A new diagnostic to distinguish between binary and single supermassive black holes using broad emission lines

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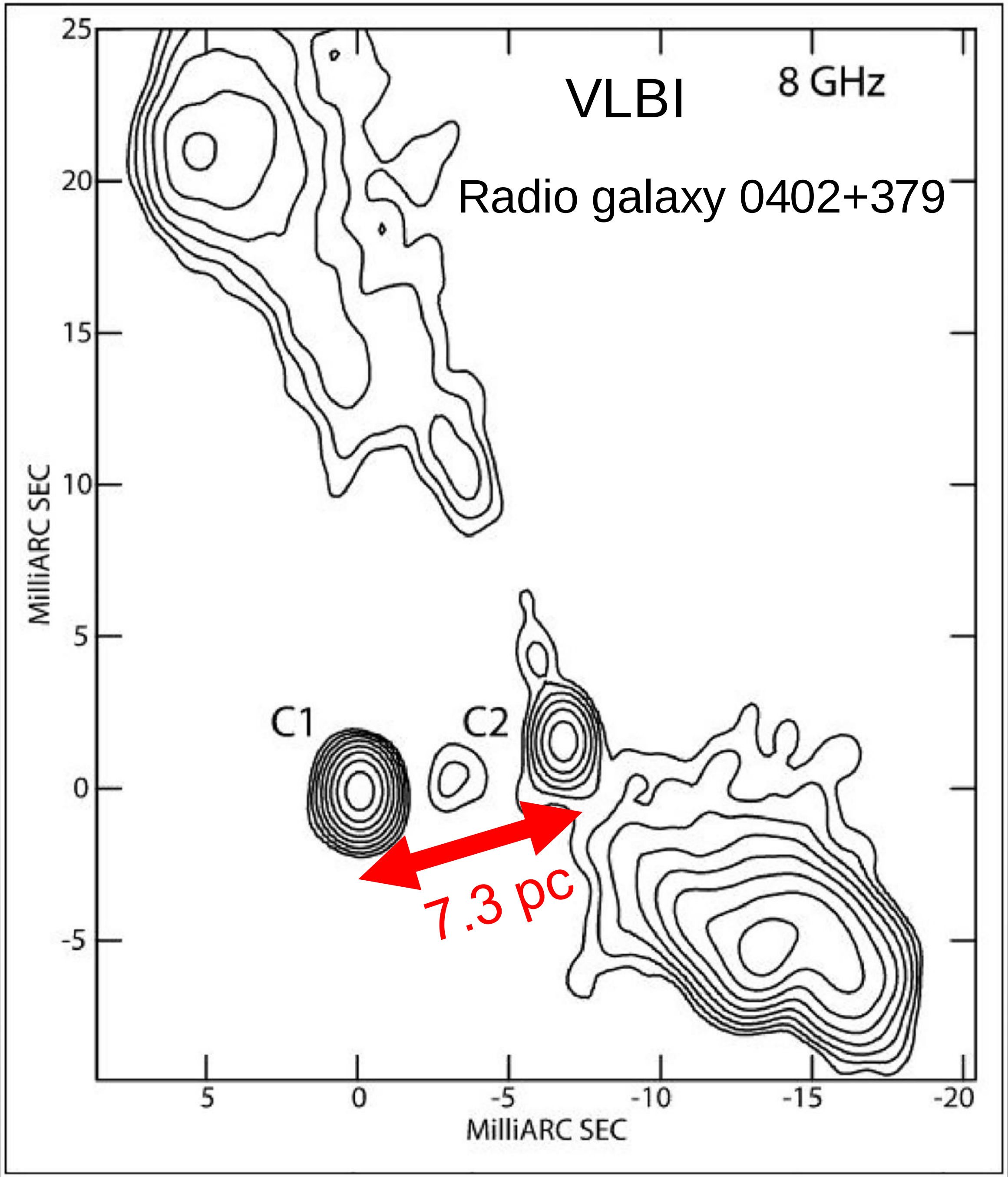
SMBBHs are important to study

- Provide crucial information about galaxy evolution and black hole growth
- Separation: 0.1 – 10 pc

(De Rosa et al. (2019))

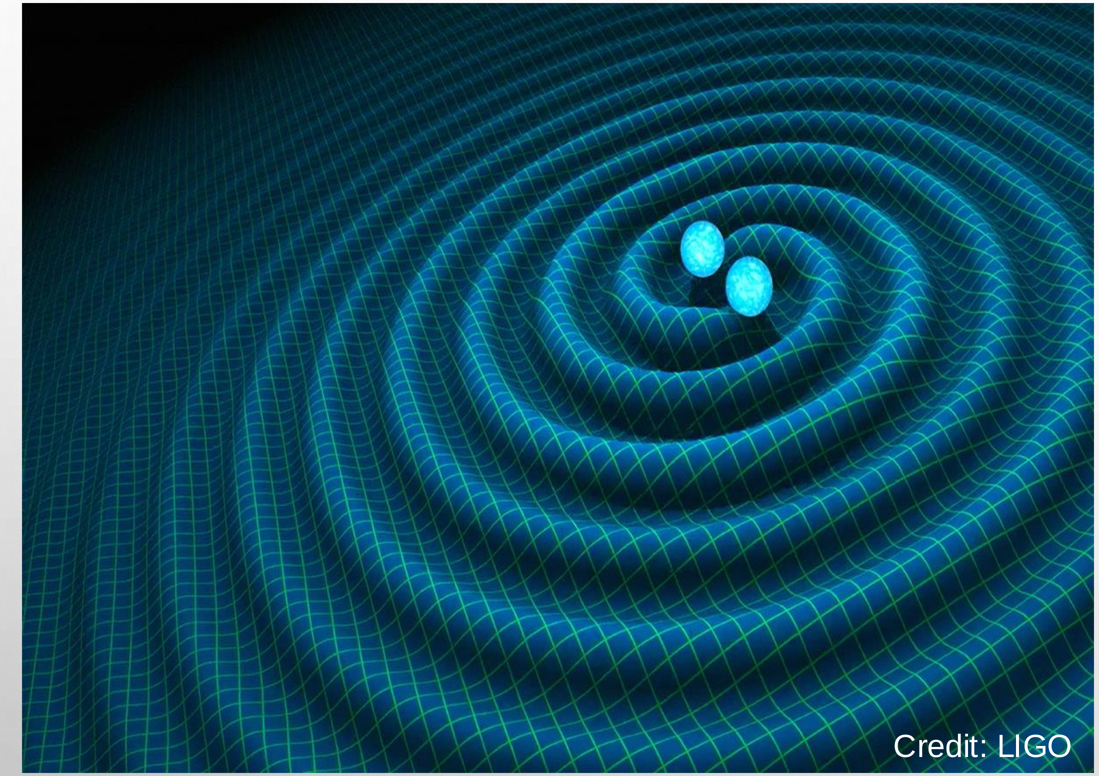
- 10% AGN are radio-loud



Credit: Rodriguez et al. (2006)

