

An aerial photograph of a vibrant turquoise lake nestled in a lush green forest. In the background, rugged mountains rise under a clear blue sky. The text is overlaid on the image in white, bold, sans-serif font.

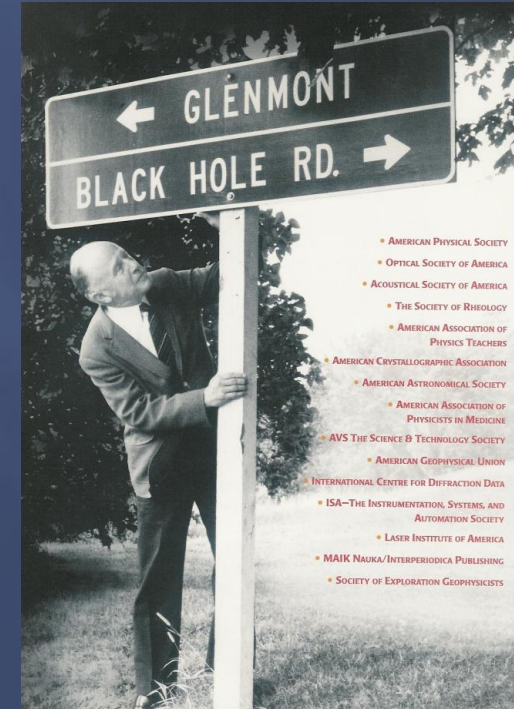
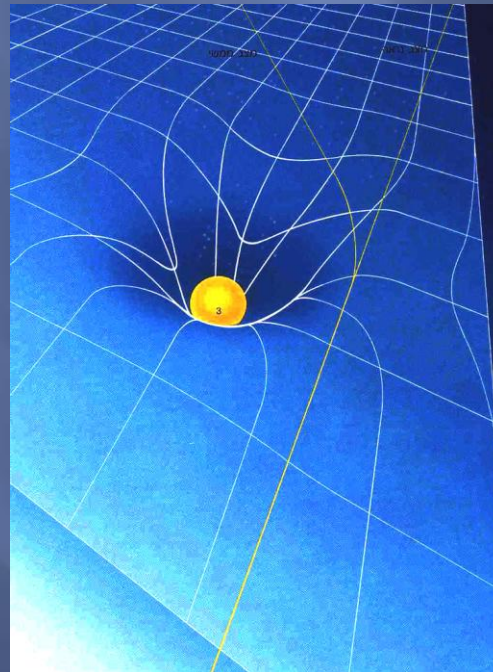
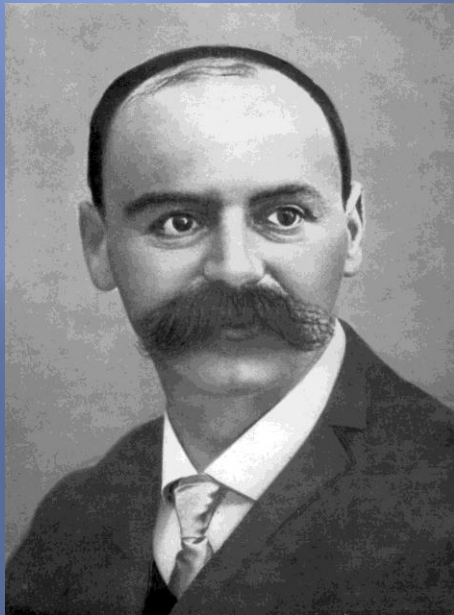
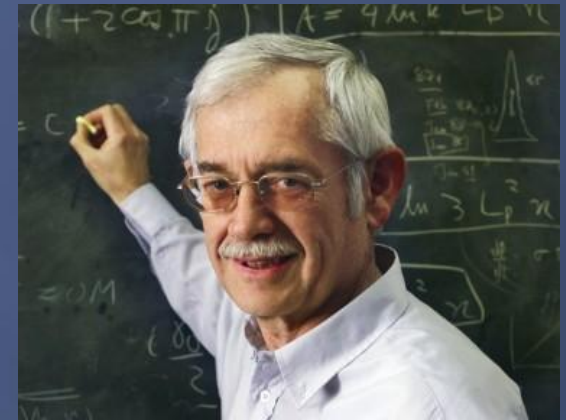
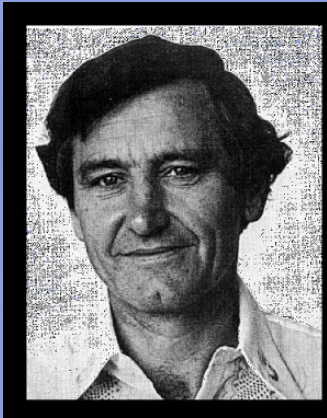
FOLLOWING SUPERMASSIVE BLACK HOLES OVER COSMIC TIME

