南極THzキックオフミーティング
３月２５日（木）（オンライン）

銀河と超巨大ブラックホールの起源

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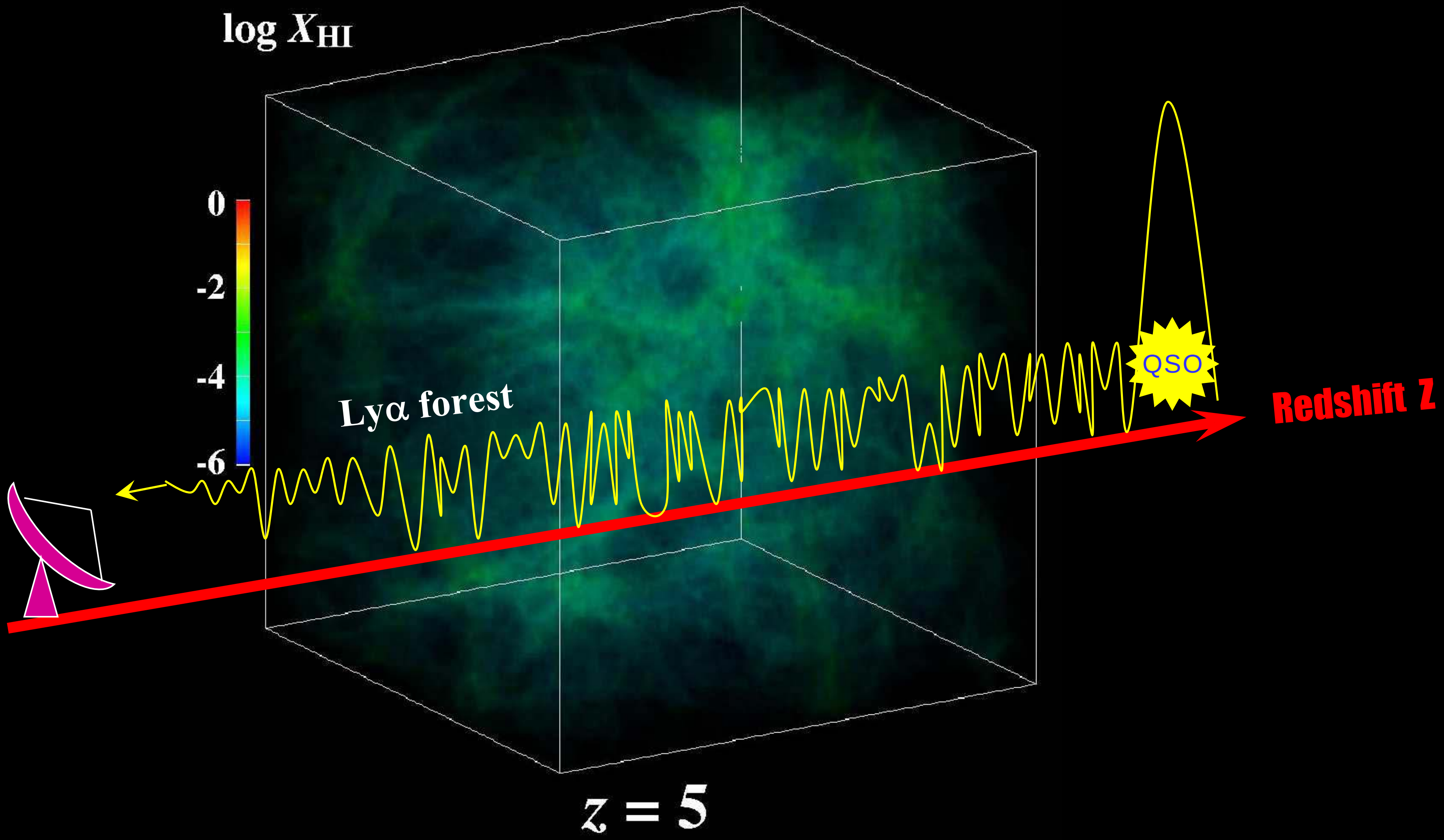
筑波大学 計算科学研究センター

宇宙再電離とLyα吸収線系のシミュレーション

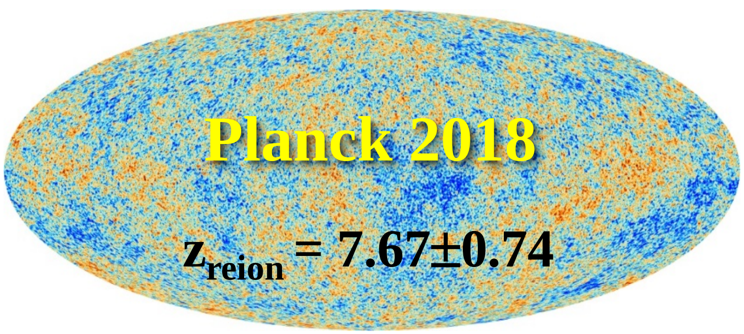


Lyα吸収の減衰

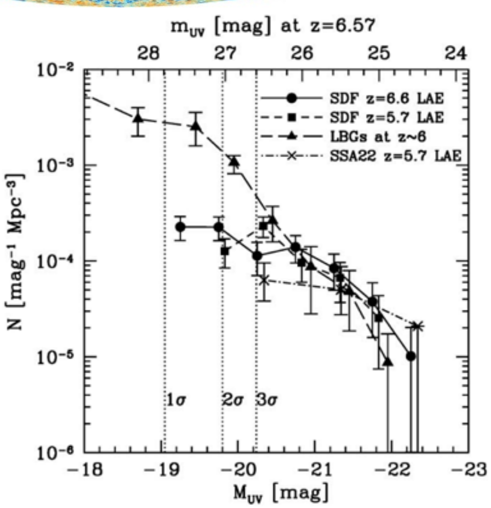
Umemura et al. 2001, ASPC, 222, 109

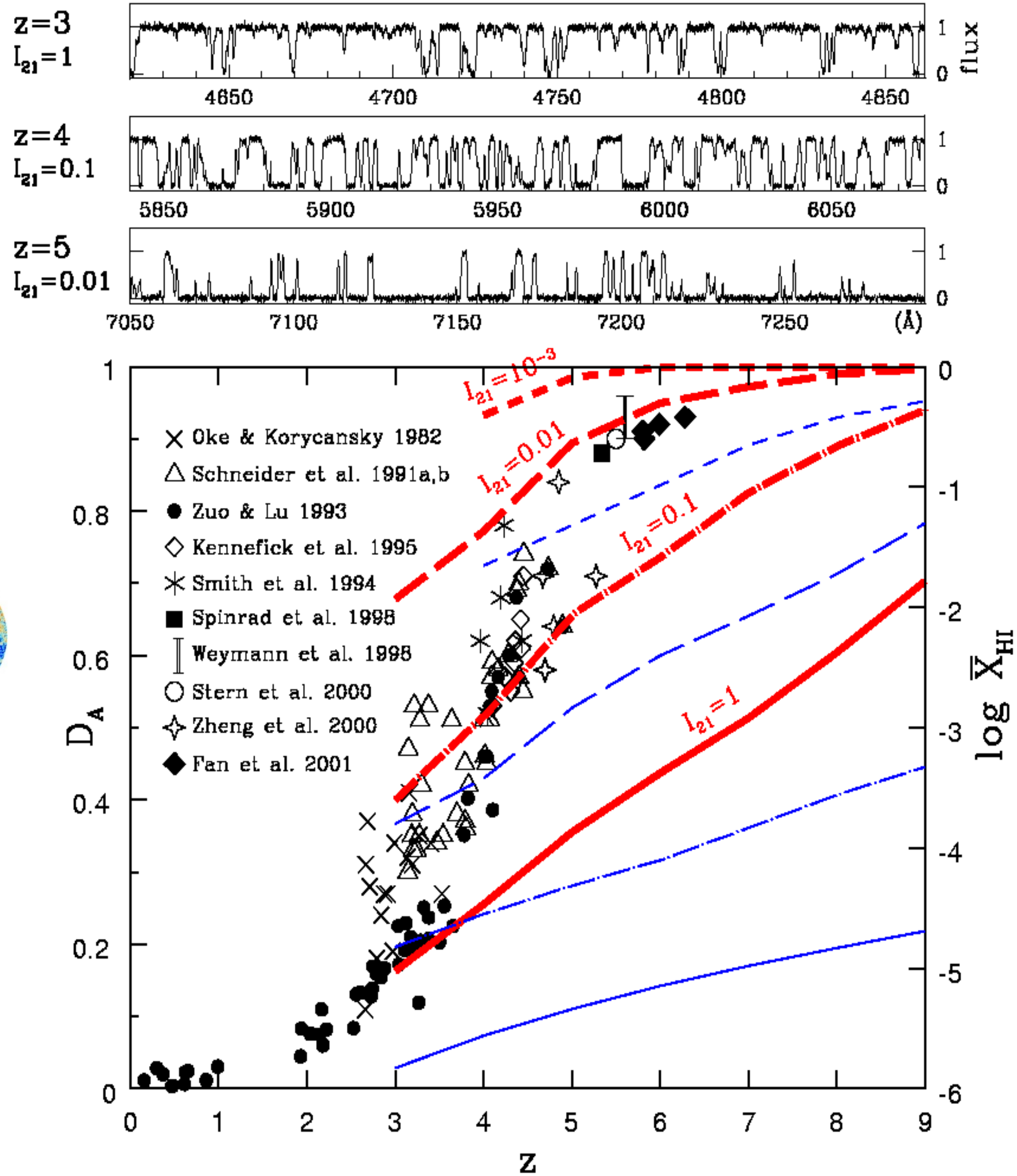
$$D_A \equiv \int_{\nu_{\mathrm{Ly}\alpha}}^{\nu_{\mathrm{Ly}\beta}} \frac{f_{\mathrm{cont}} - f_{\mathrm{obs}}}{f_{\mathrm{cont}}} d\nu \Big/ (\nu_{\mathrm{Ly}\beta} - \nu_{\mathrm{Ly}\alpha})$$