SMBBHs exhibit unique signatures

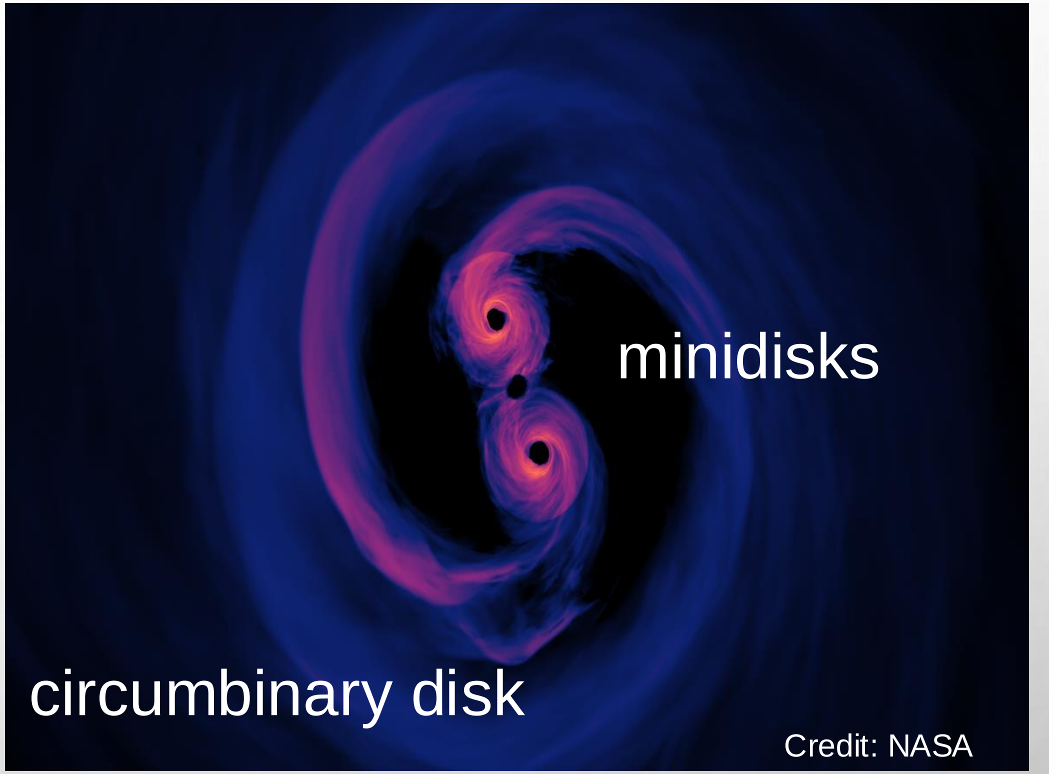
Gravitational waves



Detectable by LISA and PTAs

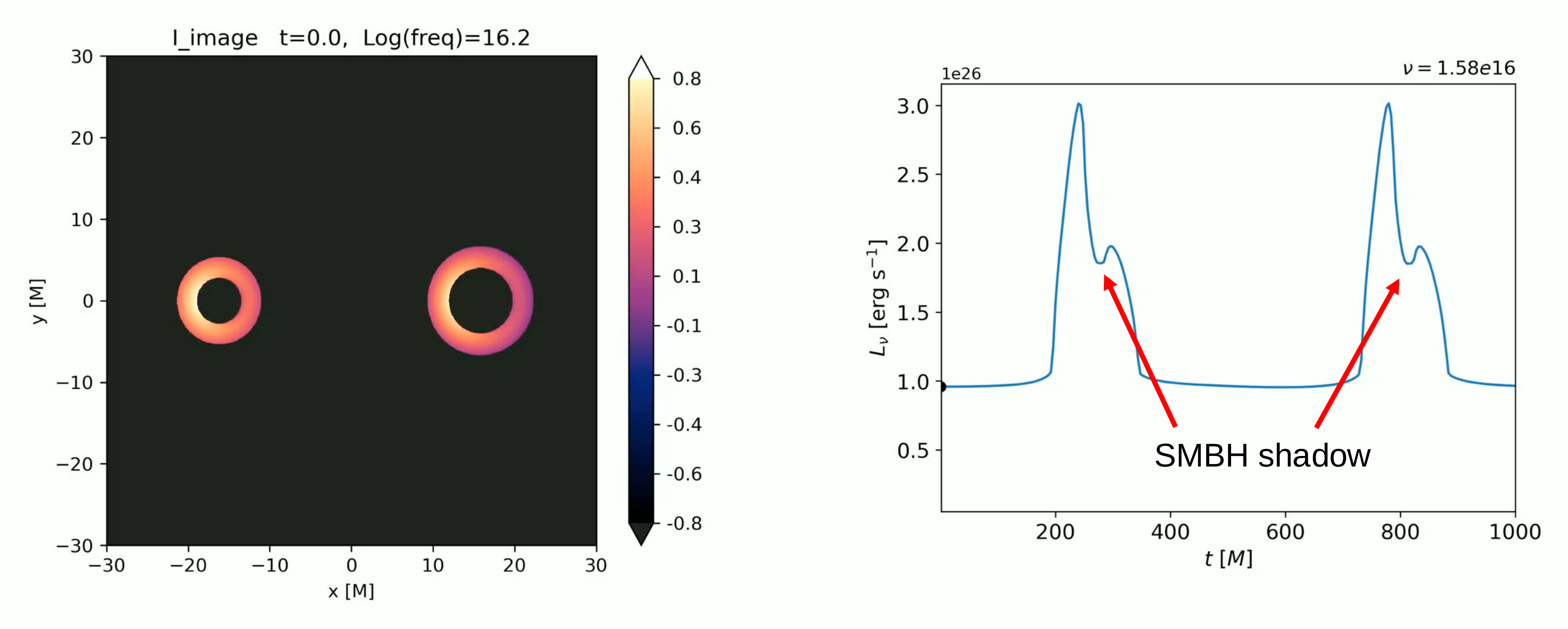
$10^4 - 10^7\ M_\odot$ $10^8 - 10^9\ M_\odot$

Electromagnetic signatures



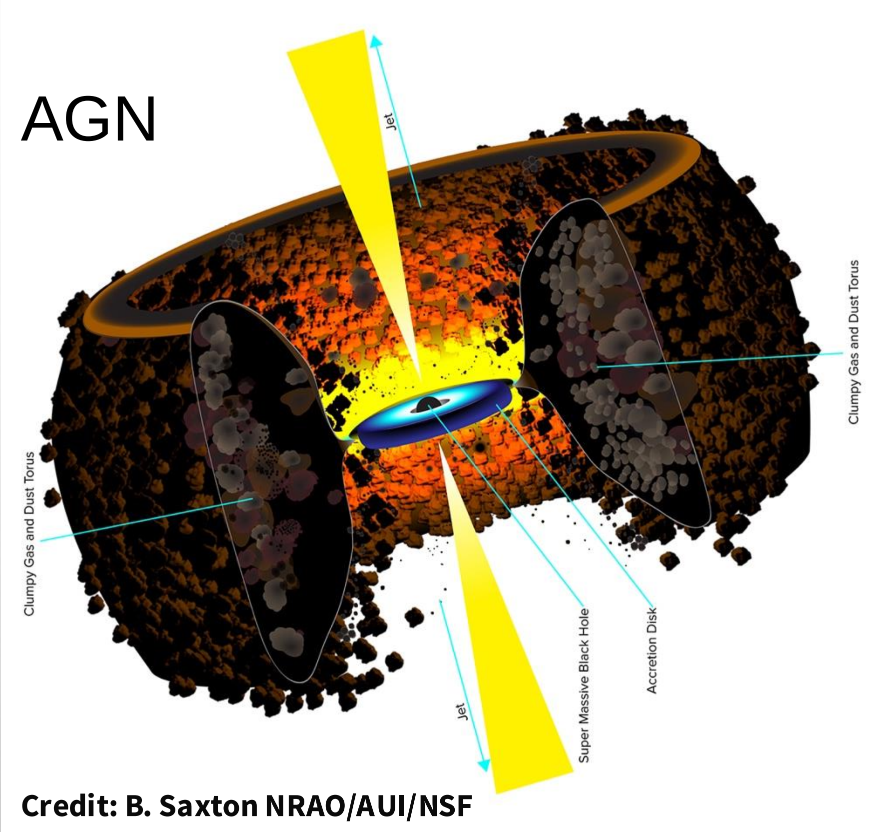
EM counterpart

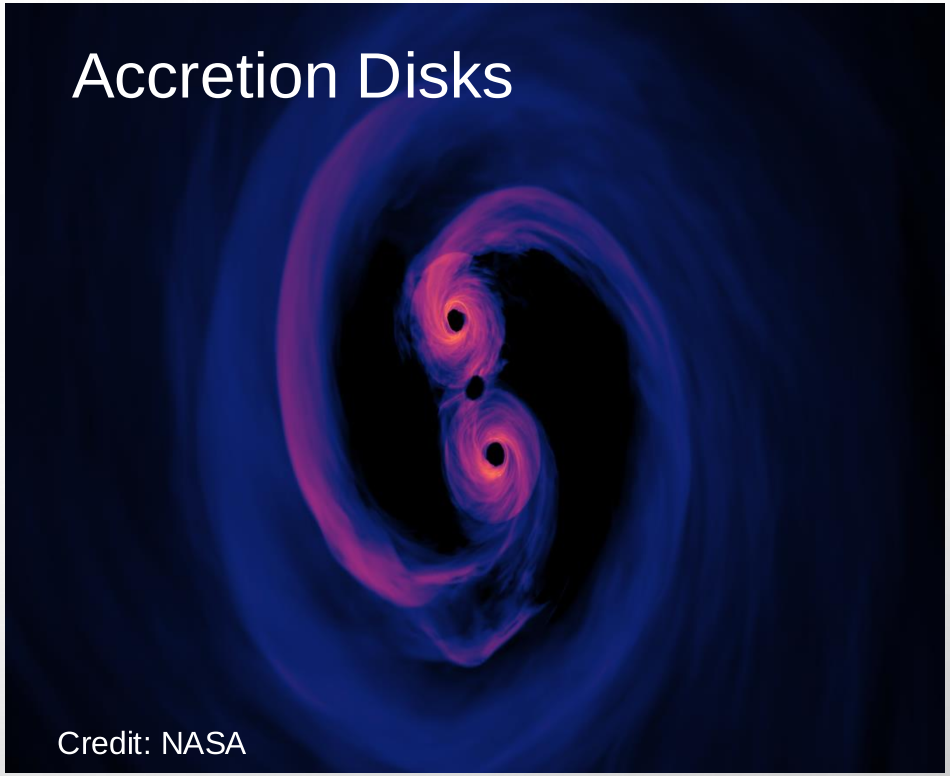
Most unambiguous EM evidence of SMBBHs: self-lensing flares



