Halo Occupation Distribution of Quasars
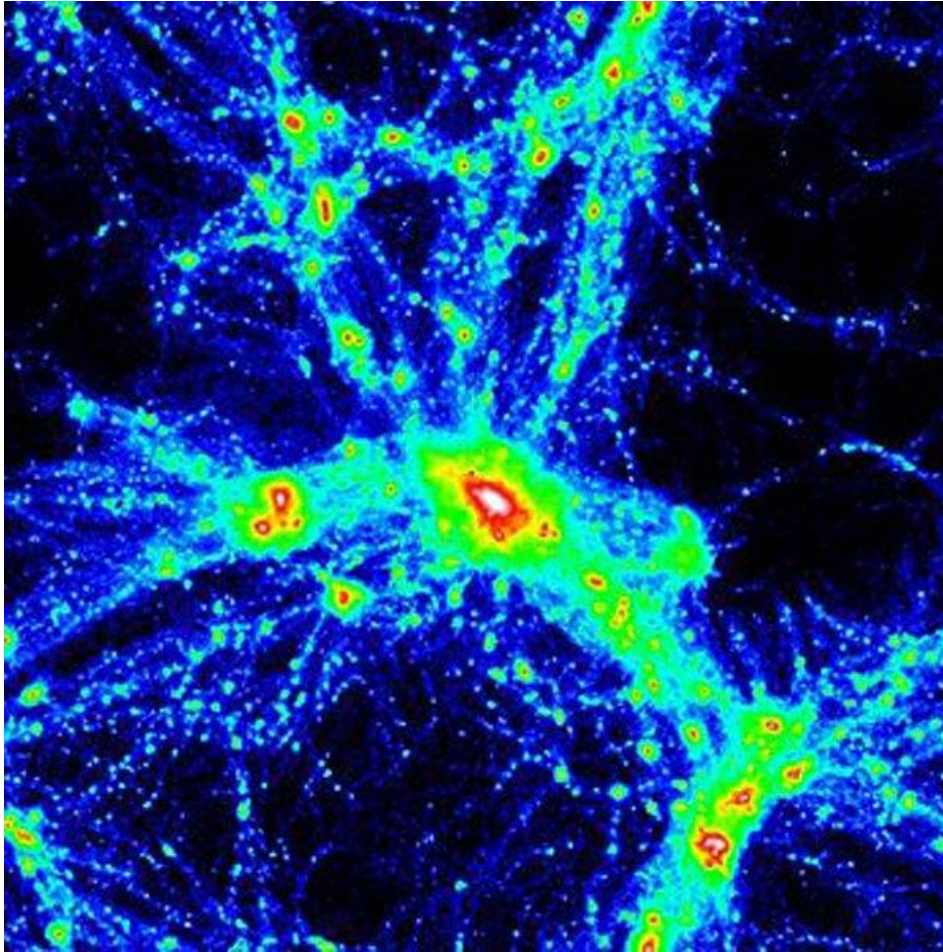
Kaustav Mitra