$z_{\mathrm{reion}} \approx$ 6-10



z= 6.5 LAEs

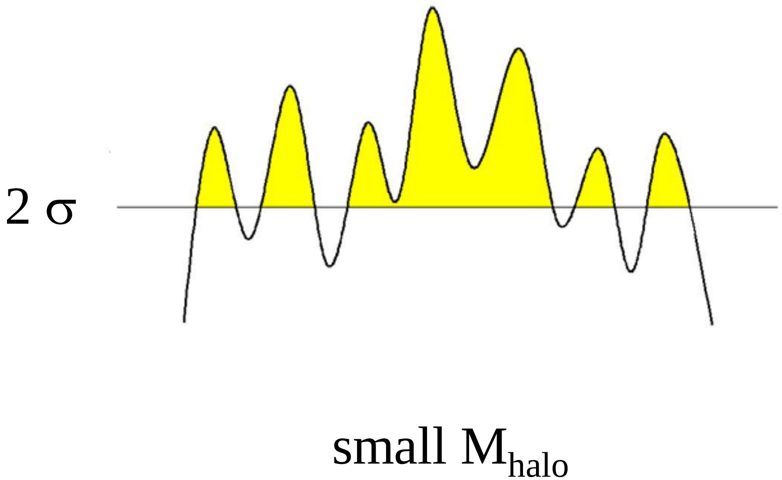


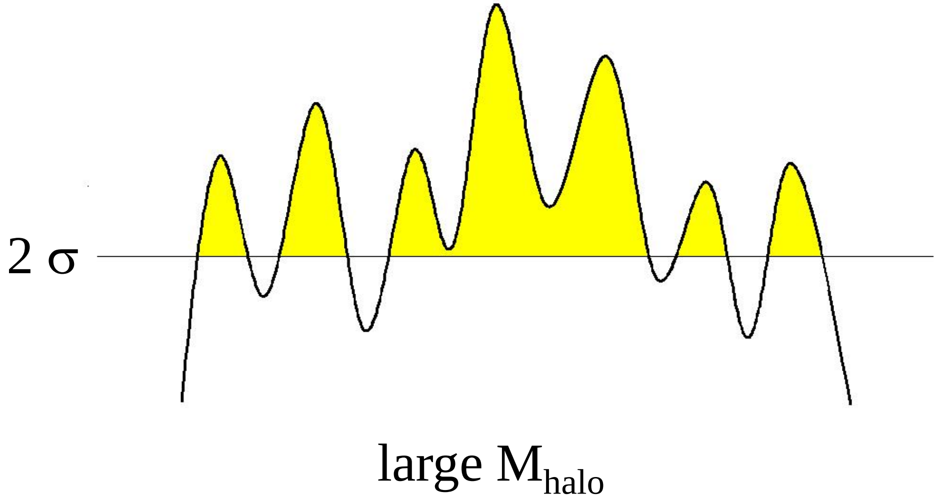


Biased Galaxy Formation

high z
(high baryon density)

low z
(low baryon density)





no downsizing
(hierarchical)

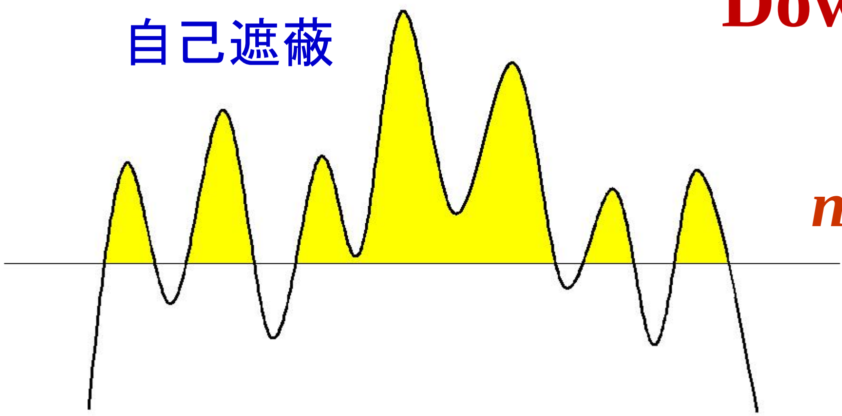
given M_{halo}

high z
(high baryon density)

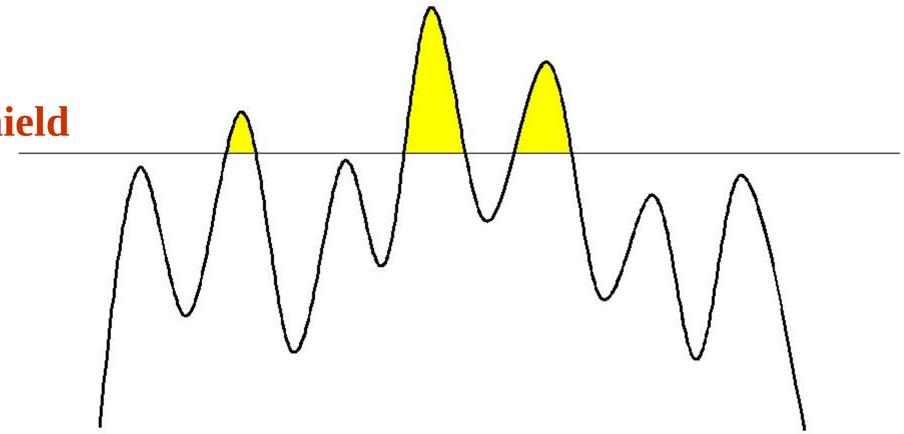
low z
(low baryon density)

