SCALING RELATIONSHIPS BETWEEN BLACK HOLE GROWTH AND GALAXY PROPERTIES

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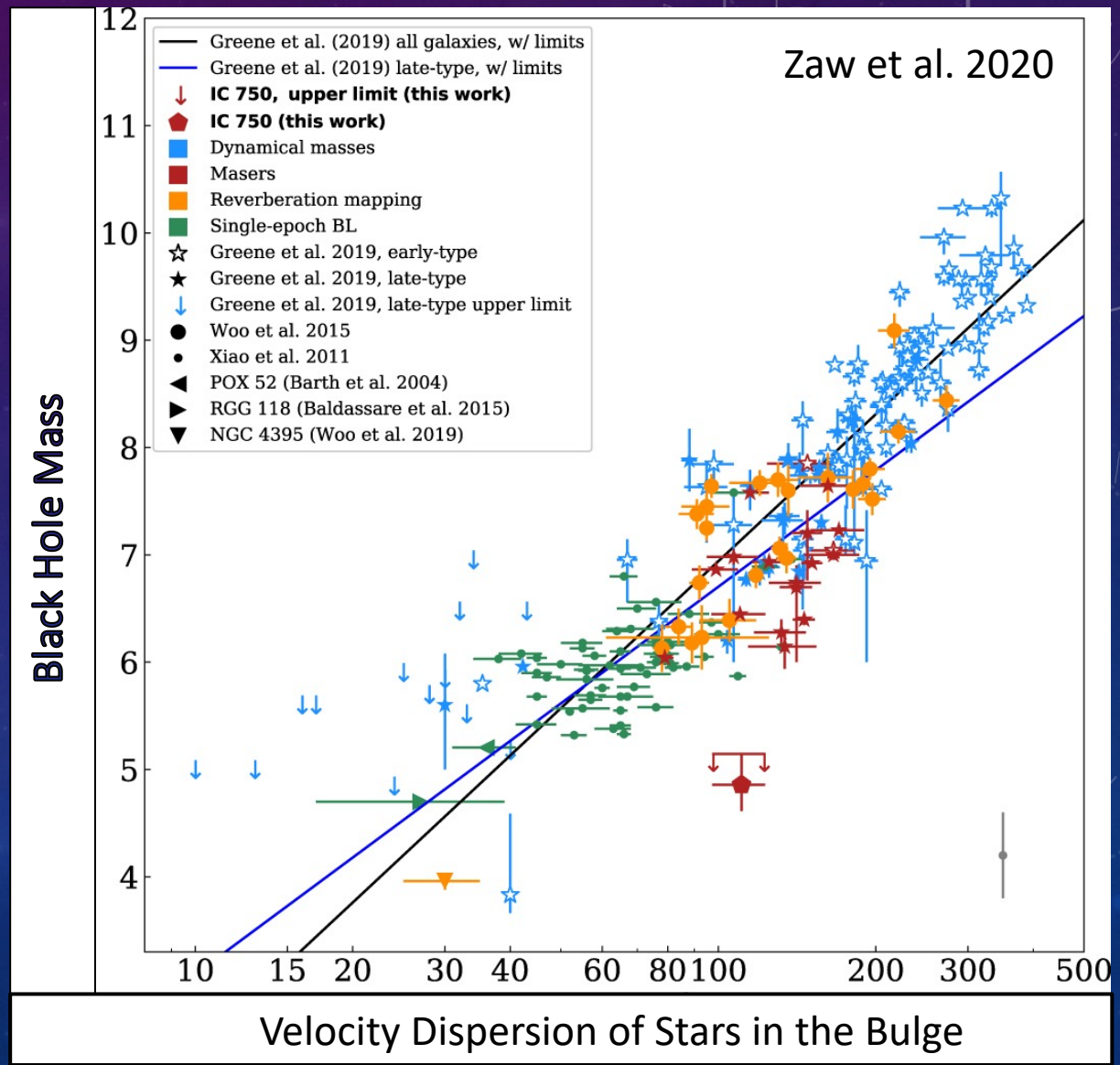
DISCOVERY OF THE M-SIGMA RELATION CONNECTS THE GROWTH OF SUPER MASSIVE BLACK HOLES TO GALAXY GROWTH

- Gas accretion grows black holes
- Super Massive Black Holes (SMBH) that accrete sufficient matter are active
- Active SMBH are AGN



WHAT ARE AGN?