Porter et al. (2024)

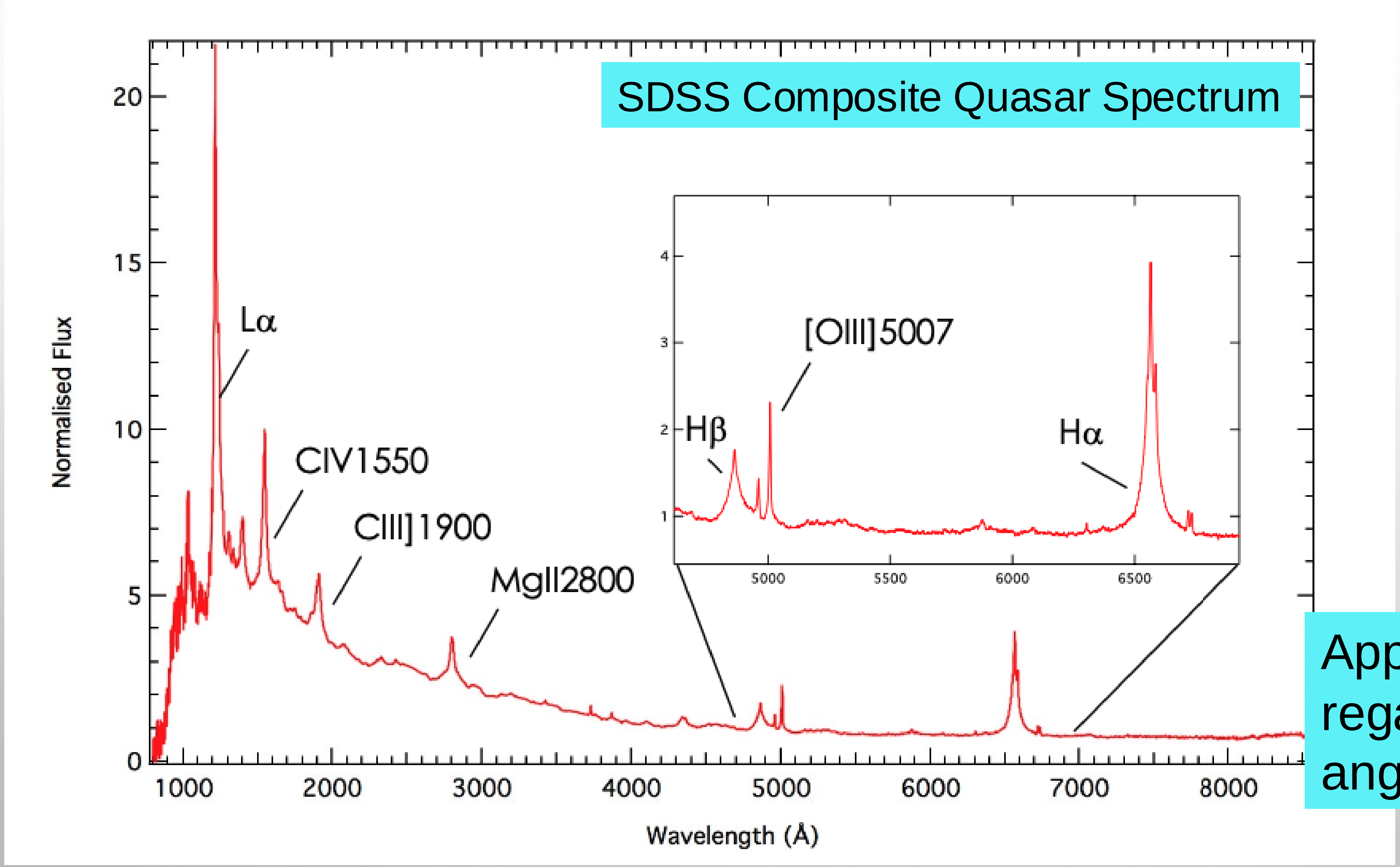
EM Diagnostic: Can we identify SMBBHs using broad emission lines?





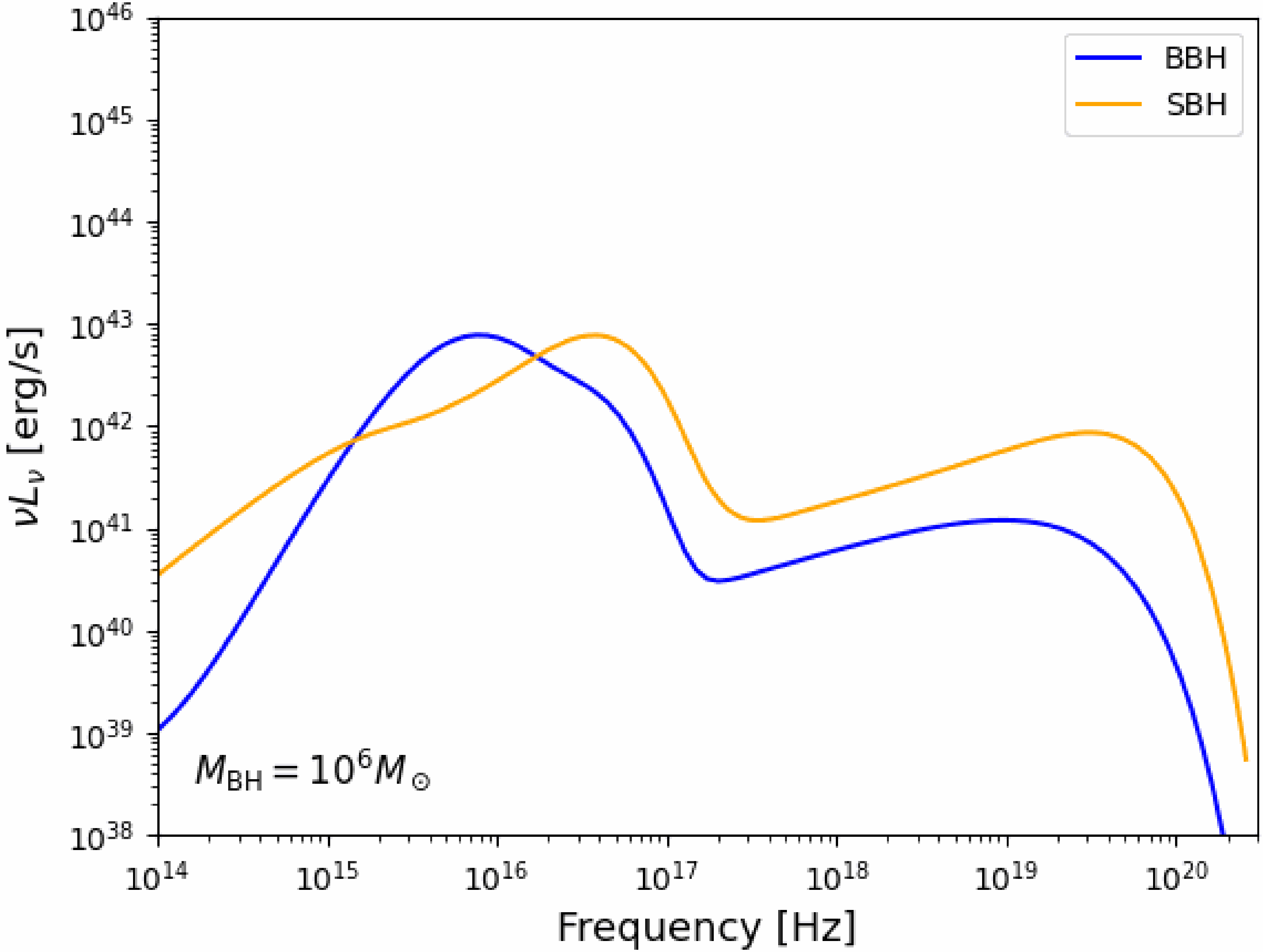
Emission lines differ?

EM Diagnostic: Can we identify SMBBHs using broad emission lines?



