INVESTIGATING THE CO-EVOLUTION OF SUPERMASSIVE BLACK HOLES AND THEIR HOST GALAXIES

ZFOURGE
FourStar Galaxy Evolution Survey

MICHAEL COWLEY

MACQUARIE University
SYDNEY·AUSTRALIA

Australian Government
Department of Industry and Science

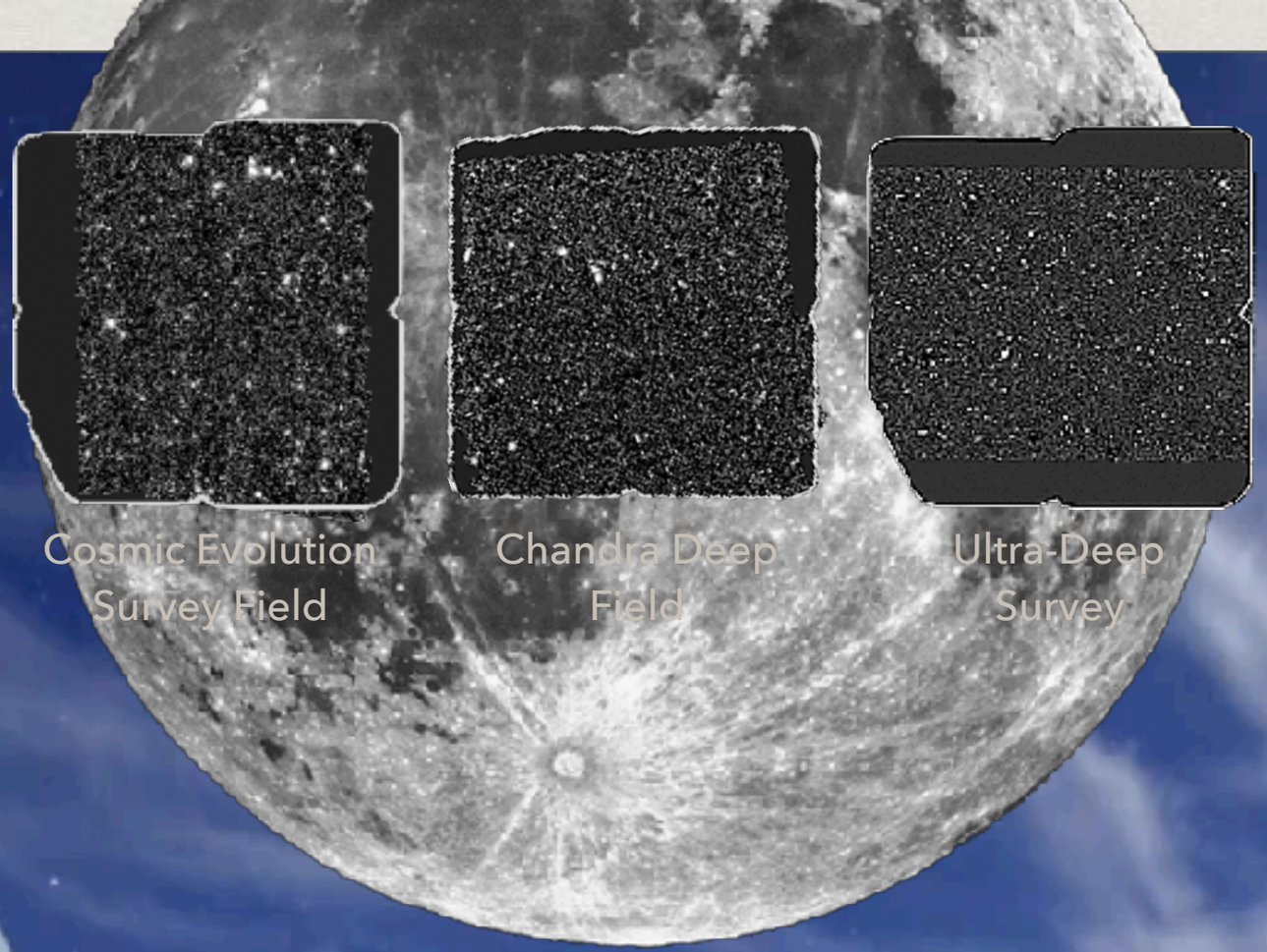
AAO

Northern Sydney Astronomical Society, August 16th 2016

NGC 1672: NASA, ESA and the Hubble Heritage Team

ZFOURGE

FourStar Galaxy Evolution Survey



What:

- ~50 nights on Magellan/
- FourStar near-IR camera
- 5 medium-band filters
- Ks broadband (NIR @ 2.2μm)

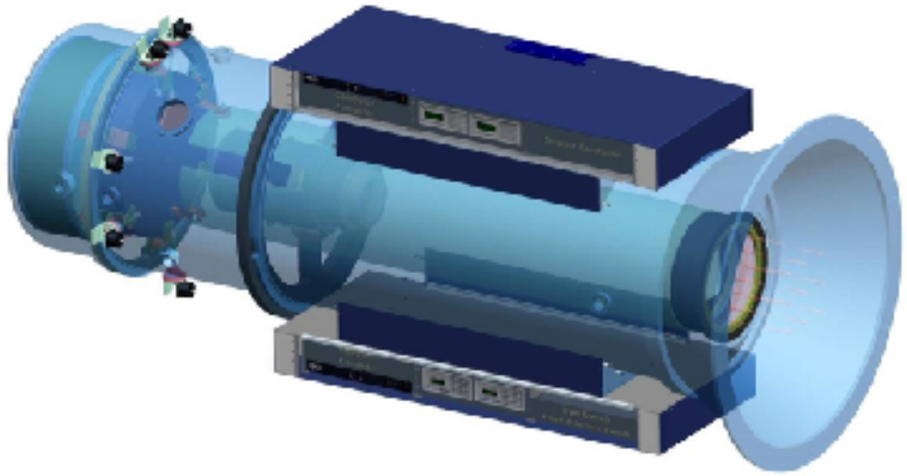
Primary goal:

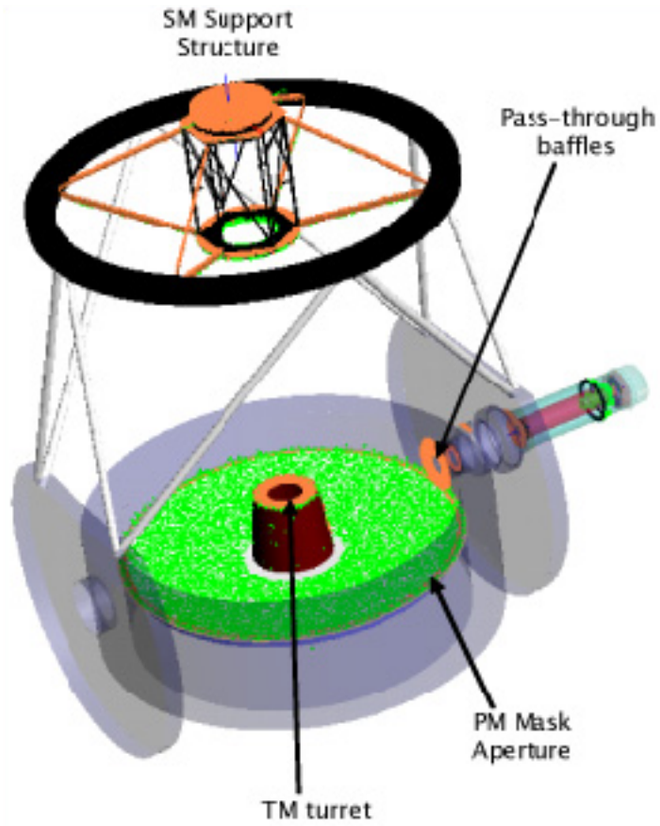
- Accurate photometric redshift of ~60,000 galaxies
- Study galaxy formation and evolution at high redshift

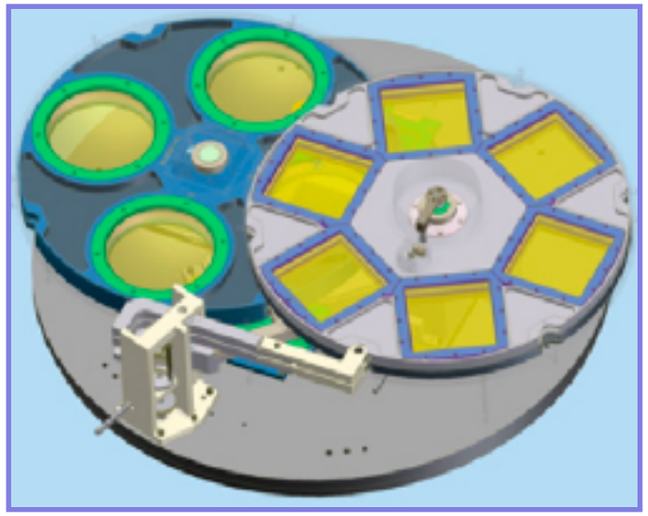
3 legacy fields

- COSMOS, GOODS-S, UDS
- 11’ x 11’ field of view

FOURSTAR

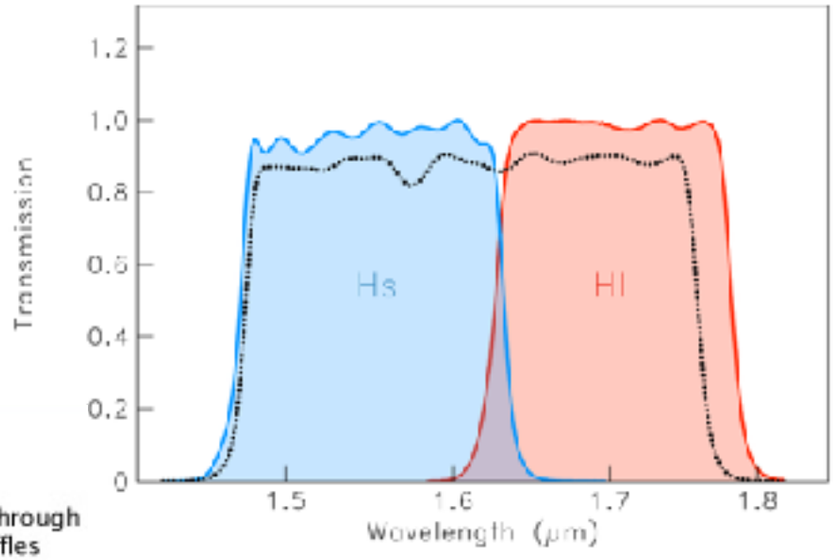


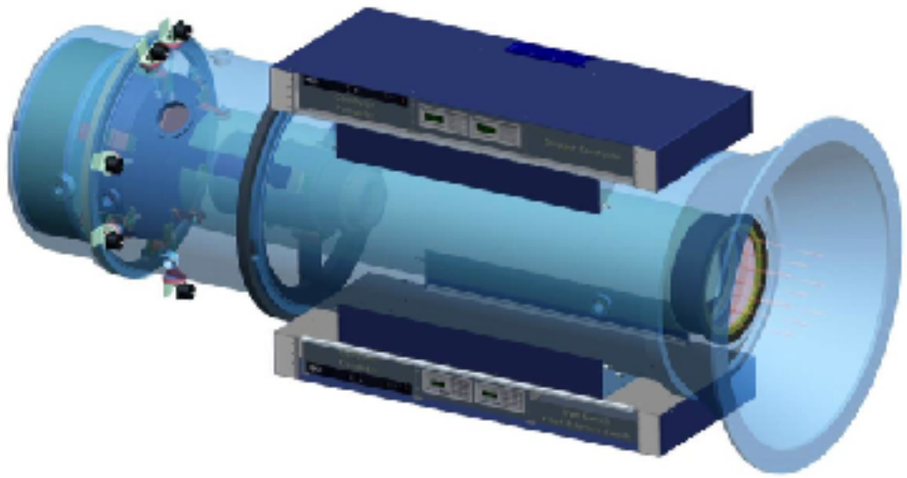


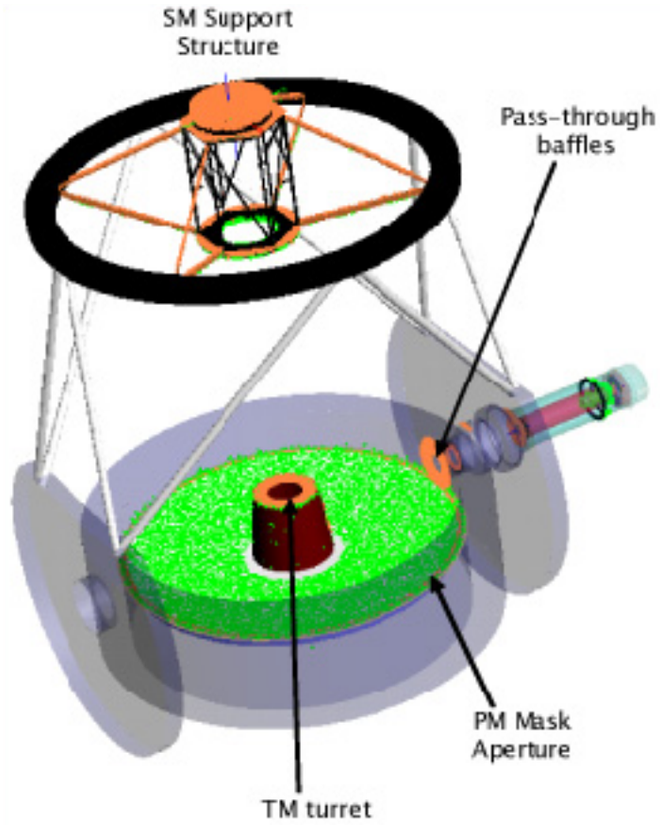


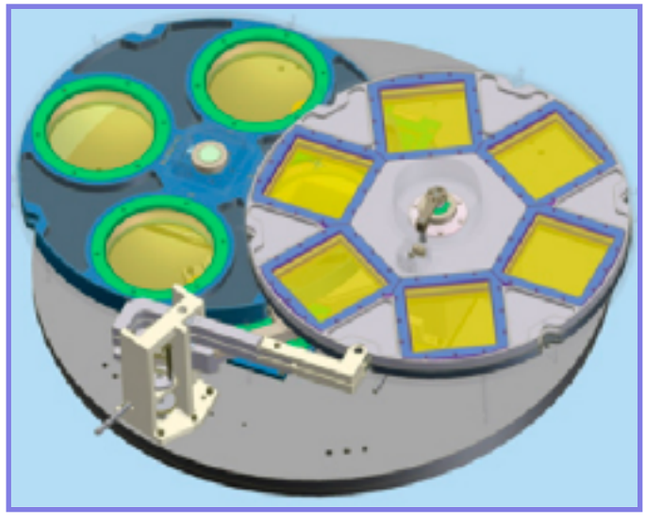
The Four Star infrared camera is a 1-2.5 micron near infrared camera for the Magellan Baade Telescope. The instrument utilises four imaging arrays in a close-packed arrangement to achieve a 4096 X 4096 equivalent pixel imaging area. The projected field size on the sky is 11' X 11'.

FOURSTAR



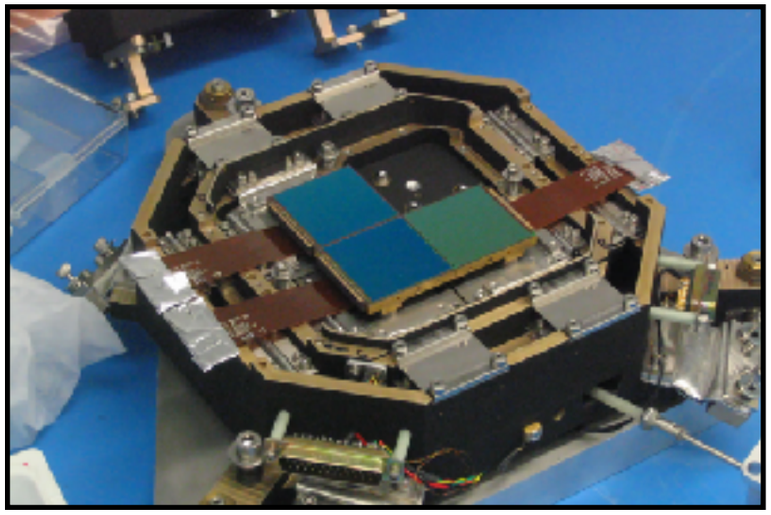




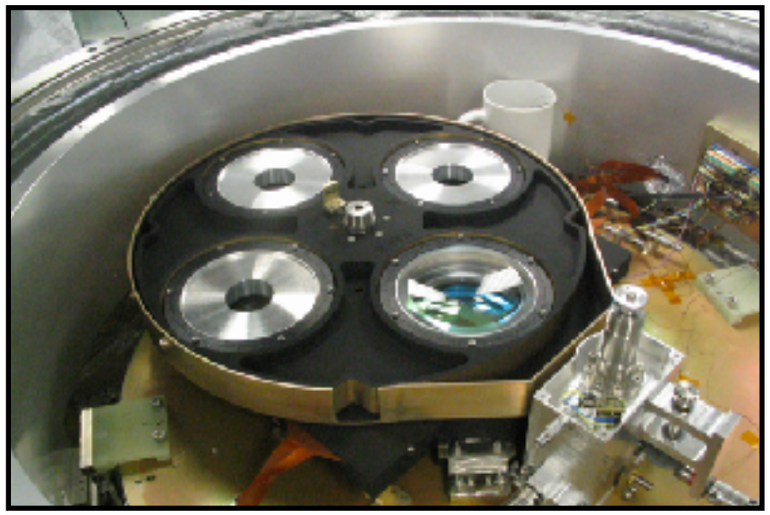


The Four Star infrared camera is a 1-2.5 micron near infrared camera for the Magellan Baade Telescope. The instrument utilises four imaging arrays in a close-packed arrangement to achieve a 4096 X 4096 equivalent pixel imaging area. The projected field size on the sky is 11' X 11'.

