Observational insights into Black Hole feedback at high-redshift

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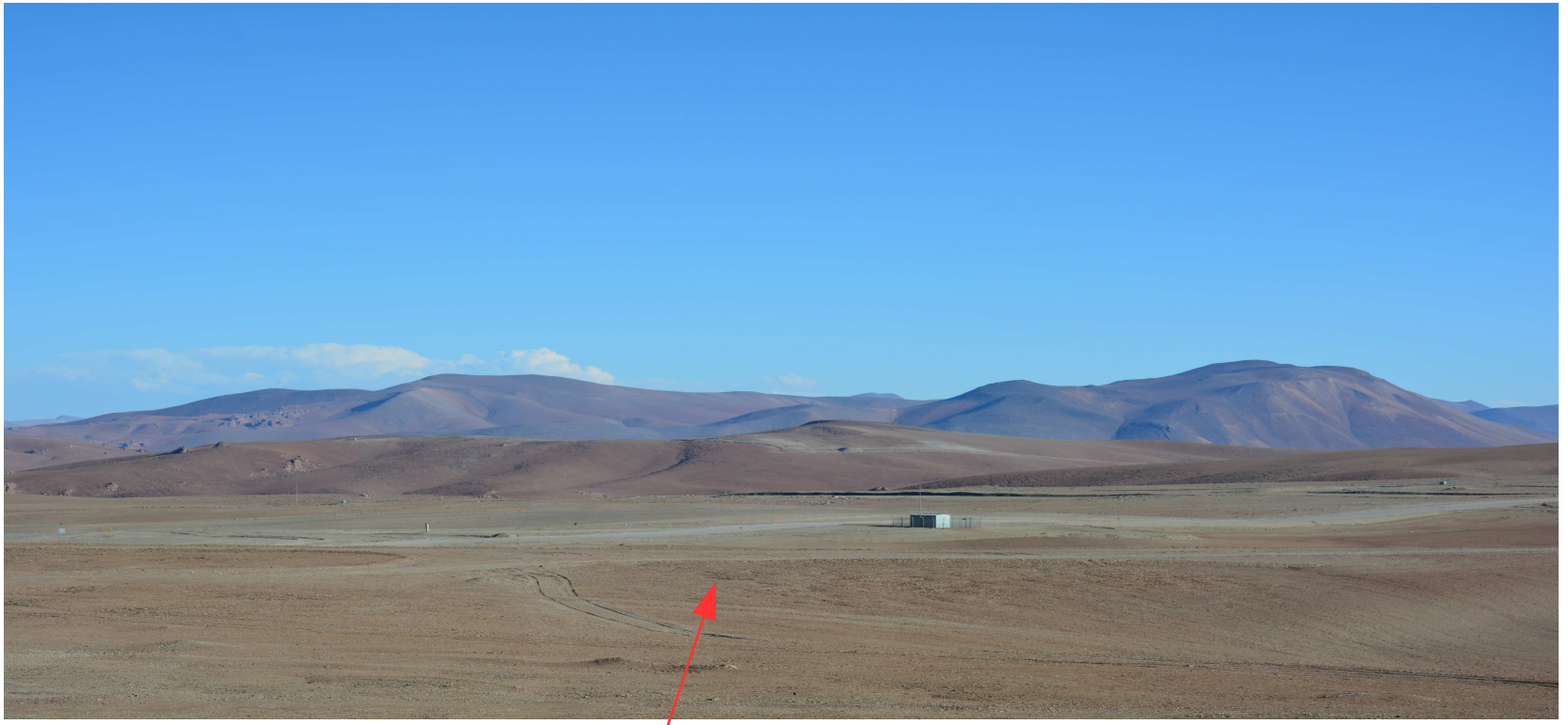
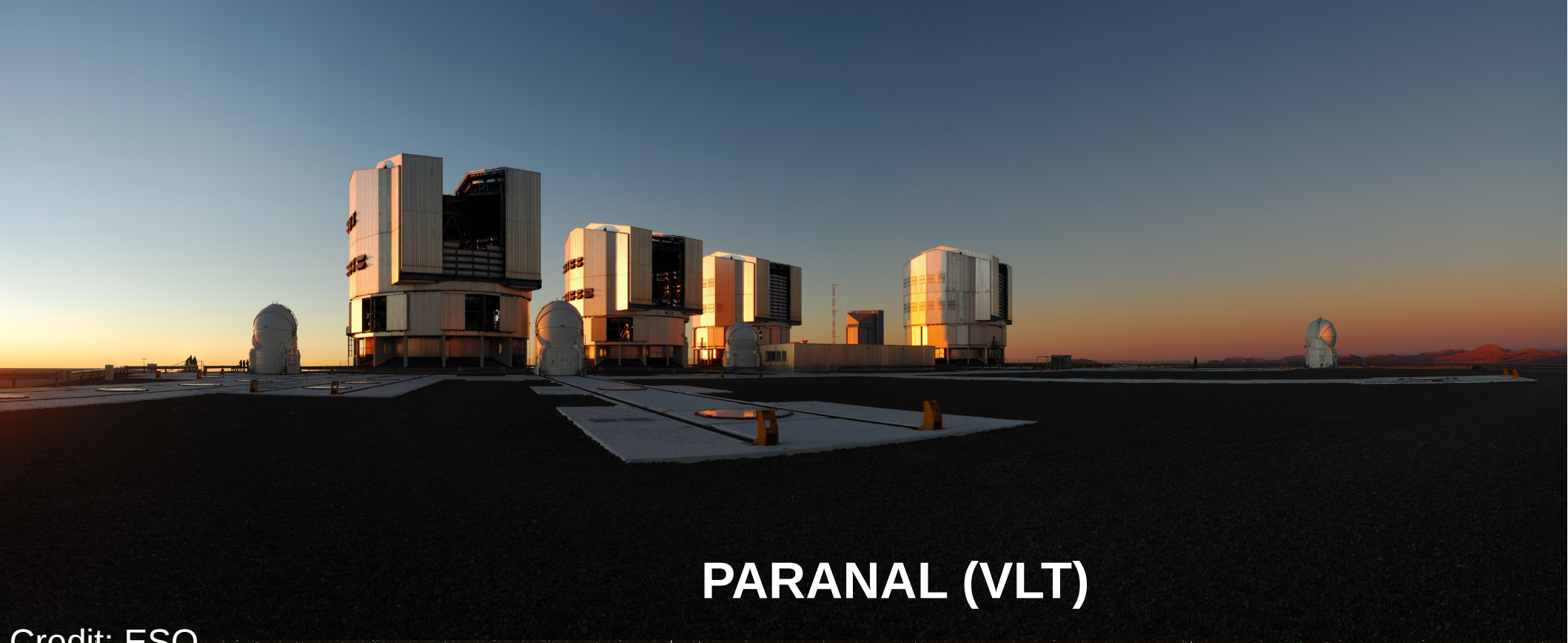
Germany




Chile

Credit: ESO



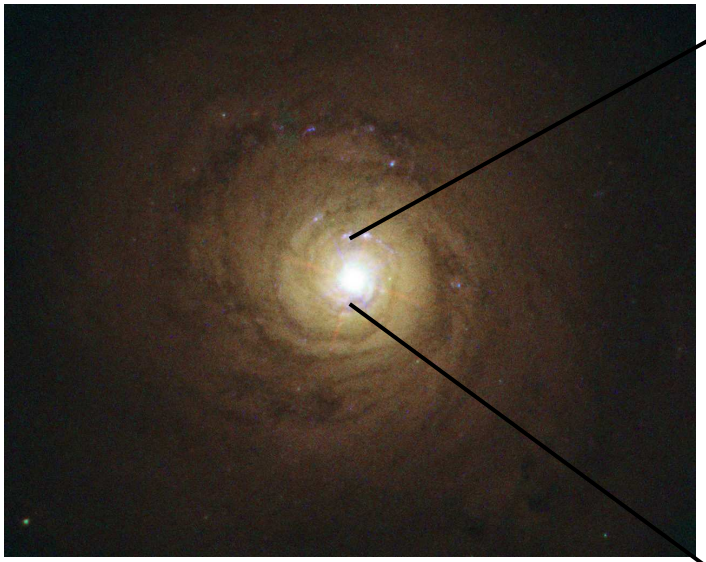
Credit: ESO

Scientific Topics

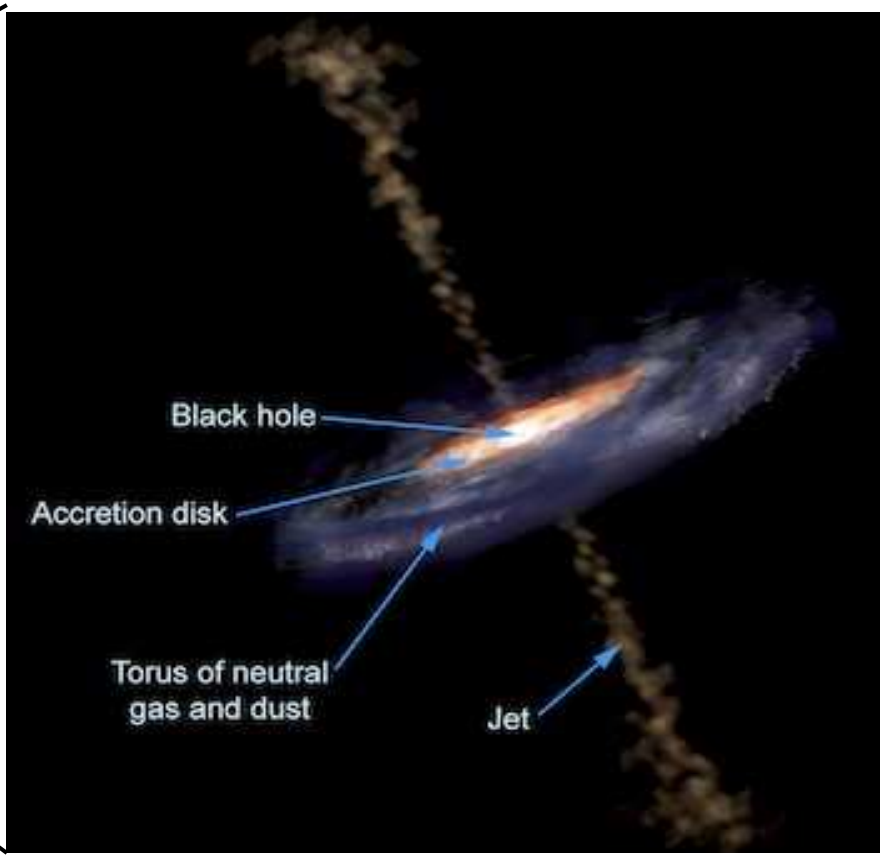
- Planets and Star Formation
- Stellar Structure and Evolution
- Stellar Populations
- Evolution of Galaxies and Interstellar Medium
- Cosmology and the early Universe