SPIG2020

Serbia August 2020

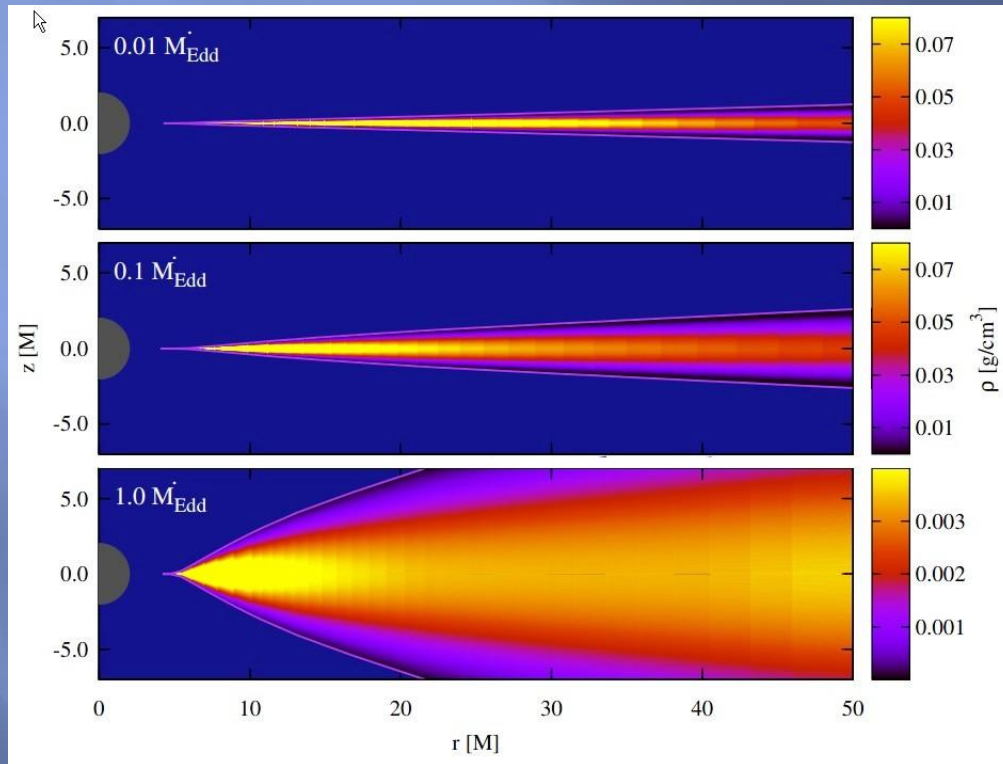
Hagai Netzer, Tel Aviv University

Black hole theory 1916–1974



- AMERICAN PHYSICAL SOCIETY
- OPTICAL SOCIETY OF AMERICA
- ACOUSTICAL SOCIETY OF AMERICA
- THE SOCIETY OF RHEOLOGY
- AMERICAN ASSOCIATION OF PHYSICS TEACHERS
- AMERICAN CRYSTALLOGRAPHIC ASSOCIATION
- AMERICAN ASTRONOMICAL SOCIETY
- AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE
- AVS THE SCIENCE & TECHNOLOGY SOCIETY
- AMERICAN GEOPHYSICAL UNION
- INTERNATIONAL CENTRE FOR DIFFRACTION DATA
- ISA—THE INSTRUMENTATION, SYSTEMS, AND AUTOMATION SOCIETY
- LASER INSTITUTE OF AMERICA
- MAIK NAUKA/INTERPERIODICA PUBLISHING
- SOCIETY OF EXPLORATION GEOPHYSICISTS

1. Black hole power house: Feeding



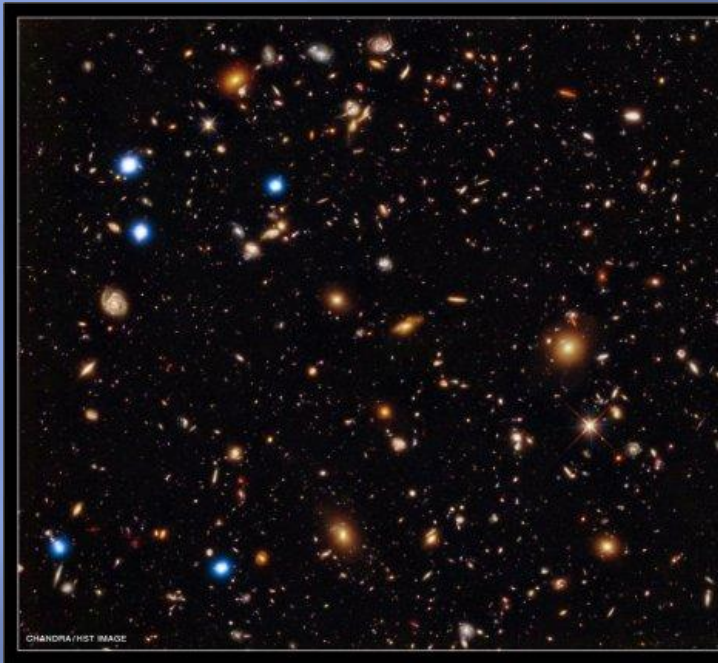
Sadowski 2011

Accretion disks

Mass to energy conversion efficiency

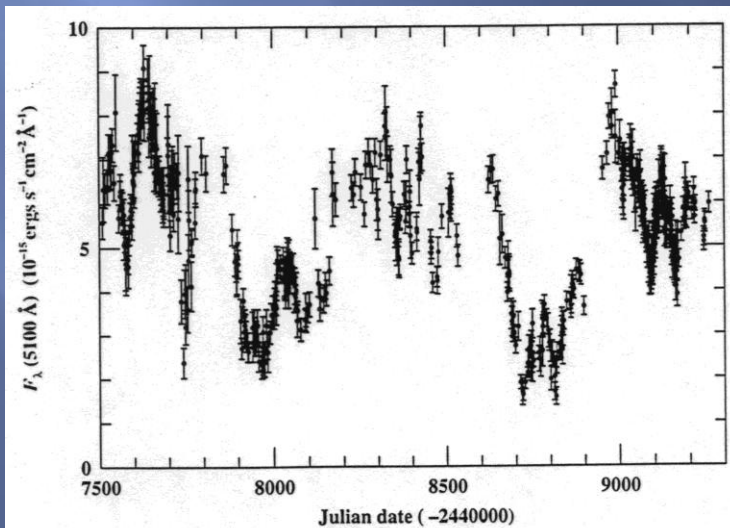
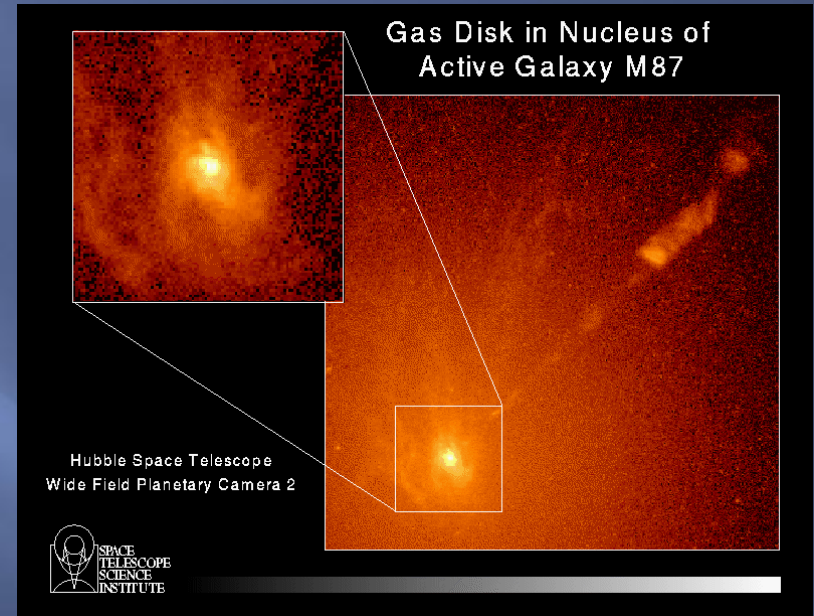
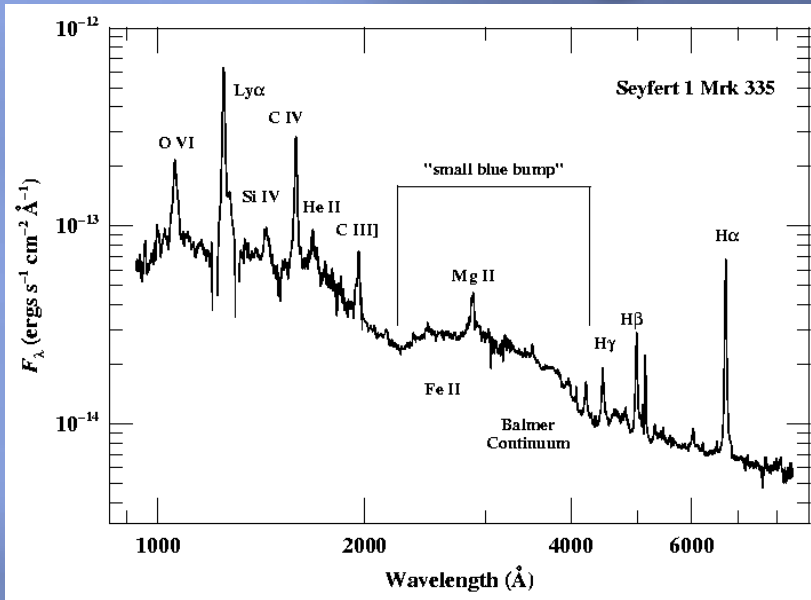
0.038 - 0.42