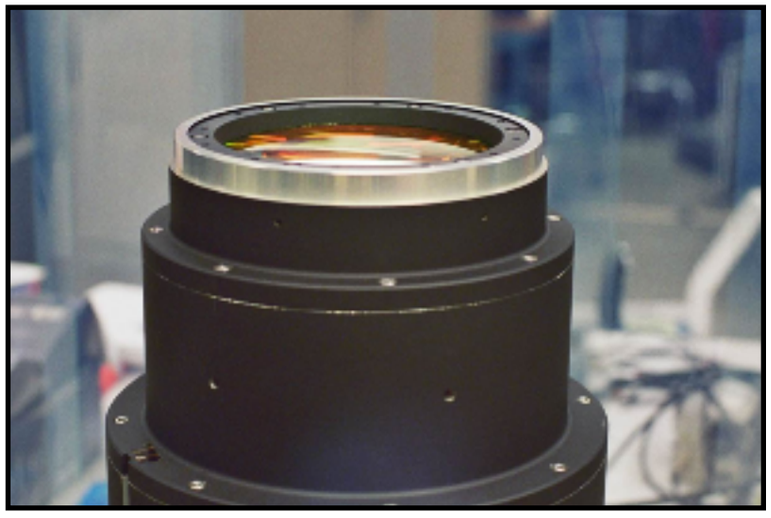
FOURSTAR



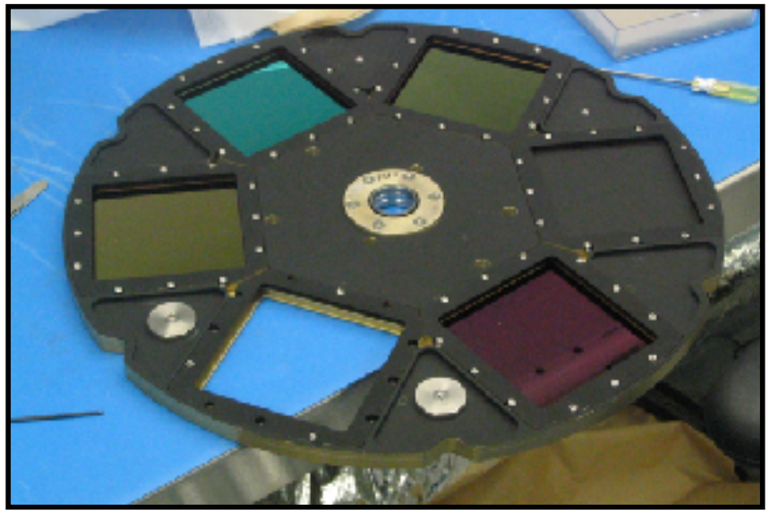
Array Module



Filters



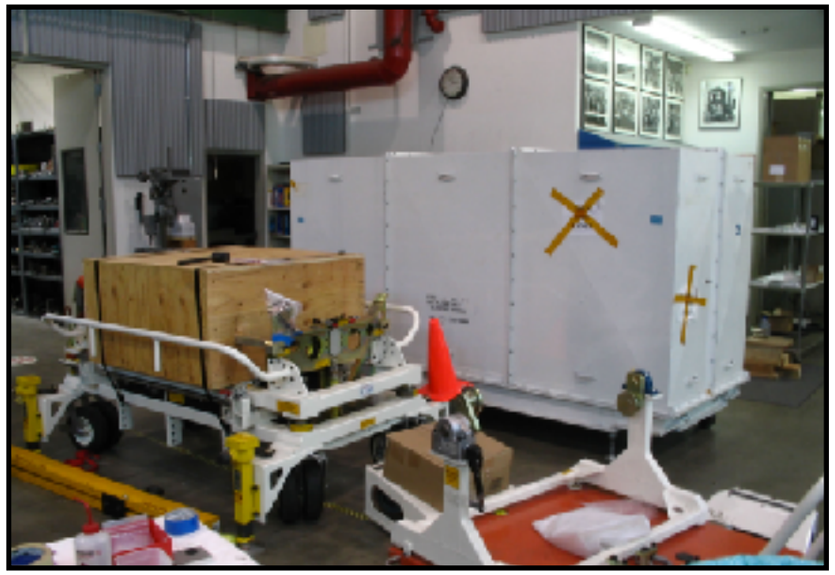
Camera Module



FOURSTAR

Assembly

FOURSTAR



Shipping

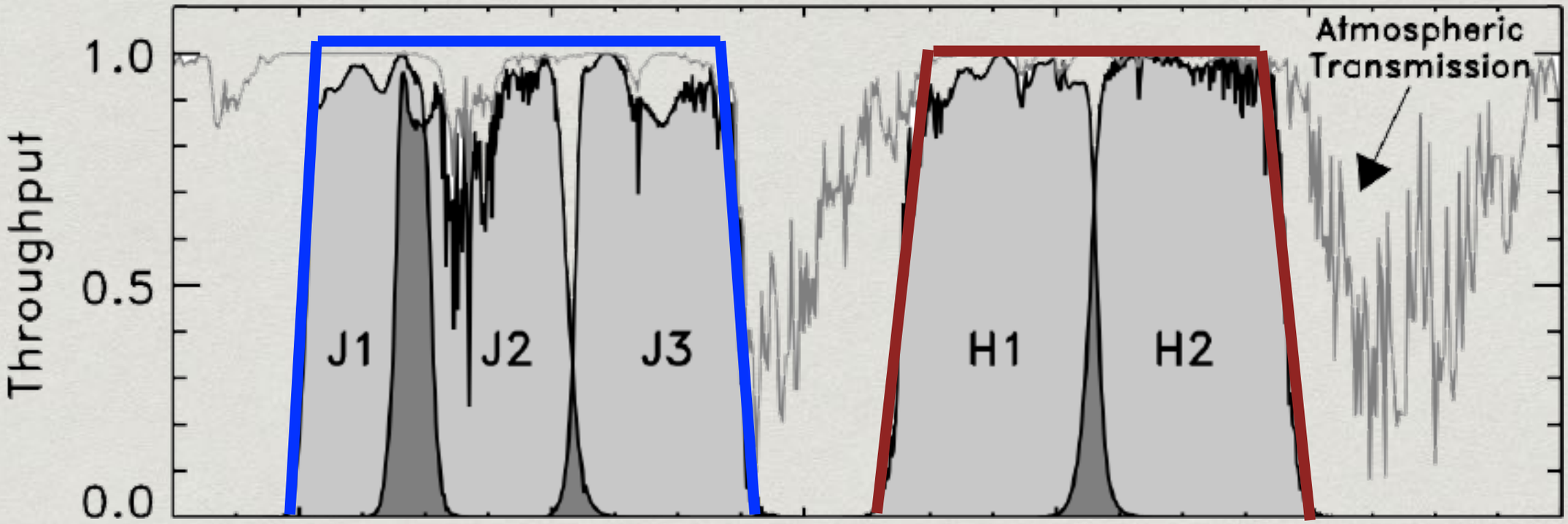
FOURSTAR

On Magellan

ZFOURGE

FourStar Galaxy Evolution Survey

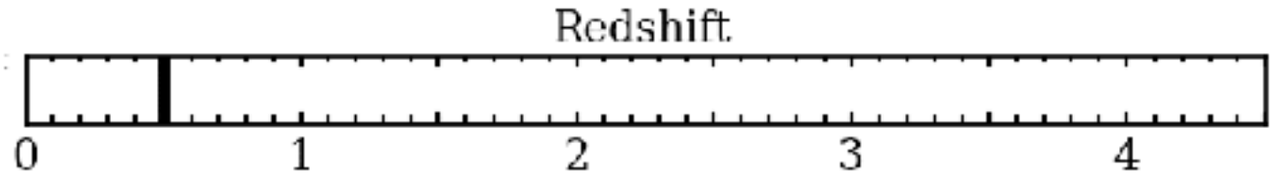
Medium Band Filters

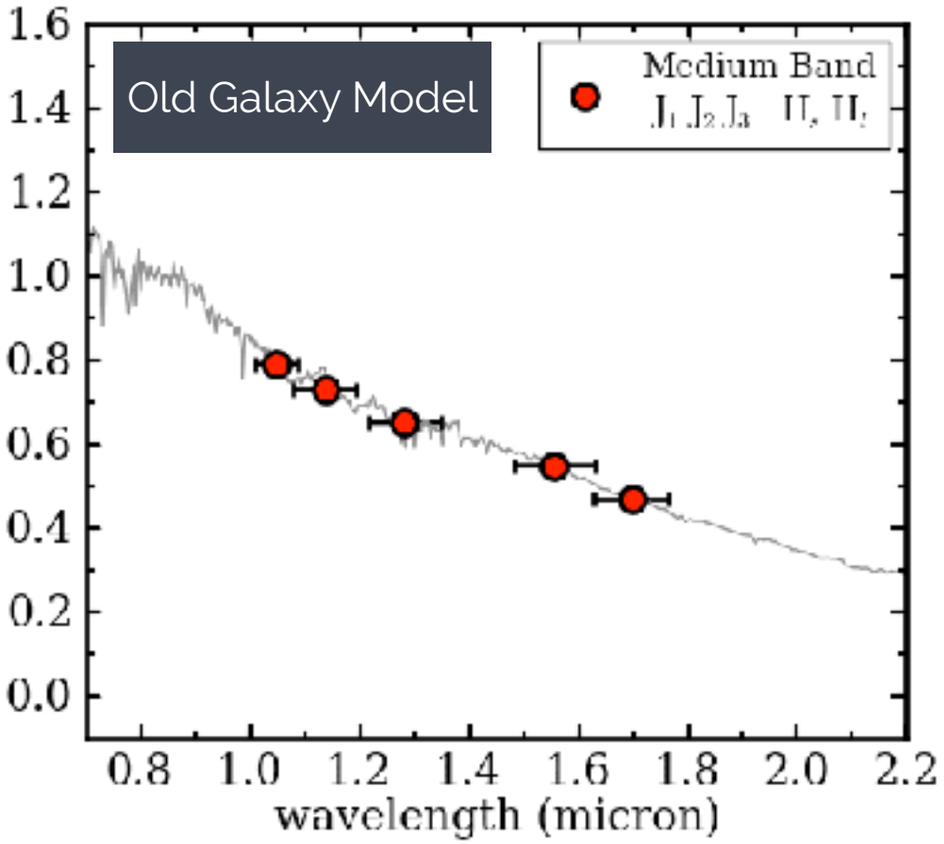


Allows highly accurate cosmological redshift calculations

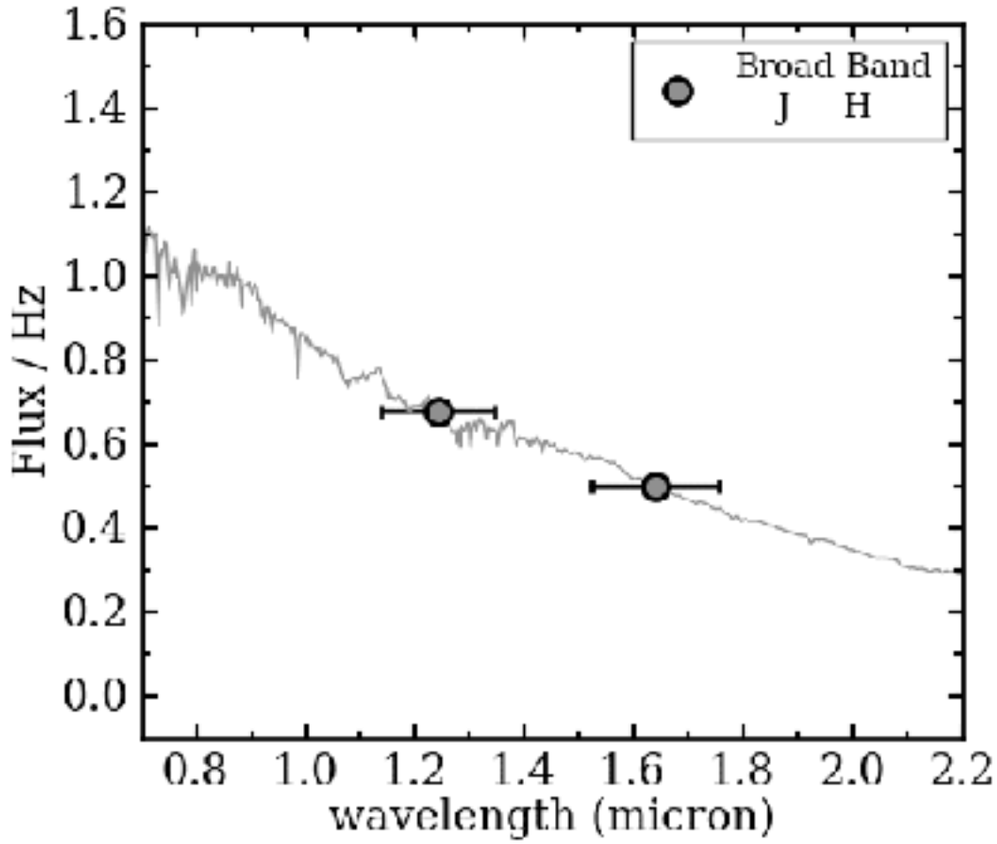
ZFOURGE

FourStar Galaxy Evolution Survey





ZFOURGE Filters



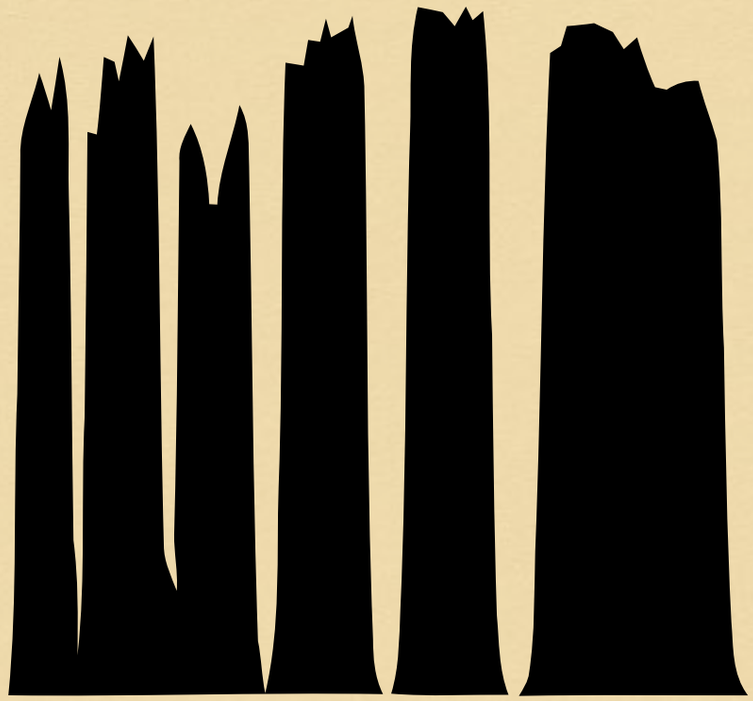
Traditional Filters

NEWFIRM 1.2”
K 12 hours
NMBS Survey

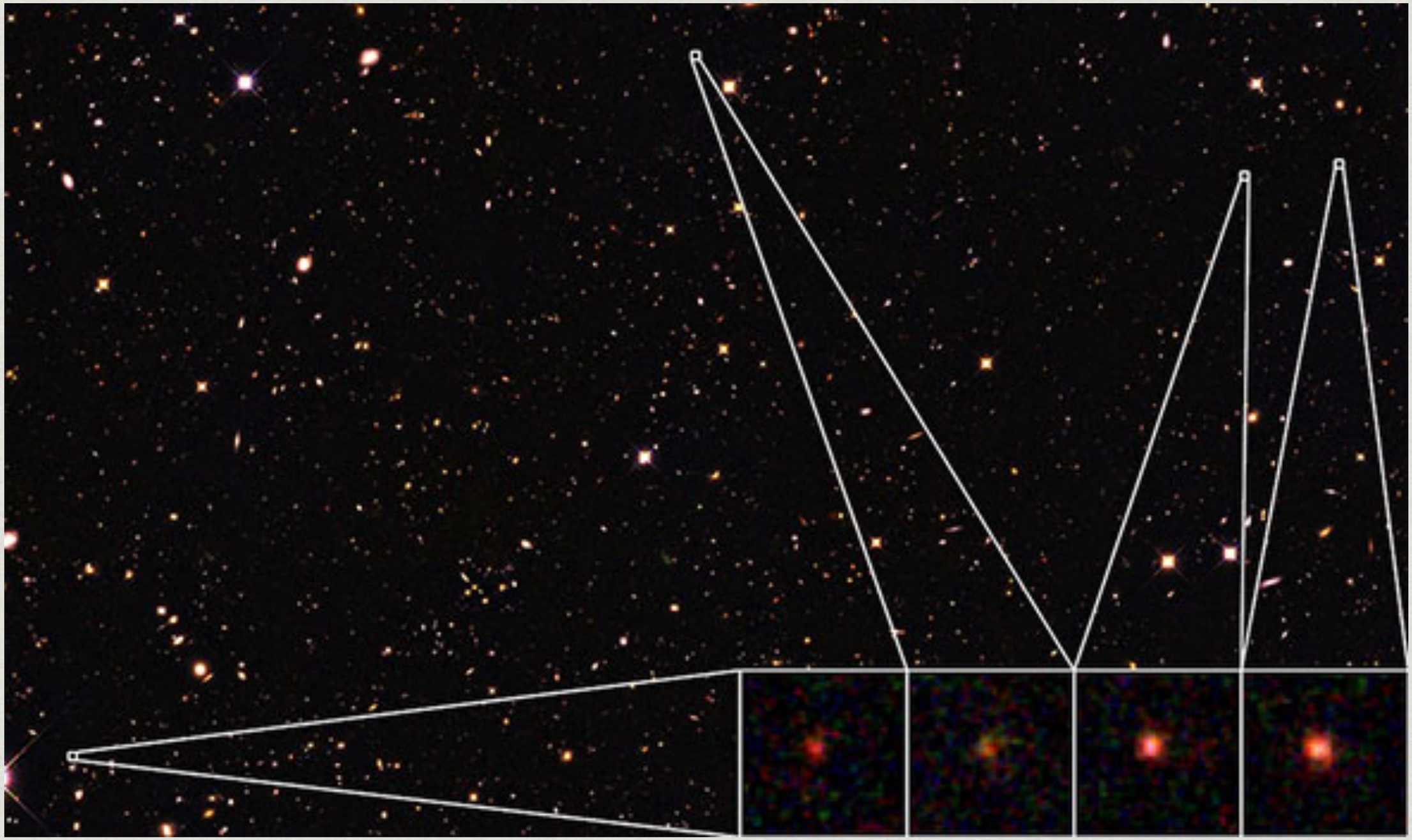
Four-Star 0.4”
K 30 minutes
ZFOURGE

A substantial population of massive quiescent galaxies at z~4 from ZFOURGE

Straatman et al. 2014

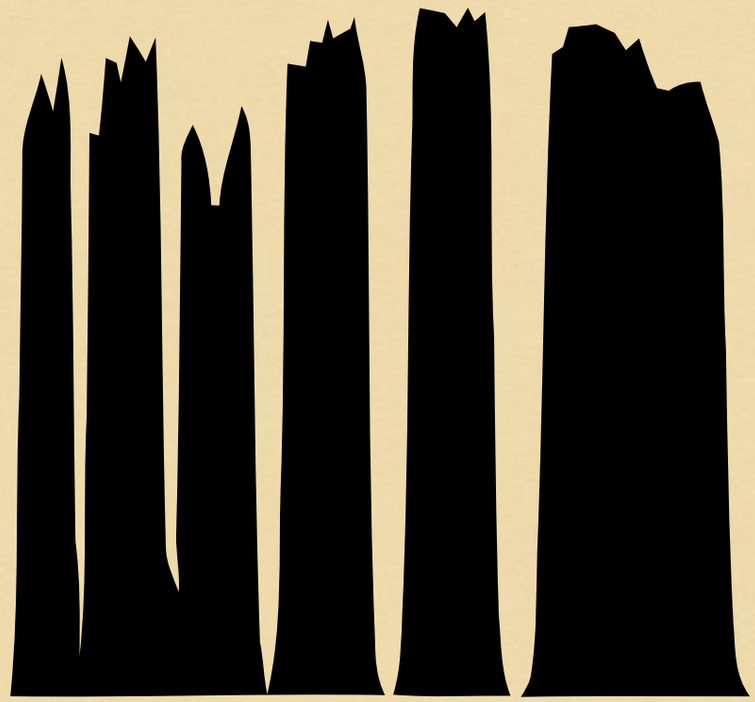


Straatman et al. 2014

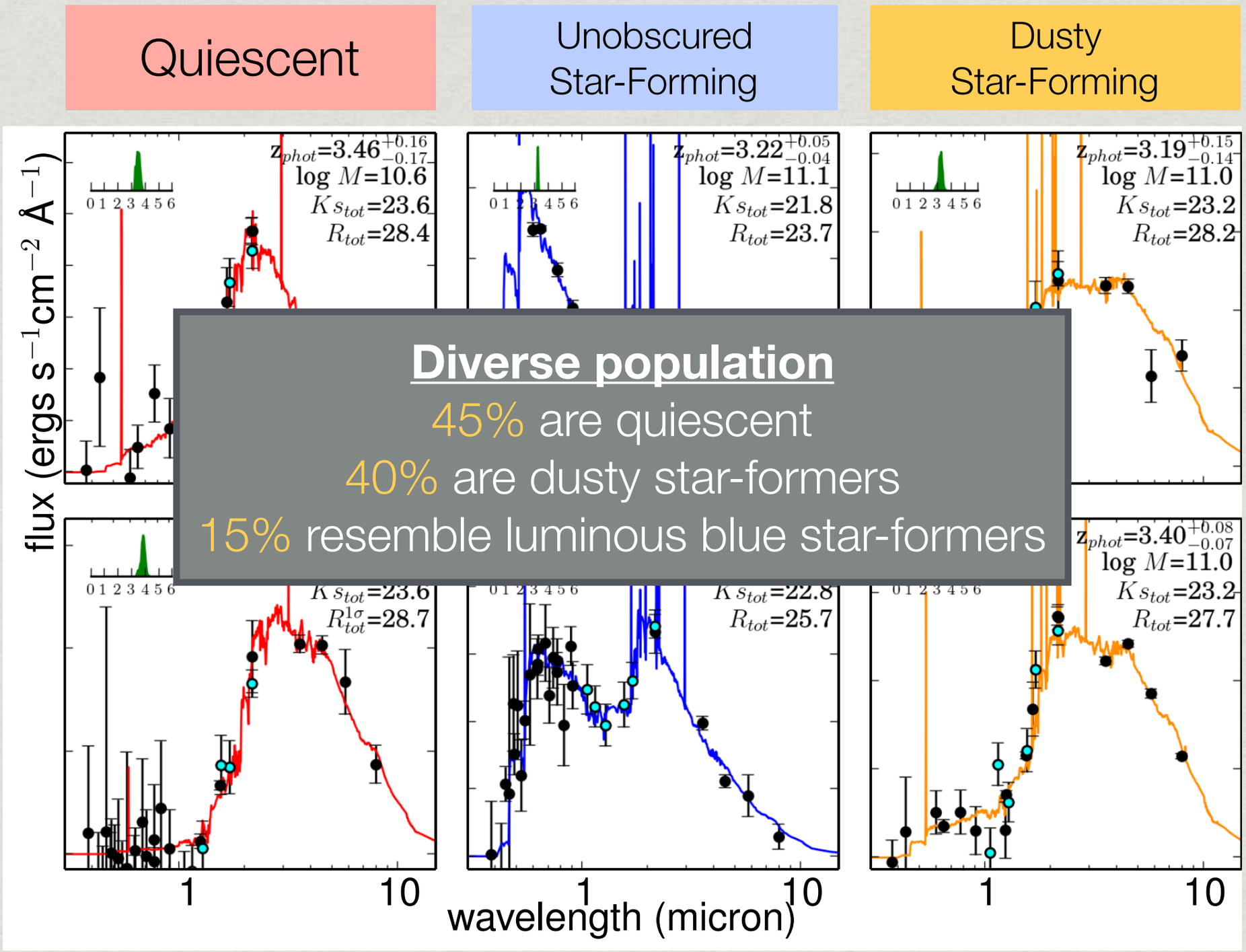


Exploring the z=3-4 massive galaxy population with ZFOURGE: the prevalence of dusty and quiescent galaxies

