THE LONG ROAD TO QUIESCENCE: A STORY OF AGN FEEDBACK

MICHAEL COWLEY

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AAASTRO SEMINAR 14 AUGUST 2015

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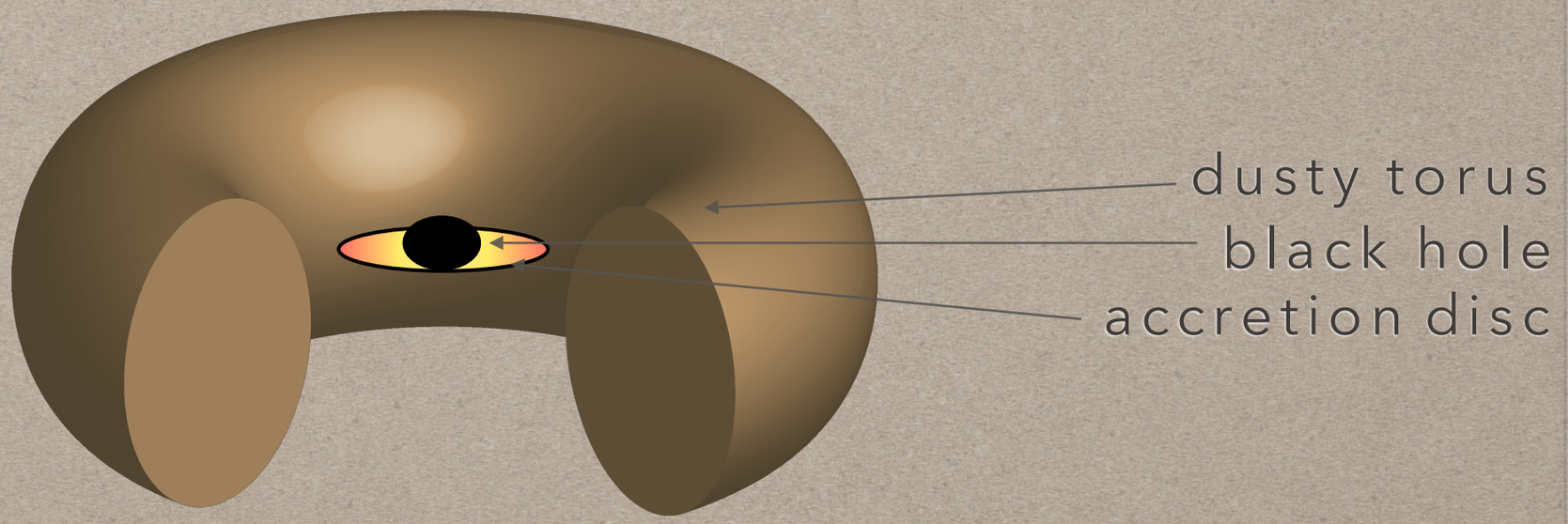
WHAT IS AN AGN?

- The term “active galactic nucleus” or AGN refers to the existence of energetic processes in the nuclei or central regions of some galaxies
- These energetic processes are not related to the normal evolution of stars


black hole

Conservation of angular momentum causes
this fuel to form a disk as it spirals in



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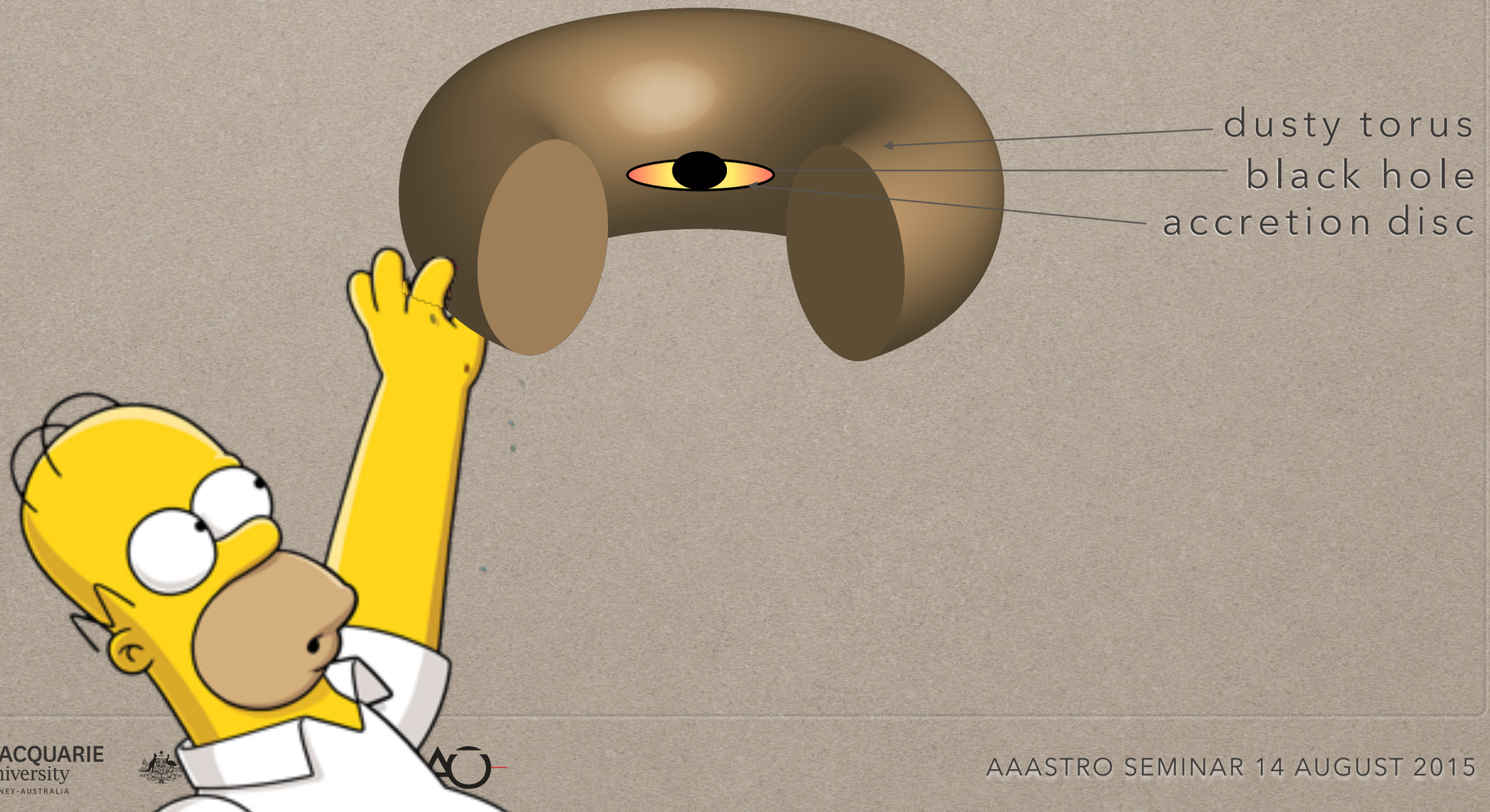

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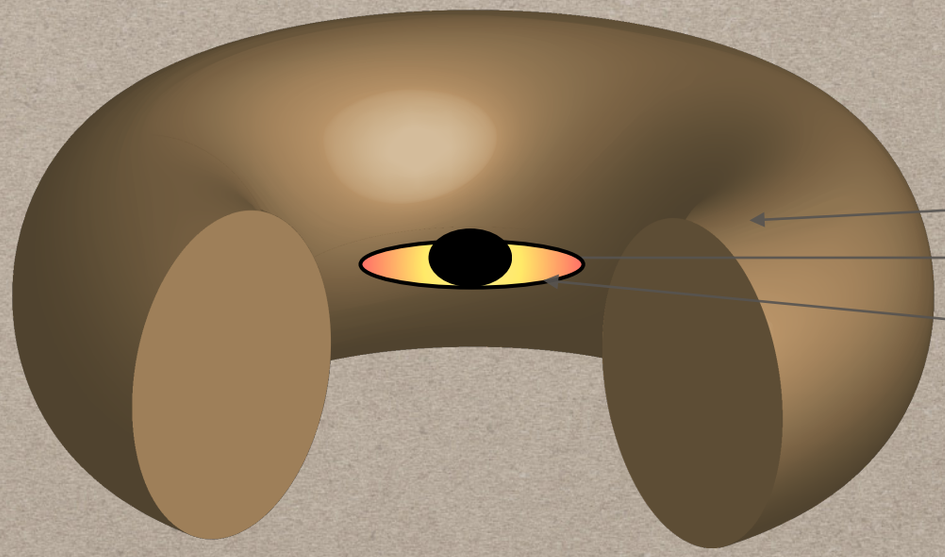
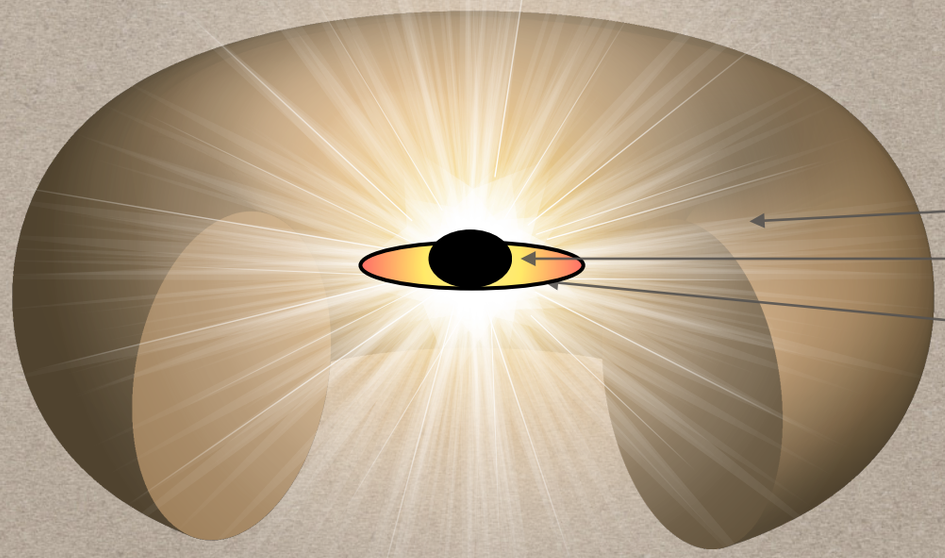


Within this disc, there will be dissipative processes,
e.g. collisions, shocks, viscous dissipation, etc.
This dissipated energy emerges as radiation

$L \sim 10^{44-48}$ erg s^{-1}

(i.e. $10^{10.5-14.5} L_{\odot}$)



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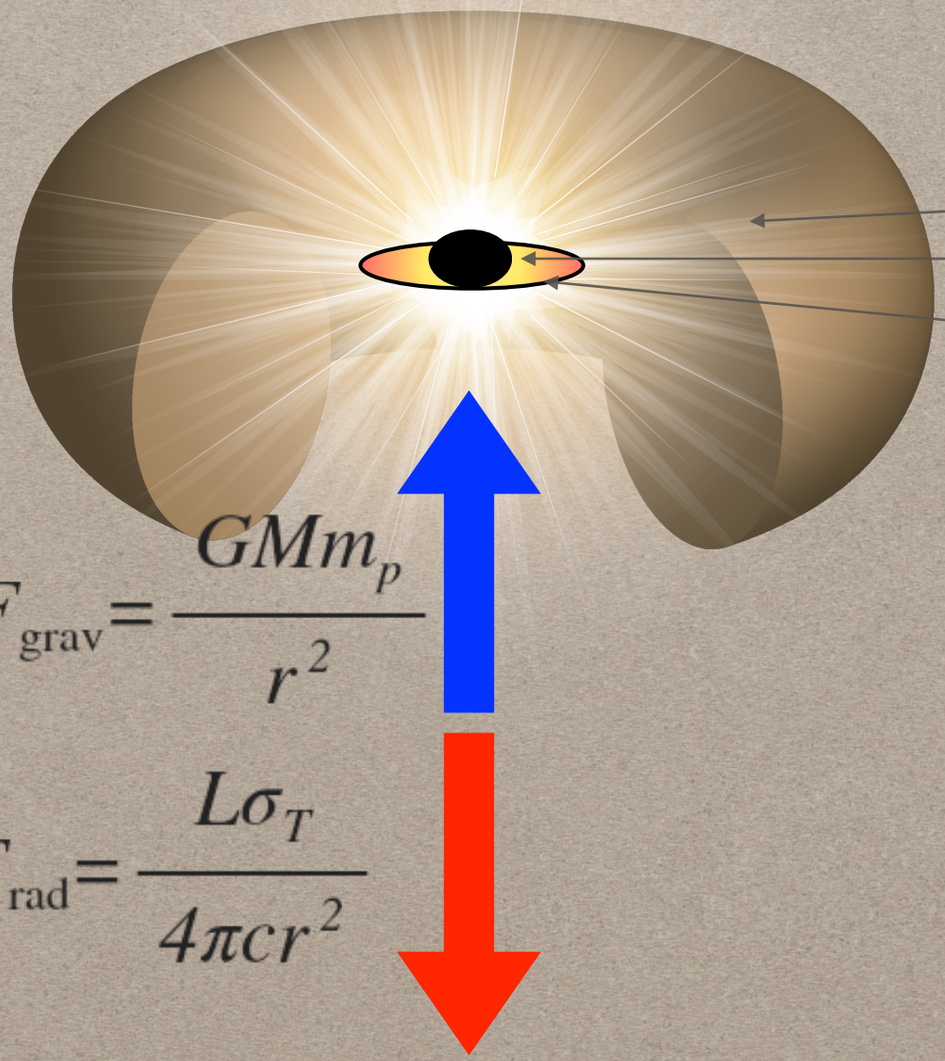


Interaction between accreted material and radiation...

$$F_{\mathrm{grav}} = \frac{GMm_p}{r^2}$$

$$F_{\mathrm{rad}} = \frac{L\sigma_T}{4\pi c r^2}$$

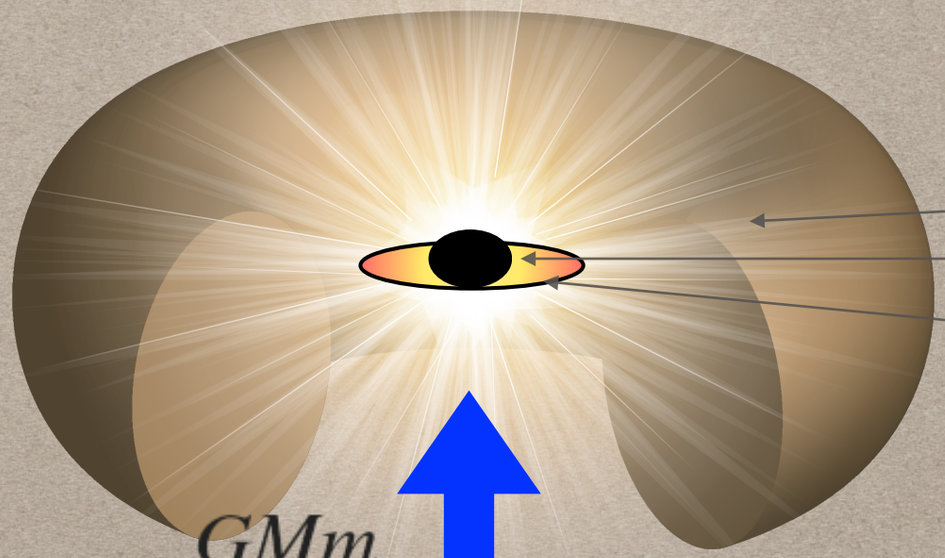
Accretion is only possible if...

$$F_{\text{grav}} > F_{\text{rad}} \rightarrow L < \frac{4\pi G M m_p c}{\sigma_T}$$

$$L < 1.3\times10^{38}\,\text{erg s}^{-1} \cdot \frac{M}{M_\odot}$$

$$L \sim 10^{44\text{-}48}\,\text{erg s}^{-1}$$

$$(\text{i.e. } 10^{10.5\text{-}14.5} L_\odot)$$



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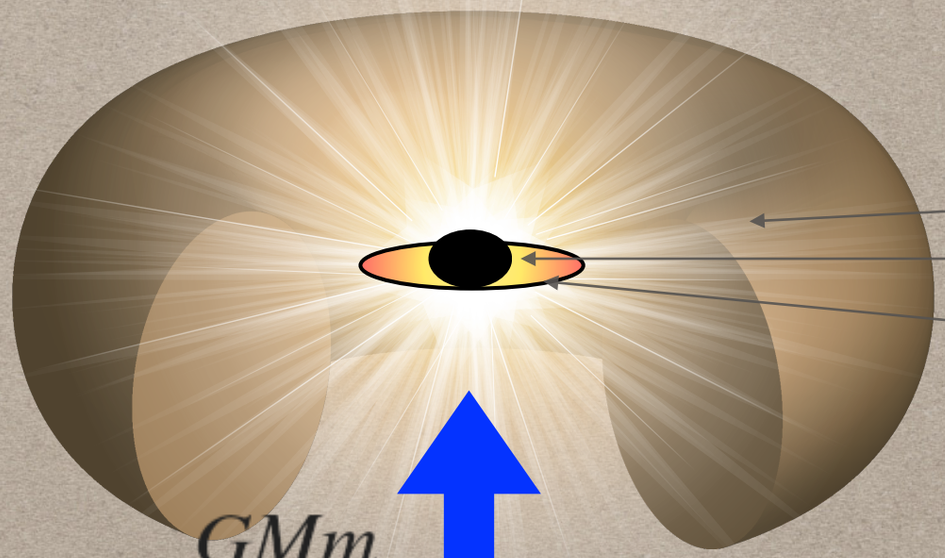

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$$L < 1.3\times10^{38}\,\text{erg s}^{-1} \cdot \frac{M}{M_\odot}$$

$$M \sim 8\times10^{5\text{-}9} M_\odot$$

$$L \sim 10^{44\text{-}48}\,\text{erg s}^{-1}$$

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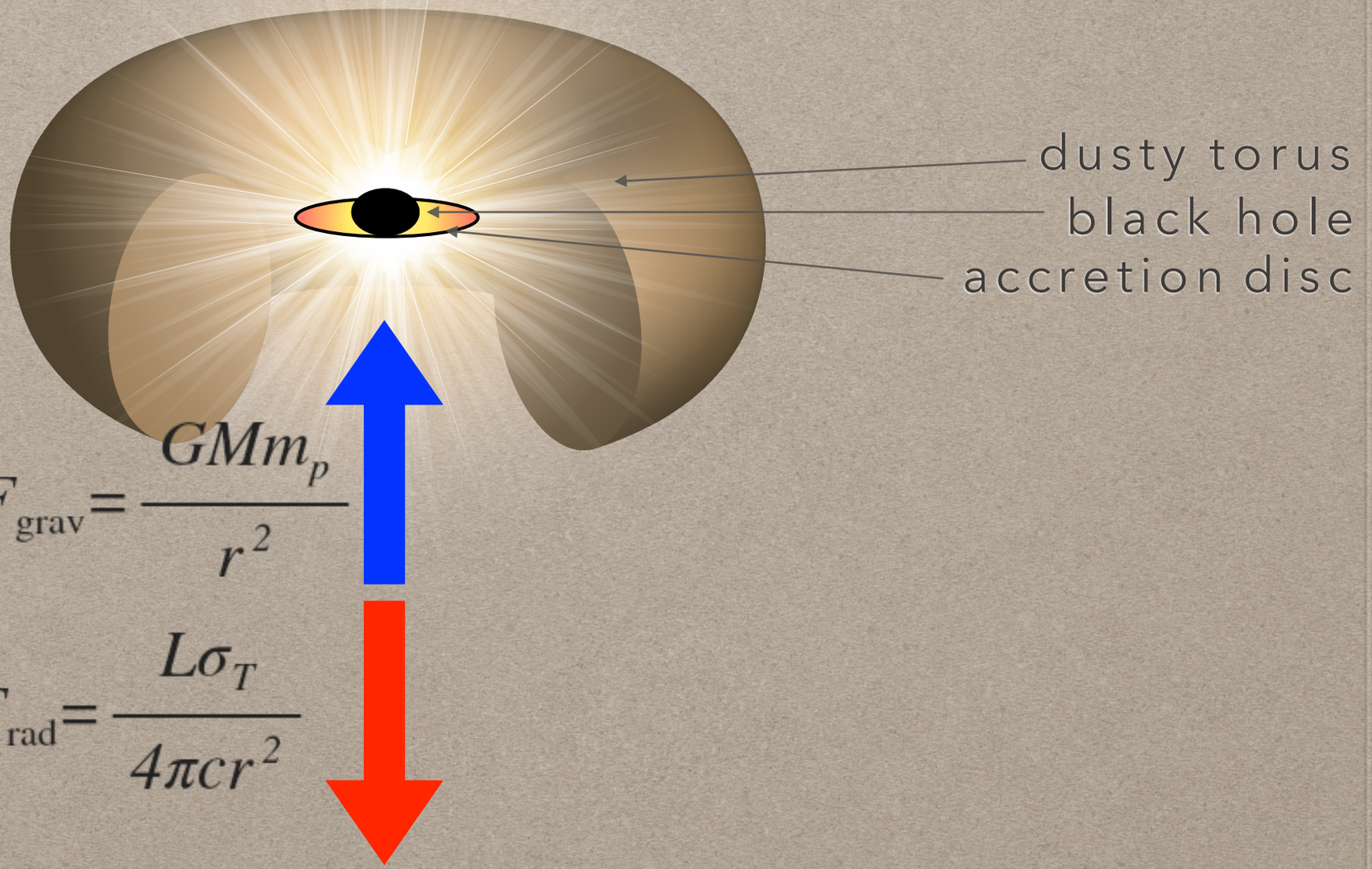

