

# How Black Holes Grow Across Cosmic Time

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**VS**

CENTER FOR **ASTROPHYSICS**

HARVARD & SMITHSONIAN

GORDON AND BETTY  
**MOORE**  
FOUNDATION

 **BLACK HOLE  
INITIATIVE**  
HARVARD UNIVERSITY

 **JOHN  
TEMPLETON**  
FOUNDATION

AAS 236<sup>th</sup> Meeting Press Conference

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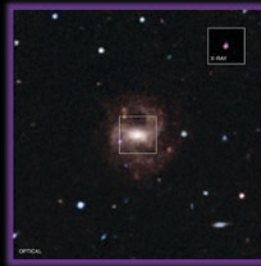
Illustrations: M. Weiss

# Black Holes Come of All Sizes

Observed mass range of black holes



Stellar  
Black Hole



Intermediate Mass  
Black Hole



Supermassive  
Black Hole

Up to 10,000,000,000



Object Mass  
(Relative to the Sun)

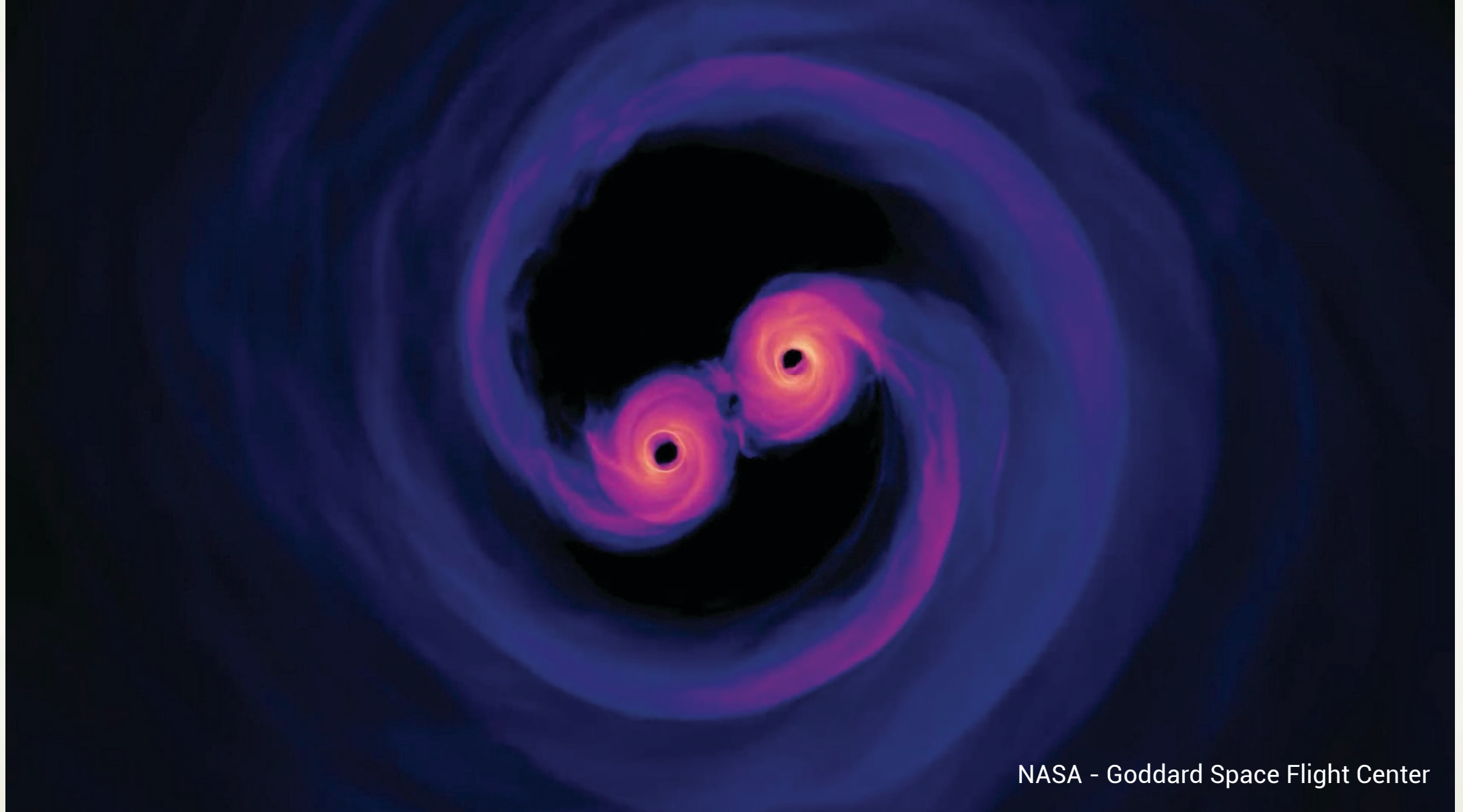
NASA/JPL – Caltech (adapted)

