The Sources of CIB Fluctuations: What They May Be and What They Are Not

Kari Helgason Sasha Kashlinsky

Near-IR Background Workshop
Austin, TX
May 15, 2012

Why new populations?

1. The amplitude of the fluctuations we measured in Spitzer IRAC data cannot be accounted for by the low-luminosity end of the distribution of "ordinary"/known galaxies (Helgason et al 2012 and see later).
2. There are no correlations between the clustering components of our CIB maps and ACS data out to 0.9 mic (KAMM4).
3. The clustering pattern of the fluctuations is inconsistent with that of the galaxy populations at recent times, and is consistent with the LCDM-distributed sources at high z (KAMM4).
4. Colors of the fluctuations from 2 to 4.5 mic are consistent with high-z very hot sources (Matsumoto et al 2011).
5. Angular spectrum of the fluctuations has now been measured to ~ 1 deg *including* the cross-power between 3.6 and 4.5 mic. The results at both IRAC channels are consistent with the sources being coeval and distributed a'la high-z LCDM model. Low(er) z known sources just would not fit the data provided we live in the LCDM Universe with the galaxies distributed from known counts and other data.

So, the Occam's razor way to interpret the observational data 1-5 is in terms of high-z populations (my personal opinion – based on the above evidence).

What are the populations producing the CIB fluctuations if at high z?

Ly-break being at > 0.9 mic today requires z>~7-8, so the time available to produce the CIB:

t(z=8)=0.6 Gyr; t(z=20)=0.2 Gyr, so Δt< 0.5-1Gyr

This requires comoving luminosity density at ~0.6-0.8[(1+z)/6]μm:

$$L_* \approx \frac{4\pi}{c} F_{CIB} (\Delta t)^{-1} (1+z) \approx 7\times 10^8 L_{Sun} Mpc^{-3} \frac{1Gyr}{\Delta t} \frac{1+z}{6} \frac{F_{CIB}}{nW/m^2/sr}$$

Or in terms of density in *'s

$$\Omega_* = 5\times 10^{-3} \frac{F_{CIB}}{nW/m^2/sr} \frac{\Gamma}{\Gamma_{Sun}} \left(\frac{1Gyr}{\Delta t}\right) \frac{1+z}{6}$$

(Today $\Omega_* \sim 2\text{x}10^{-3}$)

This corresponds to Γ = M/L << $(M/L)_{SUN}$ in order to reproduce reasonable Ω_*:

This means that these sources had to have very large L/M – may be P3 stars, but also may be BHs as well (or have an admixture of less massive *'s).