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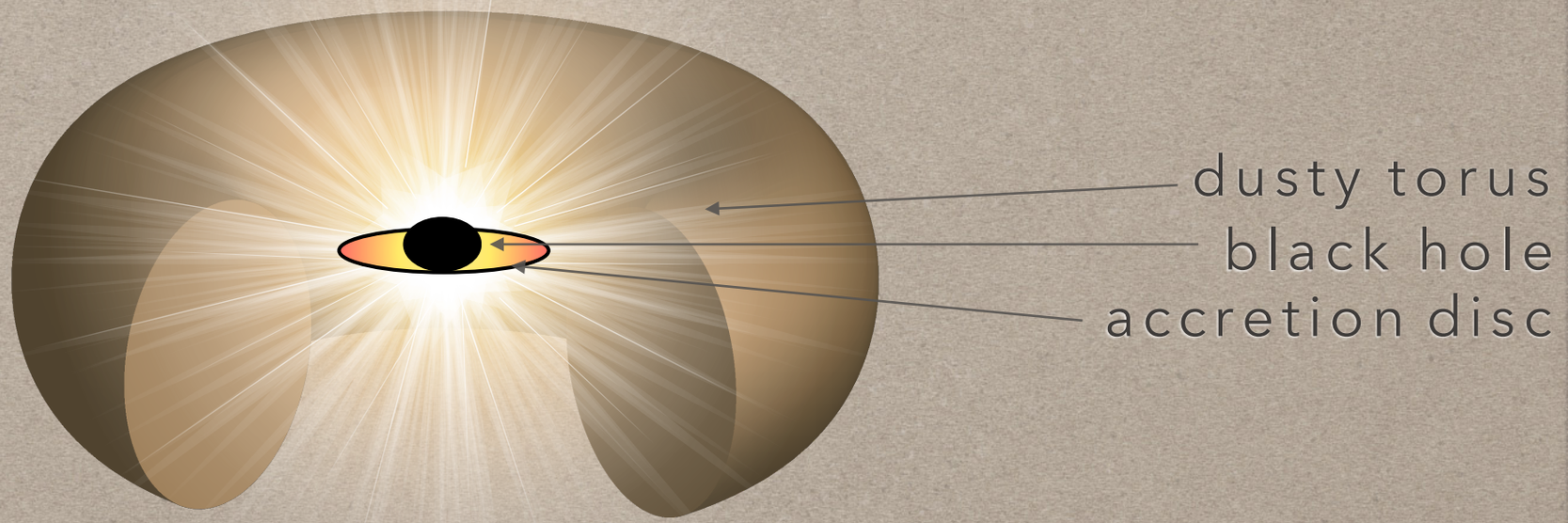
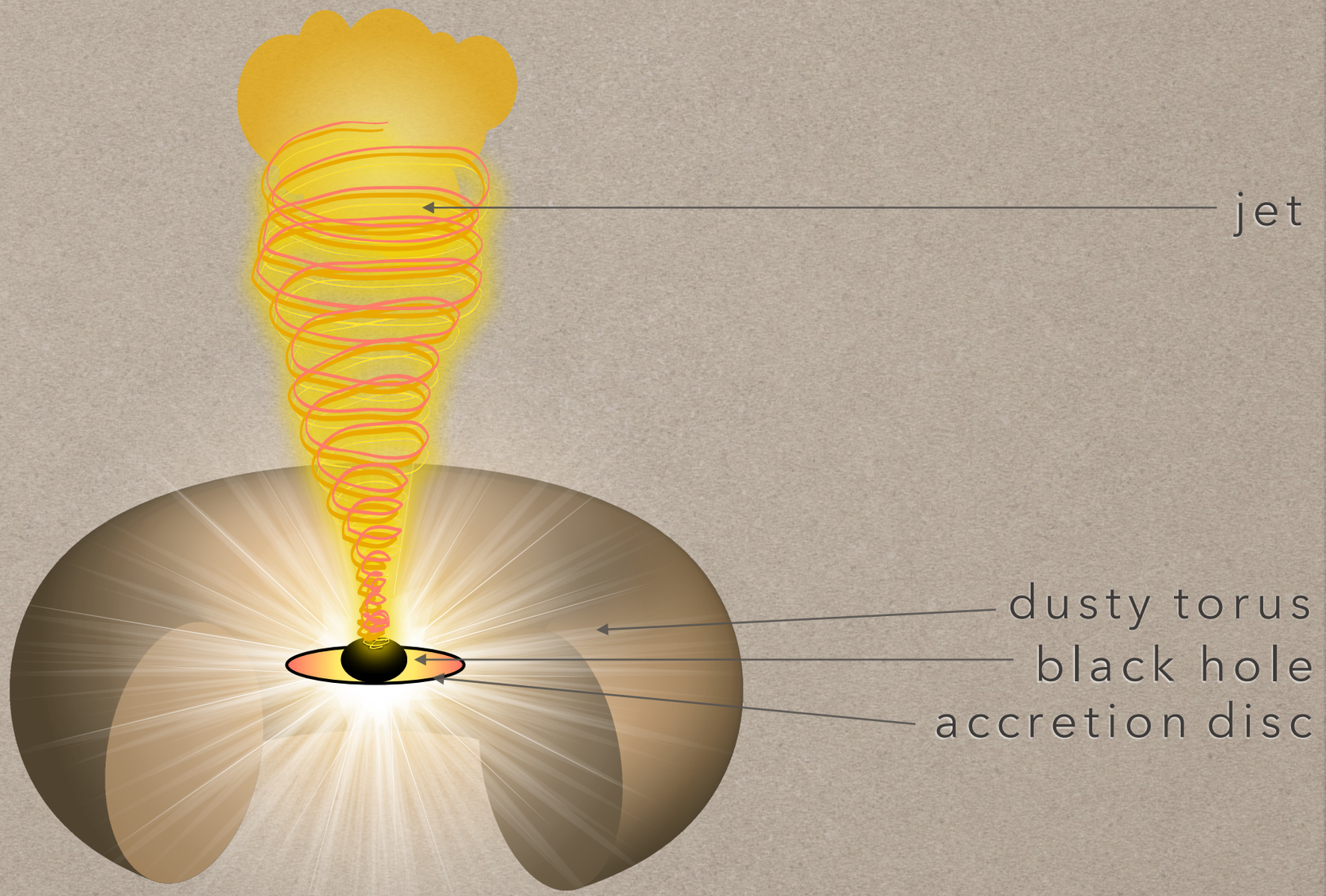
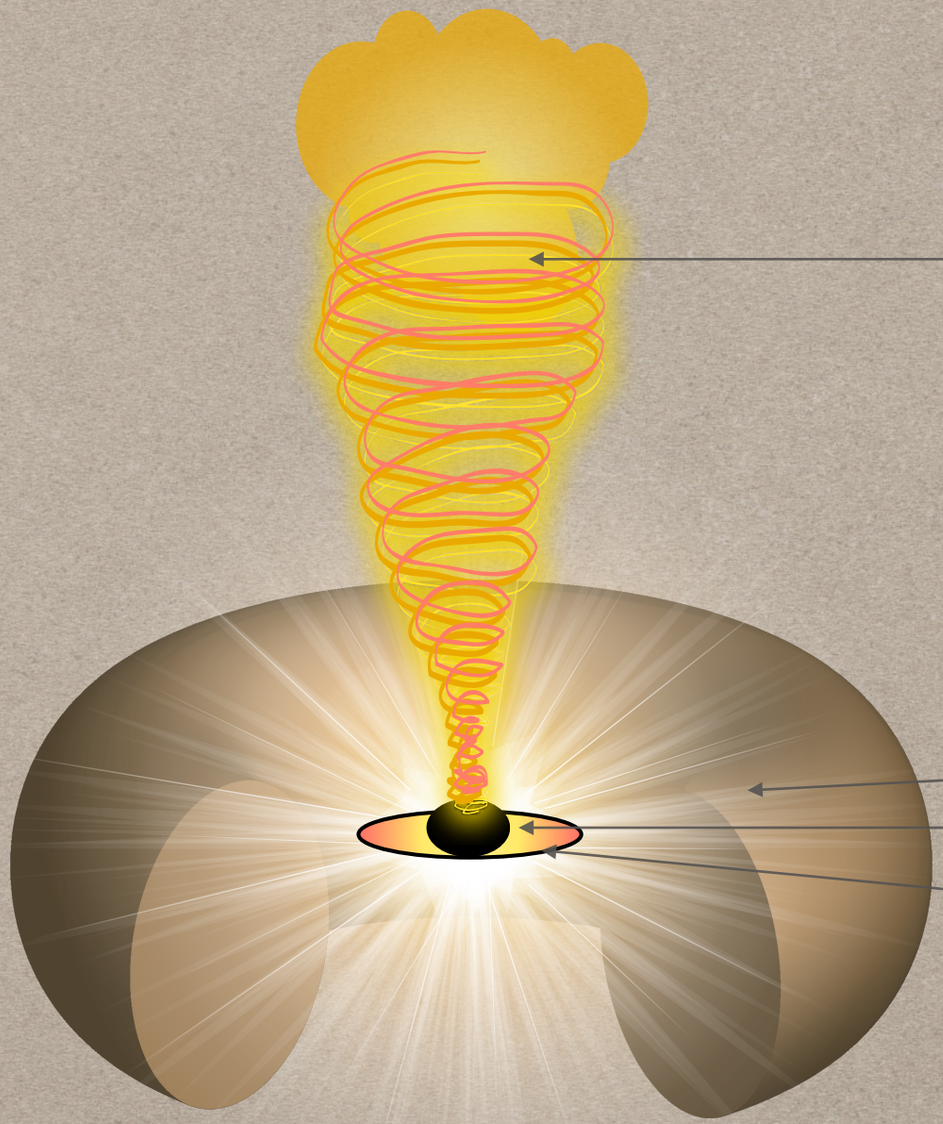
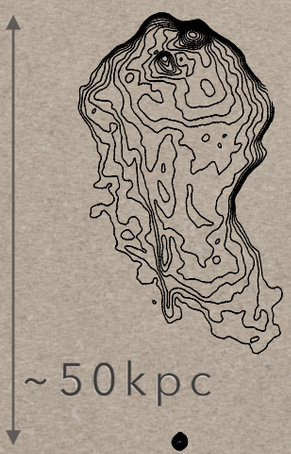

dusty torus
black hole
accretion disc



Radio (synchrotron) emission is produced in many AGN, collimated into jets and propagates in a direction that is perpendicular to the plane of the accretion disc





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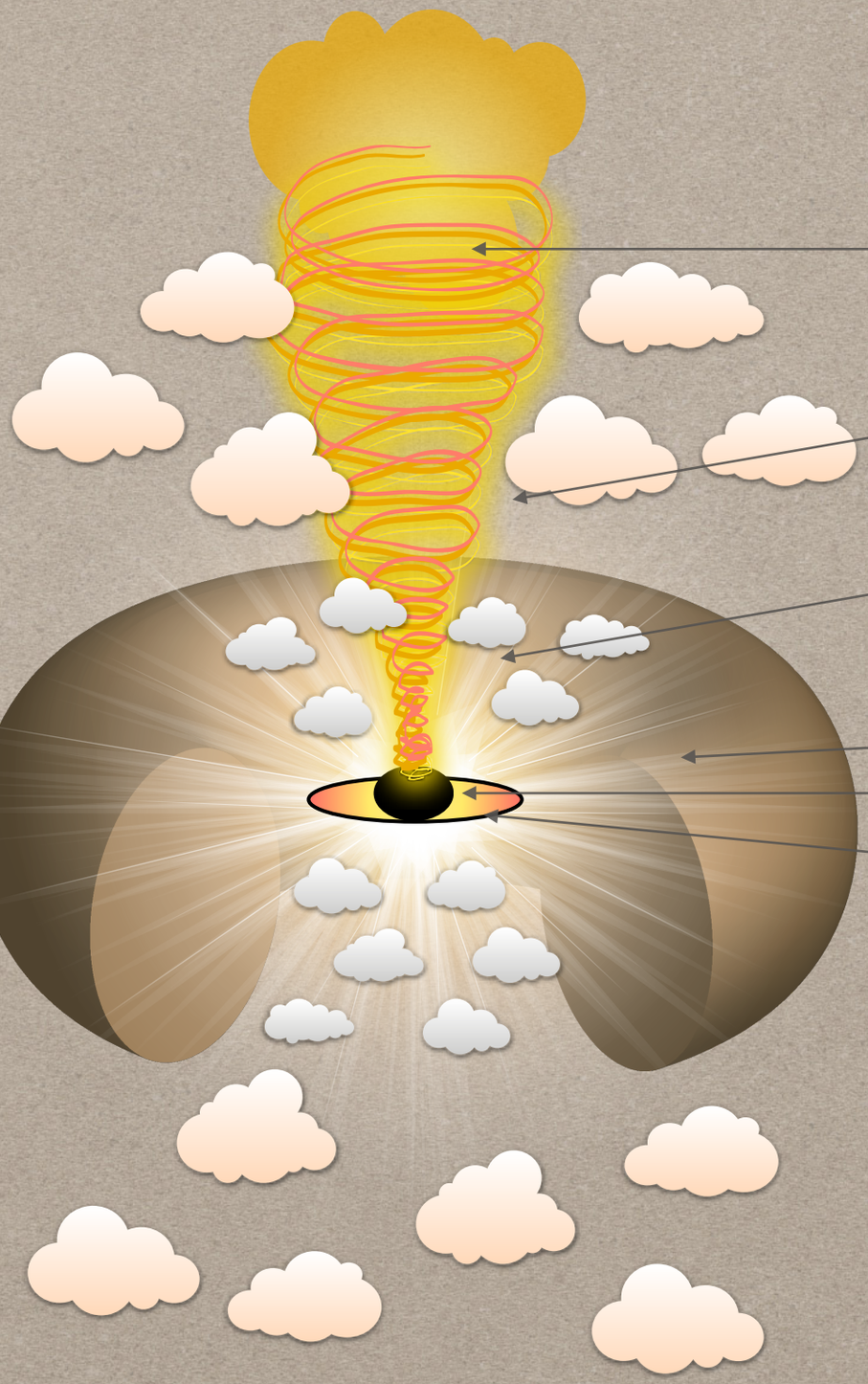
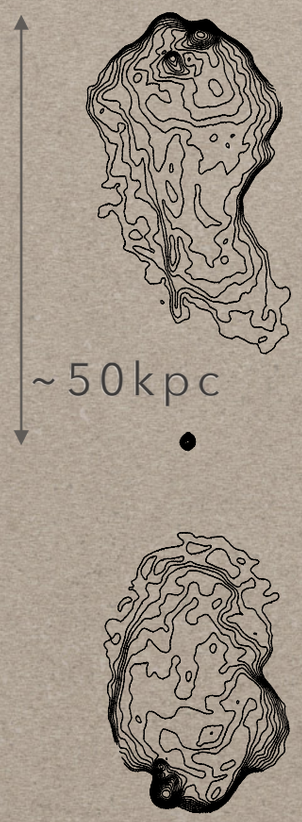

jet
narrow line region
(v ~ 500- 1000 km/s)
broad line region
(v ~ 1000-5000 km/s)
dusty torus
black hole
accretion disc


~50kpc

FR-I

Fanroff & Riley 1
Lower *L* and faint lobes

Quasar

Quasai-Stellar Radio Source

RL QSO

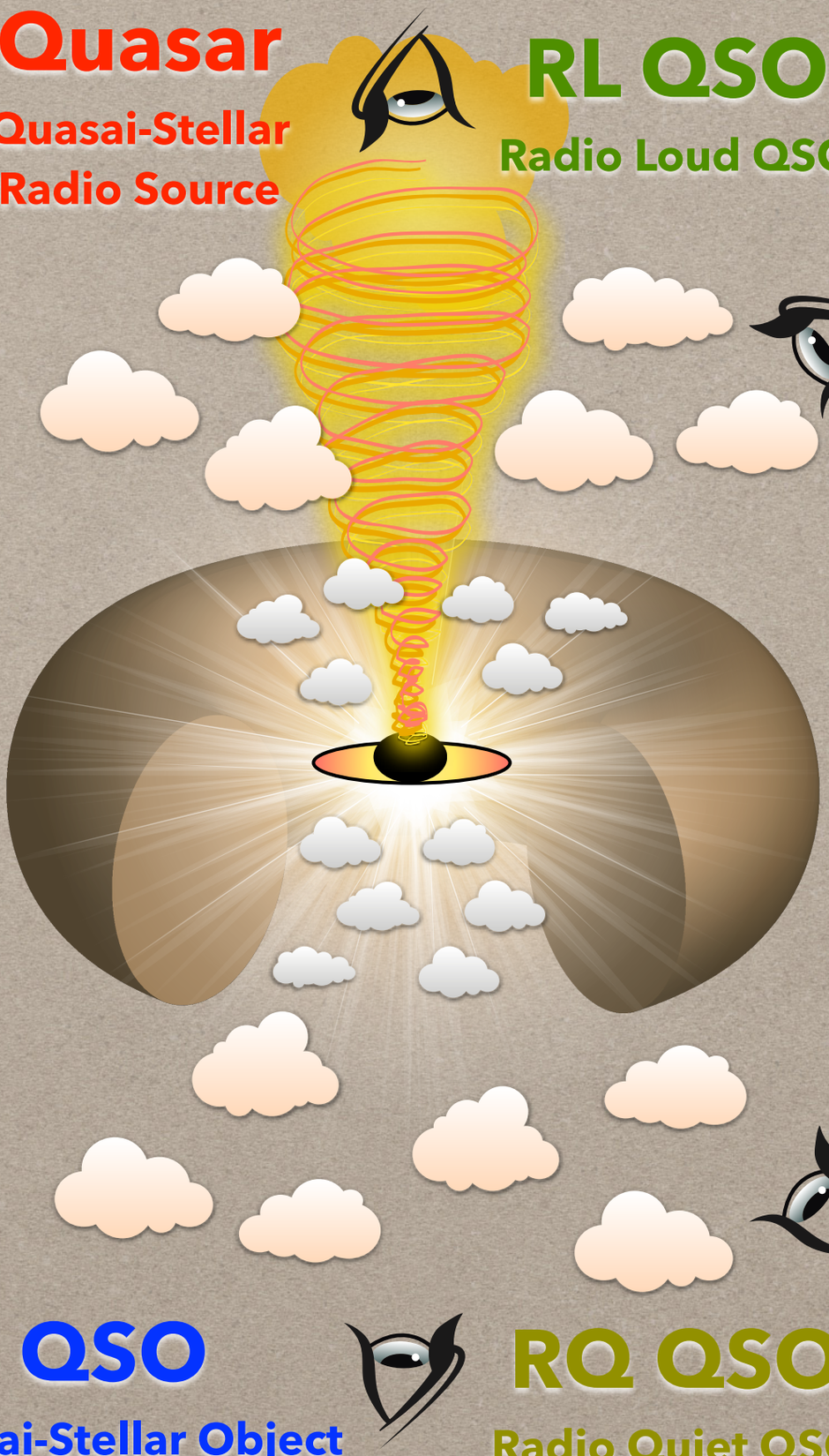
Radio Loud QSO

BLRG

Broad Line (+NLs) Radio Galaxy

NLRG

Narrow Line Radio Galaxy



FR-II

Fanroff & Riley 2
Higher *L* and bright lobes

Seyfert-2

Dust Obscured, Narrow Line

Seyfert-1.x

Weaker Broad Lines for numerically larger

Seyfert-1

Unobscured, Broad Lines & Narrow Lines

QSO

Quasai-Stellar Object

RQ QSO

Radio Quiet QSO

FR-I

Fanroff & Riley 1
Lower *L* and faint lobes

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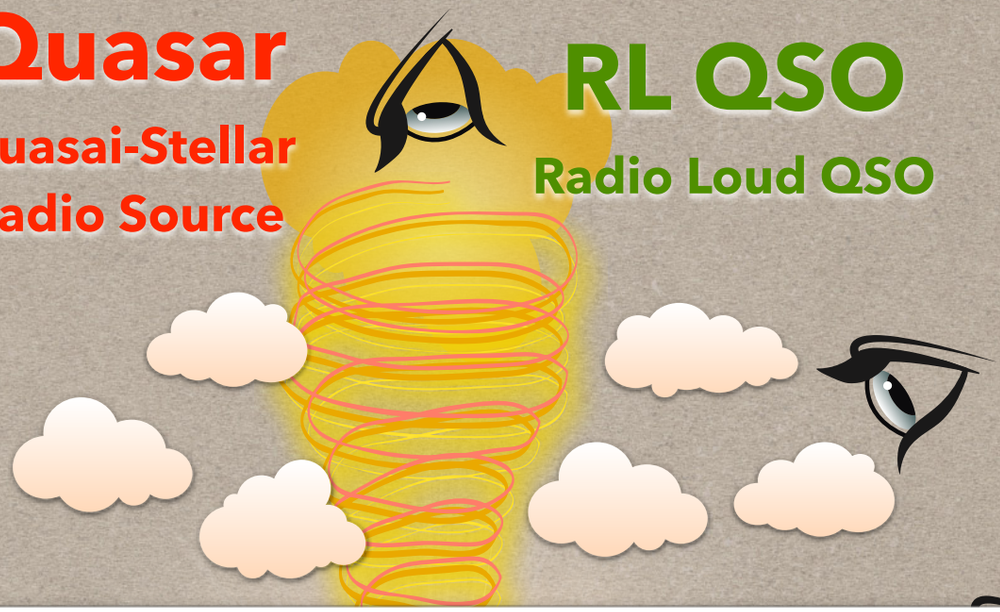