Observing proposal deadline: ****28 September, 2017****

Active Galactic Nuclei

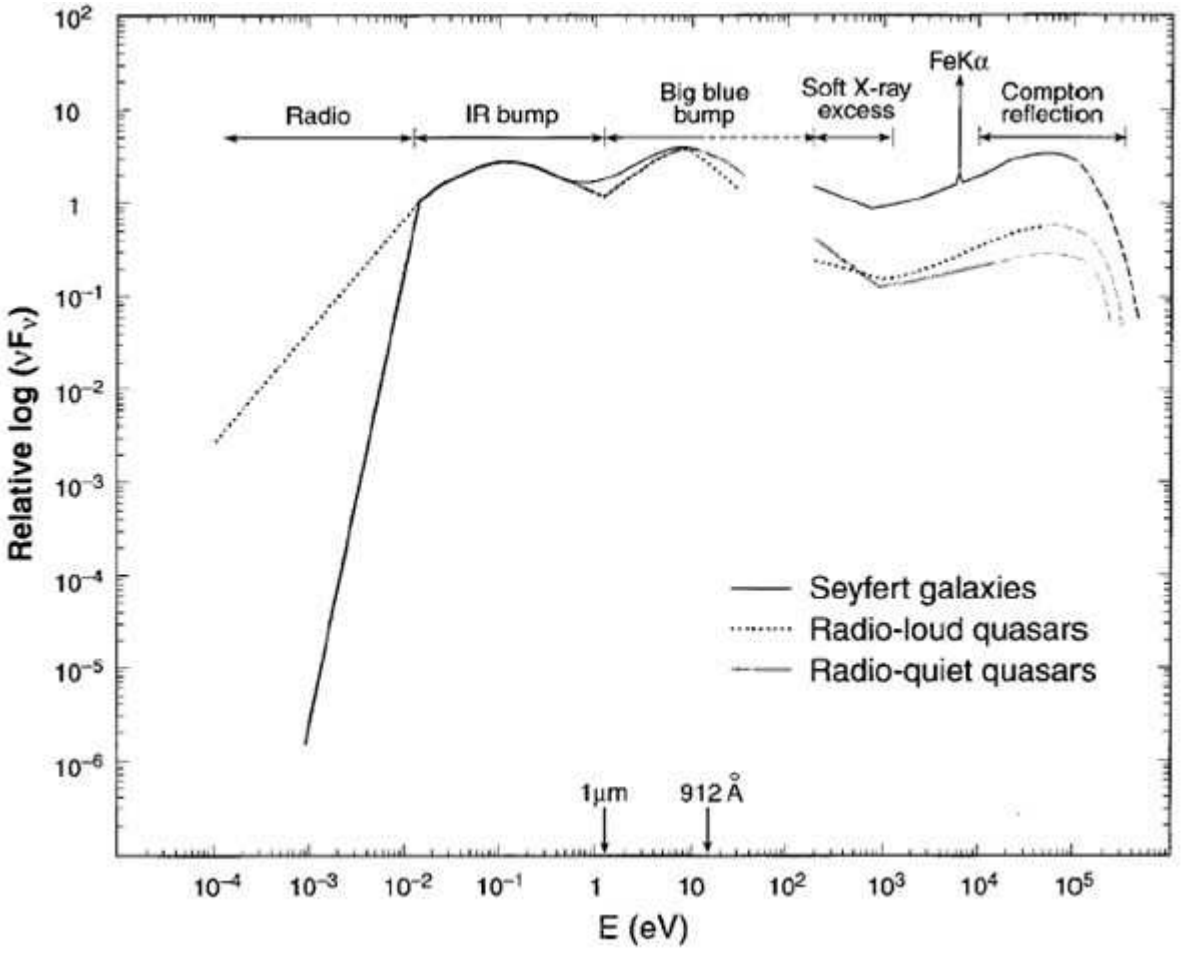


Credit:ESA/NASA



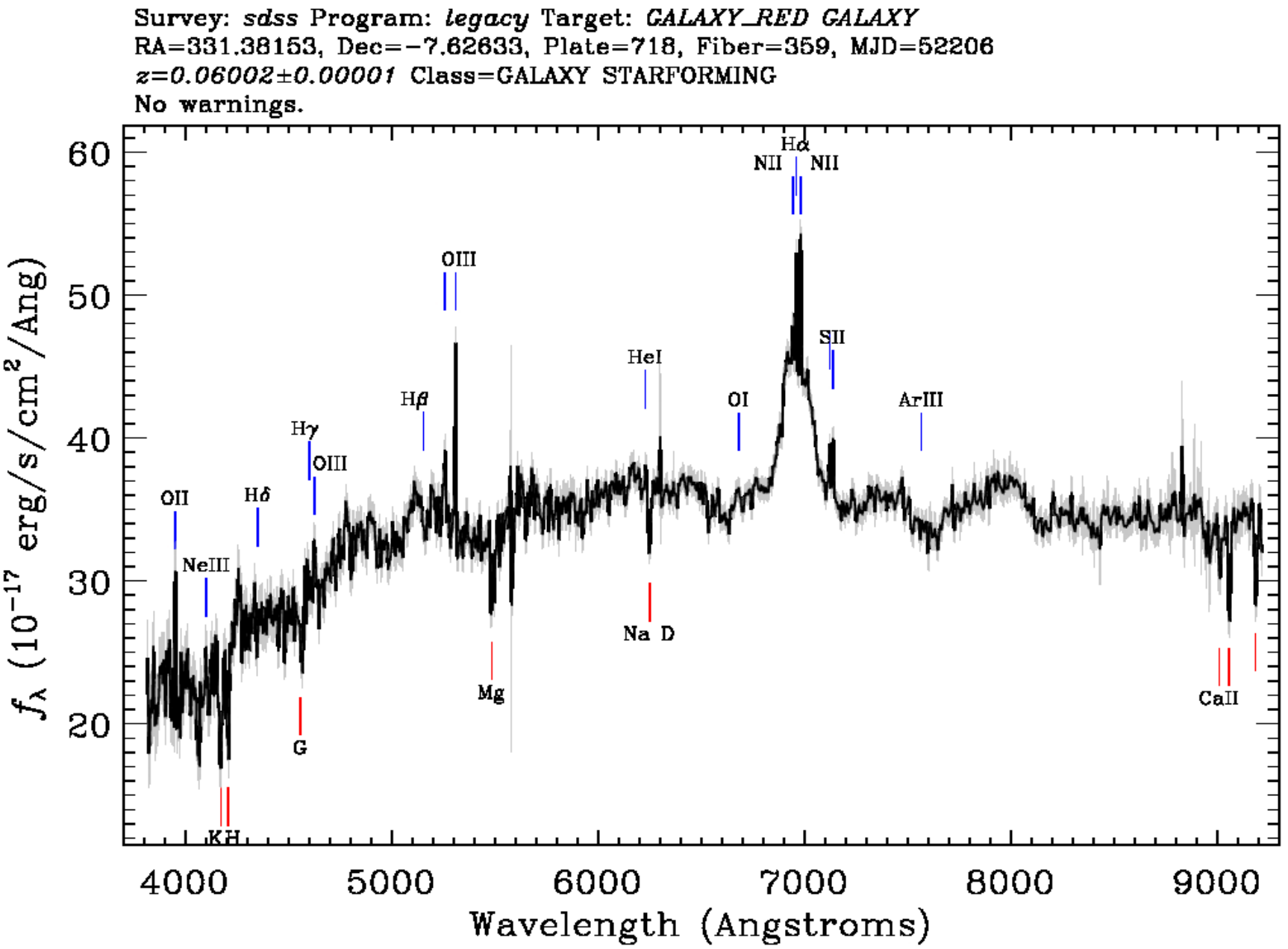
Every massive galaxy has a black hole at it's center
Including the Milky Way

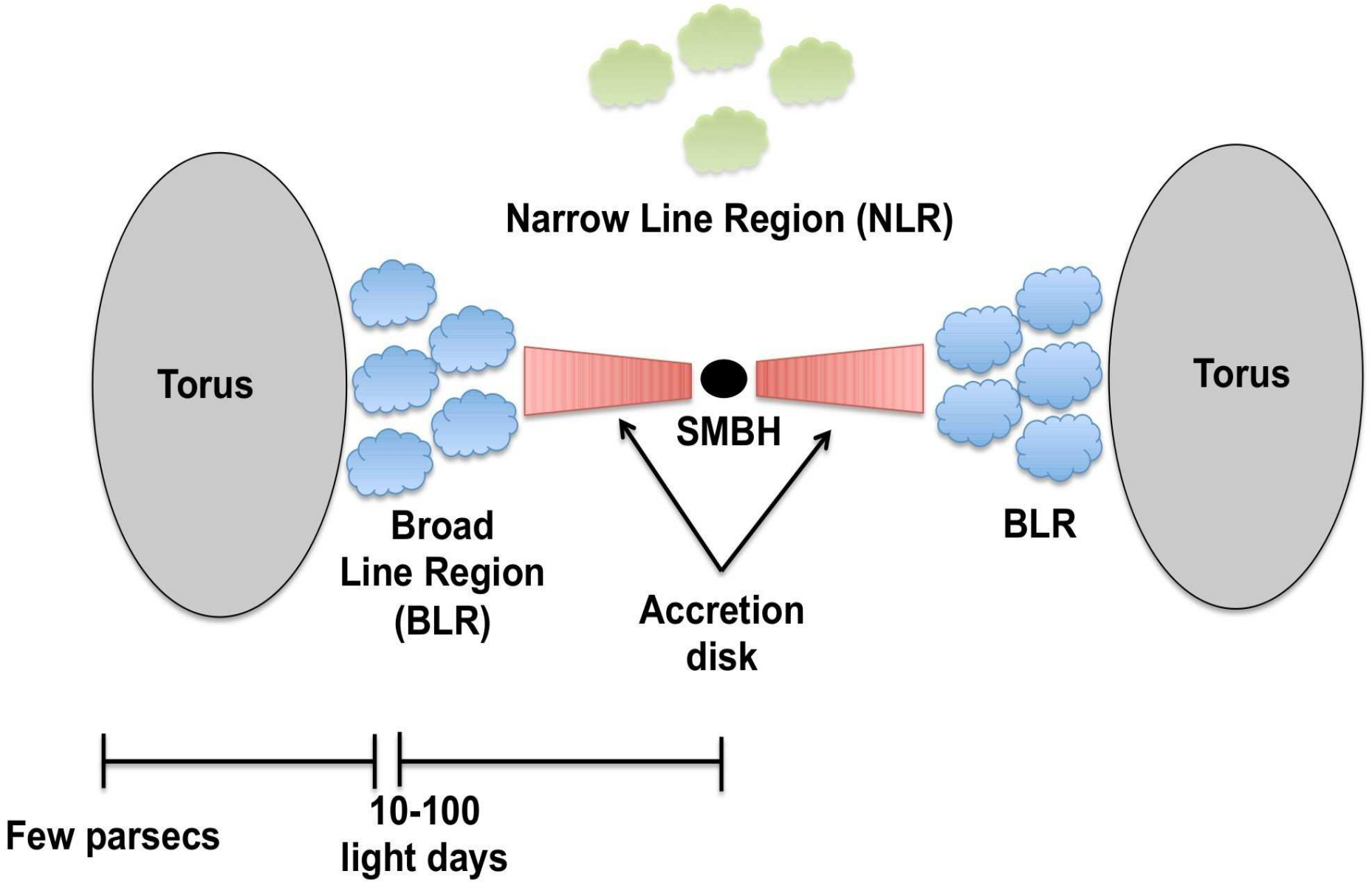
Spectral Energy Distribution



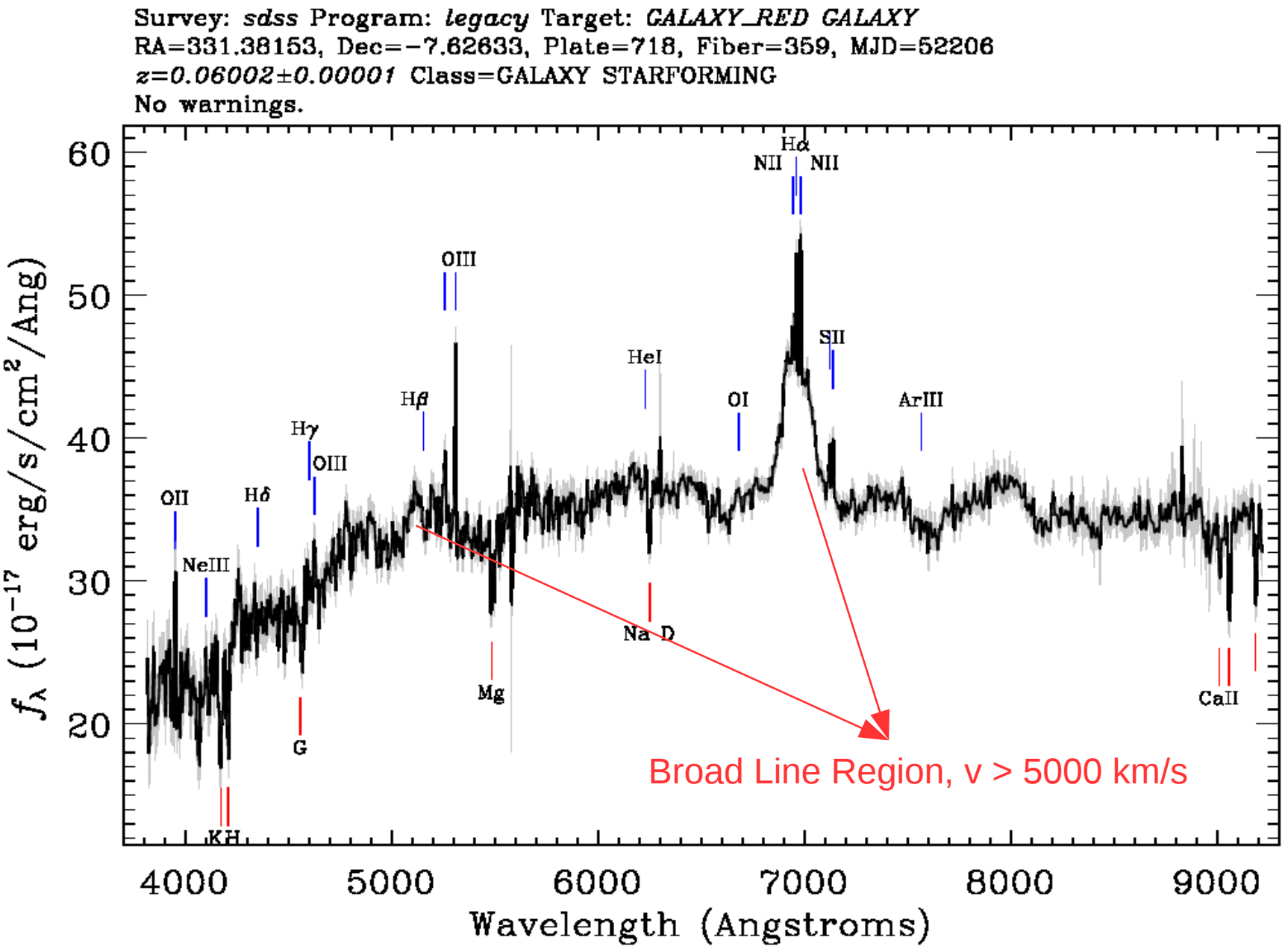
AGNs are visible in almost every wavelength

