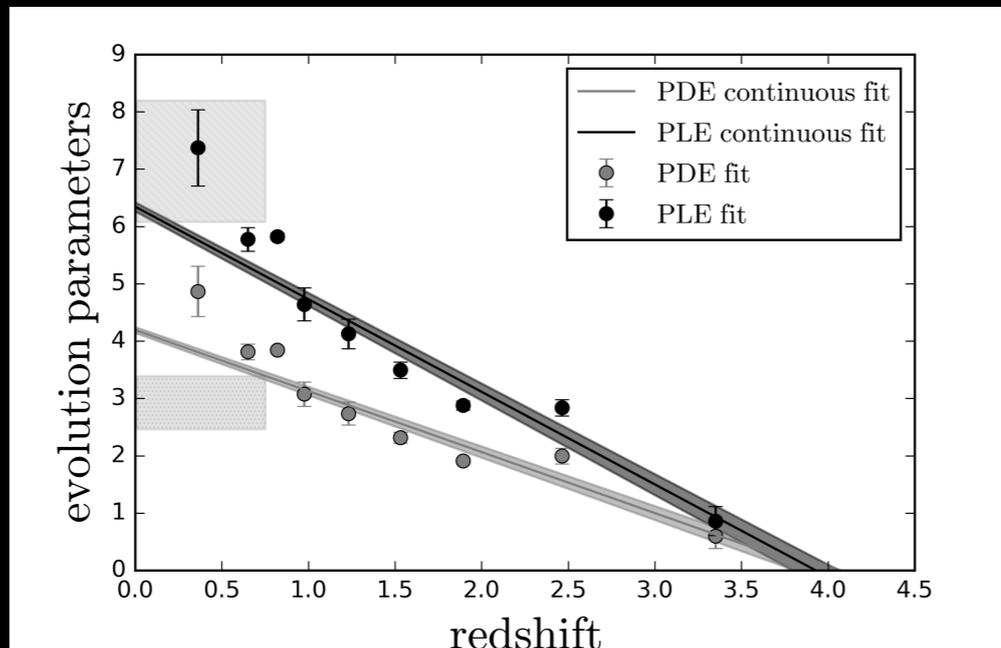
- constructed using AGN luminosities
- not possible to constrain local luminosity function (area too small)
- fitting local luminosity function (Pracy et al. 2016) to our LF points