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Radio Loud QSO

BLRG

Broad Line (+NLs) Radio Galaxy

NLRG

Narrow Line Radio Galaxy

Other subclasses include: **NLSy1** (very narrow-line) Seyferts; **OVV** (Optically Violently Variable) quasars; **BAL** (Broad Absorption Line) quasars; **HPQ** (Highly Polarized Quasars); **LPQ** (Low Polarization Quasars); **SSRQ** (steep-spectrum radio quasars); **FSRQ** (flat-spectrum radio quasars); compact radio sources; superluminal sources; **blazars** etc., etc...

Fanro
Hig
bri

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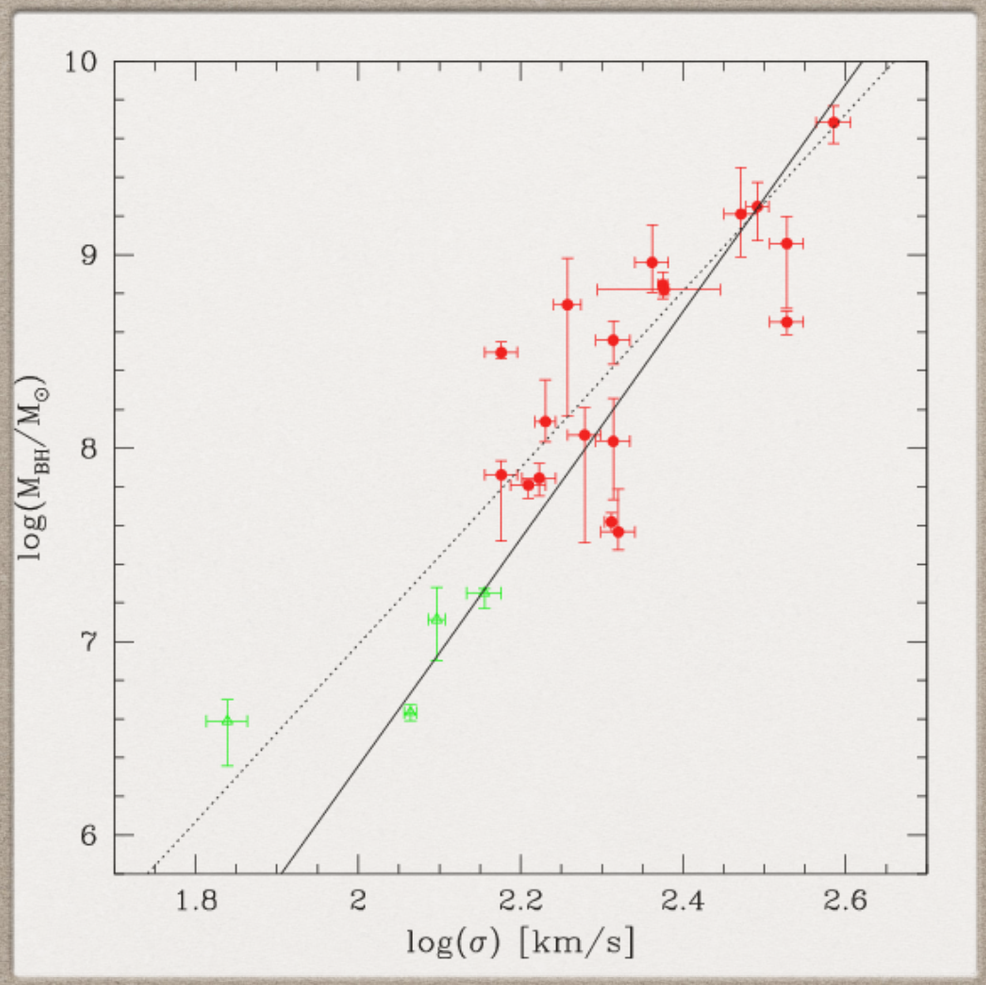
WHY DO WE CARE ABOUT ACTIVE GALACTIC NUCLEI (AGN)?

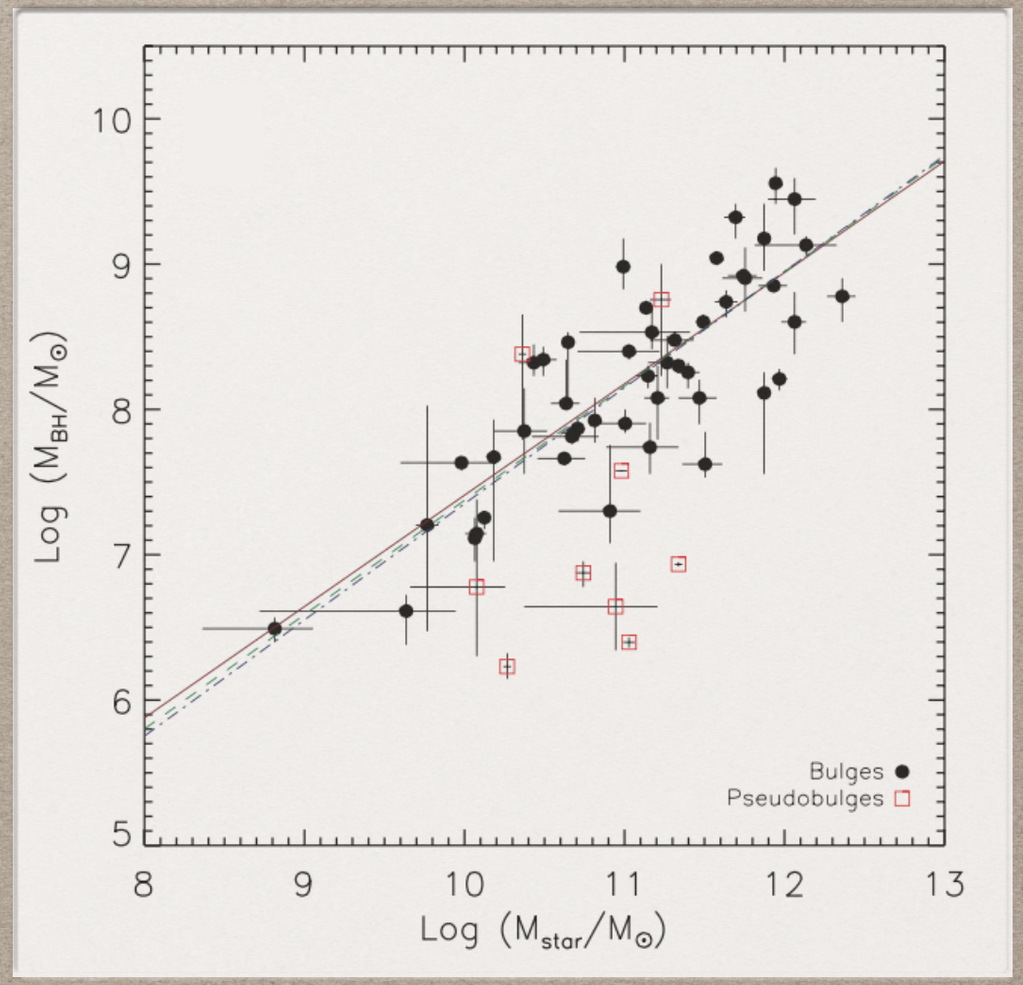
There's a **close connection** between AGN and their hosts

Rhode 2012



Velocity Dispersion

Sani+ 2011



Host Galaxy Mass

HOW DOES THE GALAXY KNOW THE SMBH IS THERE?

The mass of the SMBH…

$$M \sim 10^{-3} M_{\mathrm{bulge}}$$

…so its gravity only influences a region…

$$R_{\mathrm{inf}} = \frac{GM}{\sigma^2} \sim 11 \frac{M_8}{\sigma_{200}^2} \mathrm{parsec}$$

$$(M_8 = M/10^8 M_\odot, \sigma_{200} = \sigma/200 \mathrm{km\ s^{-1}})$$

…which is far smaller than the bulge (MW ~ 5 kpc)

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AGN FEEDBACK

The gravitational energy of material falling into the centre of a galaxy toward the central supermassive black hole is released in the form of

- **radiation in the IR/optical/UV/X-rays**
- **mildly relativistic accretion disk winds**
- **collimated relativistic jets**

The radiation, jets and winds are believed to strongly affect the evolution of the host galaxy by “feeding back” energy and momentum to the interstellar medium (ISM) or even the wider intergroup/intercluster medium (IGM/ICM)

AGN FEEDBACK

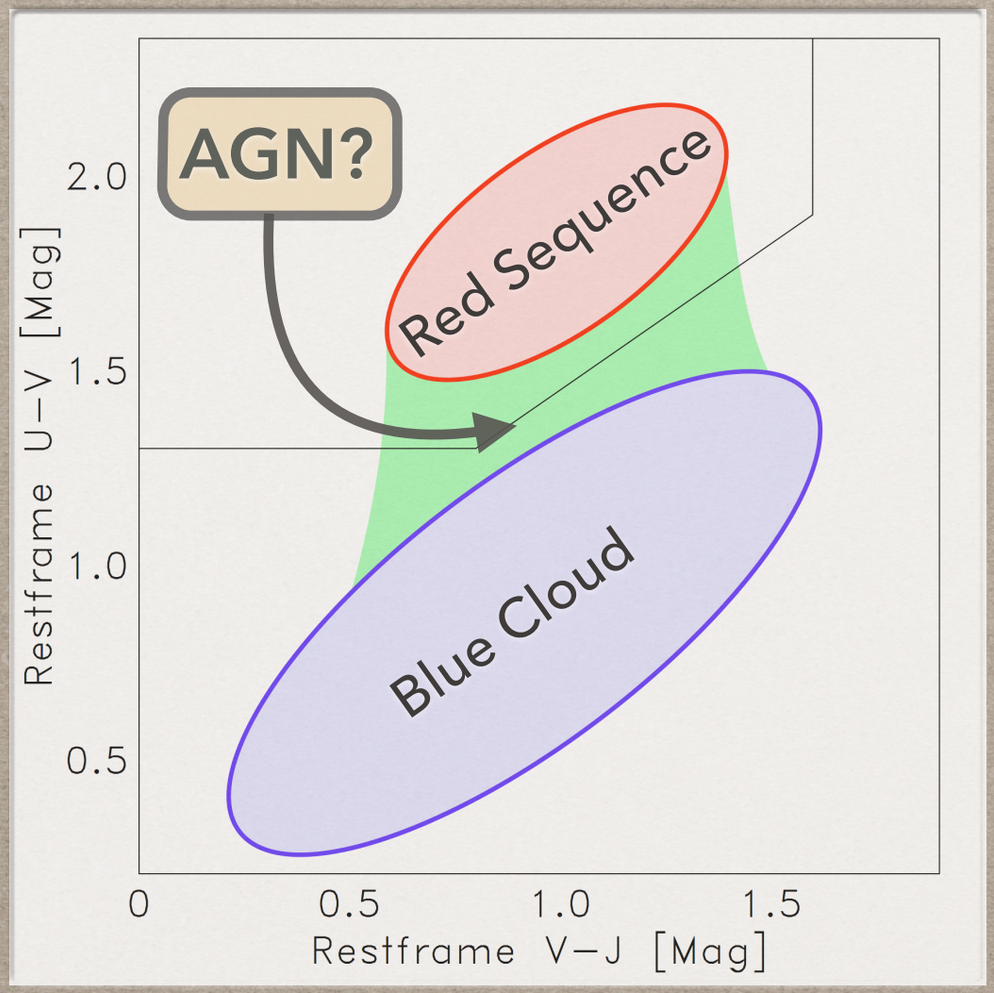
Radiatively Efficient or
"quasar mode"

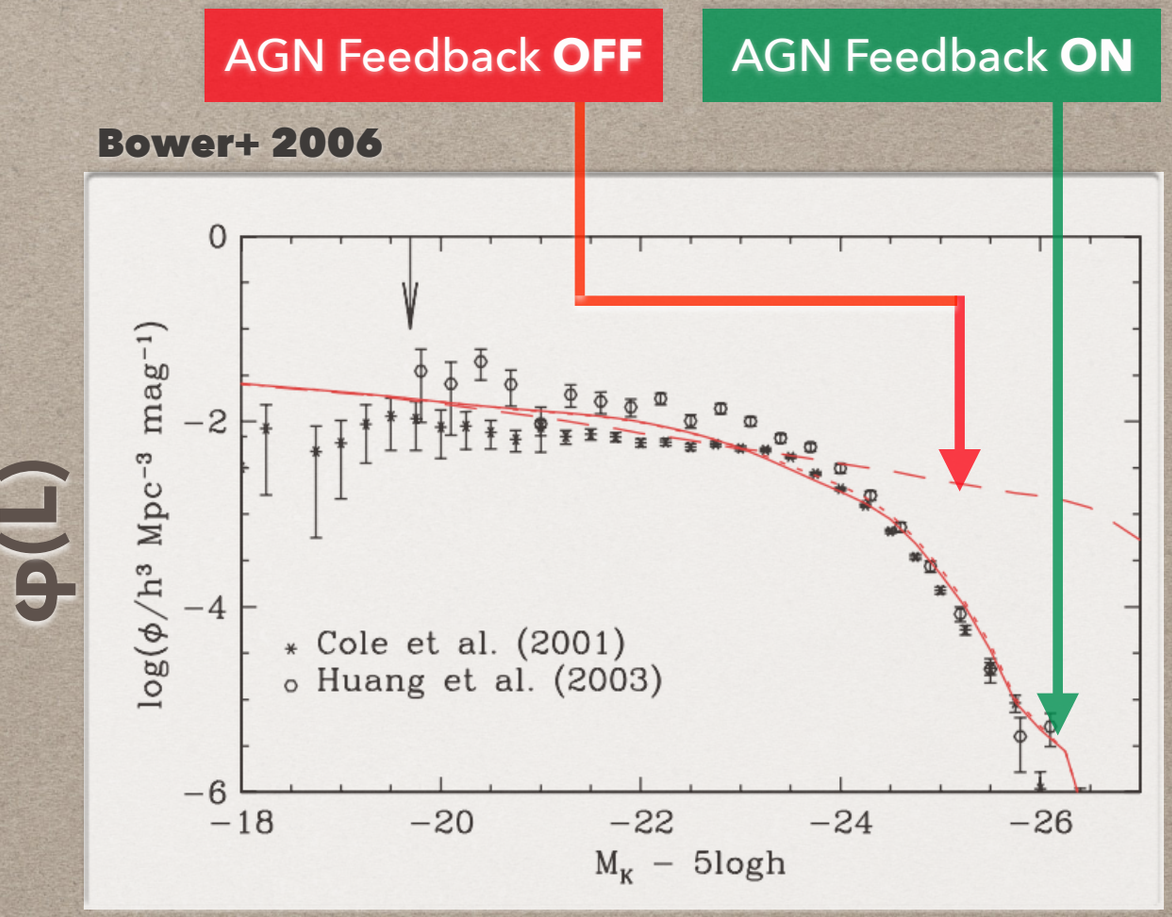
- radiation in the IR/optical/UV/X-rays
- mildly relativistic accretion disk winds
- collimated relativistic jets

Radiatively Inefficient or
"radio mode"

WHY DO WE CARE ABOUT ACTIVE GALACTIC NUCLEI (AGN)?

