Accretion Activity in Dwarf Galaxies: Key Diagnostic Tools

Shobita Satyapal
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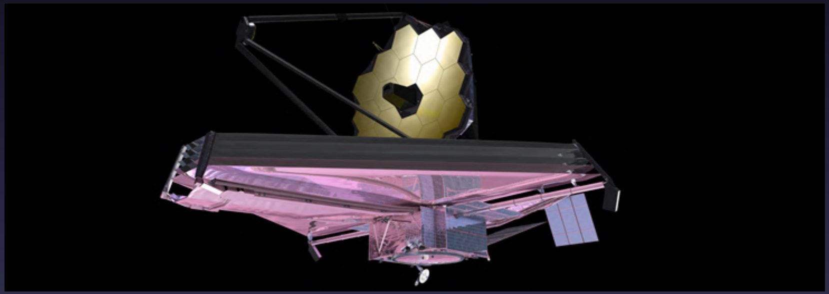


Overview: Why do we care?

- **AGNs can be an important source of feedback**
- Quench star formation
- Reduce the number of DGs
- Can help mitigate “too-big-to-fail” problem
- Impact on the core density profile of DGs

(Silk 2017)

Overview: Why do we care?

AGN feedback in DGs cannot be ignored

Theory

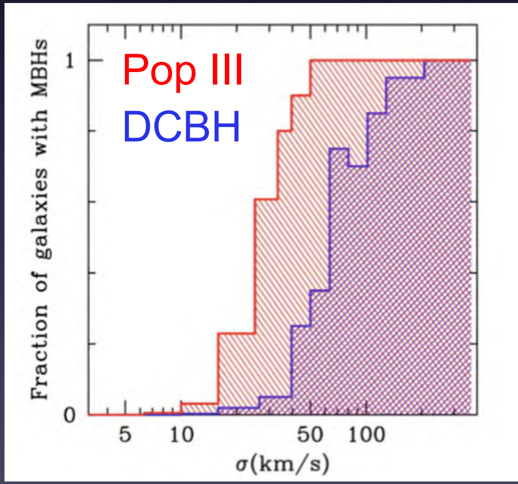
- Koudmani et al. 2019
- Reagan et al. 2019
- Barai et al. 2019
- Zubovas 2018
- Dashyan et al. 2018

Observations

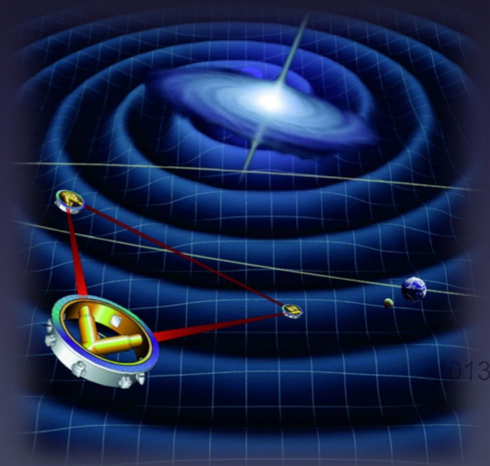
- Manzano-King et al. 2019
- Mezcua et al. 2019
- Dickey et al. 2019
- Kaviraj et al. 2019
- Penny et al. 2018
- Bradford et al. 2018

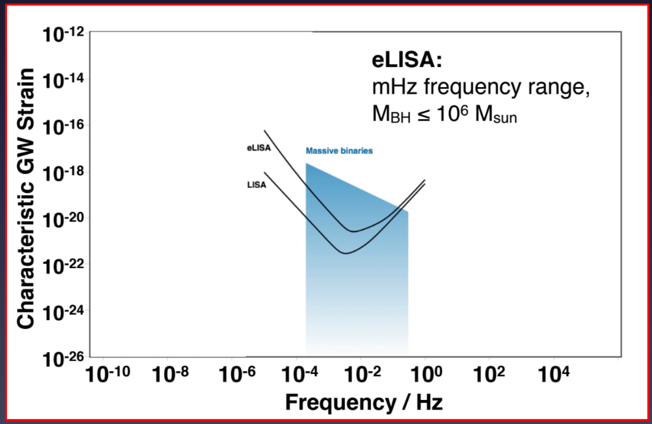
Overview: Why do we care?

- IMBHs crucial for understanding origin of SMBHs
- IMBHs mergers are prime targets for LISA
- IMBHs can teach us about fundamental physics of accretion in low mass regime



Volonteri et al. 2008





The Problem:
Low mass SMBHs are hard to find!

Sphere of influence of a $10^5\ M_\odot$ black hole at 10 Mpc is only 0.01”

The black hole mass desert

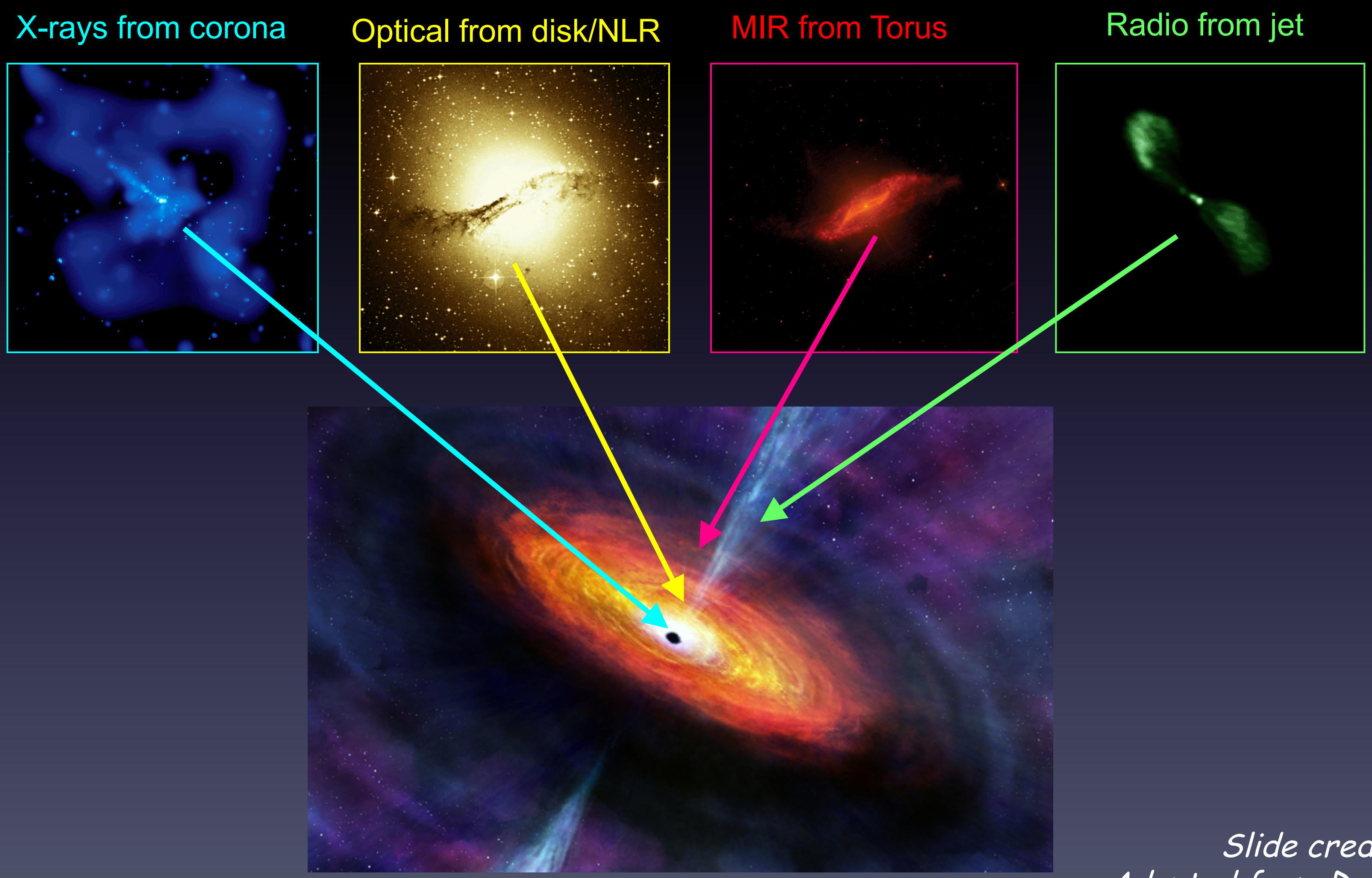
There is no direct evidence for black holes between 60-1x10^4 $M_\odot$

IMBHs can only be found when accreting

Goal: Hunt for AGNs in low mass galaxies

Challenges

- **AGN identification**



Slide credit:
Adapted from D. Alexander

Challenges

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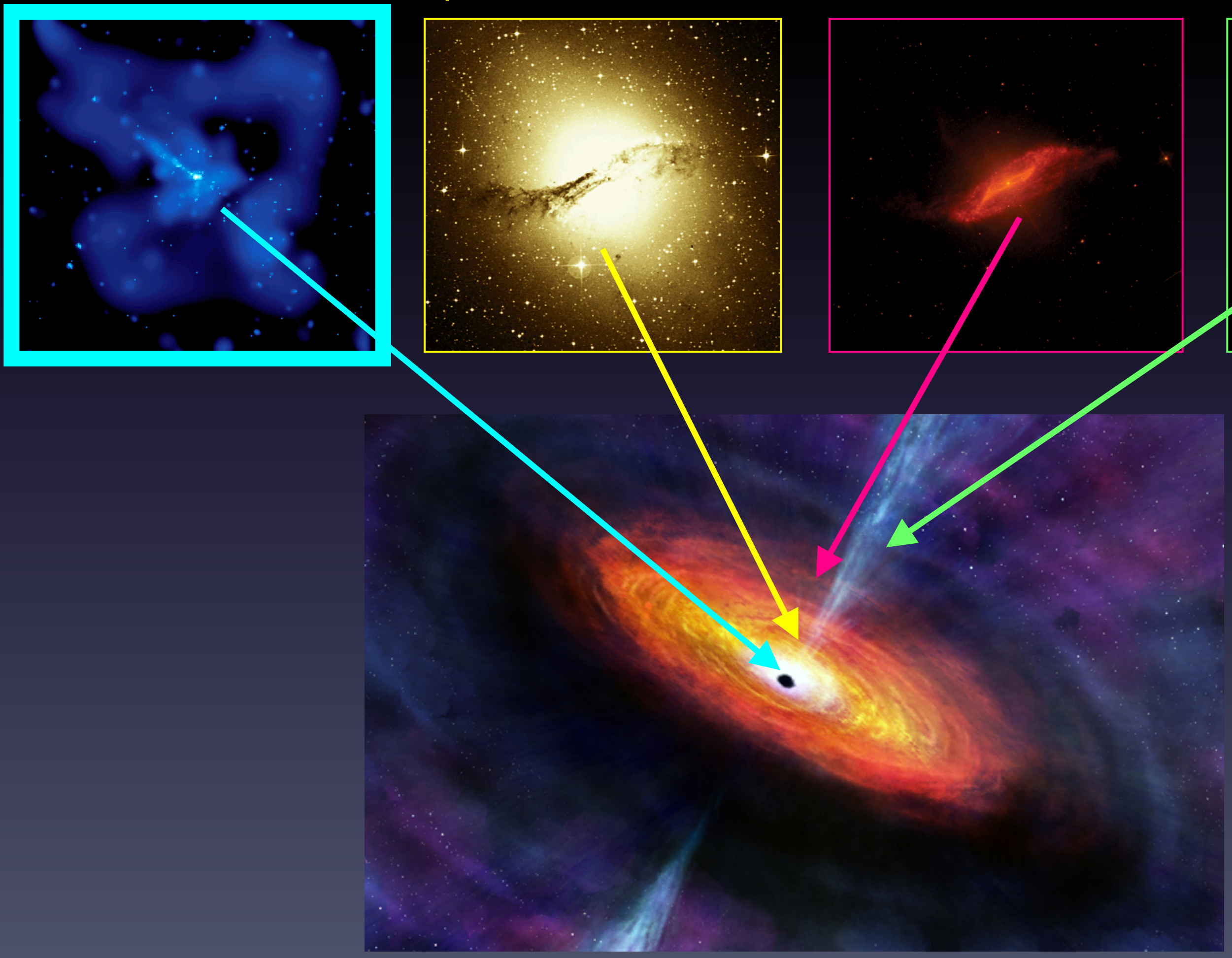