Presidency University, Kolkata

TCGCA-ER4, IISER, Kolkata

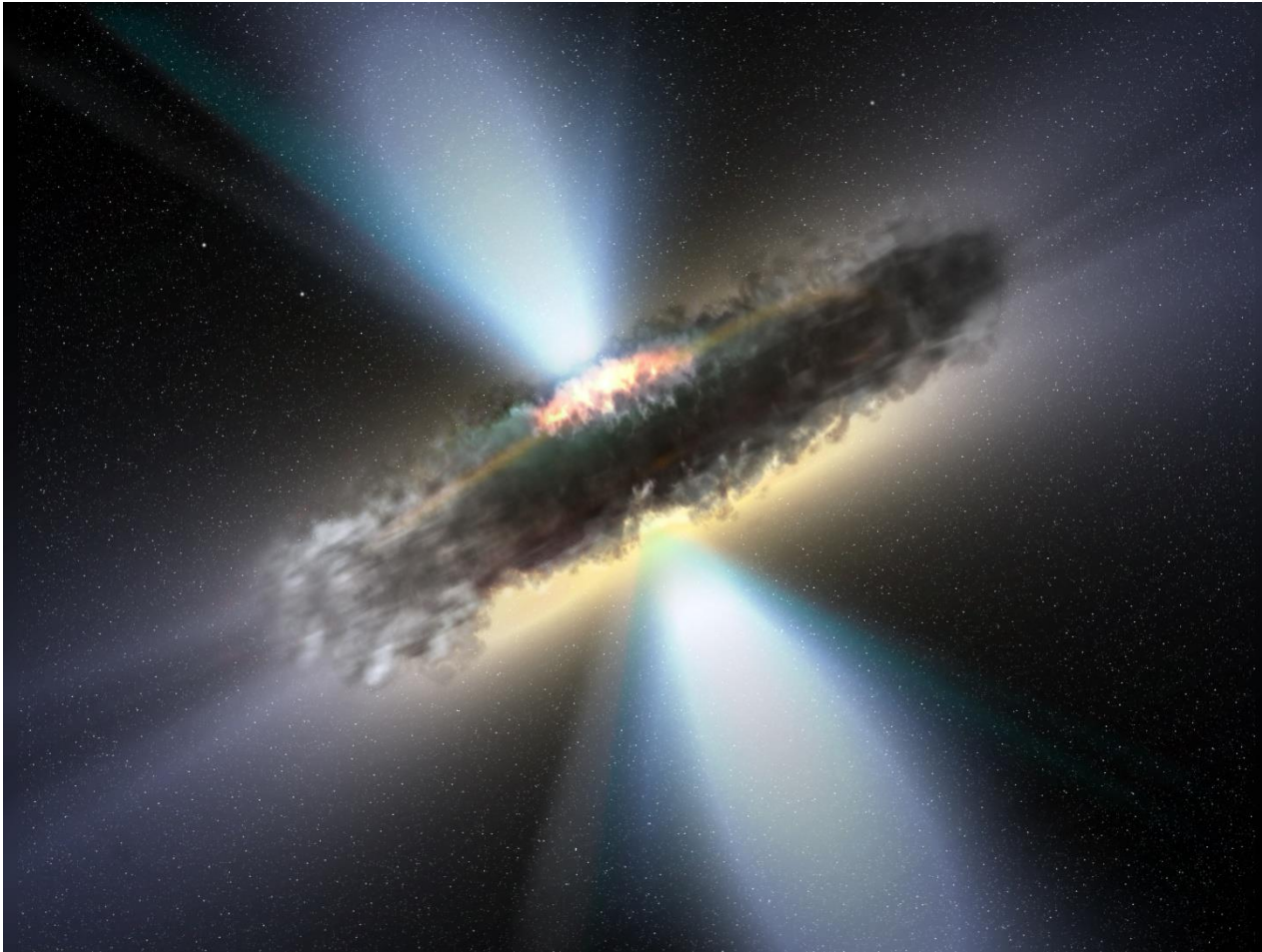Sep. 19, 2015

Dark Matter Halo

Galaxies lie in dark matter halos

Each galaxy hosts a super massive black hole

32-Mpc simulation of large-scale structure in a standard cold-dark matter Universe.
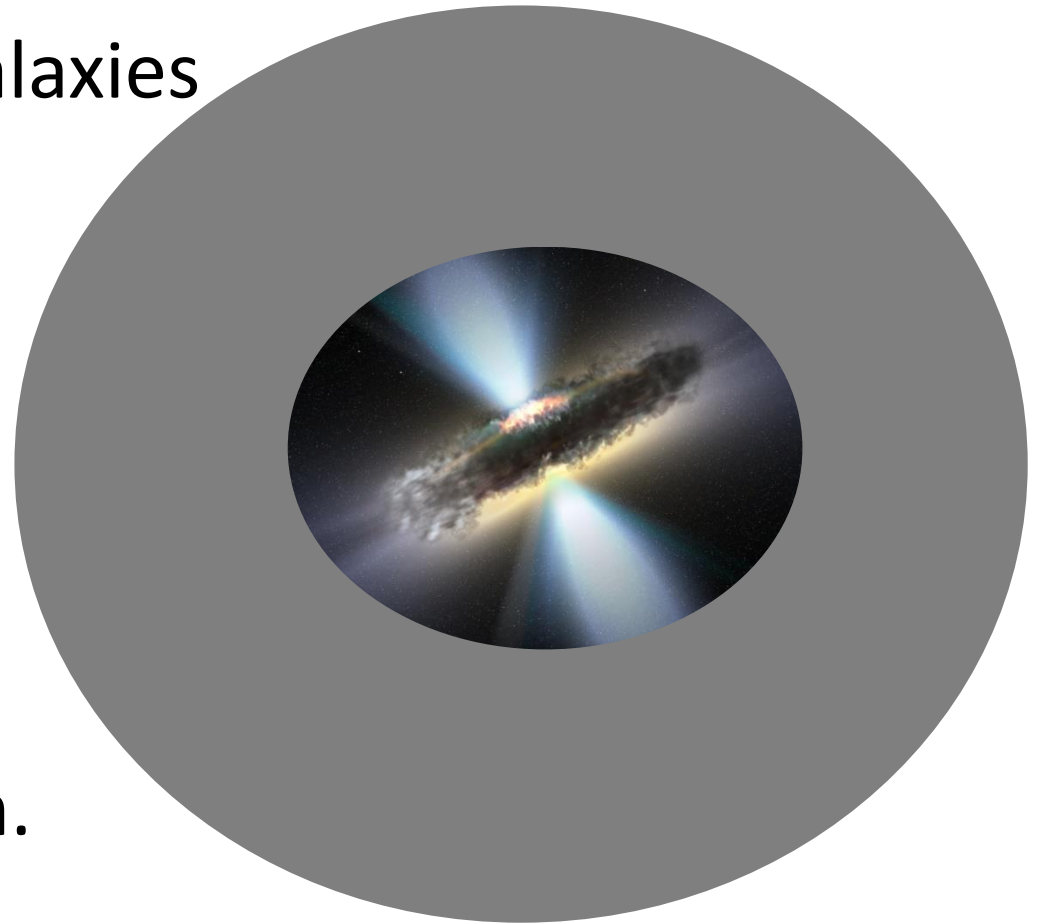Courtesy : R. Cen, Princeton University.

Quasars

Courtesy : ESA | V. Beckmann (NASA-GSFC)

Quasars
in Dark Matter Halos

Co-evolution Of Galaxies

and Super Massive

Black Holes

with

Large

scale Dark

Matter distribution.
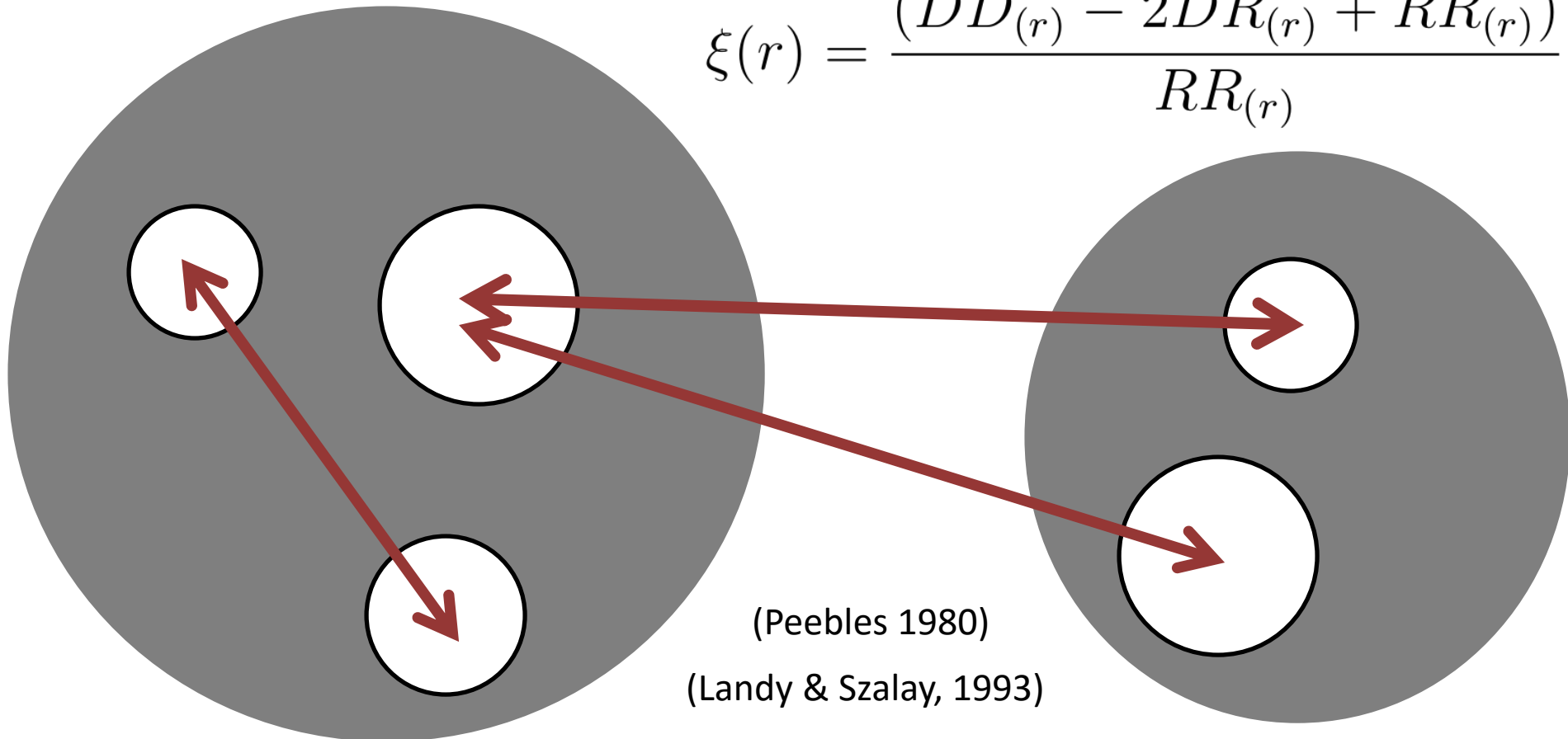
Clustering of Quasars

How are quasars distributed in Dark Matter halos?