Negative feedback from AGN helps **suppress ongoing star formation** and **reduce the number of massive galaxies**





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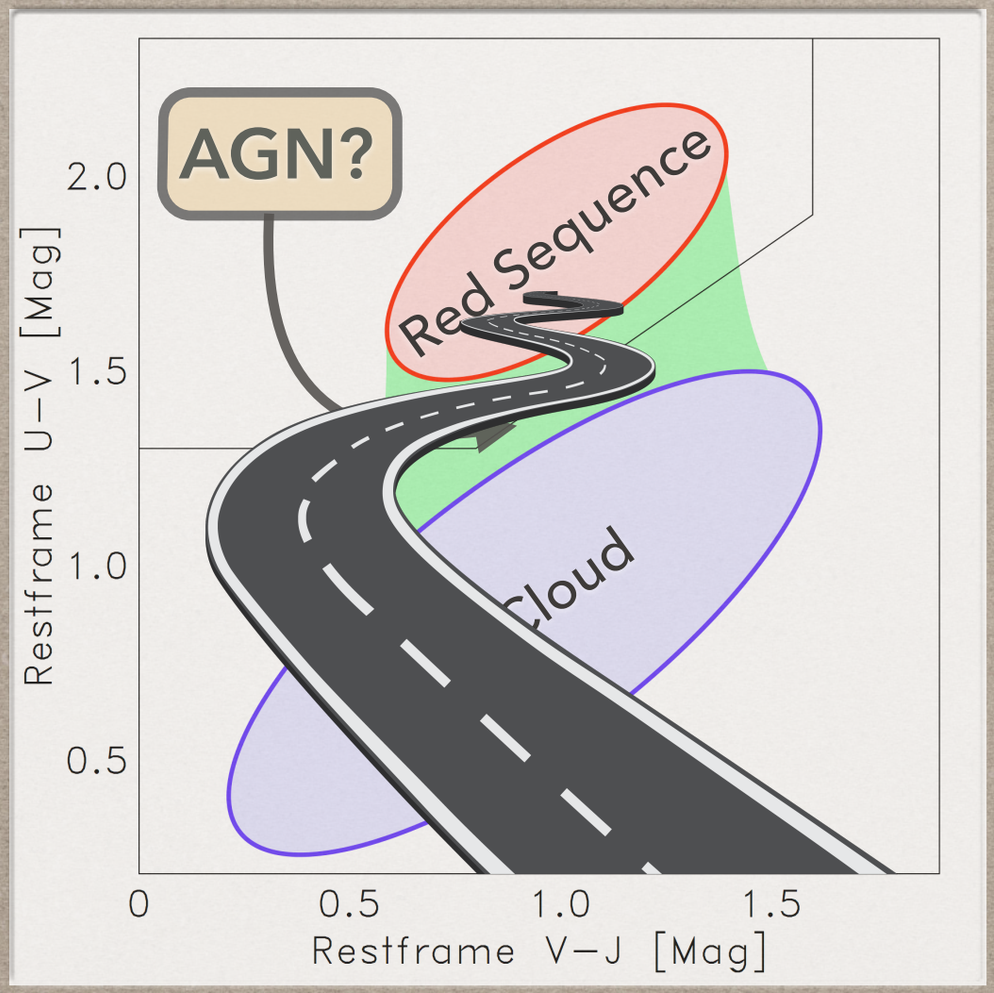

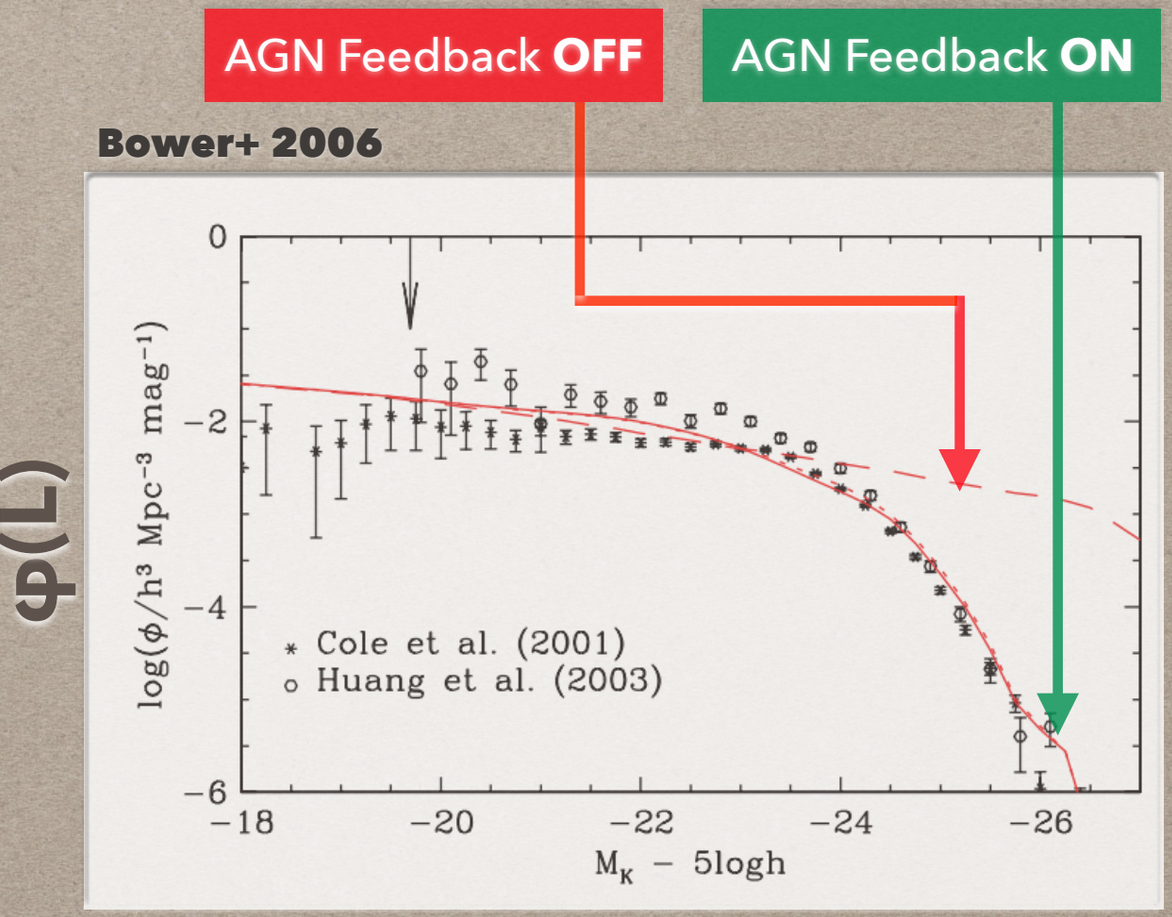

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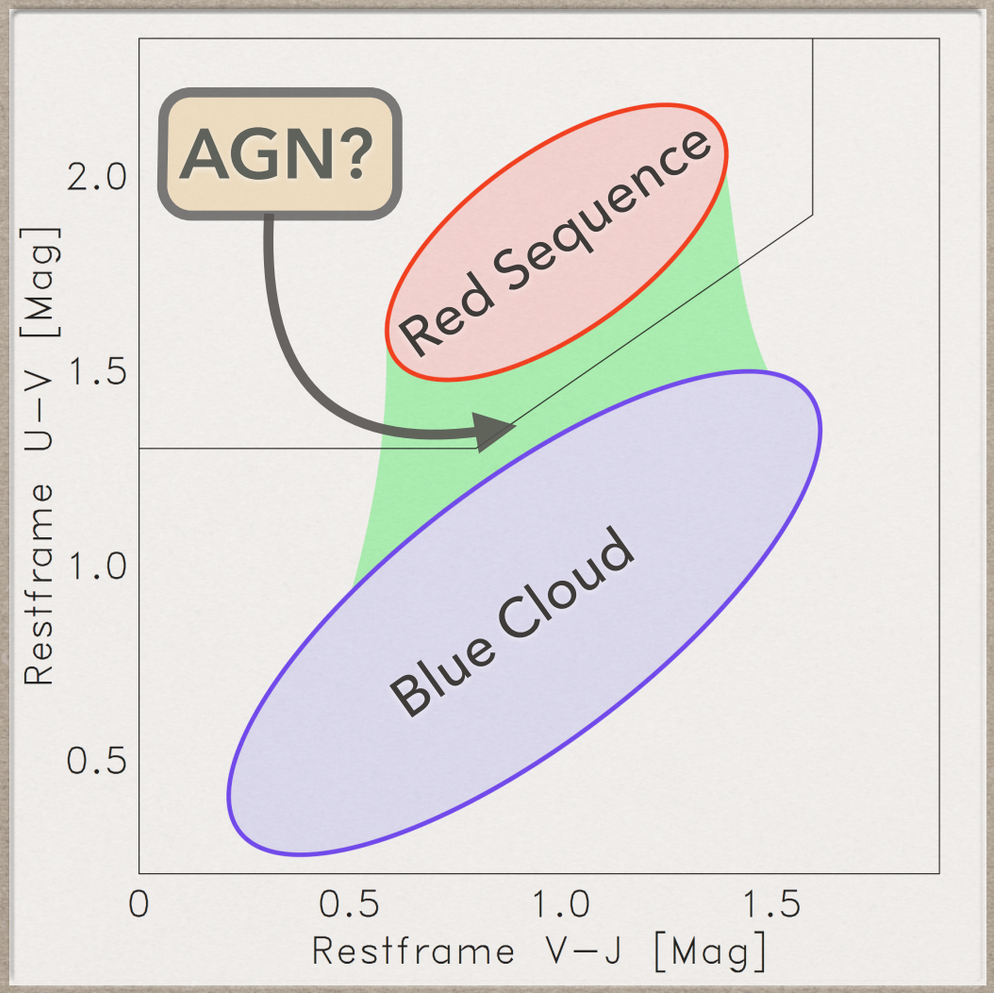
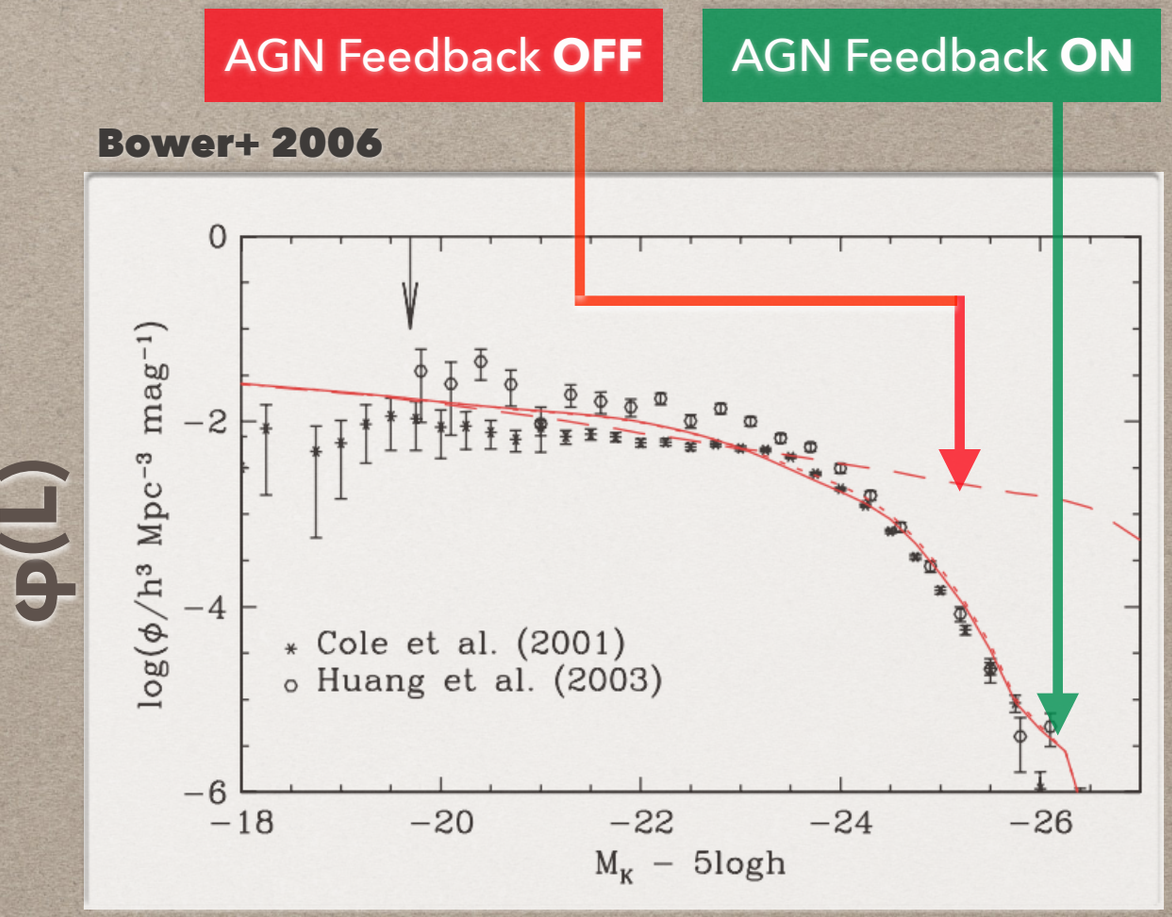
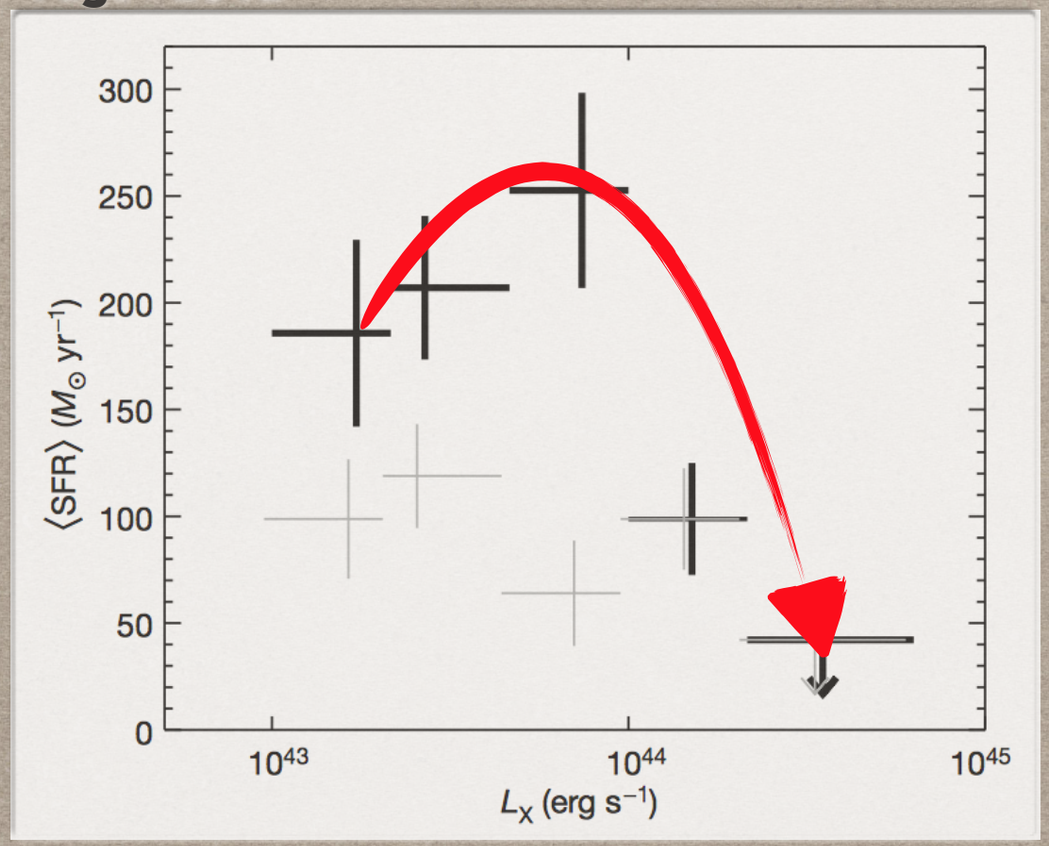




NEGATIVE FEEDBACK

Direct evidence for star formation quenching by AGN negative feedback?

Page+ 2012

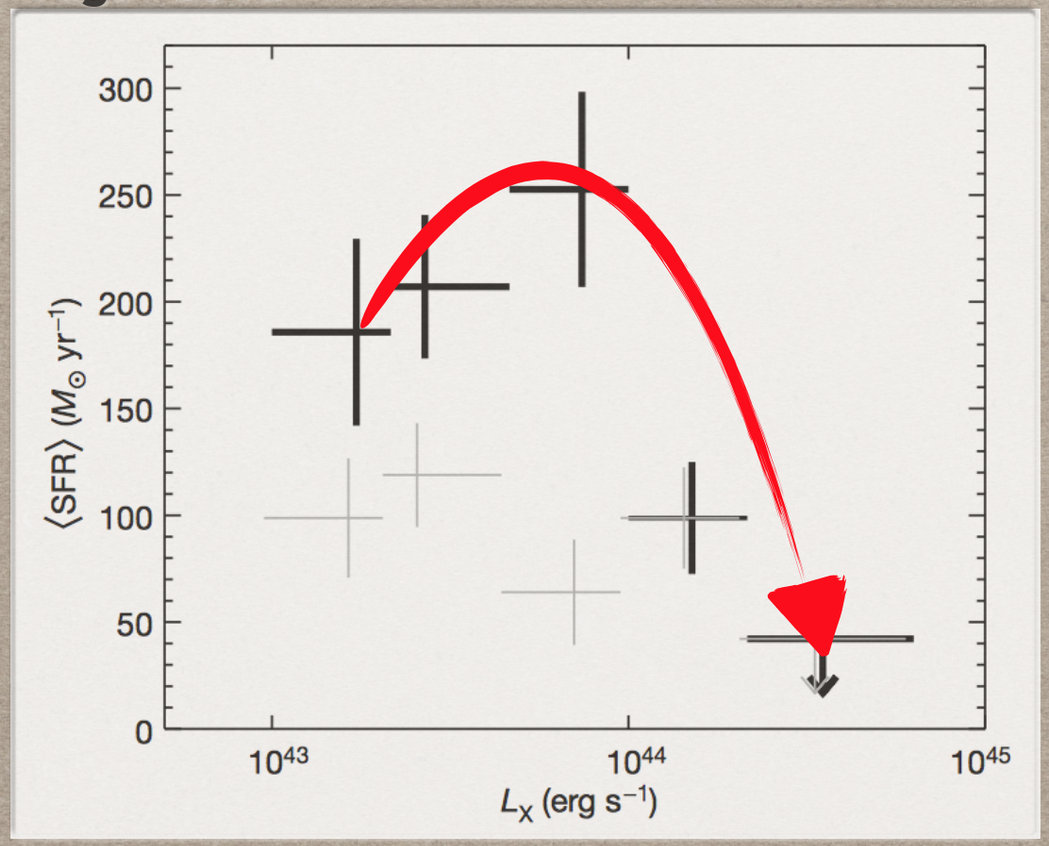


NEGATIVE FEEDBACK OR POSITIVE FEEDBACK?

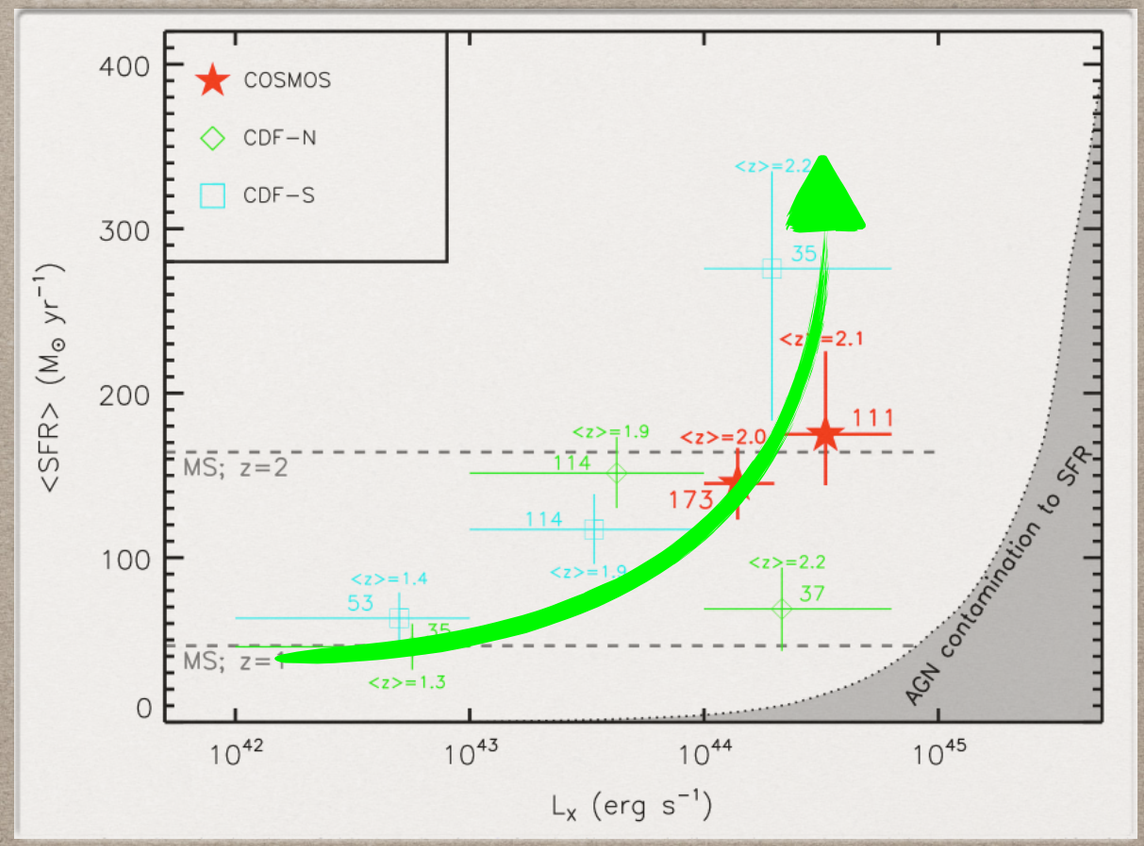
Direct evidence for star formation quenching by AGN negative feedback?

The details of this feedback are not well understood!