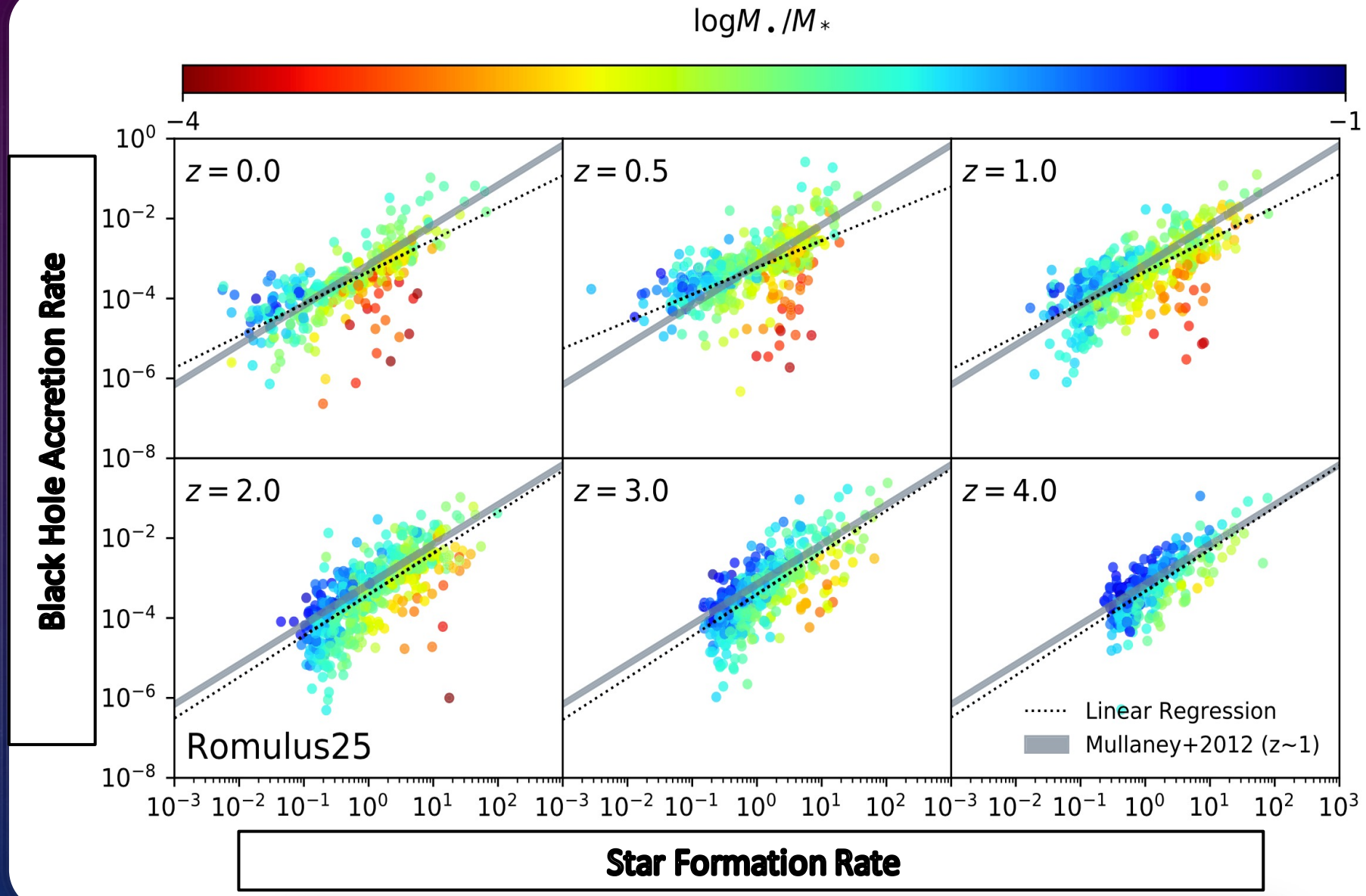
- Active Galactic Nuclei (AGN)
  - Super Massive Black Holes that emit energy in a large range on the electromagnetic spectrum
  - Often located at the centers of gas rich galaxies
  - Reines et al. 2019 and Baldassare et al. 2016 found AGN in dwarf galaxies, indicating that the presence of massive black holes is more commonplace than previously believed
  - AGN feedback could influence galaxy evolution
    - Quasars may be capable of inhibiting star formation in nearby halos (Habouzit et al. 2018)

Credit: ESO/WFI (Optical); MPIfR/ESO/APEX/A. Weiss et al. (Submillimetre); NASA/CXC/CfA/R. Kraft et al. (X-ray)

TRACKING GALAXY PROPERTIES OVER THE AGE OF THE UNIVERSE

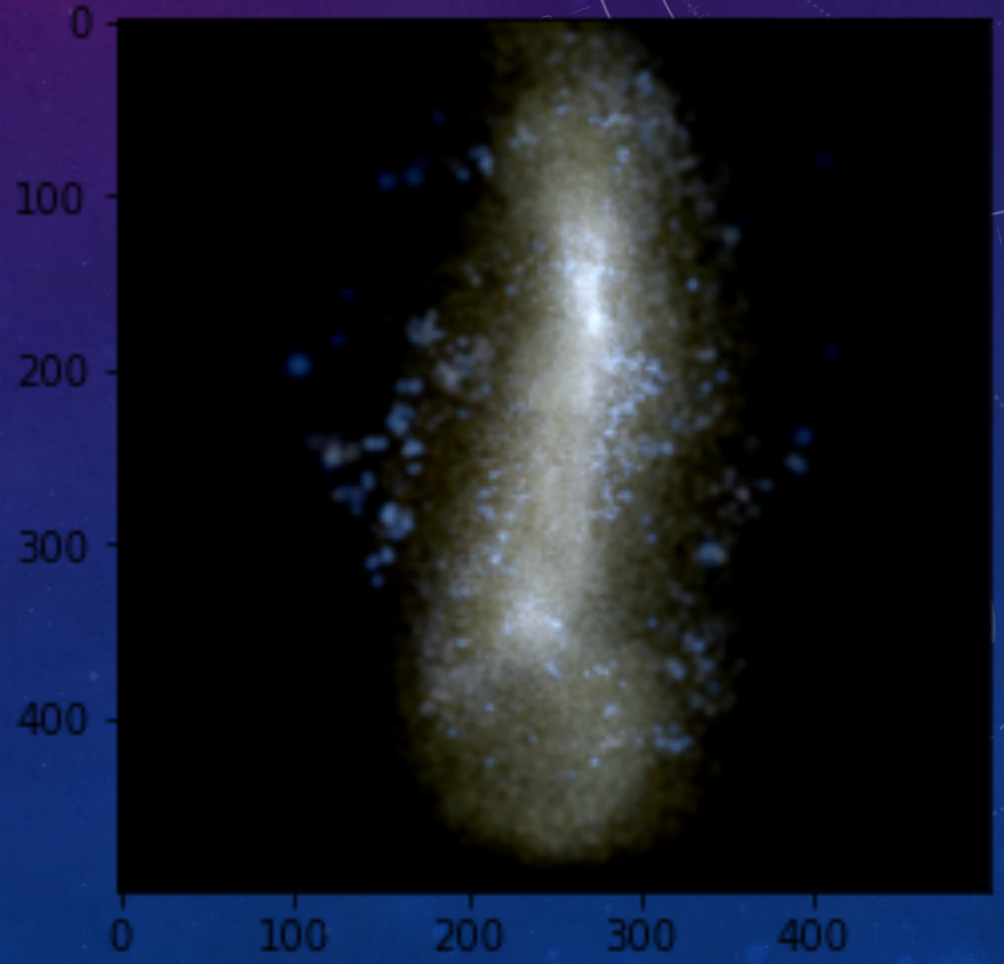
- Cosmological simulations of galaxies from redshift z = 20.0 to z=0.0 (t = 0.18 Gyr – 13.8 Gyr)
- N-Body + SPH simulations
  - Stars and Dark Matter interact under gravity
  - Gas through hydrodynamics
- ROMULUS Simulations
  - ROMULUS25: simulation of a 25 Mpc patch of the Universe – includes satellite + field galaxies but my research focusses on field galaxies