Downsizing

自己遮蔽



$n>n_{shield}$

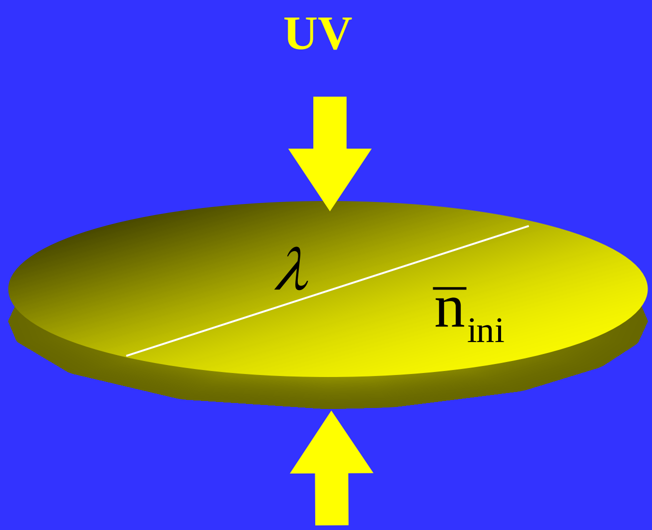


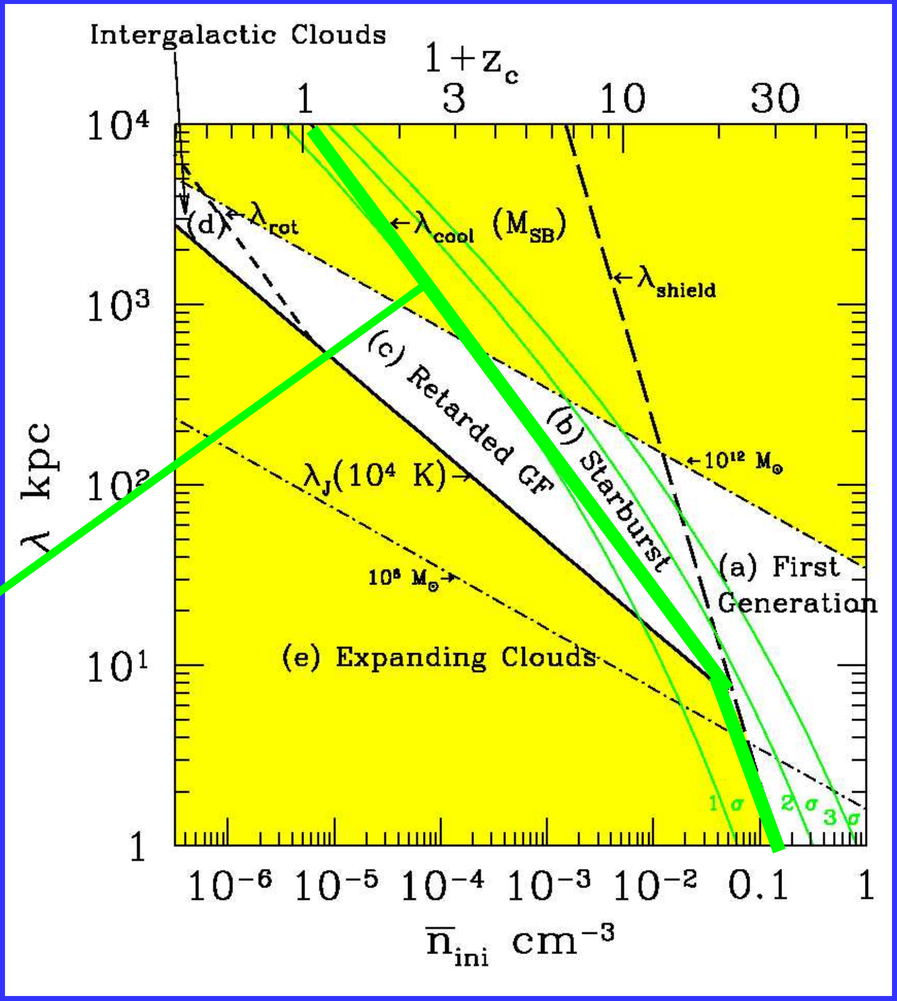
Large bulge の形成
（ low M/L ）

Small bulge の形成
（ high M/L ）

電離宇宙における銀河形成

Susa & Umemura (2000, ApJ, 537, 578)





Dynamics: Sheet Hydrodynamics

UV: Radiative transfer

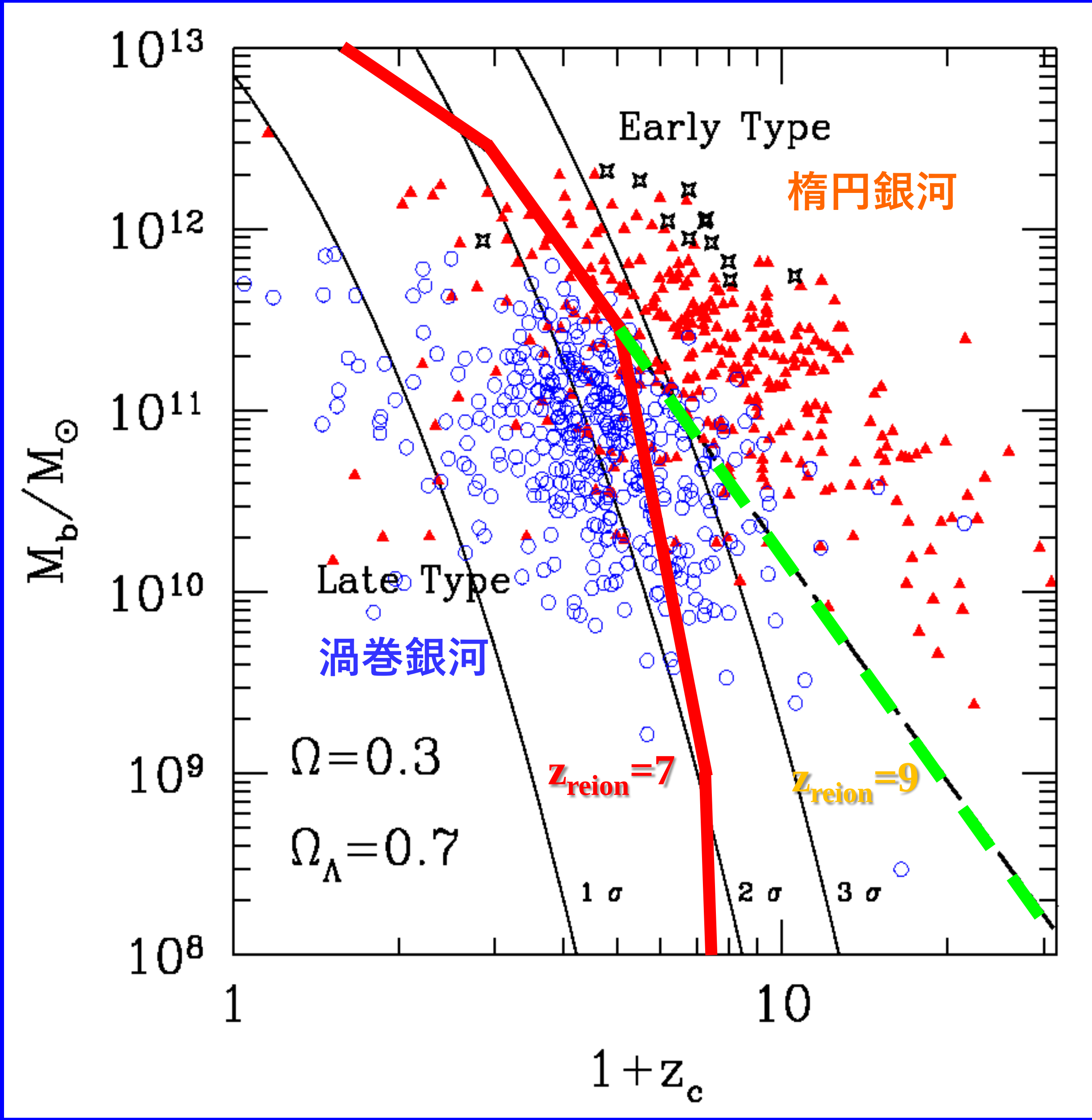
H_2 : Non-equilubrium chemistry

Initial Starburst Criterion

$$M_{SB} = 2.2\times10^{11} M_\odot \left[(1+z_c)/5\right]^{-4.2}\left(\frac{I_{21}}{0.1}\right)^{0.6}$$

Ultraviolet-background-induced bifurcation of galactic morphology

Susa & Umemura (2000, MNRAS, 316, L17)



z=9.11 OIII Emission Galaxy

Hashimoto et al. 2018, Nature, 557, 392

z_{Lya}=9.11, z_{coll}〜15 (t〜2.5億年)
$M_{star}=1\times10^{9}\,M_{\odot}$, $M_{dyn}=4\pm3\times10^{9}\,M_{\odot}$, $M_{dust}<5\times10^{5}\,M_{\odot}$
$Z=0.0\text{-}0.4Z_{\odot}$
cf. $M_{dust}=0.01\times0.1M_{star}(Z/Z_{\odot})=2\times10^{5}M_{\odot}$ よって，metal-poor か gas-poor