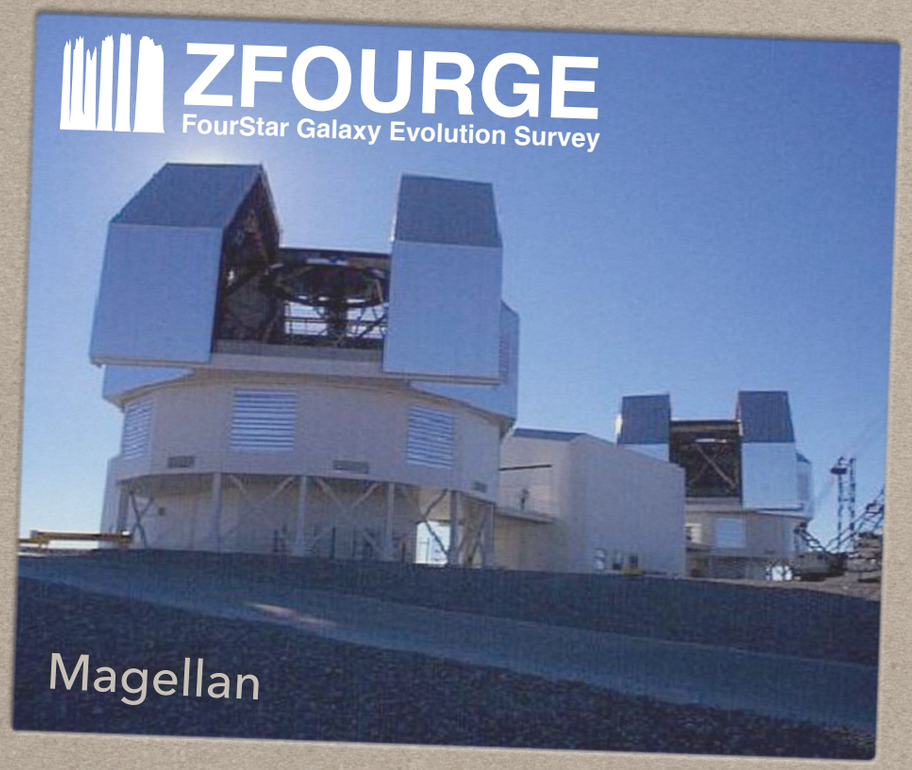
Page+ 2012



Harrison+ 2012a



GOAL: COMPARE STAR FORMATION ACTIVITY IN AGN HOSTS AND NON-AGN



OVERVIEW

- ~50 nights on Magellan/ FourStar near-IR camera
- 5 medium-band filters & Ks broadband
- 3 legacy fields (COSMOS, GOODS-S and UDS)
- Accurate photo-z of ~30,000 galaxies to z = 4
- Primary science to study galaxy formation and evolution at z > 1

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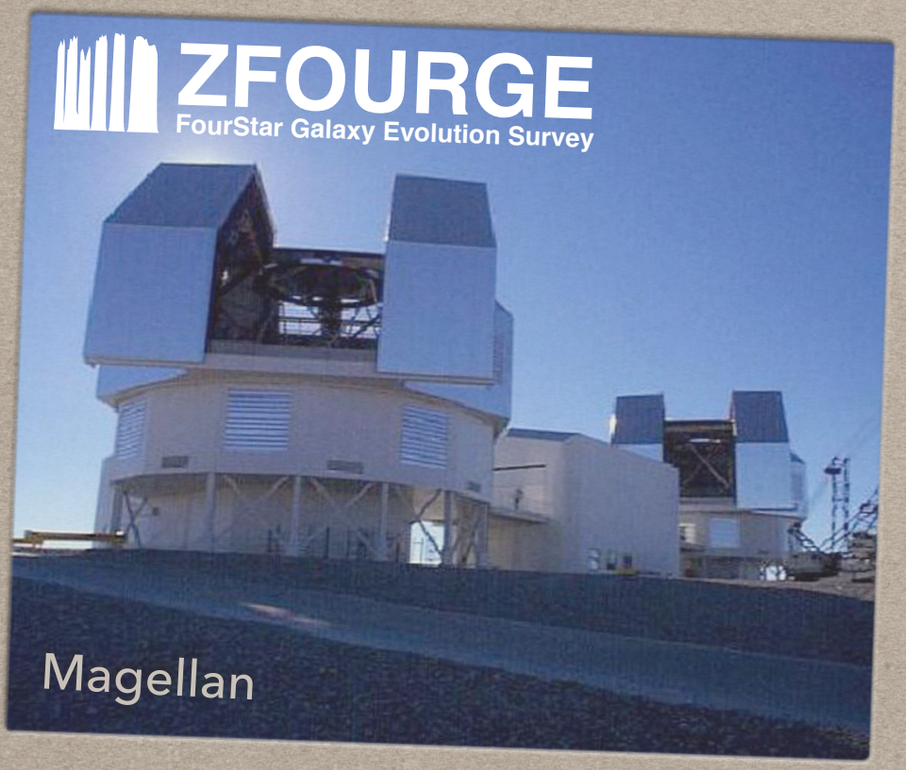

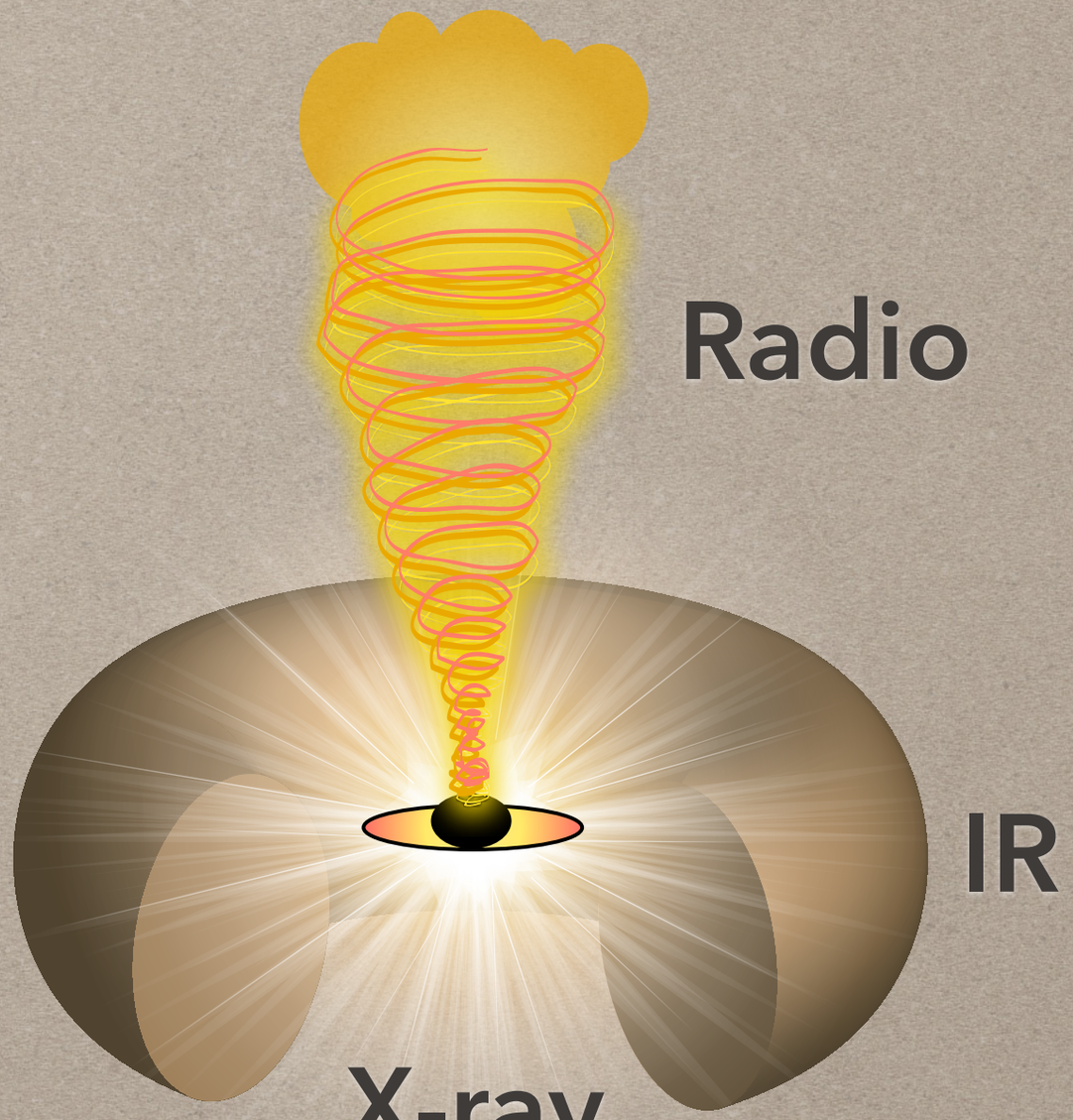

Requires a **multi-wavelength** approach

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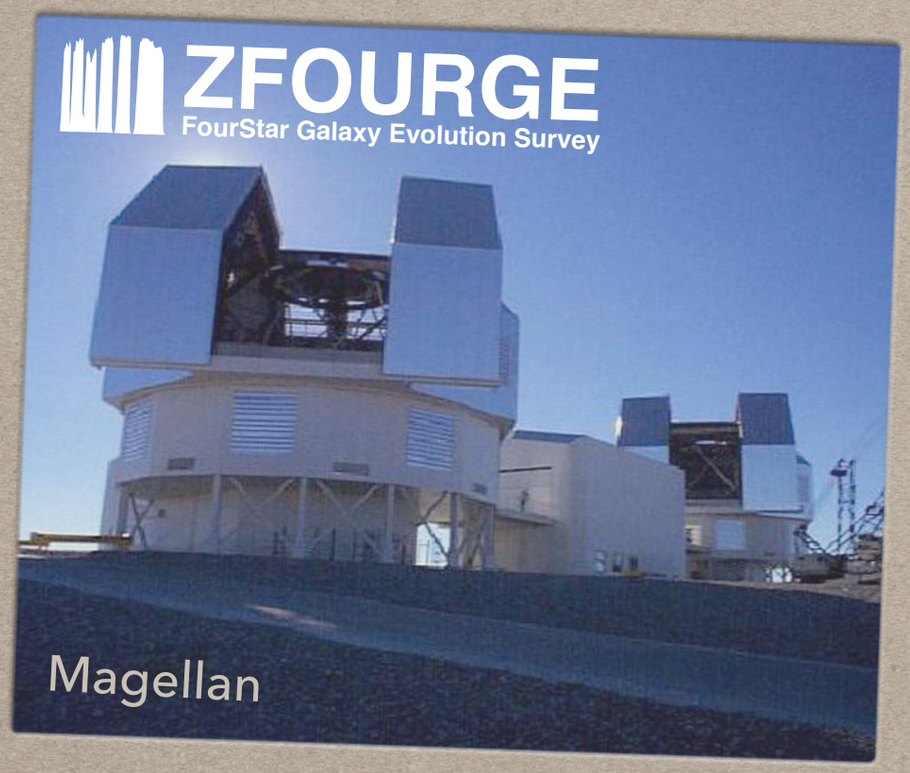
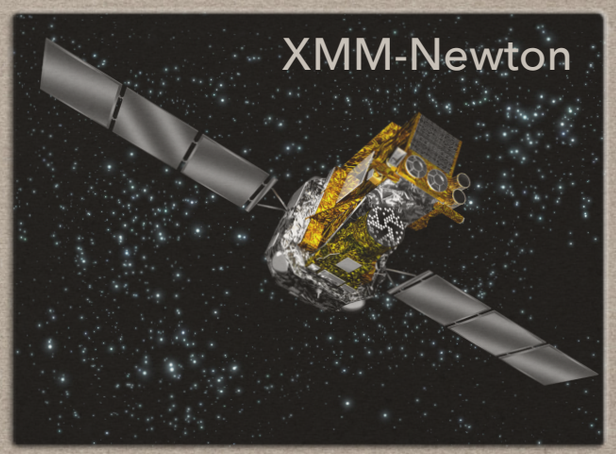




Requires a **multi-wavelength** approach

IDENTIFYING AGN IN ZFOURGE

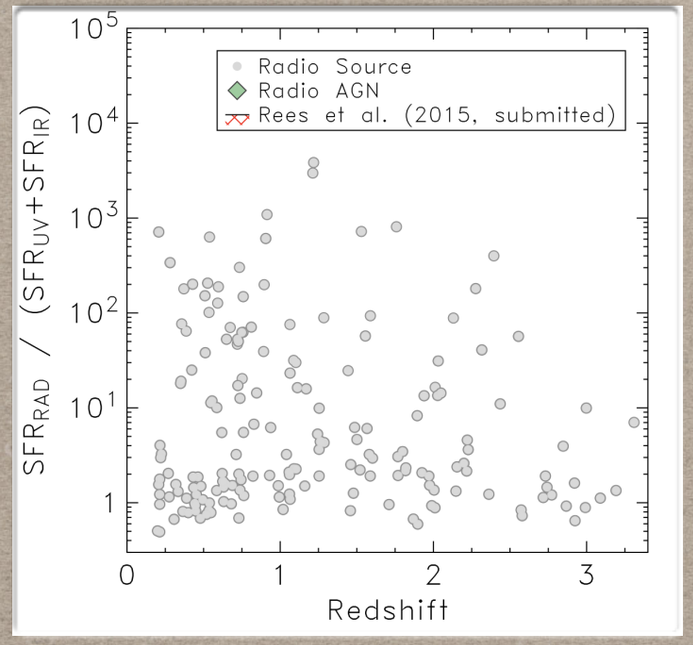
Requires a multi-wavelength approach

A source with excess radio emission is identified as a radio AGN

A source with excess X-ray emission is identified as a X-ray AGN

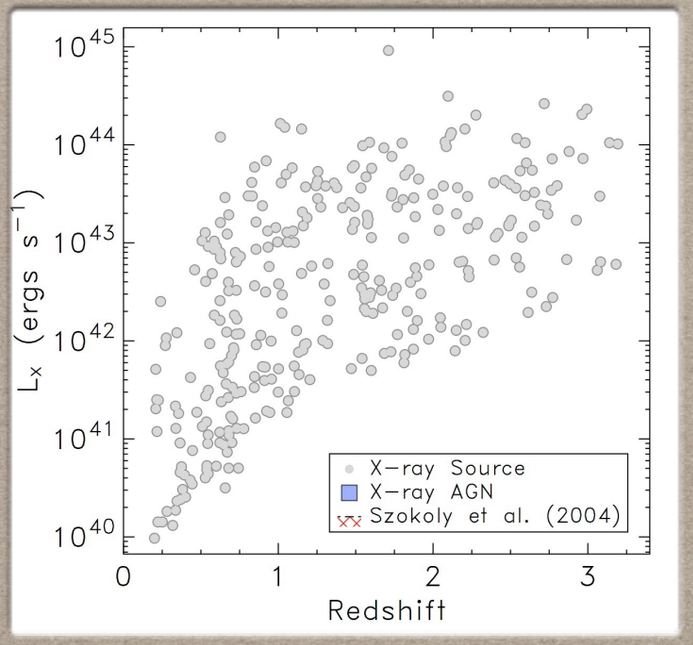
A source in Messias+12 colour space is identified as an infrared AGN

Radio SFR / IR+UV SFR



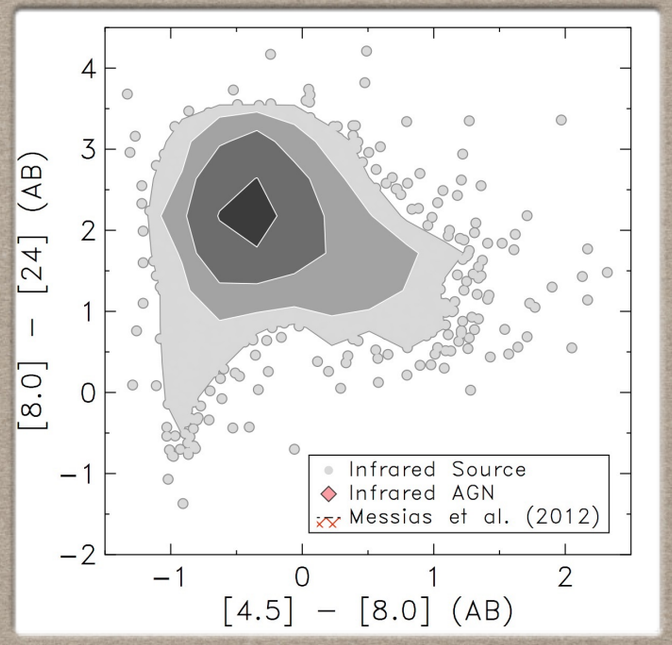
Redshift

X-Ray Luminosity



Redshift

IRAC CH4 - MIPS24



IRAC CH2-CH4

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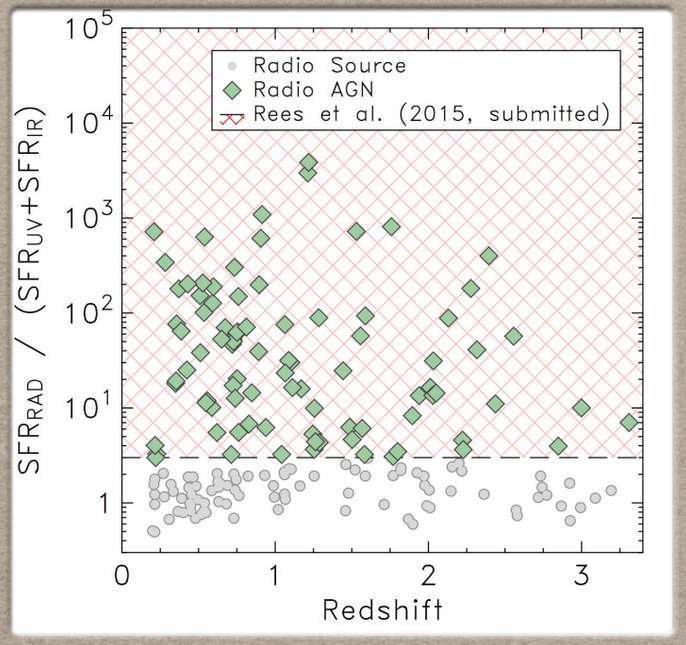

Redshift

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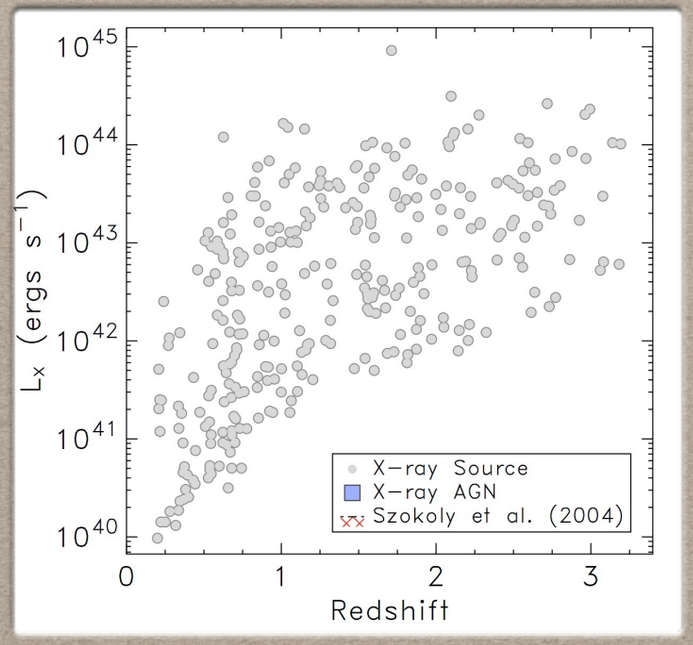

Redshift

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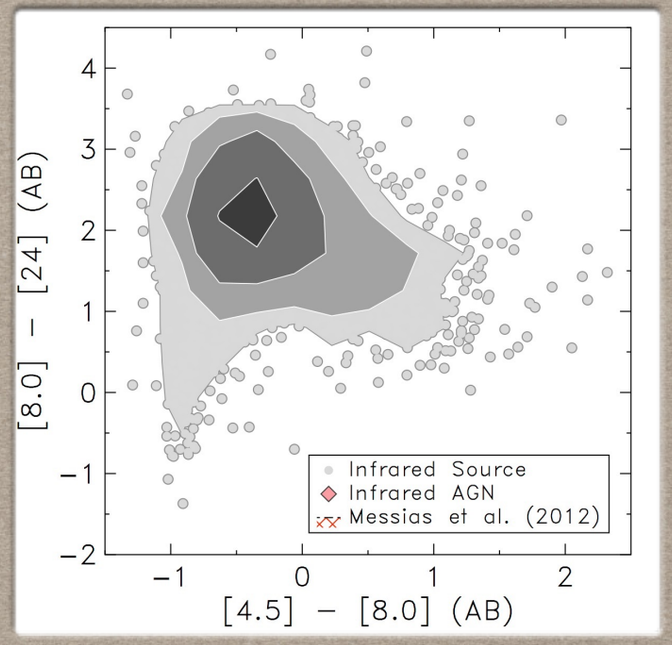