The Coma Cluster. Credit: NASA, ESA, and the Hubble Heritage Team (STScI/AURA) . Acknowledgment: M. Carter (Liverpool John Moores University) and the Coma HST ACS Treasury Team.

Clustering Statistic

Counting the number of pairs of quasars at different clustering scales

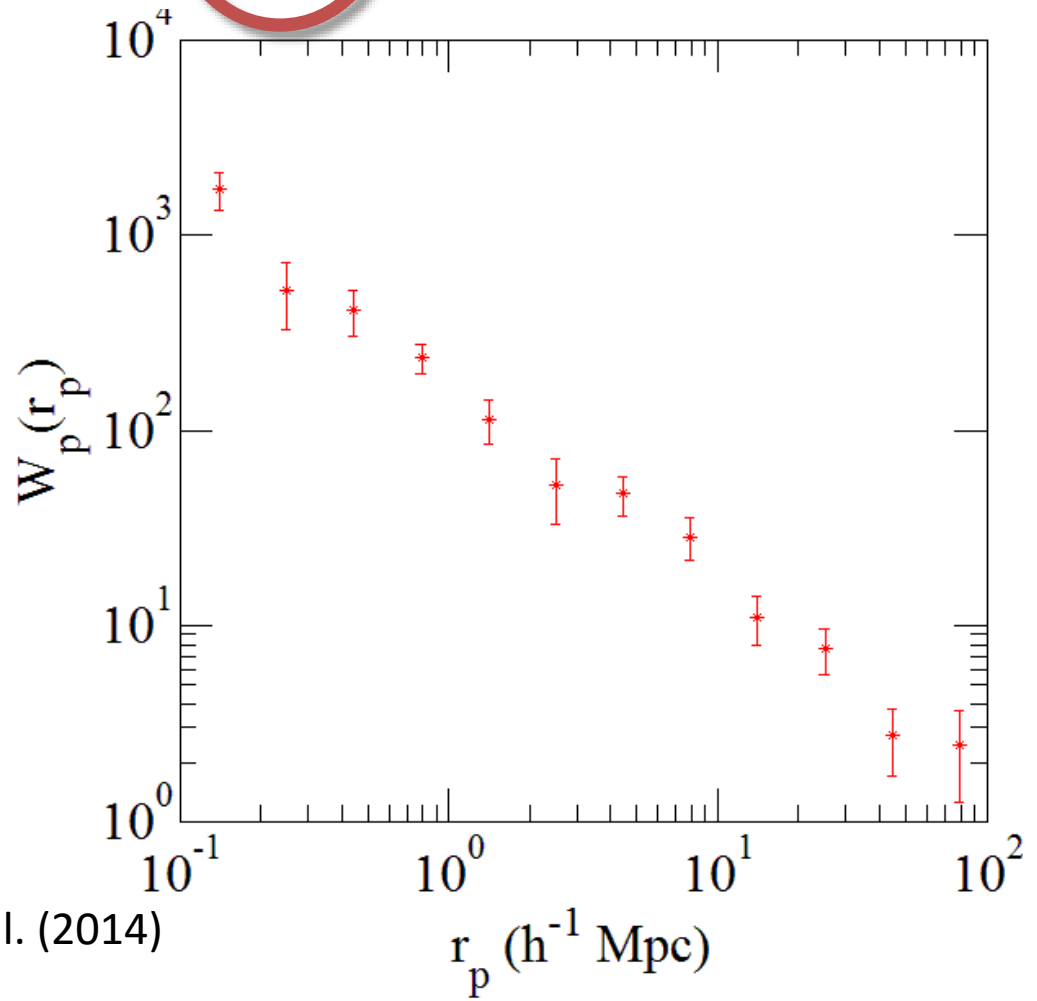$$\xi(r) = \frac{(DD_{(r)} - 2DR_{(r)} + RR_{(r)})}{RR_{(r)}}$$

(Peebles 1980)

(Landy & Szalay, 1993)

Two Point Correlation Function

$$P(r) = n^2[1 + \xi(r)]dV_1 dV_2$$

(Peebles 1980)