Applicable to large datasets, regardless of the viewer angle

Spectral Energy Distributions

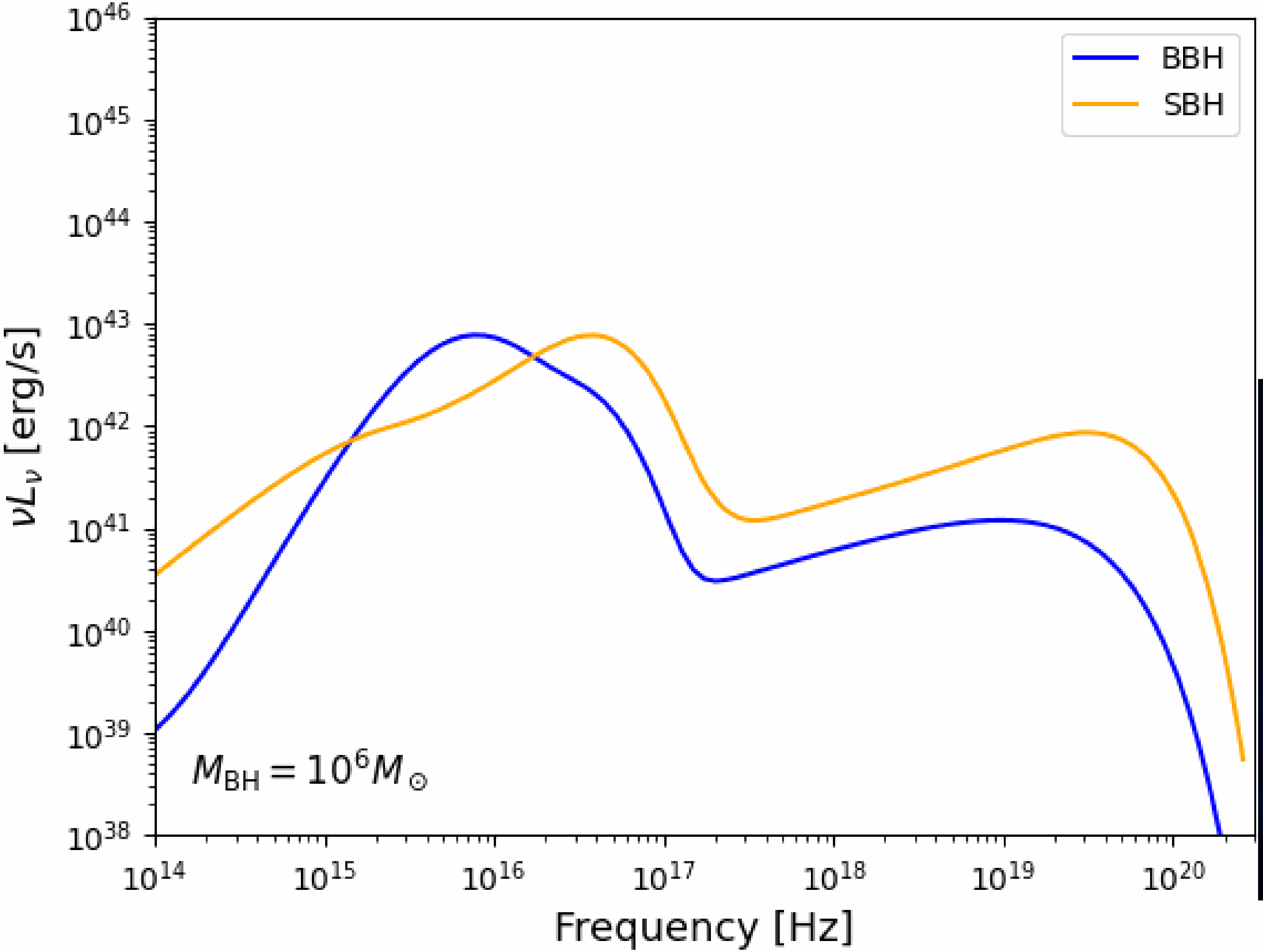


BBH: GRMHD simulation
[Gutiérrez *et al* (2022)]

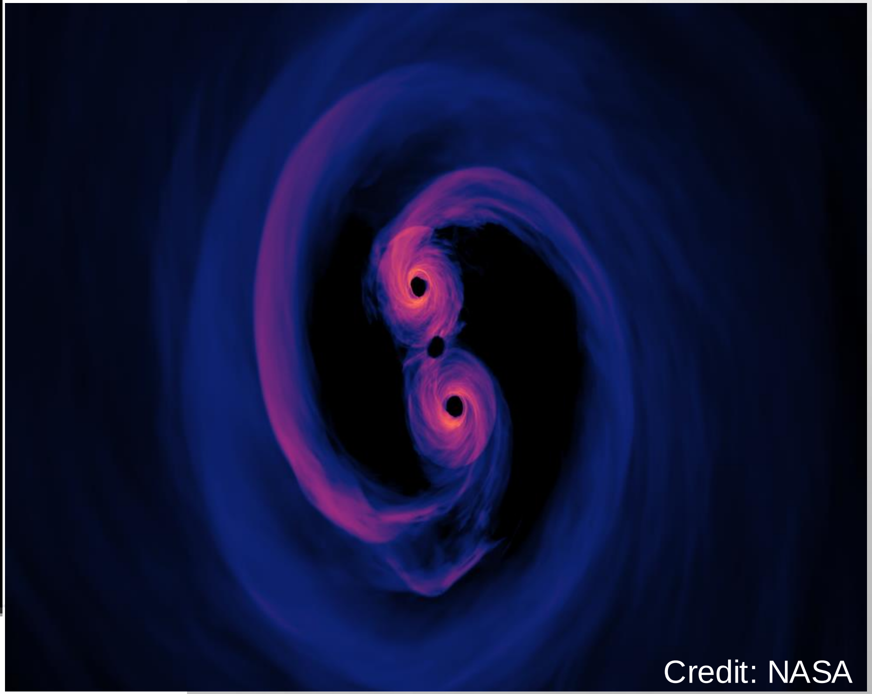
SBH: optxagnf simulation
[Done et al (2012)]