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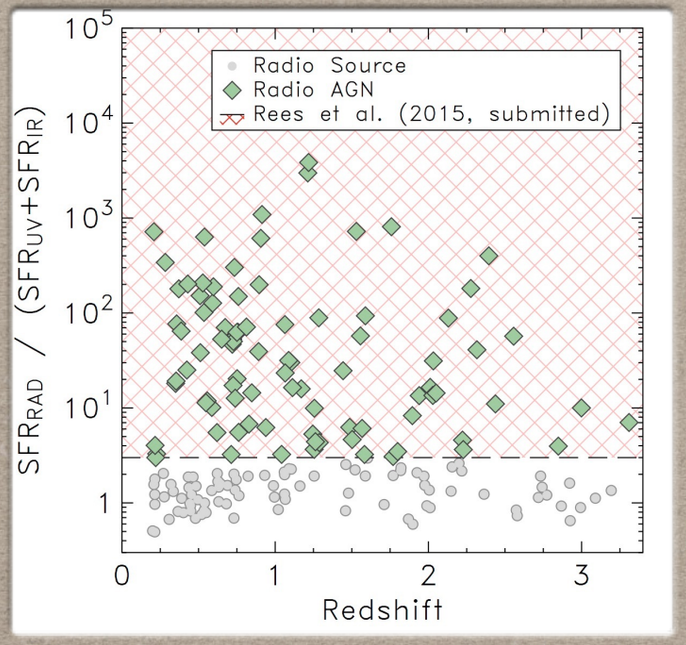
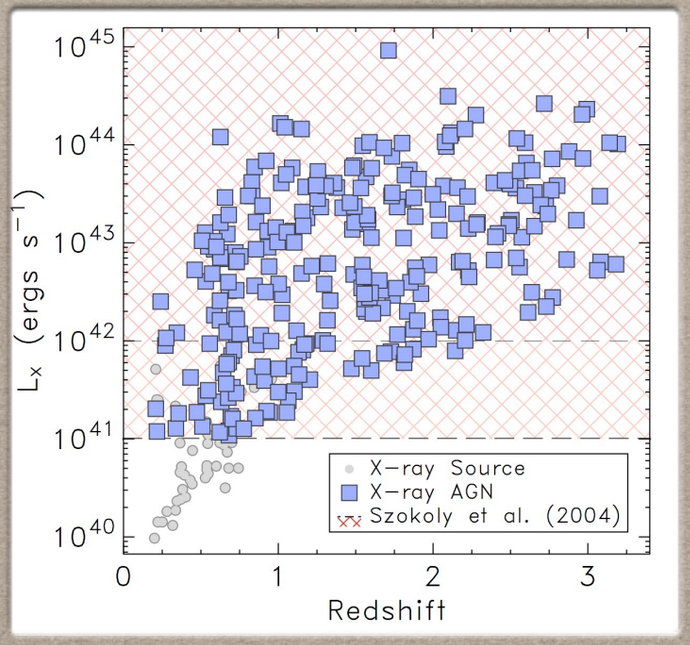


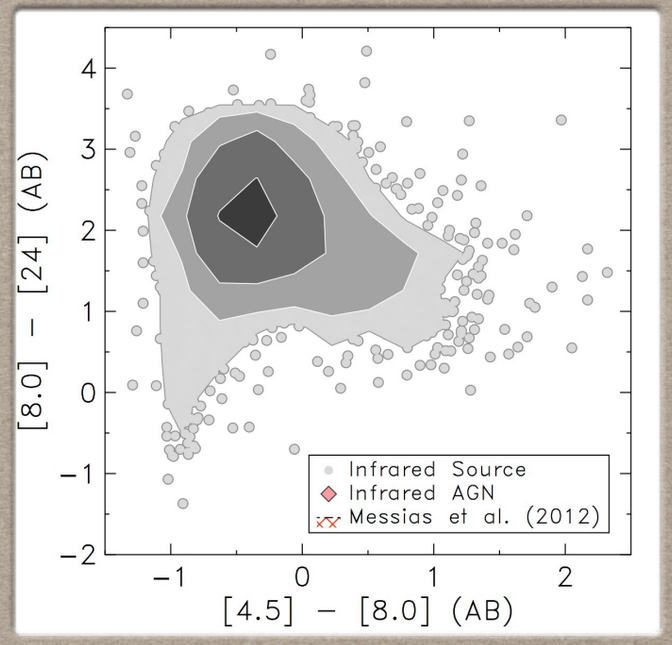
Redshift

X-Ray Luminosity



Redshift

IRAC CH4 - MIPS24



IRAC CH2-CH4

IDENTIFYING AGN IN ZFOURGE

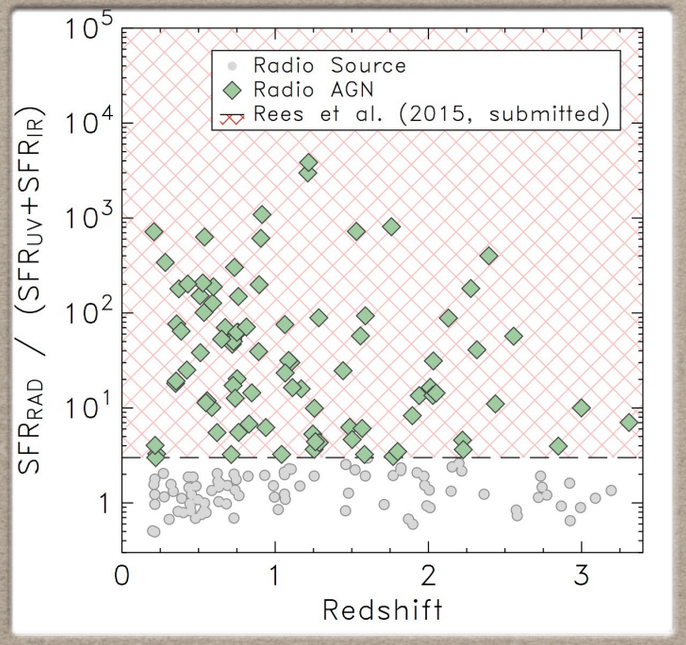
Requires a multi-wavelength approach

A source with excess radio emission is identified as a radio AGN

A source with excess X-ray emission is identified as a X-ray AGN

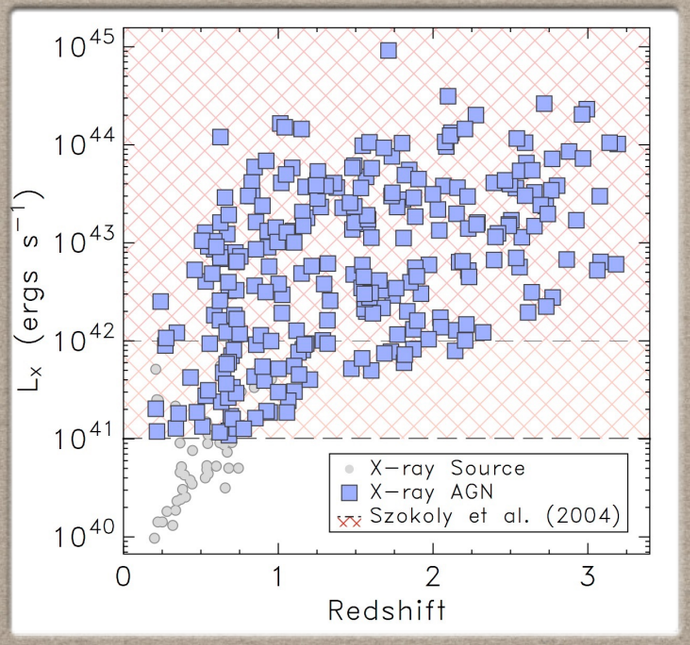
A source in Messias+12 colour space is identified as an infrared AGN

Radio SFR / IR+UV SFR



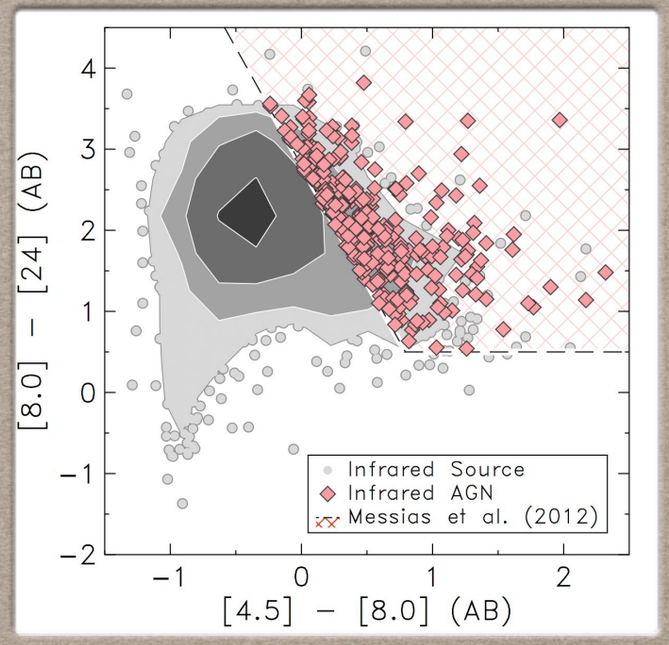
Redshift

X-Ray Luminosity



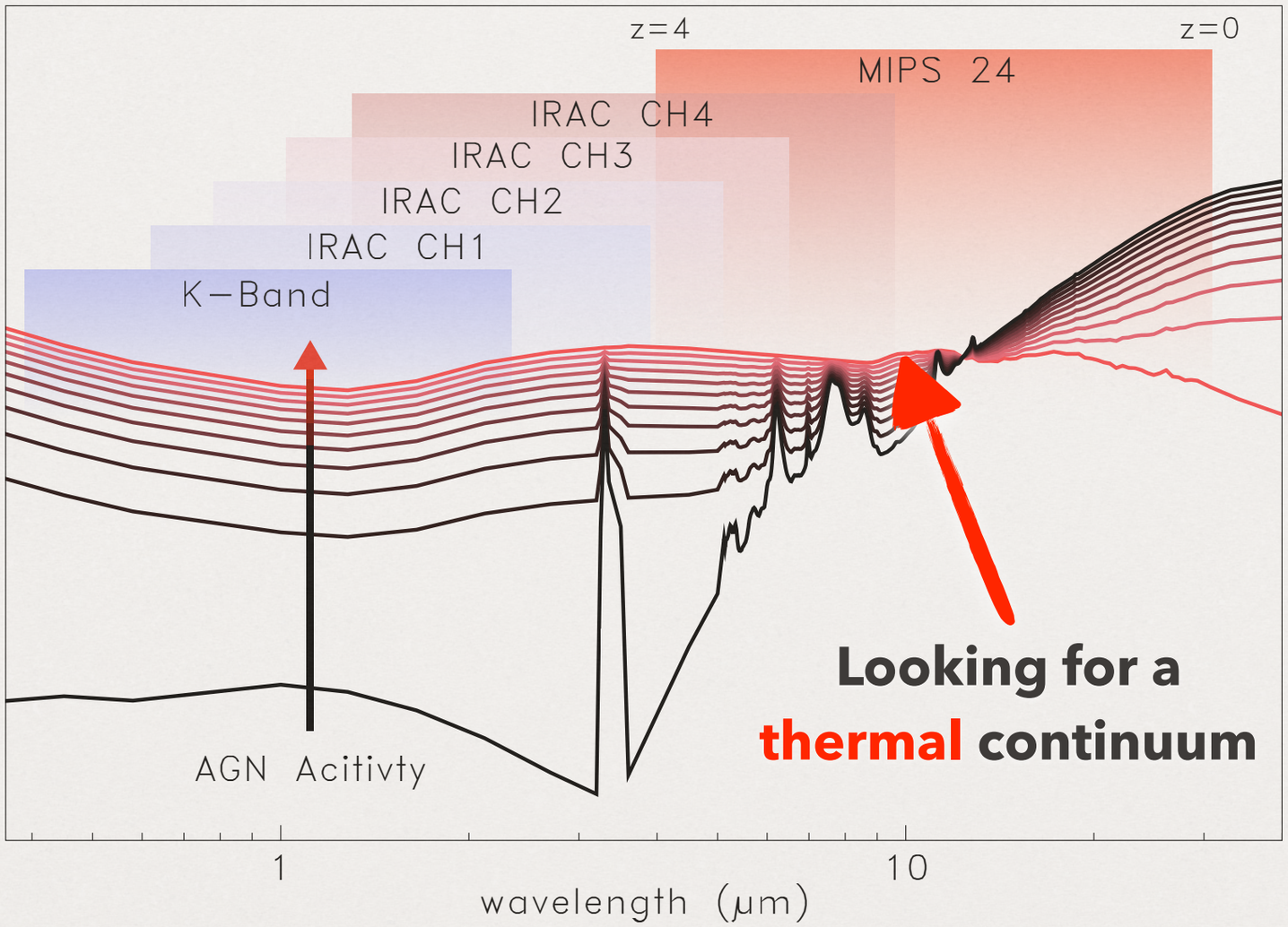
Redshift

IRAC CH4 - MIPS24

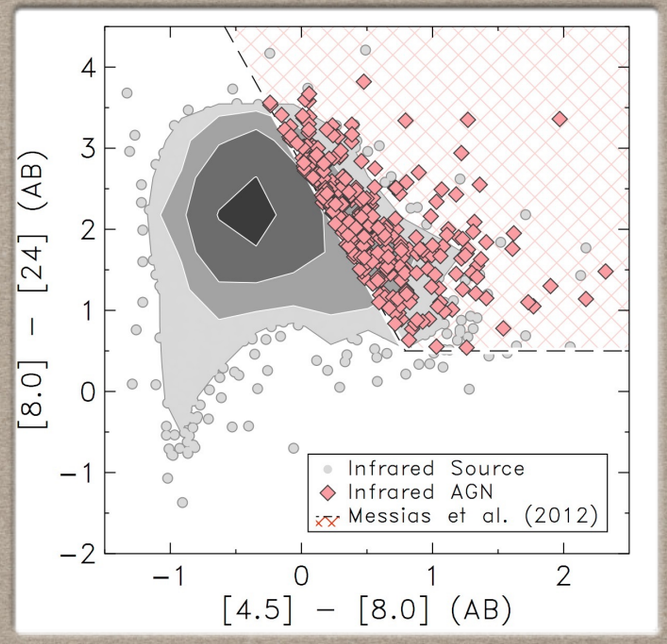


IRAC CH2-CH4

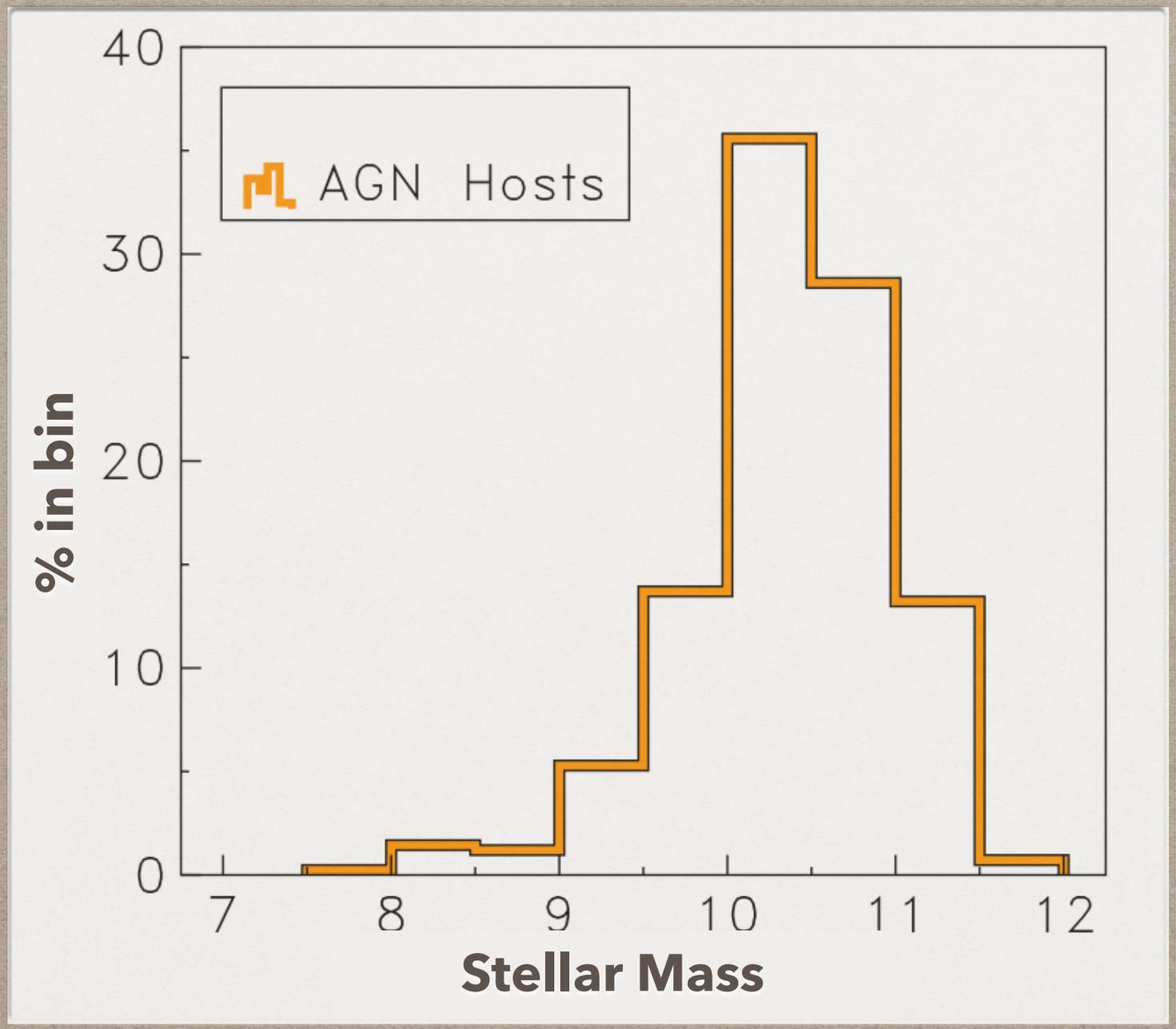
IDENTIFYING INFRARED AGN IN ZFOURGE



A source in Messias+12 colour space is identified as an infrared AGN



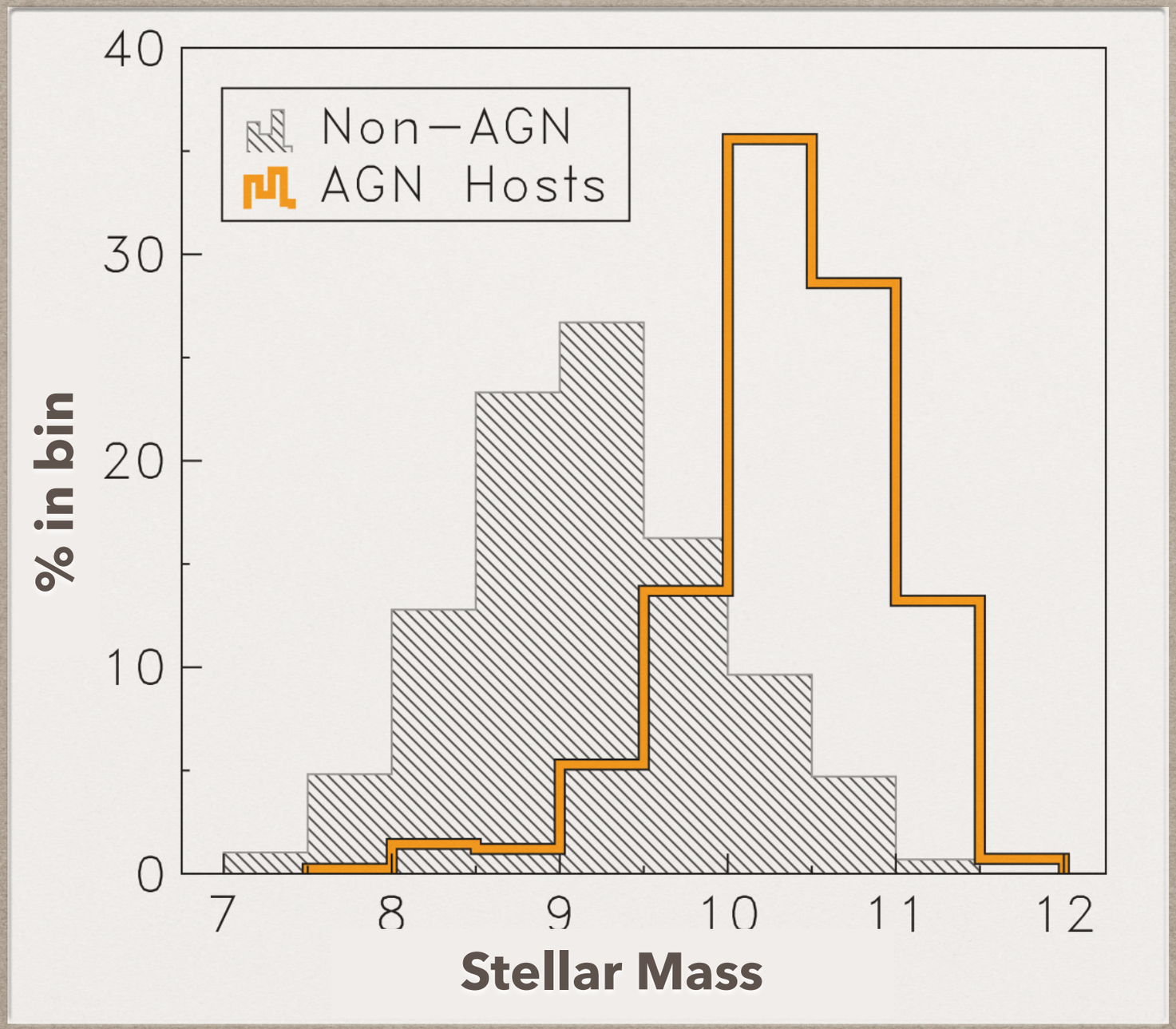
GOAL: COMPARE STAR FORMATION ACTIVITY IN AGN HOSTS AND NON-AGN



AGN are preferentially hosted in galaxies with high stellar mass (e.g., Aird+12)