- **X-rays can be absorbed**
- **XRB contamination**

- Optical can be obscured
- Host galaxy dilution

- IR sensitive only to dominant AGNs

- Only 10% AGN are radio loud

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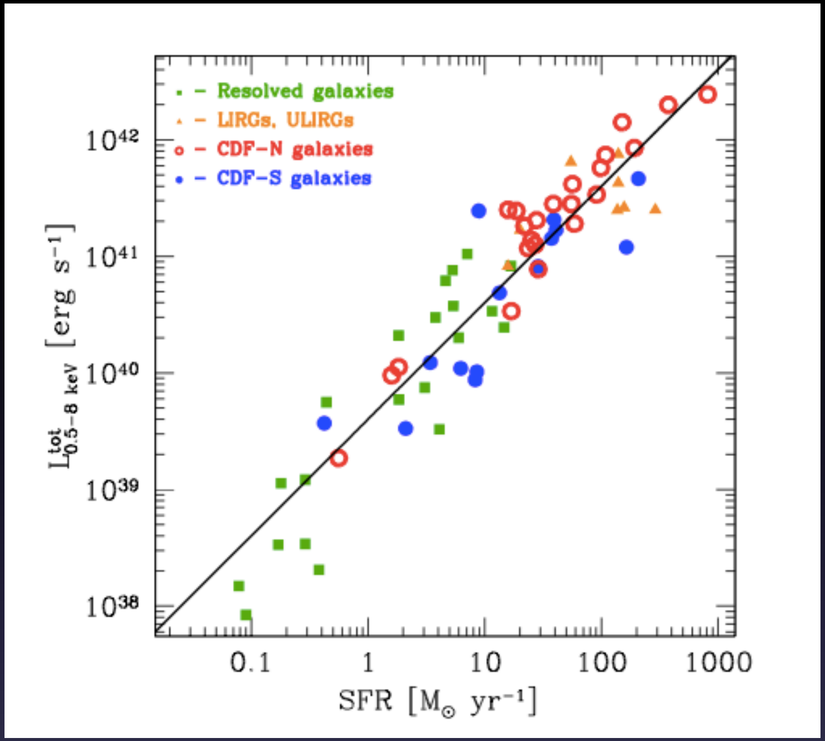
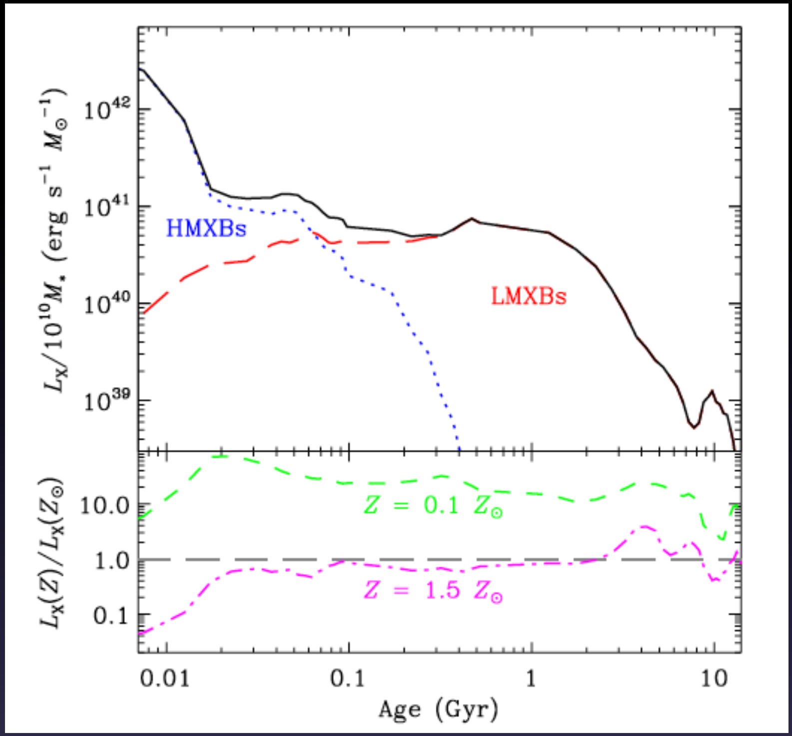
Adapted from D. Alexander

Limitations with X-ray Diagnostics



(Mineo et al. 2014)



(Fragos et al. 2013)

- Contamination by XRBs
- X-ray enhancement with metallicity
- Also ULXs?

More significant in low mass galaxies

Challenges

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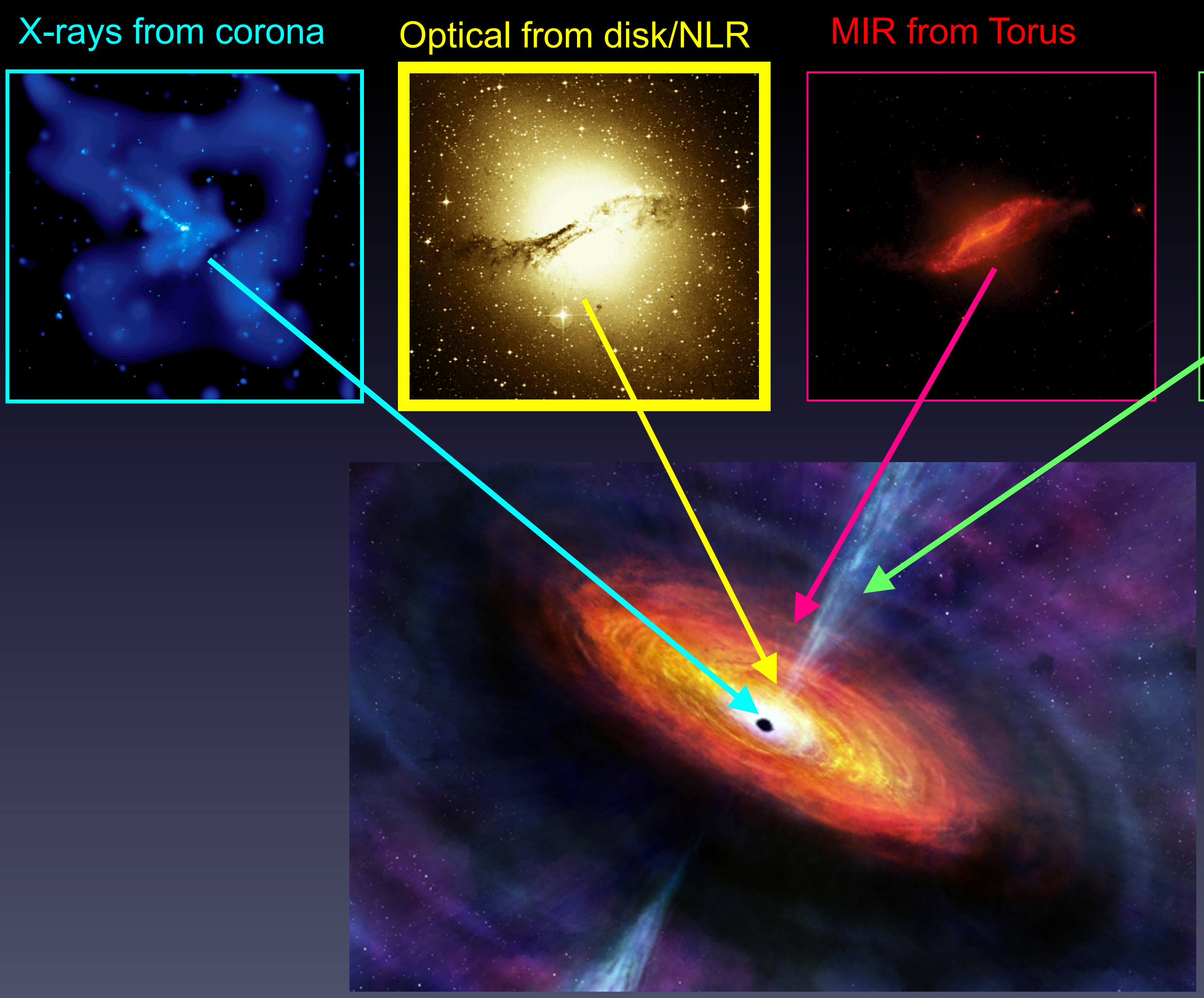

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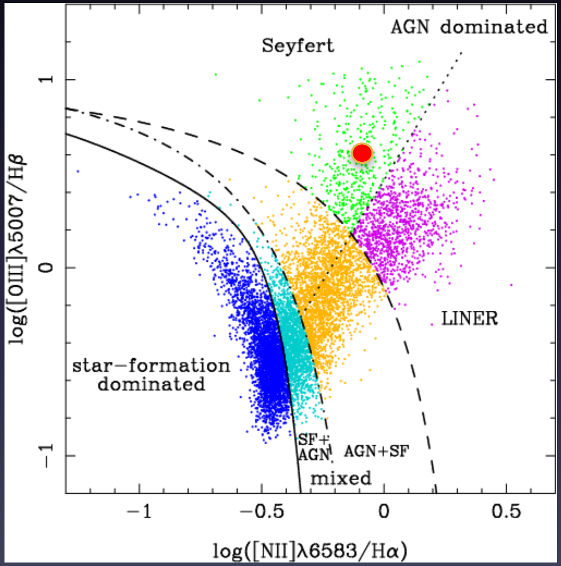
Limitations with Optical Diagnostics

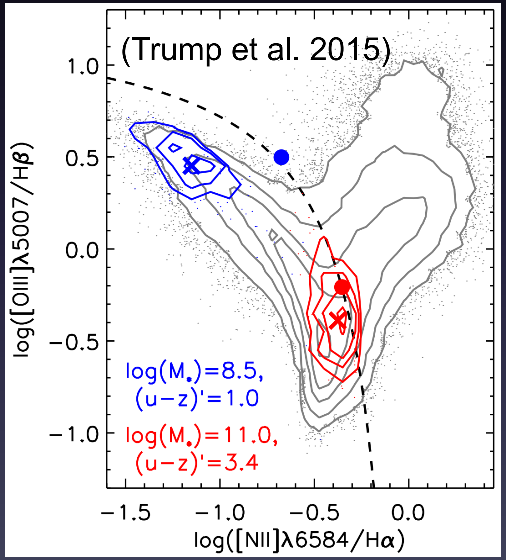
- Dust obscuration

(LLAGN can have very high N_H; Annuar et al. in prep, Ricci et al. 2015)

- Optical lines dominated by SF

- Overlap in low metallicity AGNs with SF on BPT





More significant in low mass galaxies

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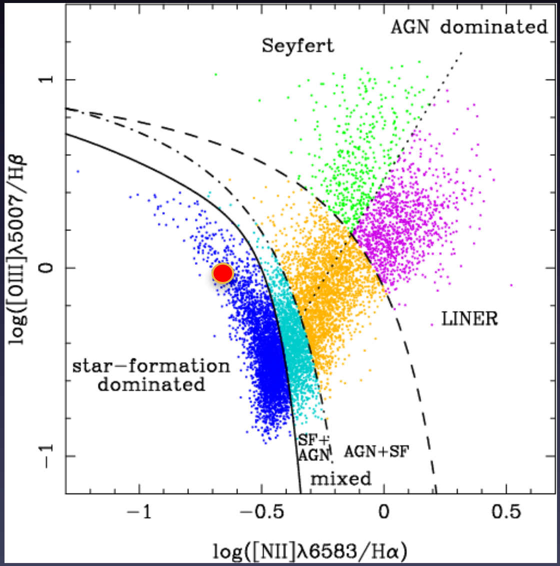
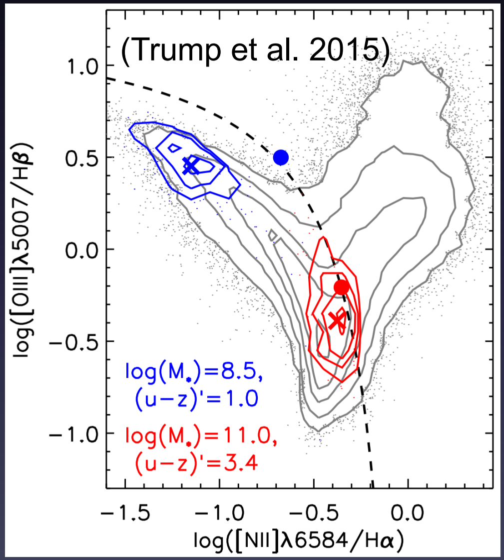
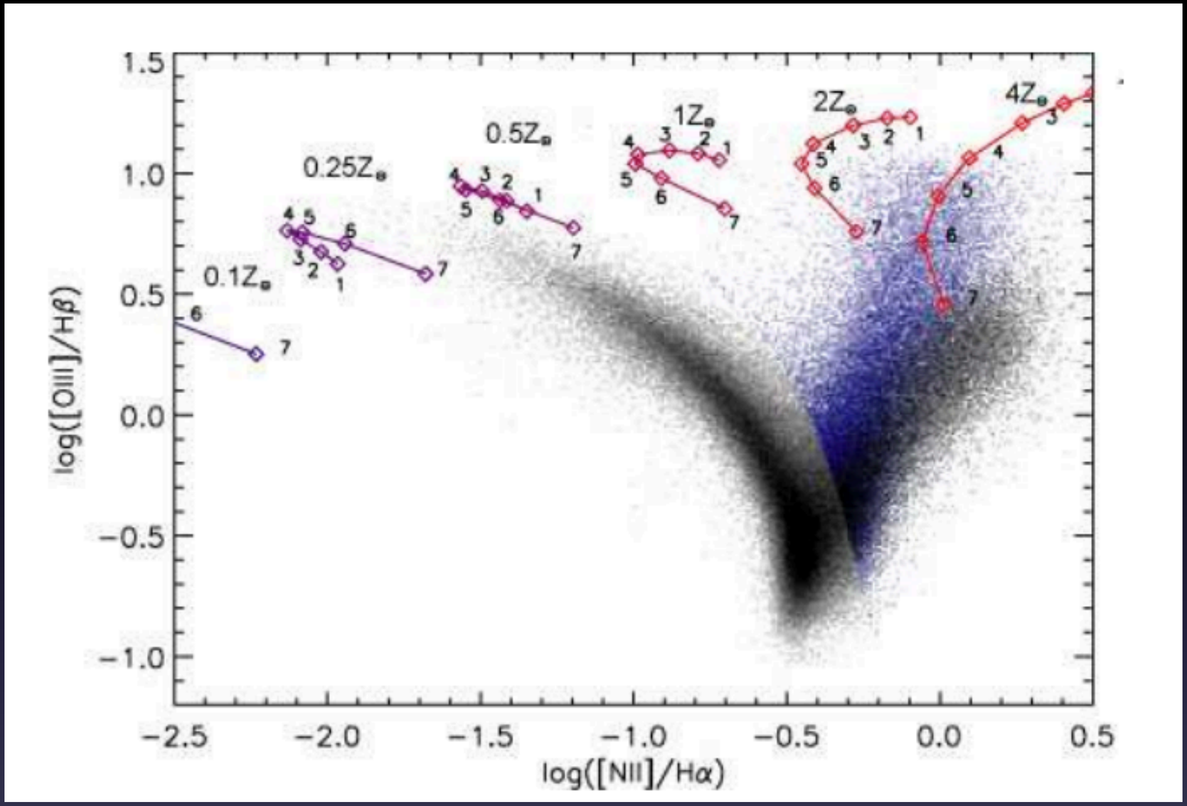