Excess probability

Of finding quasar

Pairs at that scale,

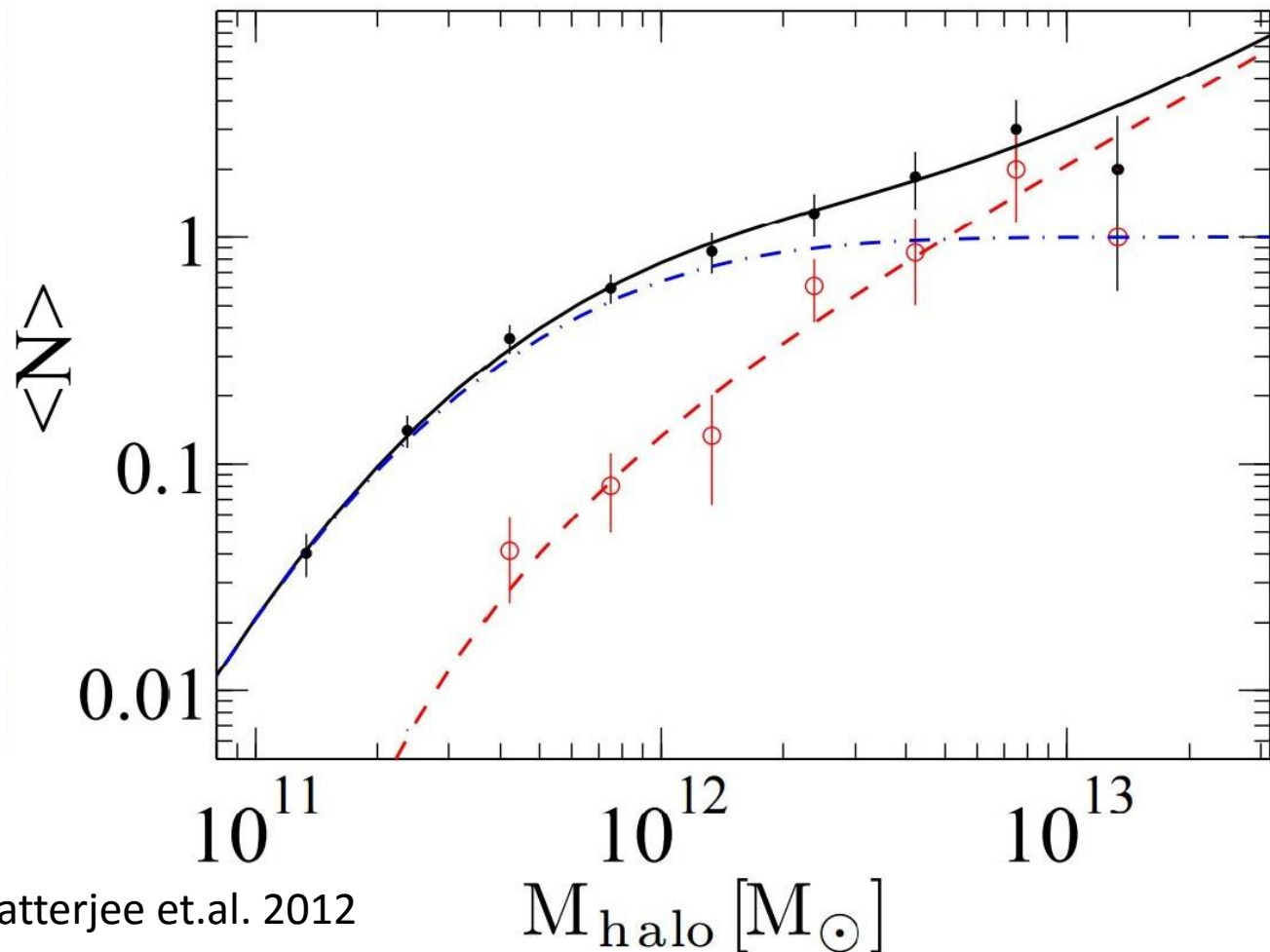hence a measure

of clustering at

different clustering

scales.

DiPompeo et al. (2014)

Mean Occupation Function

$$\langle N(M)\rangle = \frac{1}{2}\left[1 + \mathrm{erf}\left(\frac{\log M - \log M_{\min}}{\sigma_{\log M}}\right)\right] + \left(\frac{M}{M1}\right)^{\alpha}\exp\left(-\frac{M_{\mathrm{cut}}}{M}\right)$$
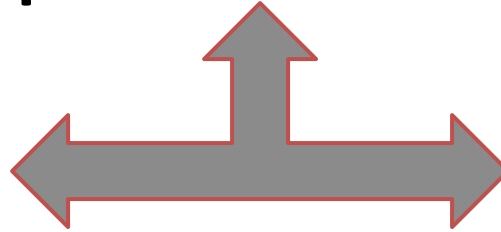
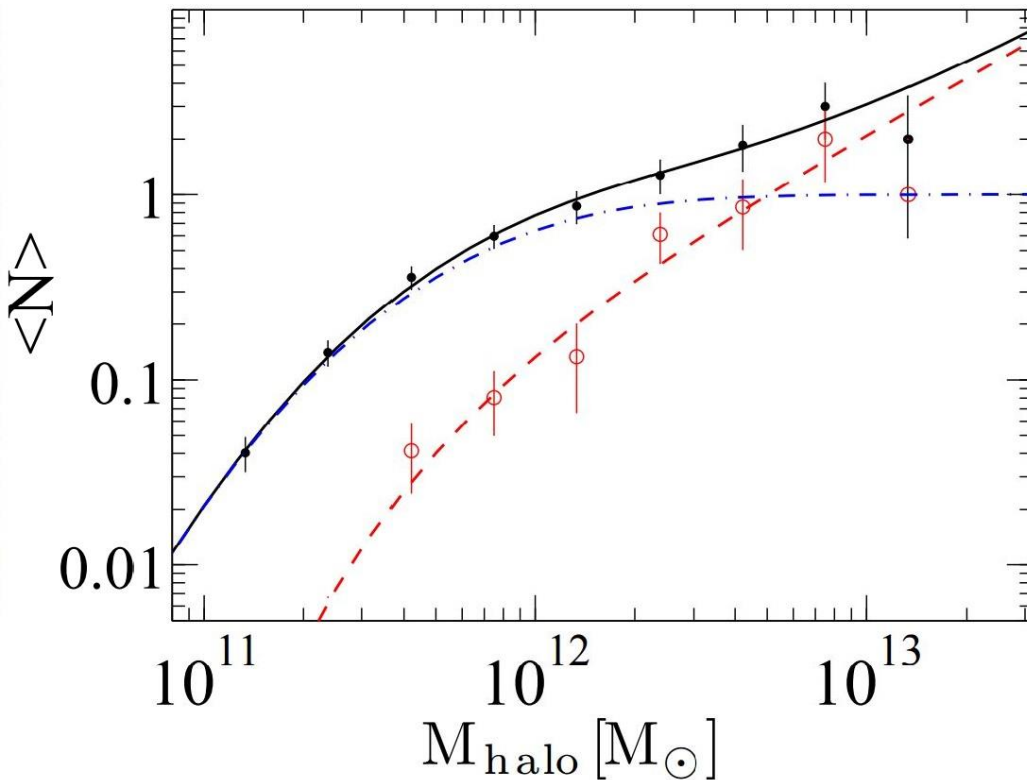Average number of quasars per dark matter halo of a given host halo mass.
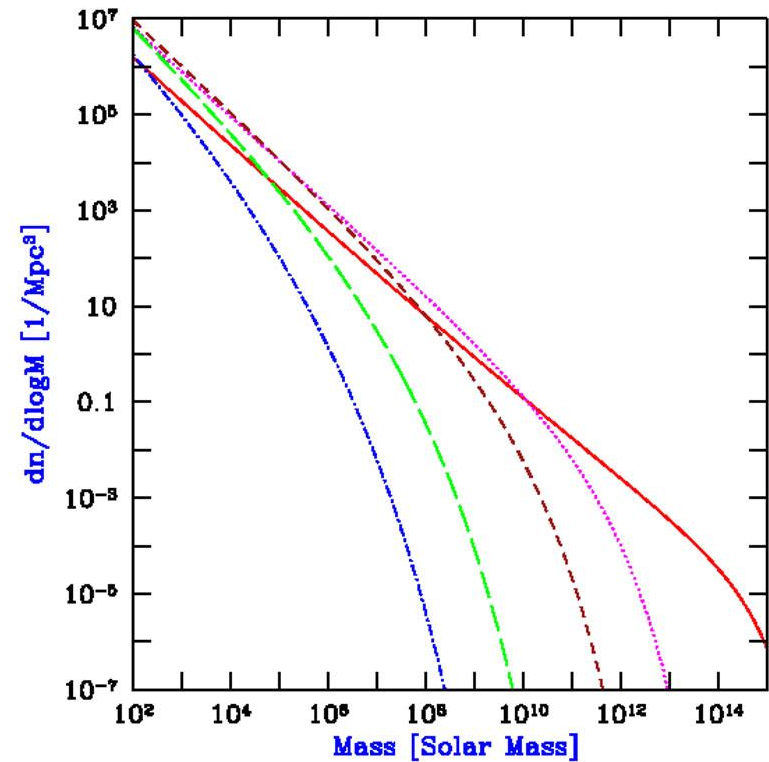