A galaxy's stellar mass is tightly correlated with its star-formation rate (e.g., Noeske+07)

GOAL: COMPARE STAR FORMATION ACTIVITY IN AGN HOSTS AND NON-AGN



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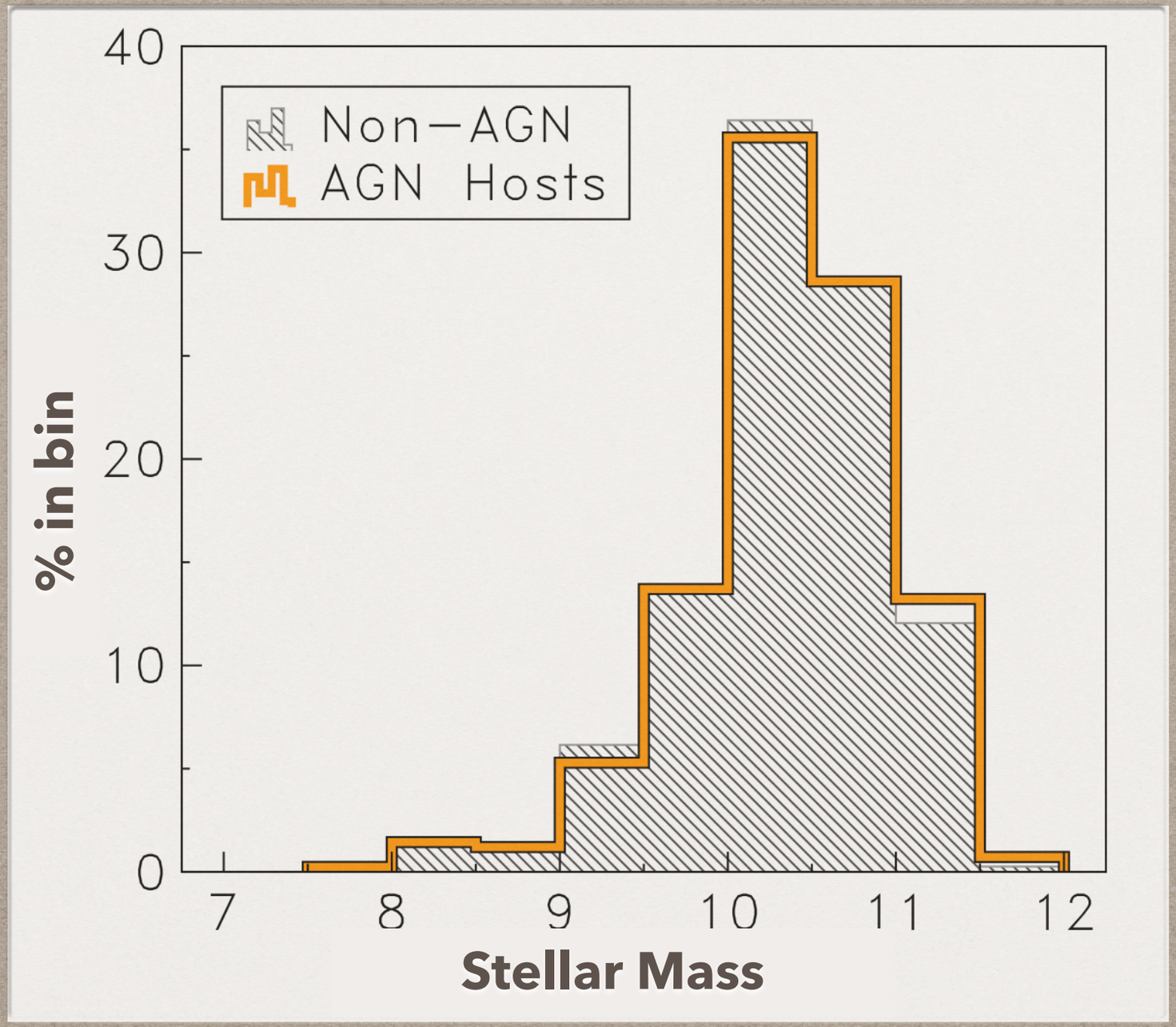
GOAL: COMPARE STAR FORMATION ACTIVITY IN AGN HOSTS AND NON-AGN ...OF SIMILAR MASS



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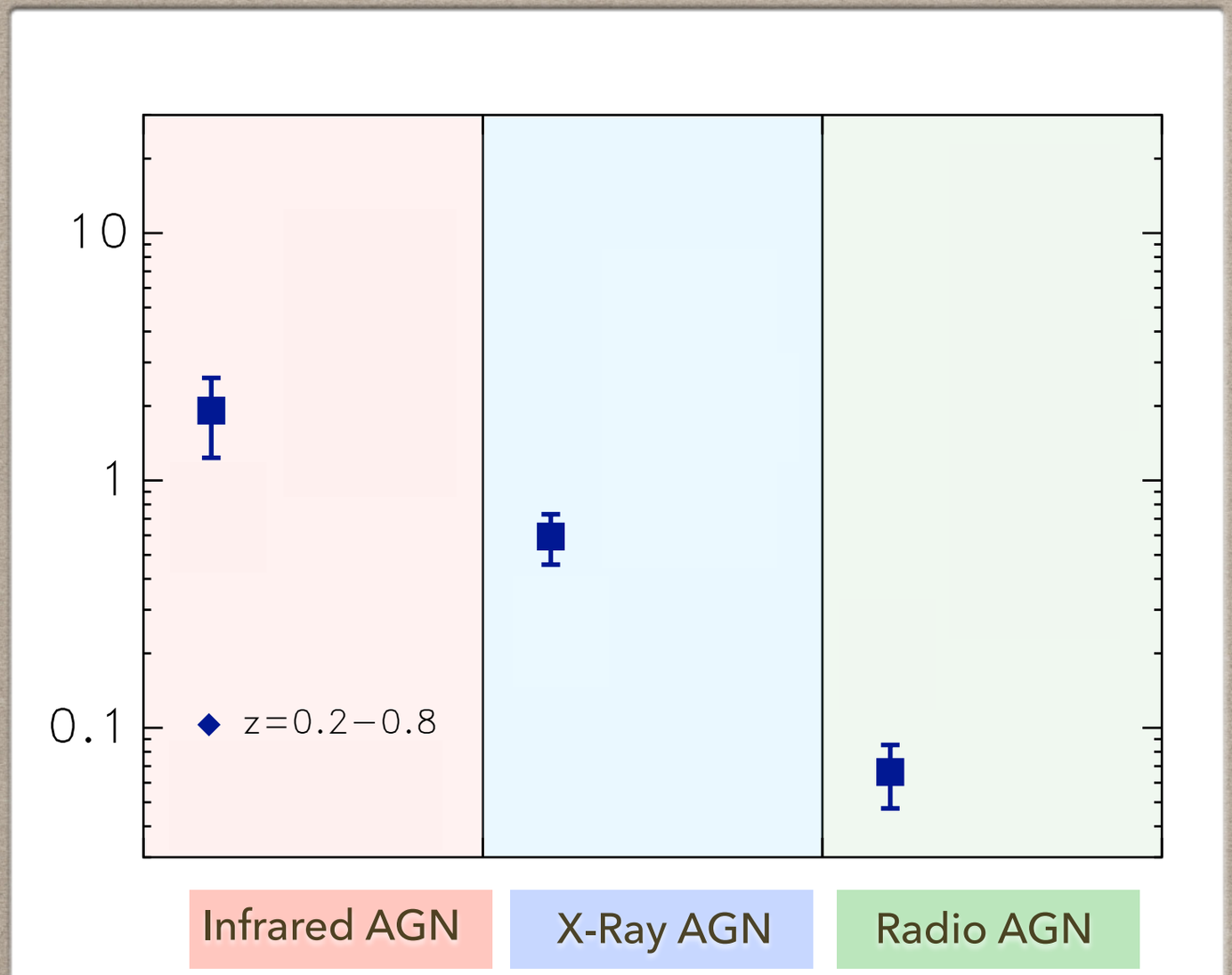
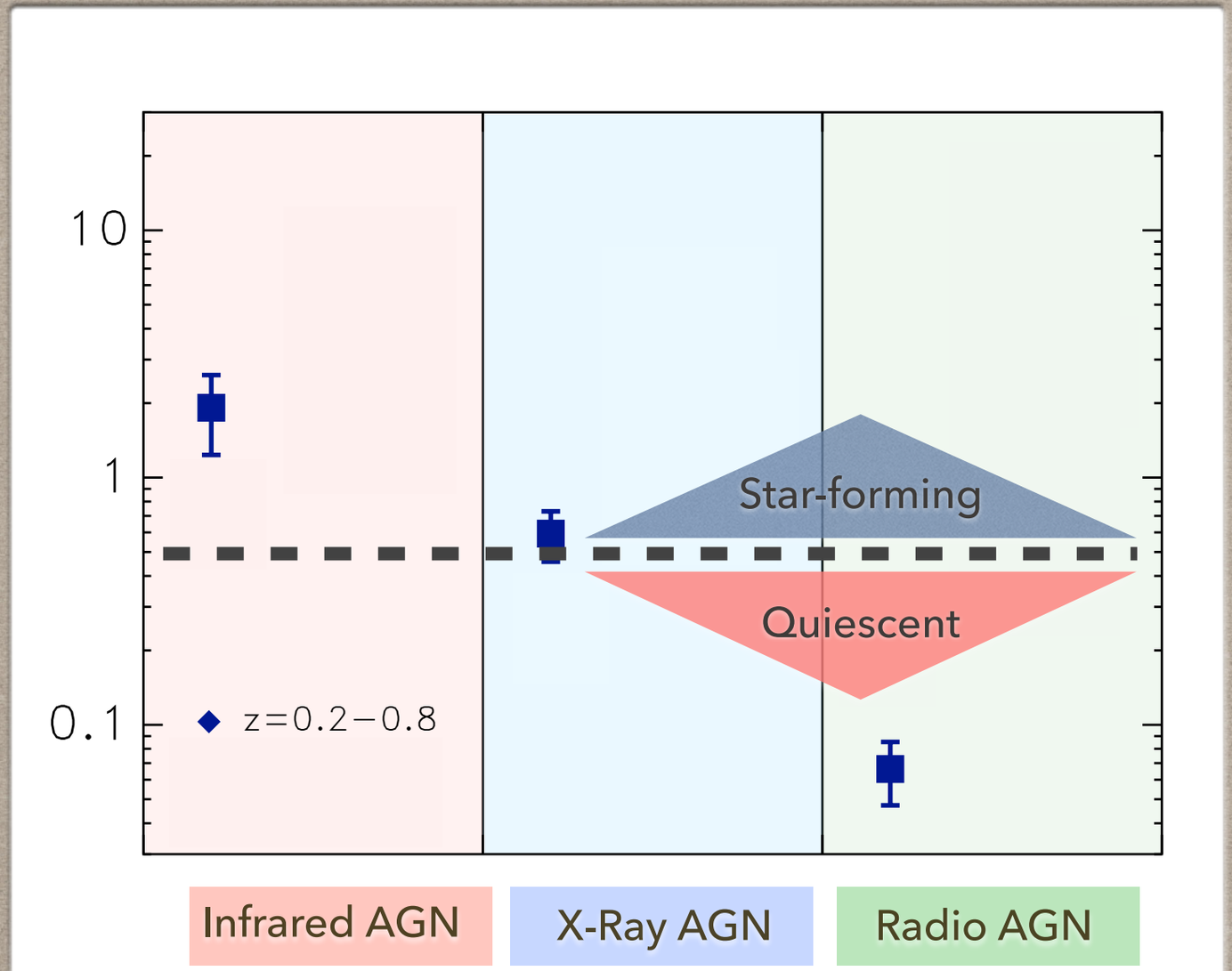
STAR FORMATION ACTIVITY OF LOW-Z AGN HOSTS