RICARTE ET. AL 2019 FOUND A TIGHT CORRELATION BETWEEN STAR FORMATION AND BLACK HOLE ACCRETION RATES



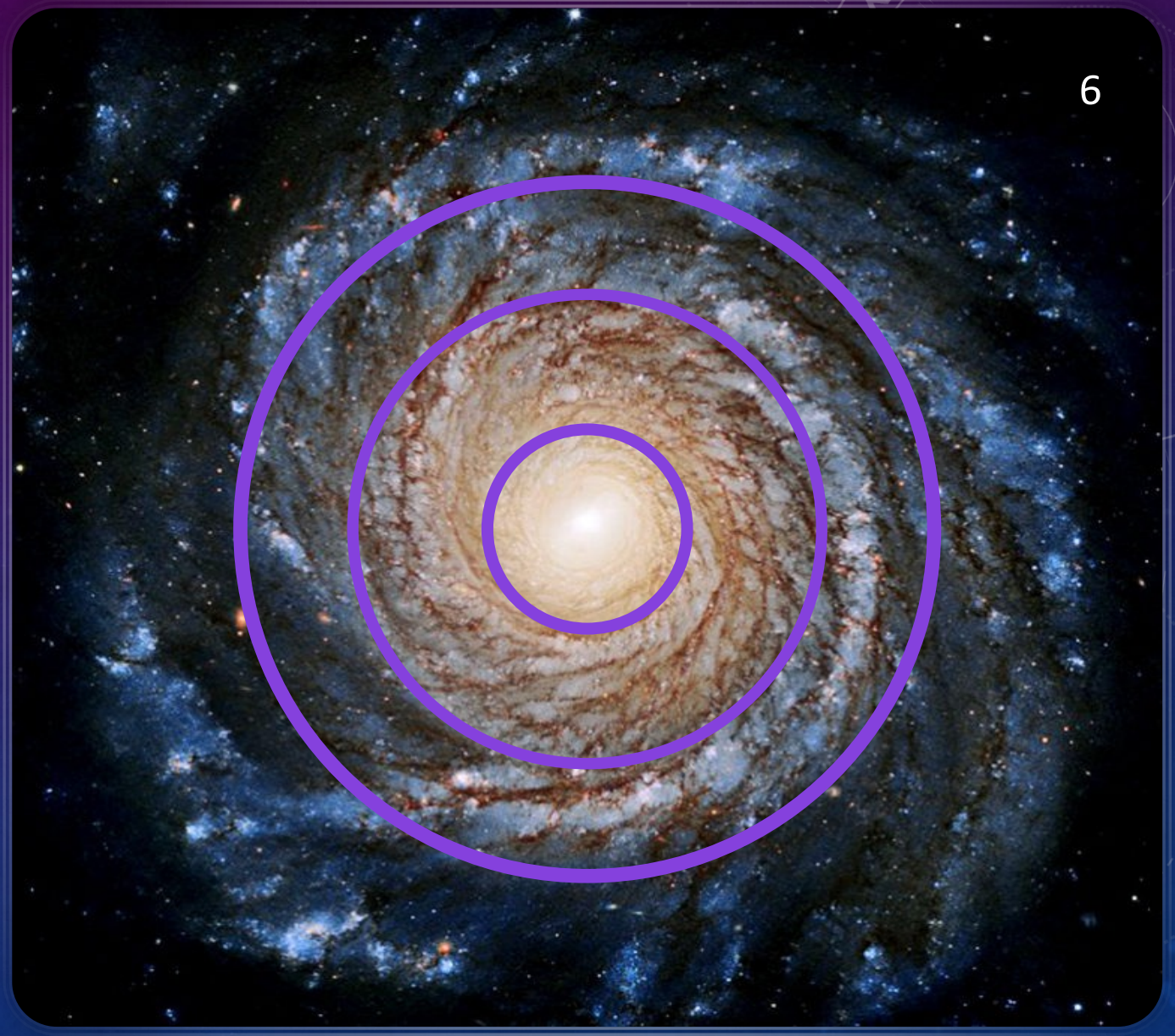
PREVIOUS RESEARCH INDICATES THAT BLACK HOLES GROW THROUGH MAINLY SECULAR PROCESSES

- Secular processes
  - Environmental – gas accretion
  - Internal – produced by spiral arms or bars
- Mergers are non-secular processes
- At the low-mass end: mergers are unimportant, secular processes dominate Black hole growth (Saglia et al. 2016)
- 35 percent of SMBH growth from mergers in HORIZON-AGN simulations (Martin et al. 2018).



AT WHAT SCALE DO THE PROPERTIES OF GALAXIES MATTER TO BLACK HOLE ACCRETION RATE?

- Black holes and galaxies exist on very different mass scales, it stands to reason that black hole growth follows local properties rather than the galaxy as a whole
- Star Formation Rate and Gas Properties as a function of radius from the center of the halo
- Gas Properties Being Investigated
  - Gas mass, Cold gas mass, HI gas mass