Chatterjee et.al. 2012

Halo Occupation Distribution

Mean Occupation Function

Halo Mass Function

Chatterjee et.al. 2012

Courtesy: Avi Loeb

So… what I did is as follows…

- Assumed Chatterjee et. al. 2012   MOF model and Tinker et. al. 2007   HMF.

- Used DiPompeo et. al. 2014 data of observed 2PCF

- Used Zheng et. al. 2007 MCMC code to find the set of free parameters that minimizes the chi-square of modeled 2PCF with that of the observed data.

- Used the free parameters to construct the **HOD of obscured and unobscured quasars**.

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Two Point Correlation Function of Obscured and Unobscured Quasars
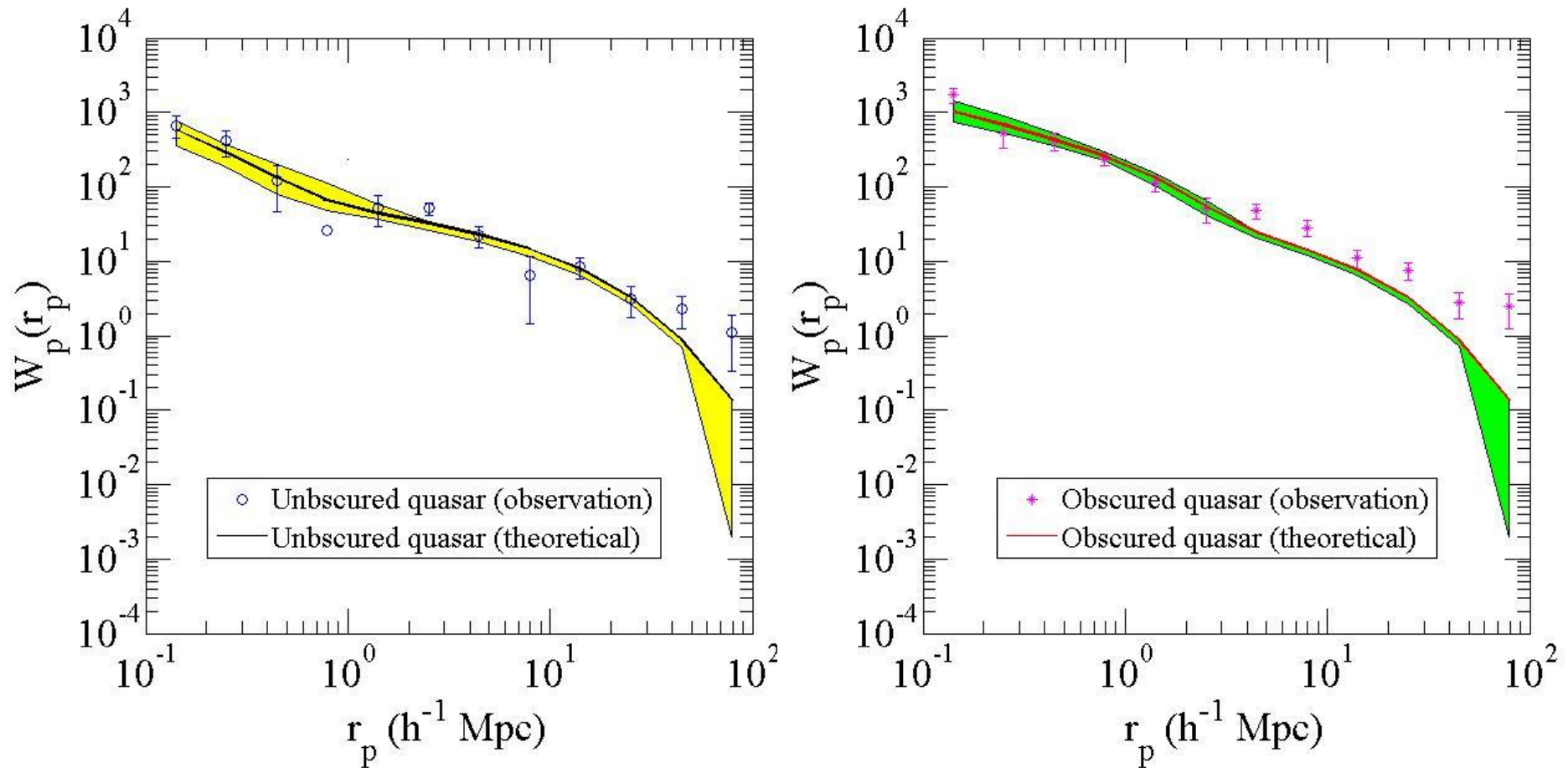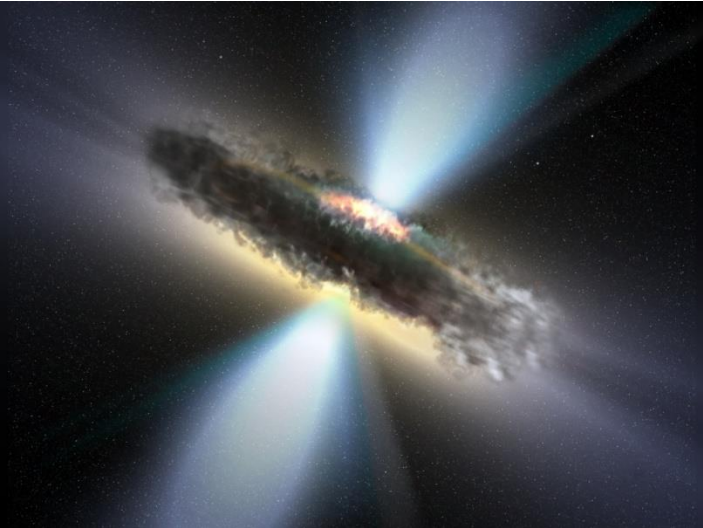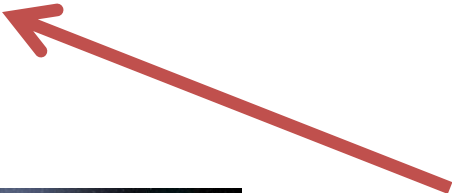