# Growth by Accretion



ESA/Hubble, NASA, M. Kornmesser

# Growth by Mergers



NASA - Goddard Space Flight Center

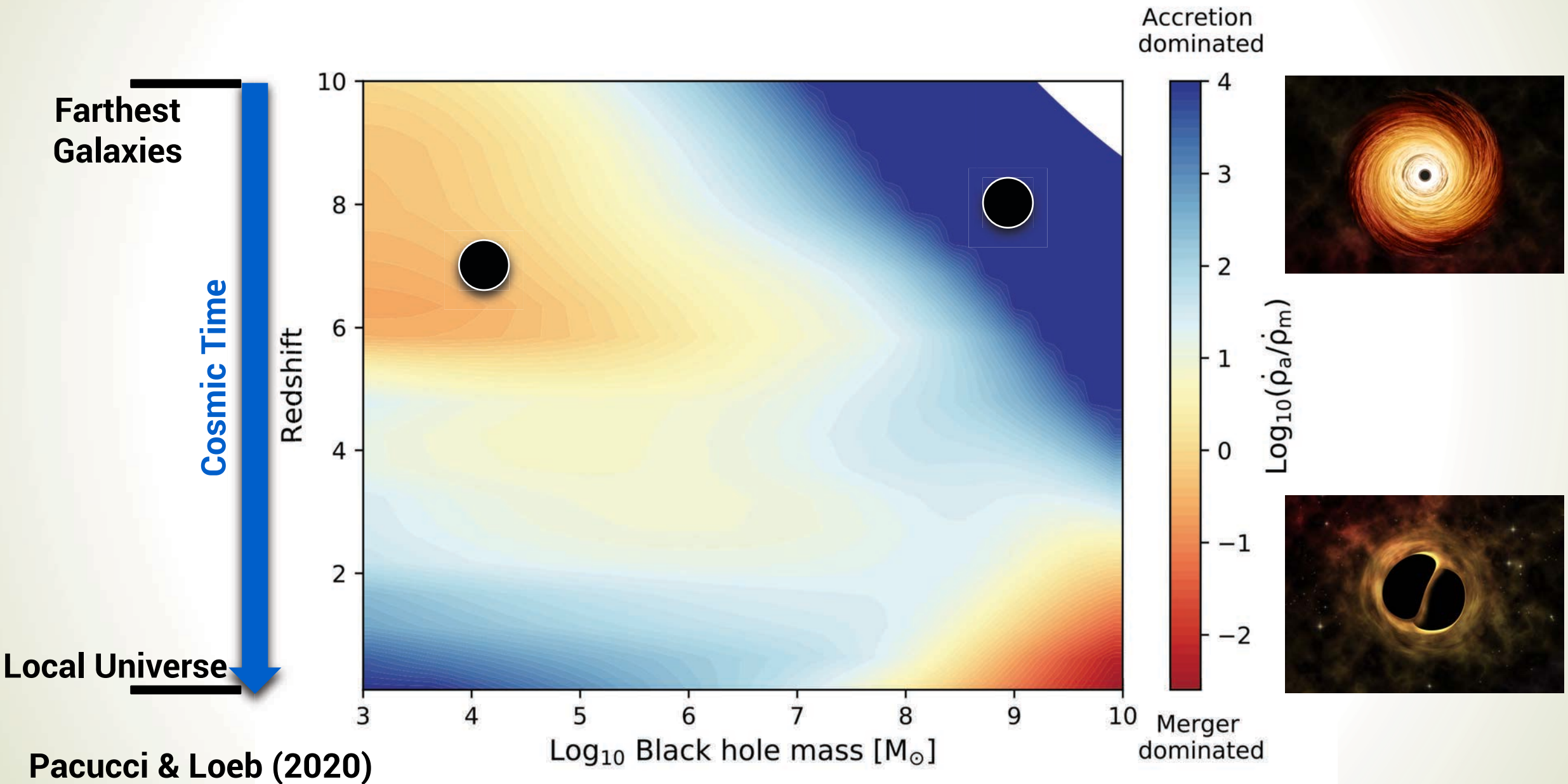
# Accretion vs. Mergers Across Cosmic Time