Observing black holes

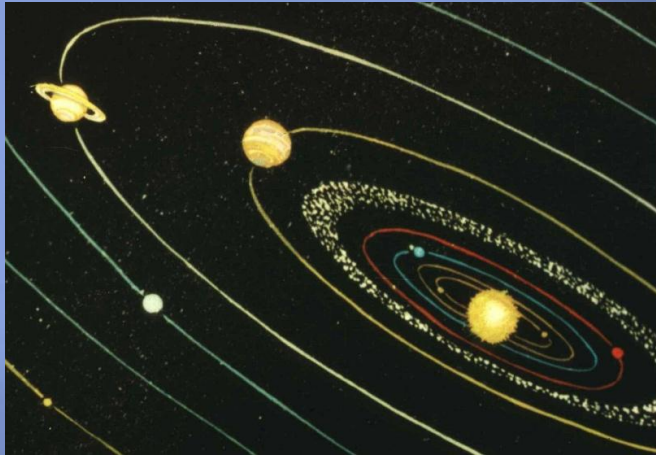


- ▣ X ray observations – Chandra
- ▣ 0.11 square degrees , 4 million seconds, 1000 detections translated to more that a billion sources all over the sky.
- ▣ About 1% of all galaxies

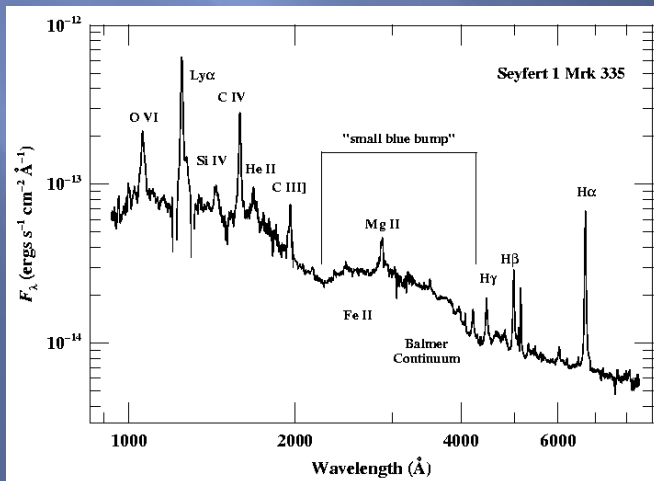
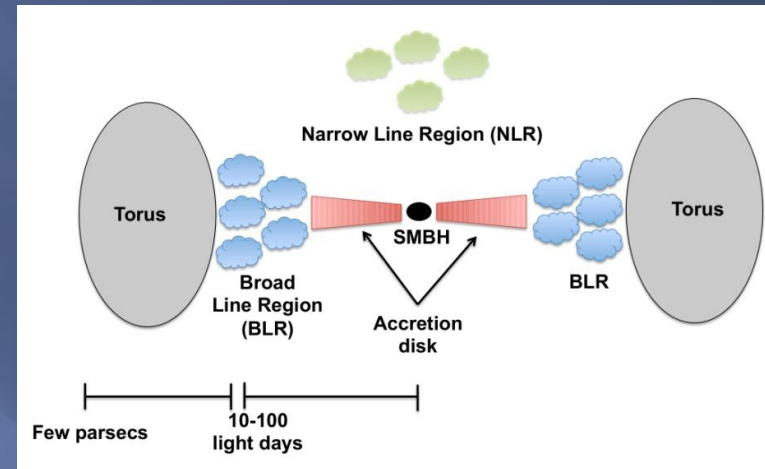
Active galaxies – AGN



Measuring black hole mass here and here

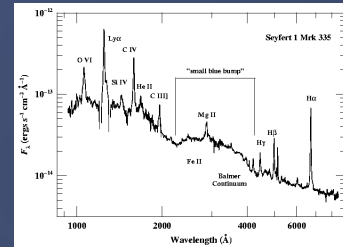
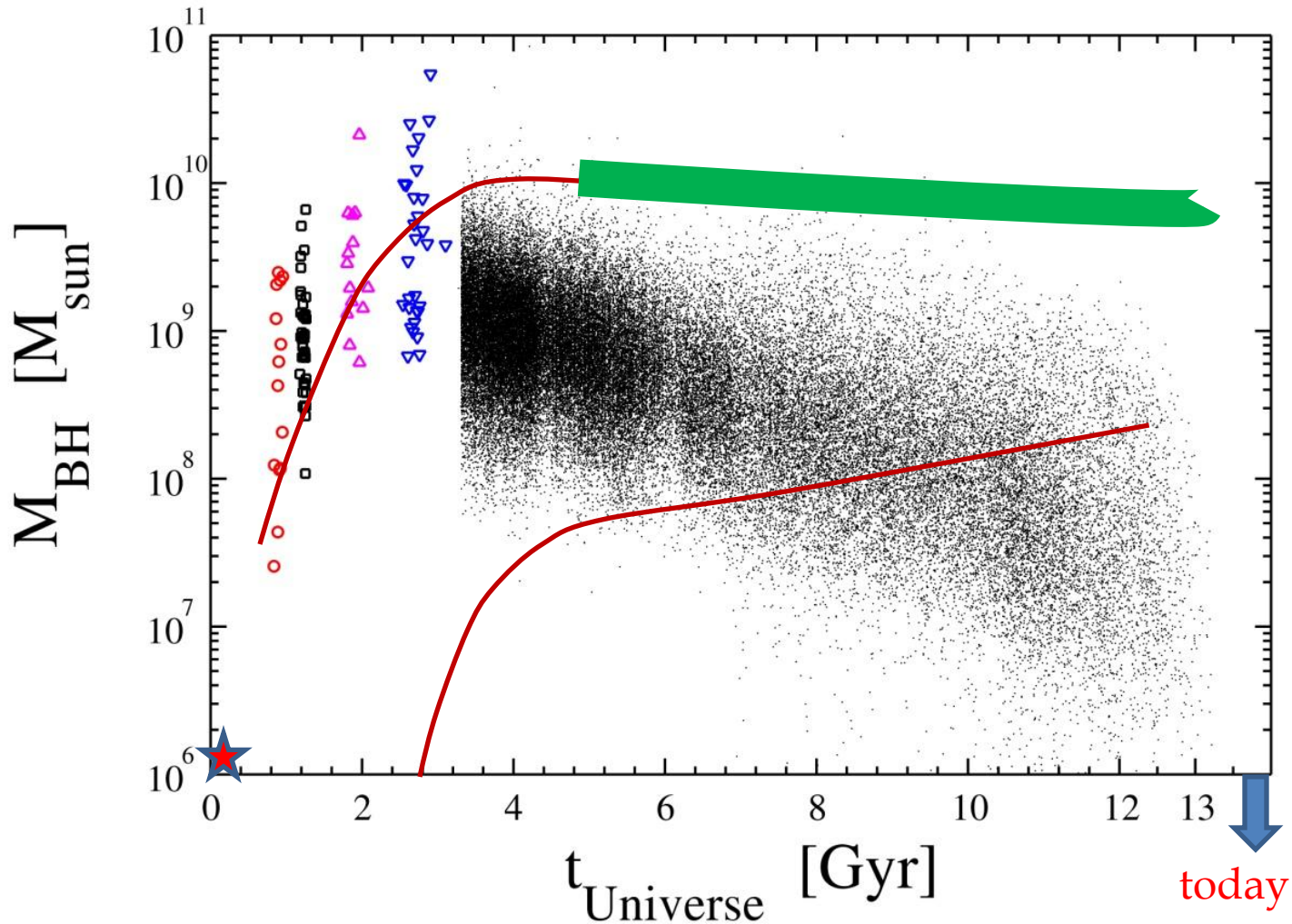