Data from   DiPompeo et al. (2014)

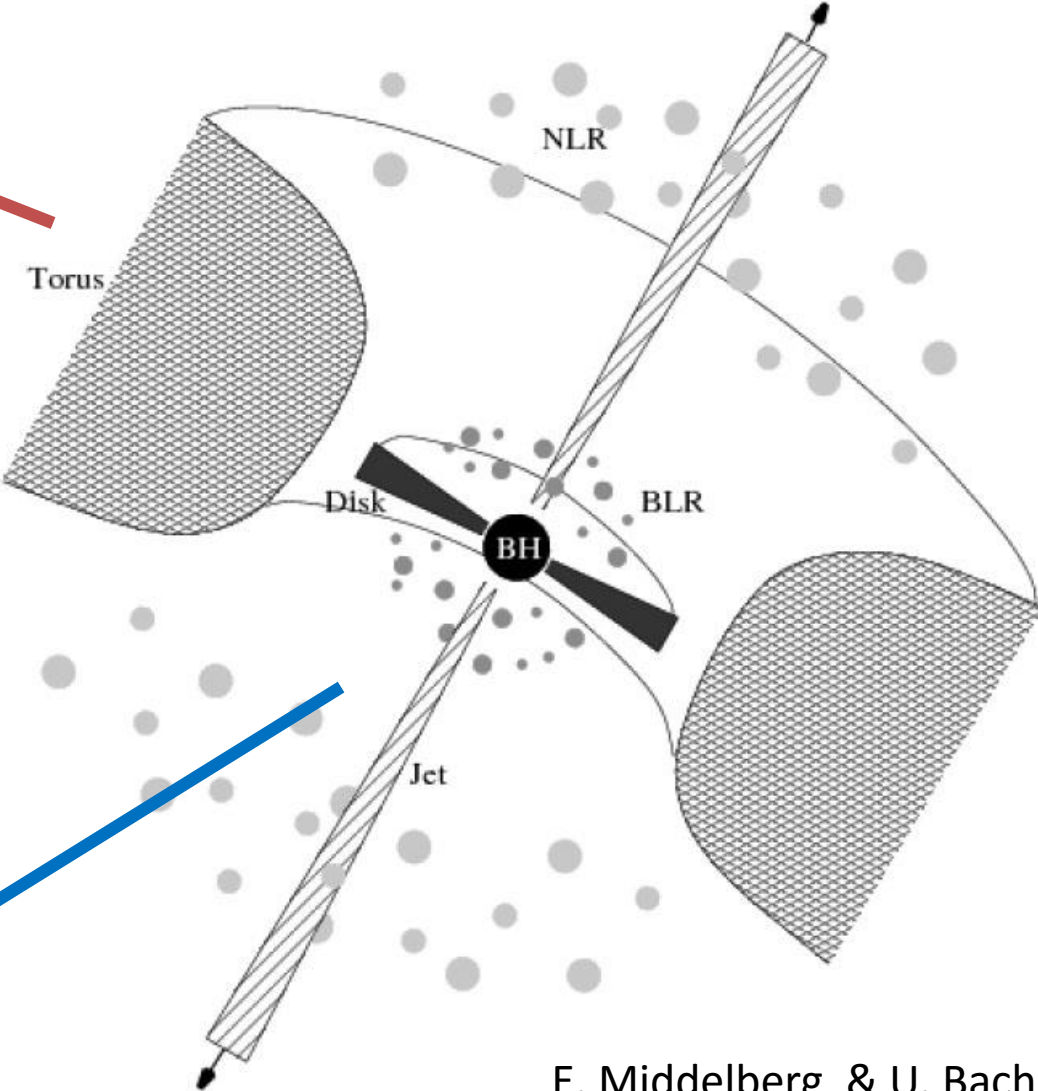# Mean Occupation Function of Obscured and Unobscured Quasars
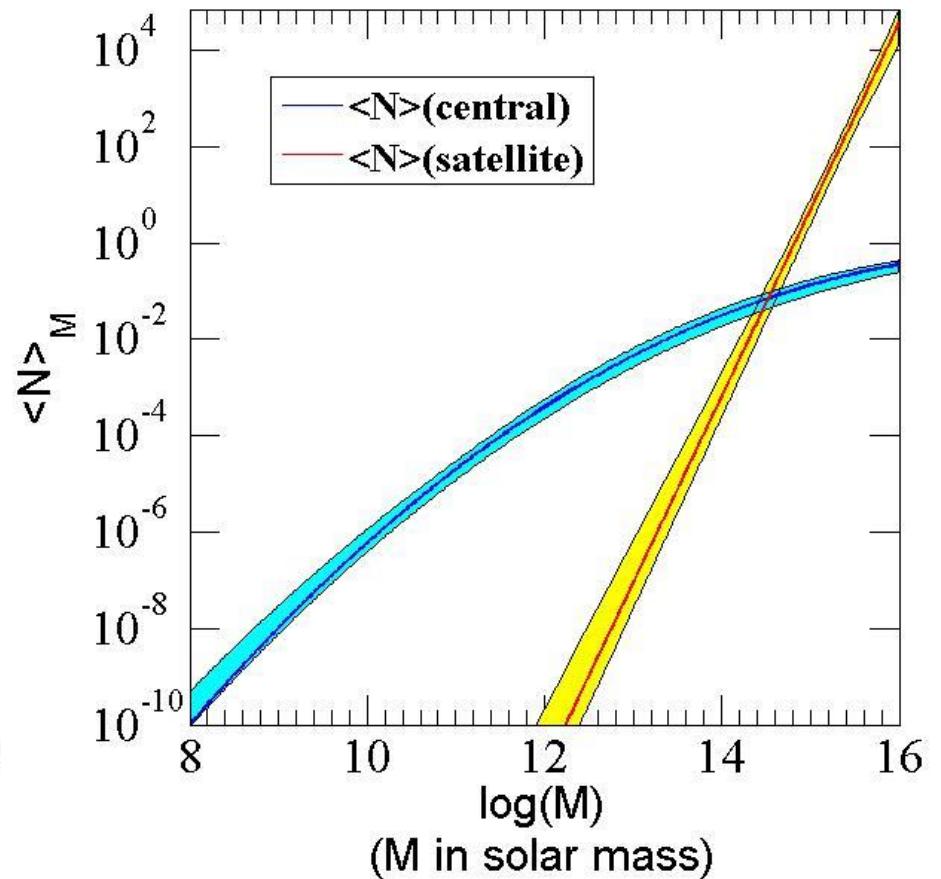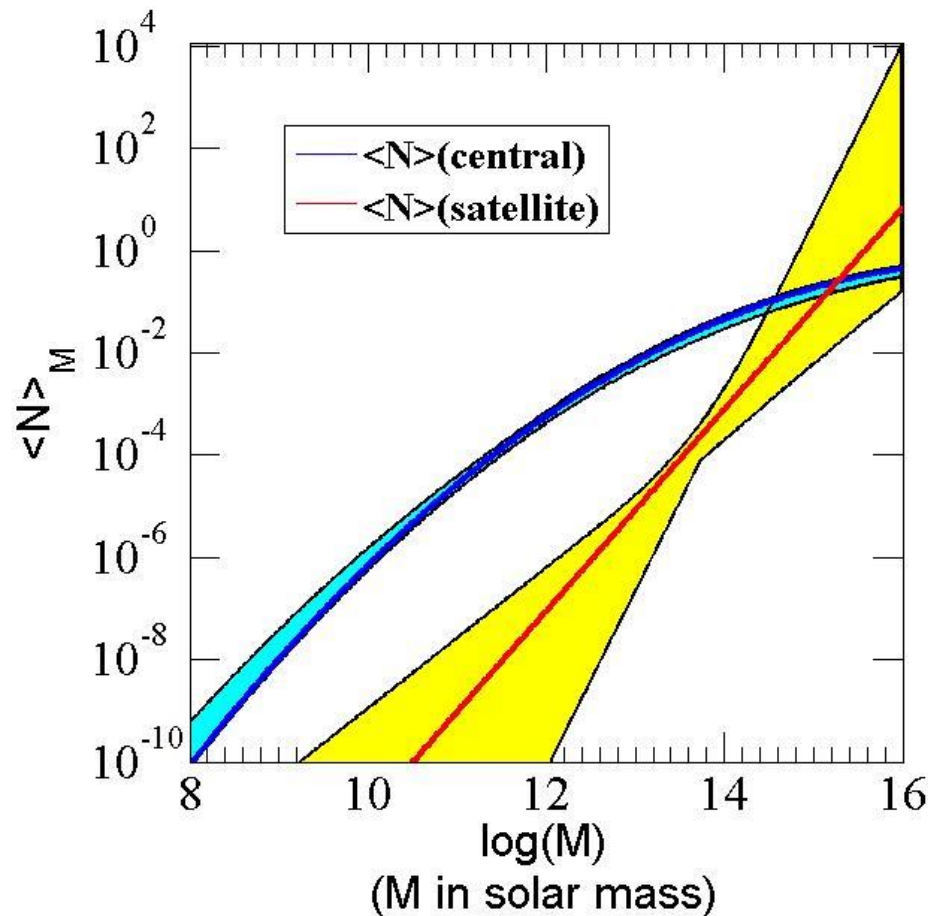