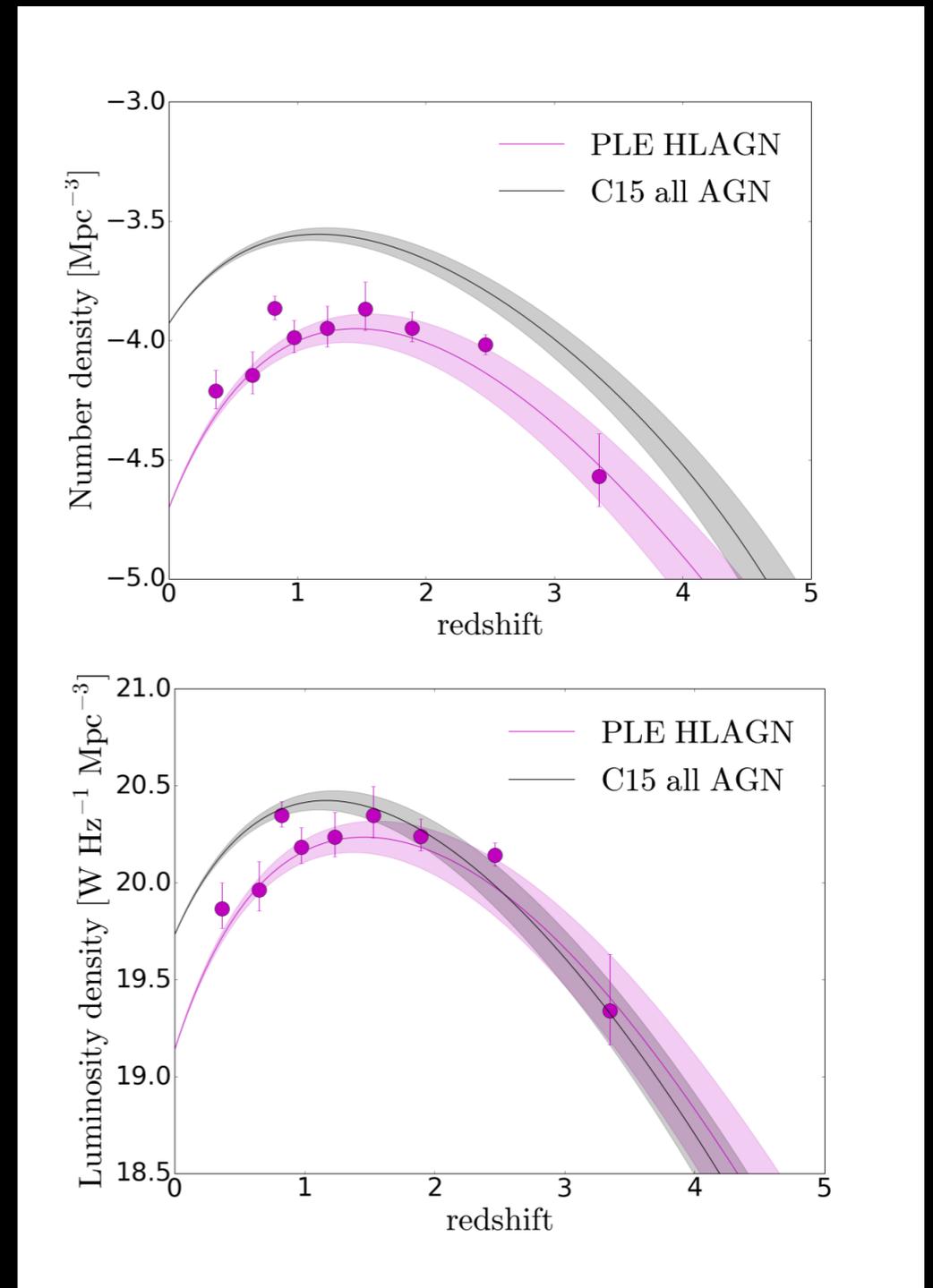
# VLA – COSMOS 3 GHz Large Project

## Evolution of higher radiative luminosity AGN

- testing pure density and pure luminosity evolution

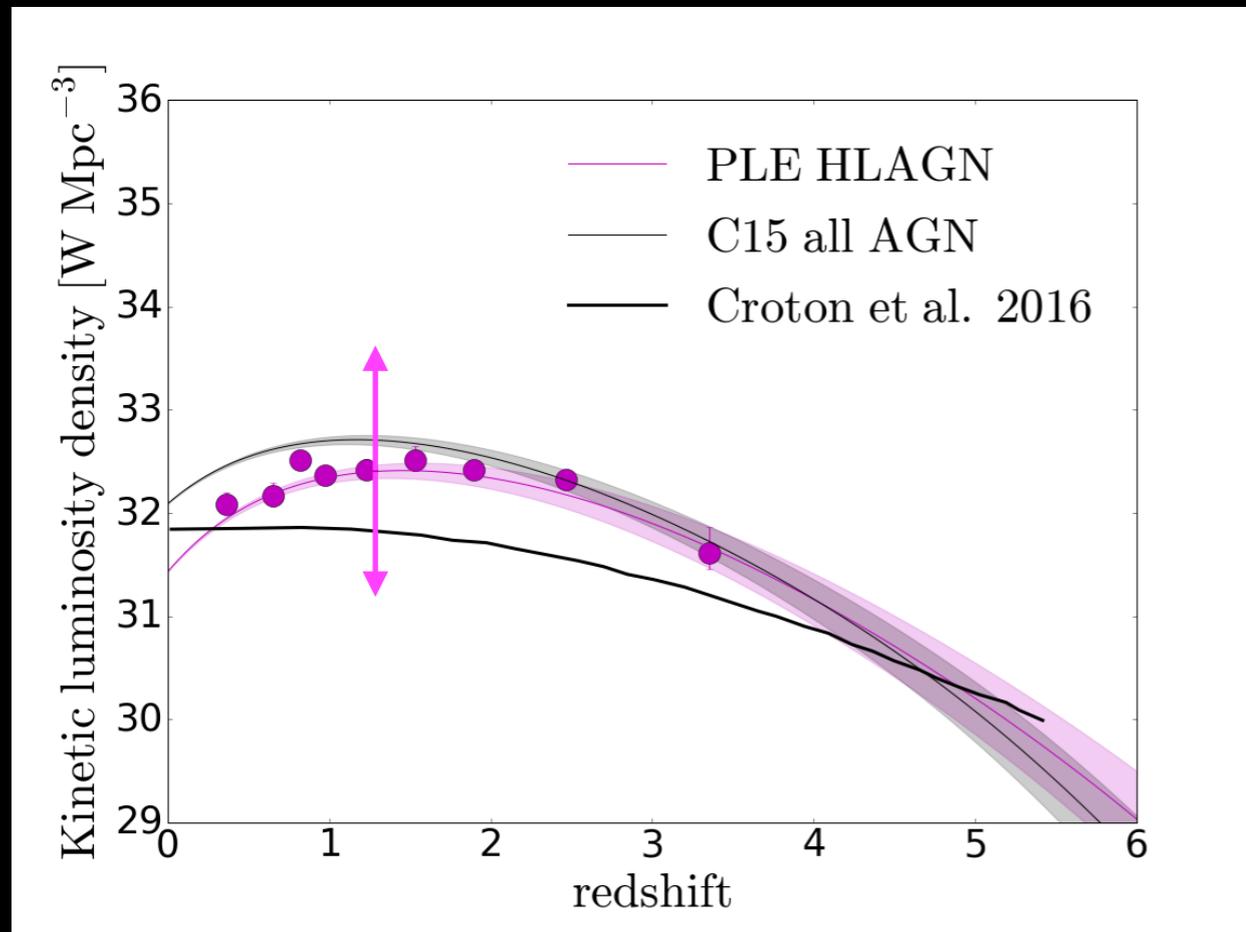


- number and luminosity density evolution curves peak at redshift  $z \sim 1.5$
- full AGN sample peaks at lower redshifts ( $z \sim 1.3$ ) suggesting that higher radiative luminosity AGN were dominant AGN population at higher redshifts