$$M = V^2 R / G$$

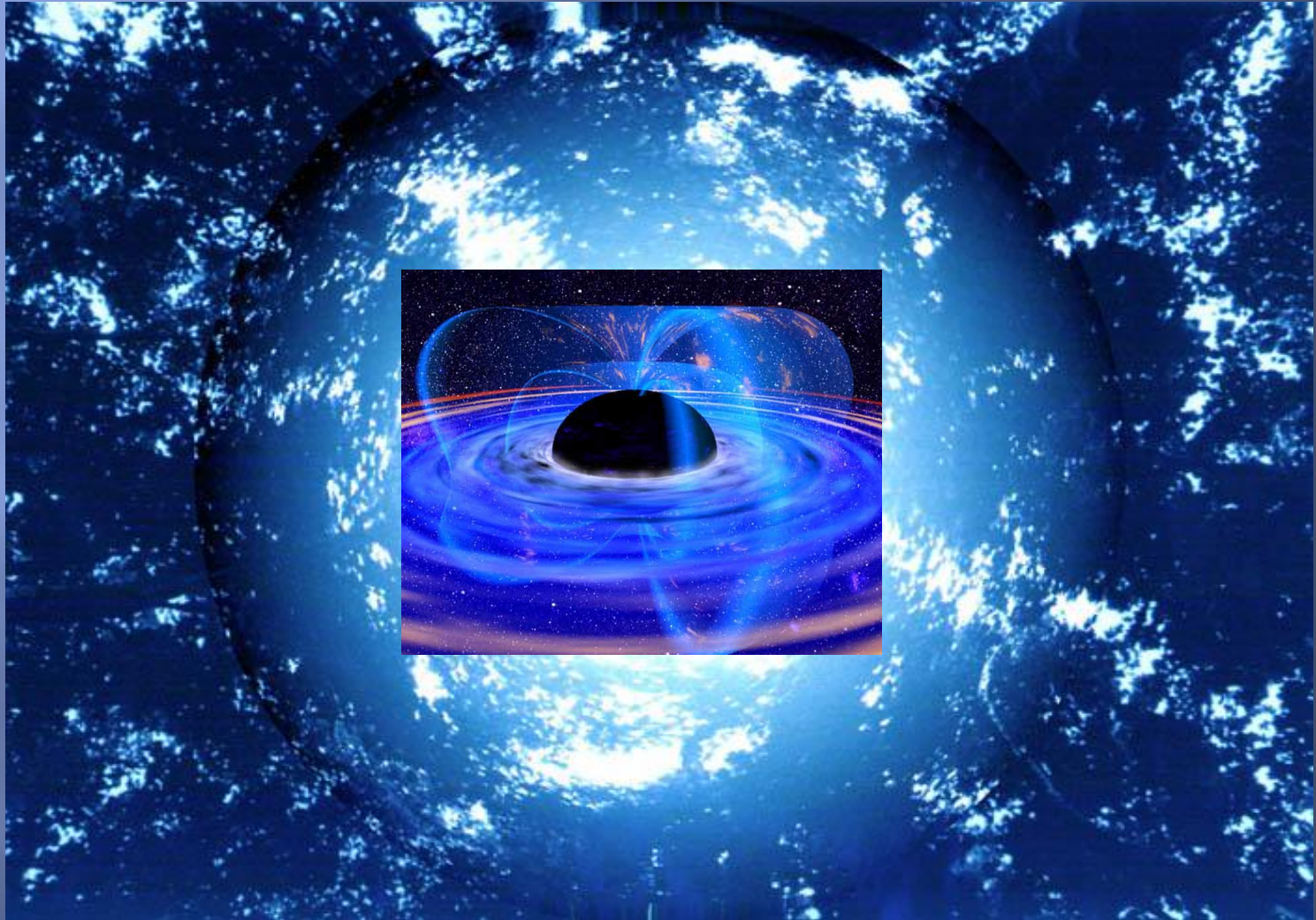


Here (Serbia) and here (Tel Aviv)