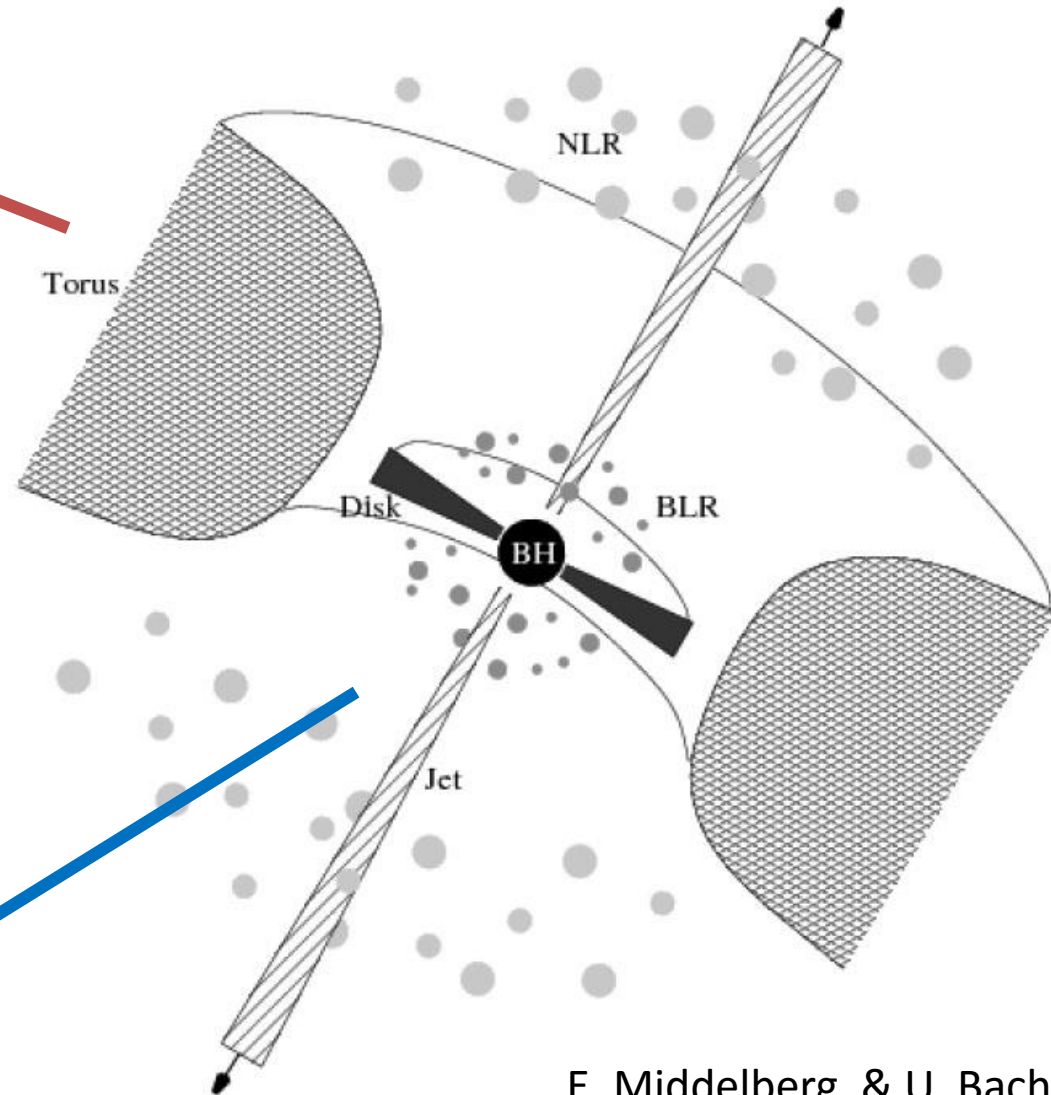
Quasars ...again

Obscured

Unobscured

ESA | V. Beckmann (NASA-GSFC)

Torus

NLR

Disk

BLR

BH

Jet

E. Middelberg & U. Bach

Are they intrinsically different?