# VLA – COSMOS 3 GHz Large Project

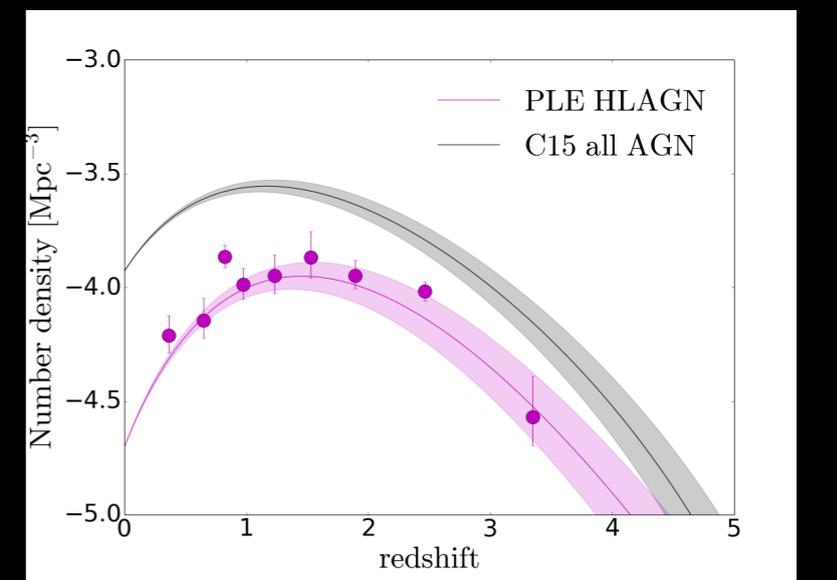
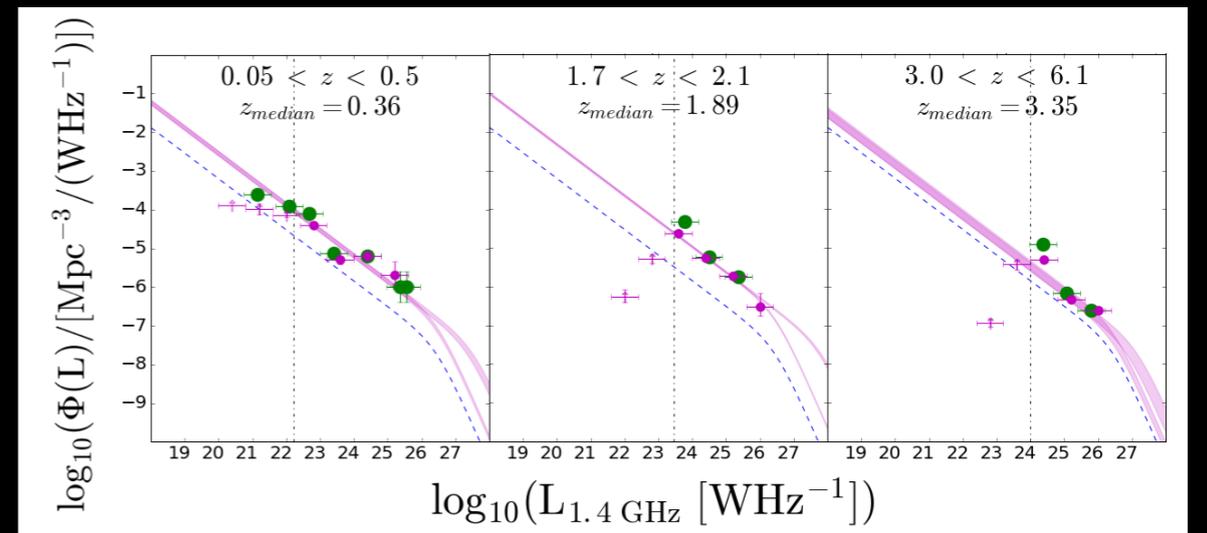
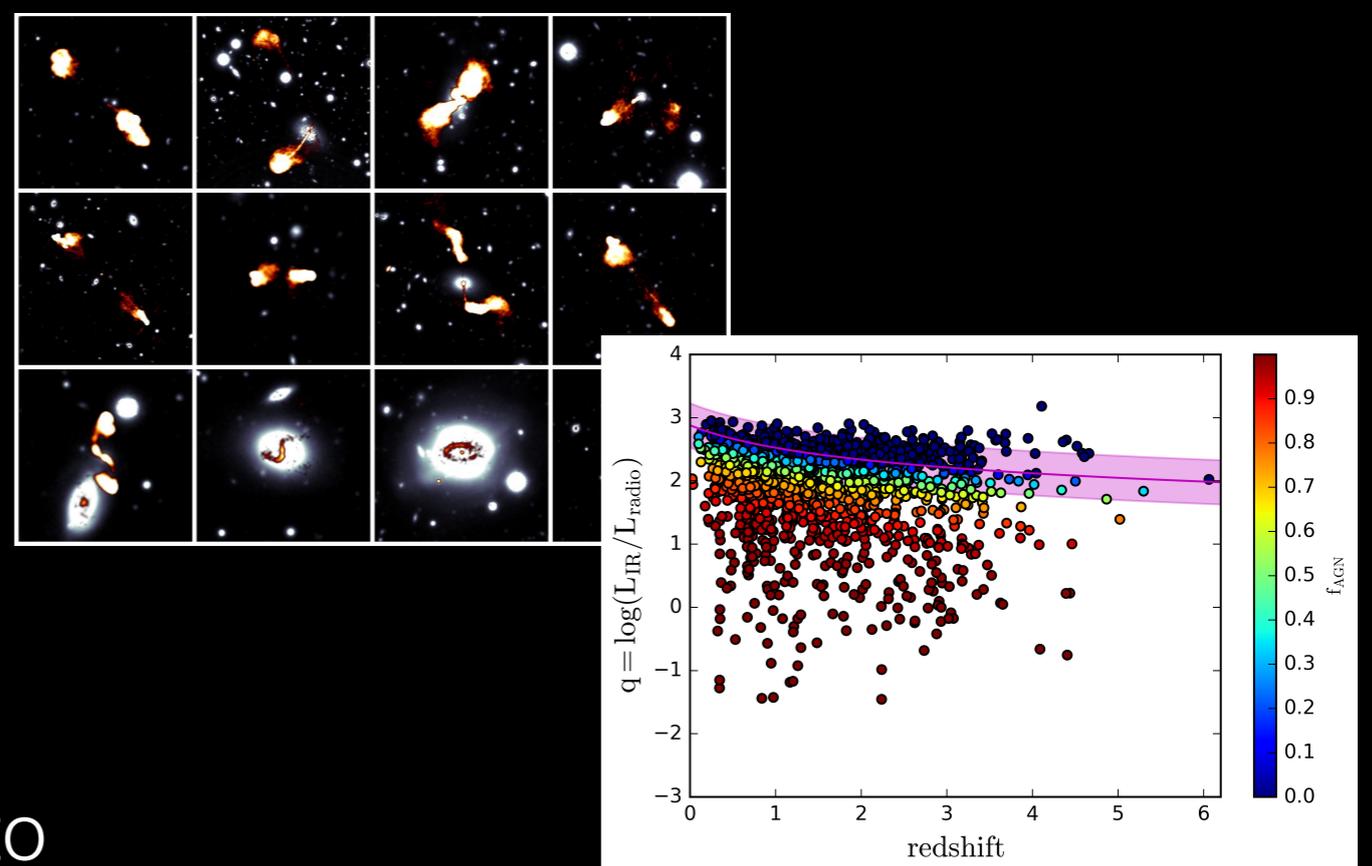
## Evolution of higher radiative luminosity AGN