2. Cosmic evolution of black holes

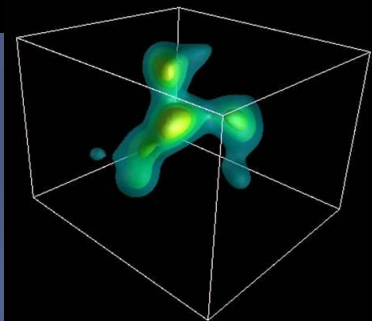
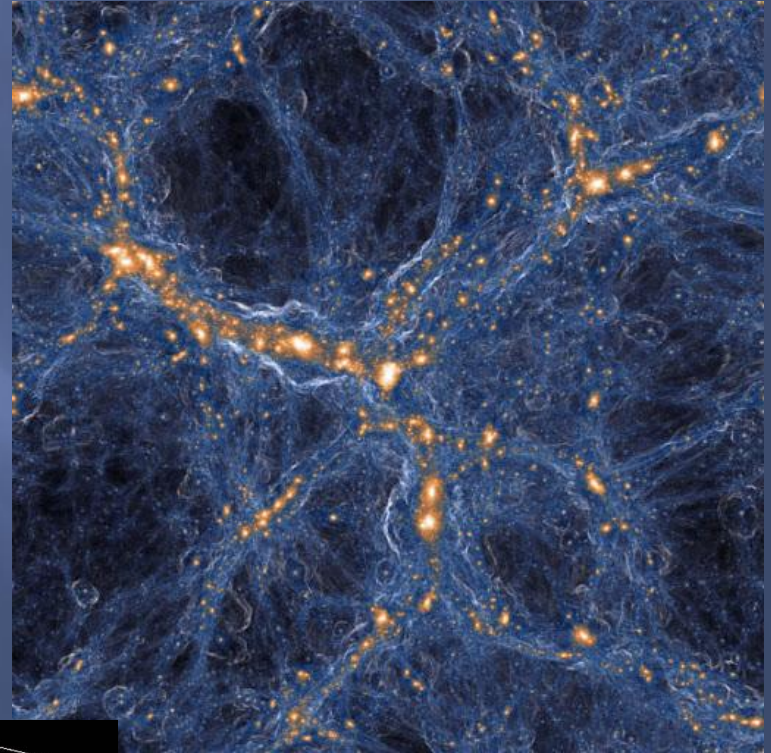
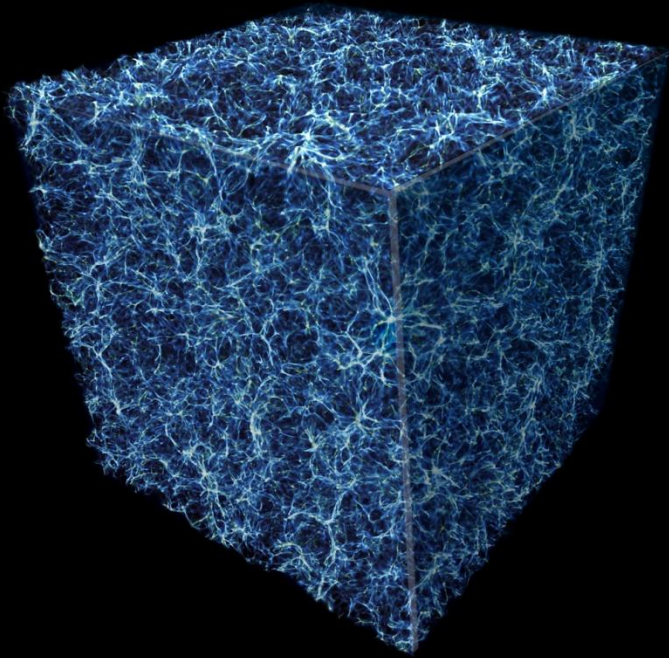


3. The first black holes

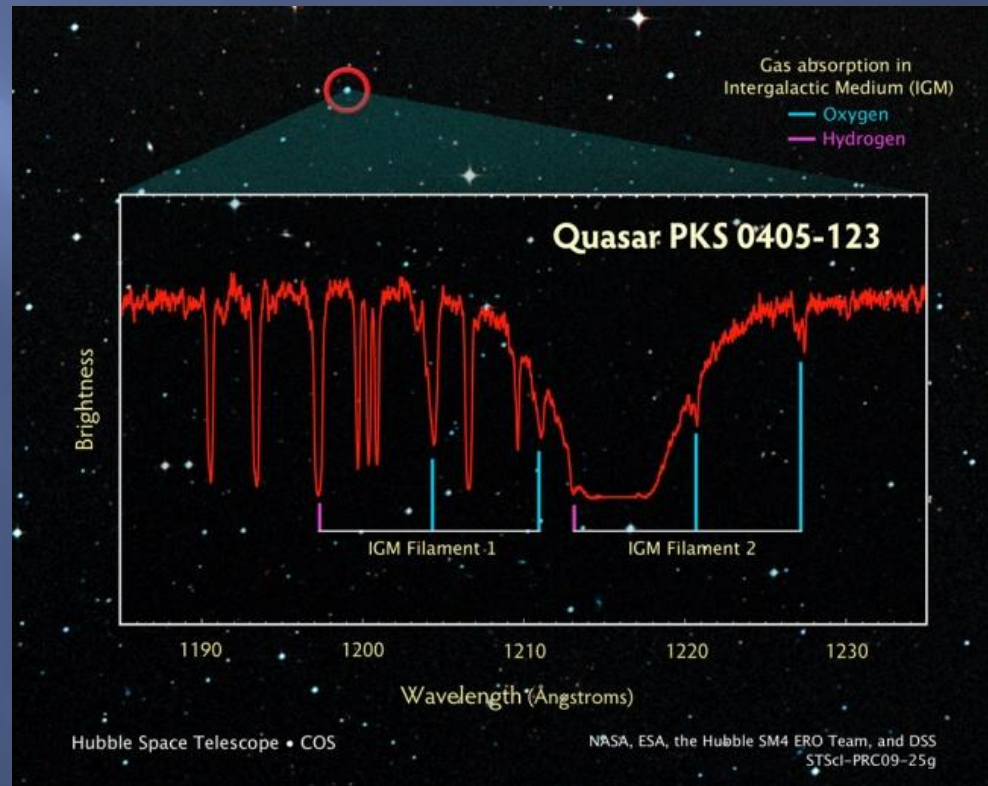
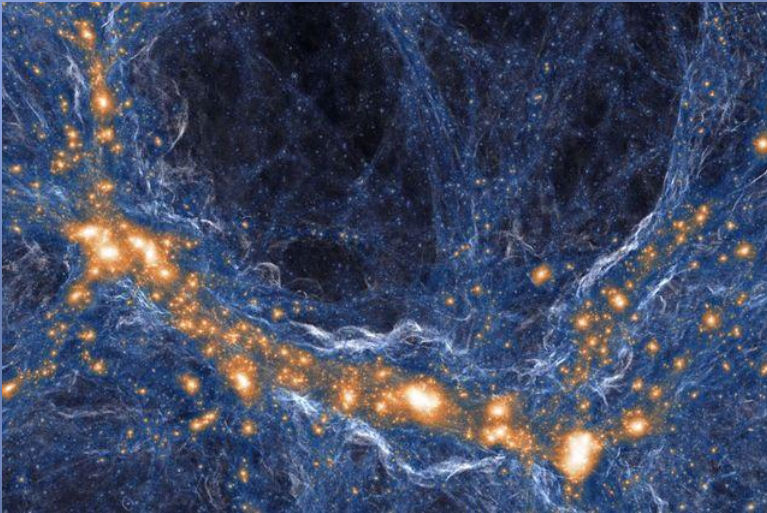