More significant in low mass galaxies

Limitations of Optical Diagnostics

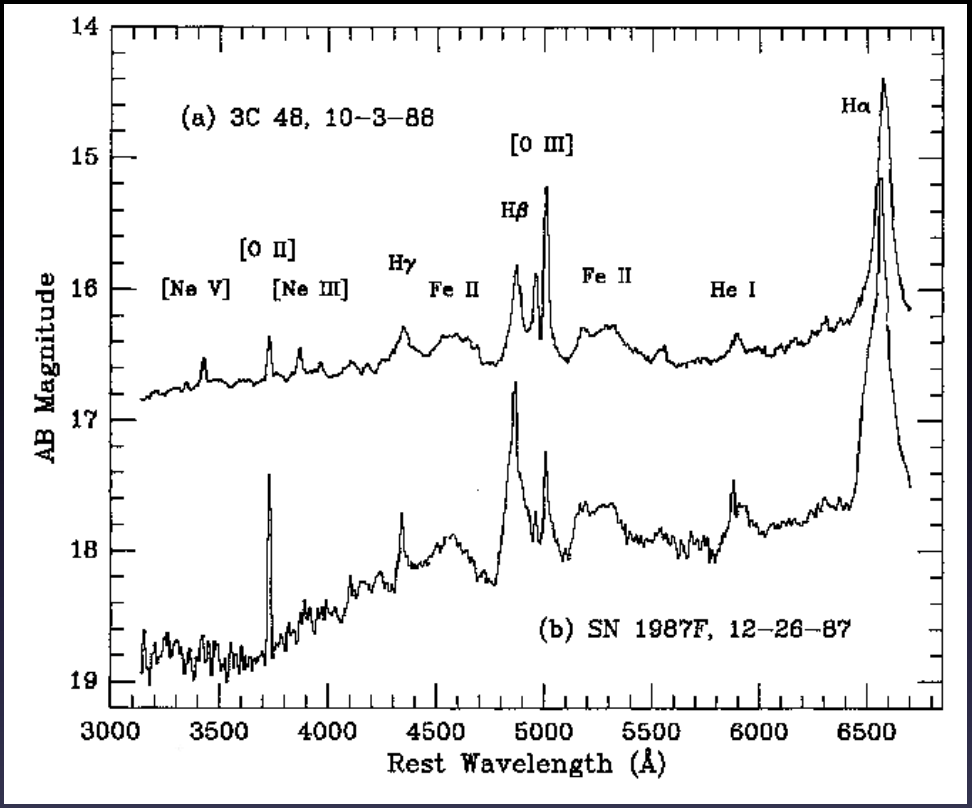


Groves et al. (2008)

Low Metallicity AGNs Look like SF Galaxies

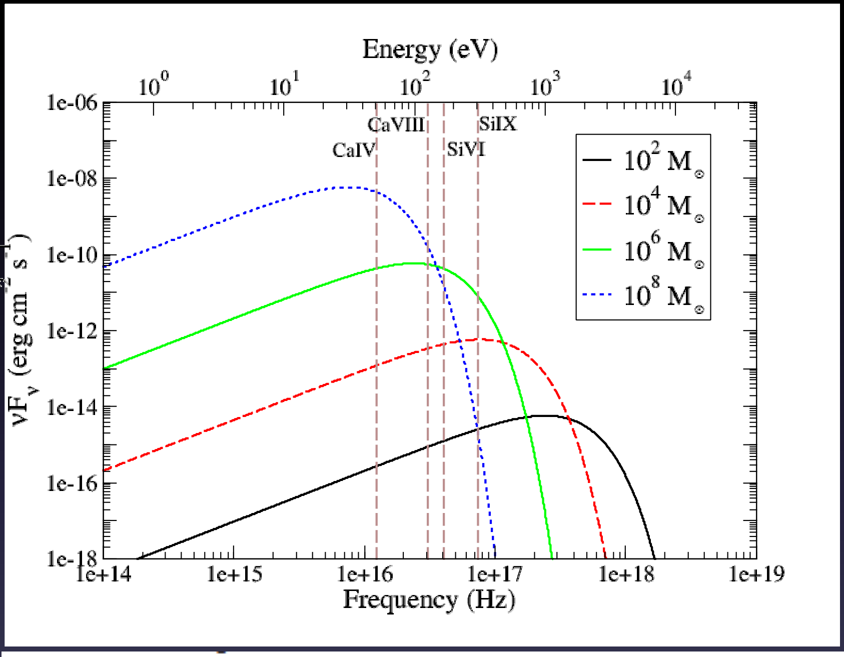
Limitations with Optical Diagnostics

- Type II SNe can look like AGNs
- $L_{H\alpha}$ from broad lines comparable to SNe (e.g. Greene & Ho 2007)
- Majority of broad lines in SF dwarfs fade within a few years (Baldassare et al. 2016)

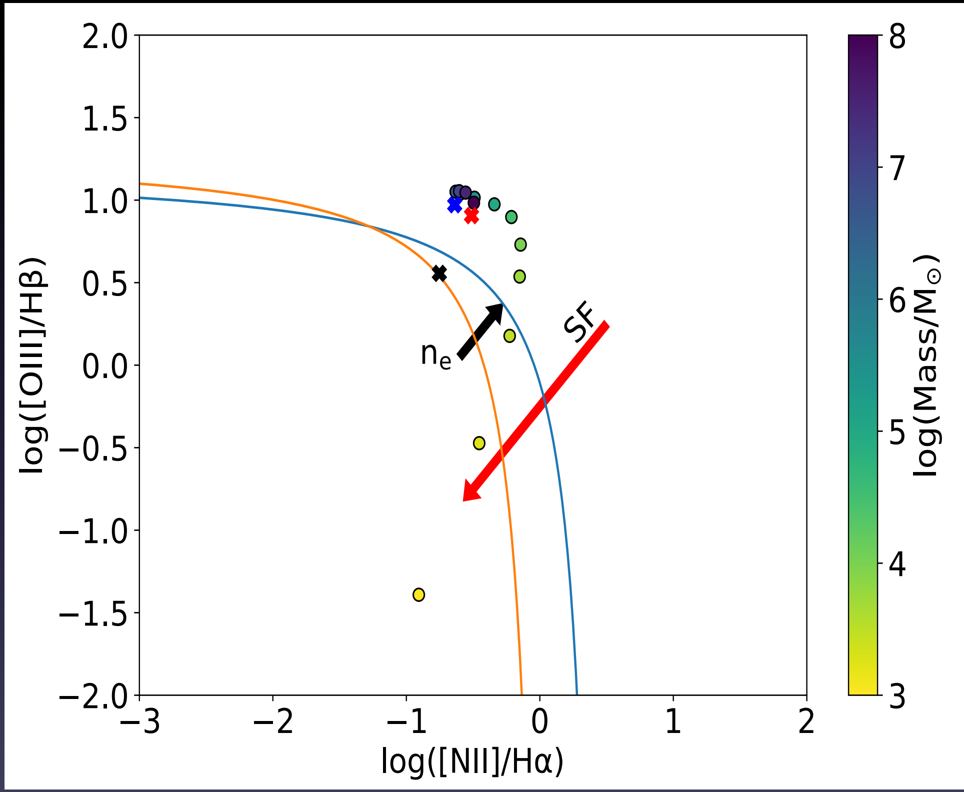


(Fillipenko 1987)

Limitations of Optical Diagnostics



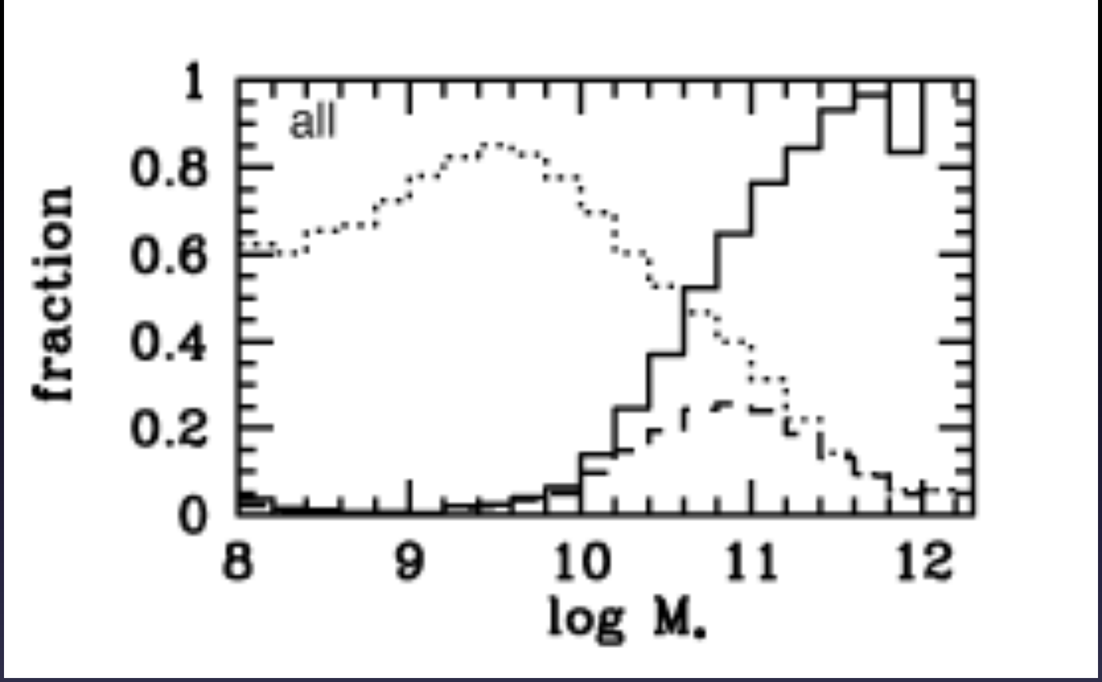
$$T(R) = 6.3 \times 10^5 \left(\frac{\dot{m}}{\dot{m}_{\rm Edd}}\right)^{\frac{1}{4}} \left(\frac{M_{BH}}{10^8 M_\odot}\right)^{-\frac{1}{4}} \left(\frac{R}{R_s}\right)^{-\frac{3}{4}} \mathrm{K}$$



Cann et al. 2019

Low Mass AGNs Look like SF Galaxies

Optically Identified AGNs: Almost all in Massive Bulge-dominated Hosts

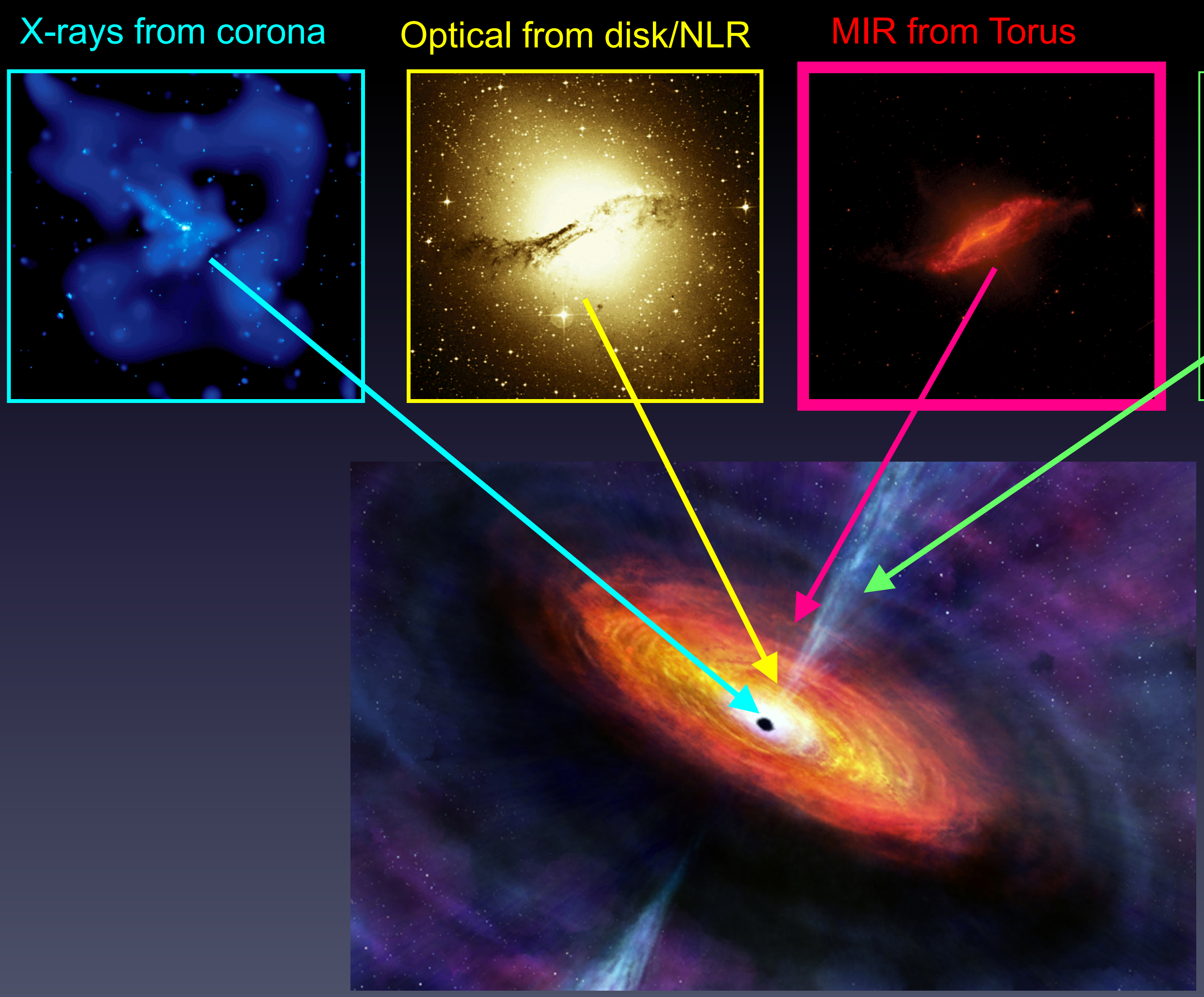


(Kauffmann et al. 2003)