STAR FORMATION ACTIVITY OF LOW-Z AGN HOSTS



Infrared AGN

Star forming hosts

X-Ray AGN

Straddles between star-forming and quiescent

Radio AGN

Quiescent hosts

STAR FORMATION ACTIVITY OF LOW-Z AGN HOSTS

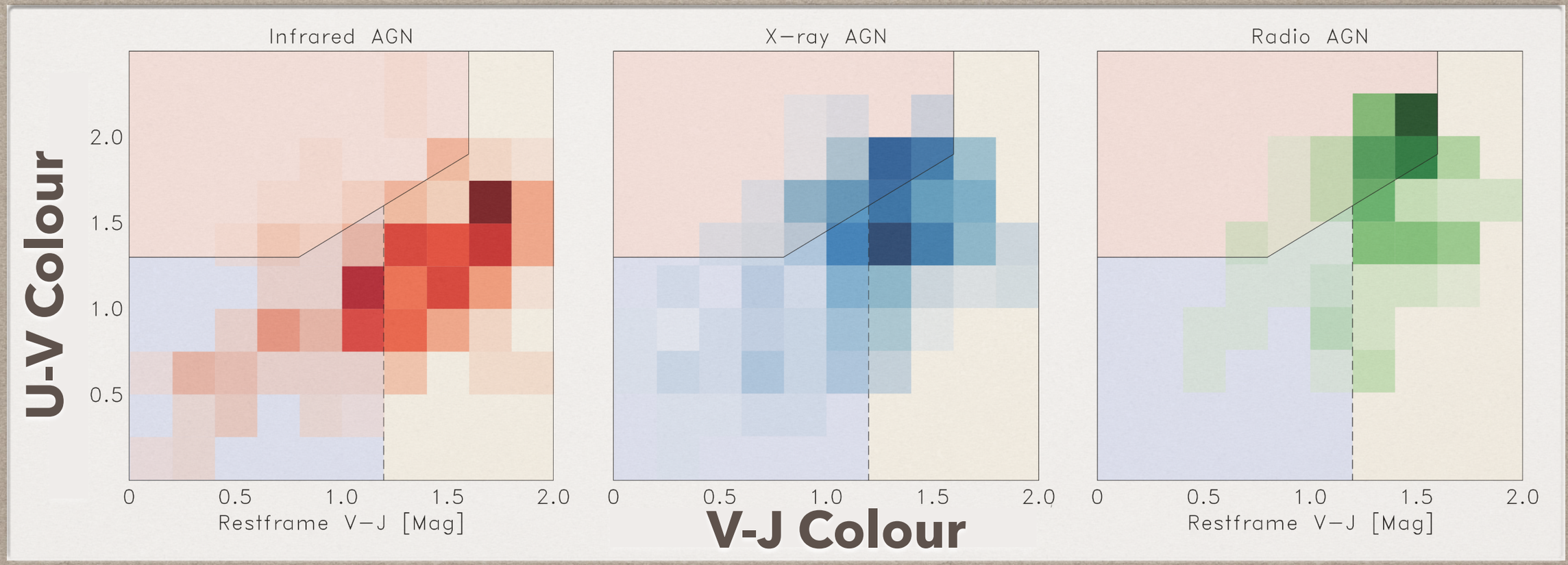
Infrared AGN	X-Ray AGN	Radio AGN
		
Star forming hosts	Straddles between star forming and quiescent	Quiescent hosts

U-V vs V-J COLOURS OF AGN HOSTS

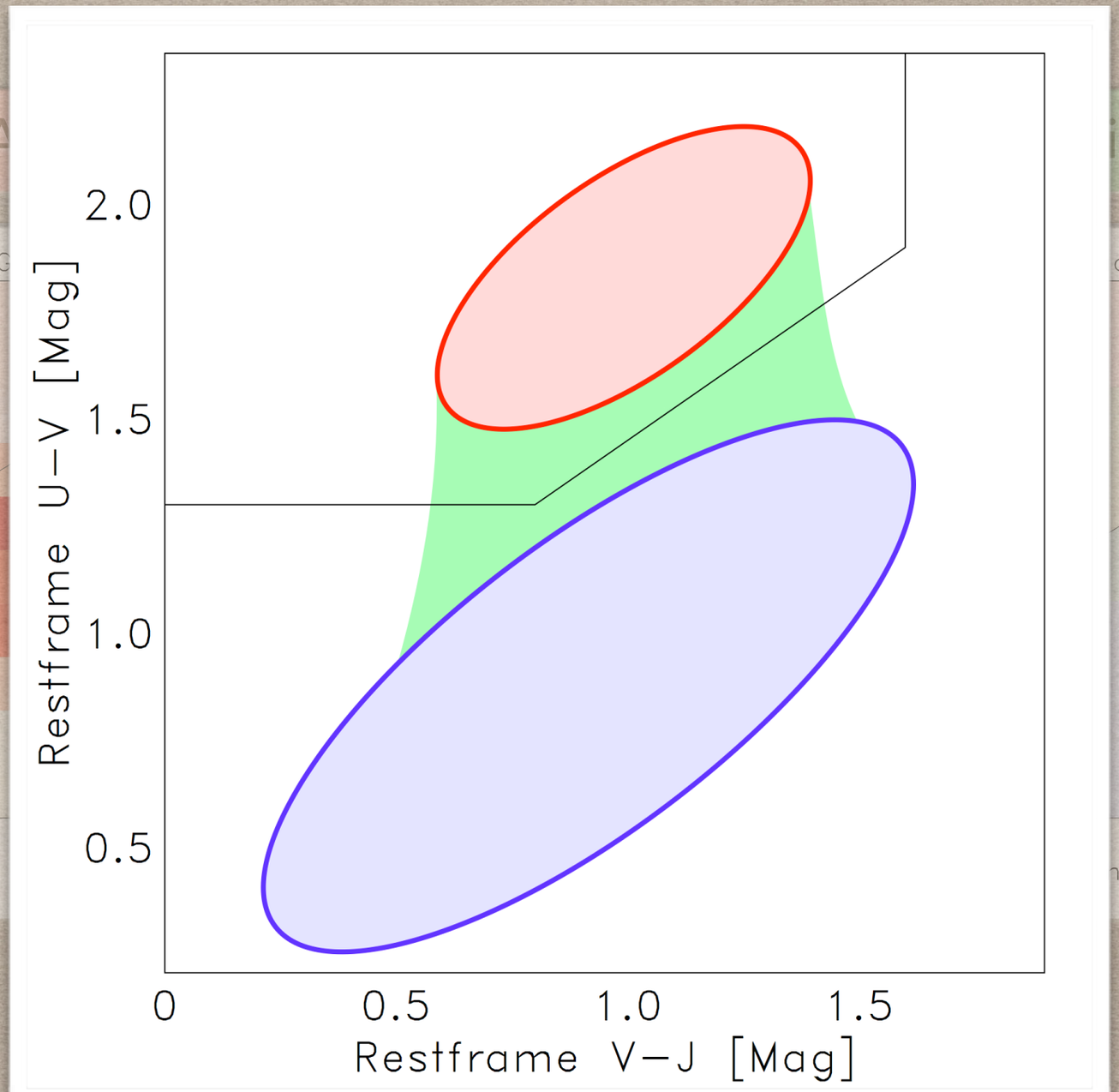
Infrared AGN

X-Ray AGN

Radio AGN



U-V vs V-J COLOURS OF AGN HOSTS

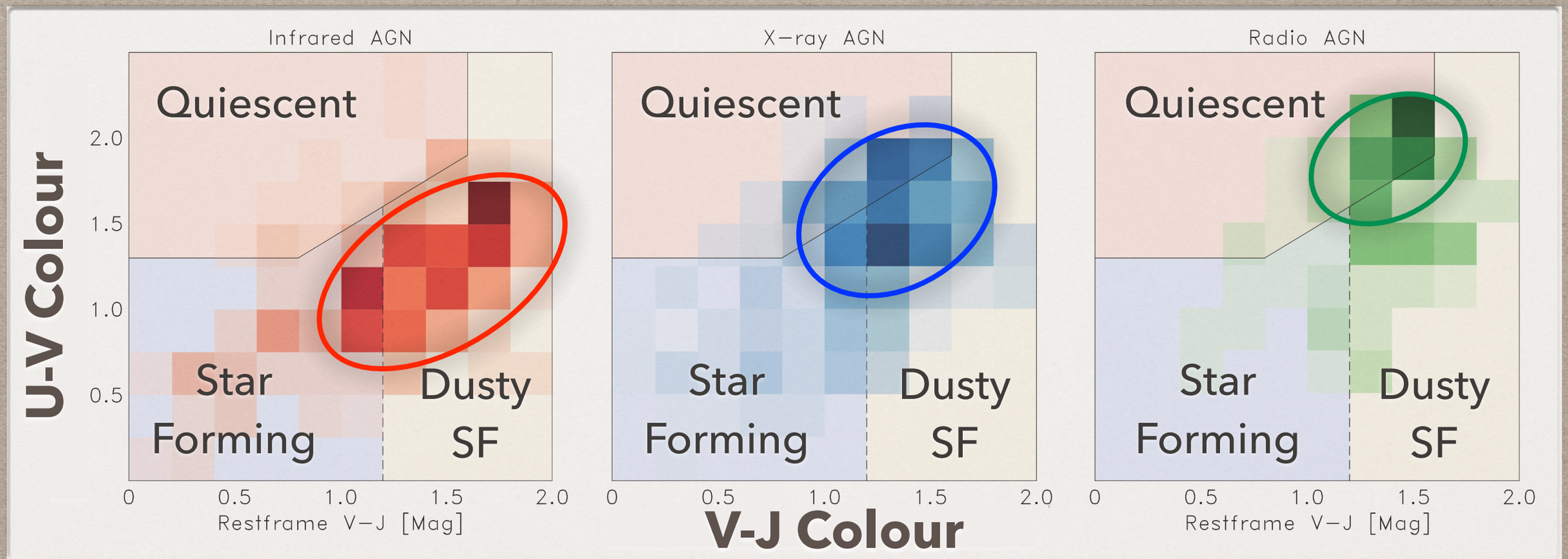


U-V vs V-J COLOURS OF AGN HOSTS

Infrared AGN

X-Ray AGN

Radio AGN

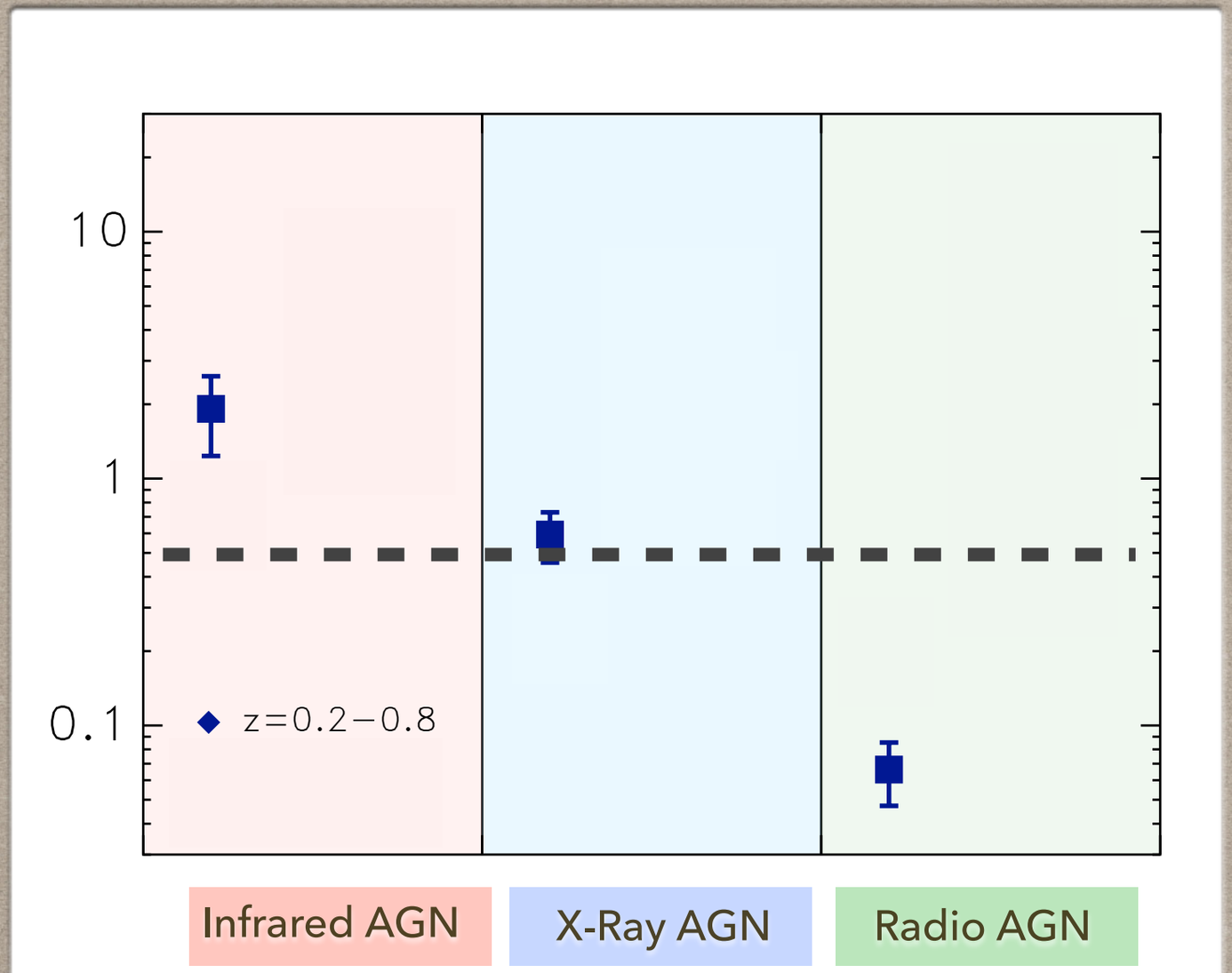


Star forming hosts

Straddles between star forming and quiescent

Quiescent hosts

STAR FORMATION ACTIVITY OF LOW-Z AGN HOSTS



Infrared AGN

Star forming hosts

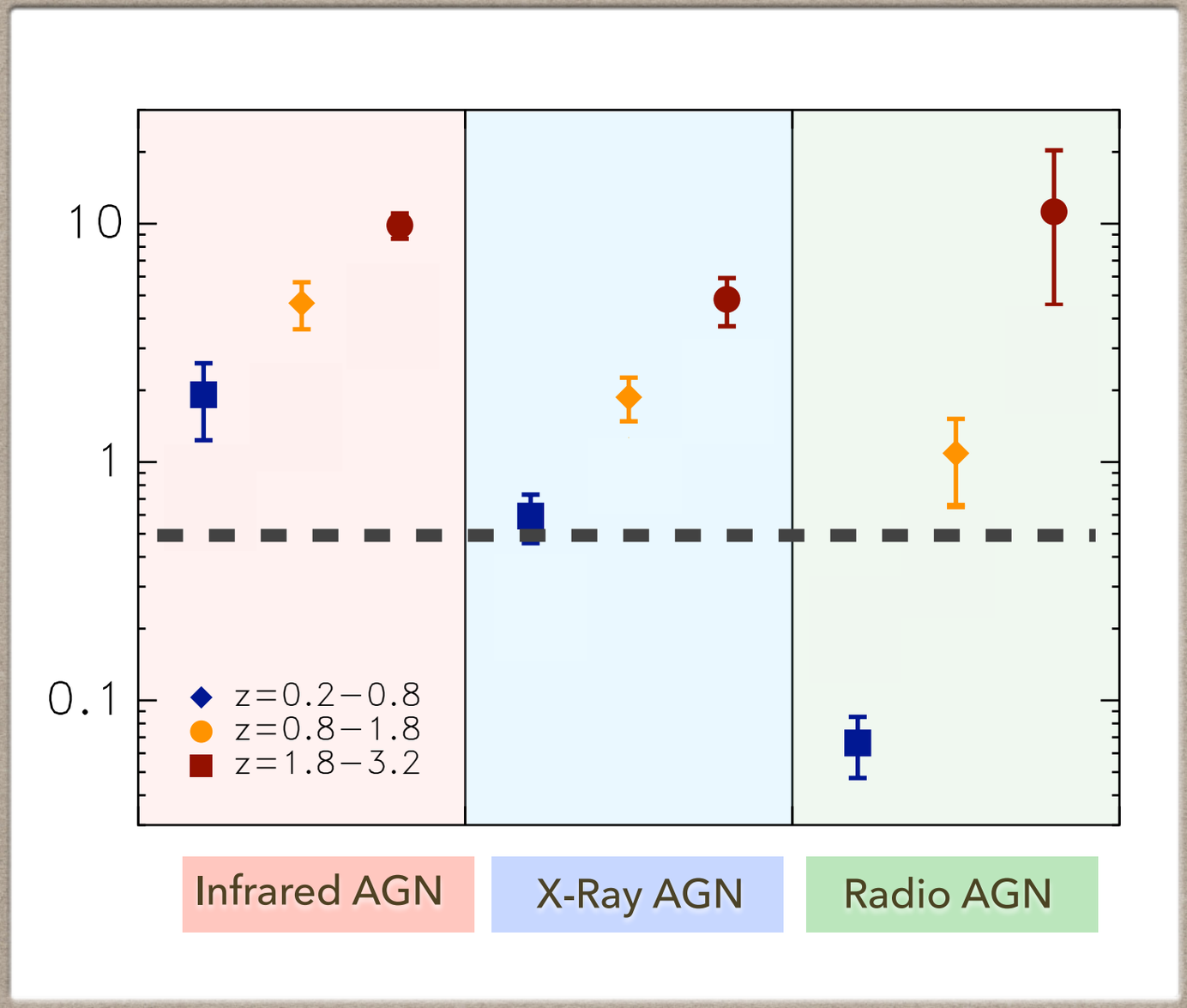
X-Ray AGN

Straddles between star-forming and quiescent

Radio AGN

Quiescent hosts

STAR FORMATION ACTIVITY OF HIGH-Z AGN HOSTS



Infrared AGN

Star forming hosts

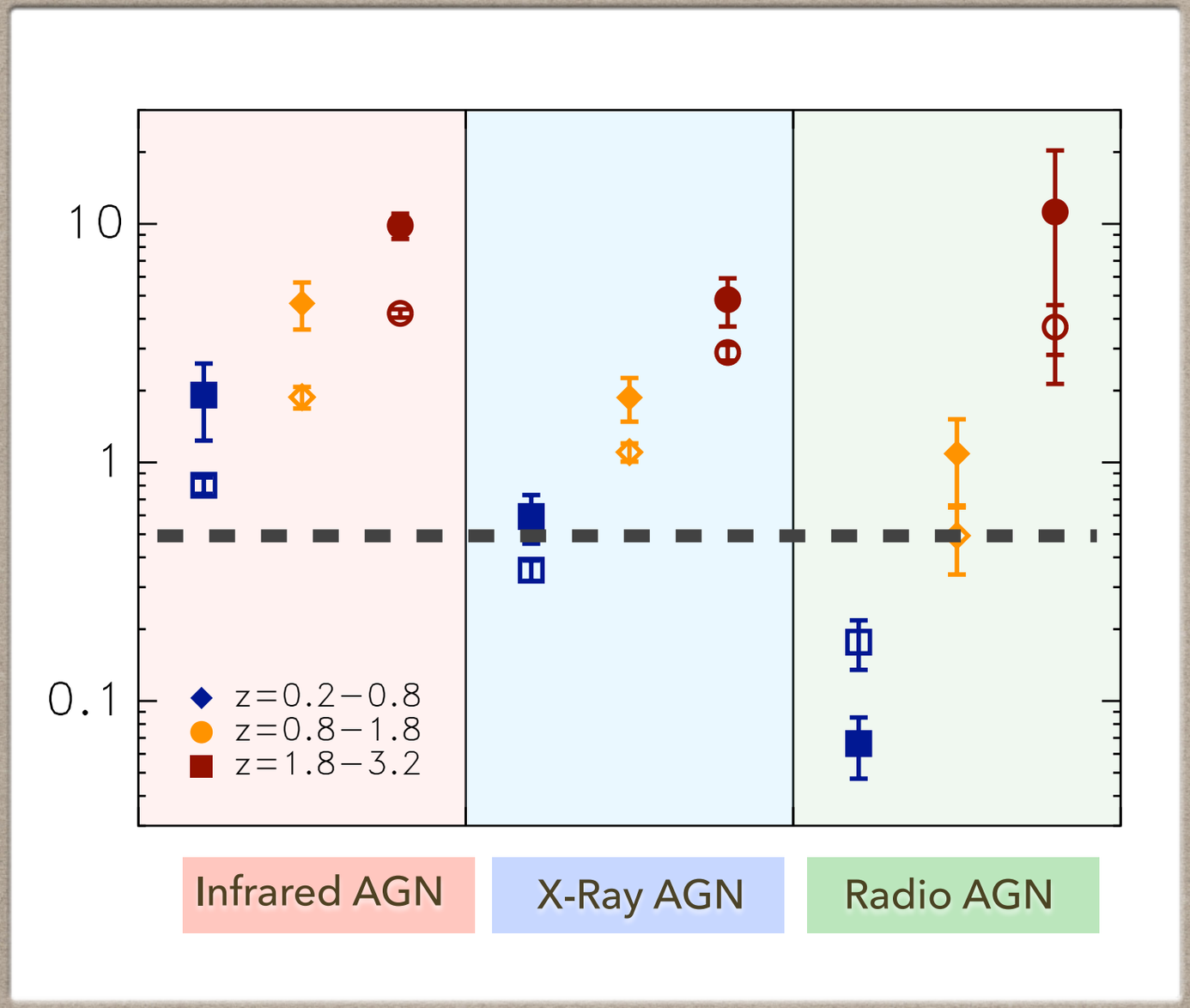
X-Ray AGN

Star forming hosts

Radio AGN

Star forming hosts

STAR FORMATION ACTIVITY OF AGN HOSTS AND NON-AGN



Infrared AGN

Star forming hosts

X-Ray AGN

Star forming hosts

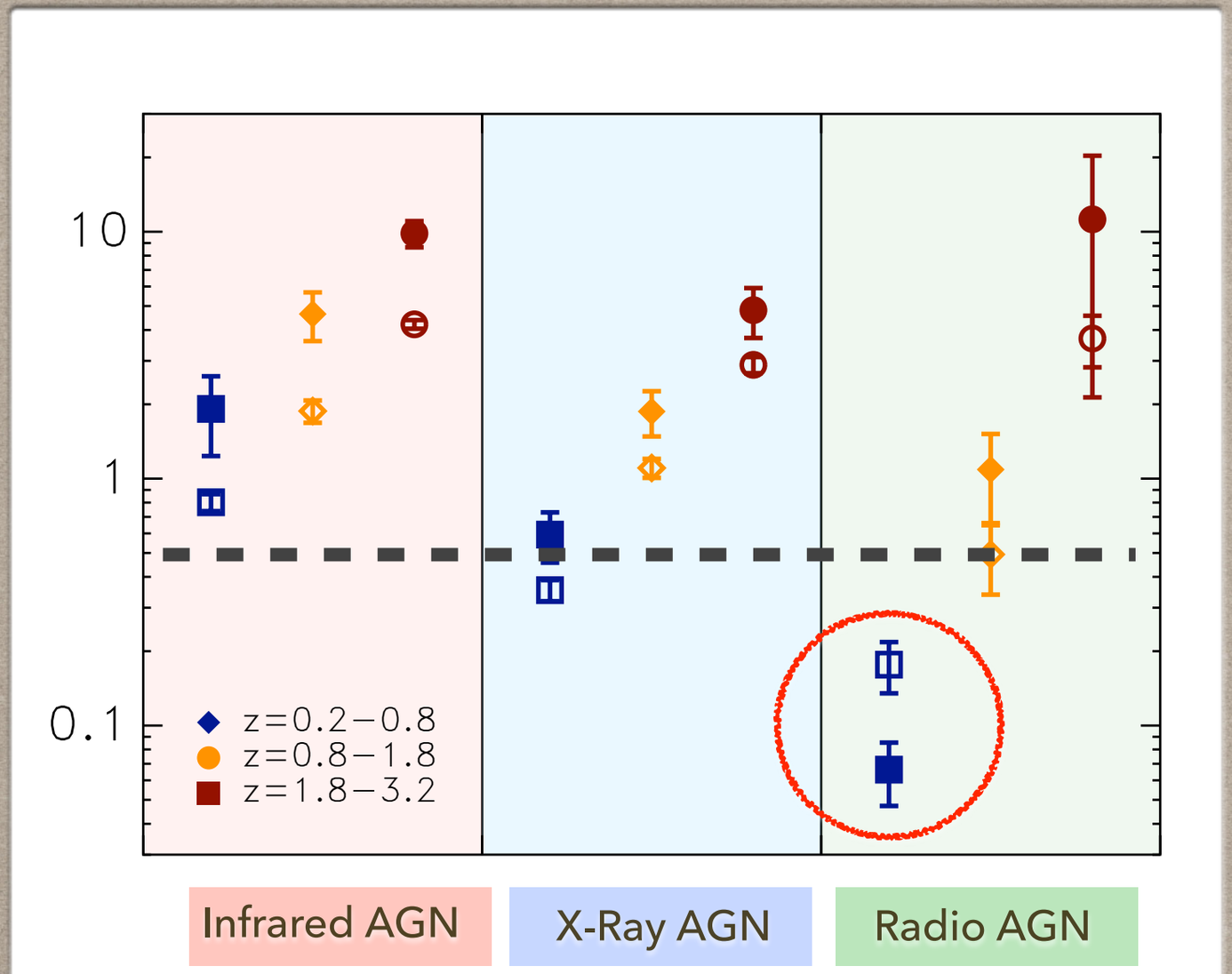
Radio AGN

Star forming hosts

Non-AGN

Lower SF activity than AGN

STAR FORMATION ACTIVITY OF AGN HOSTS AND NON-AGN



Infrared AGN

Star forming hosts

X-Ray AGN

Star forming hosts

Radio AGN

Star forming hosts

Non-AGN

Lower SF activity than AGN

AGN FEEDBACK

Radiatively Efficient or
"quasar mode"

- radiation in the IR/optical/UV/X-rays
- mildly relativistic accretion disk winds
- collimated relativistic jets

Radiatively Inefficient or
"radio mode"

SUMMARY

- AGN Taxonomy is confusing
- The relative importance of quasar-mode feedback remains unclear
- Radio-mode AGN feedback is a likely candidate for quenching, but…
- There's no **direct** evidence for AGN quenching star-formation