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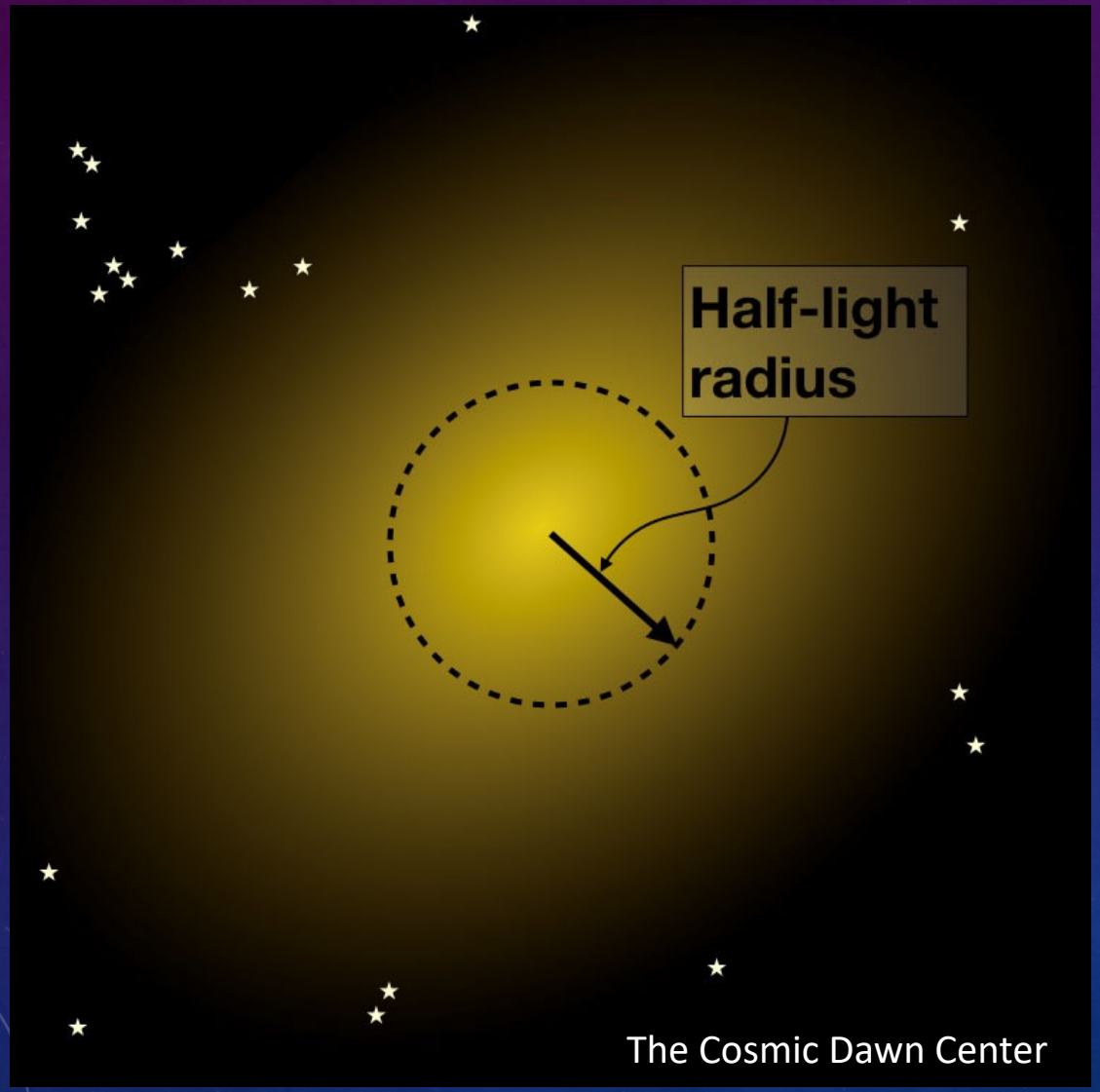
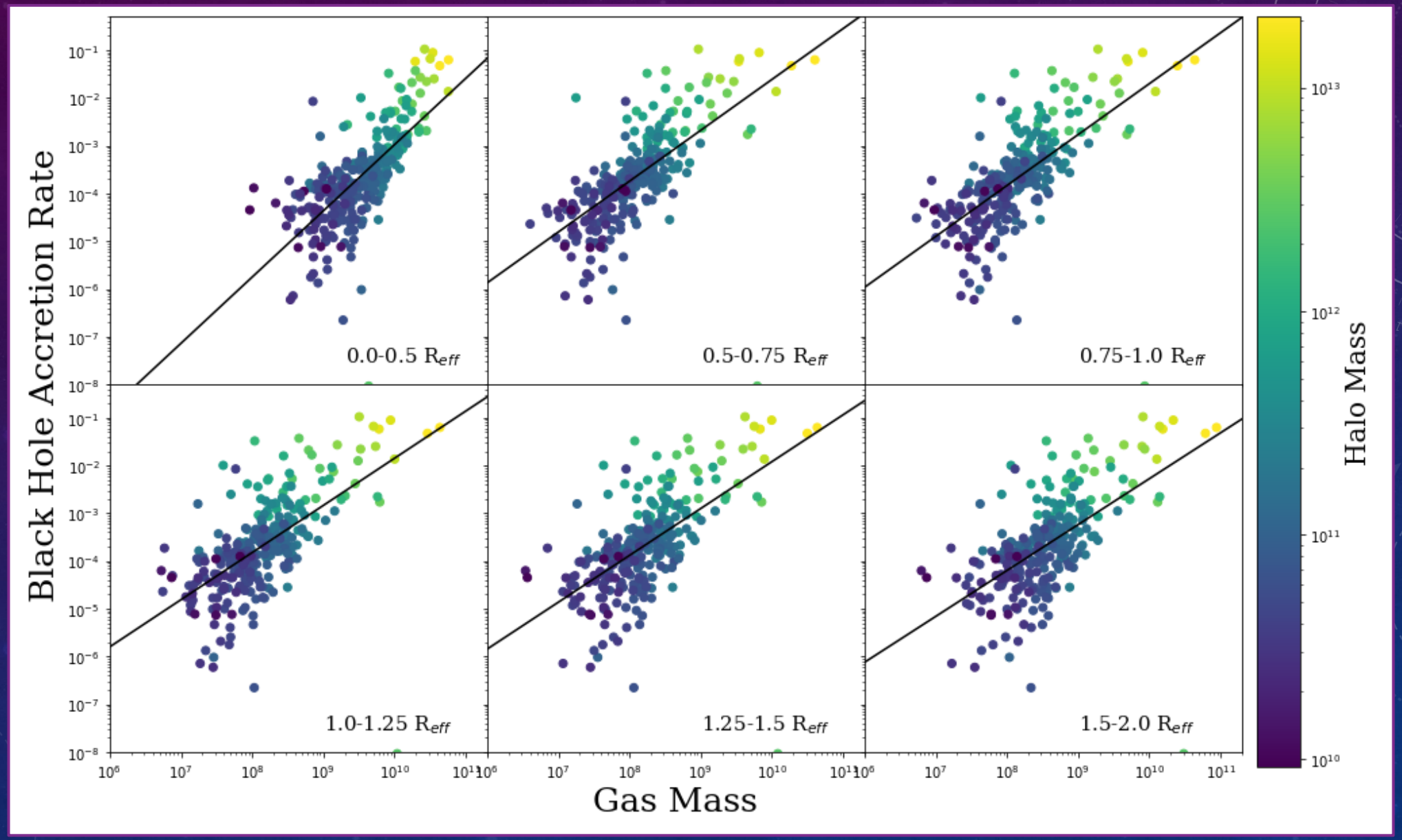
DIFFERENT METHODS OF MEASURING QUANTITIES AS A FUNCTION OF RADIUS