- kinetic feedback due to strong radio jets from higher radiative luminosity AGN with high (>0.5) AGN fractions
- estimate based on Willott et al. 1999 luminosity conversion; uncertainties highly affect normalisation of kinetic luminosity density curve

# Summary

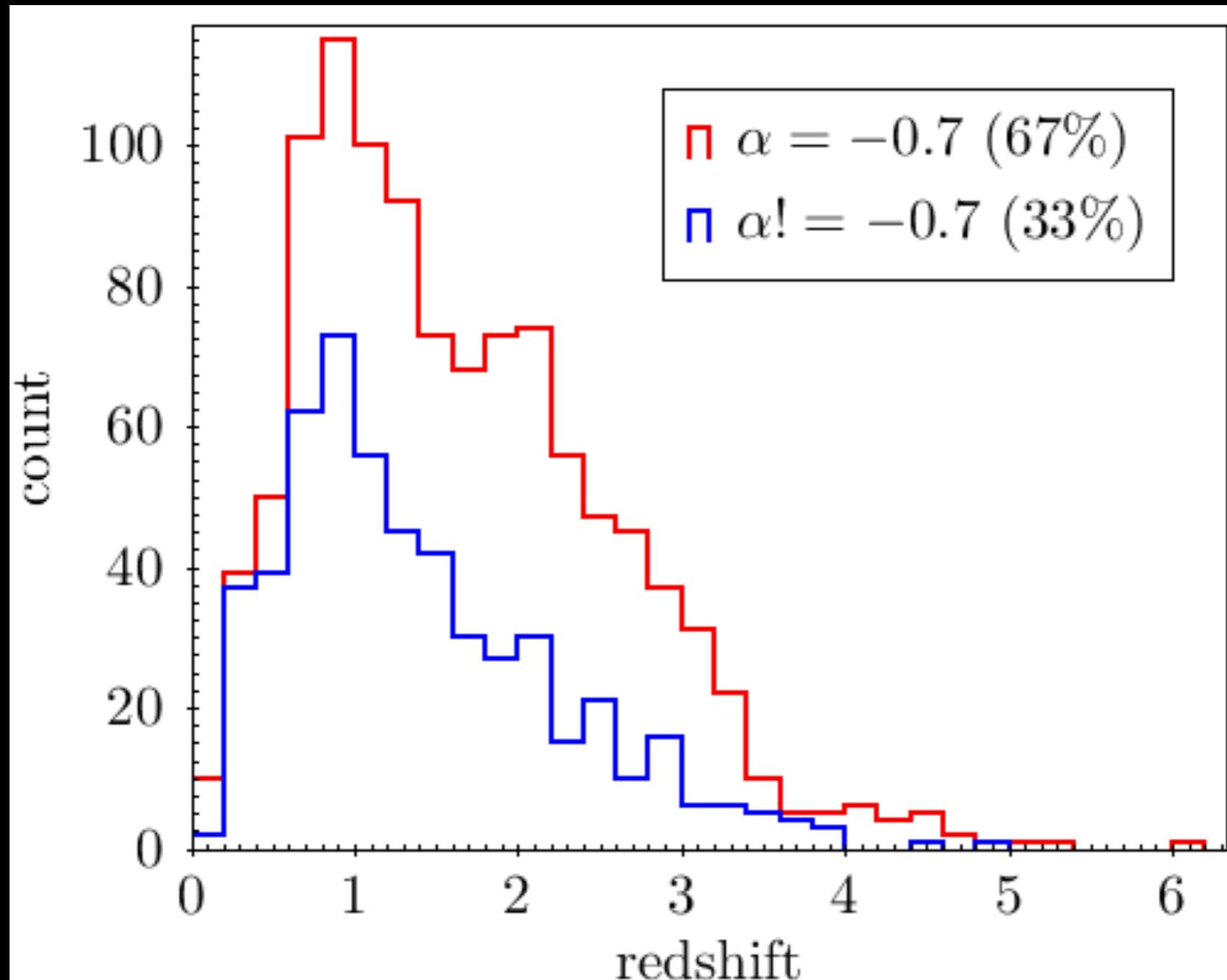
- VLA-COSMOS 3 GHz Large Project
- Luminosity decomposition onto SF and AGN contributions
- AGN luminosity functions of higher radiative luminosity AGN
- Cosmic evolution of higher radiative luminosity AGN peaks at higher redshifts than that of total AGN sample