Difference diminishes as mass increases

Spectral Energy Distributions

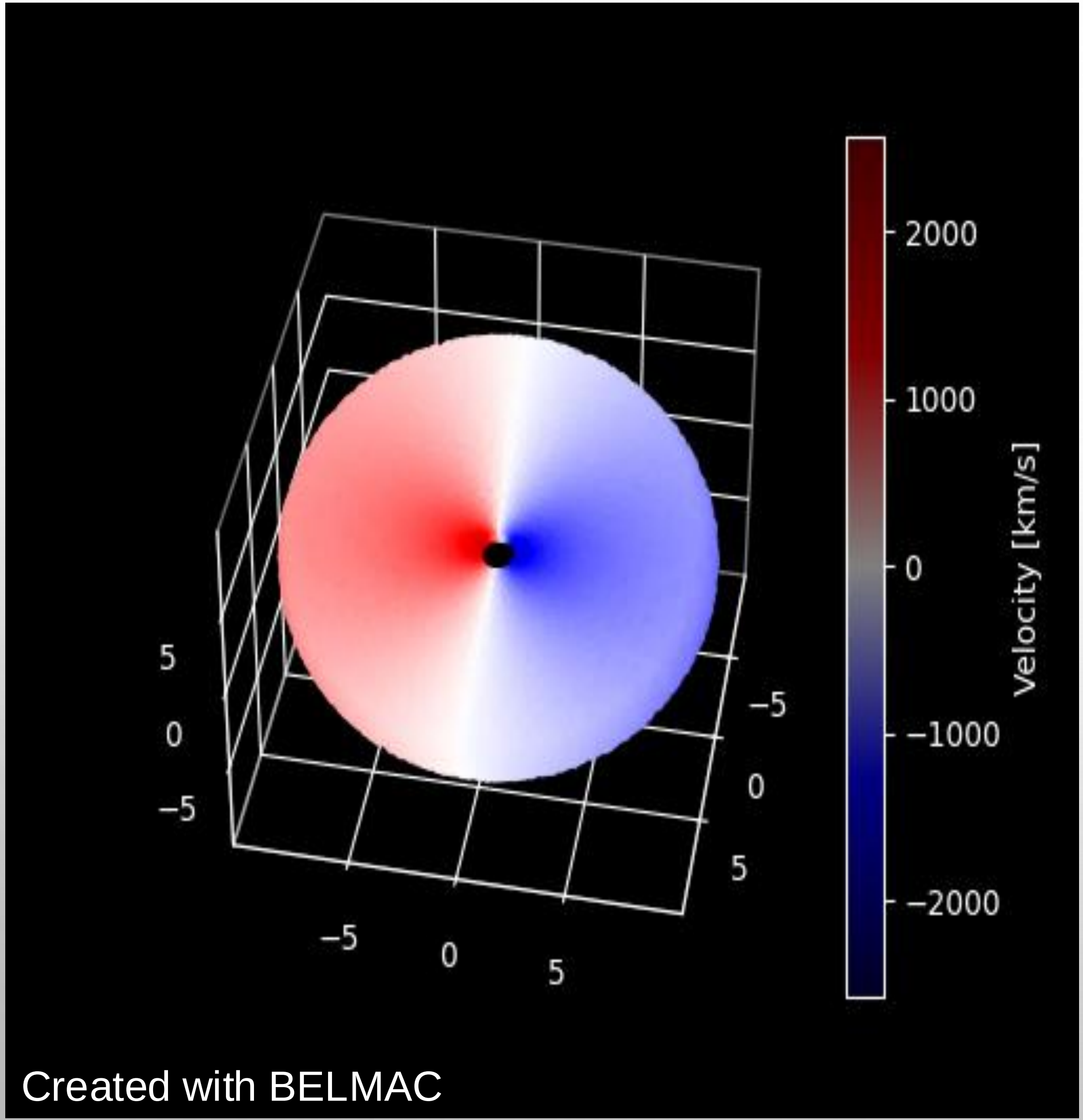


Difference diminishes as mass increases



Credit: NASA

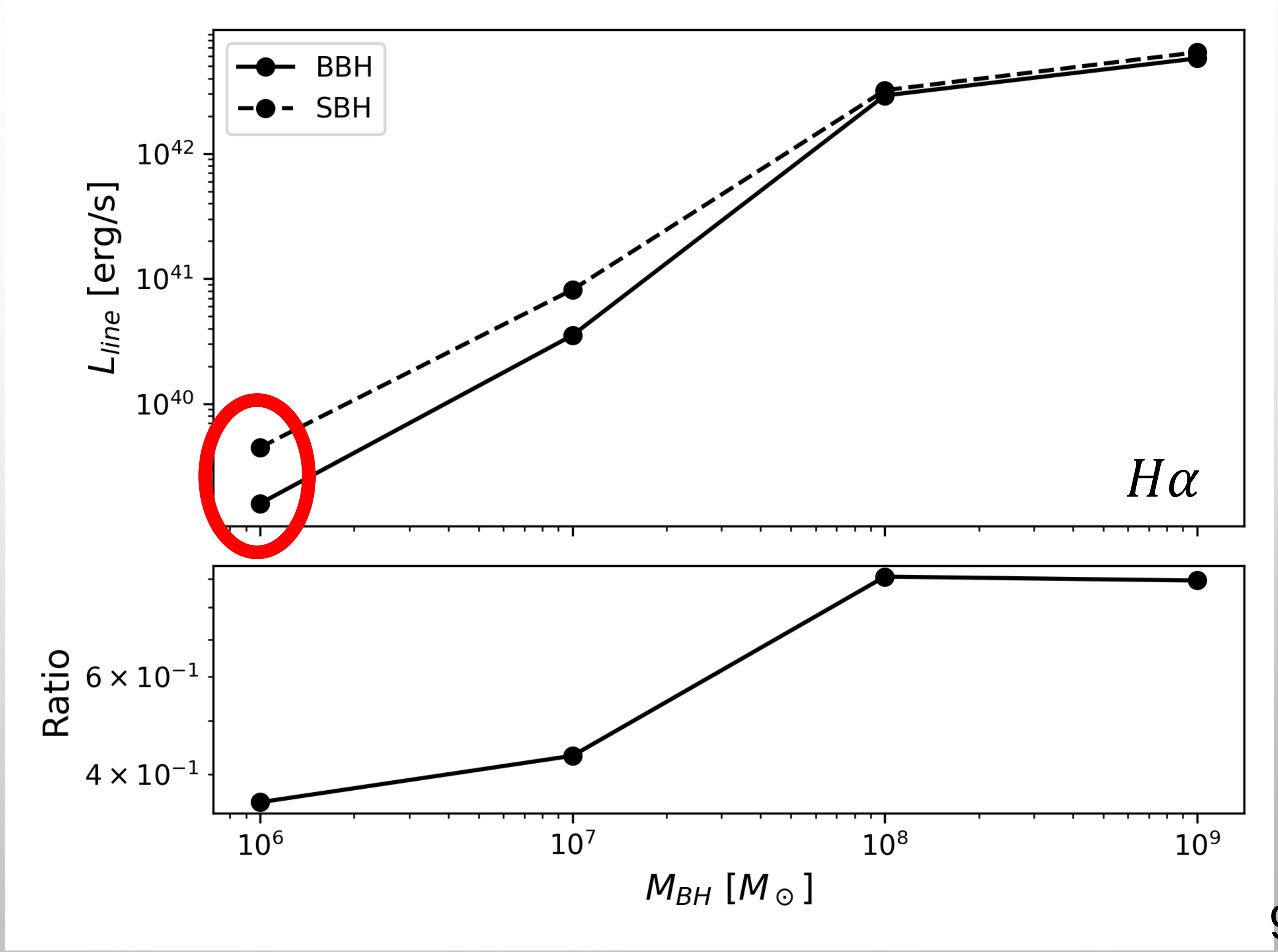
BLR Photoionization Models with BELMAC



- Broad Emission Line MApping Code (Rosborough et al. (2024))
- Cloud-ensemble models
- Same parameter sets:
  - ❖ Bolometric luminosity
  - ❖ Black hole mass
  - ❖ Illuminating fraction

Emission line strengths differ!