Only ~1% of dwarf galaxies host AGNs based on optical and X=ray surveys (e.g., Reines et al. 2013, Pardo et al. 2016)

Challenges

- **AGN identification**



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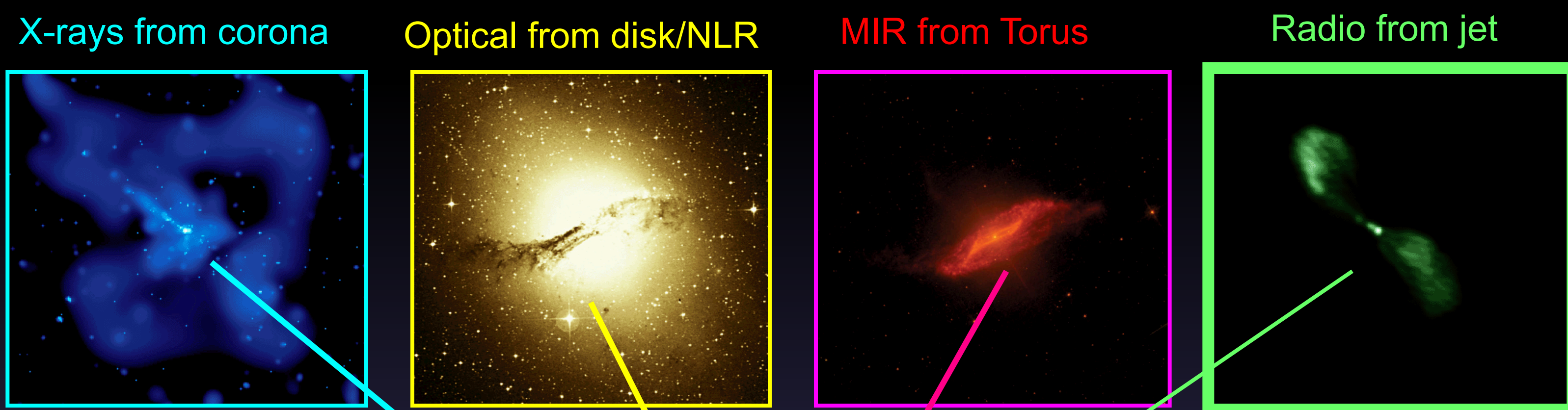

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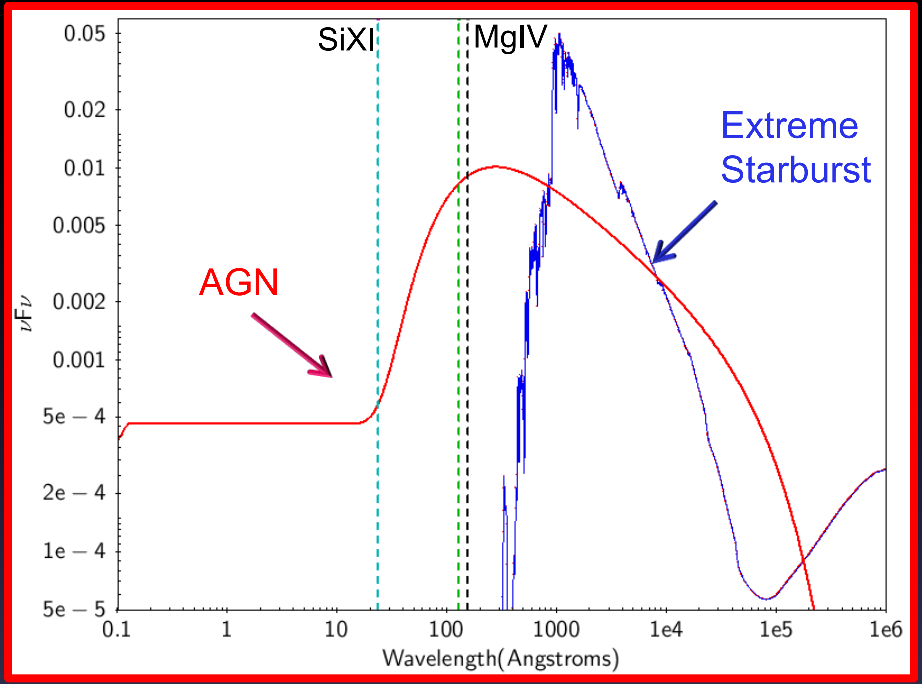
Can't see IMBHs with current tools?

Infrared Spectroscopic Diagnostics
THE POWER OF JWST

- Insensitive to extinction
- Insensitive to dilution by SF
- No confusion with XRBs, ULXs



Robust way to find low luminosity AGNs

Infrared Spectroscopic Diagnostics

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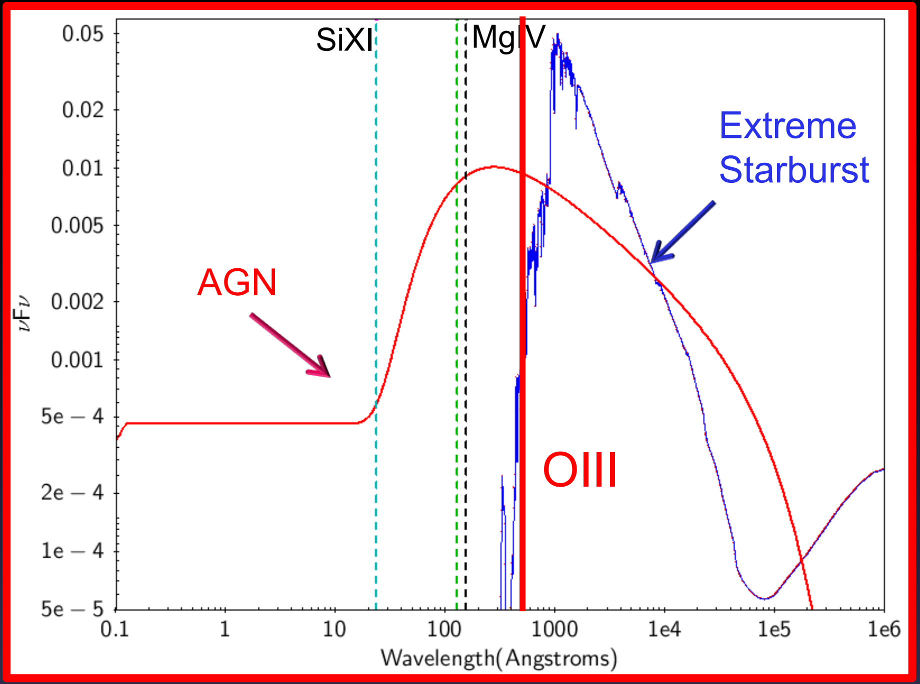
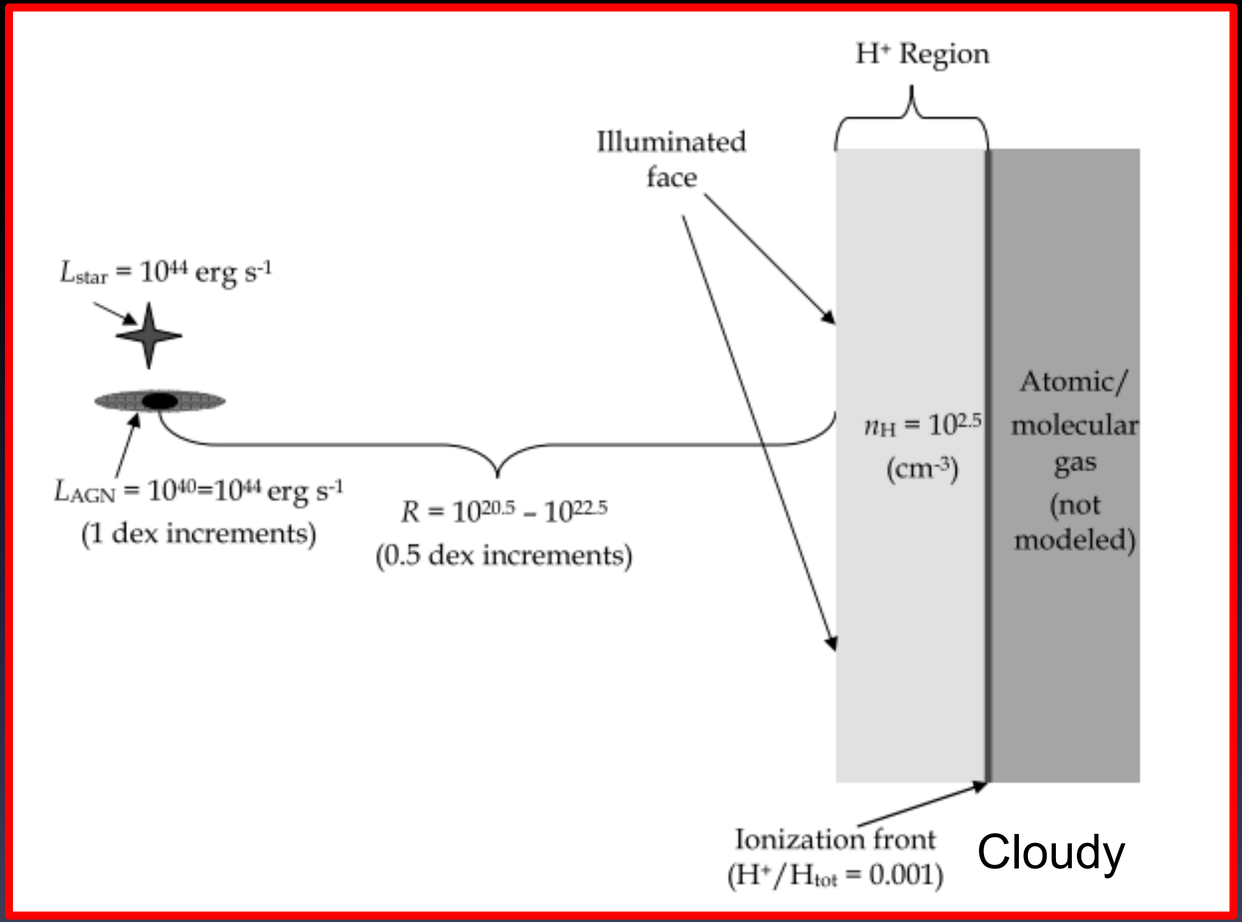
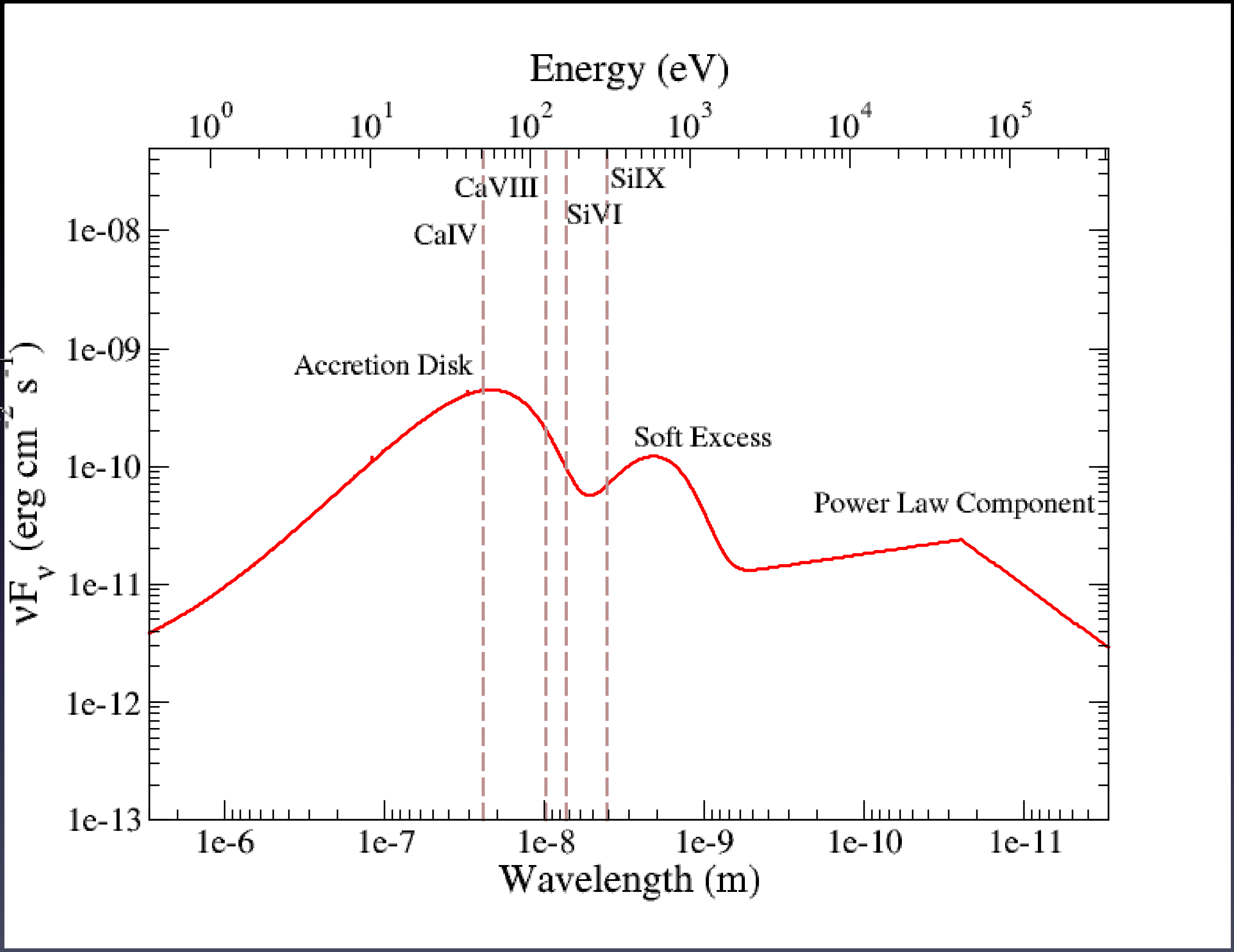