Obscured

Orientation v/s Evolutionary Theories of Quasars…?

Unobscured

NLR

Torus

Disk

BLR

BH

Jet

E. Middelberg & U. Bach

And Finally…
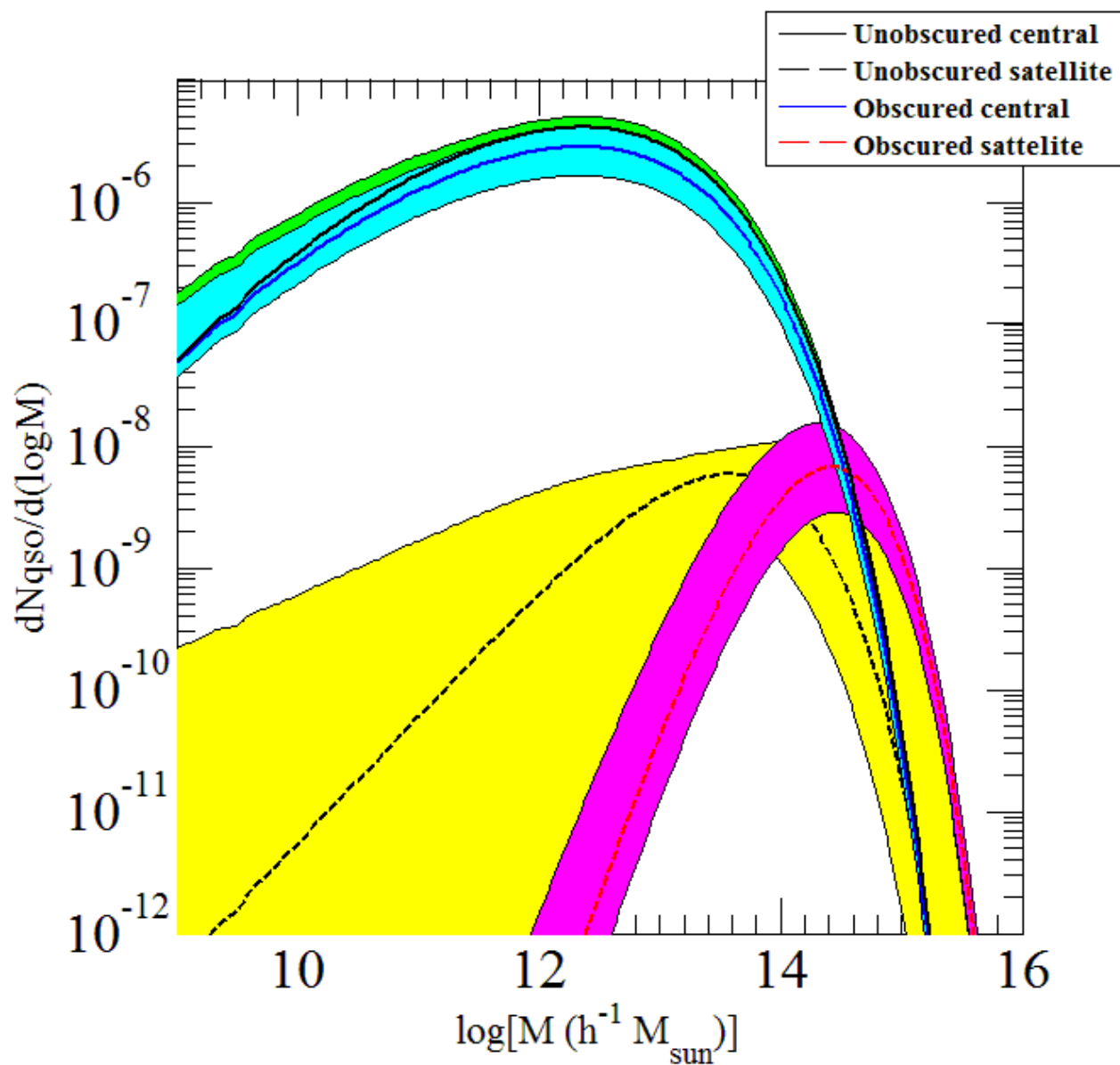
To quasars and beyond …!!

- Our results match brilliantly with the Richardson et. al. 2012 results on HOD of SDSS quasars.

- The broader goal to compare with HOD of different classes of AGNs and analyze the galaxy-DM halo co-evolution.

- There are several scopes of improving, and we will do that, but as far as our preliminary results are concerned, the take-home-message is ….

Obscured and Unobscured Quasars are sitting in very similar Dark Matter Halos, and at least from the HOD perspective, the orientation theory of quasars strongly holds its ground.

ESA | V. Beckmann (NASA-GSFC)
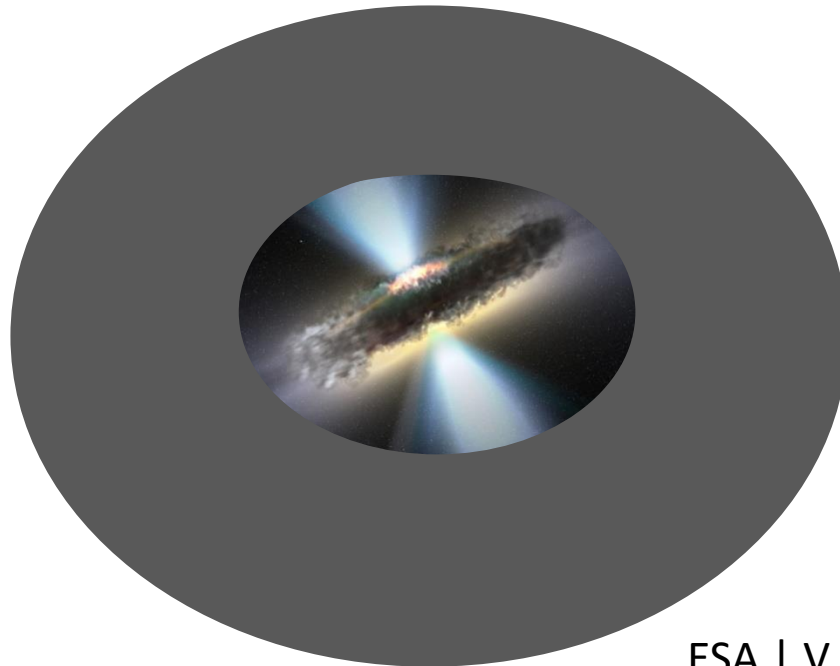
Thank you !!!

S. Chatterjee

Z. Zheng

M. DiPompeo

R. Hickox

J. Richardson

A. Myers