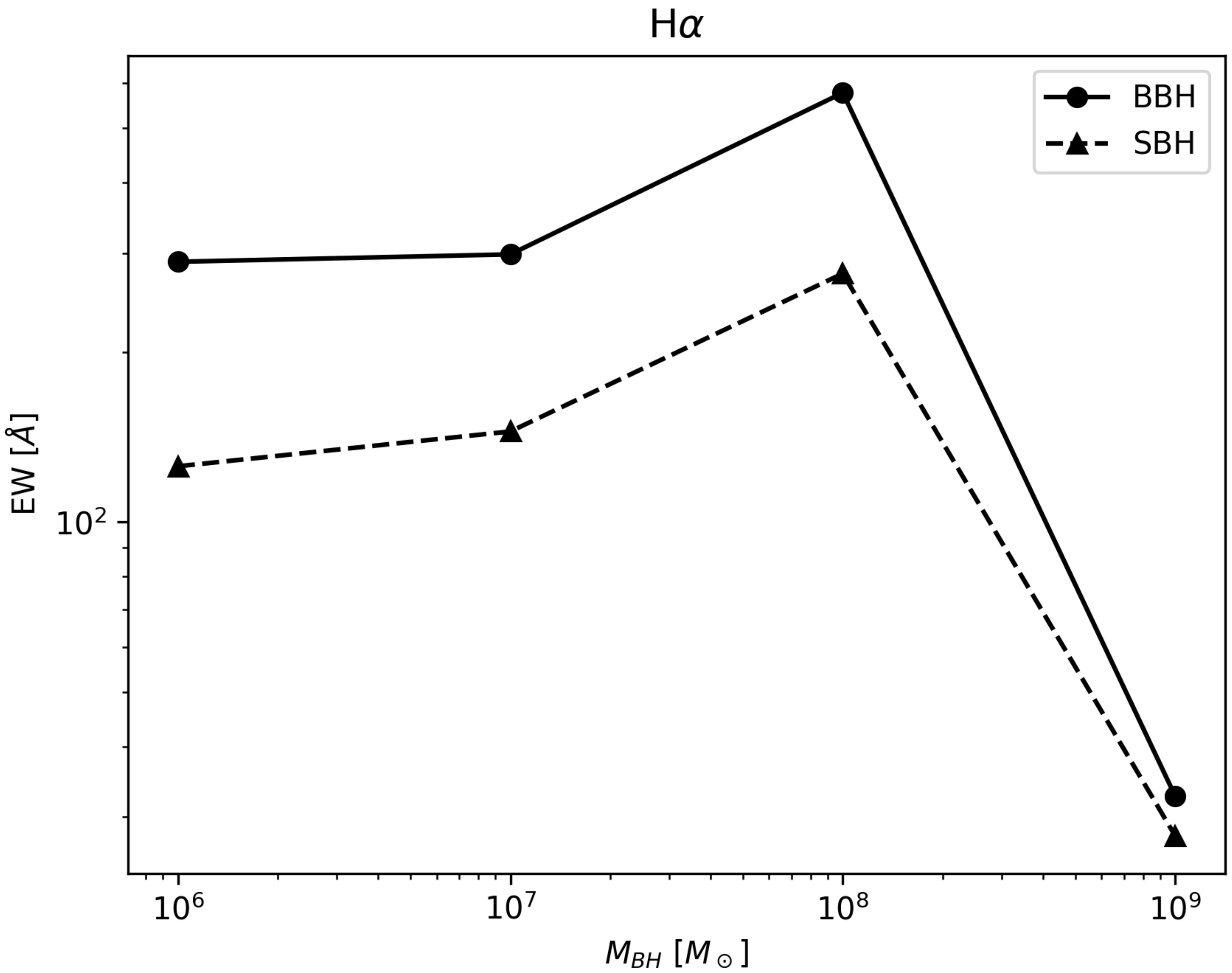
Biggest difference at $10^6\ M_\odot$



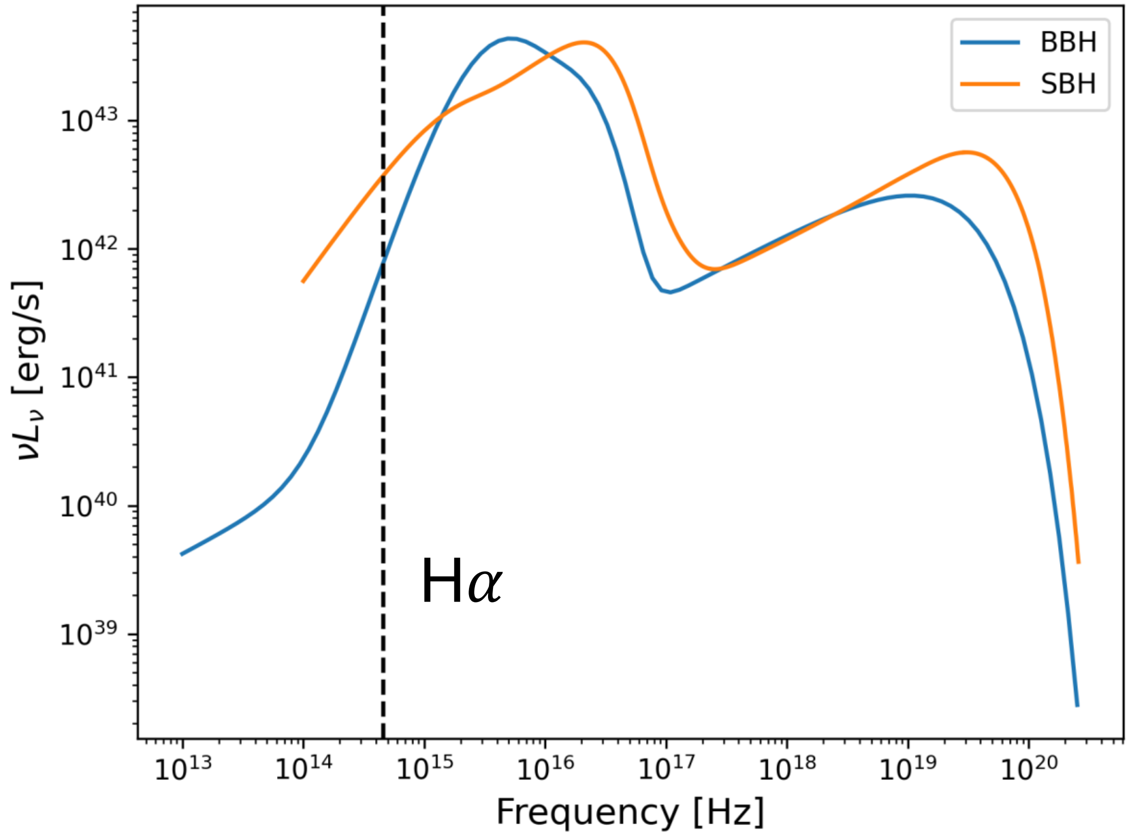
Simulated line equivalent width differs

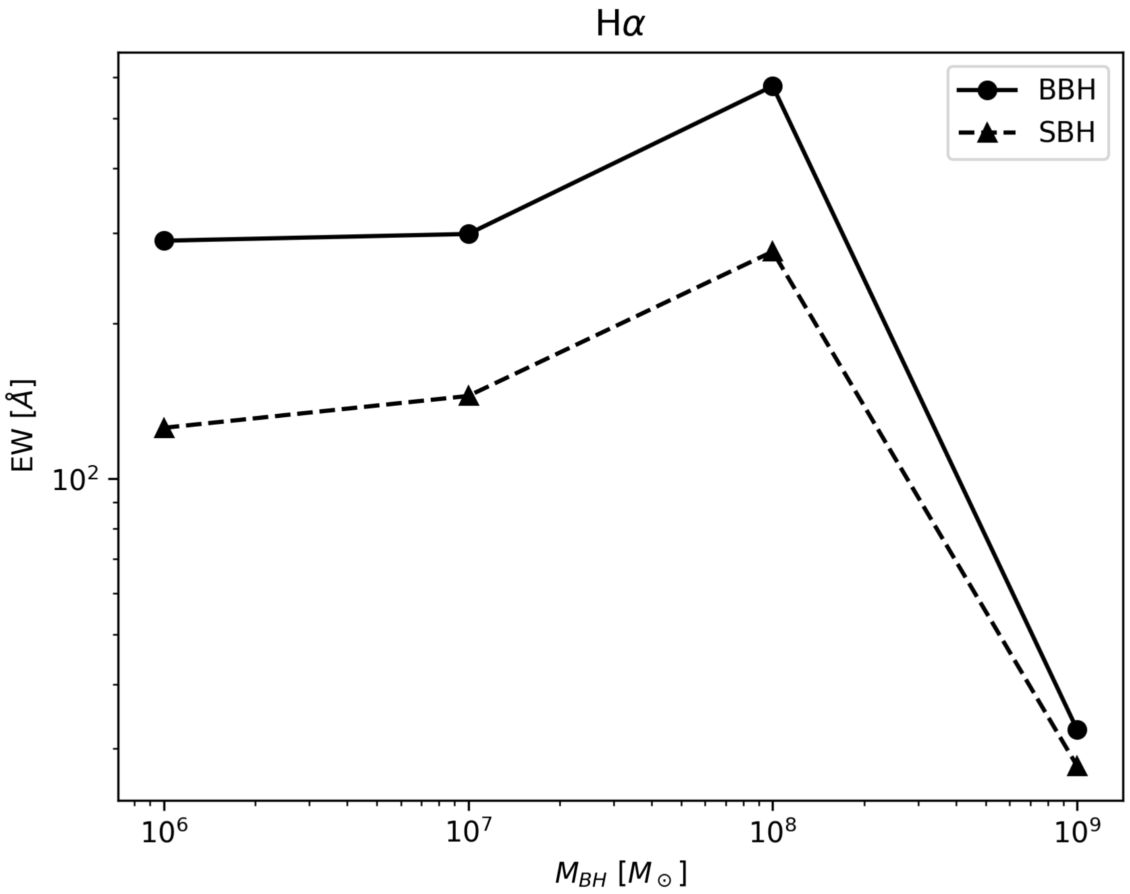
$$EW = \frac{L_{line}}{L_{c,\lambda}}$$

Distance-independent



BBH continuum level shows a steeper decrease





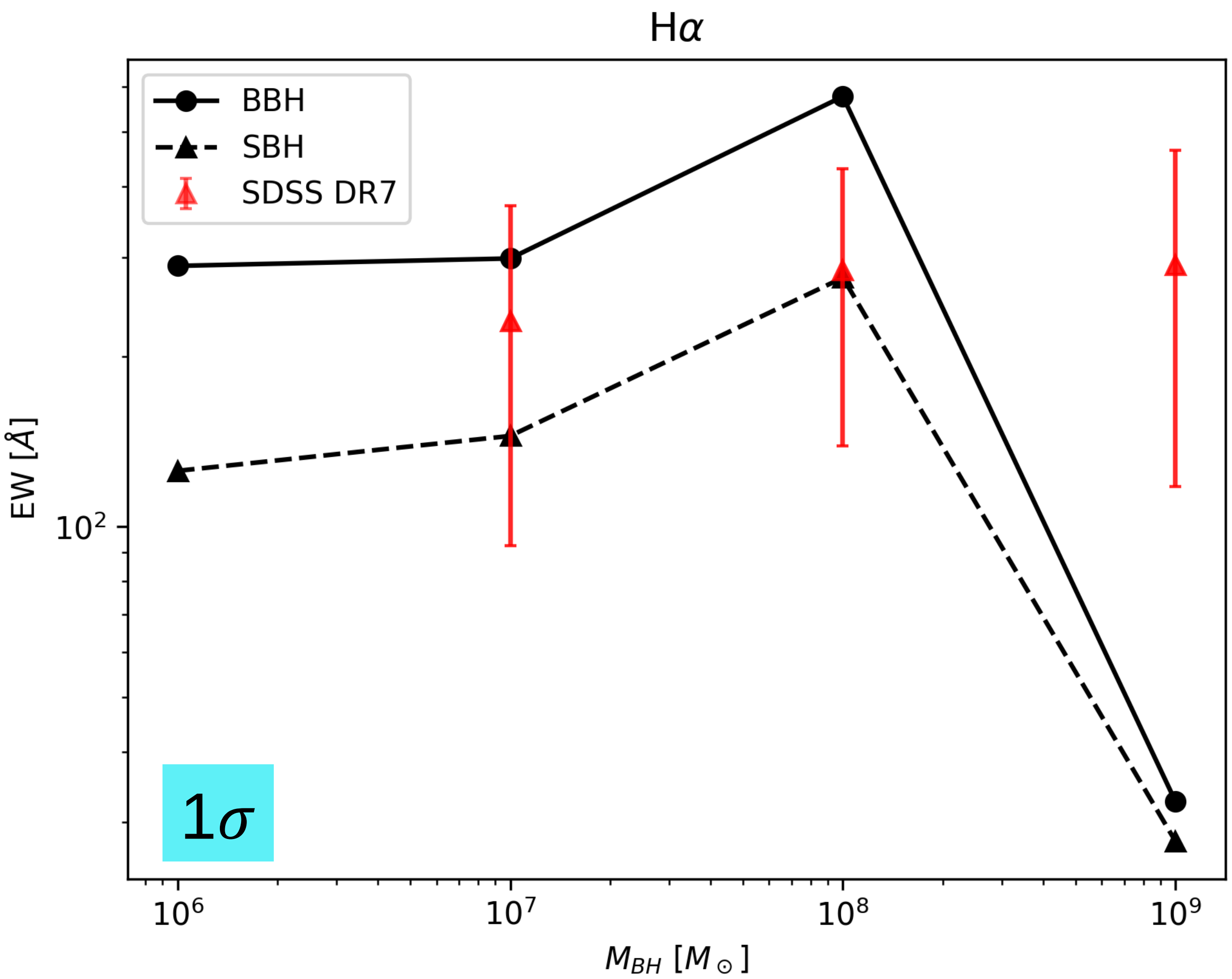
Simulated vs. Observed equivalent width

Dataset: SDSS (Sloan Digital Sky Survey) DR 7 Quasar Catalog (Shen et al. (2010))