Black hole and galaxy environment at early times

Simulation of cosmic web



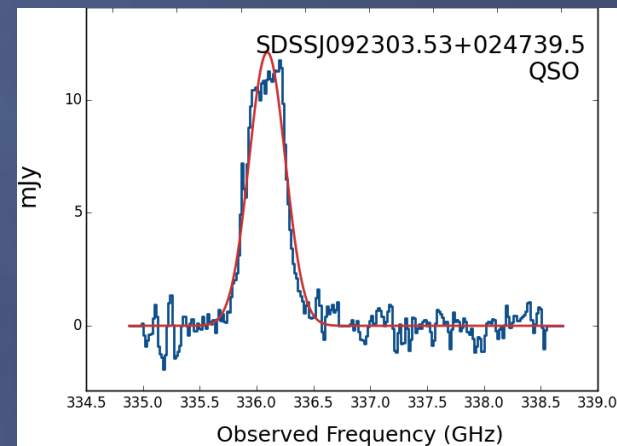
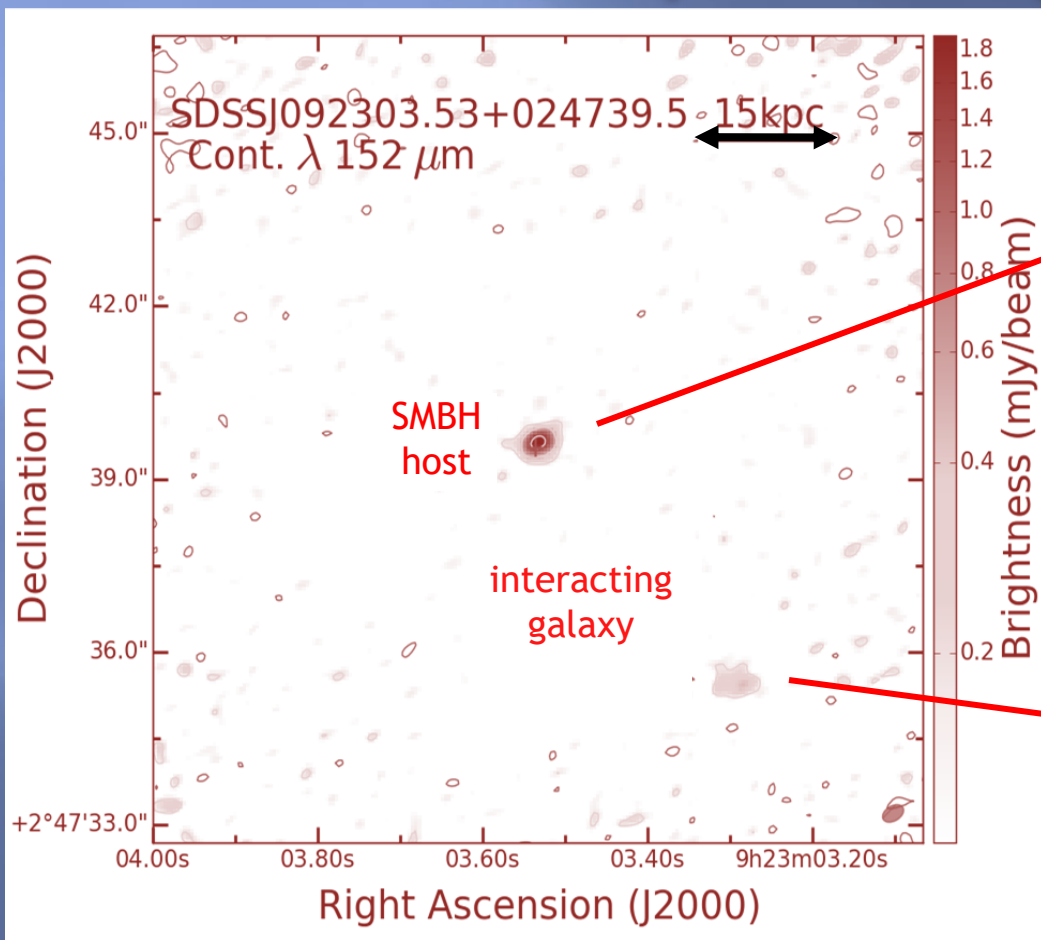
Probing the cosmic web with high redshift lamp-posts



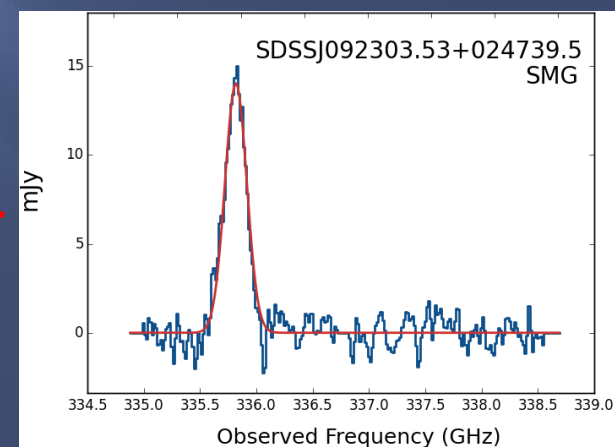
Black holes and their companion galaxies at $z=5$ ($t_{\text{universe}} = 1.2 \times 10^9 \text{ yr}$)