# Additional slides

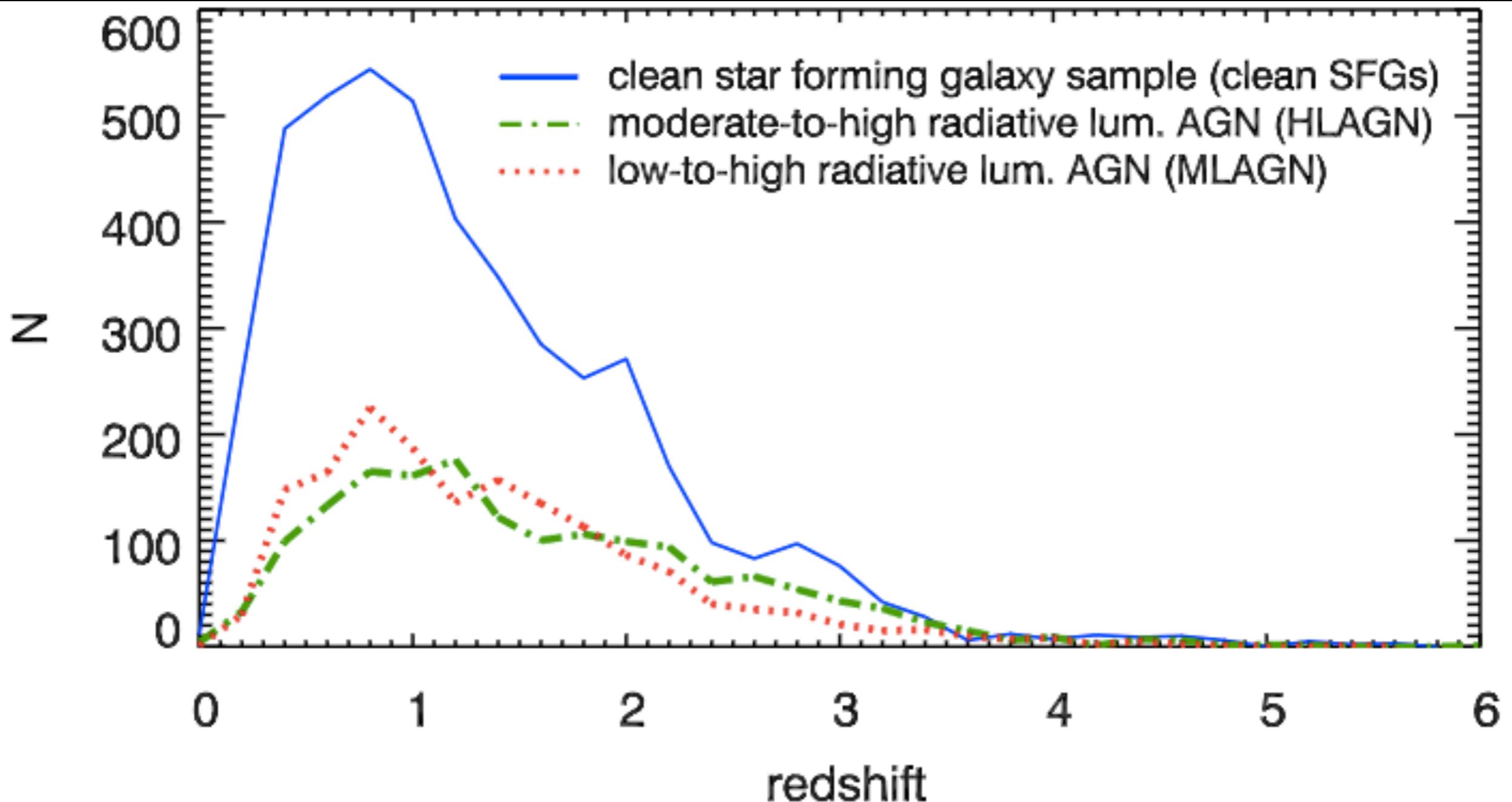
# The VLA – COSMOS 3 GHz Large Project

## Redshift distribution of higher radiative luminosity AGN



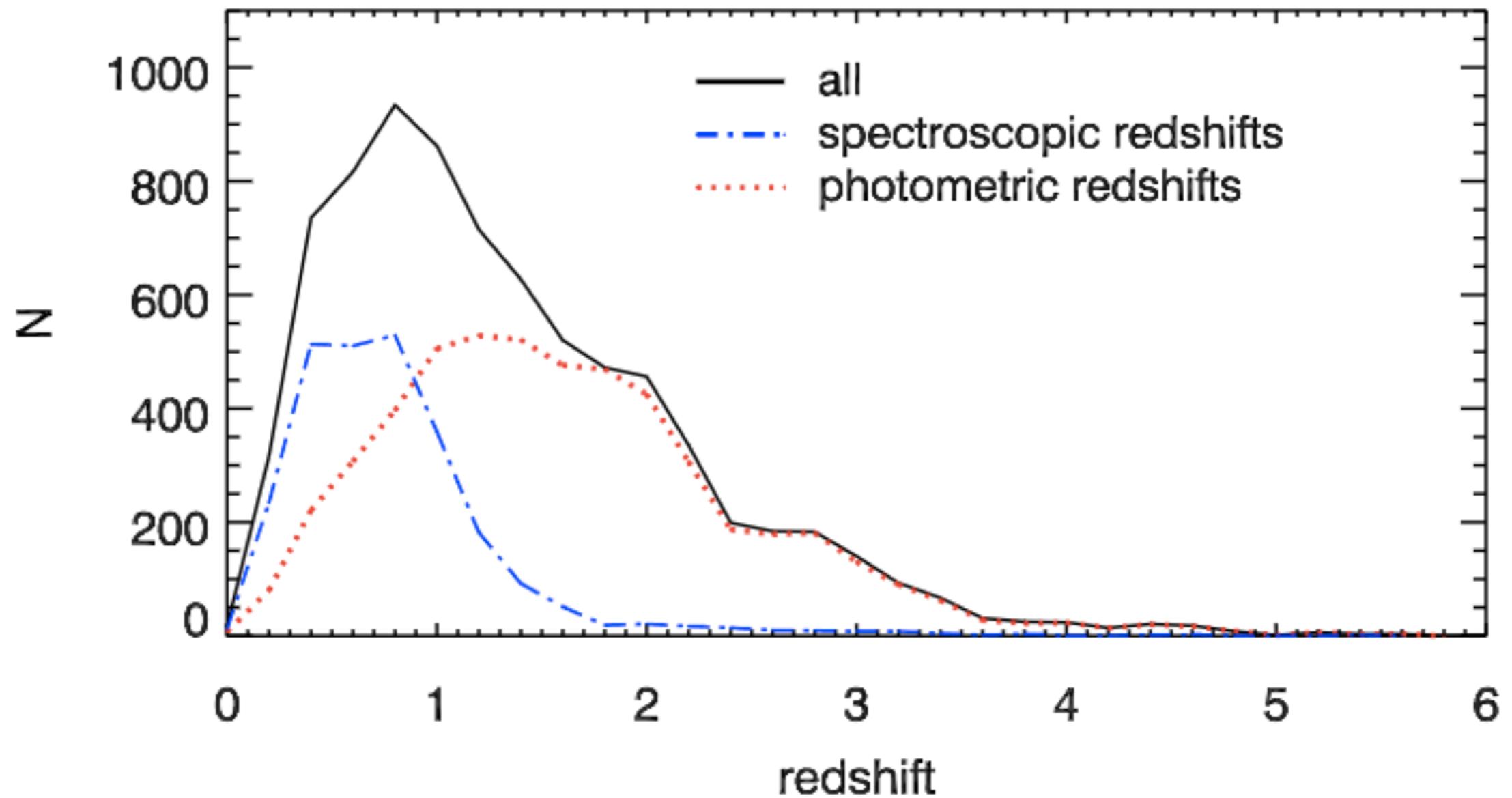
# The VLA – COSMOS 3 GHz Large Project

## Redshift