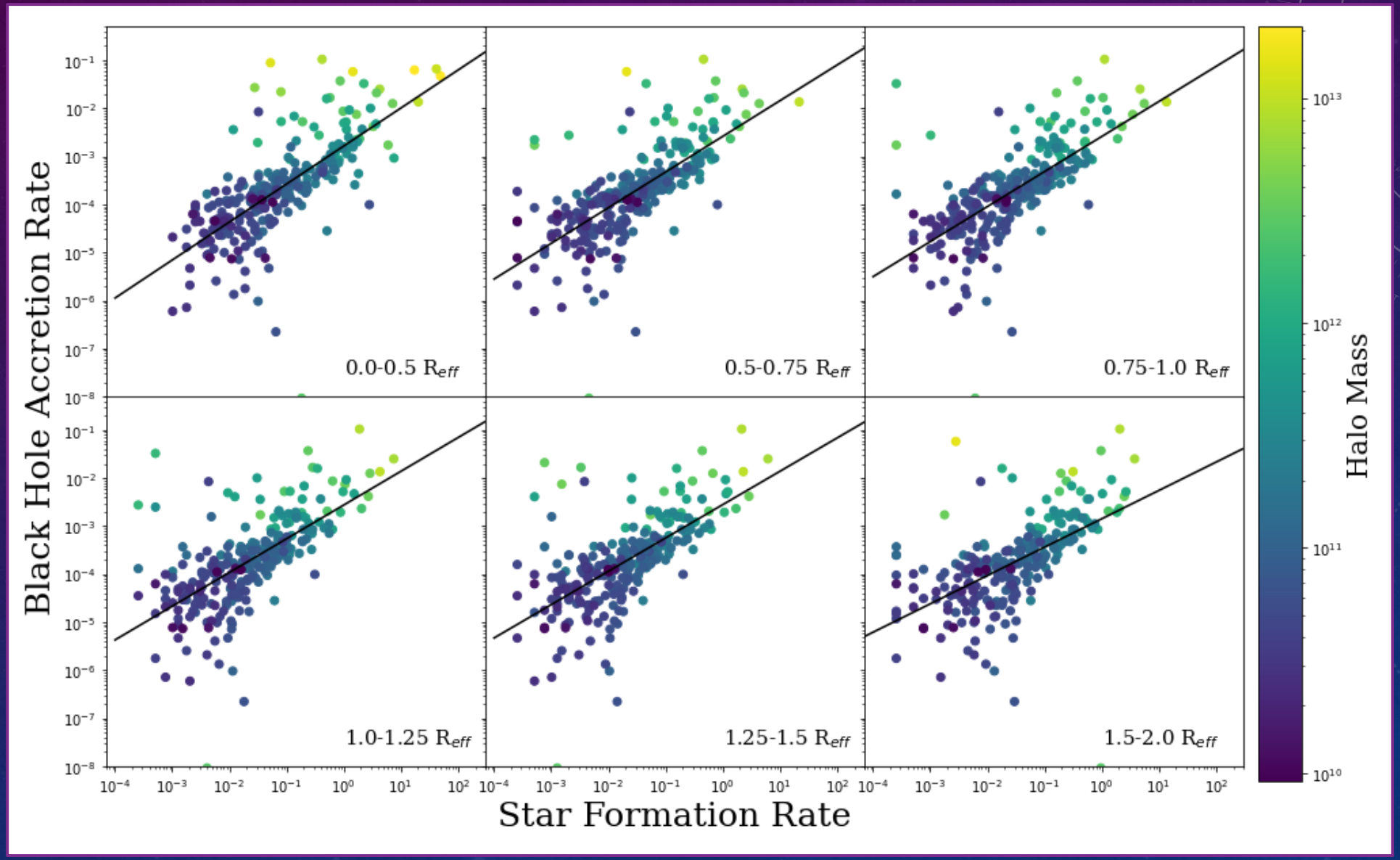


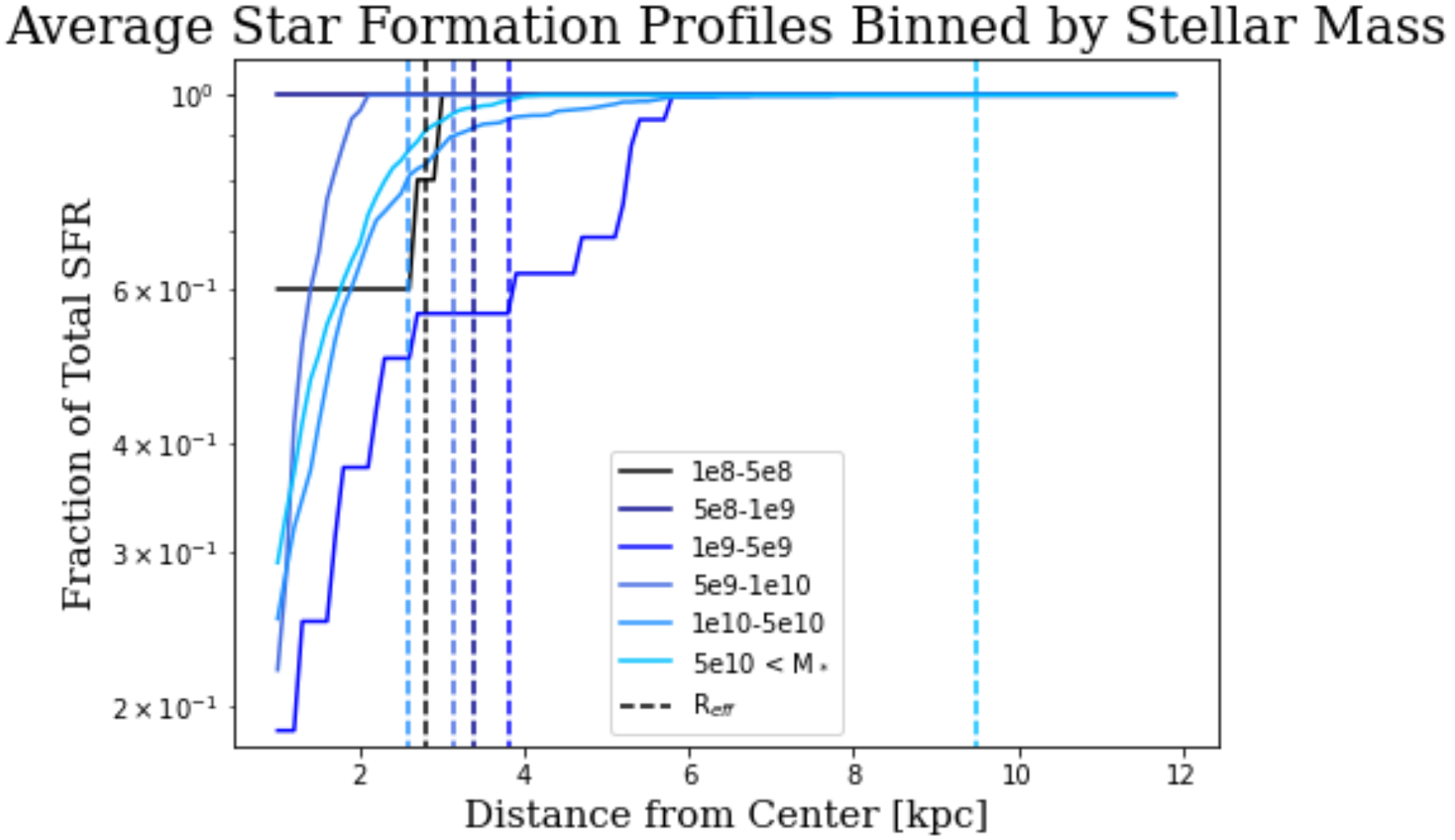
- Radius or Annulus
  - Kiloparsecs [kpc]
  - Effective Radius (R_{eff})
  - Virial Radius (R_{vir})