Spitler et al. 2014



Spitler et al. 2014



Diverse population

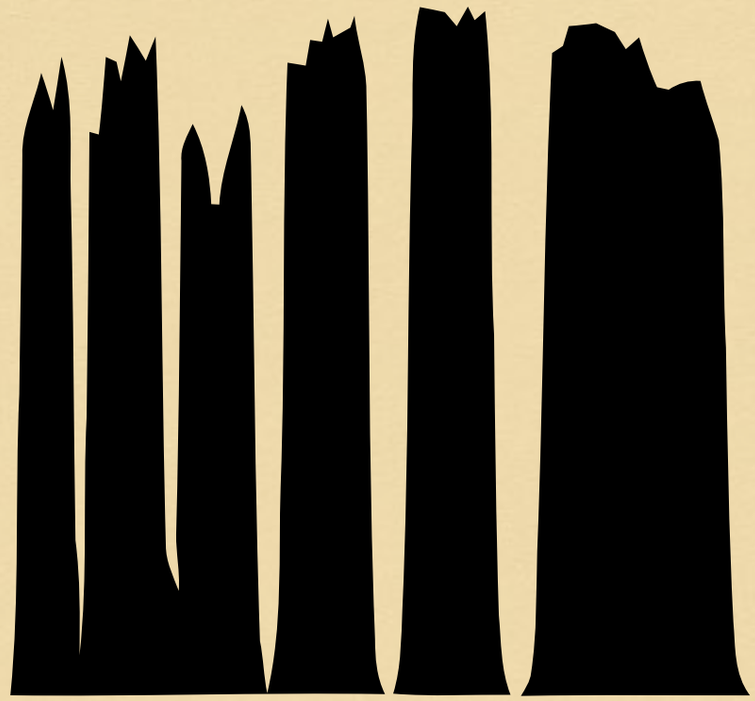
45% are quiescent

40% are dusty star-formers

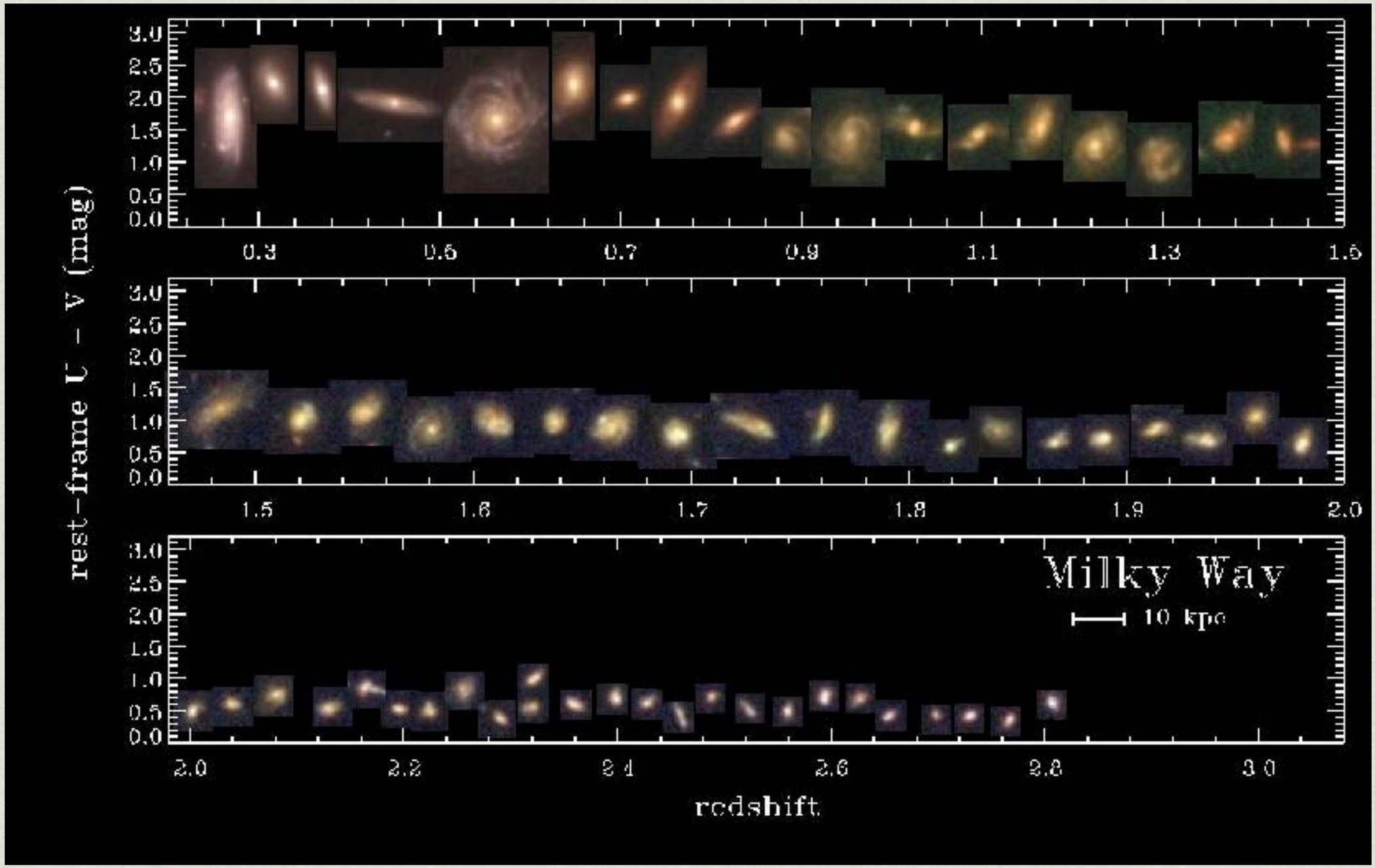
15% resemble luminous blue star-formers

On the evolution of MW/M31 progenitors from z = 3

Papovich et al. 2015

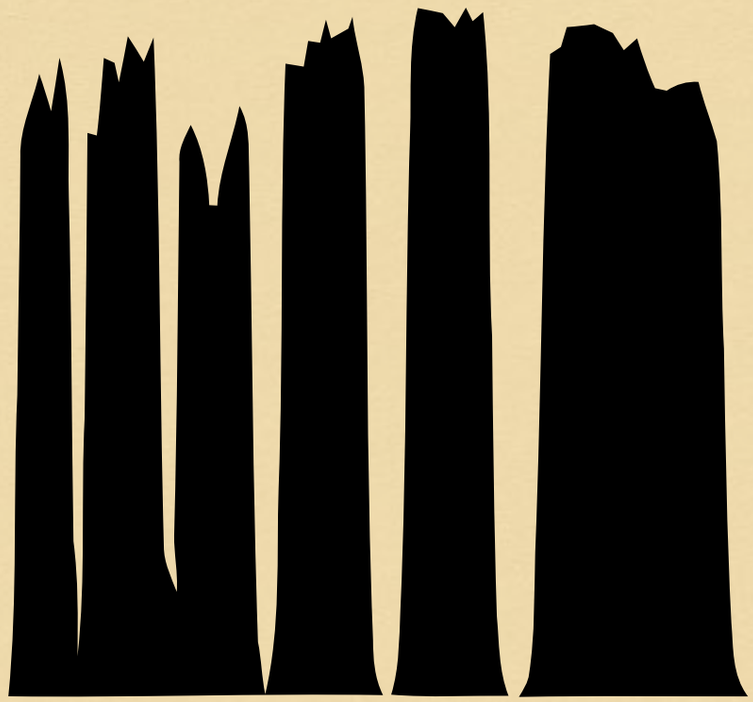


Papovich et al. 2015

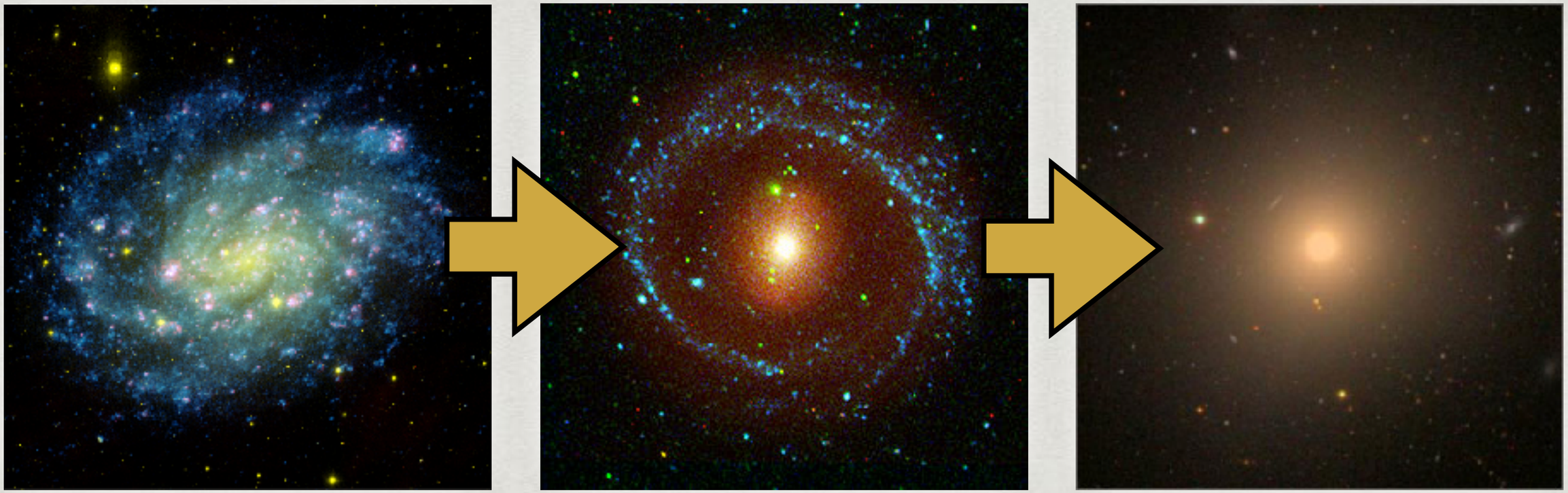


ZFOURGE Catalogue of AGN Candidates: A Comparison of Star-Formation Activity in Active and Non-active Galaxies

Cowley et al. in prep



WHAT **SUPPRESSES** STAR-FORMATION IN GALAXIES?



Younger Galaxies **Transitional** **Older Galaxies**

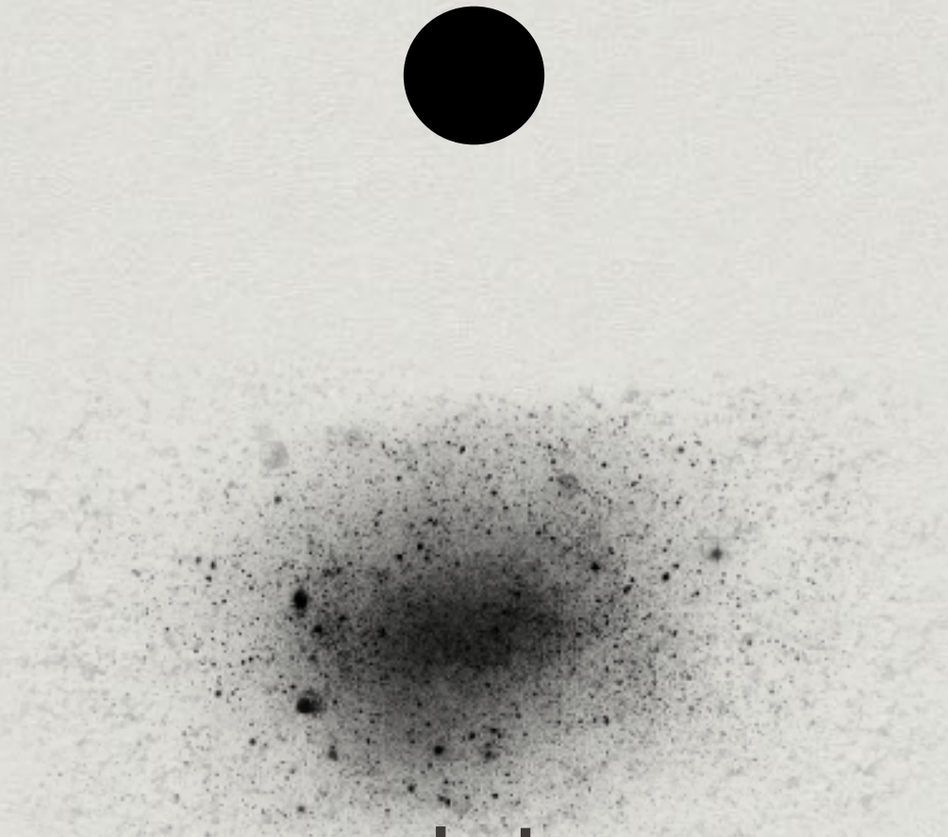
Understanding this is central to building a coherent picture of galaxy evolution

Image Credit: NASA/JPL-Caltech

SUPERMASSIVE BLACK HOLE

FEEDING A SUPERMASSIVE BLACK HOLE

gas



dust

stars

MACQUARIE University
SYDNEY AUSTRALIA

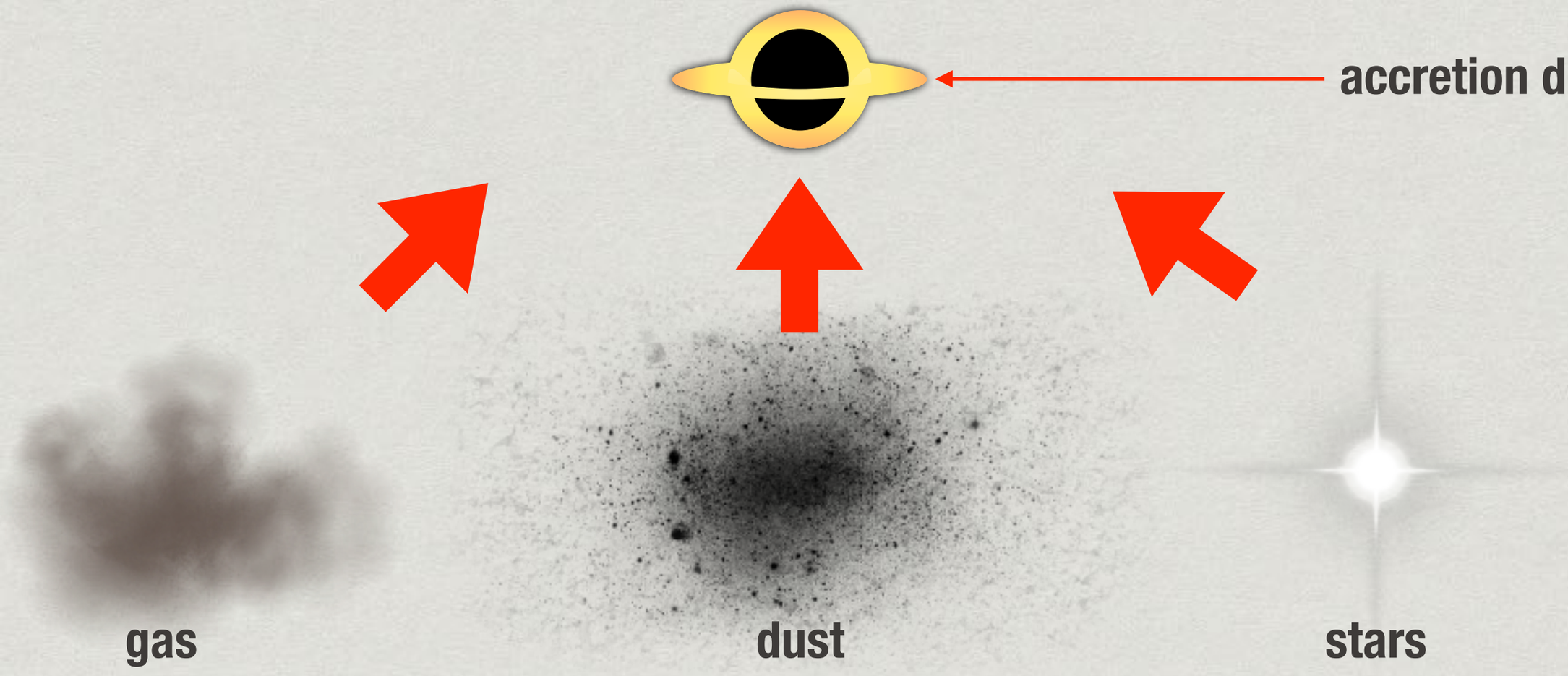
Australian Government
Department of Industry and Science