## FINAL GOAL

Determine the main growth channel as a function of:

- BLACK HOLE MASS
- REDSHIFT

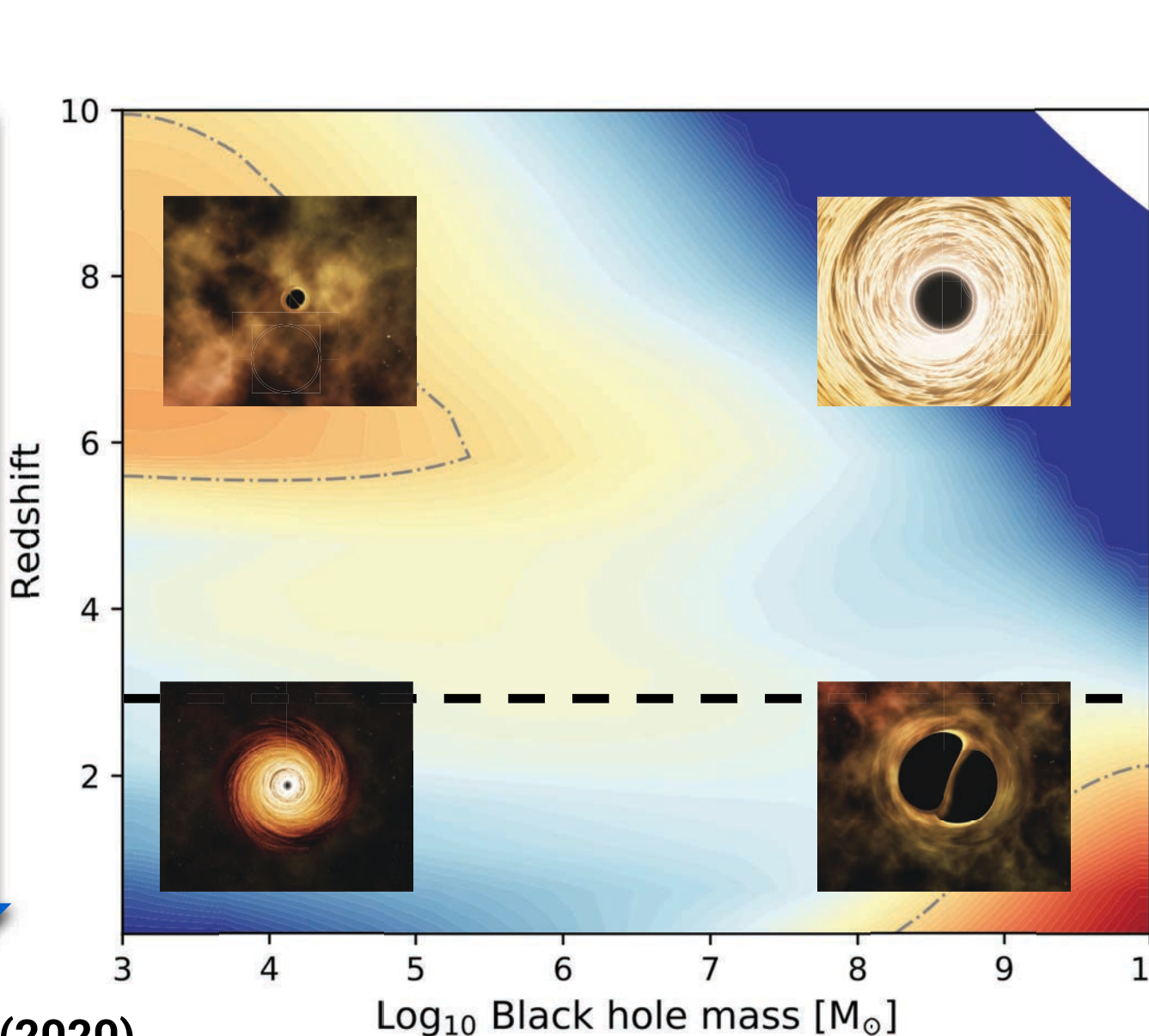
# Accretion vs. Mergers Across Cosmic Time