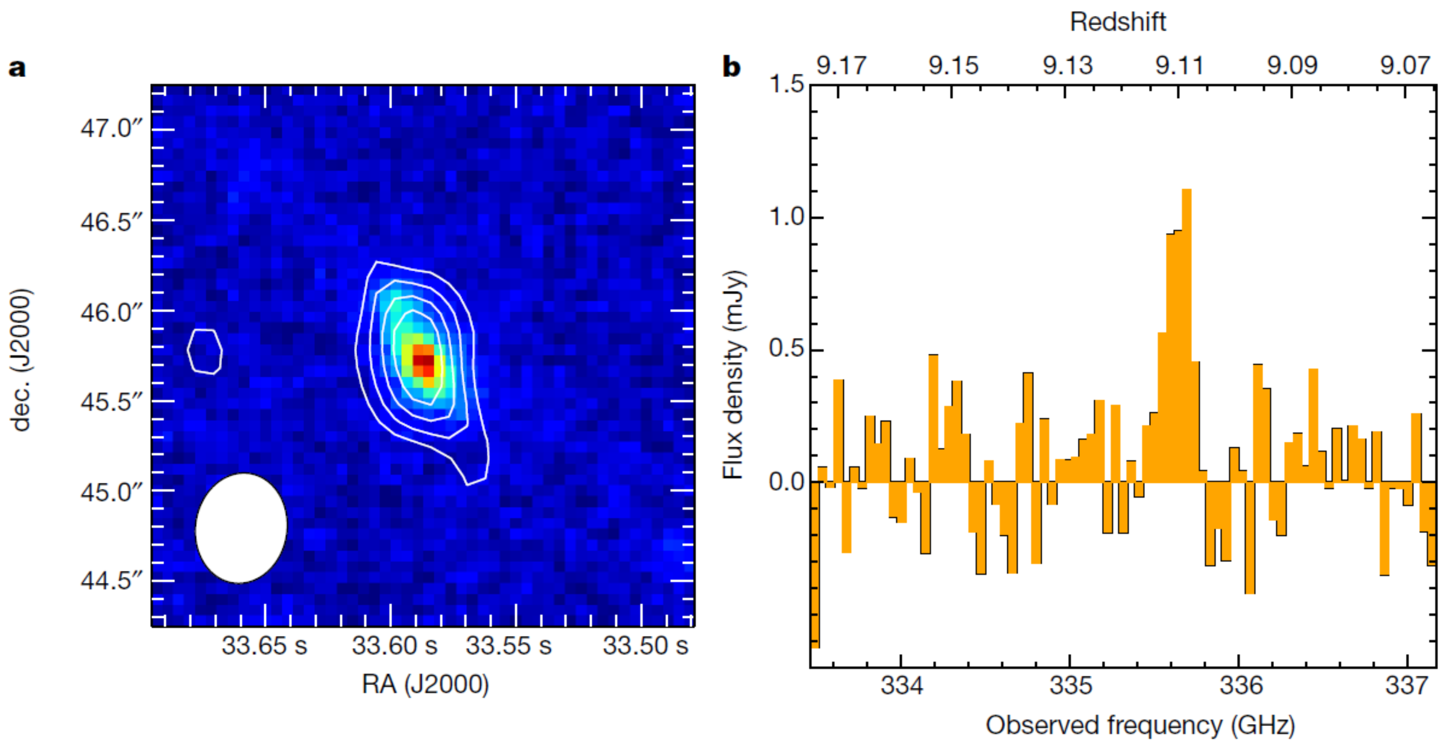


Fig. 1 | ALMA [O III] contours and spectrum of MACS1149-JD1. **a**, Magnification of an HST image (F160W), with the ALMA [O III] contours overlaid. Contours are drawn at -3σ (dashed line), 3σ, 4σ, 5σ and 6σ, where $\sigma = 17.5$ mJy km s^{-1} per beam. The ellipse at the lower left corner indicates the synthesized beam size of ALMA. RA is the right ascension and dec. denotes the declination, both expressed in J2000 coordinates. **b**, The ALMA [O III] 88-μm spectrum in frequency space, obtained with a resolution of about 42 km s^{-1}.

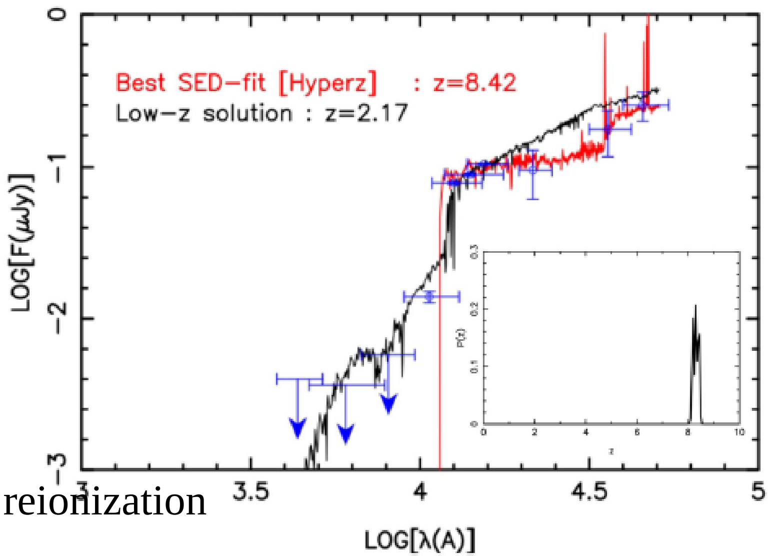
z~8.38 Dusty Galaxy

Laporte et al. 2017, ApJ, 837, L21

A2744_YD4

A gravitationally lensed Y-band dropout
ALMA Band 7 observations
1 mm continuum flux (dusty star-forming galaxy)
Lya emission at a redshift z=8.38.
[O III] 88 μm emission

stellar mass 2×10^{9} $M_{\odot}$
a star formation rate of 20 $M_{\odot}$ yr^{-1}
dust mass of 6×10^{6} $M_{\odot}$
formation of such a dust mass only 200 Myr after cosmic reionization



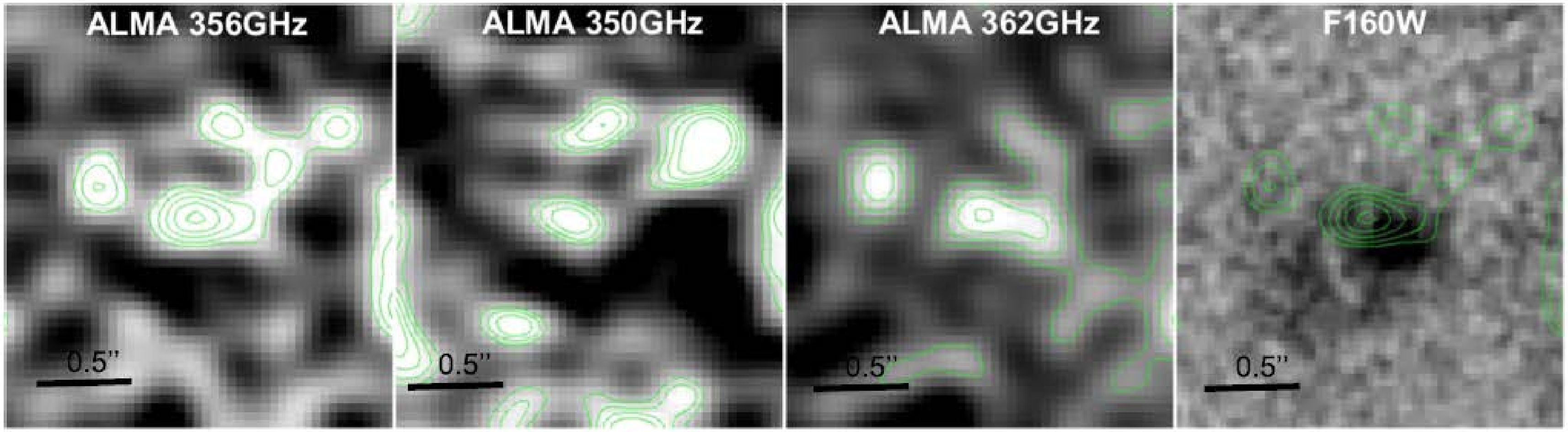
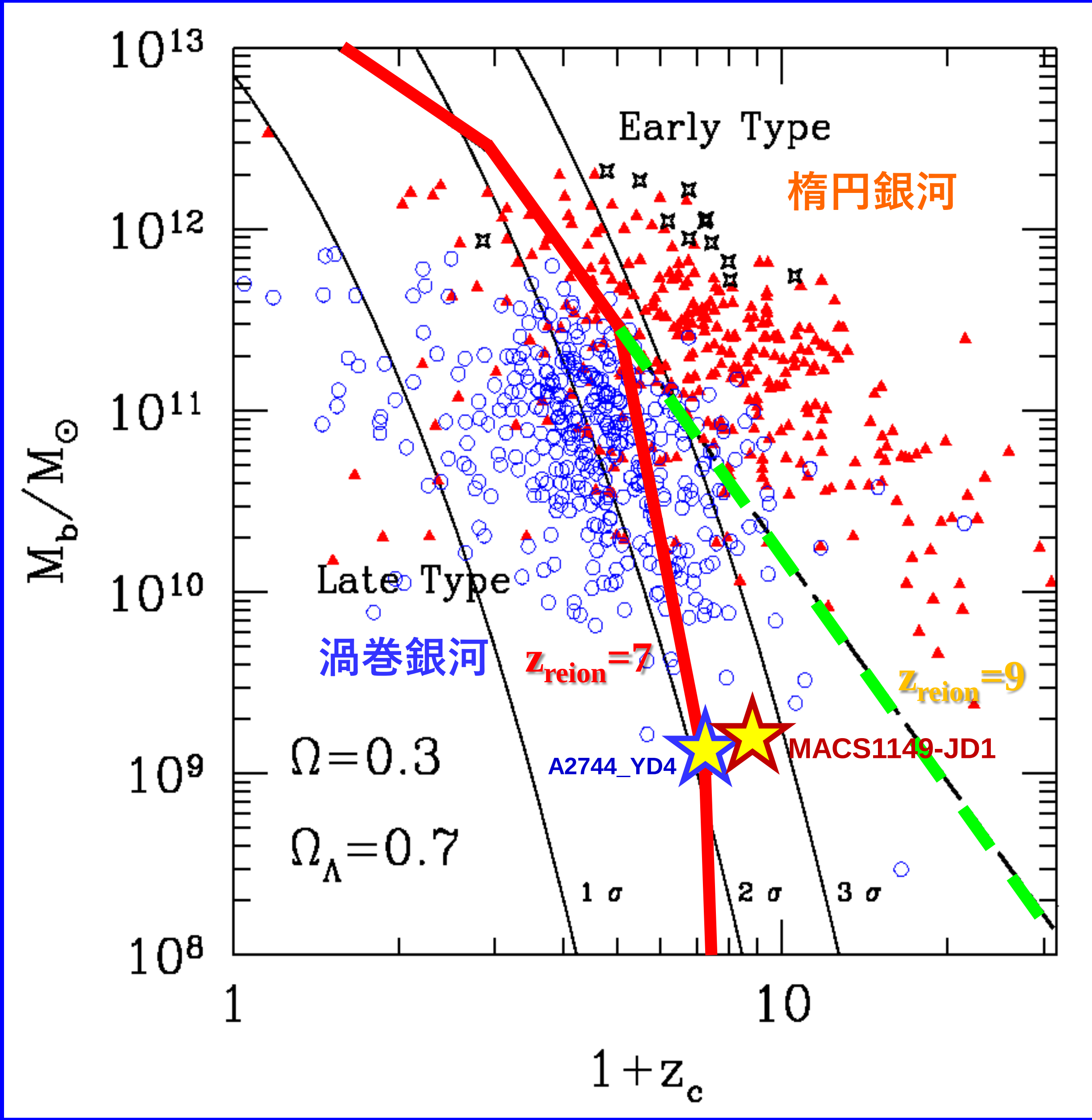