AAO

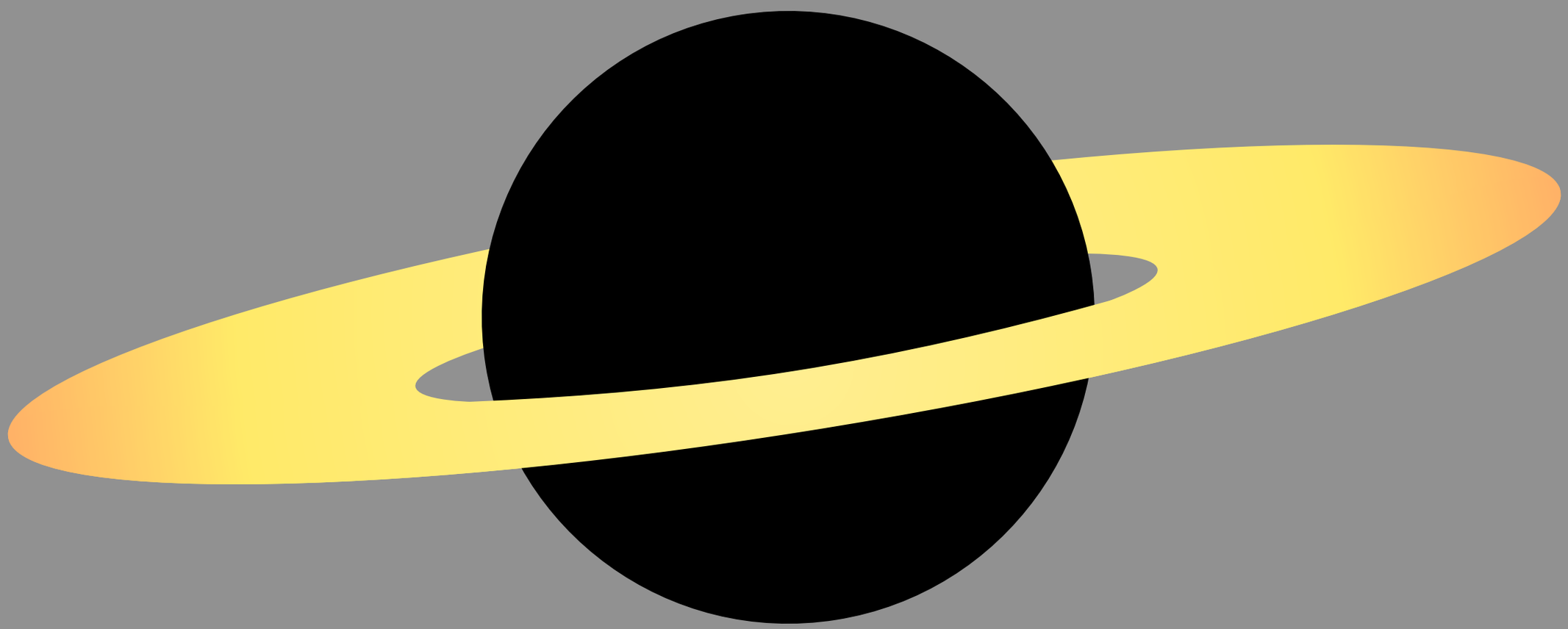
Northern Sydney Astronomical Society, August 16th 2016

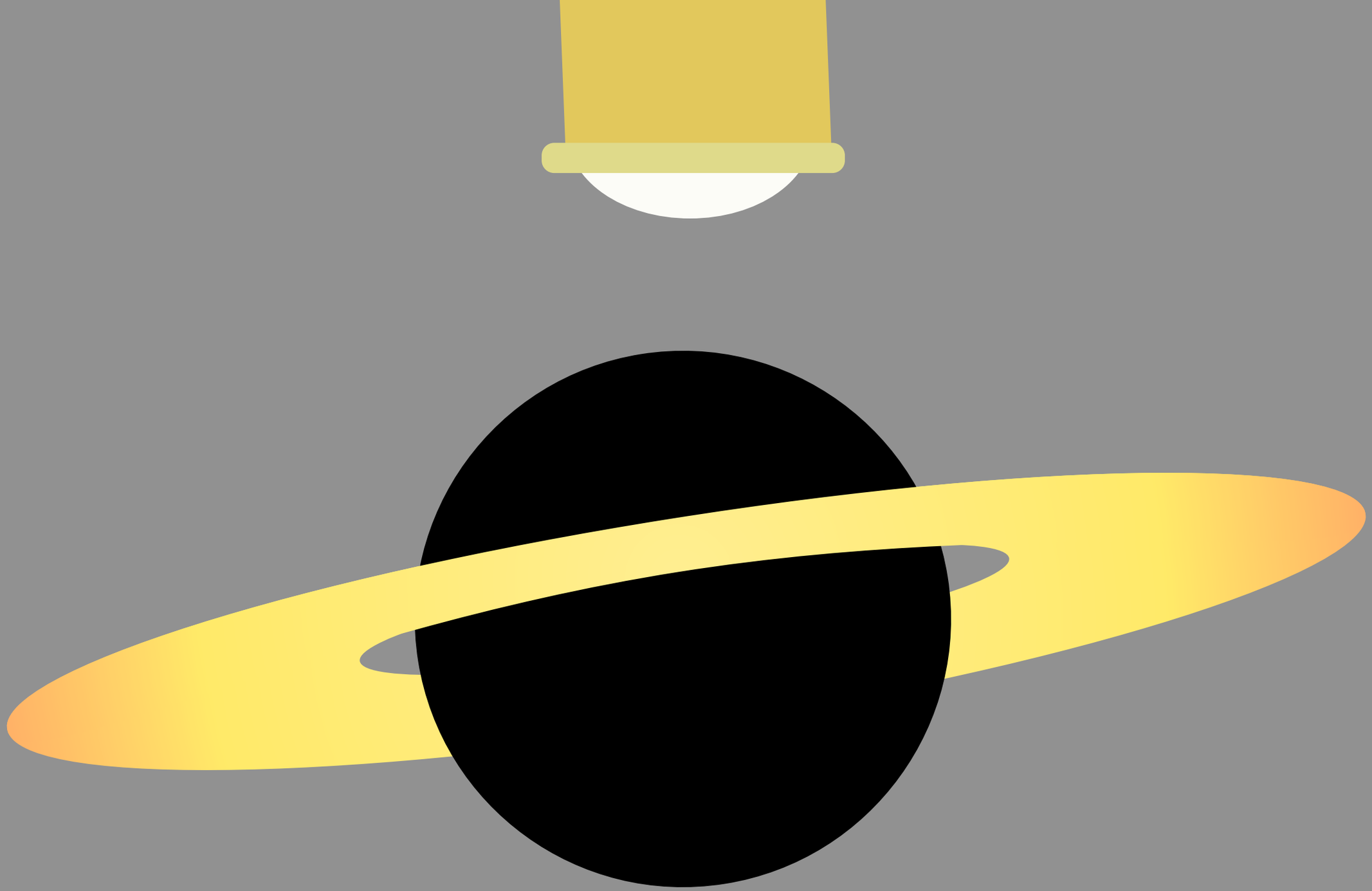
FEEDING A SUPERMASSIVE BLACK HOLE

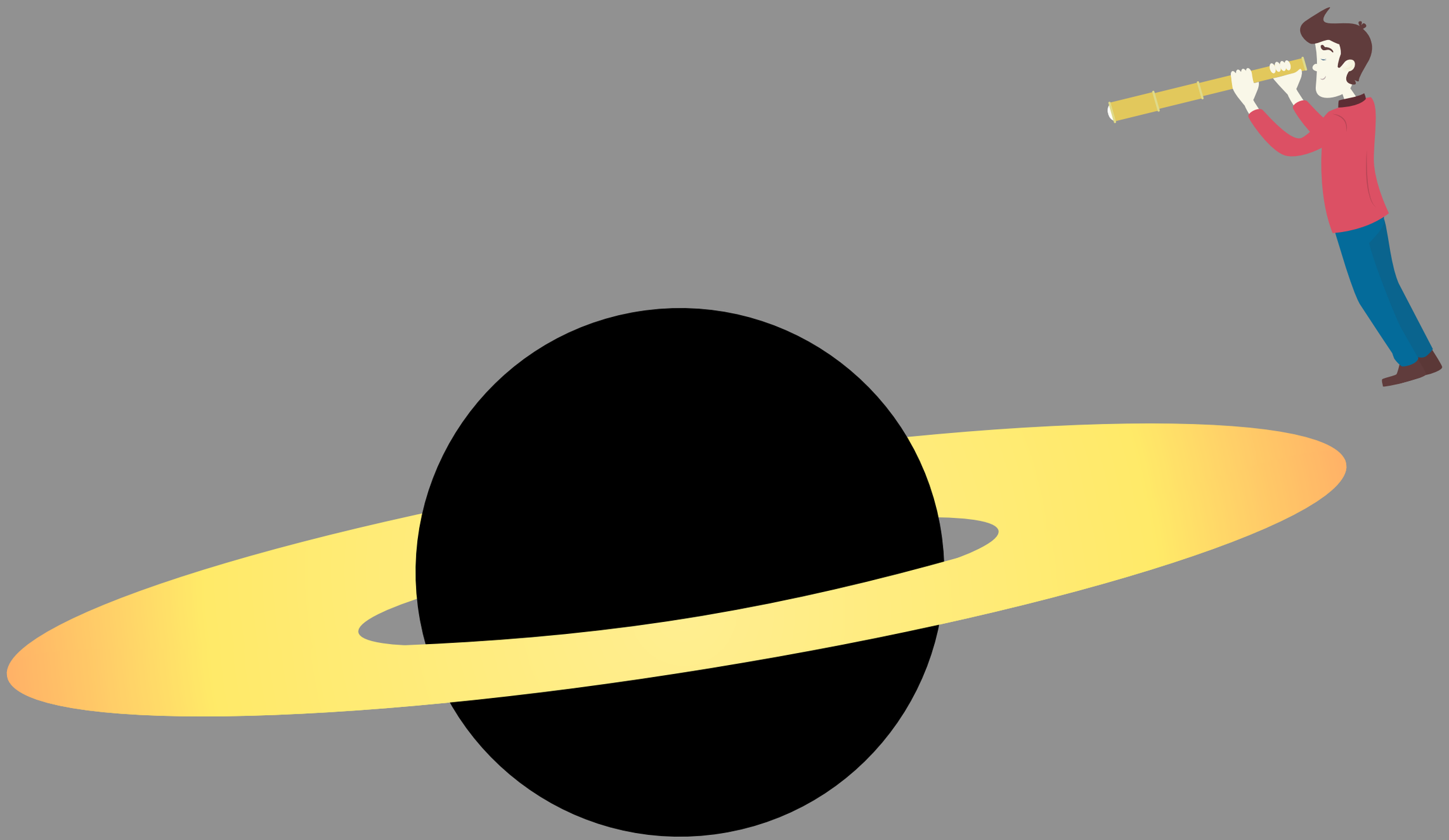
Conservation of angular momentum causes fuel to form a disk as it spirals in