# Accretion vs. Mergers Across Cosmic Time

Farthest Galaxies

Cosmic Time



Accretion dominated



$\text{Log}_{10}(\dot{\rho}_a/\dot{\rho}_m)$



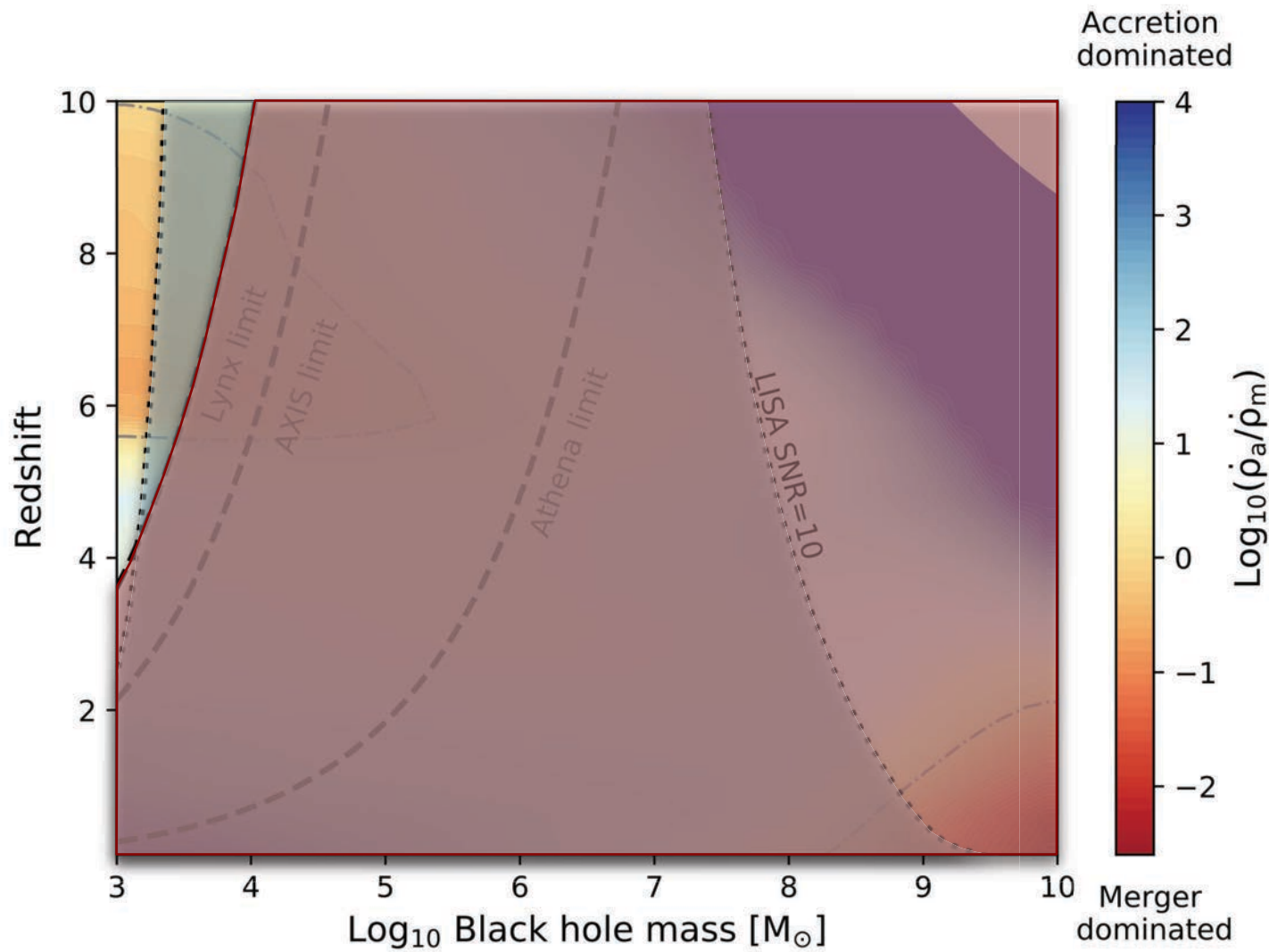
Merger dominated

Peak of Quasar Activity

Local Universe

Pacucci & Loeb (2020)