Figure 1. ALMA Band 7 continuum detection for A2744_YD4. (left) Map combining all frequency channels; (middle left and middle right) independent maps for two equal frequency ranges. Contours are shown at 1, 2, 3, 4, and 5σ adopting a noise level from an area of 0.5 × 0.5 arcmin. (right) *HST* F160W image with combined ALMA image contours overplotted.

Ultraviolet-background-induced bifurcation of galactic morphology

Susa & Umemura (2000, MNRAS, 316, L17)



銀河-AGN共進化

Cosmic SF History vs Massive BH Accretion History

Madau & Dickinson, 2014, ARA&A, 52, 415

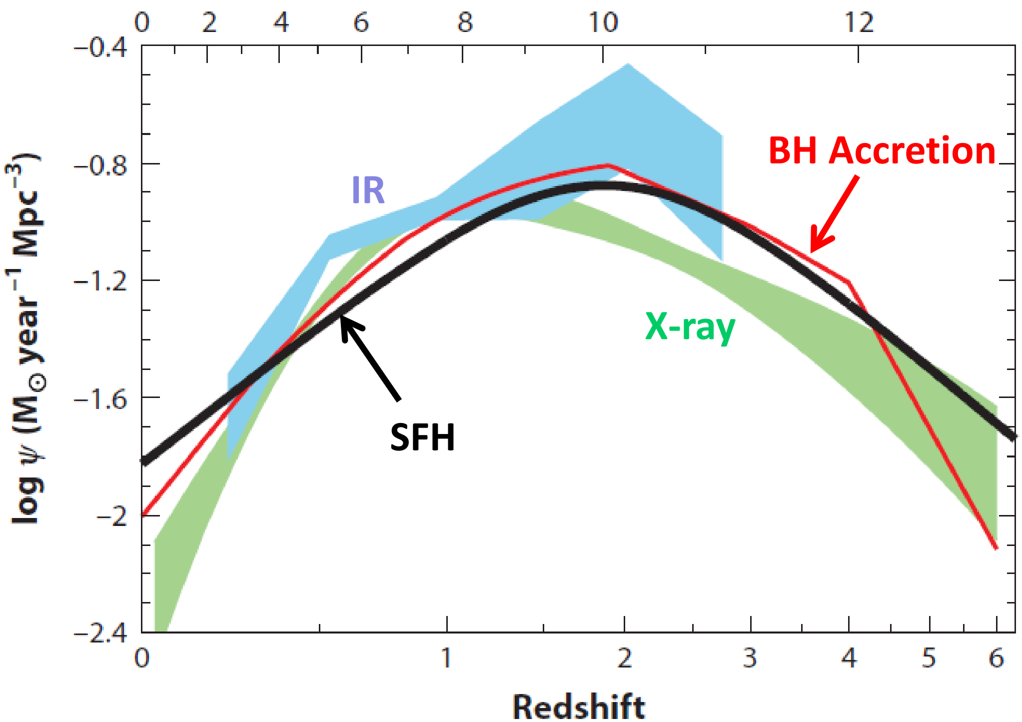


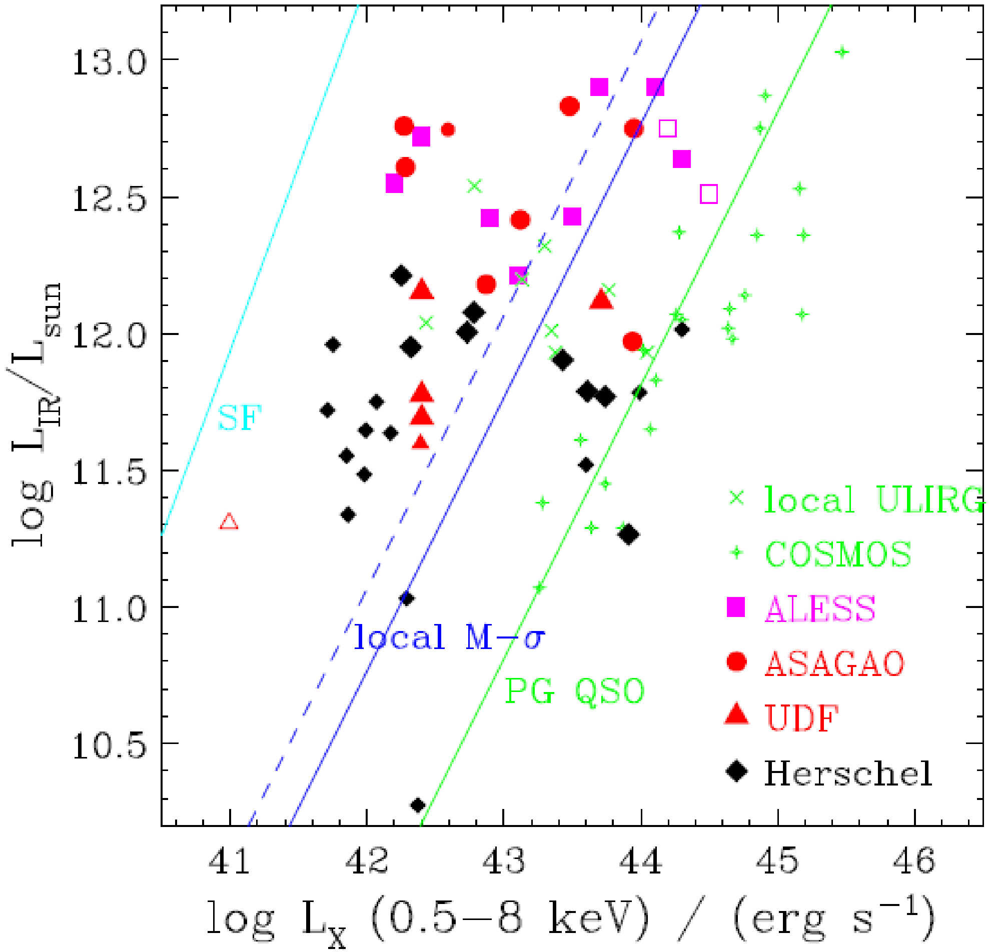
Figure 15

Comparison of the best-fit star-formation history (*thick solid curve*) with the massive black hole accretion history from X-ray [*red curve* (Shankar et al. 2009); *light green shading* (Aird et al. 2010)] and infrared (*light blue shading*) (Delvecchio et al. 2014) data. The shading indicates the $\pm 1\sigma$ uncertainty range on the total bolometric luminosity density. The radiative efficiency has been set to $\epsilon = 0.1$. The comoving rates of black hole accretion have been scaled up by a factor of 3,300 to facilitate visual comparison to the star-formation history.