distribution of the full sample (AGN+SF)

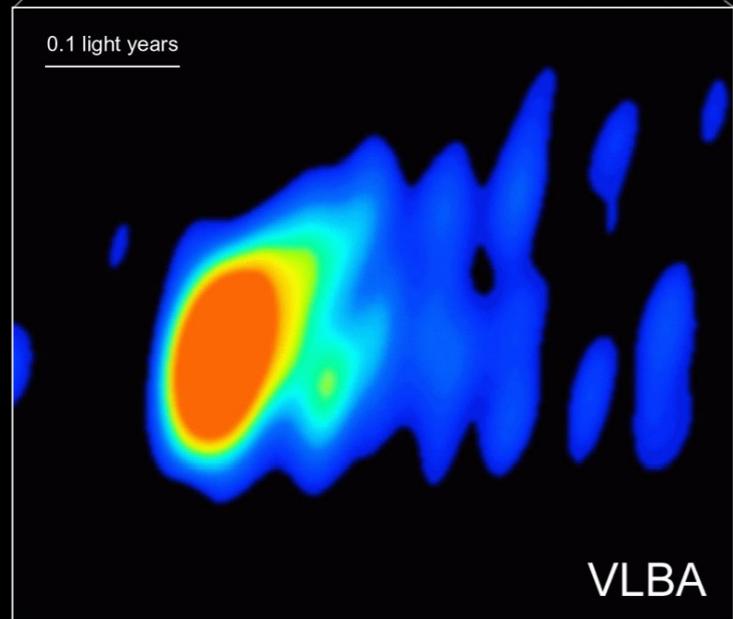
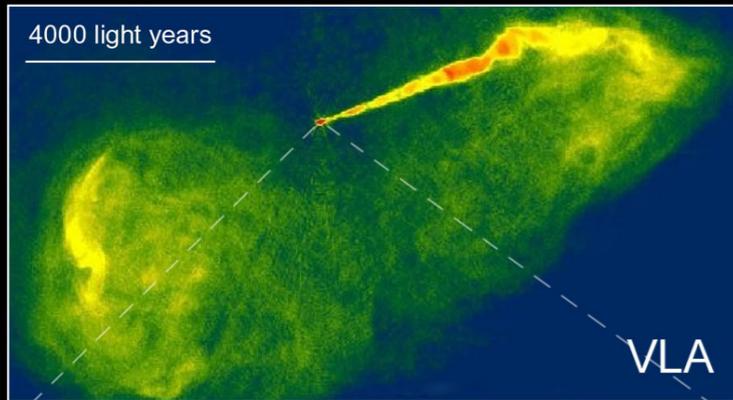


# The VLA – COSMOS 3 GHz Large Project

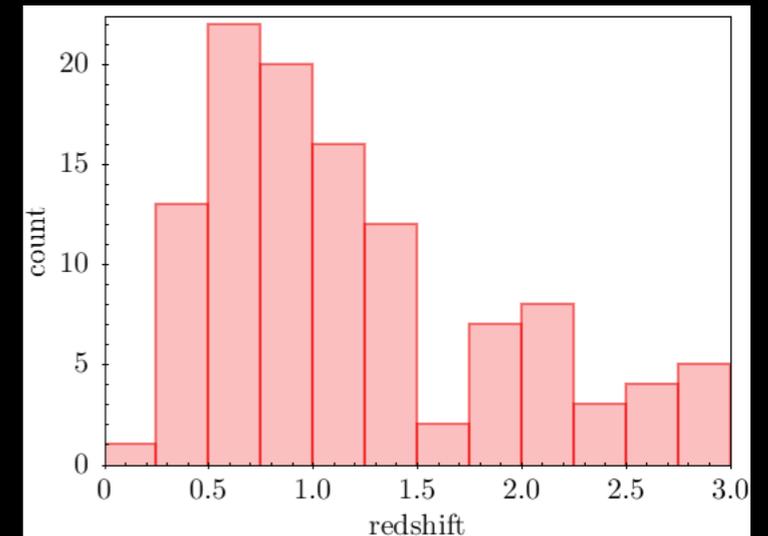
Redshift distribution of the full sample (spec. vs photo.)