Typical Spectrum of an AGN

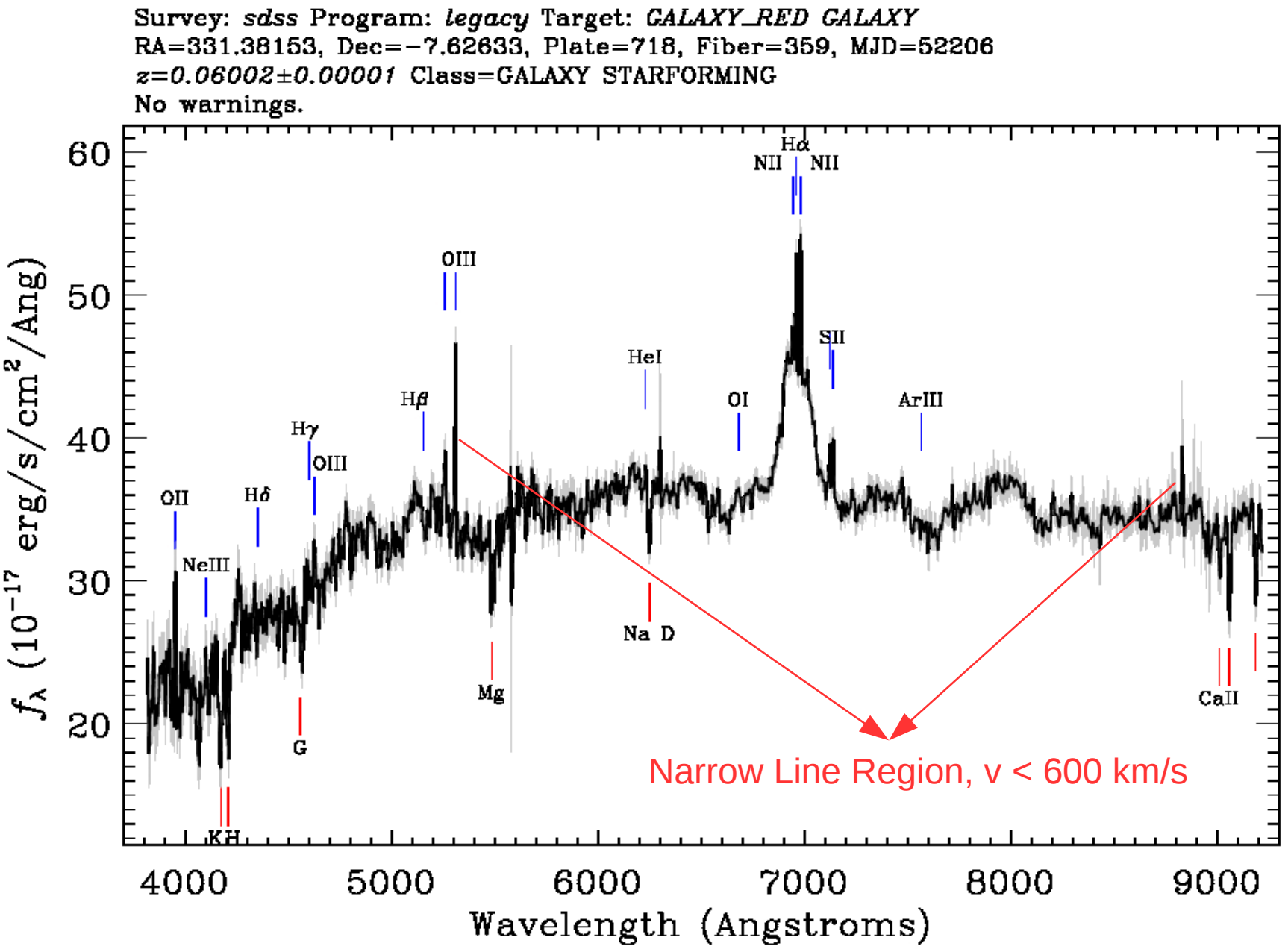



Narrow Line Region (NLR)
Torus
Torus
SMBH
Broad
Line Region
(BLR)
BLR
Accretion
disk
Few parsecs
10-100
light days