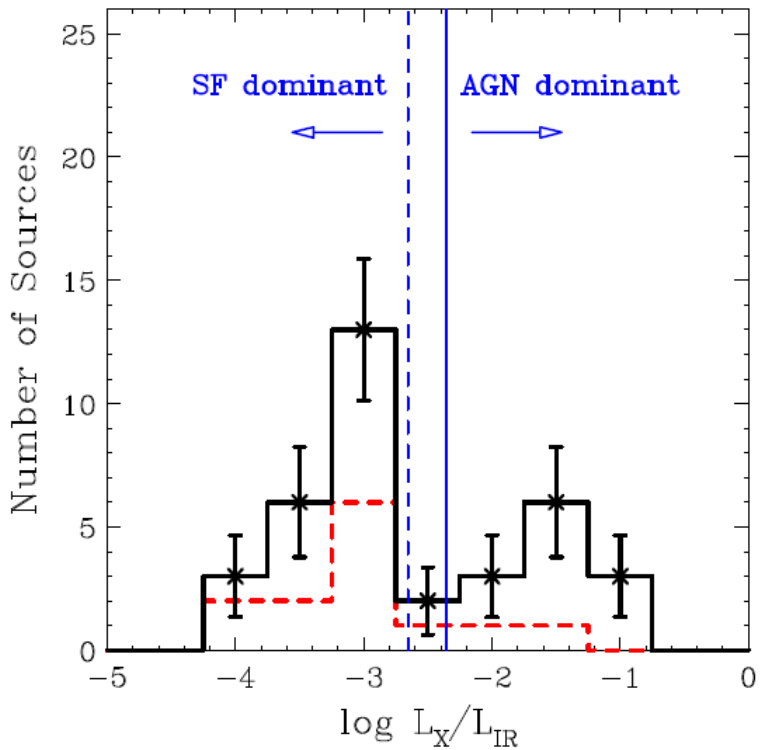
ALMA twenty-Six Arcmin^2 survey of Goods-south At One-millimetre (ASAGAO)

L_x vs L_{IR} Relation

Ueda et al. 2018, ApJ, 853, 24



About 2/3 are SF-dominant, while the rest is AGN-dominant

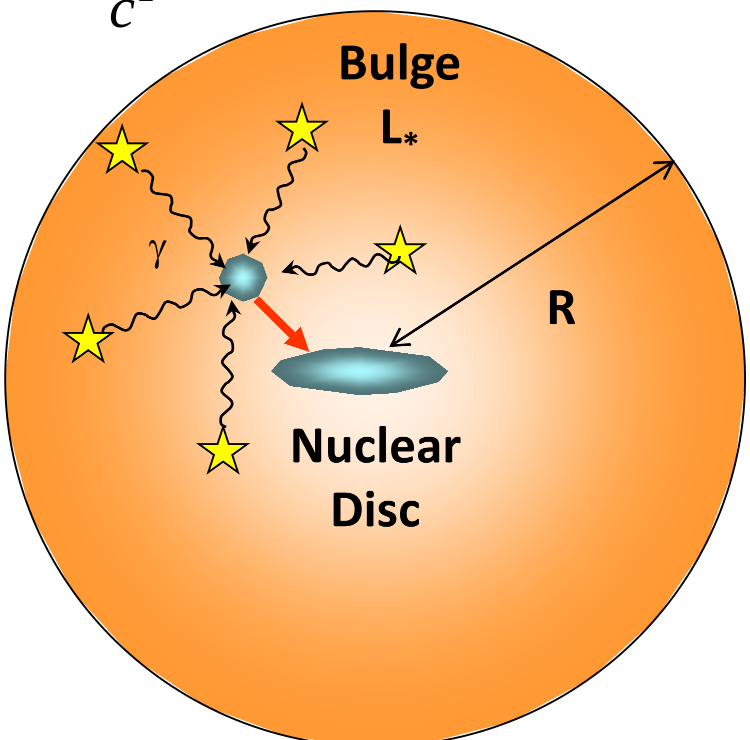


Coevolution of SMBH and Galactic Bulge

Umemura, 2001, ApJ, 560, L29

Poynting-Robertson Effect in galactic bulge

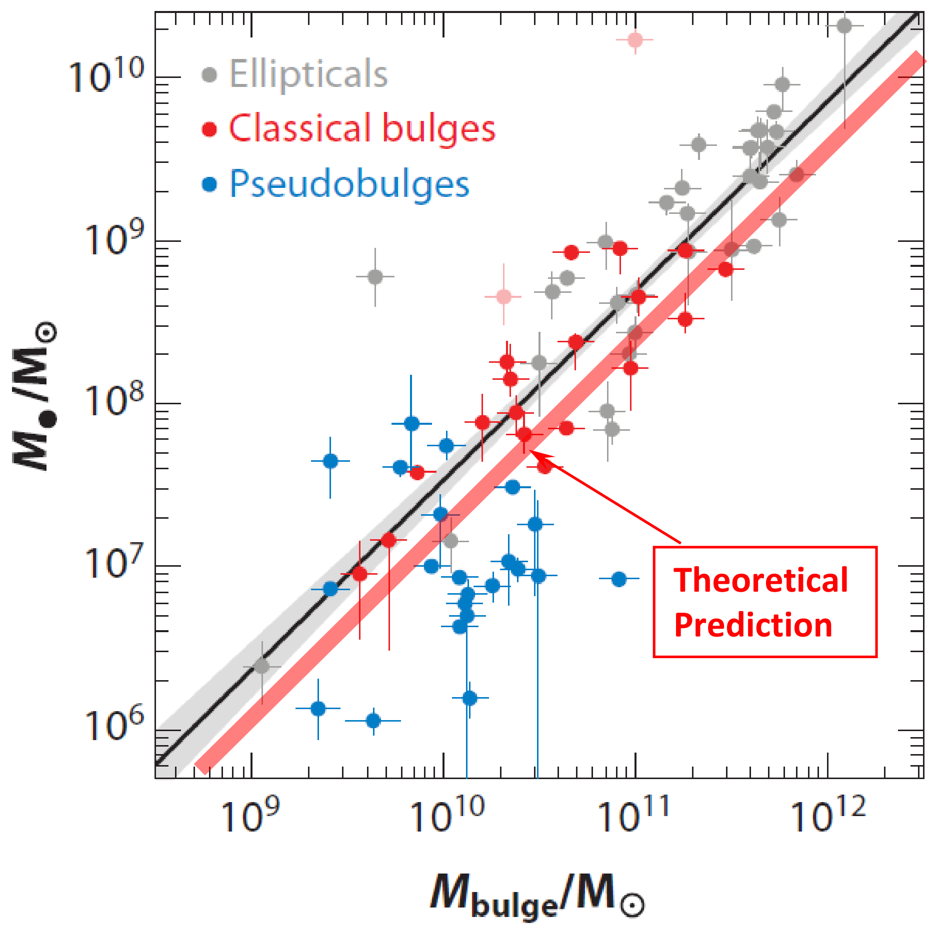
$$\dot{M} \simeq \frac{L_*}{c^2}(1-e^{-\tau})$$