PLOTTING GAS MASS AGAINST BLACK HOLE ACCRETION RATE AT DIFFERENT ANNULI SHOWS THAT BLACK HOLE GROWTH FOLLOWS GAS MASS AT LOCAL AND GLOBAL SCALES



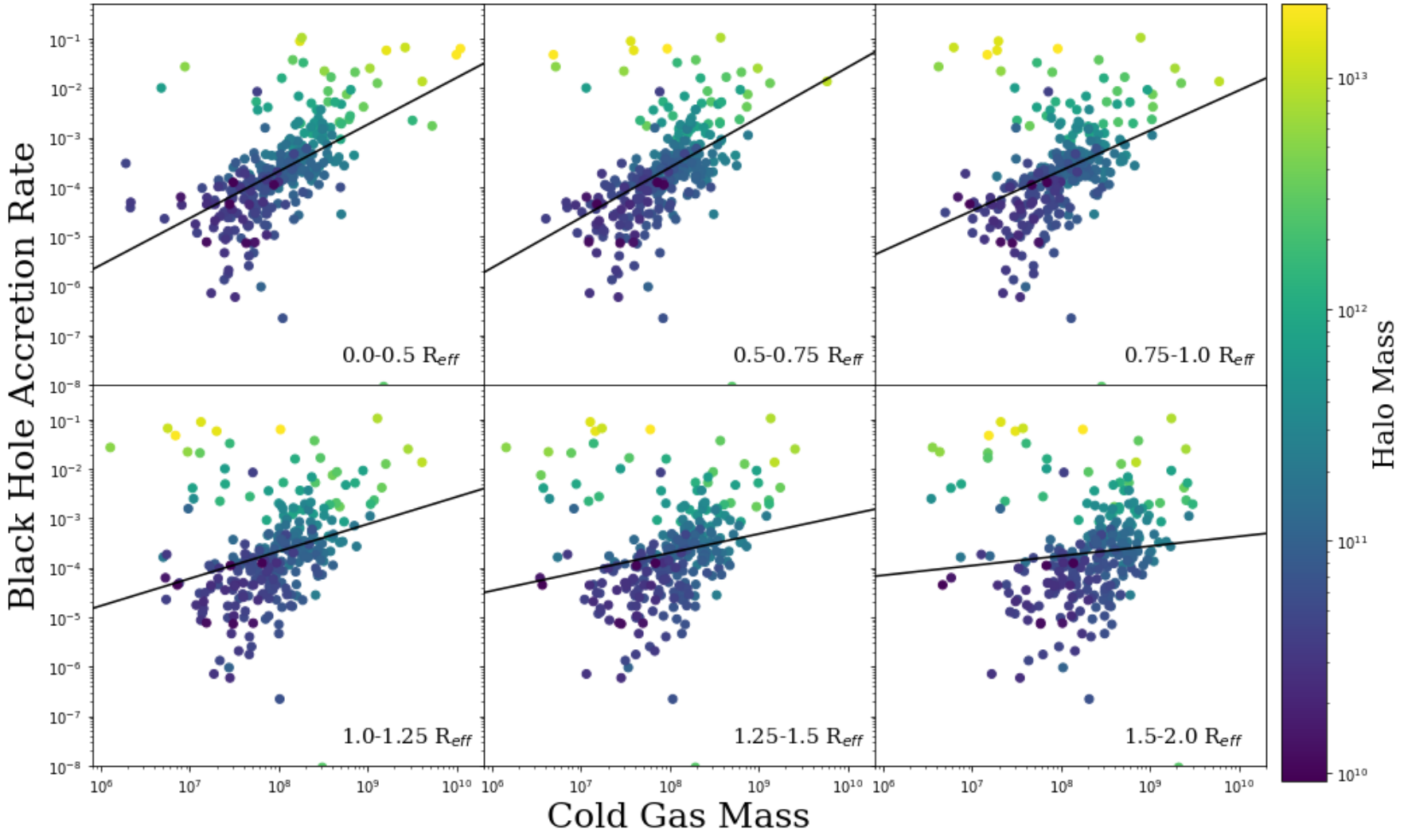
BLACK HOLE GROWTH FOLLOWS THE STAR FORMATION RATE OF THE ENTIRE HALO, NOT JUST STAR FORMATION AT THE CENTER