Robust way to find low luminosity AGNs

Photoionization Models

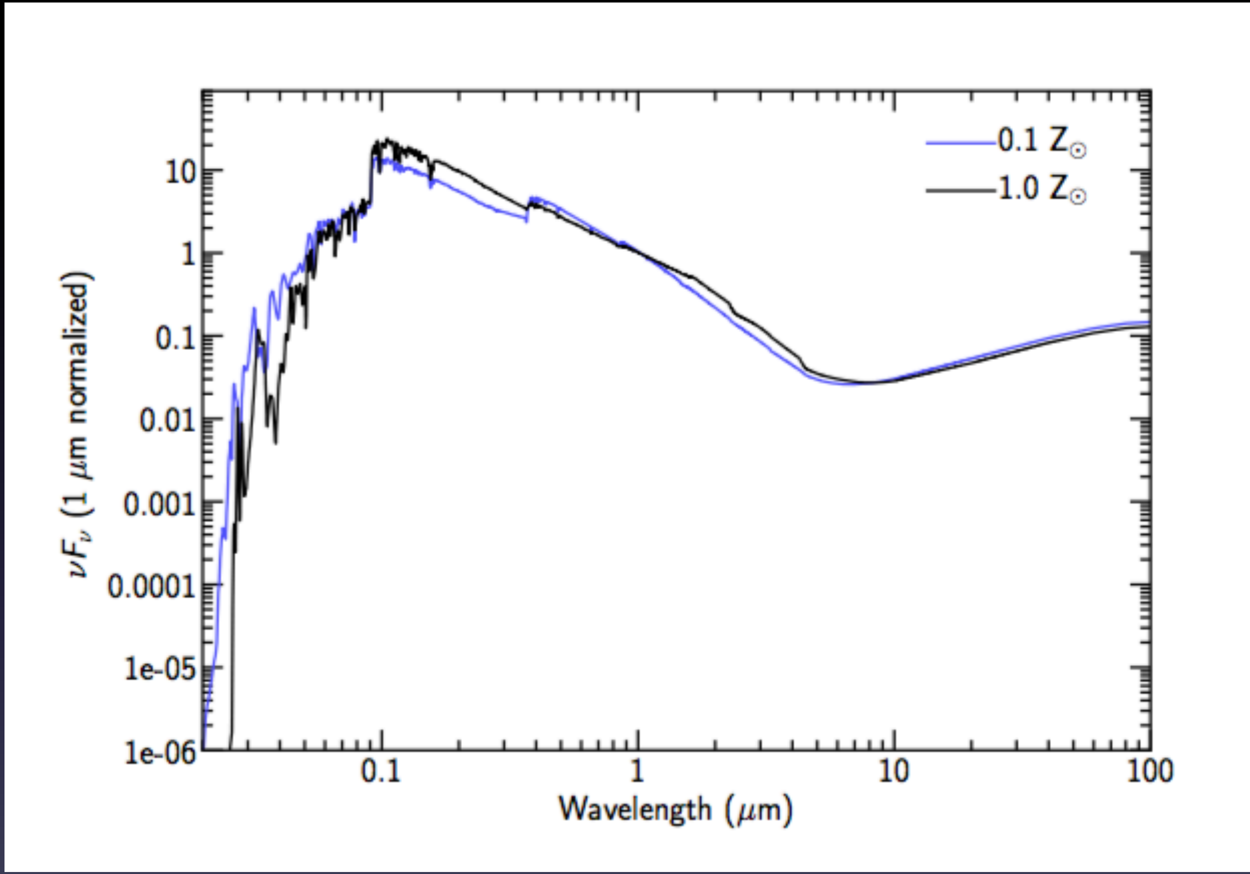


AGN SED

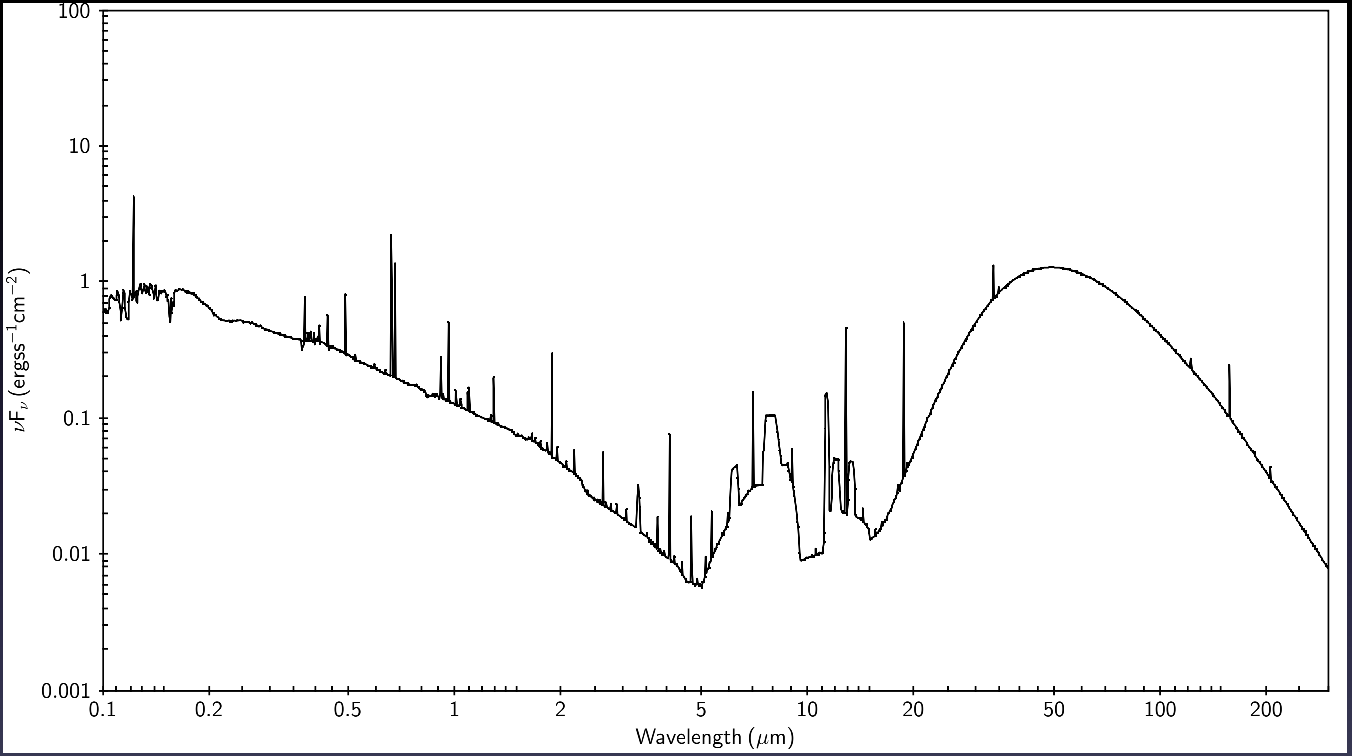


Energy (eV)
10^0
10^1
10^2
10^3
10^4
10^5
CaVIII
SiIX
SiVI
CaIV
Accretion Disk
Soft Excess
Power Law Component
1e-08
1e-09
1e-10
1e-11
1e-12
1e-13
νF_ν (erg cm^{-2} s^{-1})
1e-6
1e-7
1e-8
1e-9
1e-10
1e-11
Wavelength (m)