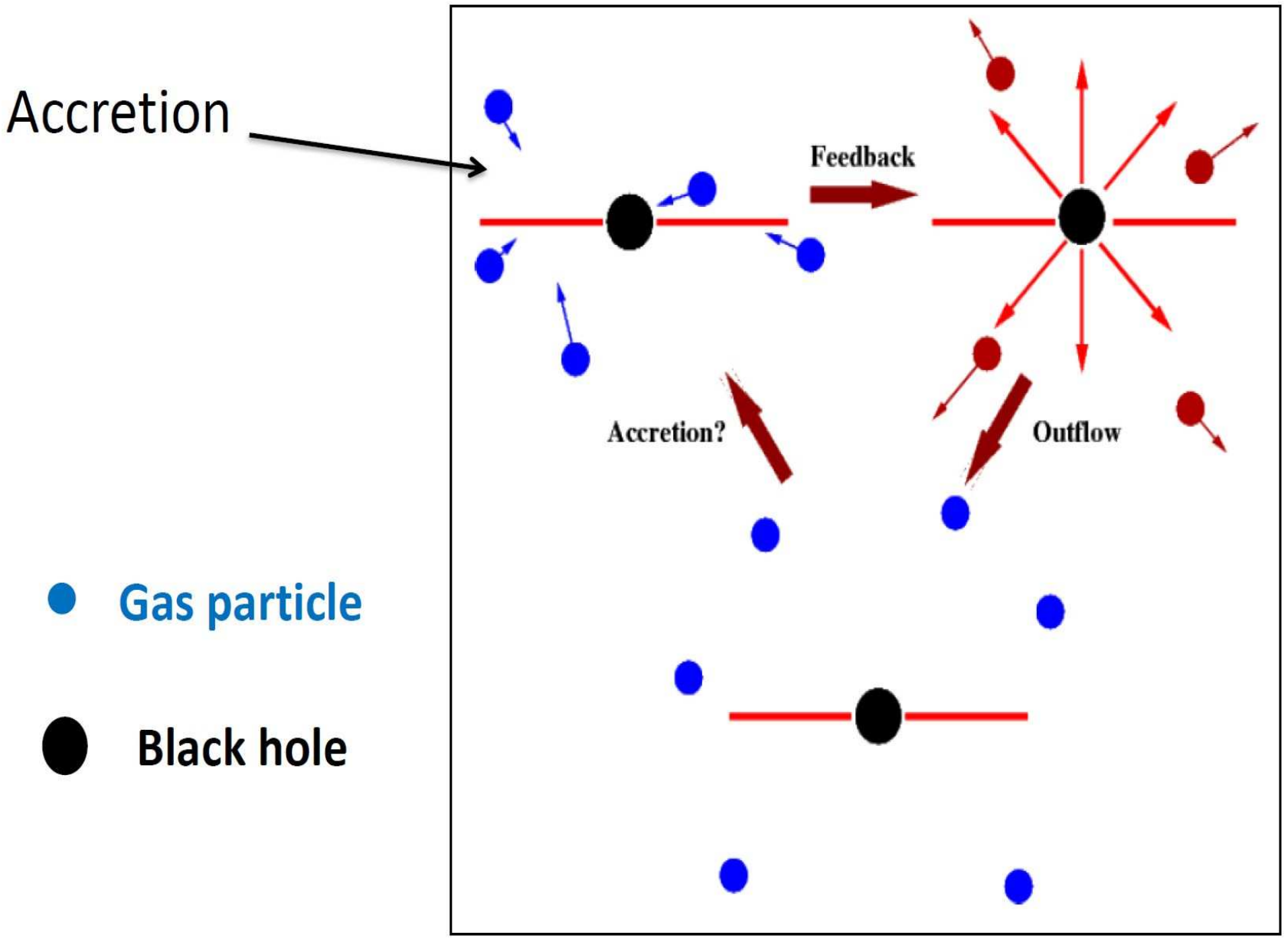
Typical Spectrum of an AGN

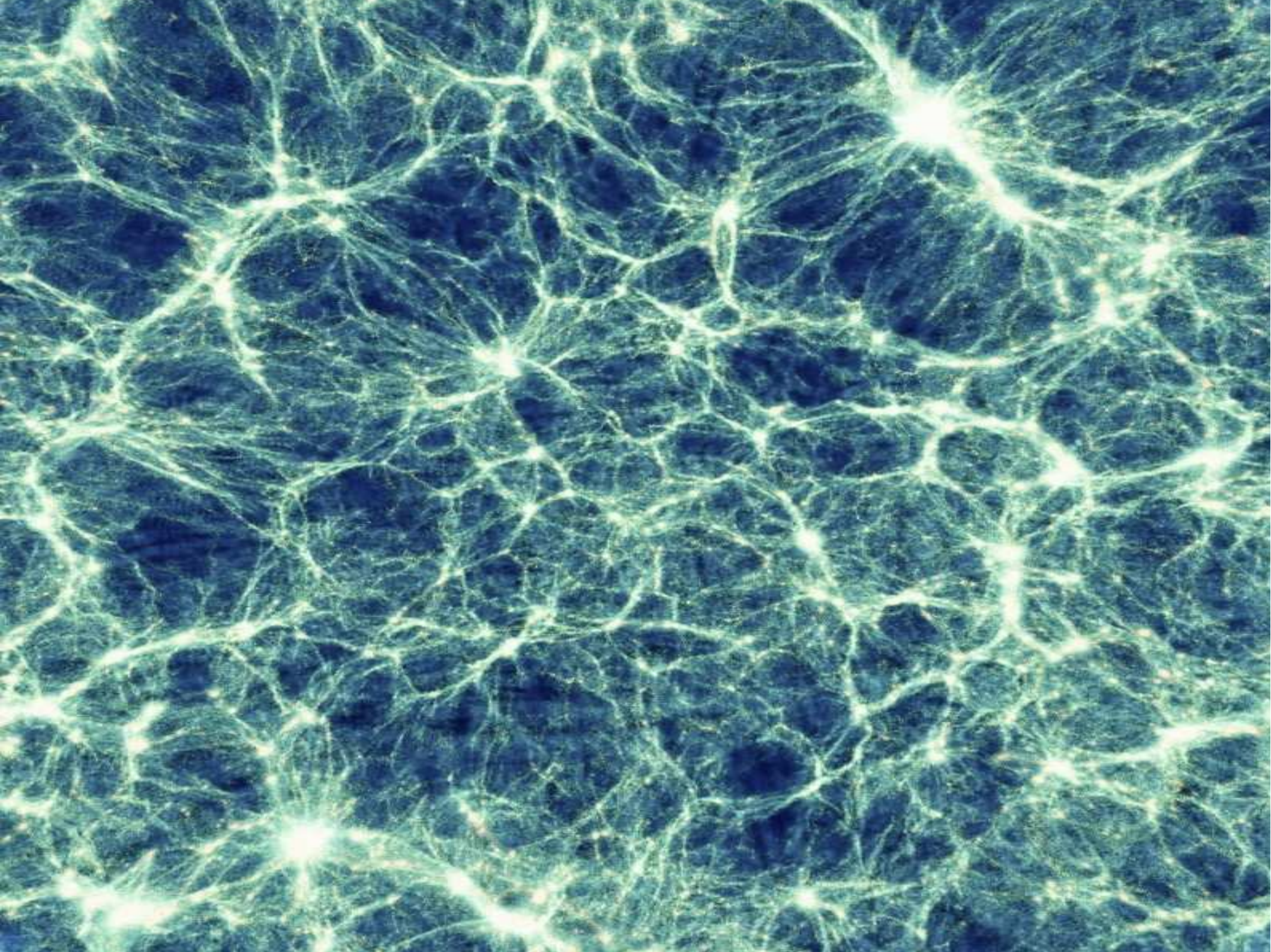


Typical Spectrum of an AGN

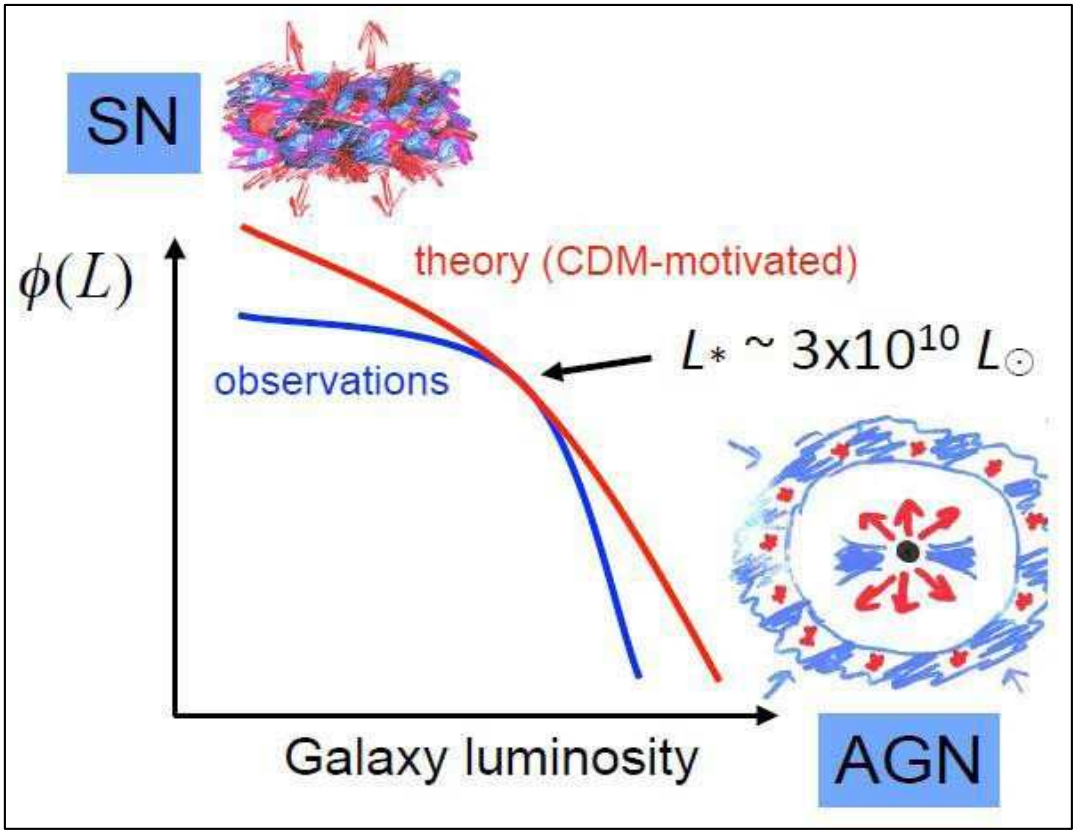


AGN feedback





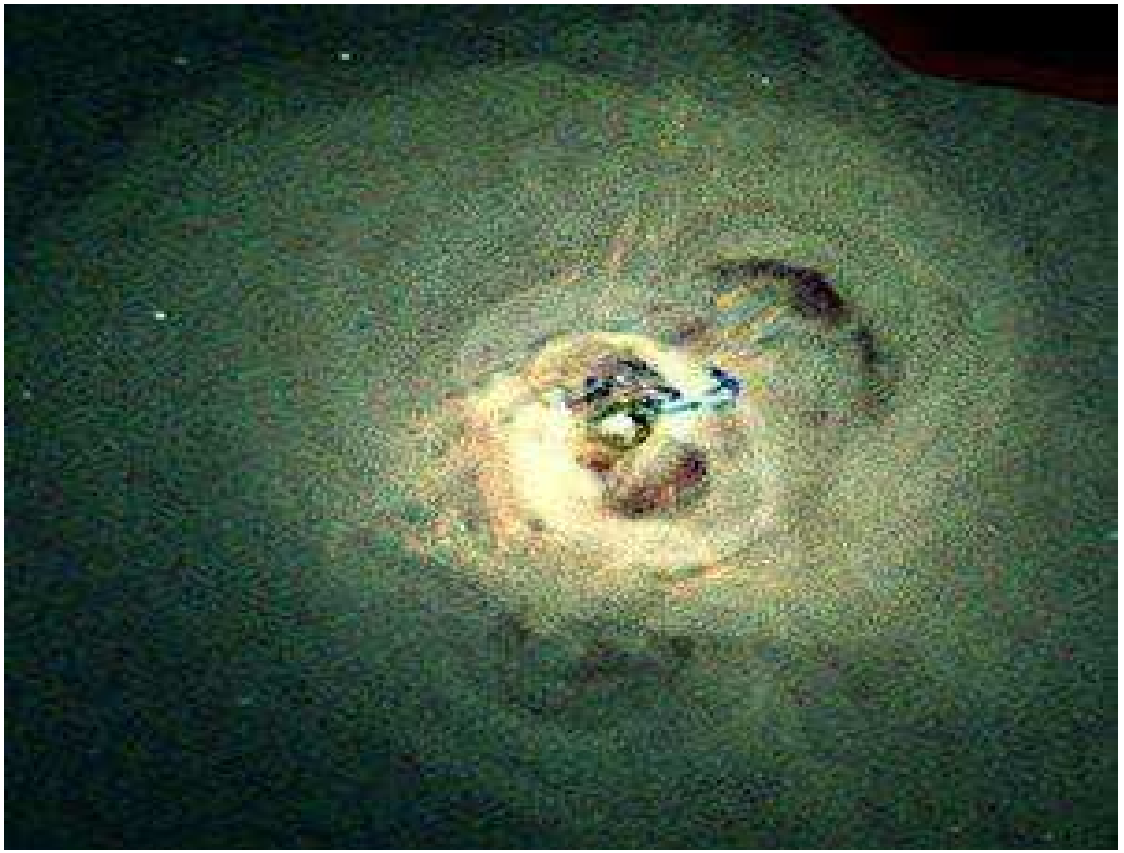
Galaxy Luminosity Functions



Silk+ 2012

A cosmological simulation without AGN feedback over-predicts the number of massive galaxies

X-ray observations of Bubbles



Fabian +2012

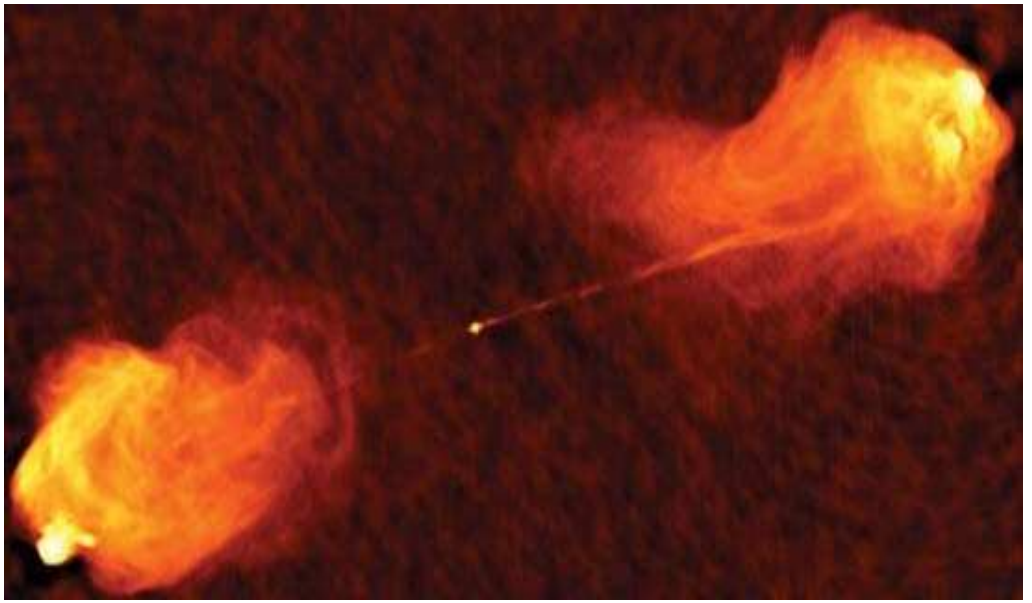
X-ray observations of Perseus cluster shows cavities believed to be blown by the central black hole