Mass Bins:

- $10^7 bin: 10^{6.5} M_\odot - 10^{7.5} M_\odot$
- $10^8 bin: 10^{7.5} M_\odot - 10^{8.5} M_\odot$
- $10^9 bin: 10^{8.5} M_\odot - 10^{9.5} M_\odot$

Mean & Standard Deviation



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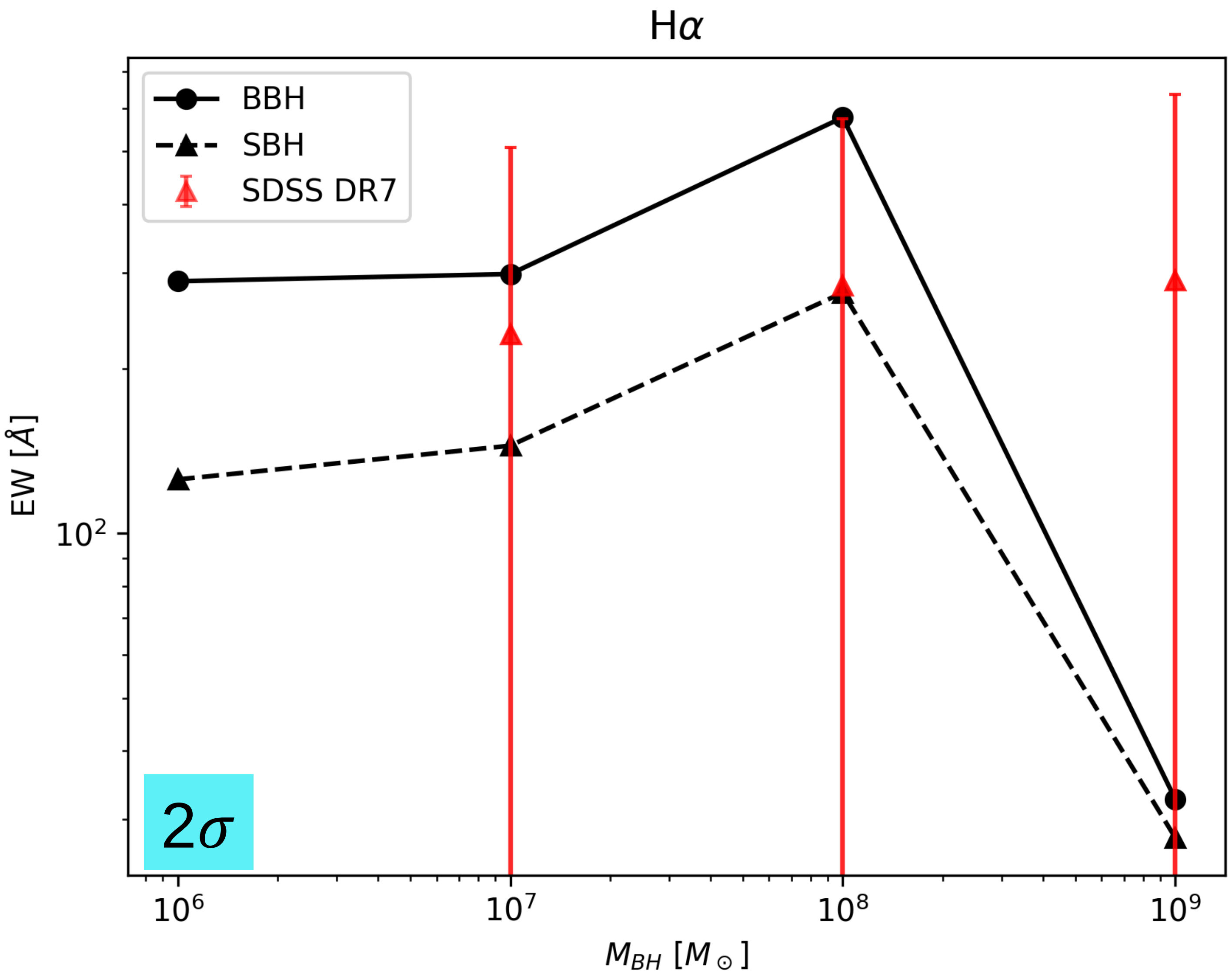
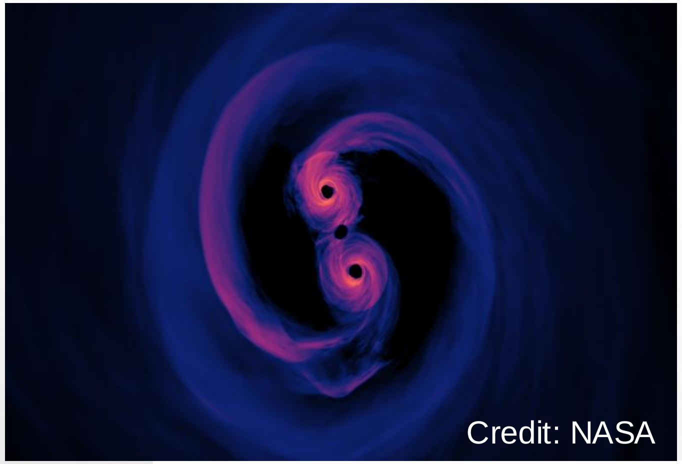
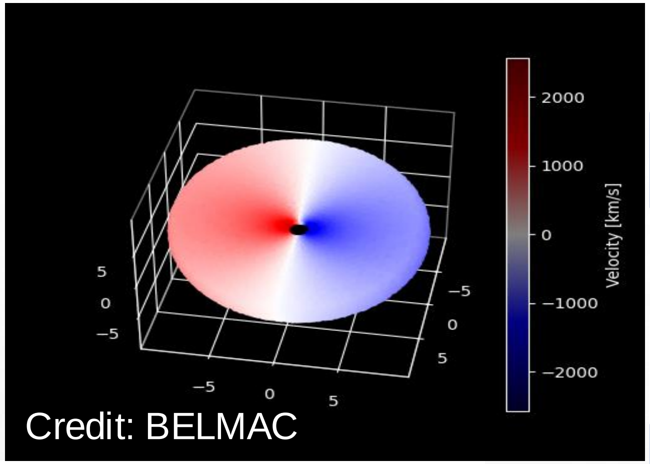
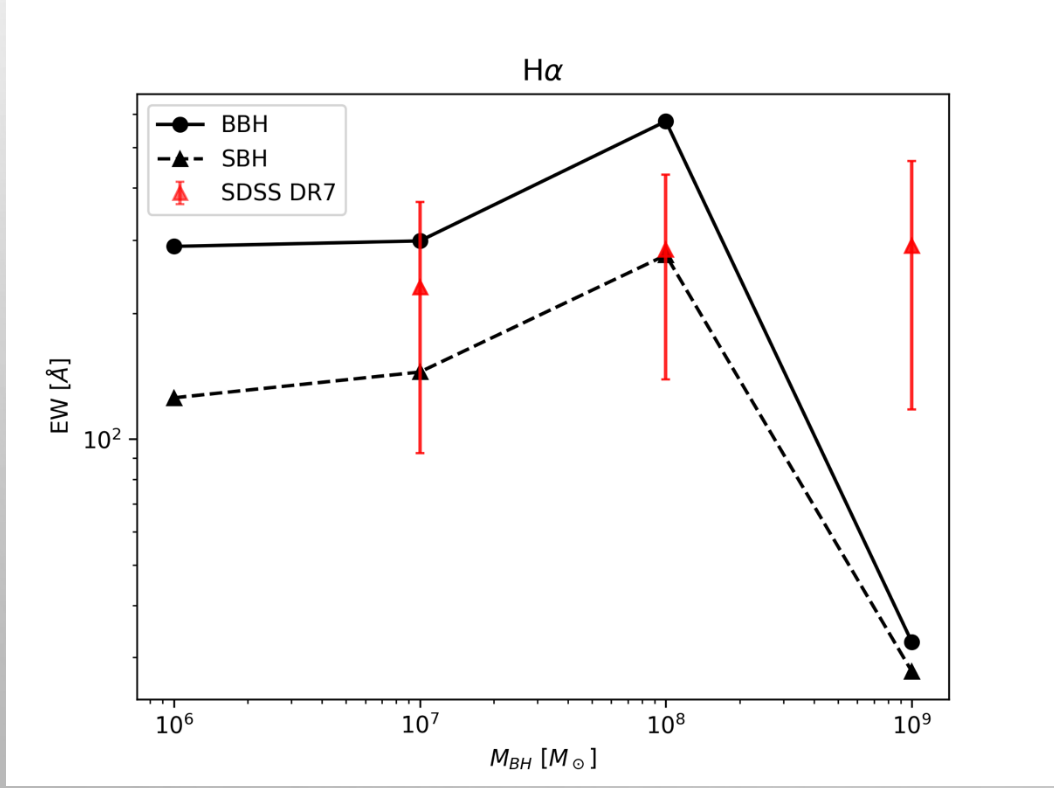