Extreme Starburst SED

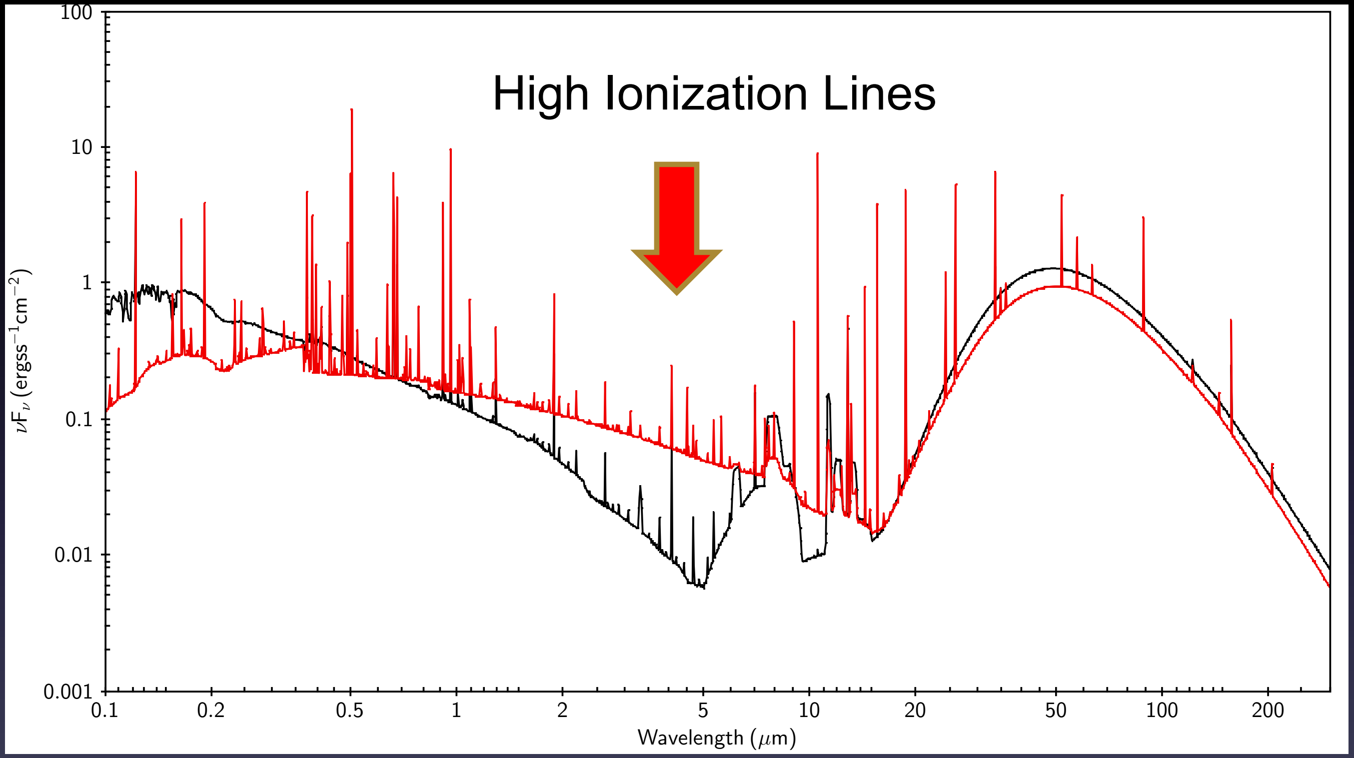


Integrated Modeling Approach



Satyapal et al. 2018

Integrated Modeling Approach



Satyapal et al. 2018

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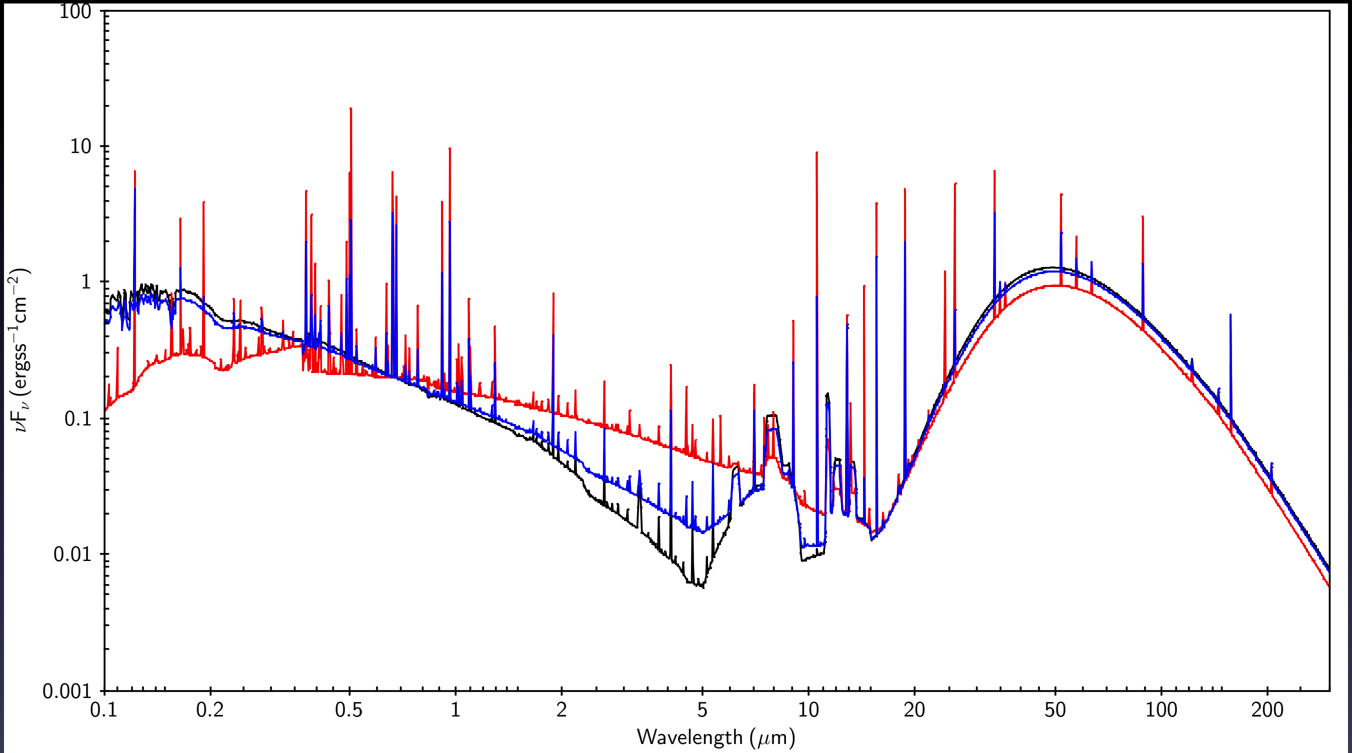

Satyapal et al. 2018

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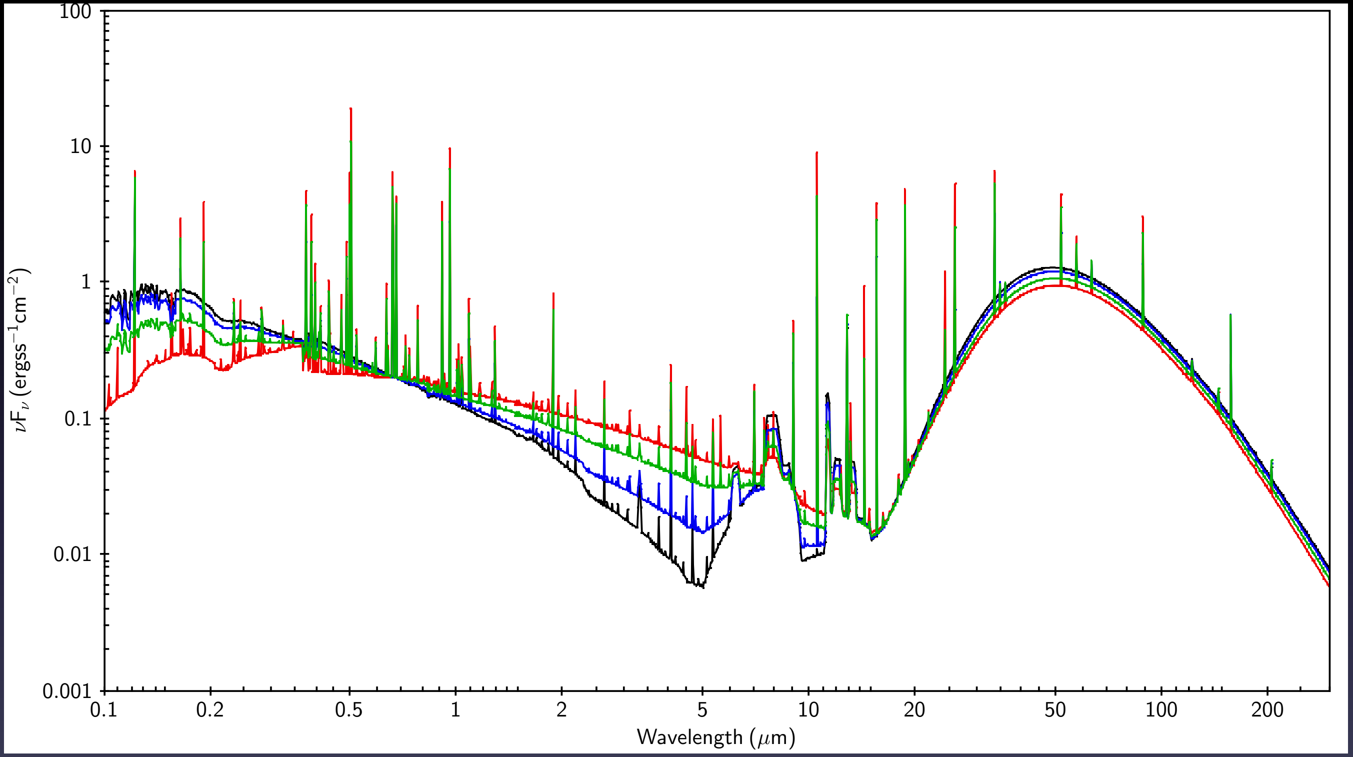
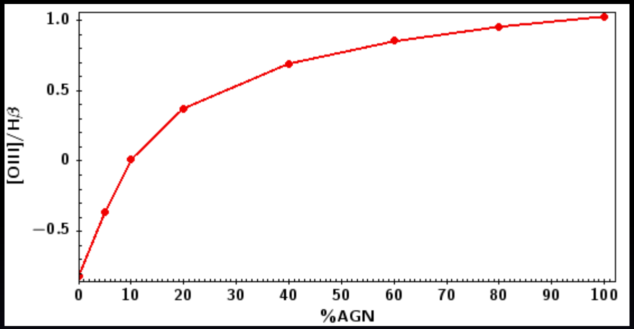
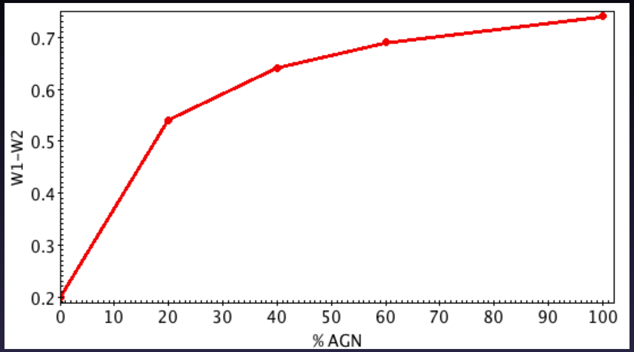
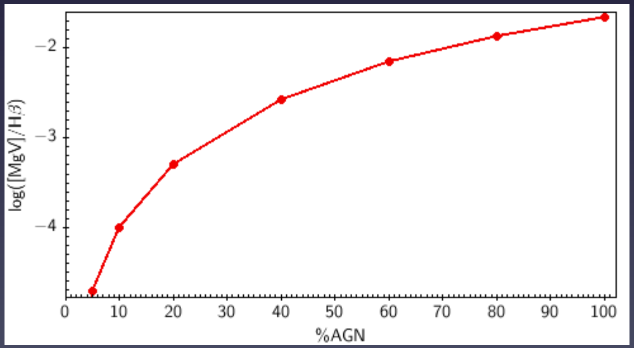