Two kinds of AGN feedback

Radiative mode

Wide angled outflows

Kinetic mode



Collimated relativistic radio jets

Image Credits: NRAO/AUI

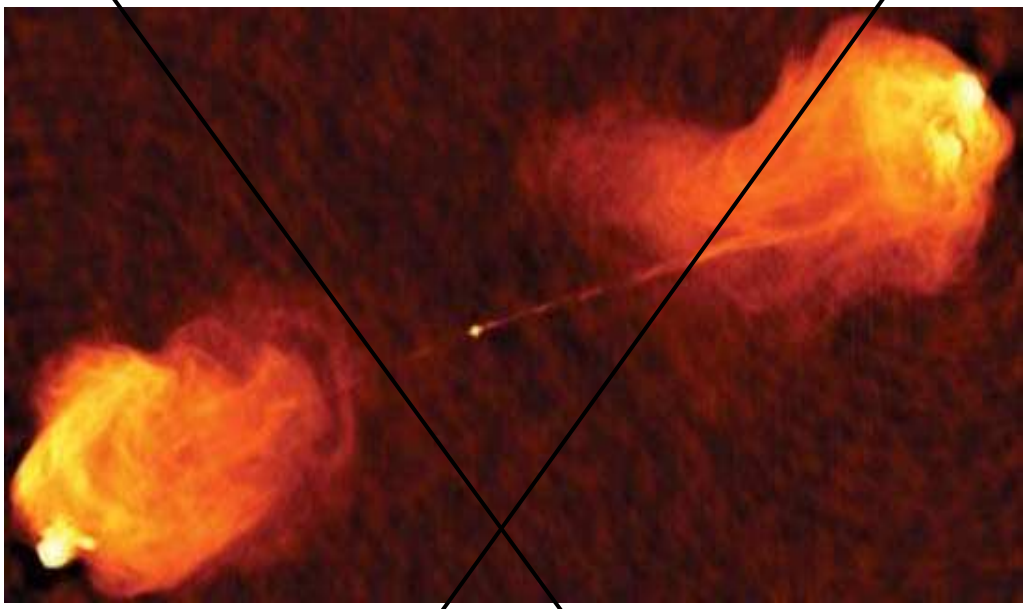
Two kinds of AGN feedback

Radiative mode

Wide angled outflows

Prevalent in high mass accretion objects

Kinetic mode

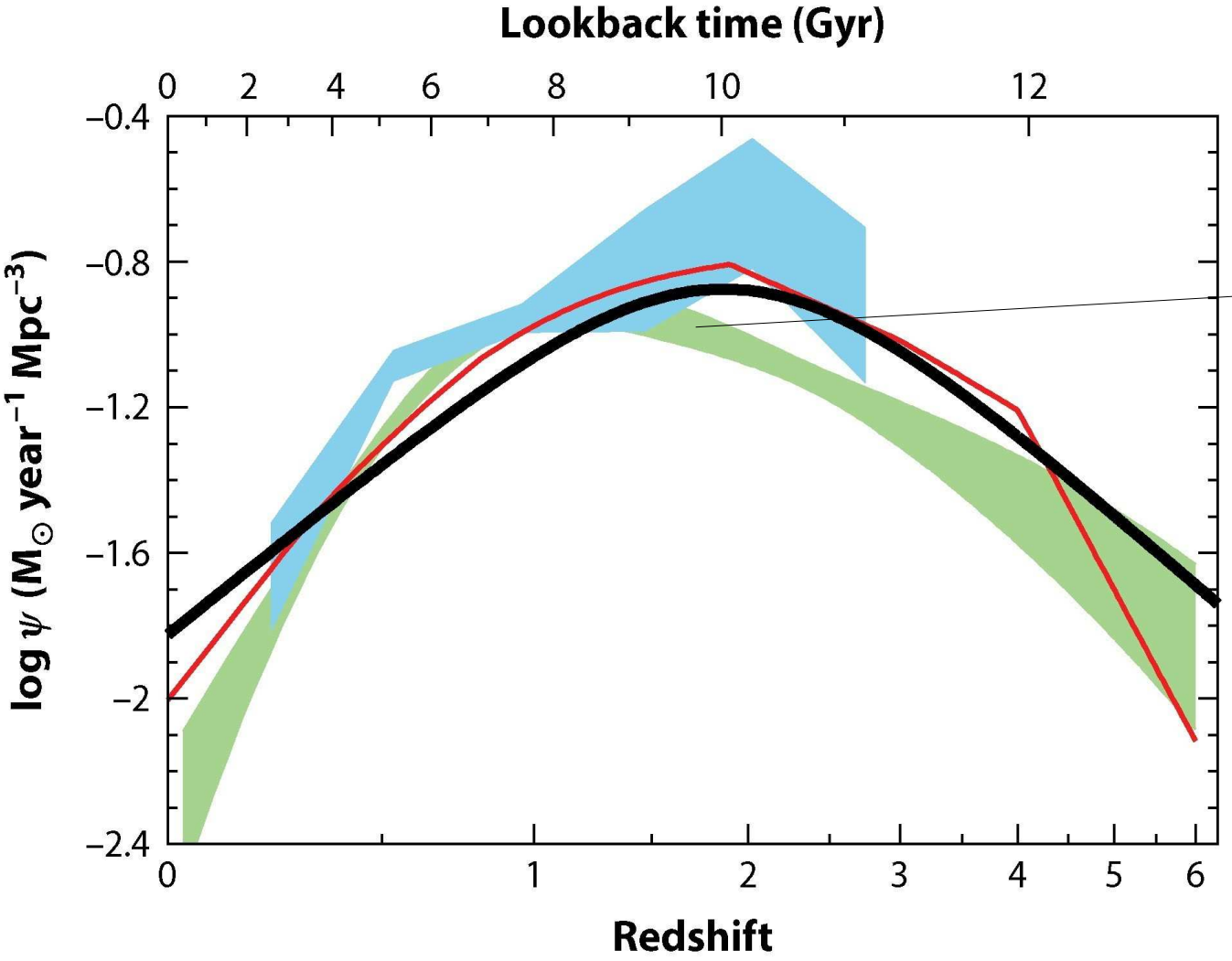


Collimated relativistic radio jets

Image Credits: NRAO/AUI

Find a direct observational evidence of radiative feedback

Black Hole growth history

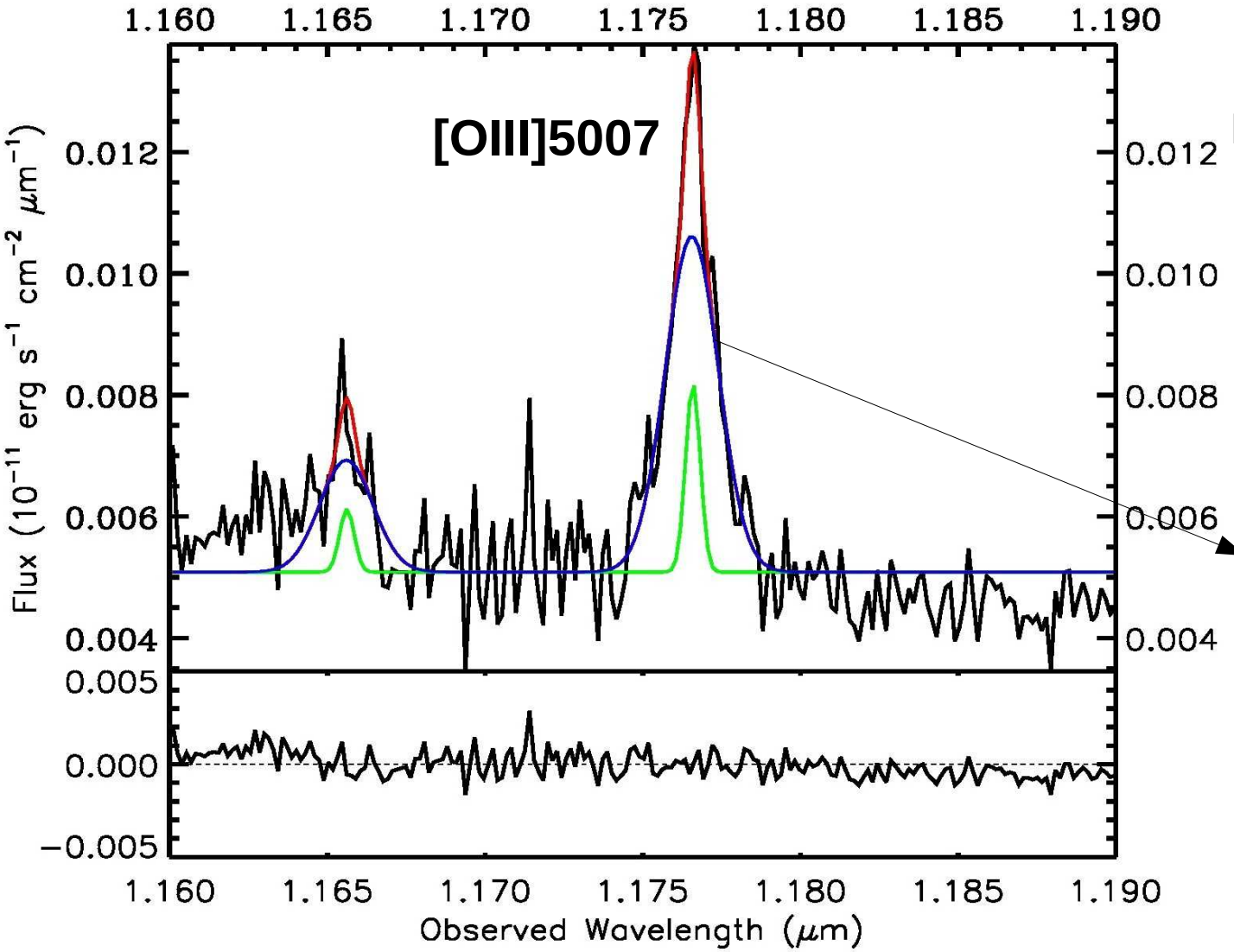


Ideal to test
Radiative feedback

Search for outflows and high velocity winds

Madau & Dickinson (2014)

Signature of outflows in NLR



In the absence of outflow, the emission lines would have been symmetrical → Gaussian

Presence of broad Gaussian components

Kakkad +2016

Quick Recap

- Line to trace → [OIII]5007
- Redshift Range → 1-3
- Targets → AGN at high mass accretion rates, preferably X-ray selected
- Outflows → Spatially resolved

Method → Integral Field Spectroscopy in the near-Infrared

Integral Field Spectroscopy

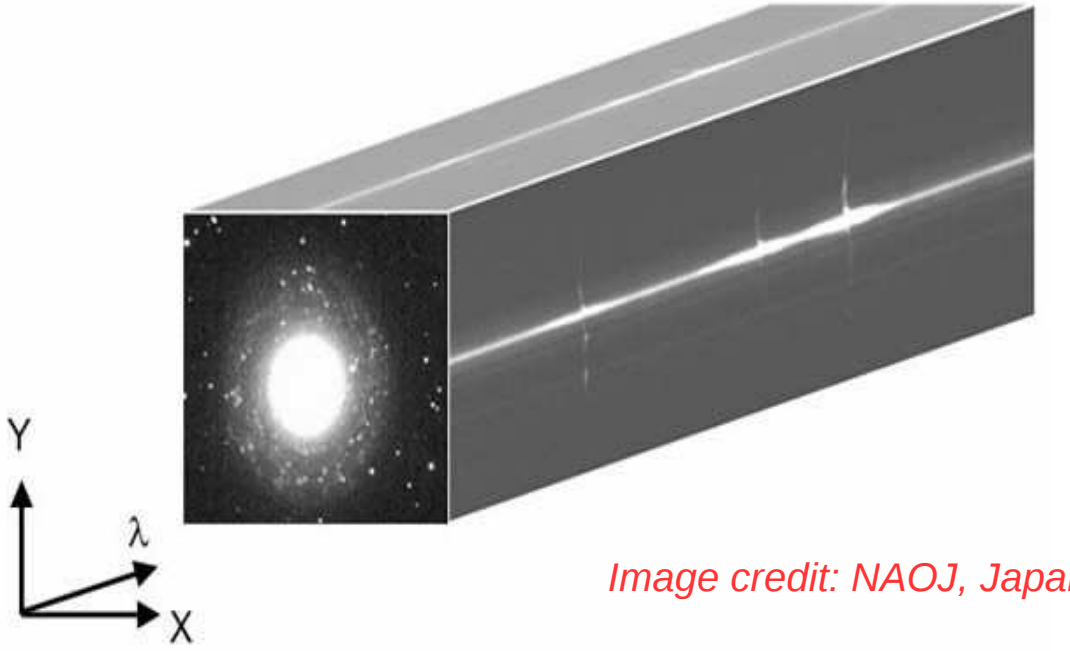
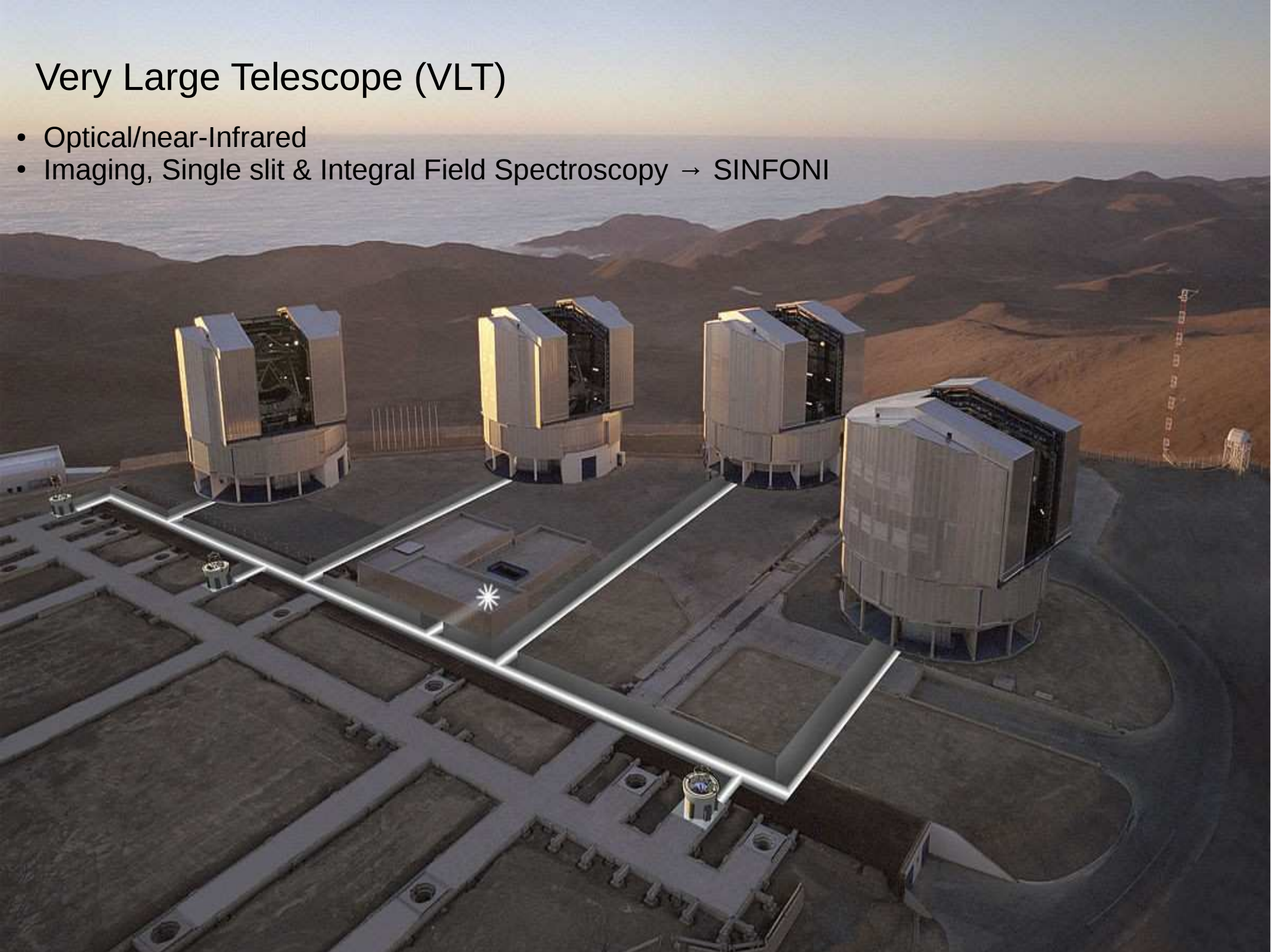


Image credit: NAOJ, Japan

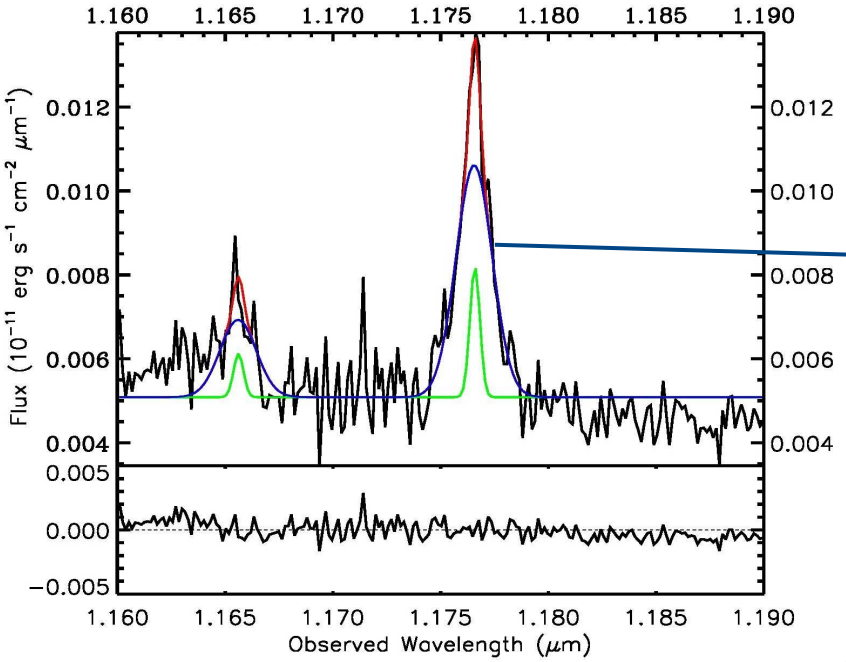
Every pixel in the image is a spectrum
→ Ideal for Spatially resolved studies