Conclusion: Line EWs differ but not very reliable. Need other evidence for BBH







Accretion Disk

Circumbinary + Minidisks

↓

SEDs

Differ most at low-mass BHs ($10^6 - 10^7\ M_\odot$)

↓

BLR

Ionization differs

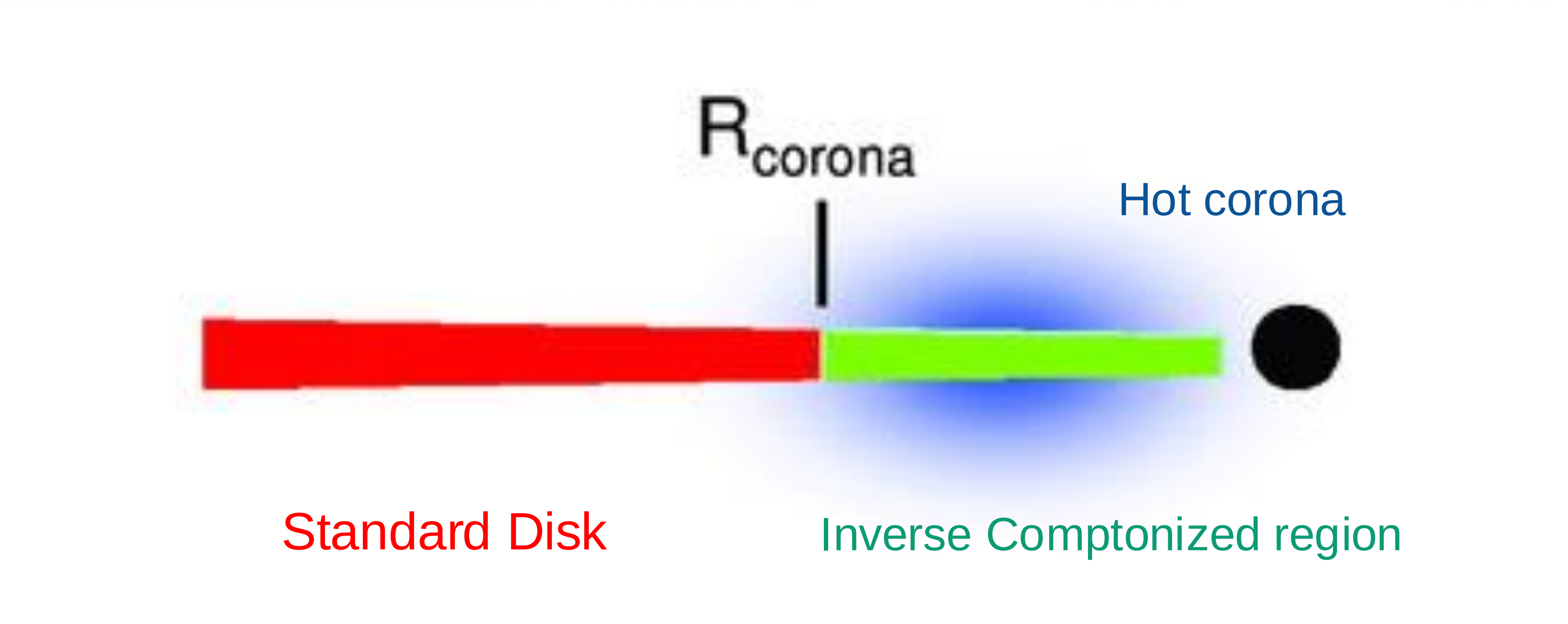
↓

Line EWs

Differ!	$2\sigma \geq$ BBH EWs > 1σ

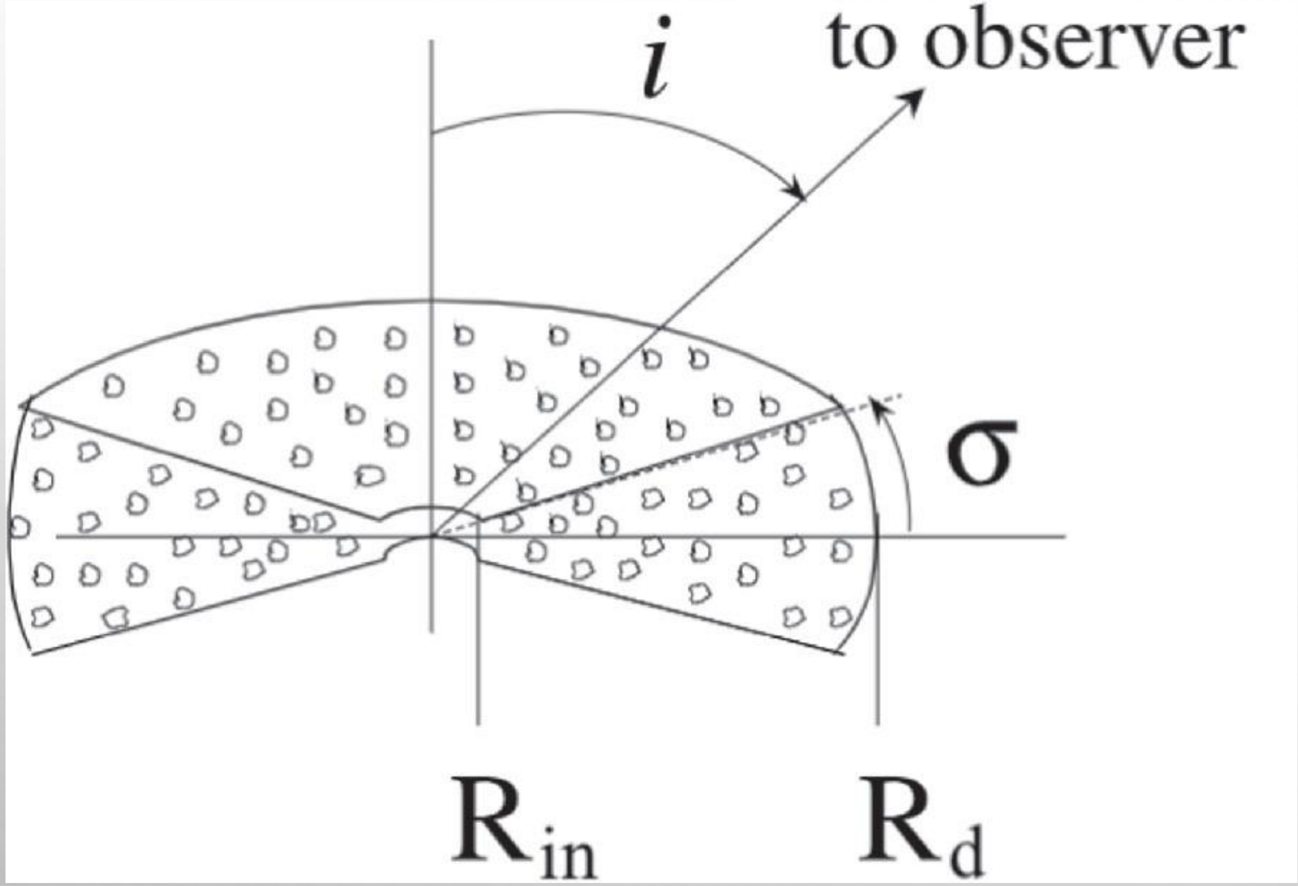
Back-up Slides

OPTXAGNF



R_{corona}
Hot corona
Standard Disk
Inverse Comptonized region

BELMAC (Broad Emission Line MApping Code)



$$U = \frac{\Phi(r)}{c n_H}$$

Other line EWs