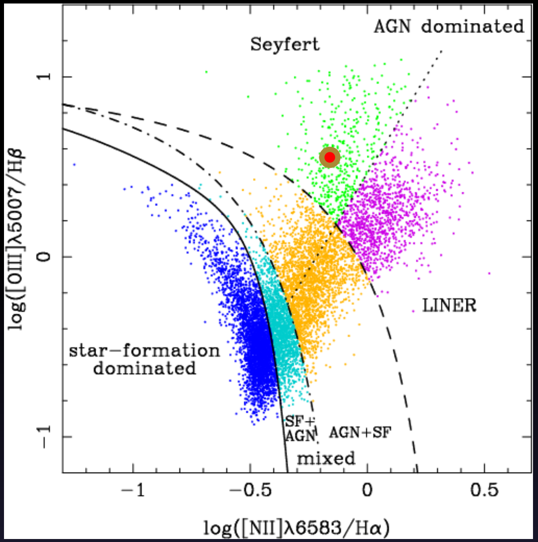
Satyapal et al. 2018

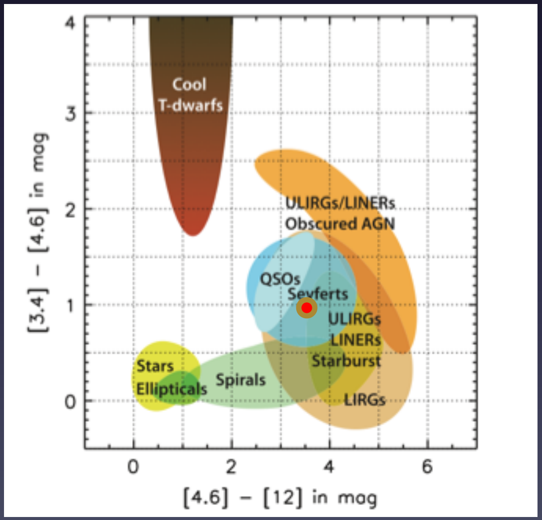
LLAGN: The Power of JWST



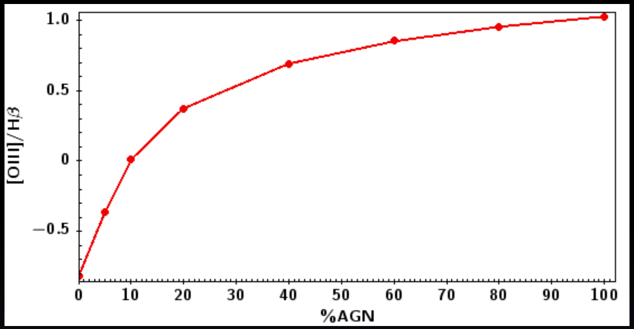


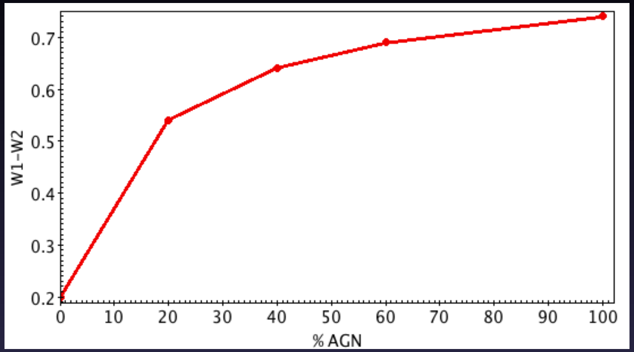


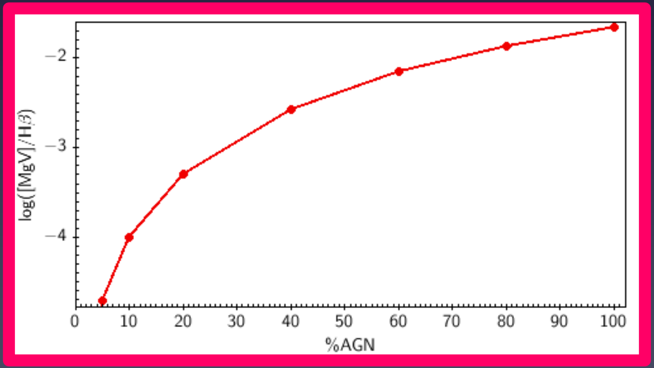




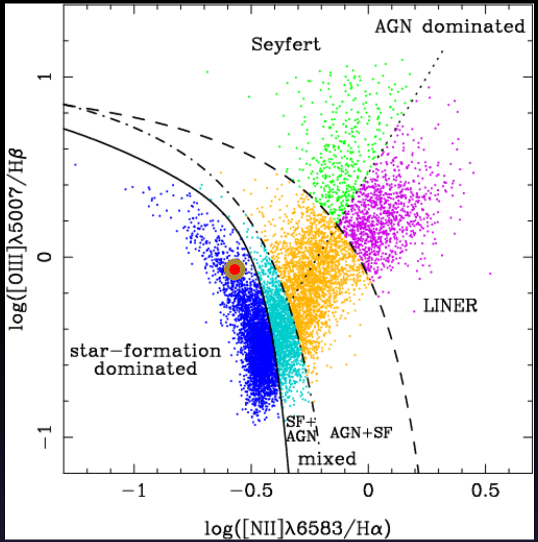
LLAGN: The Power of JWST

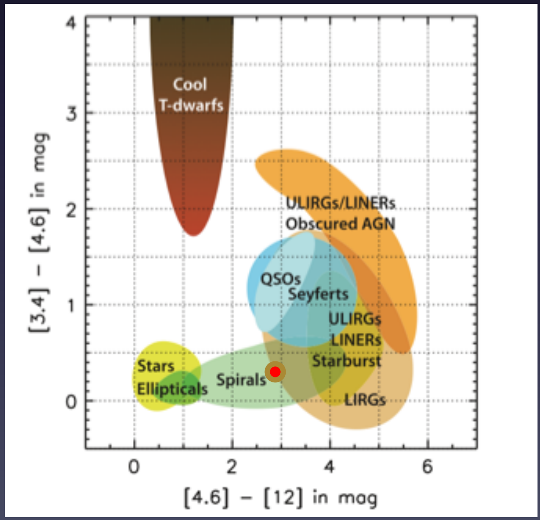






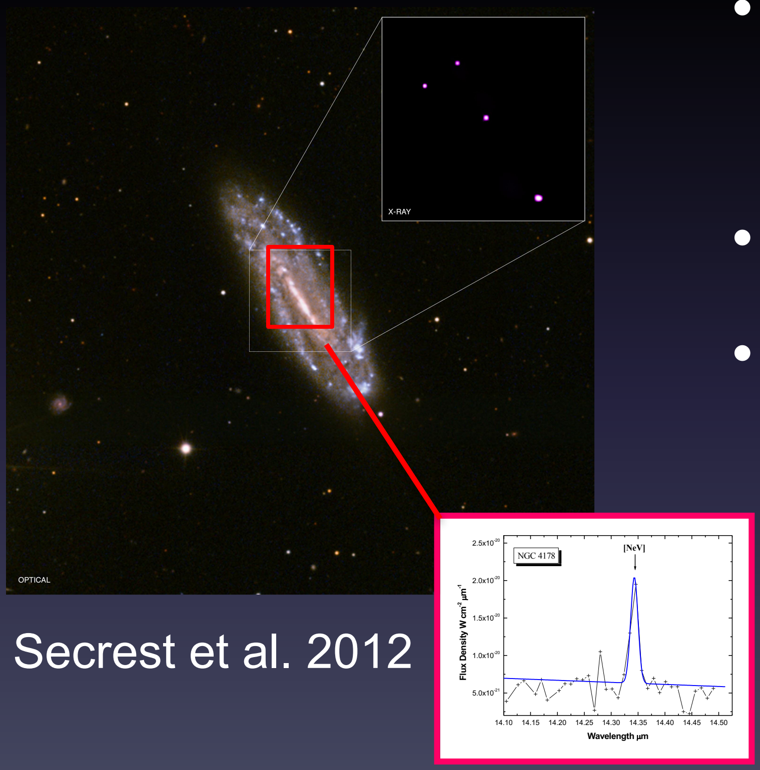
Finds AGN





Satyapal et al. 2019, in prep

The Power of Infrared Spectroscopic Diagnostics

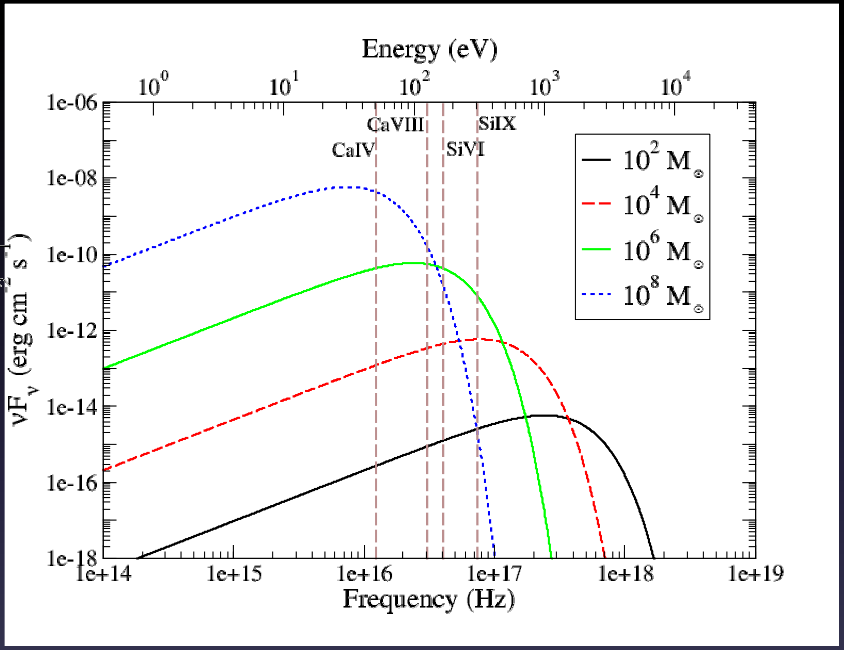


Secrest et al. 2012

- Spitzer finds AGNs in low bulge mass regime
- No sign of AGN in optical
- Detection rate 4X higher than optical studies

(Satyapal et al. 2007,2008, 2009)

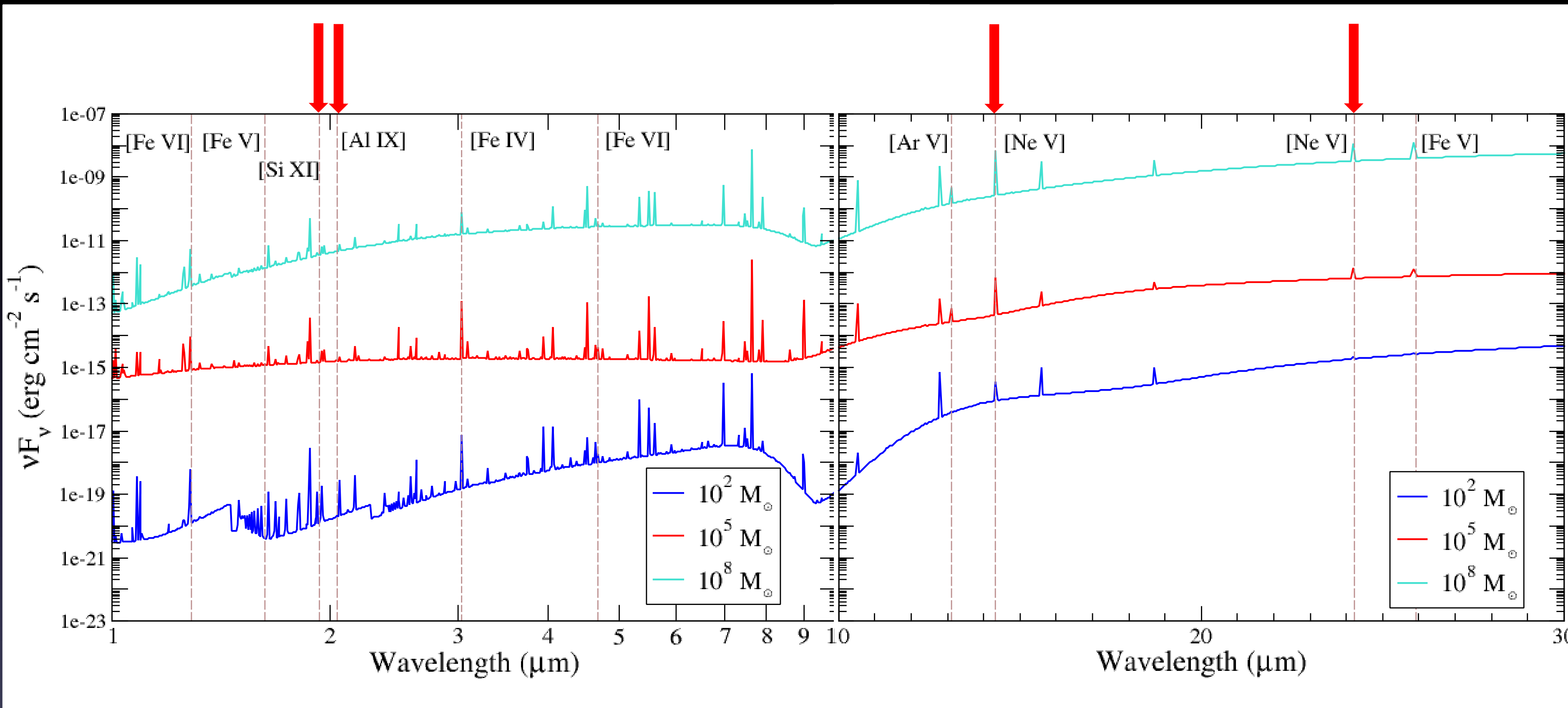
IR Spectroscopy
Diagnostic Potential



- Lower mass black holes have hotter accretion disks
- Harder SED can result in emission from higher ionization species

Black hole mass indicator?

Simulated Spectra



Cann et al. 2018

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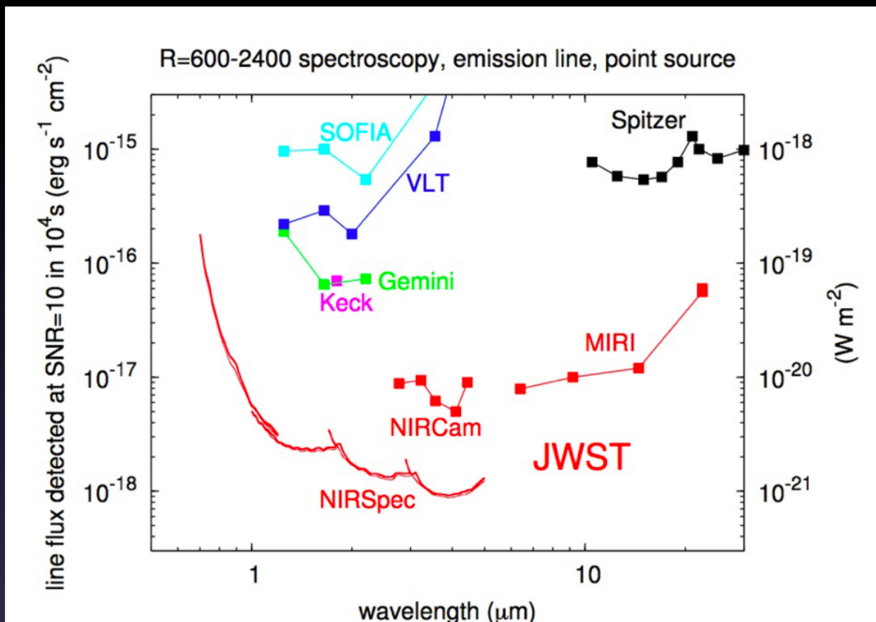
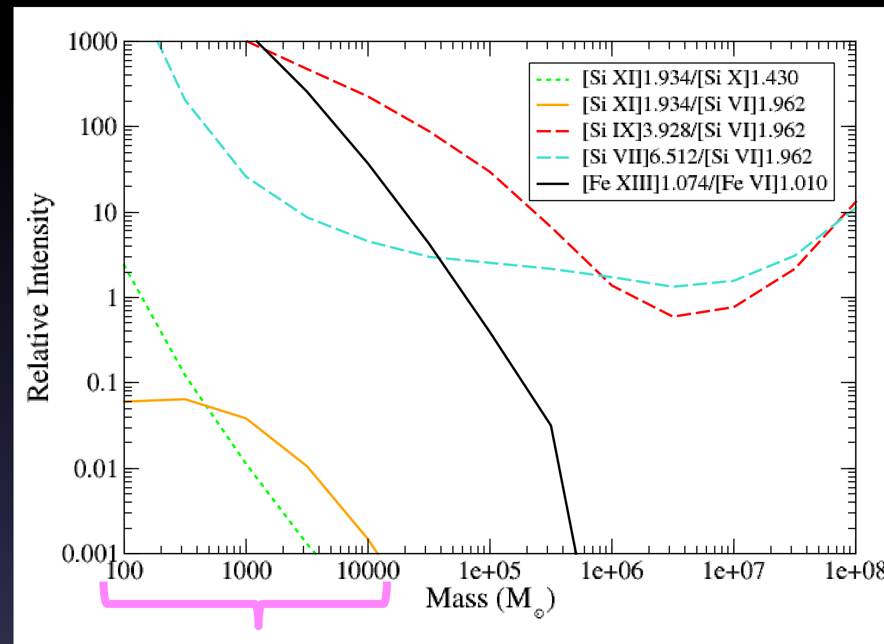