ALMA observations of fast growing $z=5$ black holes and their companion galaxies



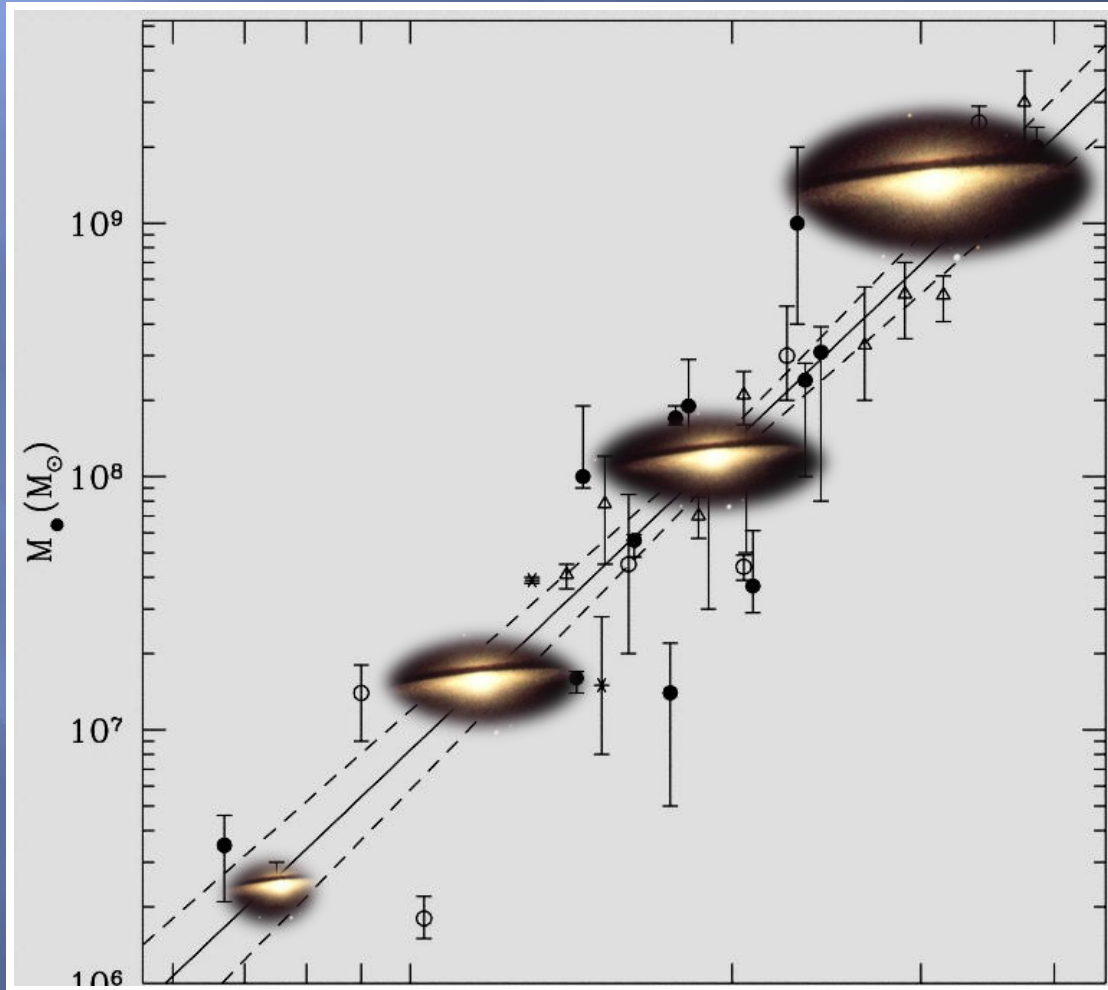
host galaxy of SMBH



companion galaxy

4. Parallel evolution of black holes and their host galaxies

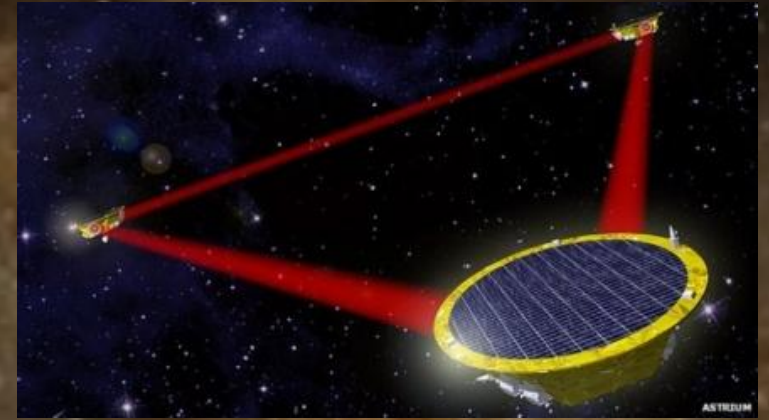
Black hole mass



Present day view

Galaxy mass

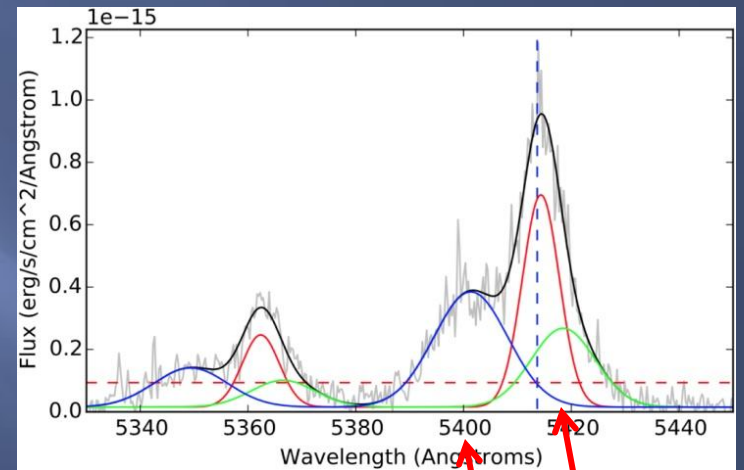
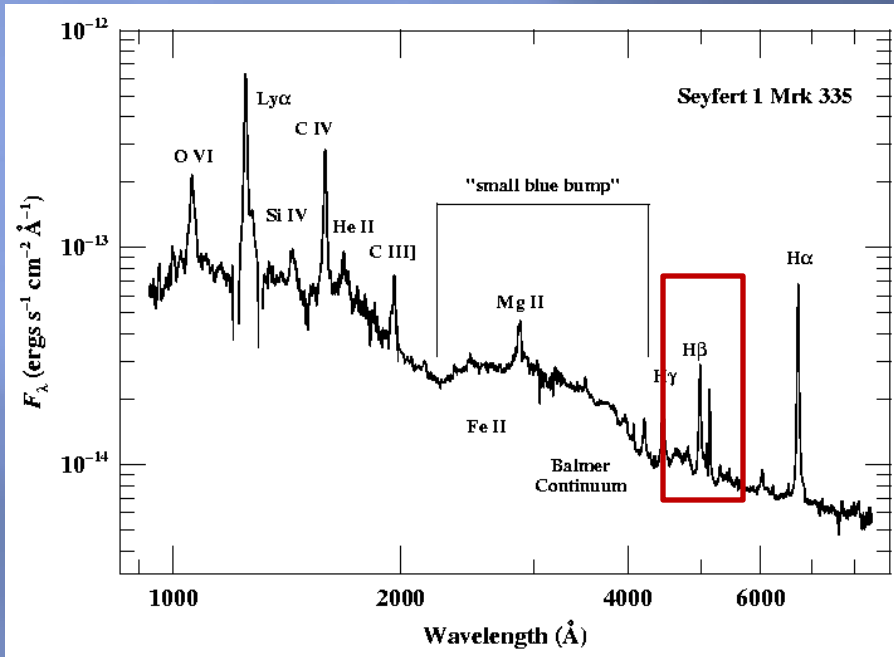
Black hole and galaxy mergers



LISA will observe it “soon”