$$\frac{M_{\rm BH}}{M_{\rm bulge}} \simeq 0.14\varepsilon \simeq 0.001$$

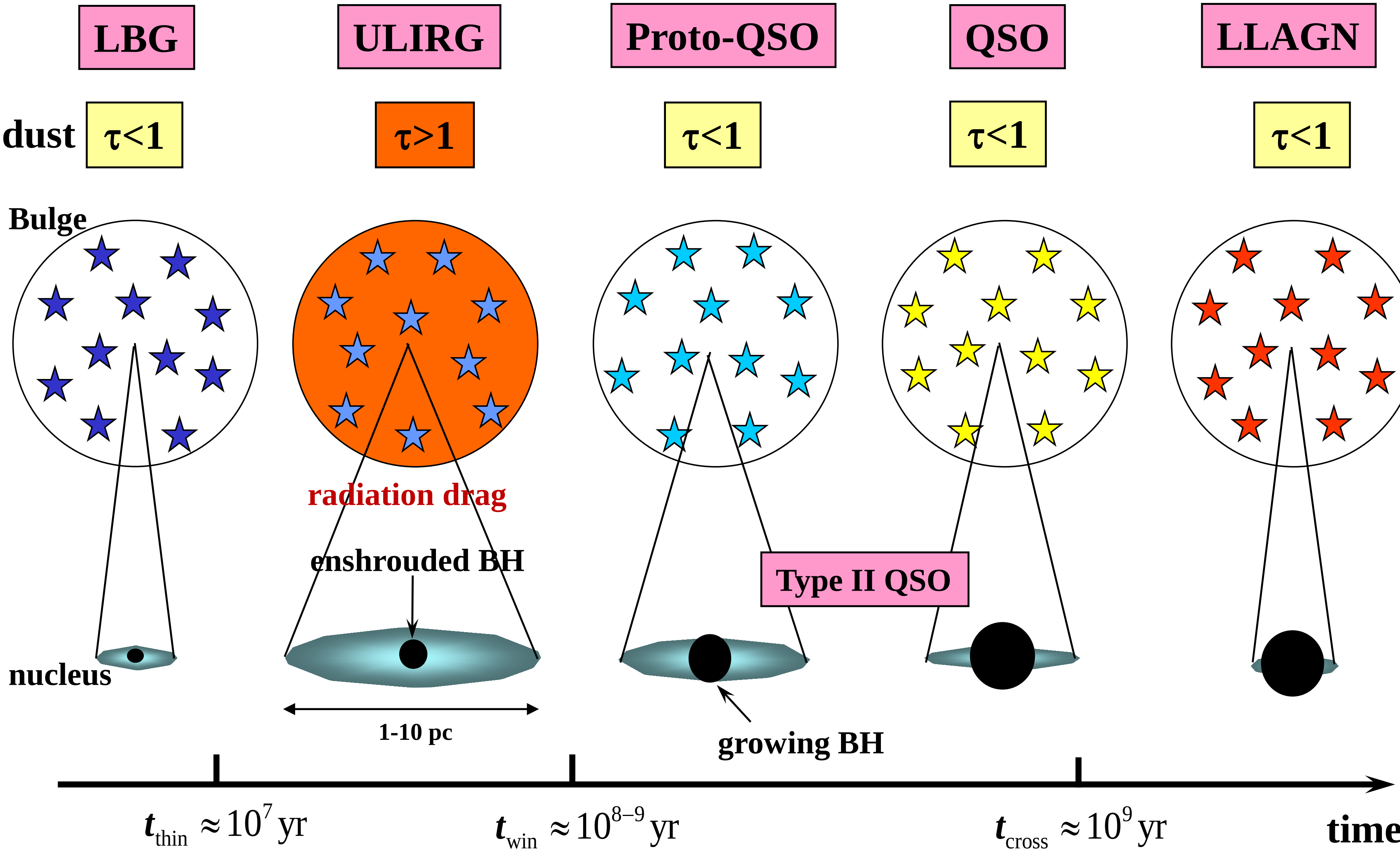
$\varepsilon = 0.007$: Hydrogen burning efficiency