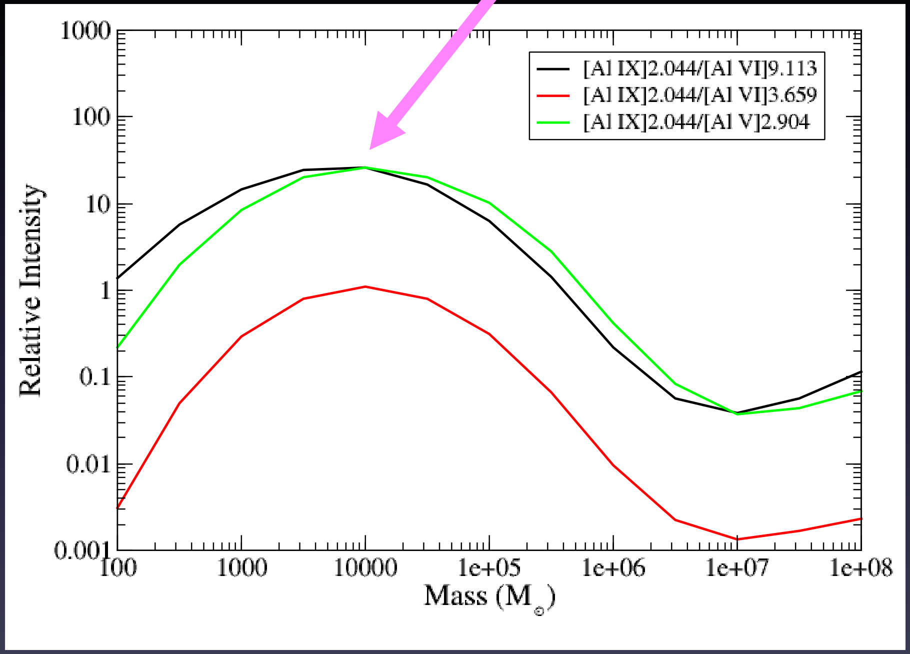


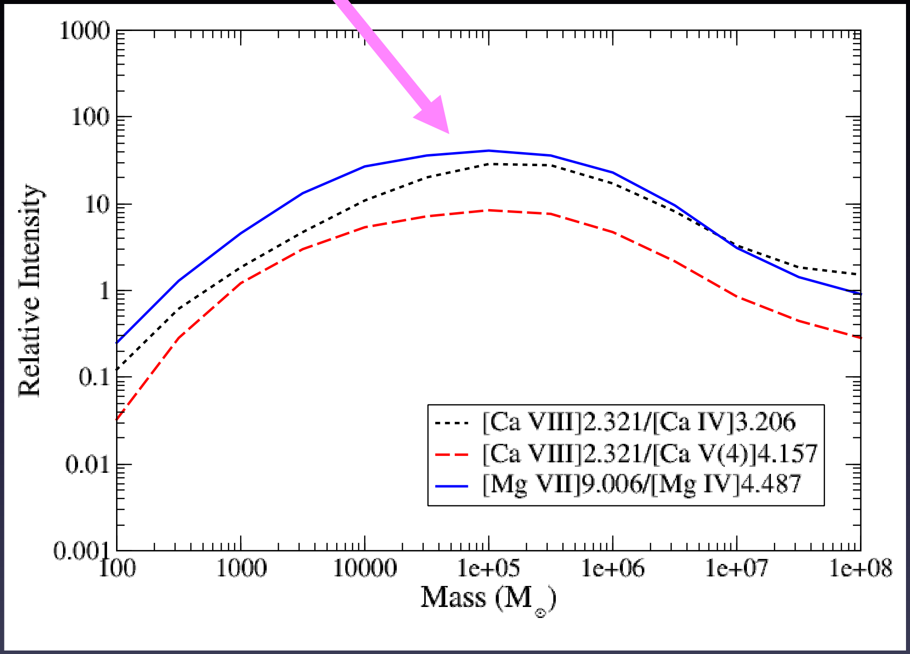
Cann et al. 2018

High ratios uniquely identify low mass black holes

IR Spectroscopy
Diagnostic Potential

High ratios uniquely identify mid-range black hole masses





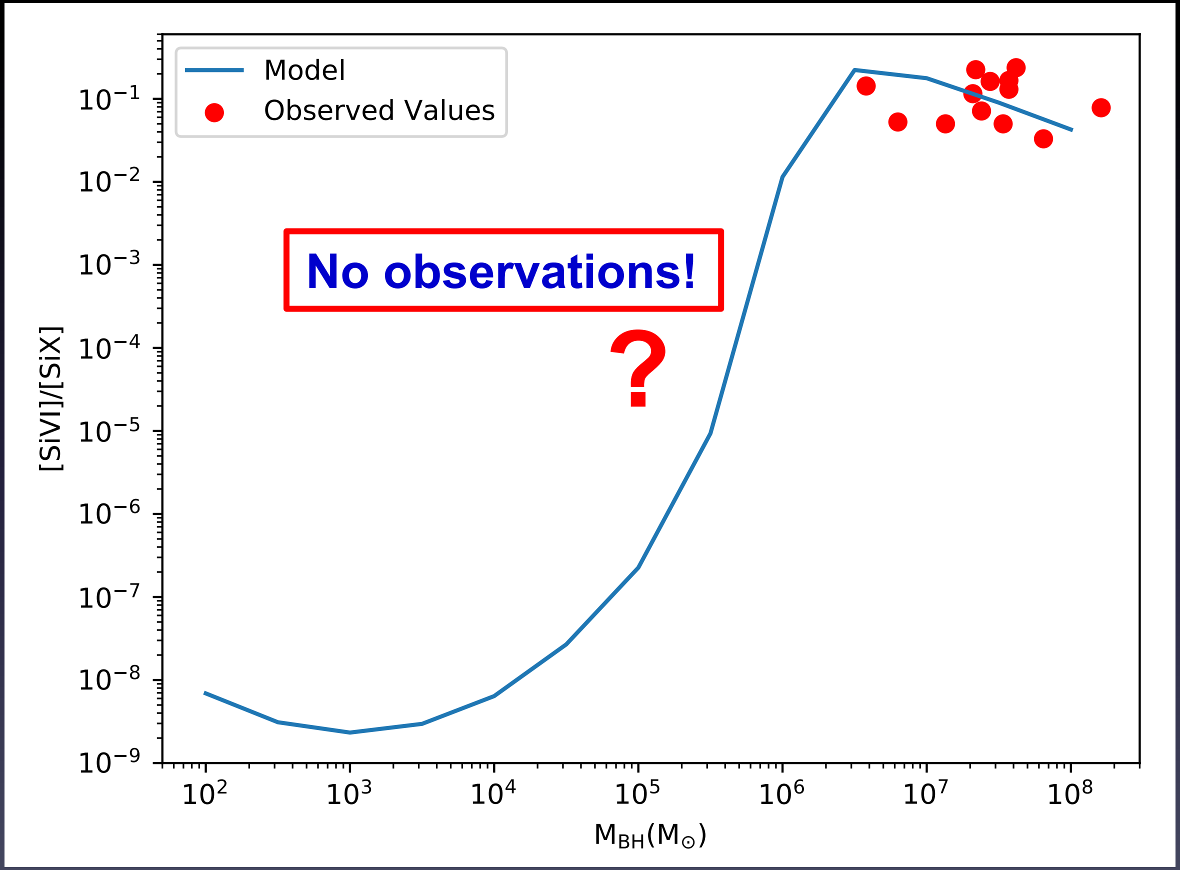
Cann et al. 2018

Diagnostic Line Ratios ($10^4\ M_\odot < M_{BH} < 10^6\ M_\odot$)

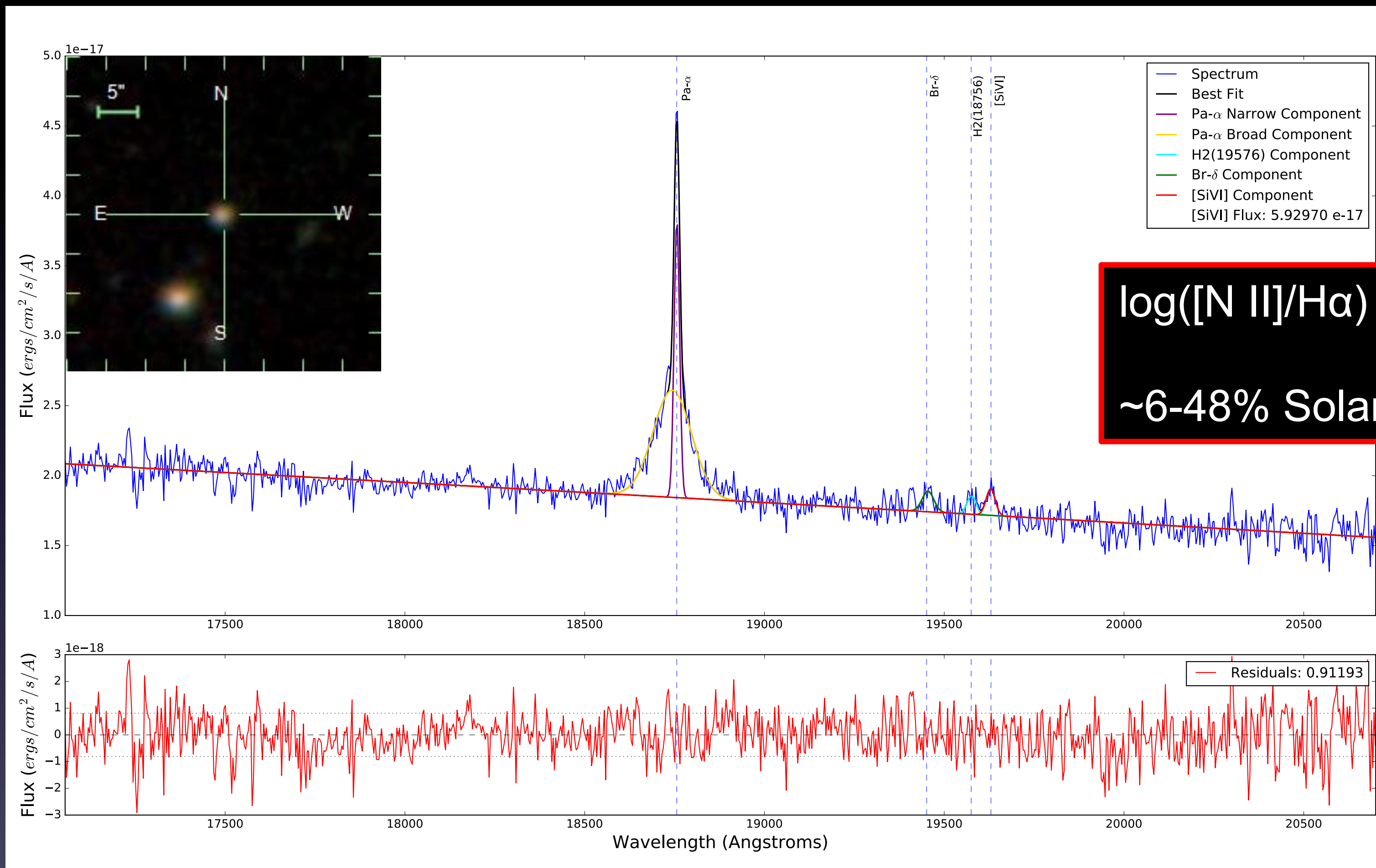
Initial comparisons to observations in high-mass regime

- [Si VI]1.962/[SiX]1.430 line flux ratios from BASS
- Masses of observed black holes generally around 10^7– 10^8 $M_\odot$

Cann et al. 2018



First Detection: J1056+3138



log([N II]/Hα) = -1.30

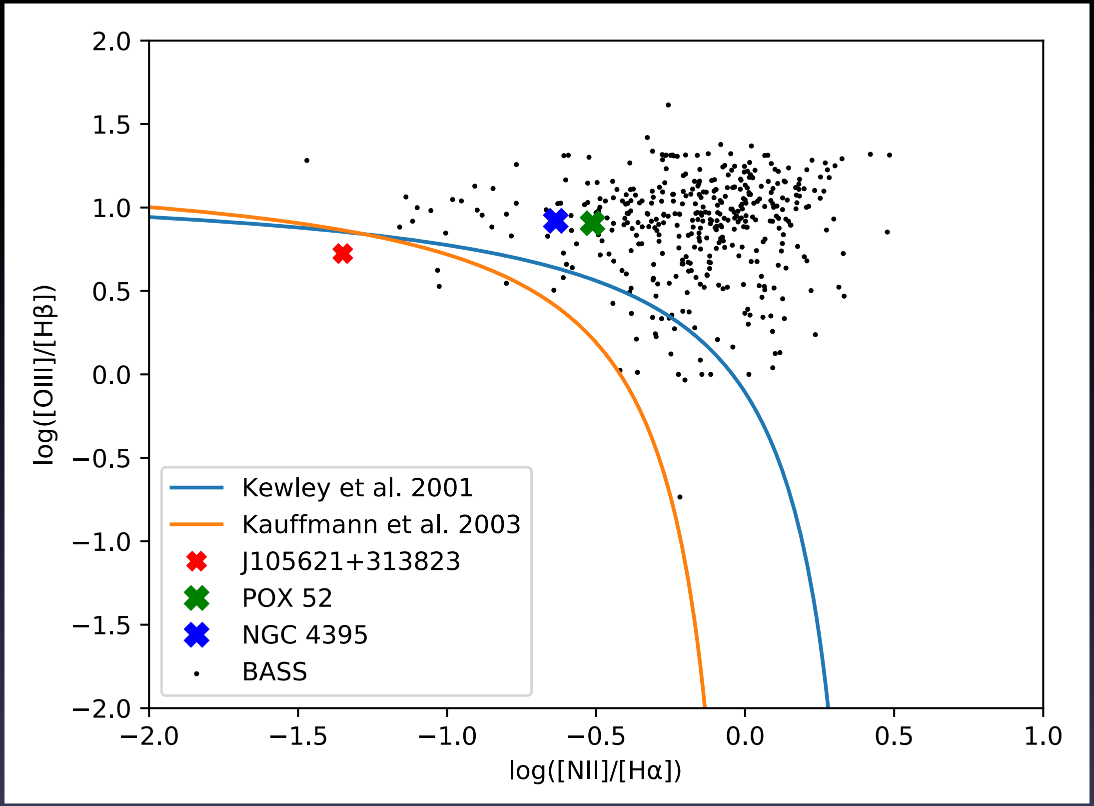
~6-48% Solar

Cann et al. 2019b, submitted

First Detection: J1056+3138

- MIR AGN
- [Si VI]19628A
- Broad Paα

- 0.25x Eddington accretion



Cann et al. 2019b, submitted

Key Take Away Points

- Dearth of IMBHs could be in part due to bias introduced by wrong set of tools to find them
- IR coronal lines may be the best way to find them
- IR coronal lines may provide insight into their mass and accretion properties
- Pilot study of J1056+3138 proves efficacy of these for BH detection in low mass, low metallicity regime

View optical and X-ray surveys of AGNs in dwarf galaxies with caution

"The real voyage of discovery consists not in seeing new landscapes, but in looking with new eyes."
-Marcel Proust


Stay tuned for JWST