Outflows: basic spectroscopy



[OIII] $\lambda\lambda 4959, 5007\text{\AA}$

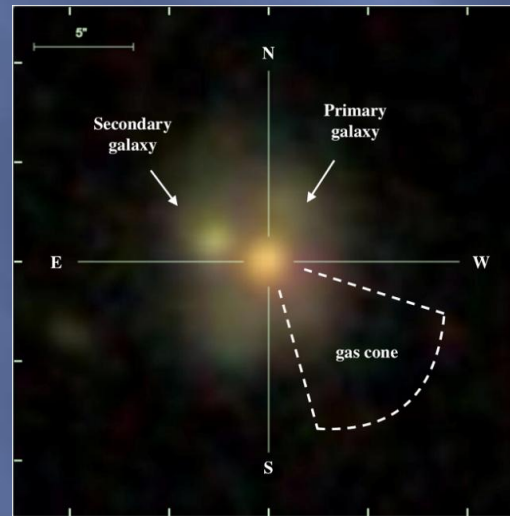
Blue wing
Line core

Outflow and Feedback

- ▣ Outflows are clearly observed in many AGN hosts at all redshifts
- ▣ Outflow can clear up gas from the galaxy thus stop star formation and stellar mass growth

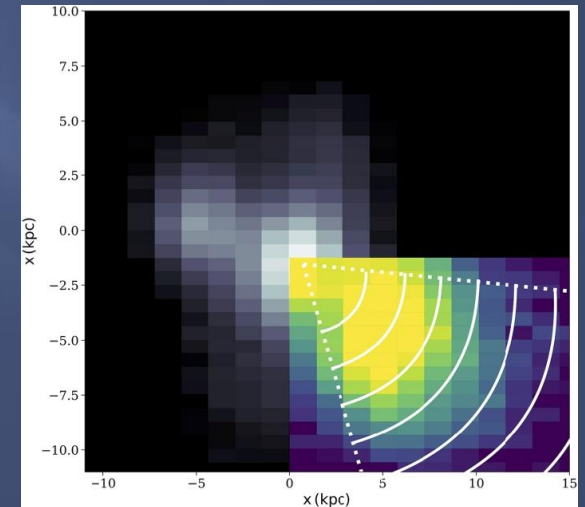


Star Formation Feedback

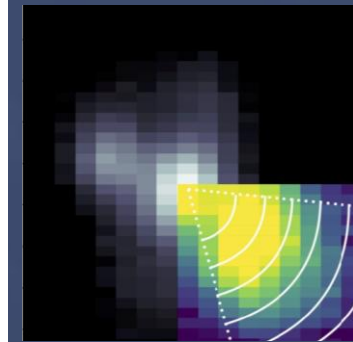
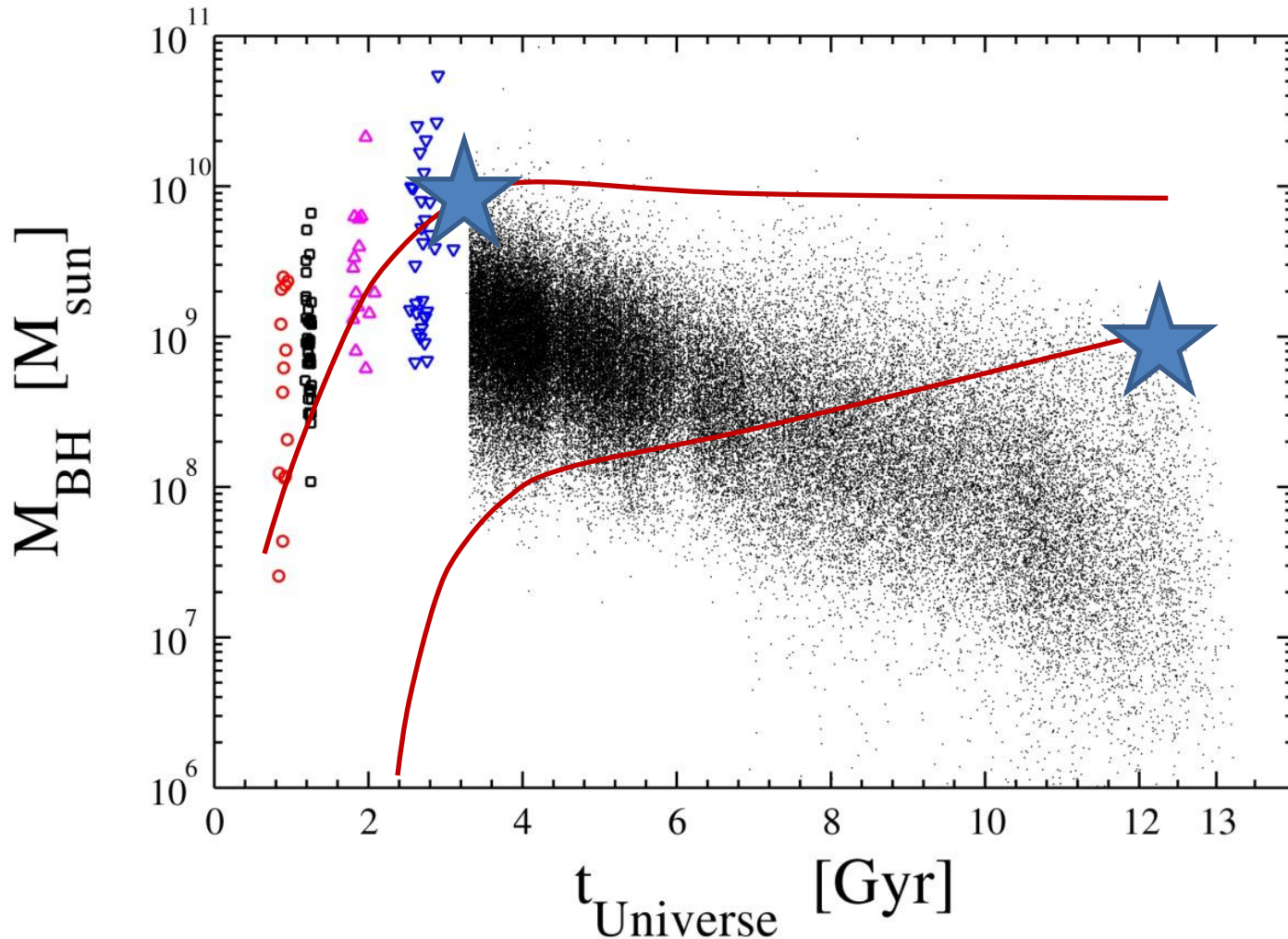


Black Hole Feedback

Baron, Netzer, Prochaska, Davies... 2018



Cosmic evolution of black holes including mergers and feedback



FOLLOWING SUPERMASSIVE BLACK HOLES OVER COSMIC TIME – 2020 VIEW

The power house of black holes

The cosmic evolution of black holes

Black holes in the early universe

Parallel evolution of black holes and their host galaxies



Thank You