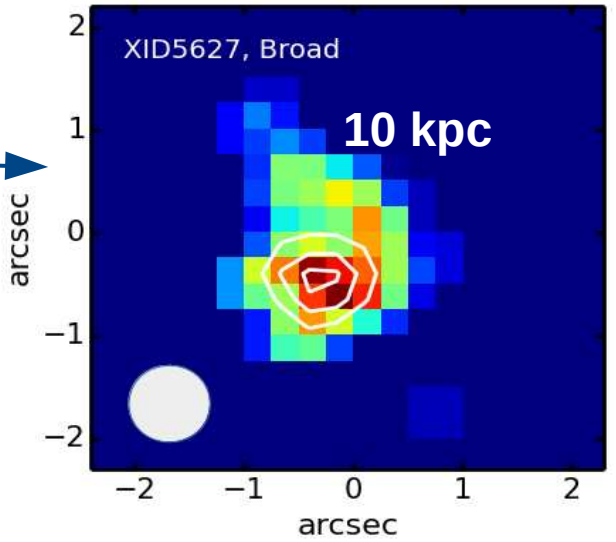
Very Large Telescope (VLT)

- Optical/near-Infrared
- Imaging, Single slit & Integral Field Spectroscopy → SINFONI



Spatially resolved outflows with IFU spectroscopy

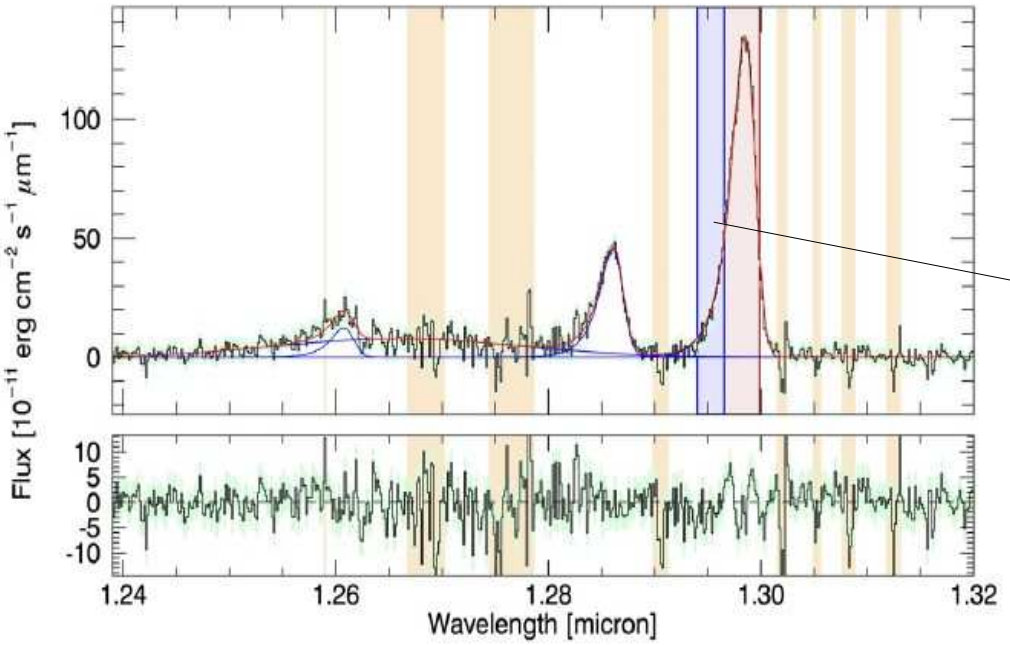


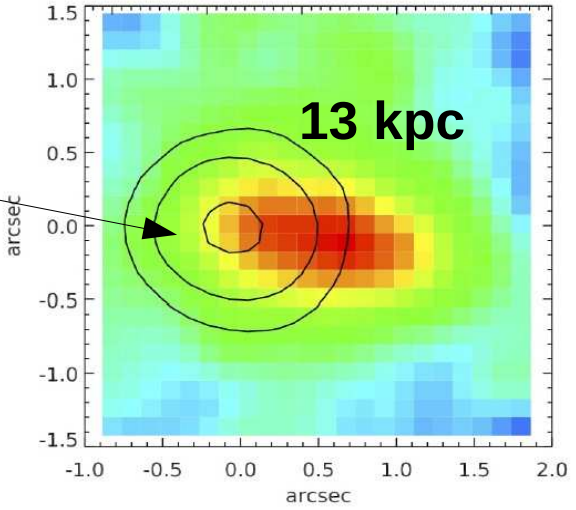


Kakkad +2016

After plotting only the broad component

Spatially resolved outflows with IFU spectroscopy

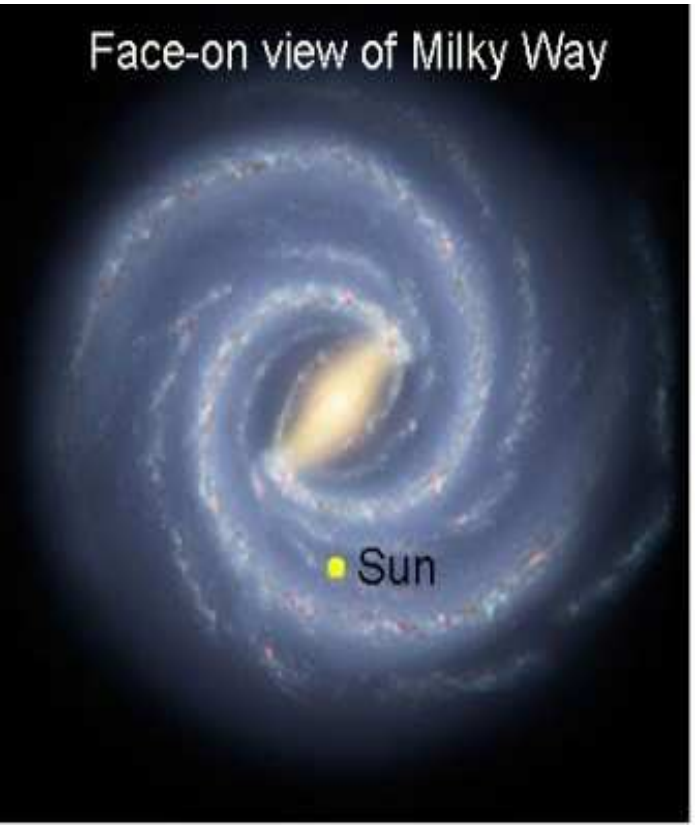


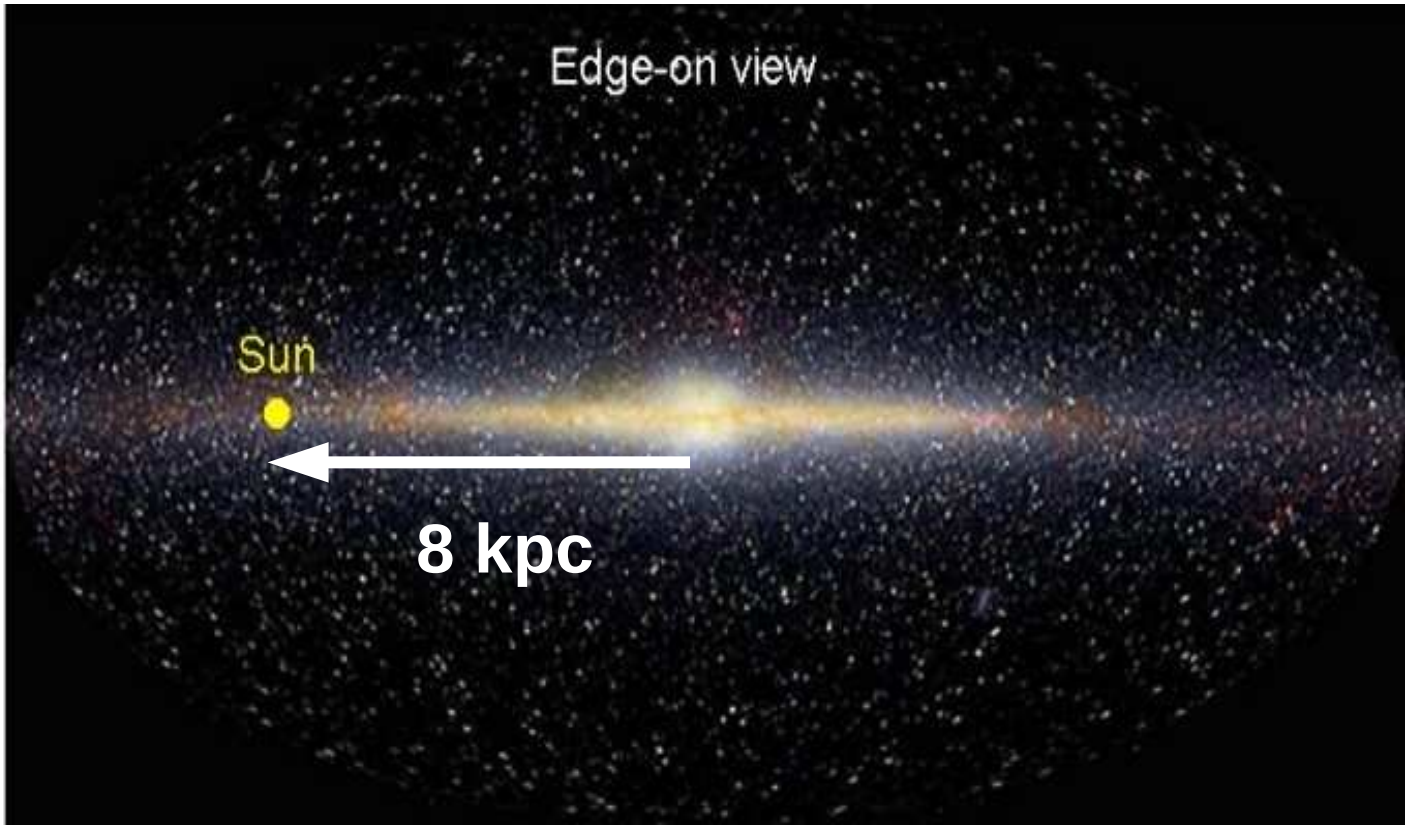


Cresci +2015

Plotting the “Blue wing”