# Growth Channel → Observation



Pacucci & Loeb (2020)

## Future Space Observatories

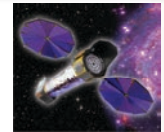
**GRAVITATIONAL WAVES**  
to probe **MERGERS**

- **LISA**



**X-RAYS**  
to probe **ACCRETION**

- **Lynx**



- **AXIS**



- **Athena**





# Accretion vs Mergers & Spin

**GROWTH MOSTLY BY ACCRETION**  
Black hole is:

1) Rapidly spinning:



2) More efficient in emitting radiation

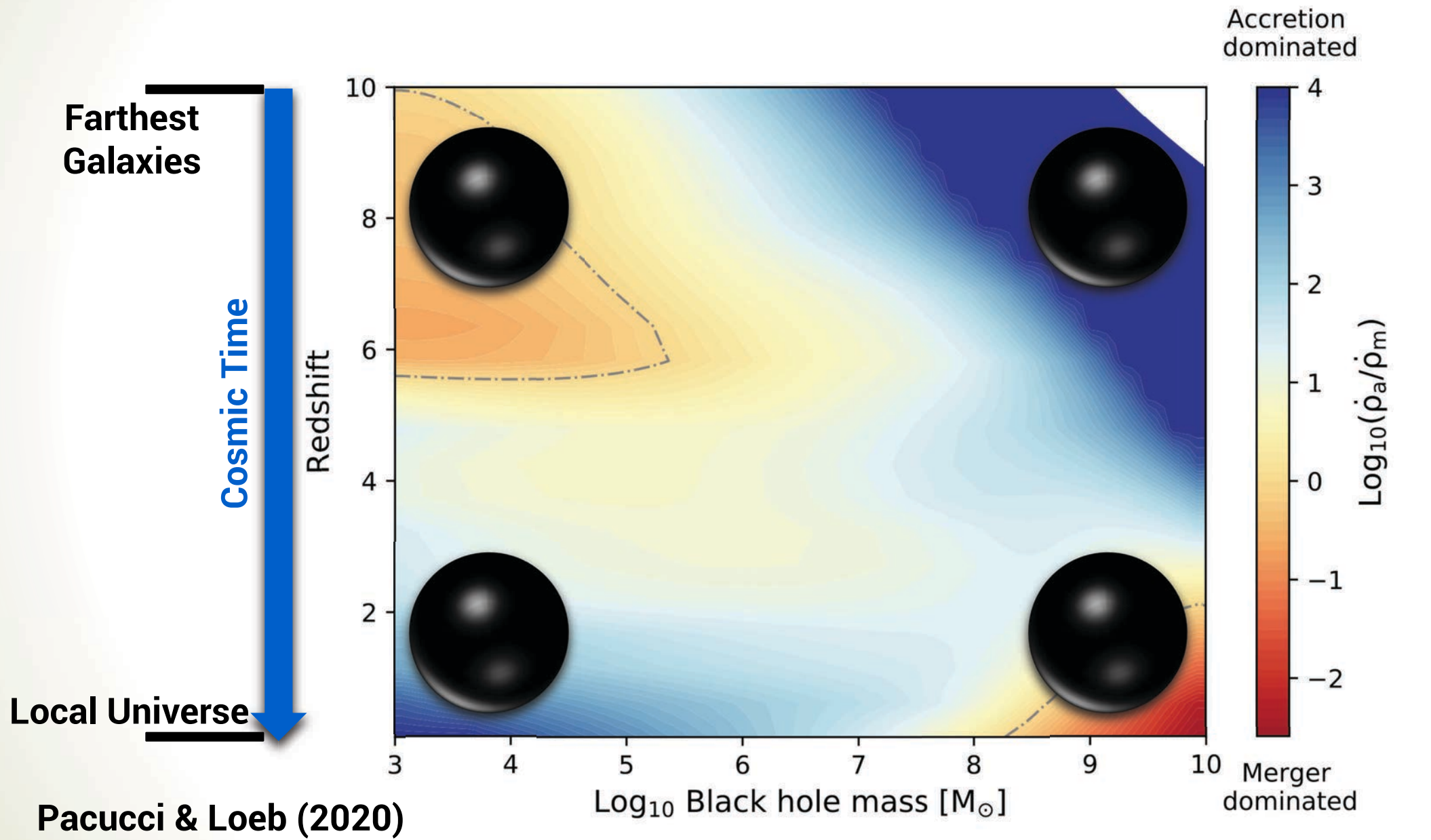
**GROWTH MOSTLY BY MERGERS**  
Black hole is:

1) Slowly spinning:



2) Less efficient in emitting radiation

# Accretion vs Mergers & Spin



# Takeaway Message

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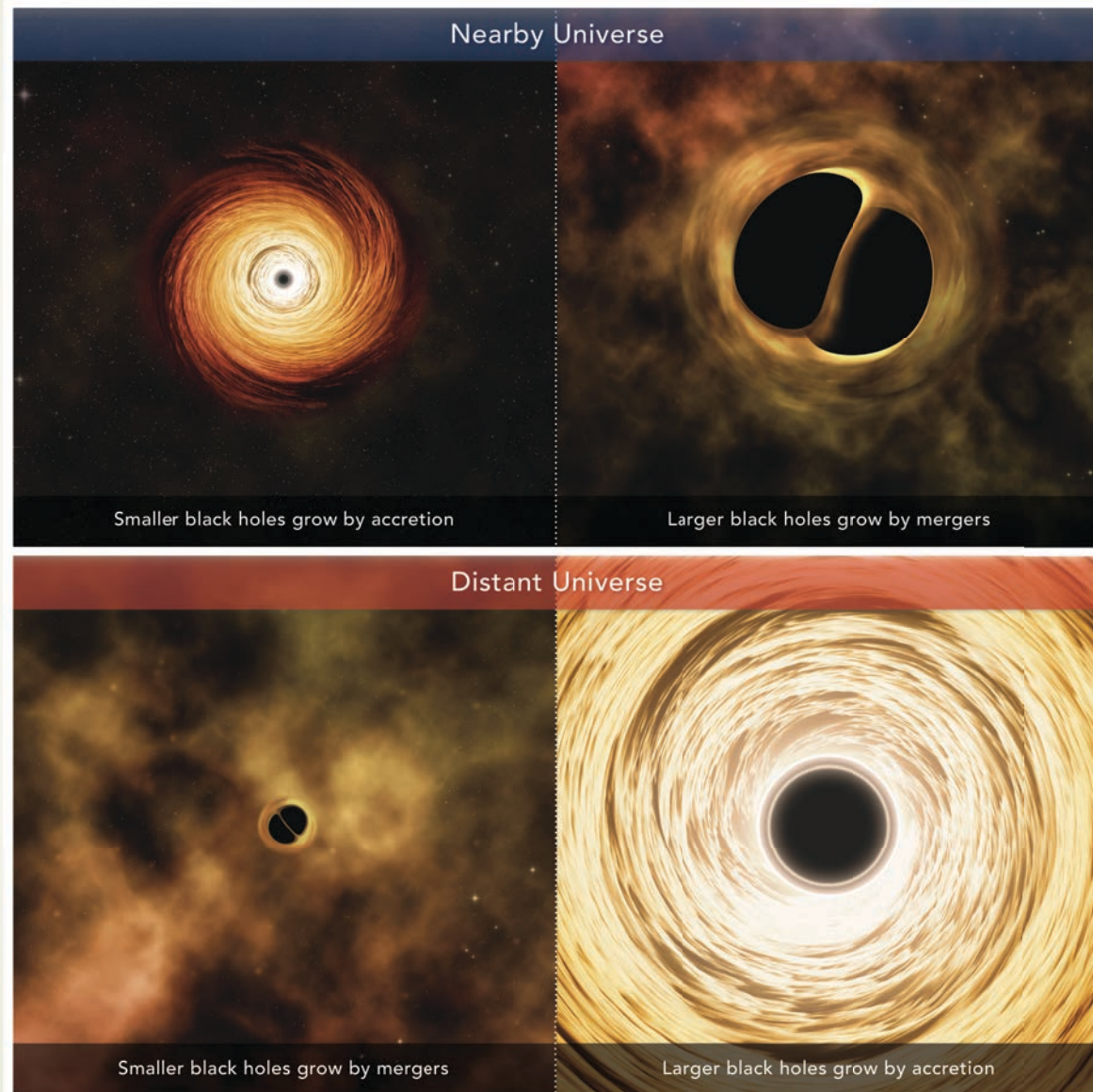
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