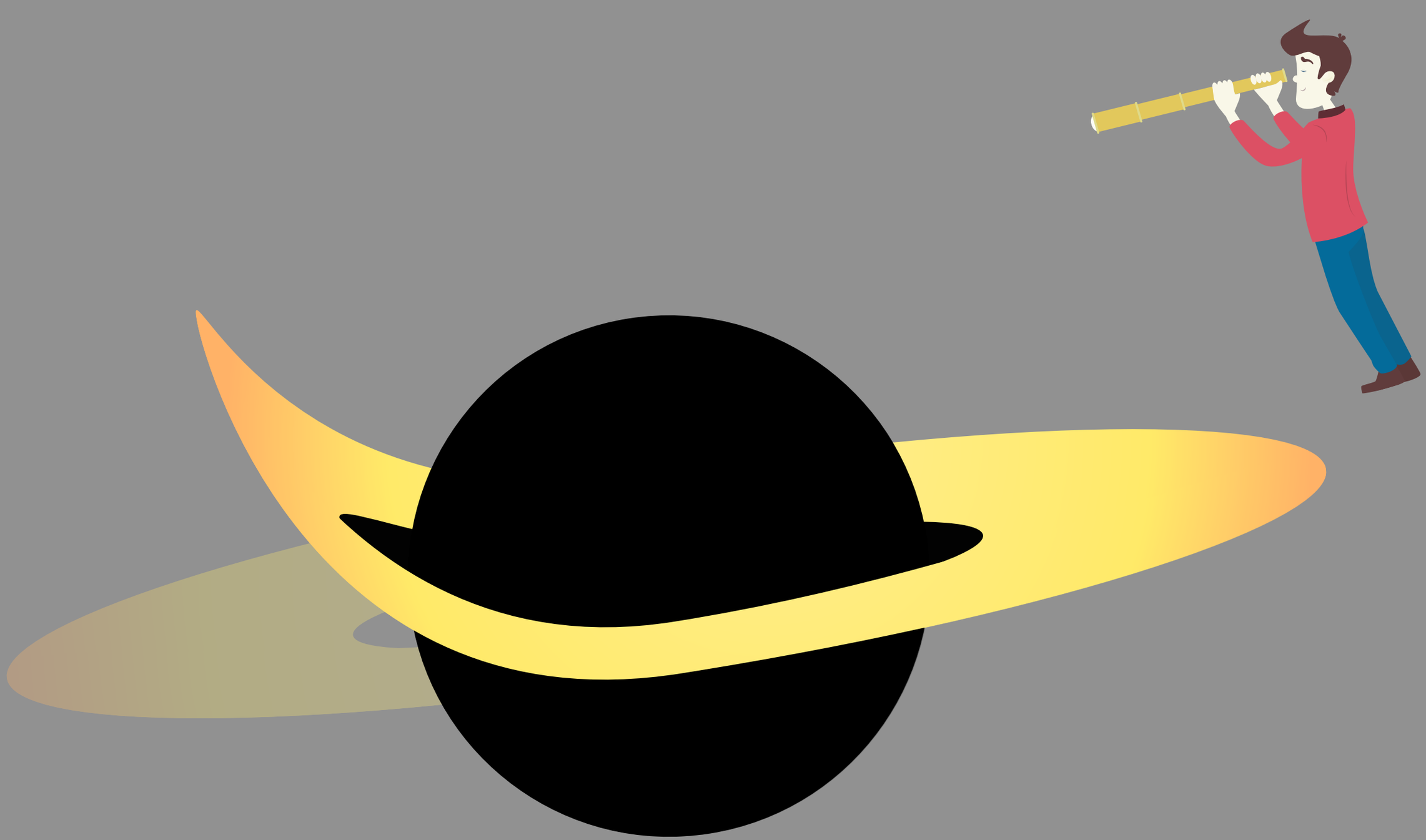


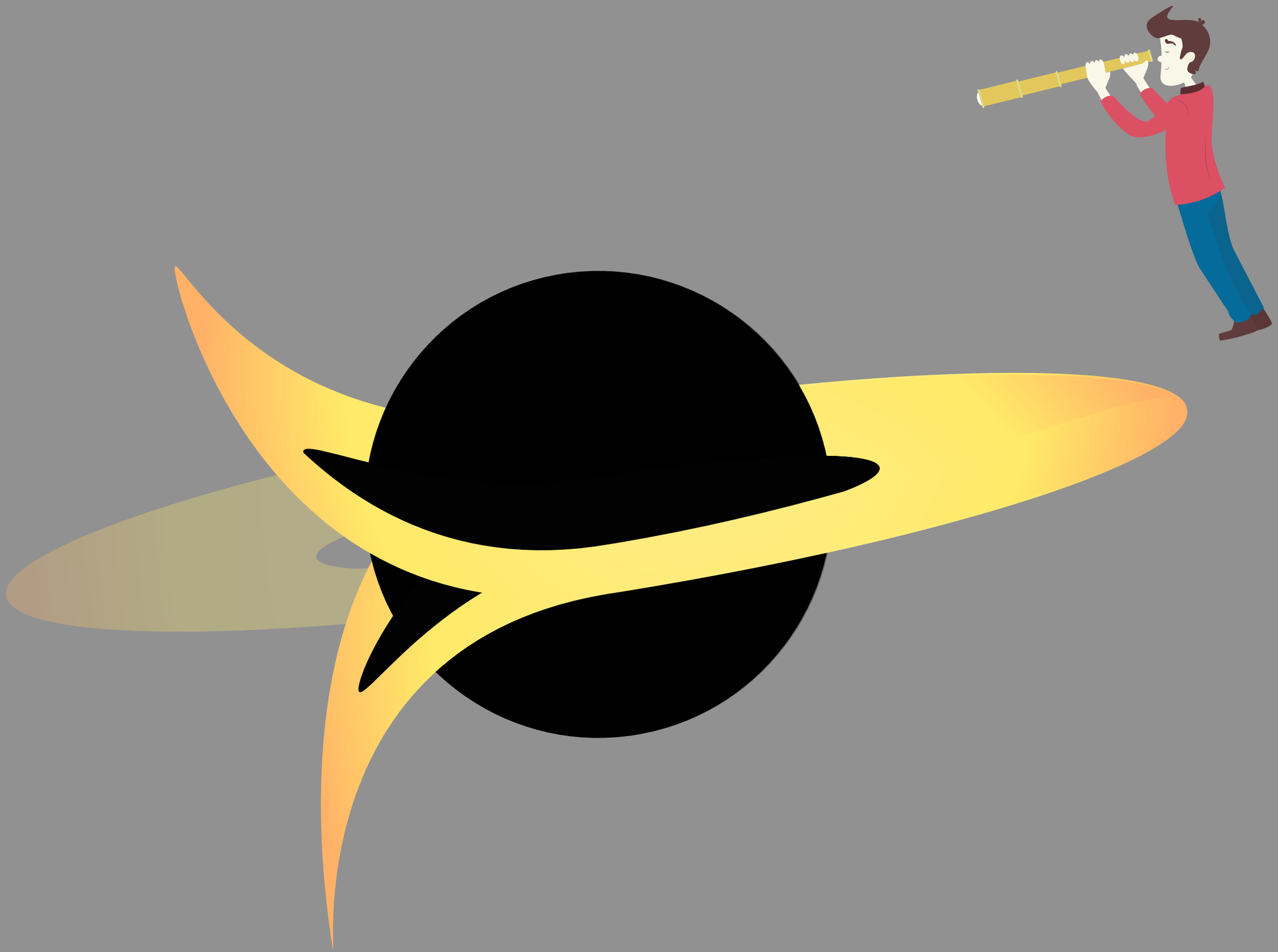

INTERSTELLAR







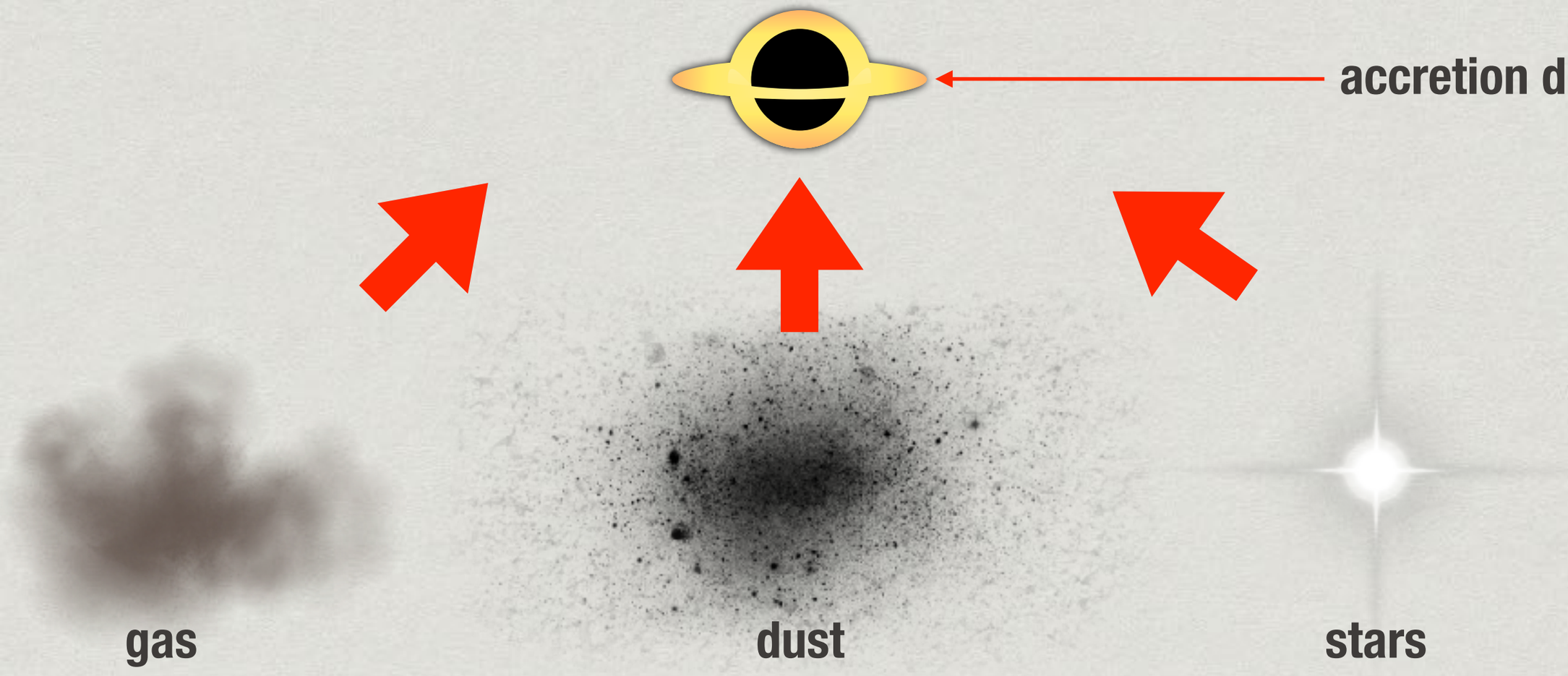




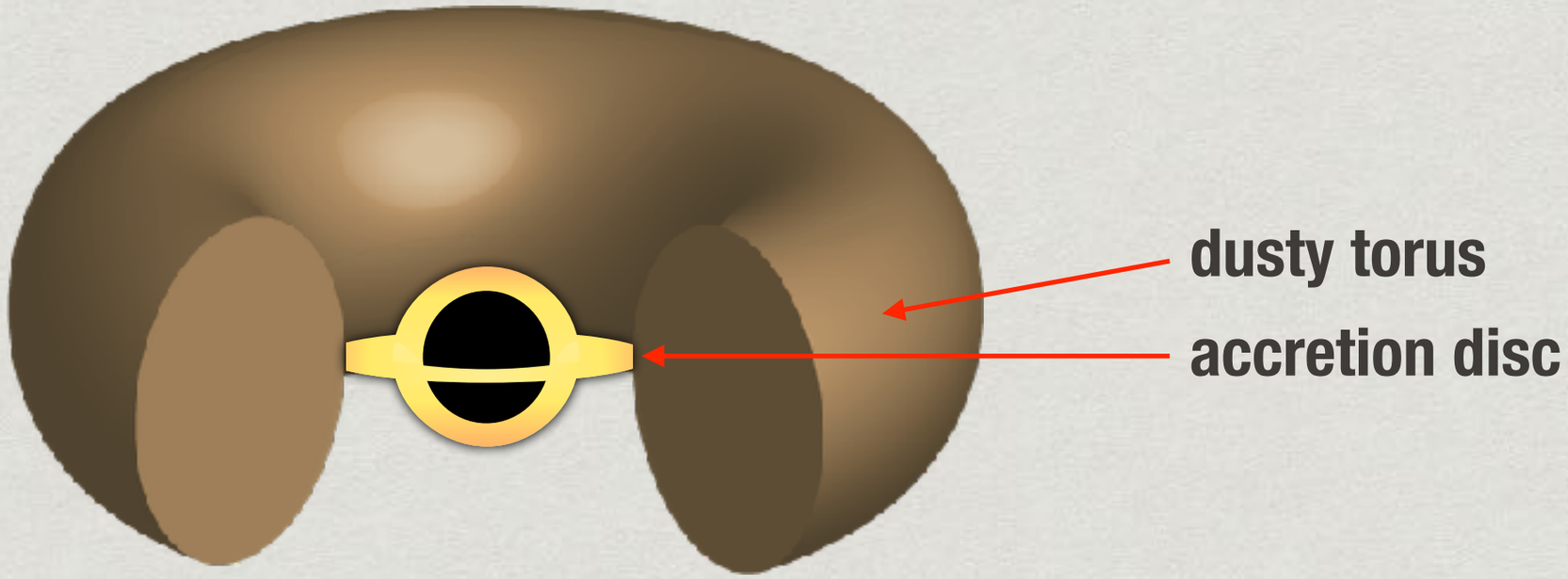

INTERSTELLAR
NASA

FEEDING A SUPERMASSIVE BLACK HOLE

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



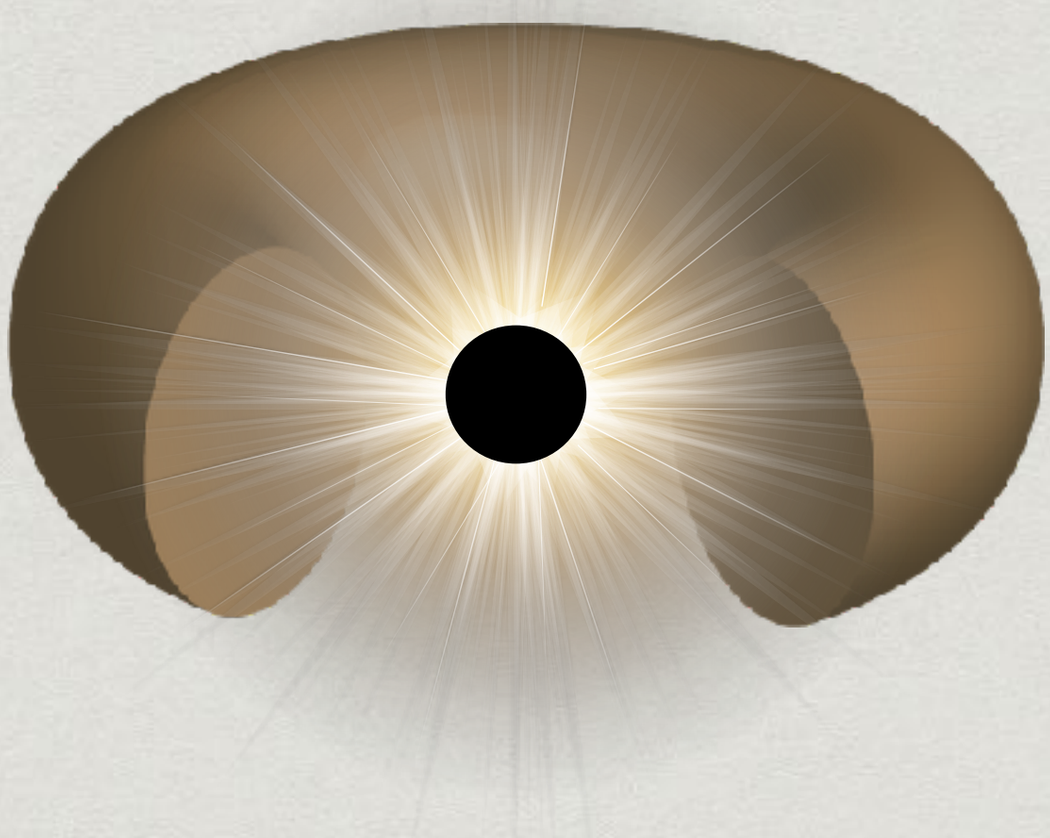
FEEDING A SUPERMASSIVE BLACK HOLE



ACTIVE SUPERMASSIVE BLACK HOLE

$L \sim 10^{37\text{-}41}$W

(i.e. $\sim 10^{10\text{-}14} L_{\odot}$)

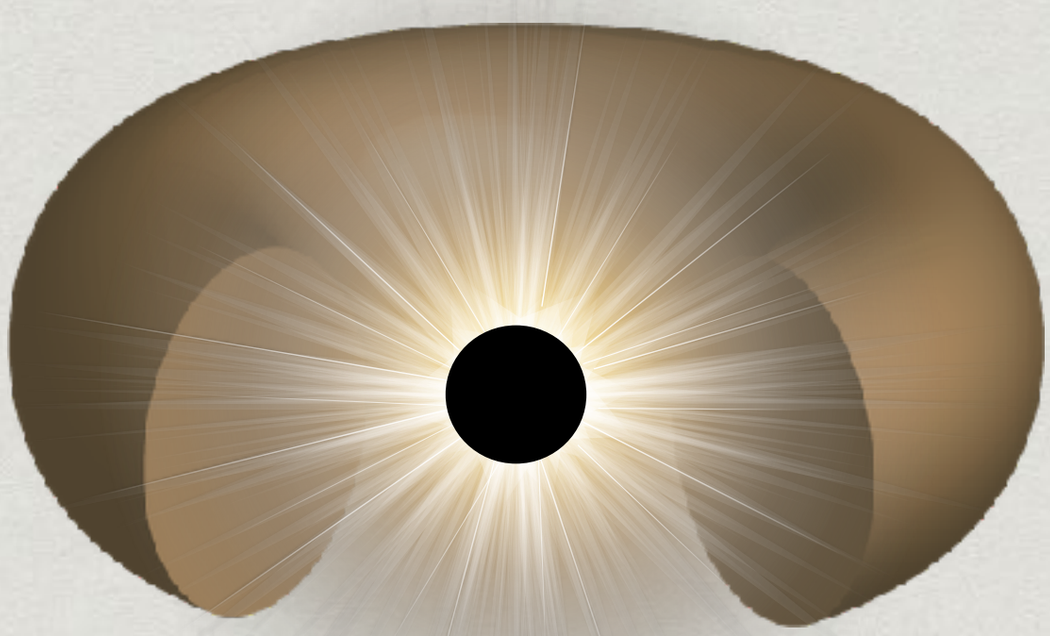


Within this disc, there are dissipative processes, e.g. collisions, shocks, etc. This dissipated energy emerges as radiation

ACTIVE SUPERMASSIVE BLACK HOLE

$L \sim 10^{37\text{-}41}\mathrm{W}$

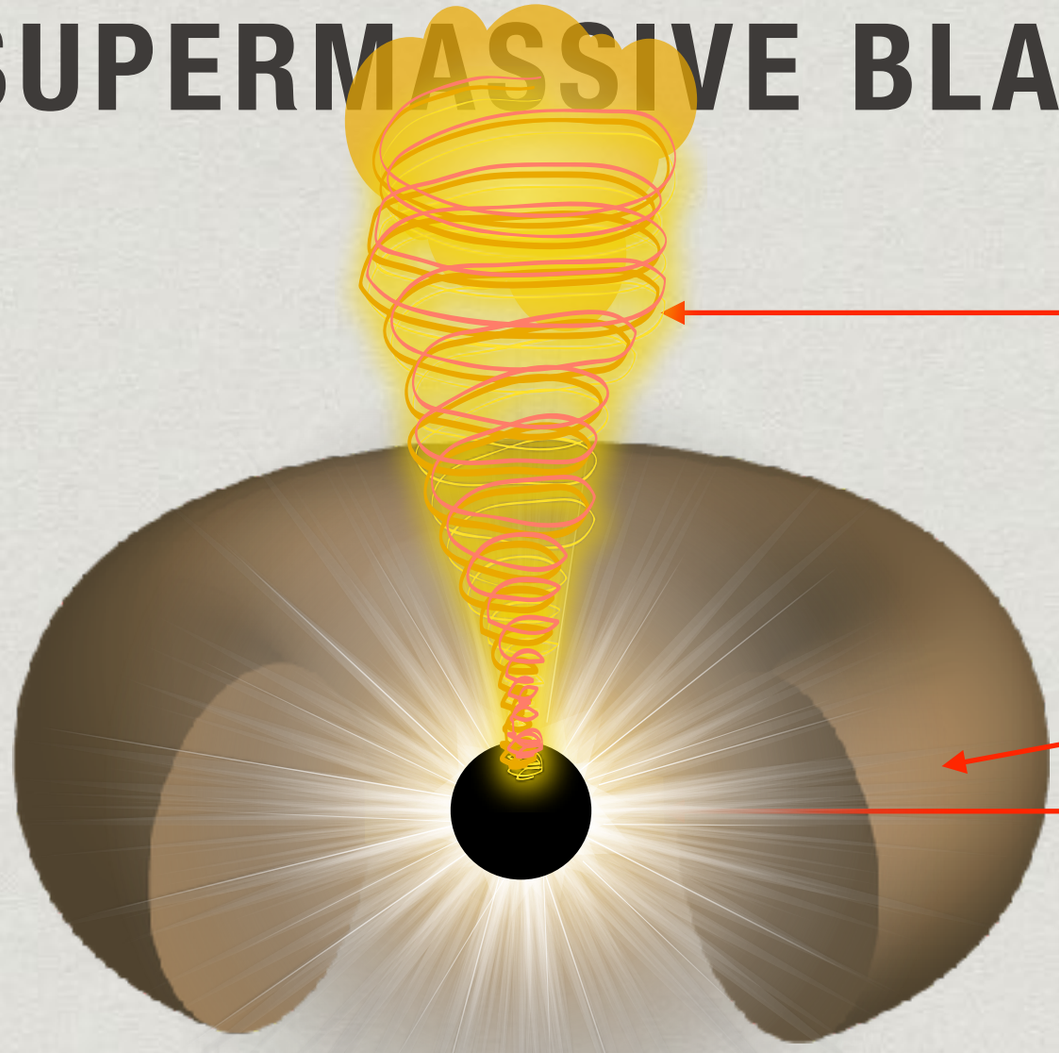
(i.e. $\sim 10^{10\text{-}14} L_\odot$)



Accretion rate…

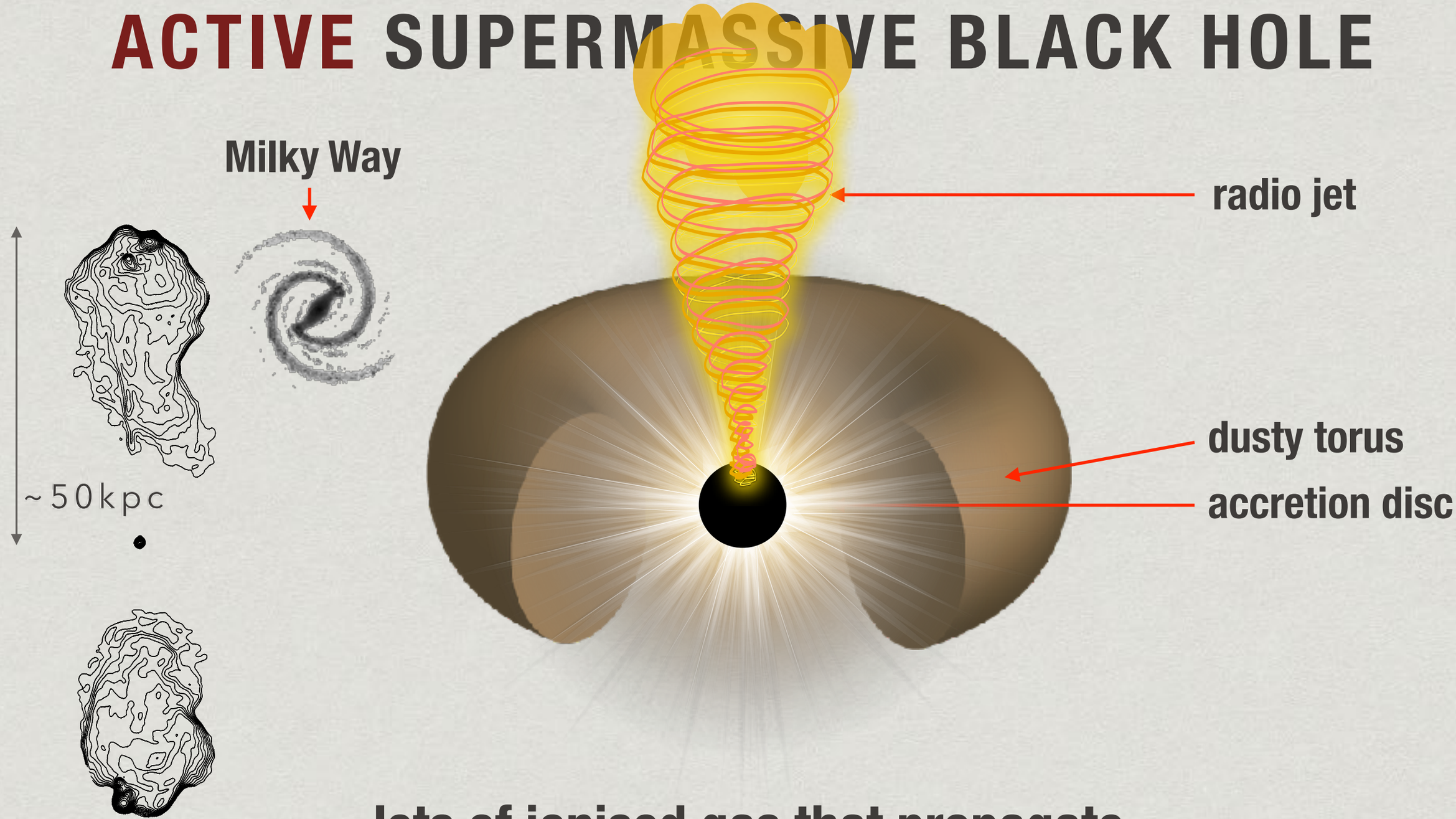
$$\dot{M} = \frac{L}{\eta c^2} = \frac{10^{10} L_\odot}{0.1 c^2} \approx 0.01 M_\odot \mathrm{yr}^{-1}$$

ACTIVE SUPERMASSIVE BLACK HOLE



Jets of ionised gas that propagate perpendicular to the plane of the accretion disc emit radio emission

ACTIVE SUPERMASSIVE BLACK HOLE



Jets of ionised gas that propagate perpendicular to the plane of the accretion disc emit radio emission

CENTAURUS A / NGC 5128

SUPERMASSIVE BLACK HOLE 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 ranging from IR to X-rays**
- **mildly relativistic accretion winds**
- **relativistic radio jets**

Radiation, winds and jets "feed back" energy and momentum into the surrounding area of the galaxy

WHY IS FEEDBACK IMPORTANT?