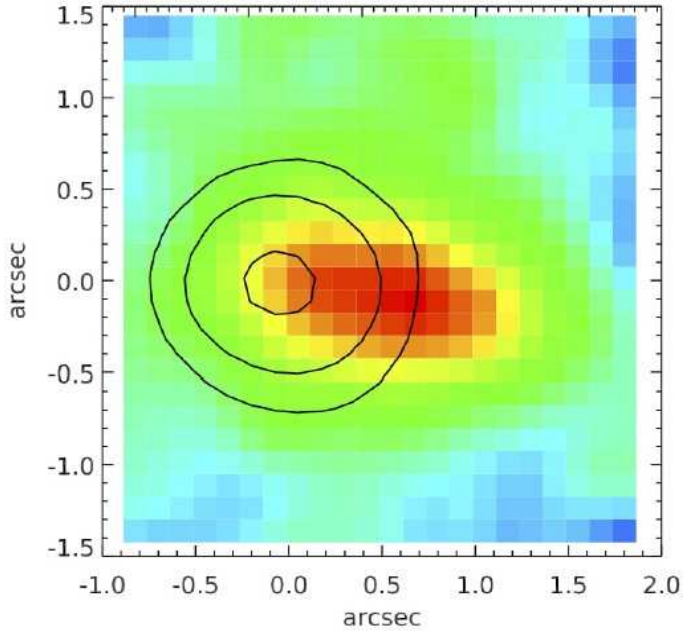
Comparison with Milky Way



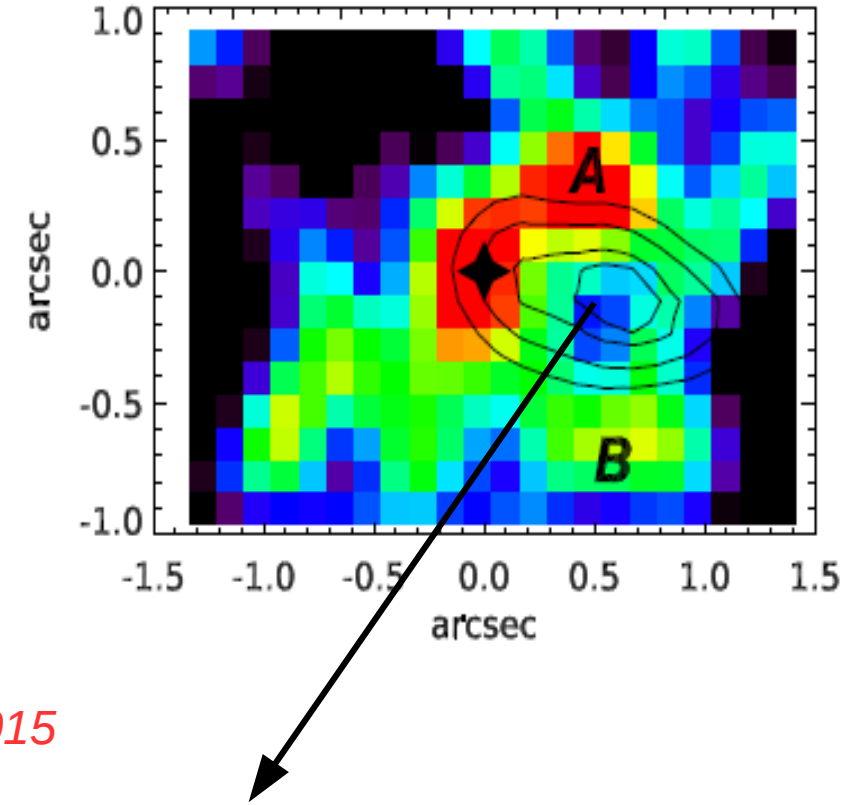


Impact on the host galaxy

Outflow map



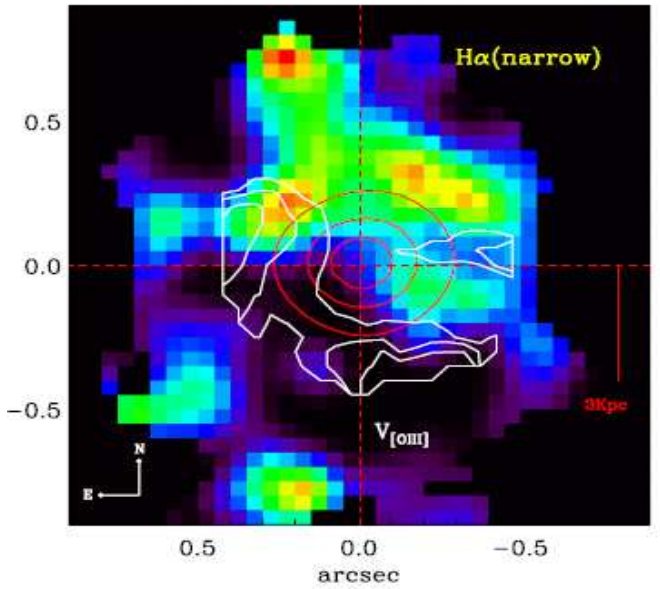
Star formation map



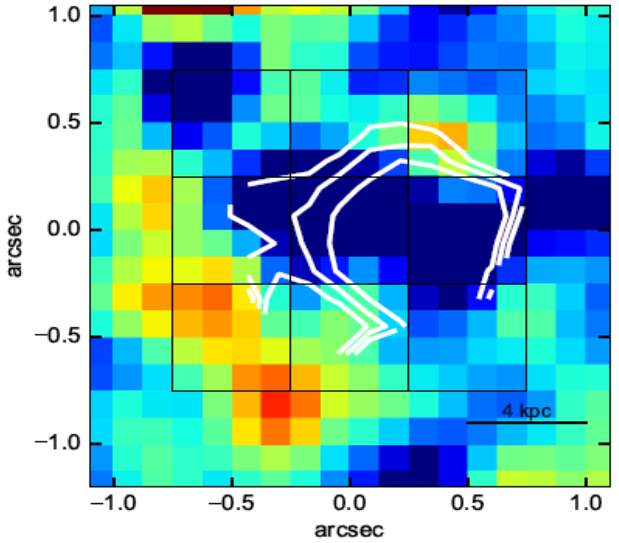
Cresci +2015

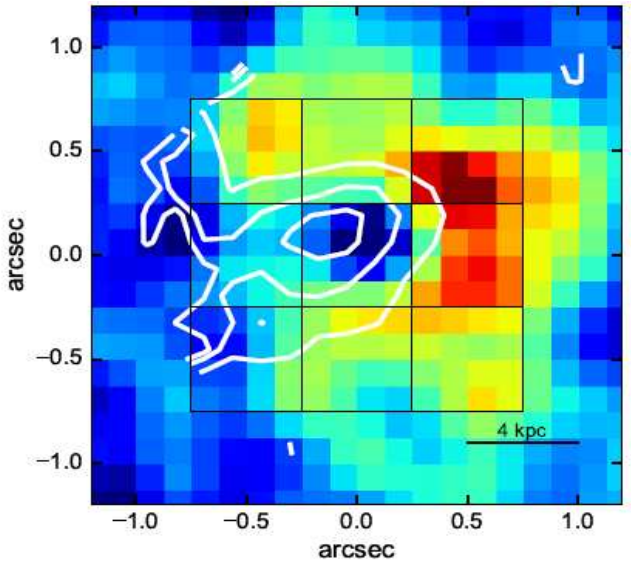
Star formation is absent where there is an outflow!!!

More examples of feedback



Cano-Diaz +2012



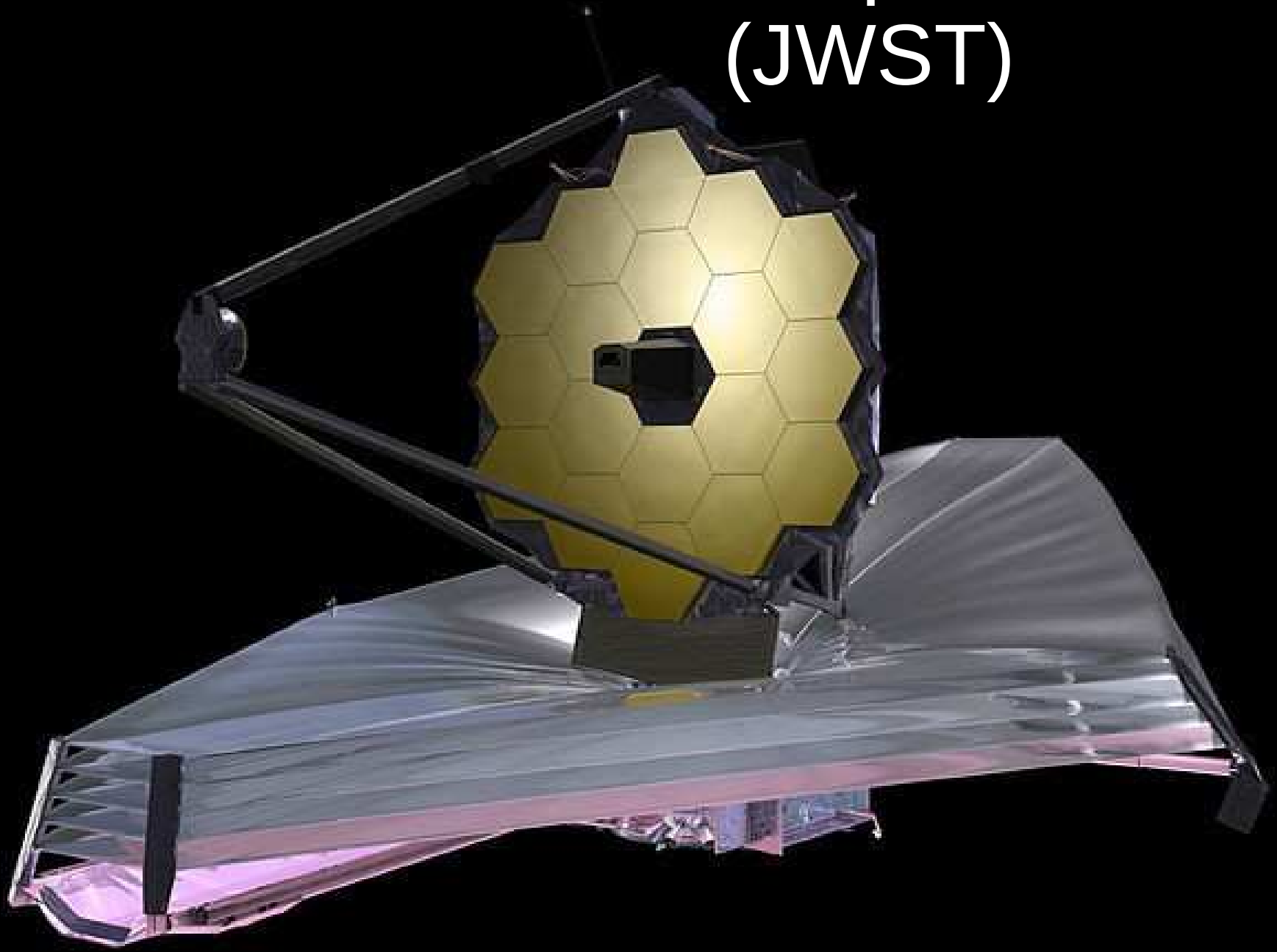


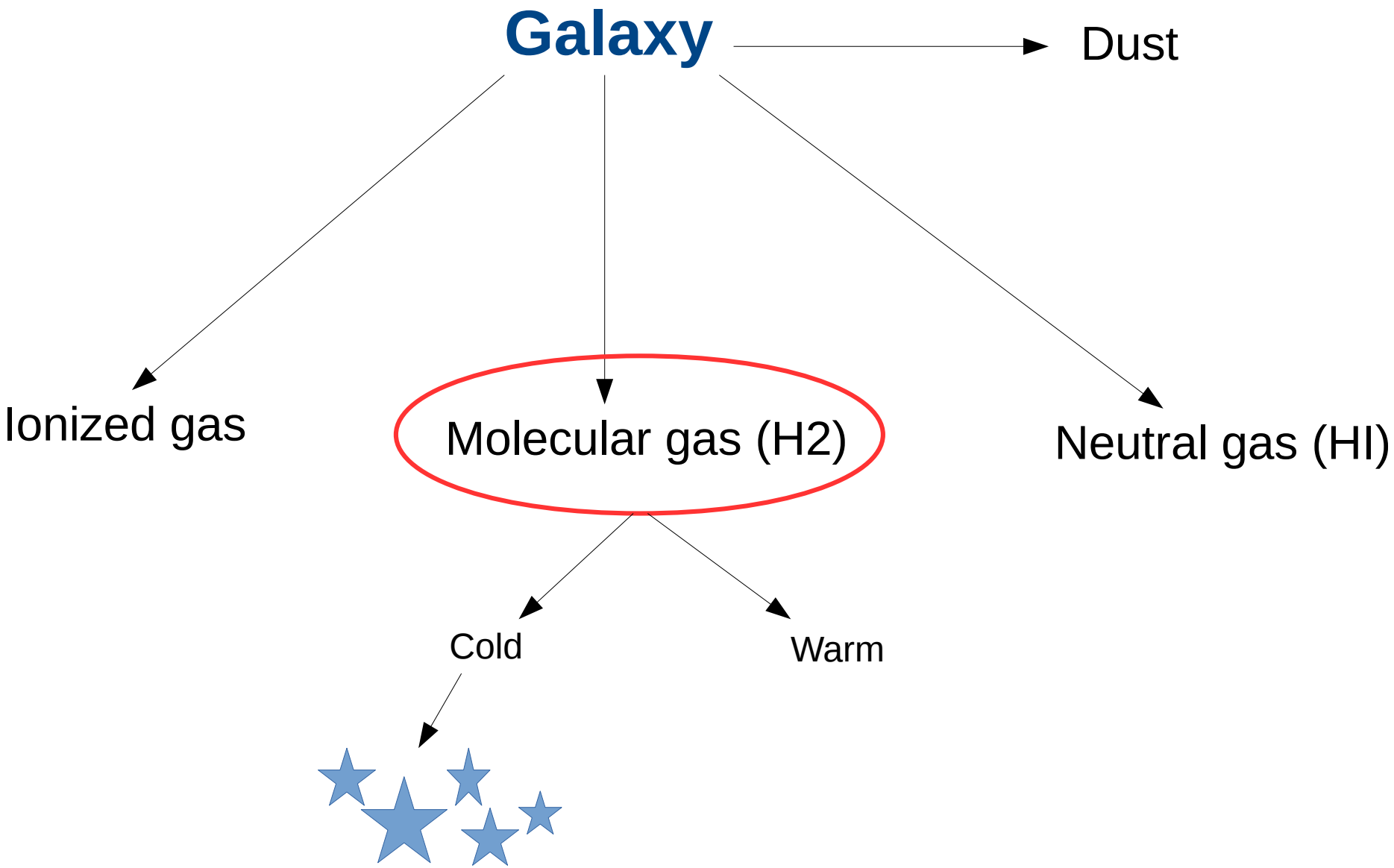
Carniani +2016

Problems

- Outflow energy calculations suffer from huge errors due to insufficient information in data → Kakkad +2016
- Consequently the source of these outflows is hard to confirm → Star formation or AGN or both?
- Calculated velocities not sufficient to remove gas → we need the removal of gas to quench star formation
- No information on ionized outflow at redshift, $z > 4$ → JWST

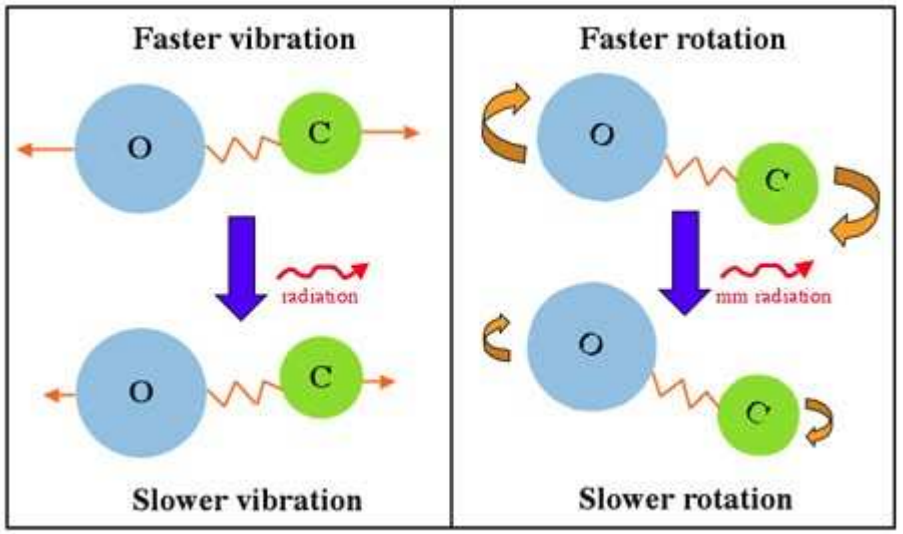
James Webb Space Telescope (JWST)





Do AGNs affect the fuel of the star formation itself?