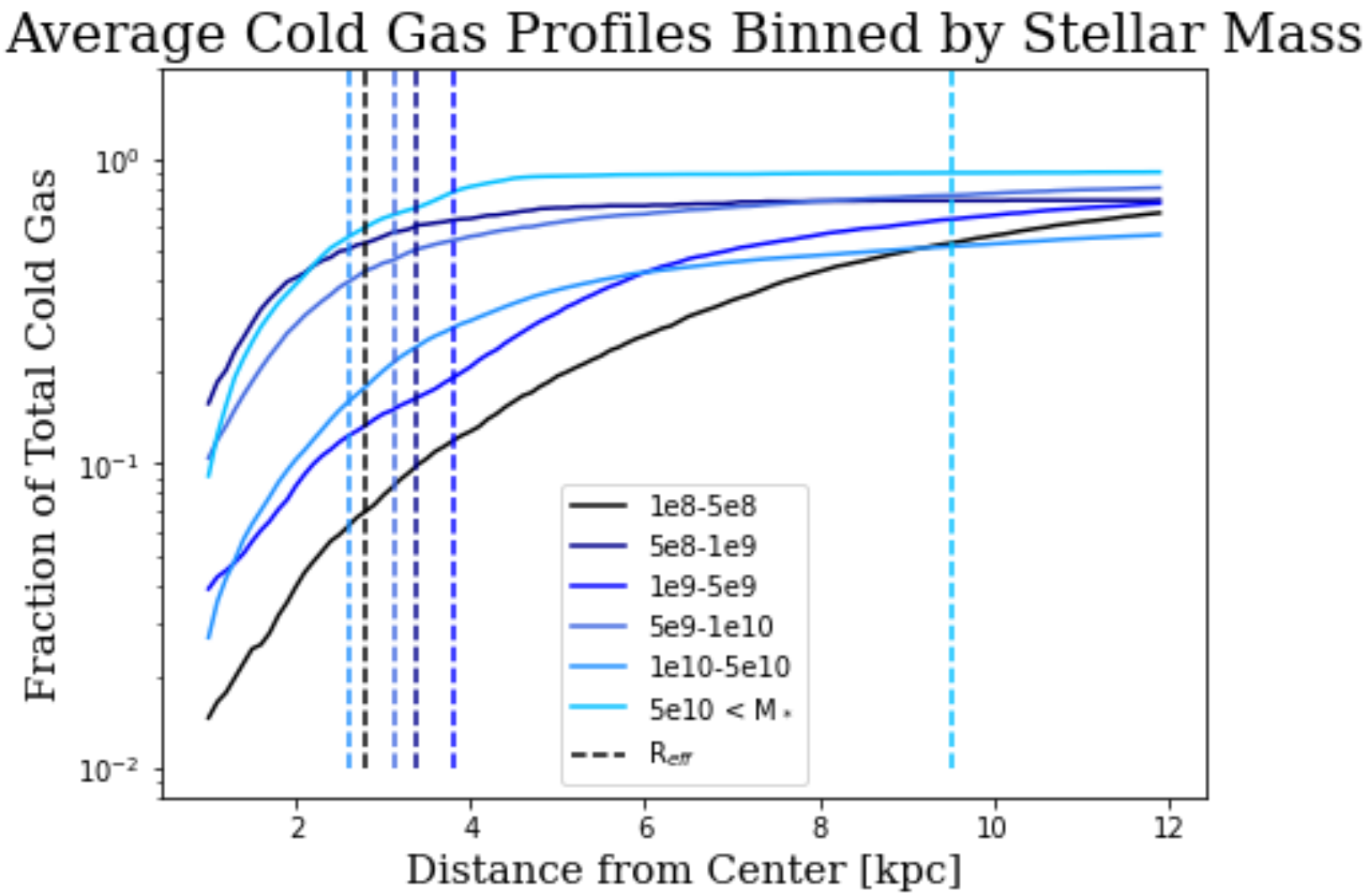




MOST OF STAR FORMATION IS CONSTRAINED WITHIN THE EFFECTIVE RADIUS, THUS TOTAL STAR FORMATION RATE IS DOMINATED BY INNER STAR FORMATION RATE