# VLA- VLBA comparison

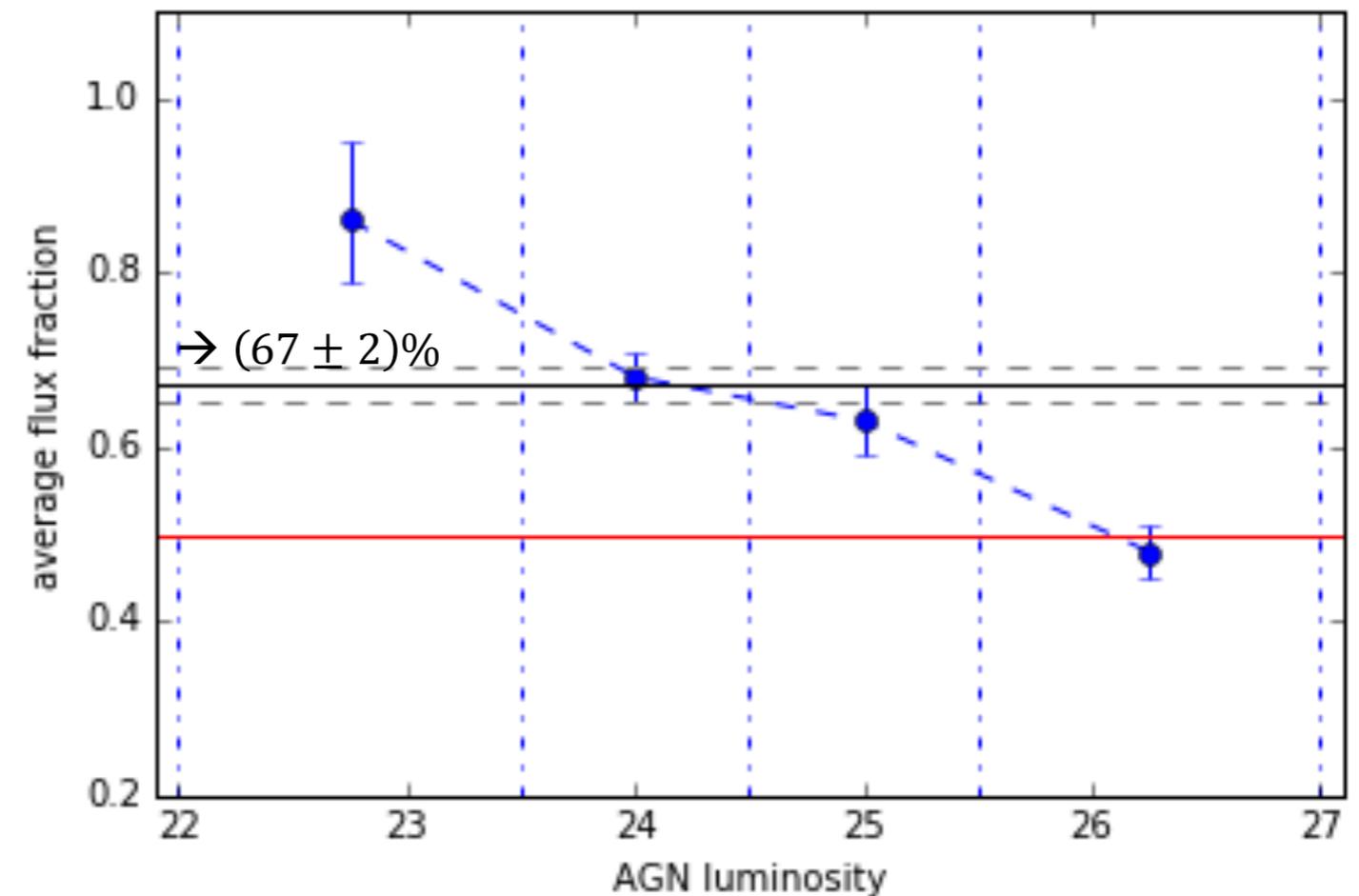


$d \sim 20$  pc at  $z=0.1$   
 $d \sim 80$  pc at  $z = 2.0$



$$\frac{\text{flux(VLBA)}}{\text{flux(VLA)}_{AGN}}$$

fluxes only from AGN emission(decomposition)



- VLBA observations of VLA 1.4 GHz COSMOS sources (Herrera Ruiz +17)
- cut HLAGN sample at 1.4 GHz flux  $5.5 \sigma$  ( $66 \eta \mu Jy$ )
- VLBA detects 113 (out of 484 possibly detectable) HLAGN (23% of detectable – flux  $> 66 \mu Jy$ , 7% of total HLAGN)