Kormendy & Ho 2013, ARA&A, 51, 511

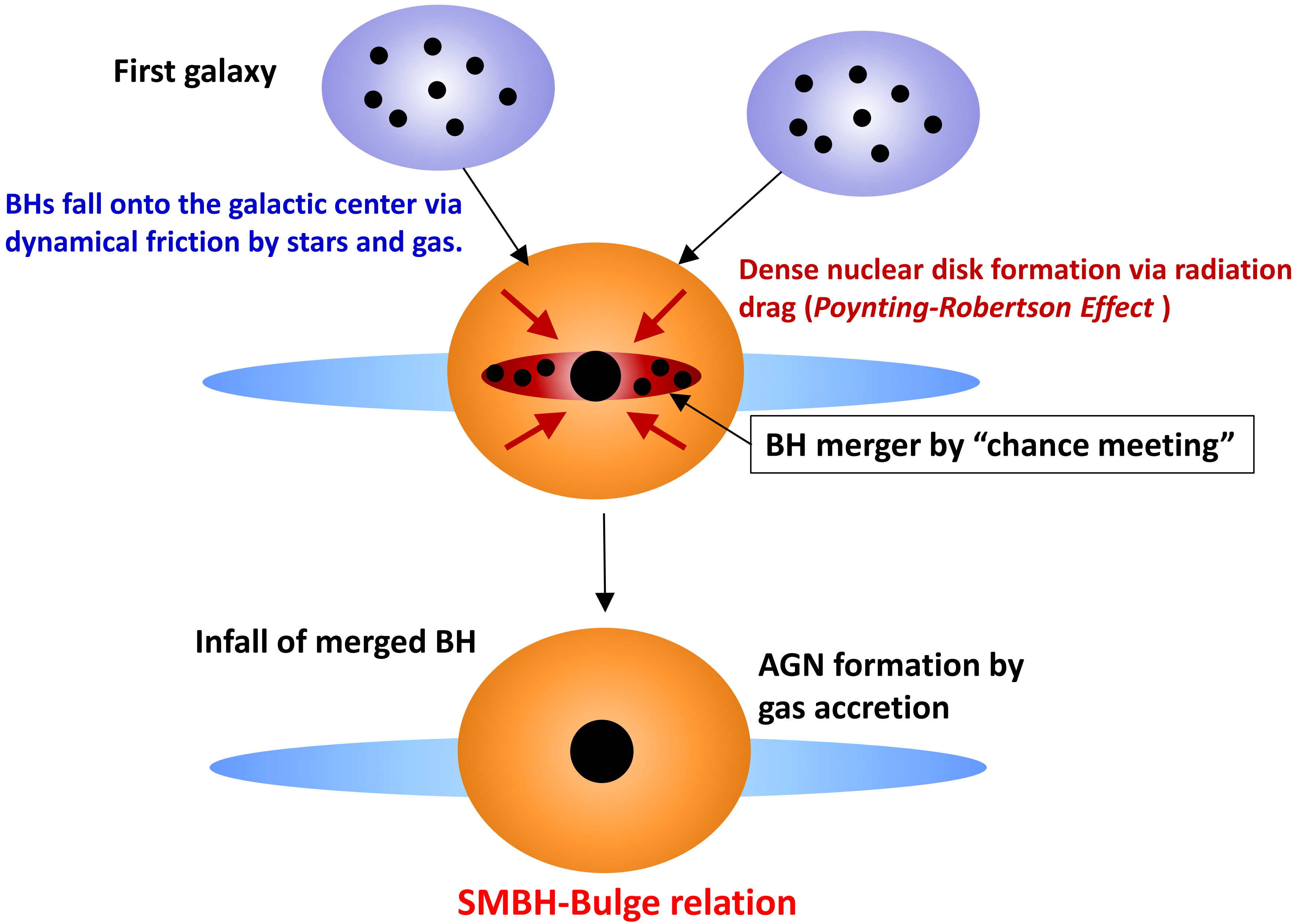


Coevolution Scenario

Umemura 2004, cbhg.sympE, 61



A Novel Scenario of Coevolution



CDM宇宙における多重AGNの理論予想

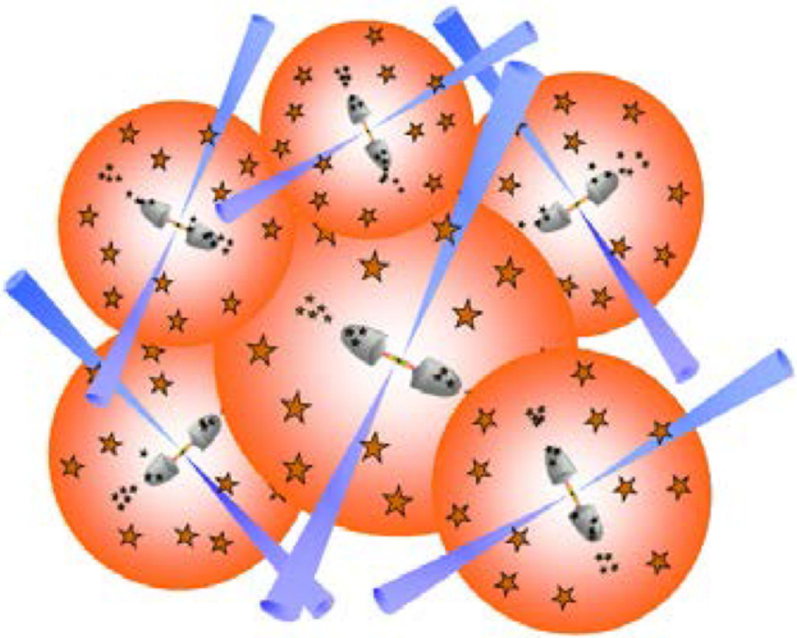


図1: 多重AGNの理論予想図
（2010年の講演スライドから）

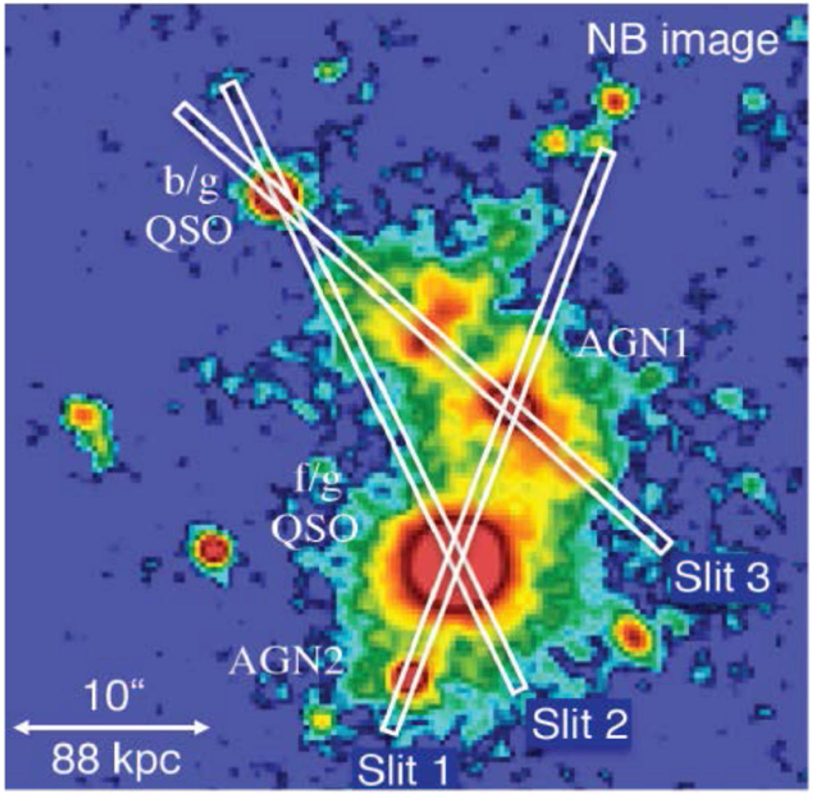


図2: 4重AGNの発見
（Hennawi et al. 2015, Science）

基盤A「多重AGNの統合研究で紐解く超巨大ブラックホールの起源」
（代表：梅村雅之, 2019-2023）

理論のアプローチ

AGNの精密理論モデルの構築
（一般相対論的輻射磁気流体計算）

AGNのSEDモデル構築
（コンプトン散乱モデル計算）

埋もれたAGNのSED計算
（ダスト銀河中の輻射輸送計算）

多重AGNと銀河の共進化計算
（宇宙論的共進化シミュレーション）

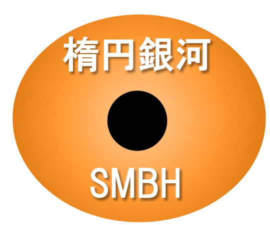
ブラックホール合体計算
（一般相対論的N体計算）

代表：梅村雅之　分担：高橋労太
協力：大須賀健, 矢島秀伸, 高橋博之,
Alex Wagner, 朝比奈雄太

解くべき問題

多重AGNの物理状態と周辺環境

多重AGNと銀河の共進化



超巨大ブラックホール(SMBH)
ー銀河バルジ関係の成立

観測のアプローチ

新規HSCフィルター製作
（NB506の製作と性能評価）

多重AGN候補天体カタログの作成
（HSCによるz=2-3多重AGN探査）

多重AGNの分光追観測
（Subaru FOCAS, VLT MUSE, Keck KCWI
による面分光観測）

多重AGN周辺環境観測
（HSC, ALMAによる周辺環境観測）

AGN-銀河共進化多波長観測
（Chandra, Subaru, ALMAによる
AGNと母銀河観測）

分担：松田有一, 大内正己, 長尾透
協力：上田佳宏, 川口俊宏, 利川潤,
菊田智史

NB506フィルター製作

朝日分光株式会社：7,920,000円（10%税込）

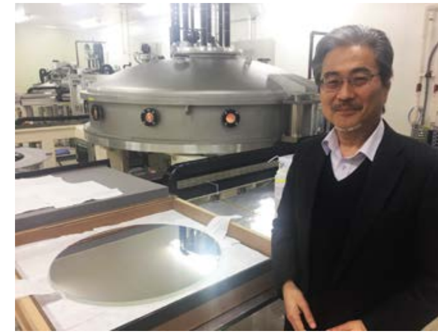
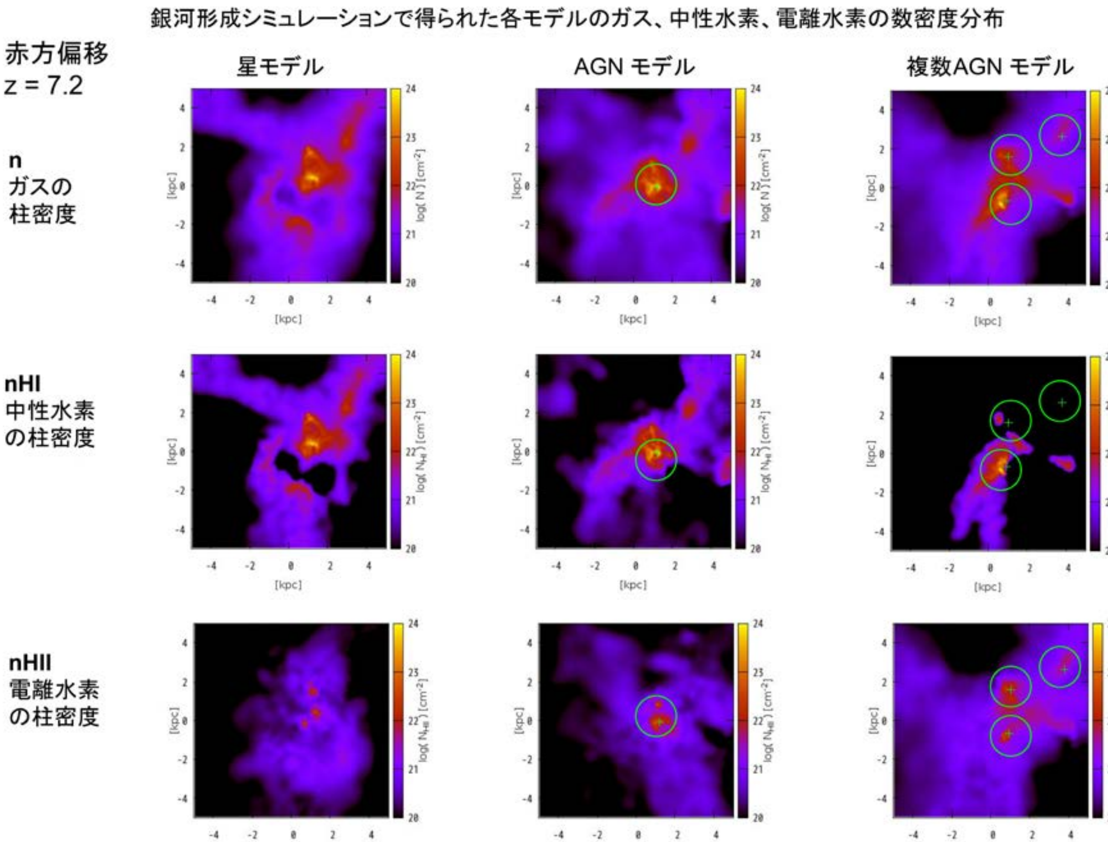


表1　フィルターと輝線中心赤方偏移の関係			
フィルター名	Lyα1216Å	CIV 1549Å	HeII 1640Å
NB387	2.18	1.50	1.36
NB391	2.22	1.52	1.38
NB395	2.25	1.55	1.41
NB400	2.29	1.58	1.44
NB468	2.85	2.02	1.85
NB497	3.09	2.21	2.03
NB506	**3.16**	**2.26**	**2.09**
NB515	3.23	2.32	2.14
NB527	3.33	2.40	2.21

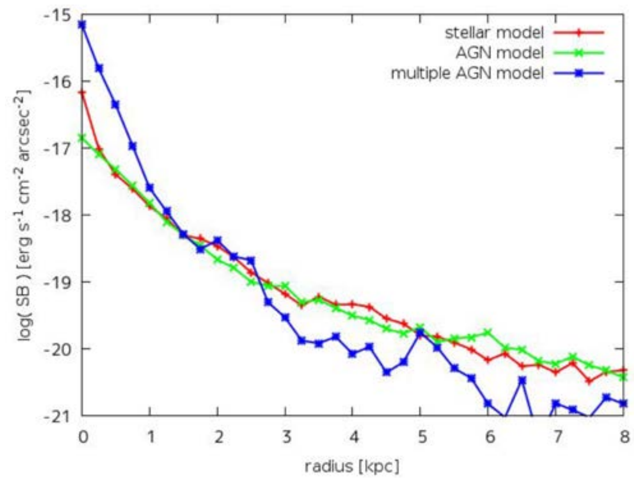
多重AGNと銀河の共進化

基盤研究 (A)（一般）2019年度～2024年度 : 梅村雅之
「多重 AGN の統合研究で紐解く超巨大ブラックホールの起源」

電離輻射流体計算とLyα輻射輸送計算



Lyα表面輝度分布



電離光子脱出確率