Feedback may help suppress ongoing star formation

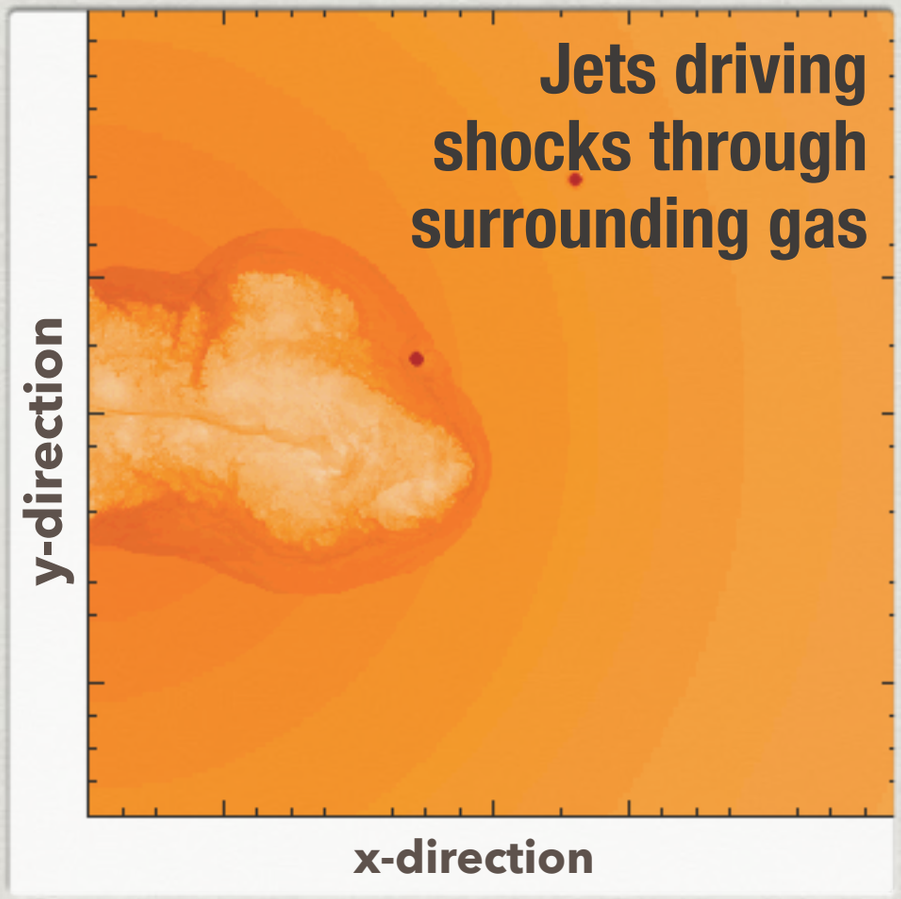
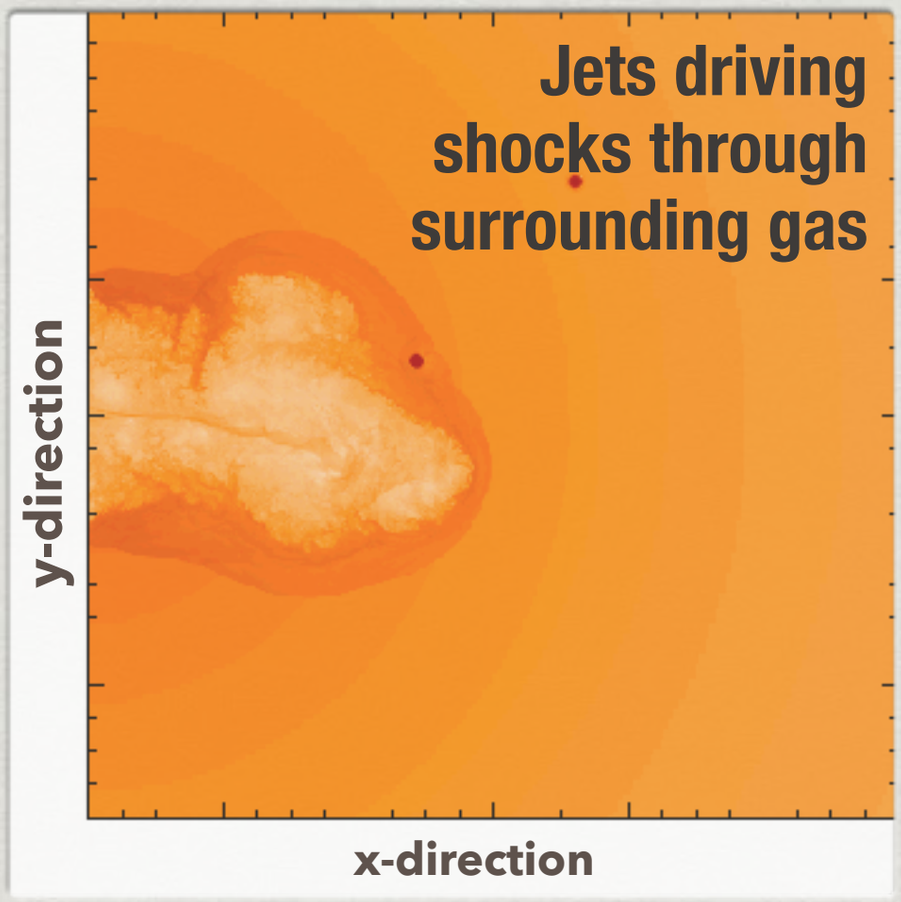


Image Credit: Vincenzo Antonuccio-Delogu

WHY IS FEEDBACK IMPORTANT?

Feedback may help suppress ongoing star formation and reduce the overproduction of massive galaxies seen in models



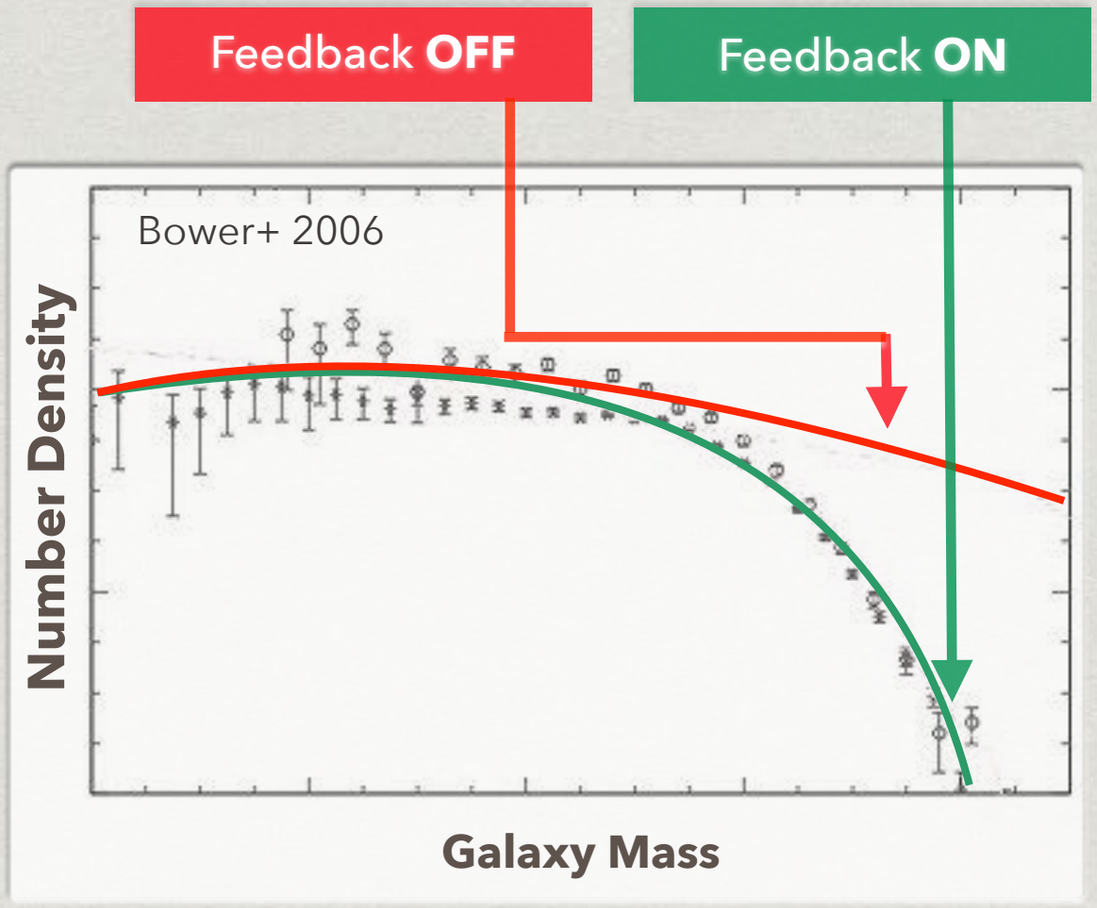


Image Credit: Vincenzo Antonuccio-Delogu

GOAL:

1) IDENTIFY A DIVERSE POPULATION OF GALAXIES HOSTING AN ACTIVE BLACK HOLE OVER A LARGE CHUNK OF COSMIC TIME

2) COMPARE THE STAR-FORMATION ACTIVITY OF THIS POPULATION WITH THOSE LACKING AN ACTIVE BLACK HOLE

GOAL:

1) IDENTIFY A POPULATION OF GALAXIES HOSTING AN ACTIVE BLACK HOLE OVER A LARGE CHUNK OF COSMIC TIME

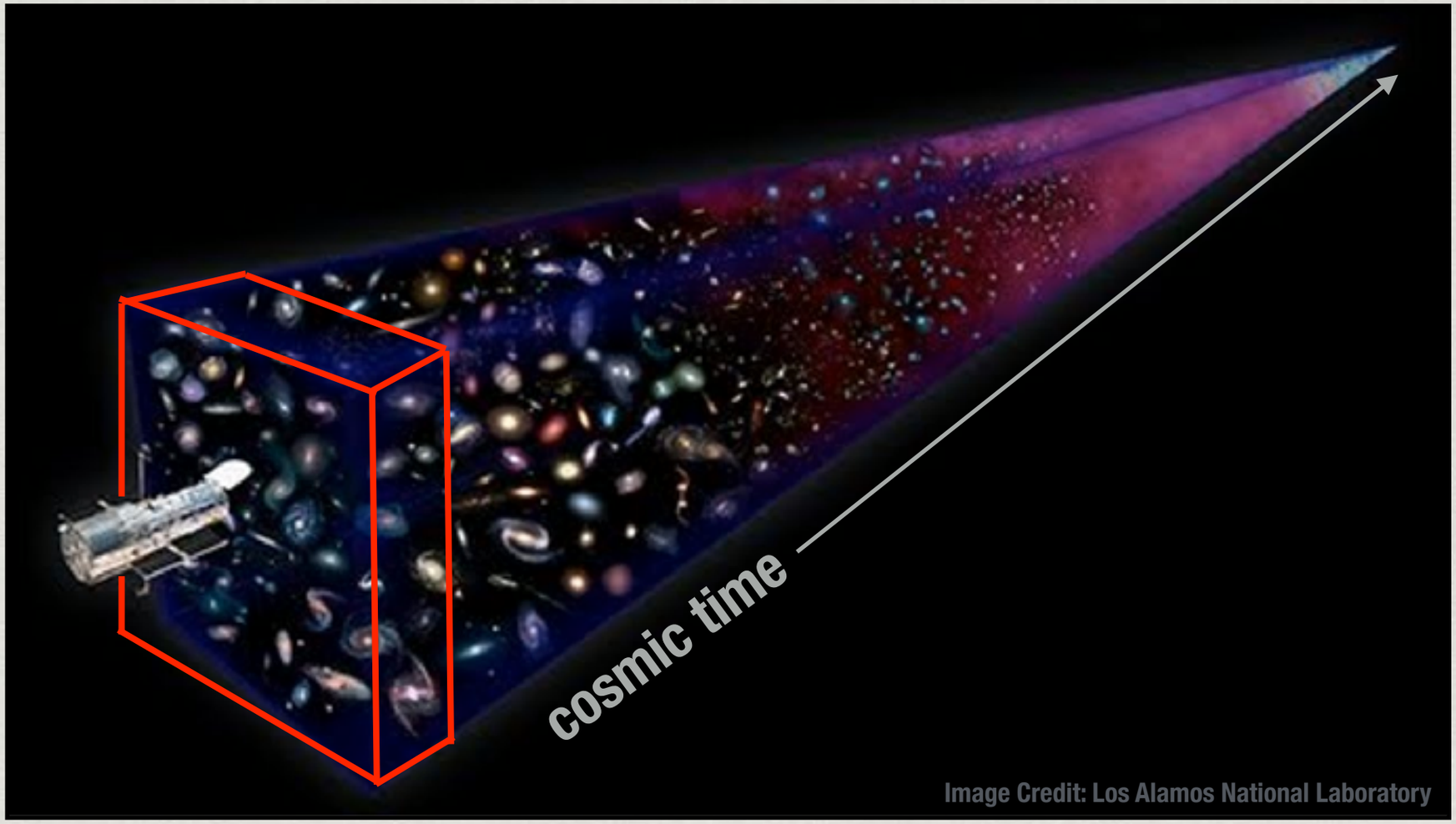


Image Credit: Los Alamos National Laboratory

GOAL:

1) IDENTIFY A POPULATION OF GALAXIES HOSTING AN ACTIVE BLACK HOLE OVER A LARGE CHUNK OF COSMIC TIME

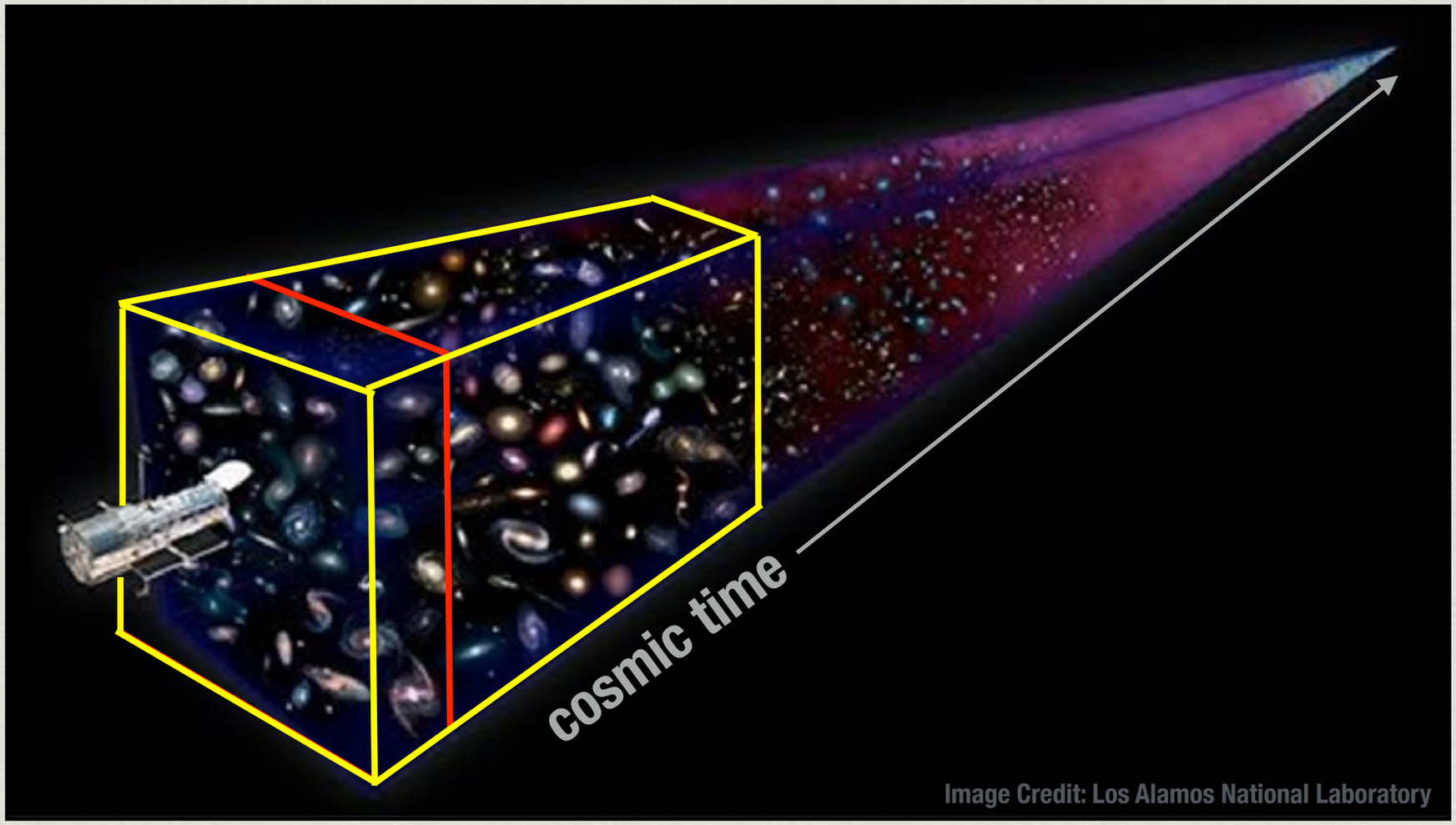


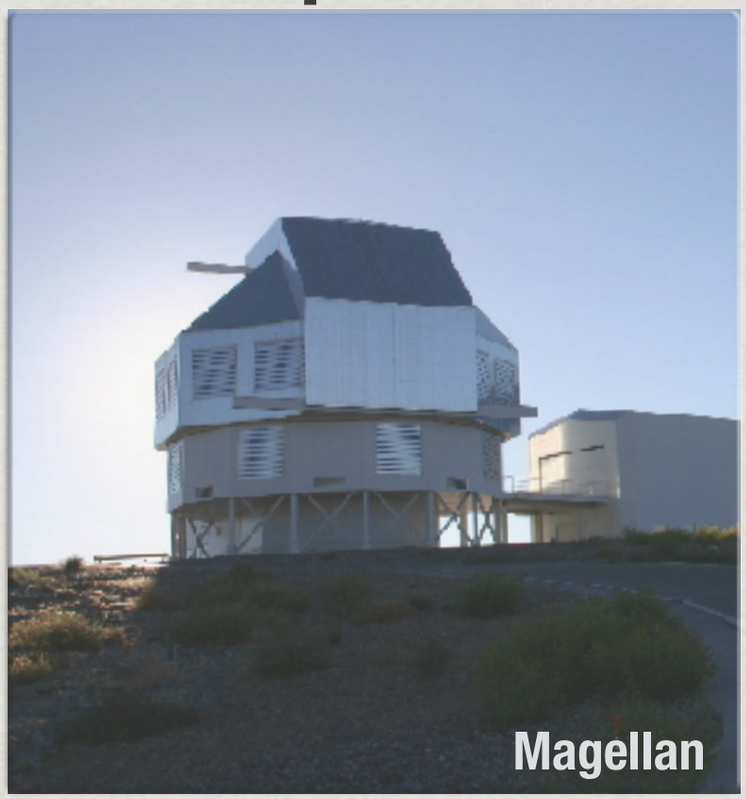
Image Credit: Los Alamos National Laboratory