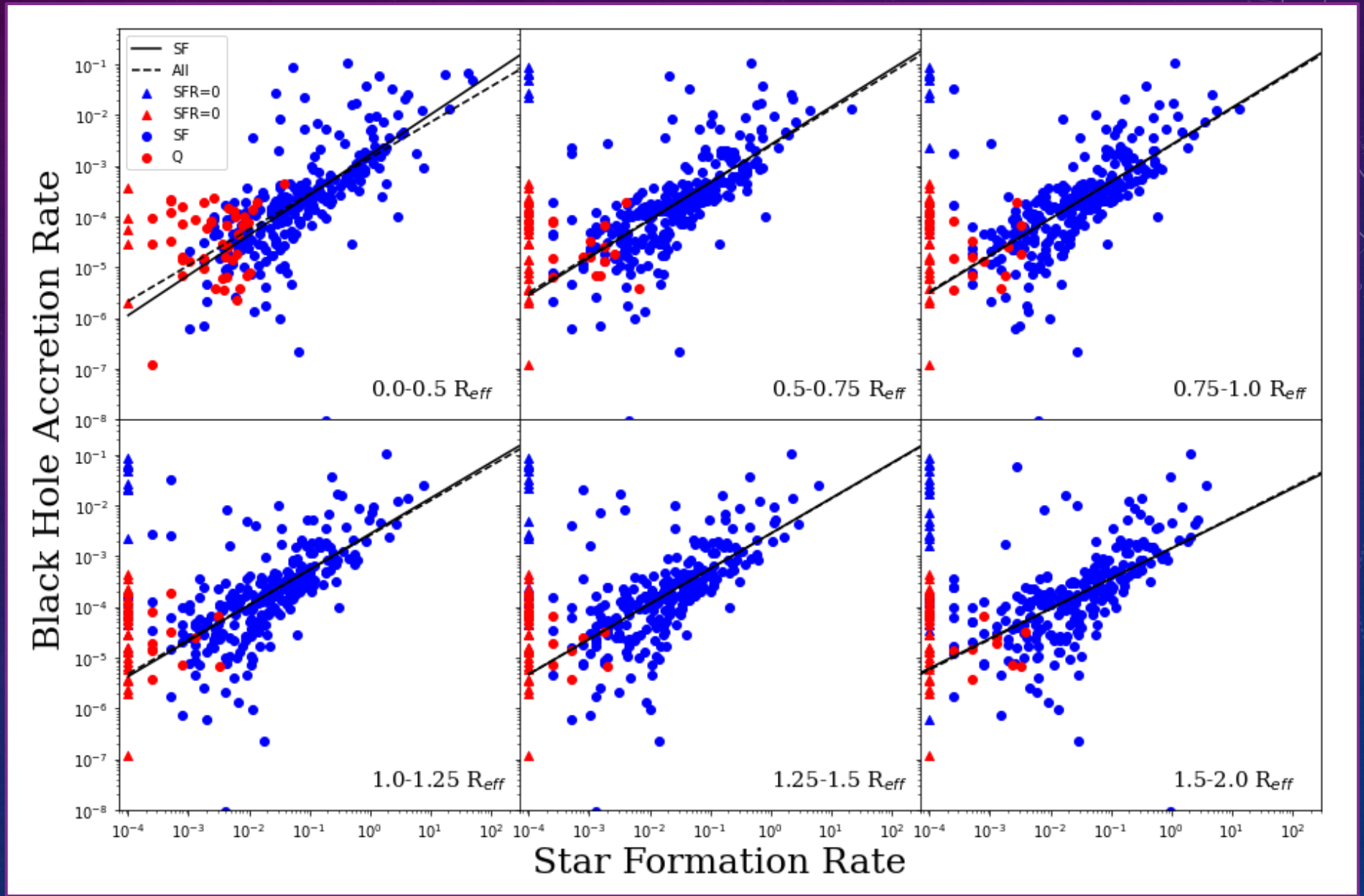
BLACK HOLE GROWTH FOLLOWS LOCAL COLD GAS MASS AT SMALL RADII



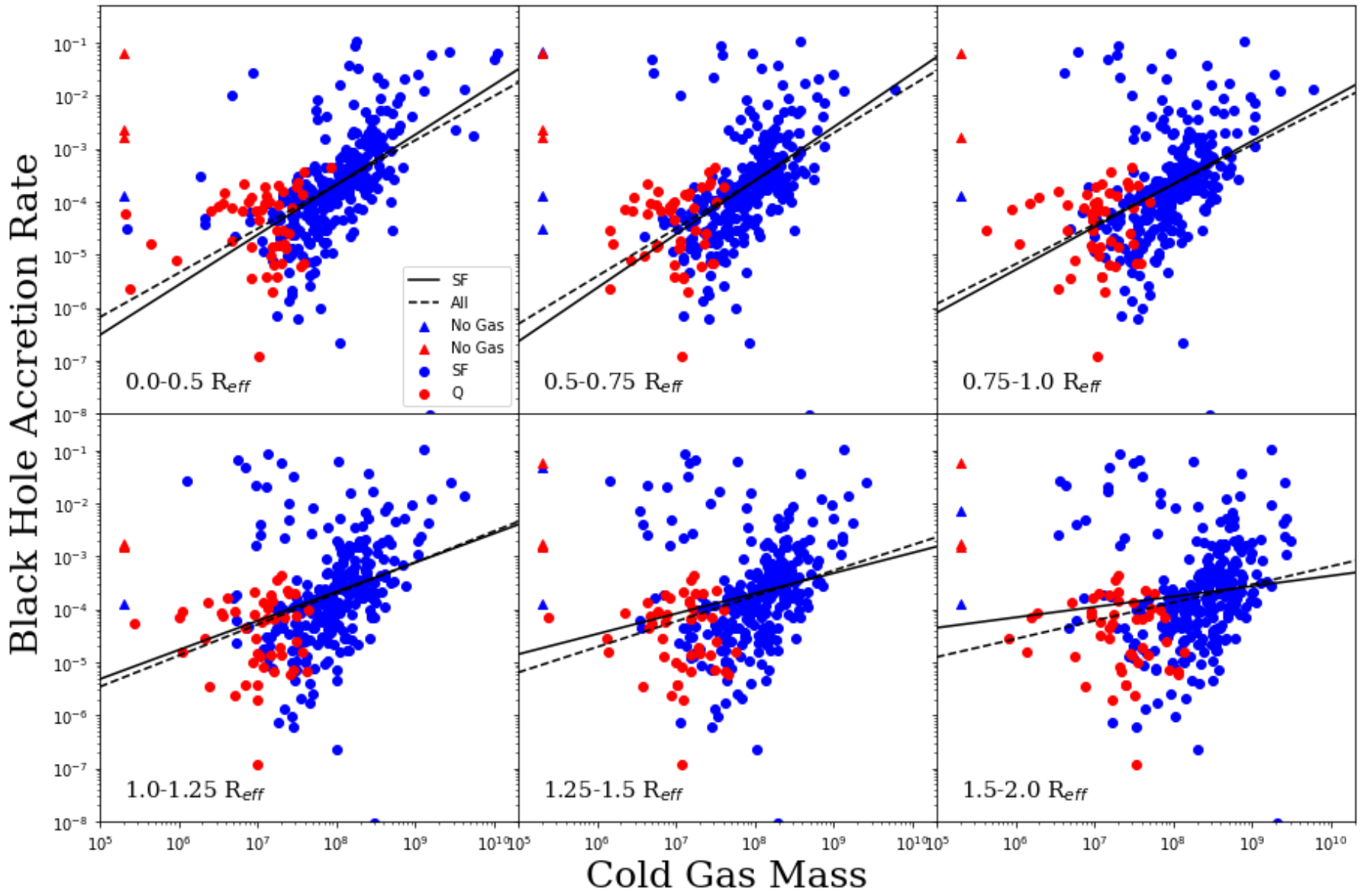


LOW MASS GALAXIES CONTAIN SIGNIFICANTLY HIGHER PERCENTAGES OF COLD GAS AT LARGER RADII IN CONTRAST TO HIGHER MASS GALAXIES WHERE NEARLY ALL COLD GAS RESIDES WITHIN EFFECTIVE RADIUS

QUENCHED GALAXIES HAVE RELATIVELY HIGH RATES OF BLACK HOLE ACCRETION AND DON'T FIT THE RELATIONSHIP ESTABLISHED BY STAR FORMING GALAXIES



QUENCHED GALAXIES FOLLOW THE SAME RELATIONSHIP OF BLACK HOLE ACCRETION RATE VS COLD GAS MASS FOUND IN STAR FORMING GALAXIES



CONCLUSIONS

- Gas Mass
  - Black hole growth does not follow local gas mass more closely than gas mass at outer radii
- Star Formation Rate
  - Total star formation is dominated by inner Star Formation Rate
  - Black hole growth follows total star formation, but this property is somewhat local
  - Star formation rate is not an accurate predictor of black hole accretion for quenched galaxies
- Cold gas Mass
  - Black hole growth only follows local cold gas mass, a tight relationship does not exist at outer radii
  - Cold gas mass is a more accurate predictor of black hole accretion for quenched galaxies

WHAT PROCESSES TRANSFER COLD GAS TO THE CENTERS OF GALAXIES?


NASA/HST

- Minor Mergers
- Bar Fraction


Hubble Space Telescope