CO as a tracer of molecular gas (H2)



- Asymmetric → Dipole moment
- Heavier → More strong lines

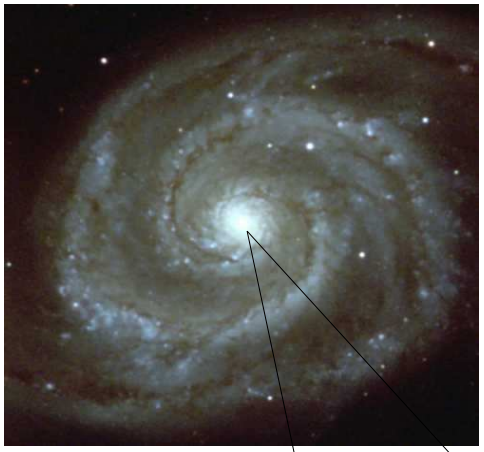
$$M(H_2) = \alpha_{CO} L(CO)$$

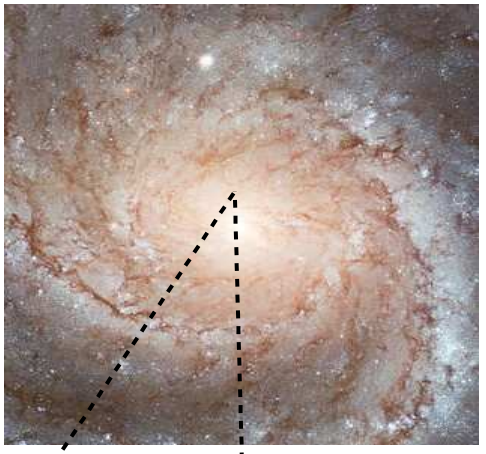
Conversion factor
For Milky Way like ISM, it is calibrated to ~4.0


Atacama Millimeter/sub-Millimeter Array
(ALMA)

Comparing Apples with Apples

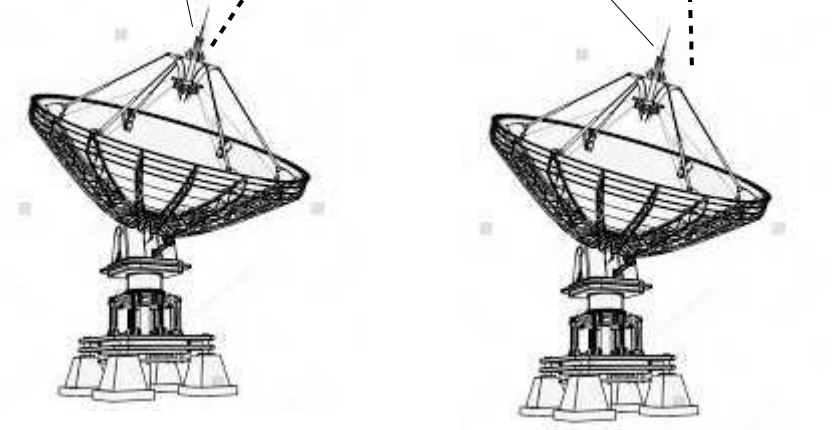
Molecular gas content in AGN hosts





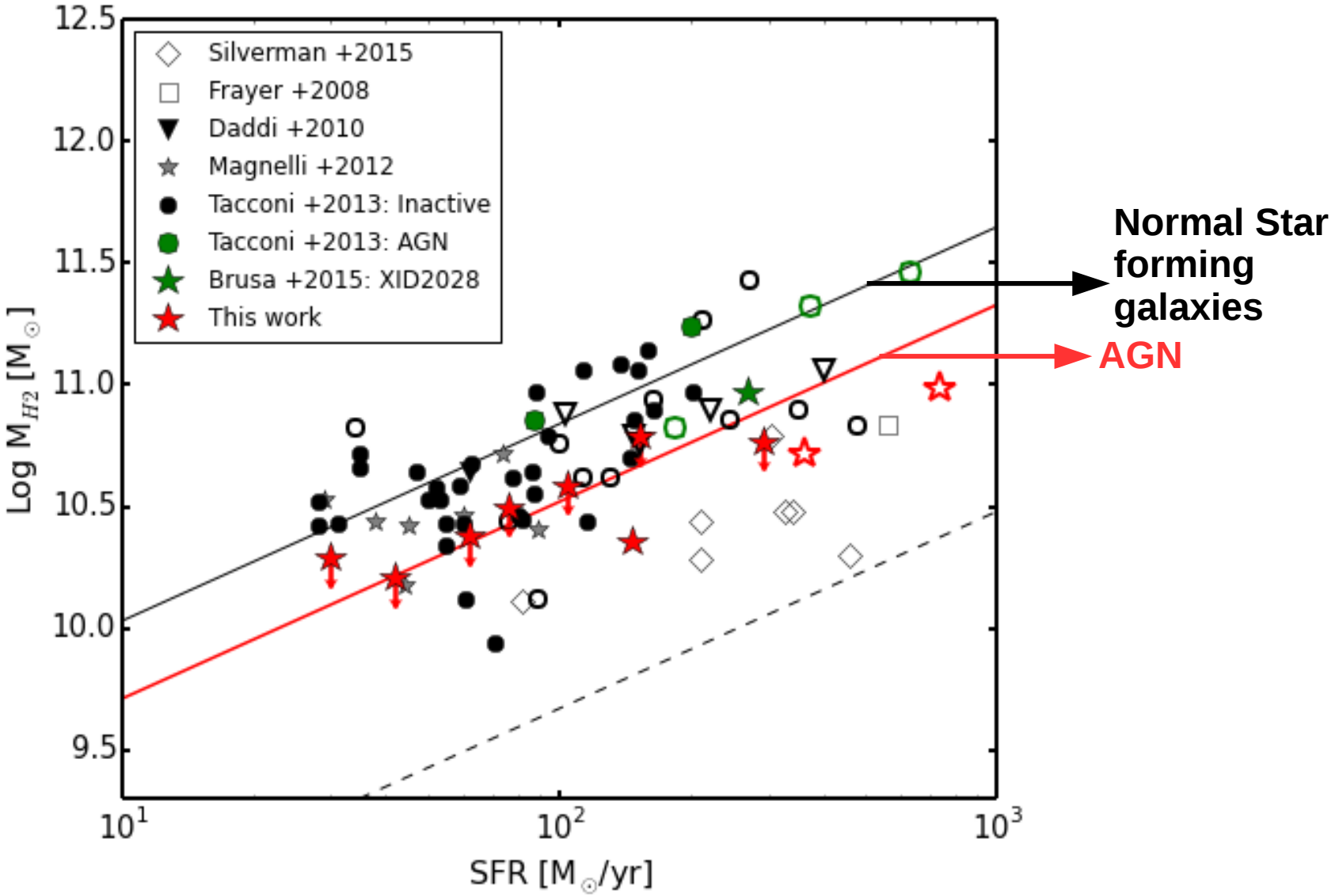
Star forming Galaxy

AGN galaxy



- *Do AGN host galaxies have different molecular gas compared to similar normal star forming galaxies?*

AGN host galaxies have less molecular gas

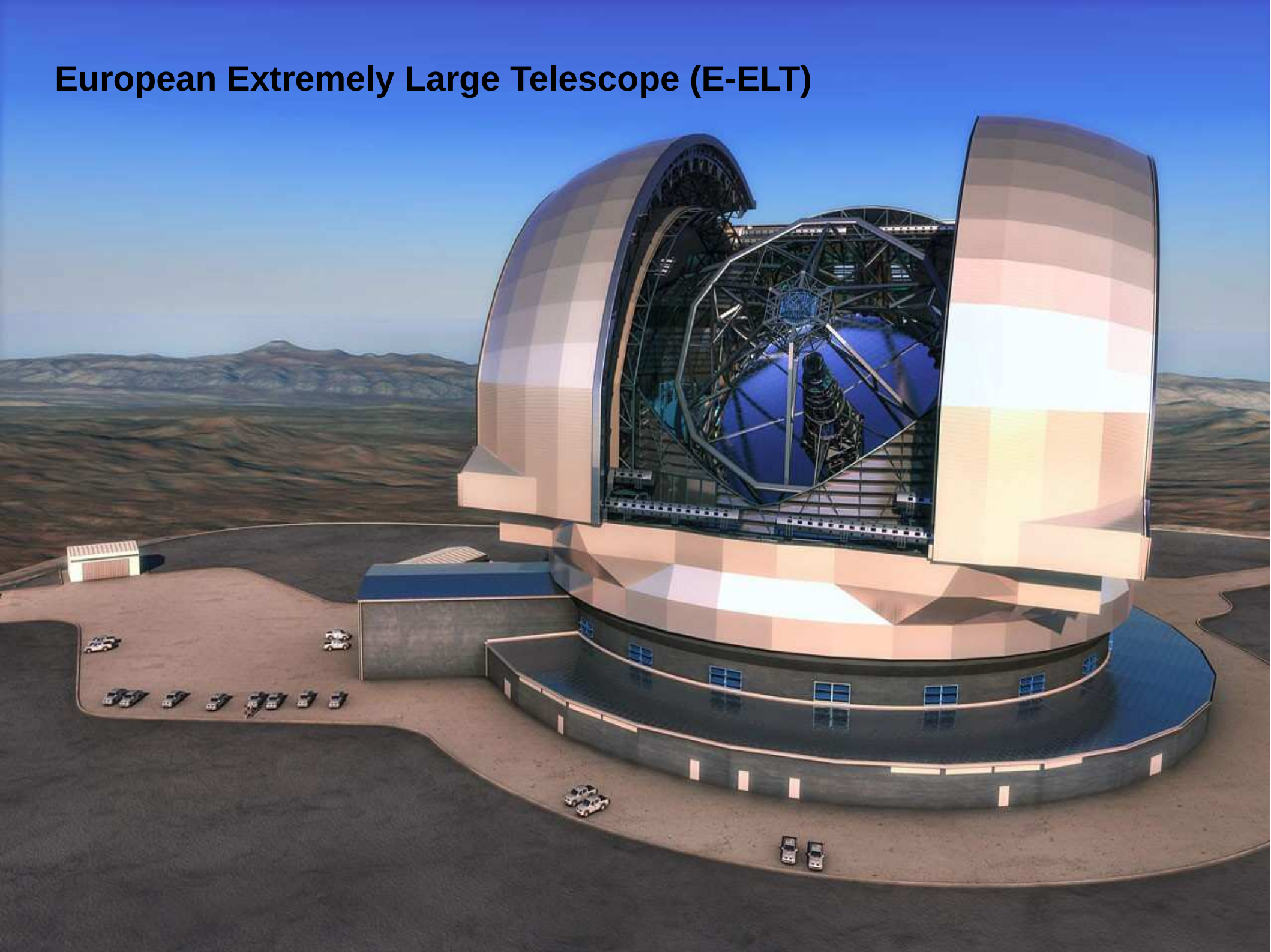


Kakkad +2017

Future Steps

- To combine ionized and molecular gas information for the same galaxies → A synergy of SINFONI and ALMA.
- Trace other gas phases → JWST will trace warm molecular gas at high redshift
- Understand the systematic uncertainties to precisely calculate the gas masses

European Extremely Large Telescope (E-ELT)



More info: www.eso.org/studentships

Summary

- A mutli-phase multi-wavelength approach to understanding AGN feedback.
- AGN host galaxies capable of driving powerful galaxy wide outflows
- They also tend to show lower molecular gas compared to normal star forming galaxies
- Future facilities (JWST, SKA, ATHENA...) might give insights into the accretion disk structure, dynamics of other gas phases with a wide coverage in redshift space

Thanks!!

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