GOAL:

1) IDENTIFY A POPULATION OF GALAXIES HOSTING AN ACTIVE BLACK HOLE OVER A LARGE CHUNK OF COSMIC TIME

A multi-wavelength approach

Optical

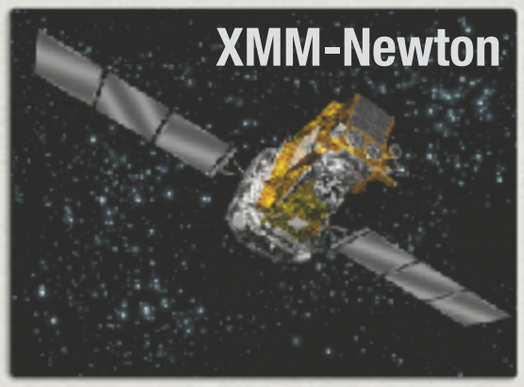


Radio

Optical/IR

Infrared

Infrared



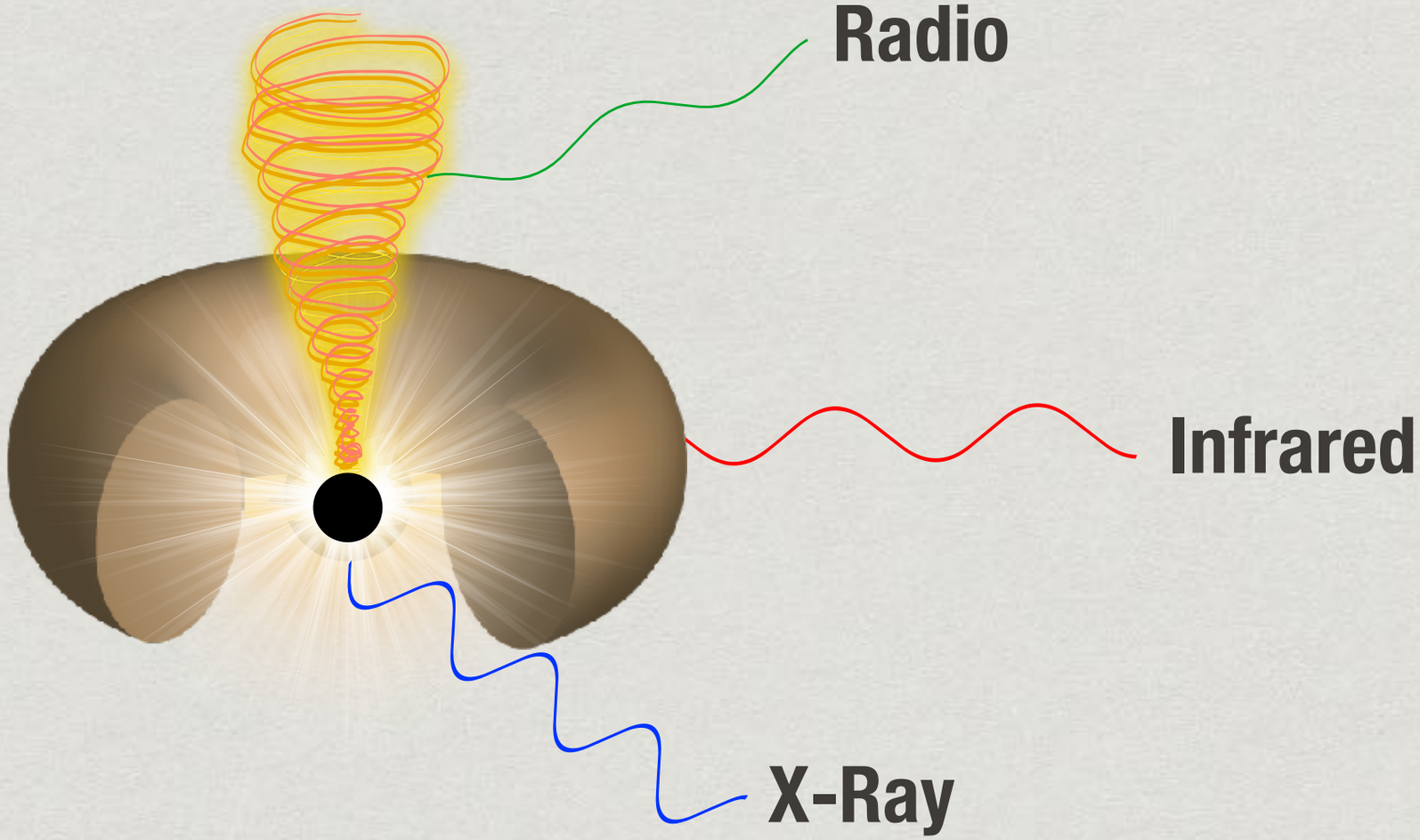
X-Ray

X-Ray

GOAL:

1) IDENTIFY A POPULATION OF GALAXIES HOSTING AN ACTIVE BLACK HOLE OVER A LARGE CHUNK OF COSMIC TIME

Requires a multi-wavelength approach



GOAL:

1) IDENTIFY A POPULATION OF GALAXIES HOSTING AN ACTIVE BLACK HOLE OVER A LARGE CHUNK OF COSMIC TIME

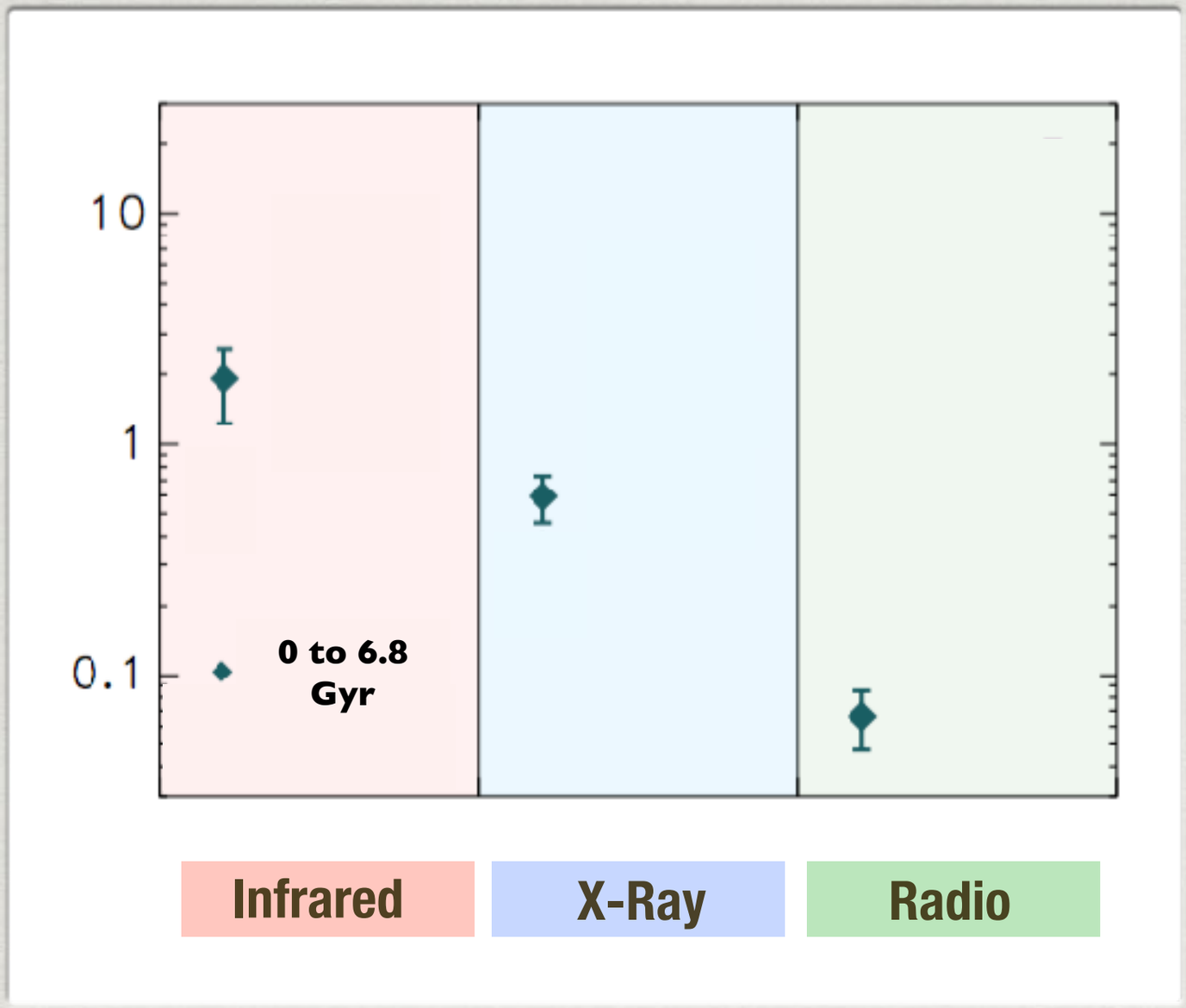
2) COMPARE THE STAR-FORMATION ACTIVITY OF THIS POPULATION WITH THOSE LACKING AN ACTIVE BLACK HOLE

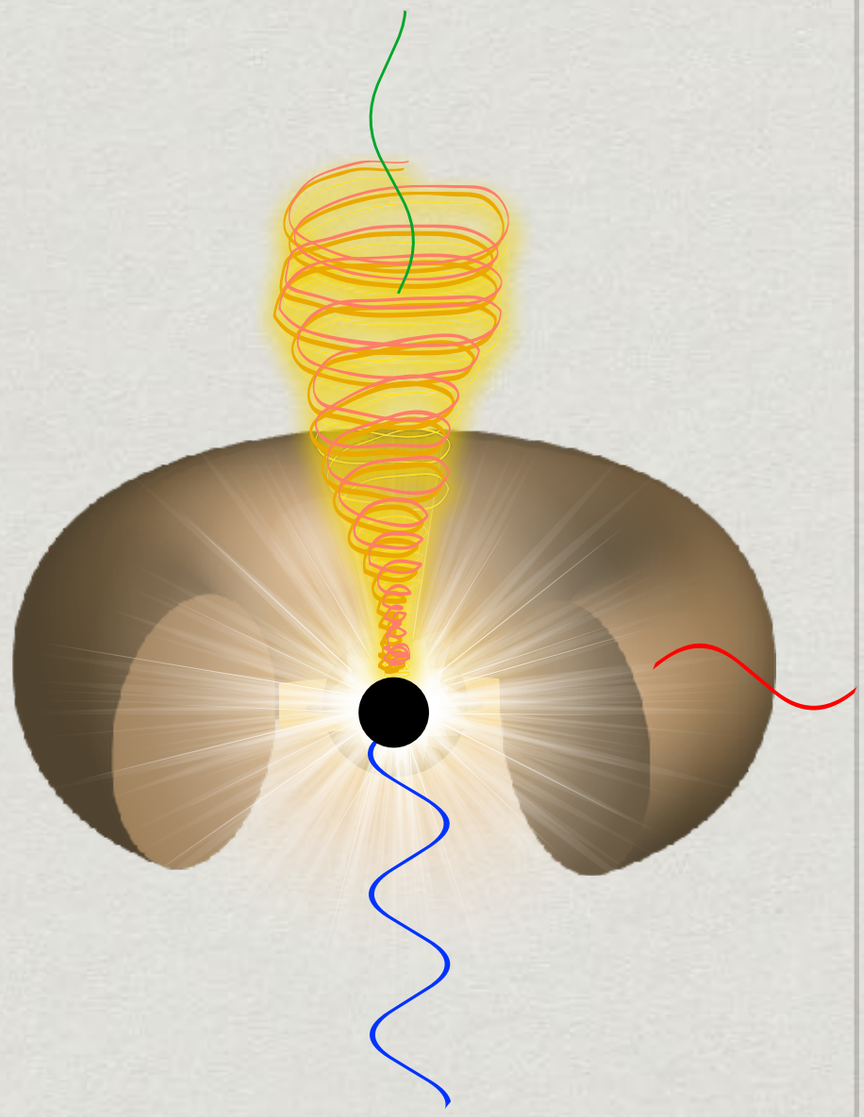
Control Sample

Image Credit: NASA/JPL-Caltech

GOAL:

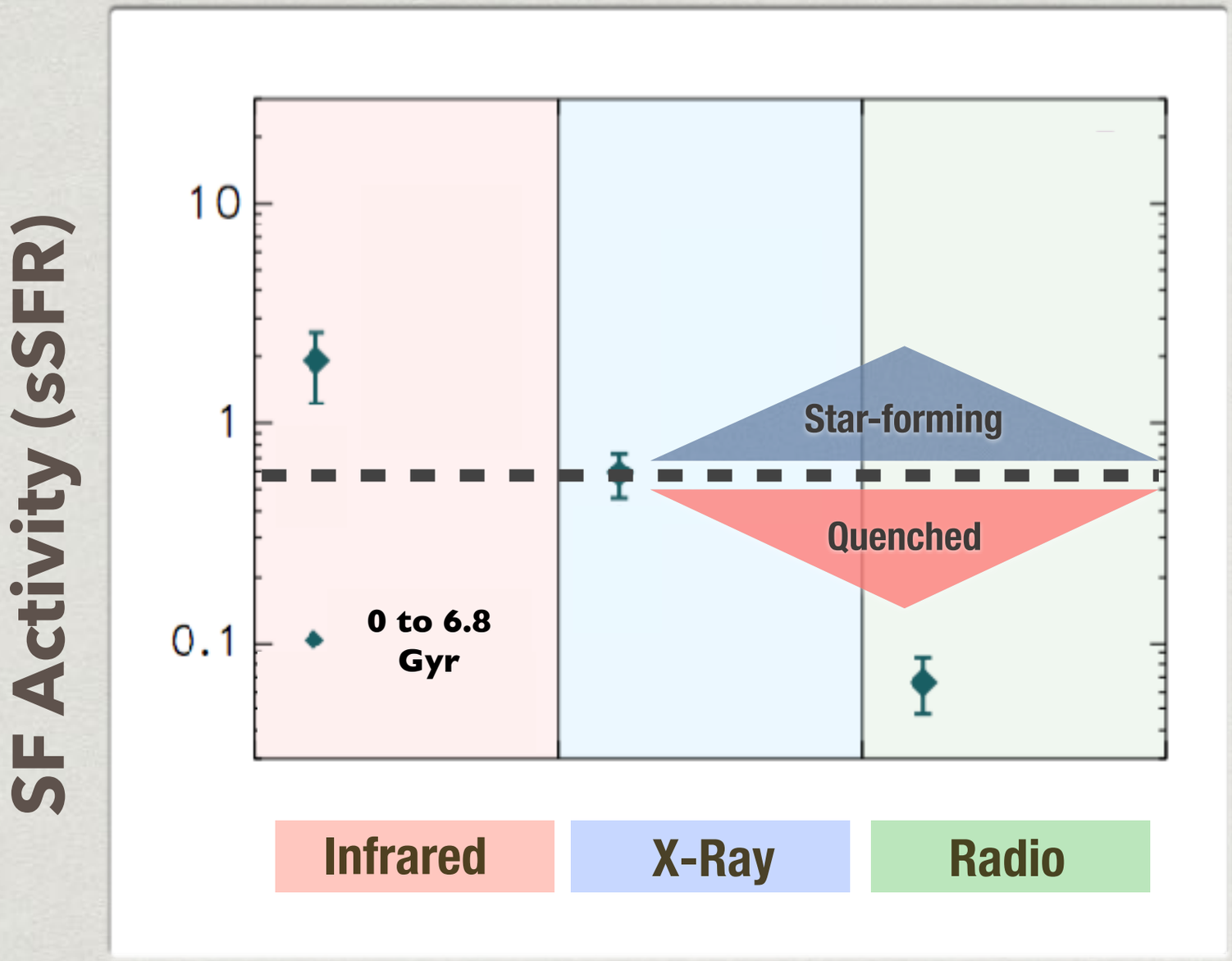
COMPARE THE STAR-FORMATION ACTIVITY OF GALAXIES HOSTING AN ACTIVE BLACK HOLE TO THOSE WITHOUT





GOAL:

COMPARE THE STAR-FORMATION ACTIVITY OF GALAXIES HOSTING AN ACTIVE BLACK HOLE TO THOSE WITHOUT



Infrared w/ Active Black Hole

Star forming hosts

X-ray w/ Active Black Hole

Straddles between star-forming and quiescent

Radio w/ Active Black Hole

Quenched hosts

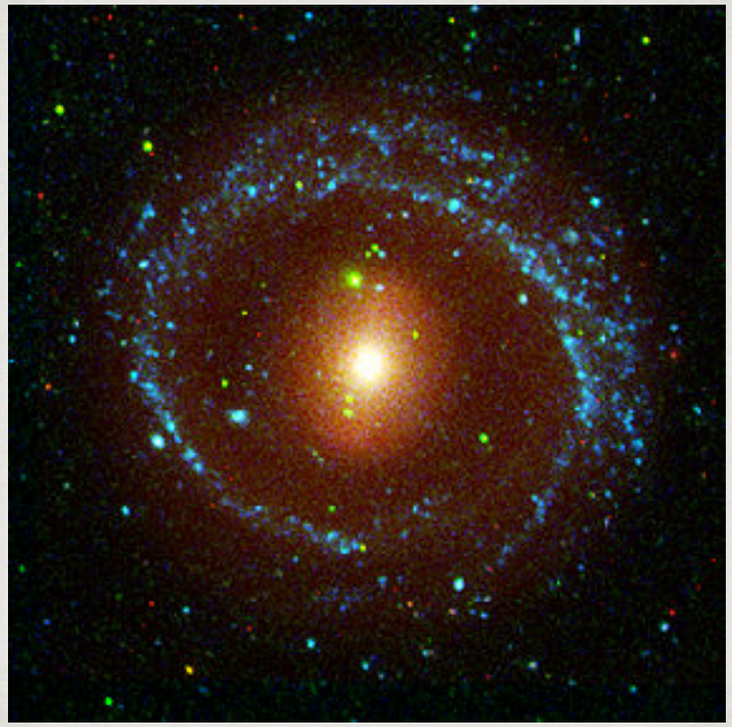
GOAL:

COMPARE THE STAR-FORMATION ACTIVITY OF GALAXIES HOSTING AN ACTIVE BLACK HOLE TO THOSE WITHOUT

Infrared w/ Active Black Hole

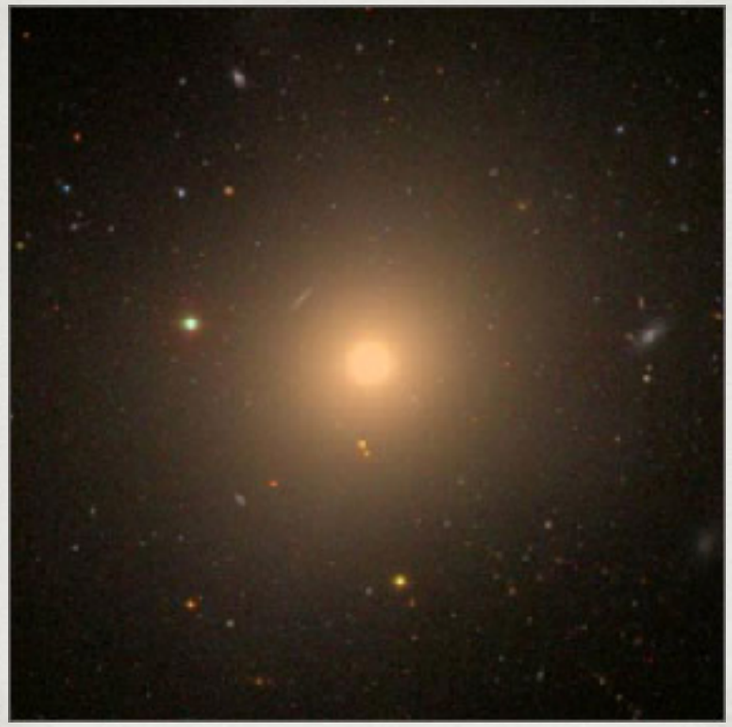
Younger Galaxies

X-Ray w/ Active Black Hole



Transitional

Radio w/ Active Black Hole

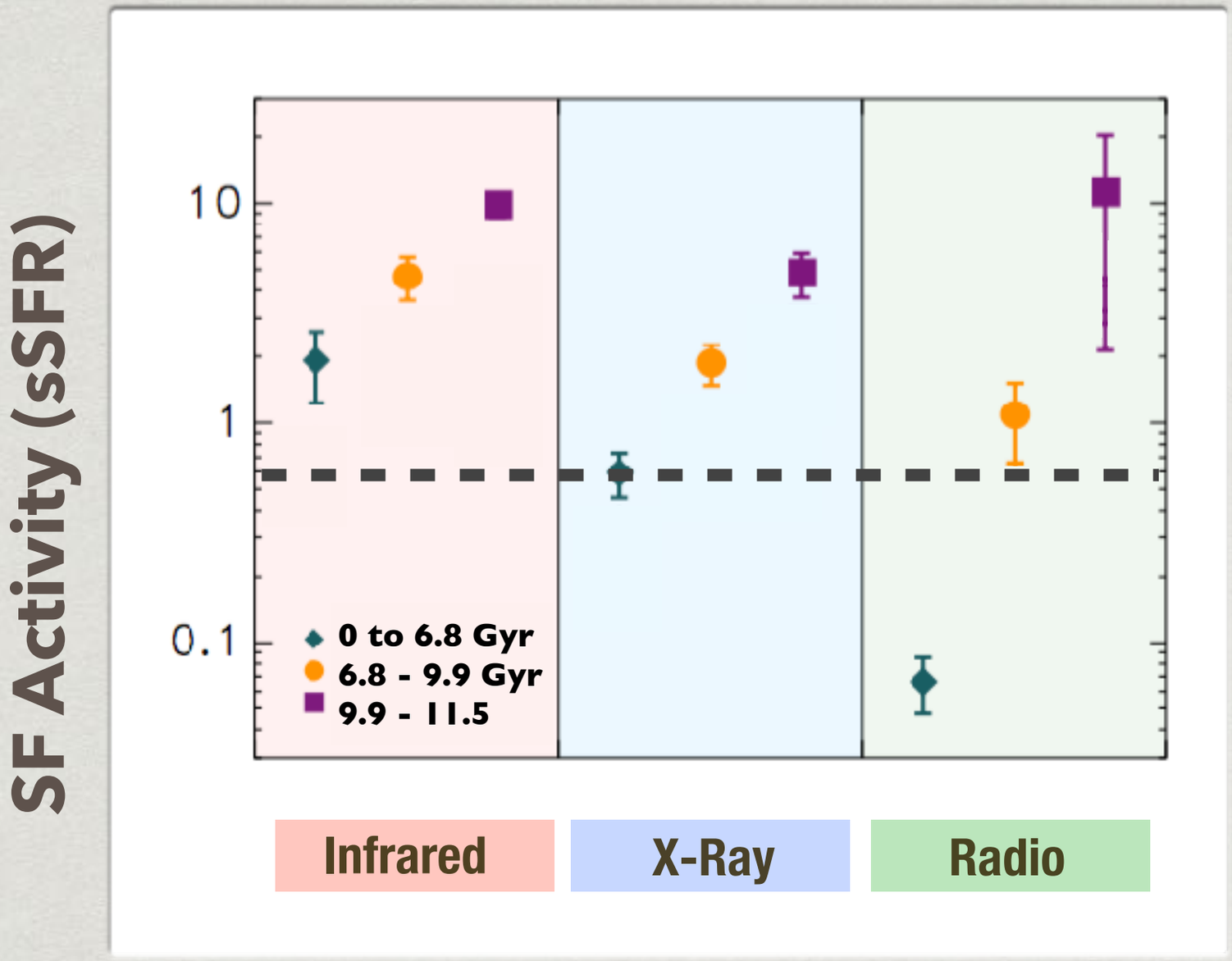


Older Galaxies

Image Credit: NASA/JPL-Caltech

GOAL:

COMPARE THE STAR-FORMATION ACTIVITY OF GALAXIES HOSTING AN ACTIVE BLACK HOLE TO THOSE WITHOUT



Infrared w/ Active Black Hole

Star forming hosts

X-ray w/ Active Black Hole

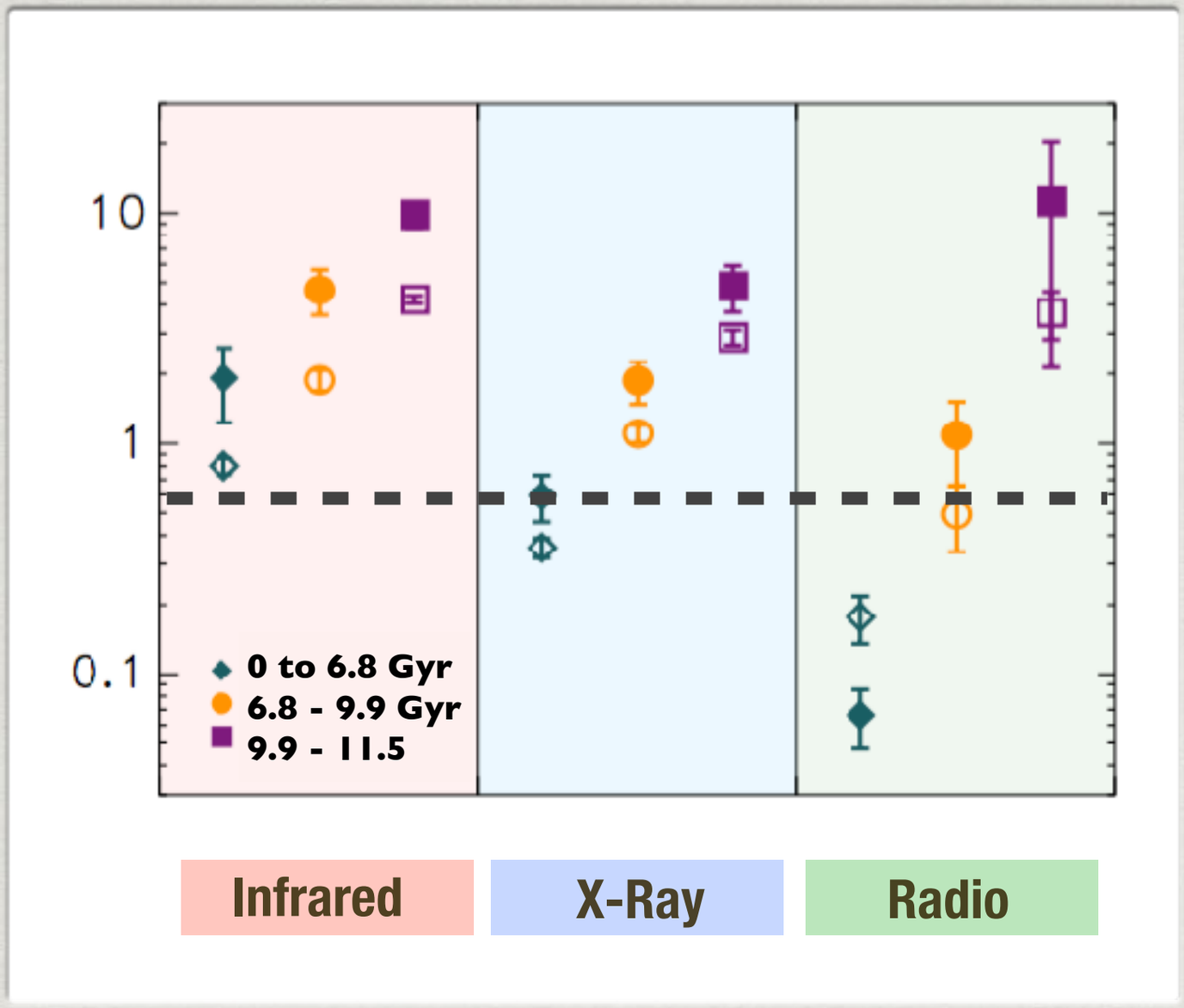
Star forming hosts

Radio w/ Active Black Hole

Star forming hosts

GOAL:

COMPARE THE STAR-FORMATION ACTIVITY OF GALAXIES HOSTING AN ACTIVE BLACK HOLE TO THOSE WITHOUT



Infrared w/ Active Black Hole

Star forming hosts

X-ray w/ Active Black Hole

Star forming hosts

Radio w/ Active Black Hole

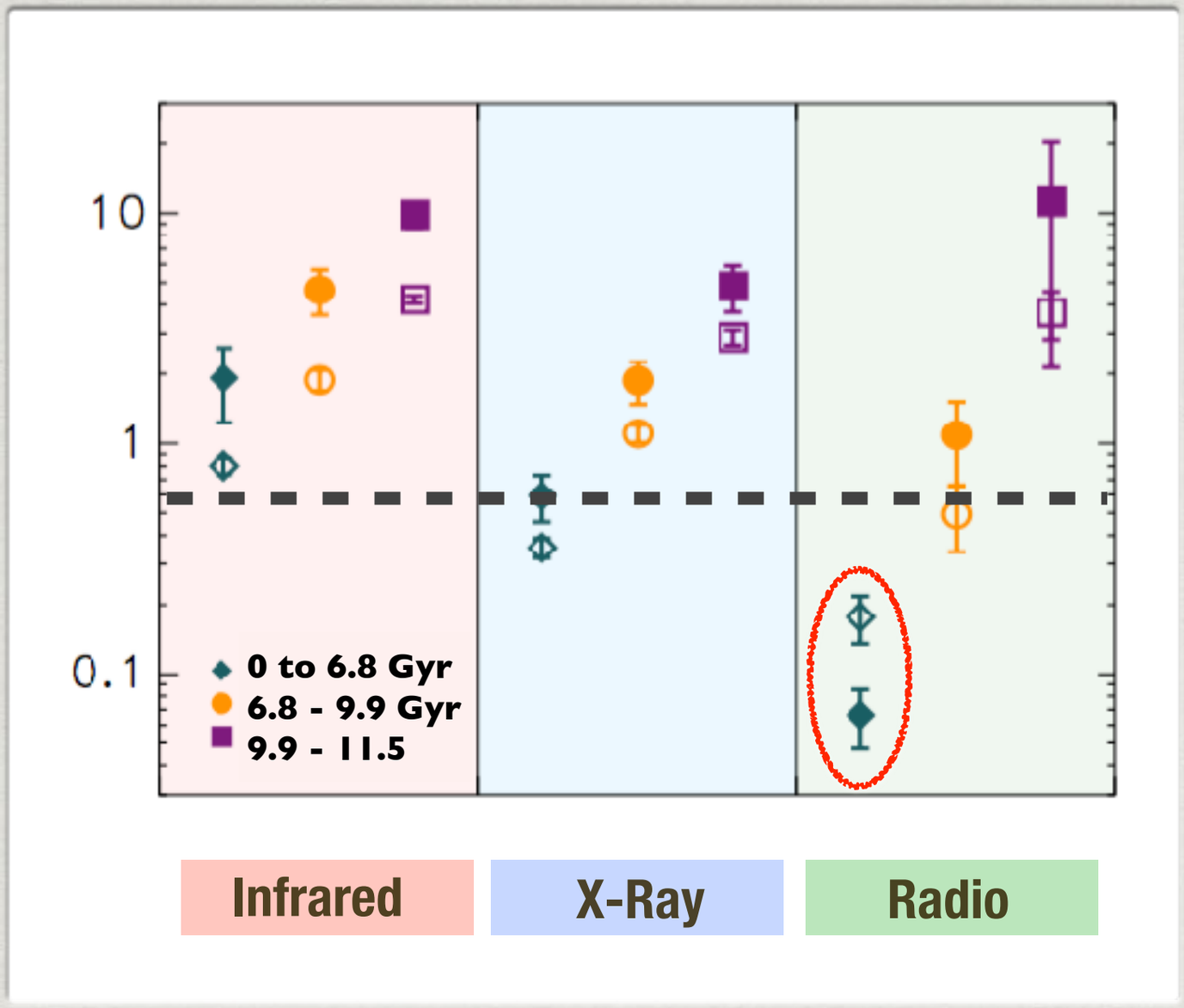
Star forming hosts

"Normal" Galaxies

Lower SF activity!

GOAL:

COMPARE THE STAR-FORMATION ACTIVITY OF GALAXIES HOSTING AN ACTIVE BLACK HOLE TO THOSE WITHOUT



Infrared w/ Active Black Hole

Star forming hosts

X-ray w/ Active Black Hole

Star forming hosts

Radio w/ Active Black Hole

Star forming hosts

"Normal" Galaxies

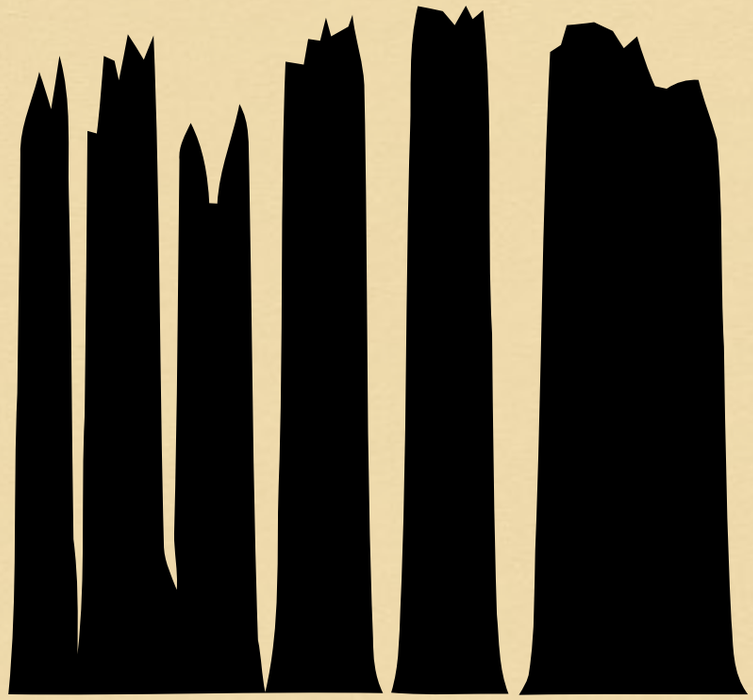
Lower SF activity!

SUMMARY

- The mean star-formation activity of the control sample or “normal” galaxies tends to be lower than galaxies hosting an active supermassive black hole
- This calls into question the significance of black hole feedback being a primary mechanism for the suppression of star-formation in galaxies
- The only instance the above is not true is the radio-selected galaxies in the “local” universe

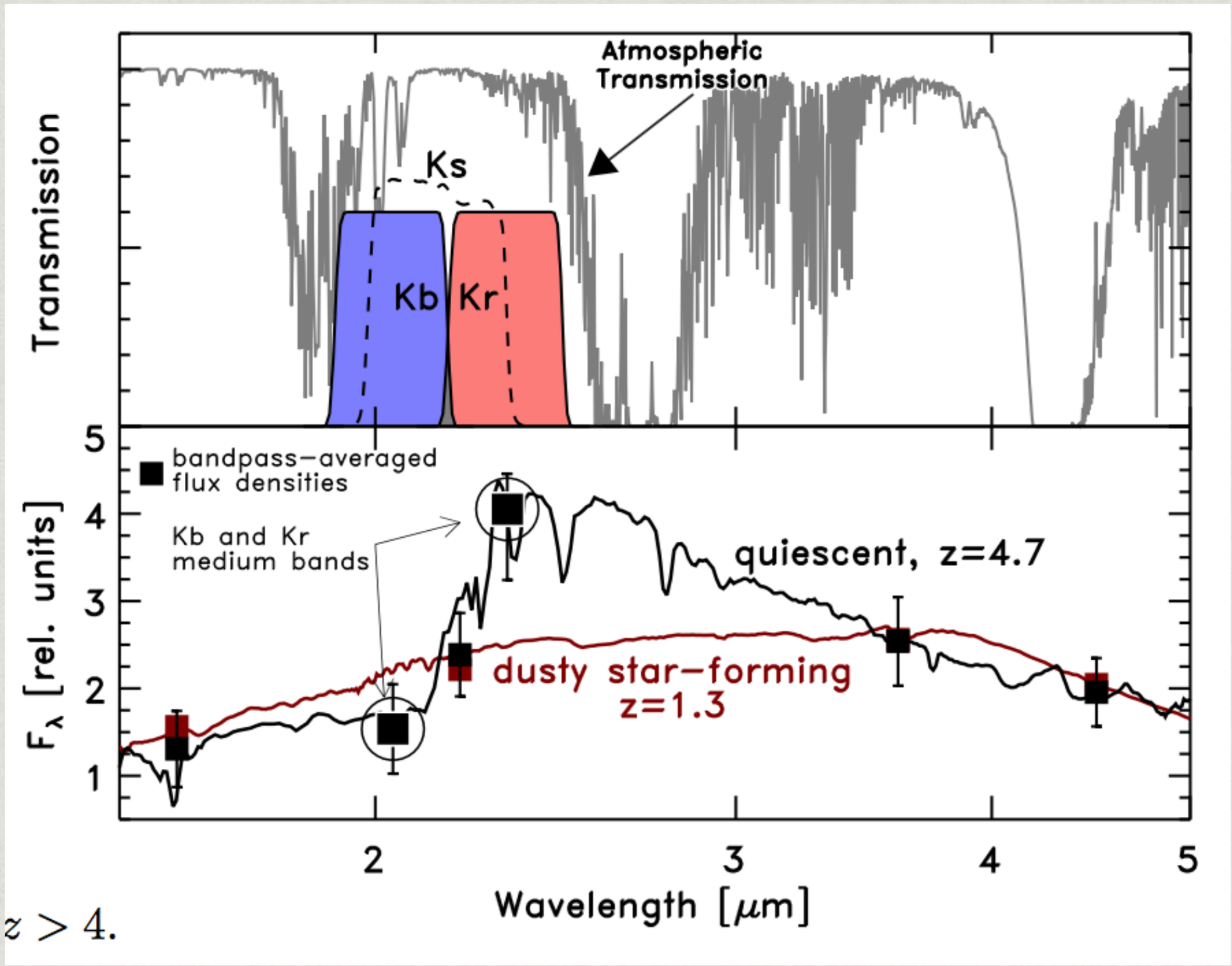
… what about the rest of cosmic time?

The Future?



ZFOURGE 2.0

FourStar Galaxy Evolution Survey



$z > 4.$

THANK YOU!
QUESTIONS?

MICHAEL COWLEY

Northern Sydney Astronomical Society, August 16th 2016

MACQUARIE University
SYDNEY·AUSTRALIA

Australian Government
Department of Industry and Science

AAO

NGC 1672: NASA, ESA and the Hubble Heritage Team