The CIB fluxes contributed by them would be around 1 nW/m^2/sr at 3.6/4.5 mic

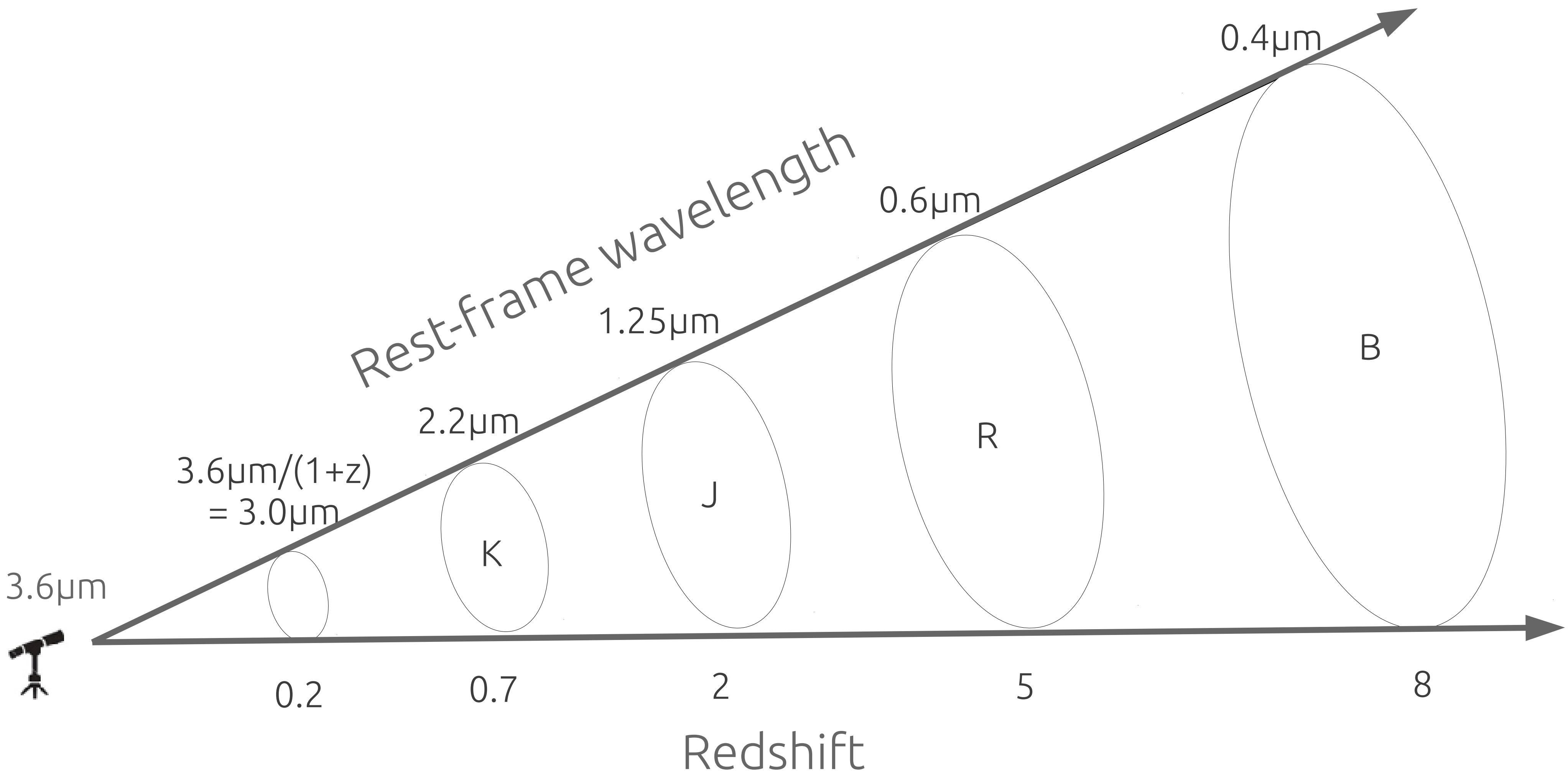
Nature of the new populations

- The signal is produced by populations with only low shot noise (P_{SN}~30-50 nJy nW/m^2/sr) and significant clustering component (δF ~ 0.05-0.1 nW/m^2/sr)
- If at high z clustering component implies net F_{CIB} >~ 1 nW/m^2/sr
- If at low z, sources would have to be very faint/small and cluster very differently from normal galaxies. Such populations have never been observed.
- Either way we are talking about new populations.
- These sources would have individual flux S~ P_{SN}/F_{CIB} <~ 10-30 nJy, or m_{AB}>~28-30
- The surface density of these new populations would be ~ P_{SN}/S^2 ~ a few arcsec^{-2}
- They would be within confusion noise and care must be taken when assembling images not to filter them out (no median filtering).

Reconstructing the Near-IR Background Fluctuations from Known Galaxy Populations Using Measured Luminosity Functions

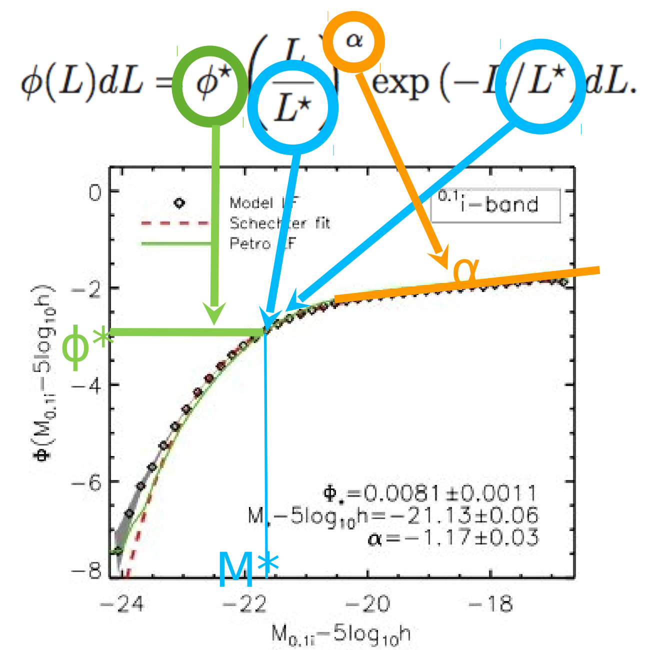
Kari Helgason, Massimo Ricotti, Sasha Kashlinsky

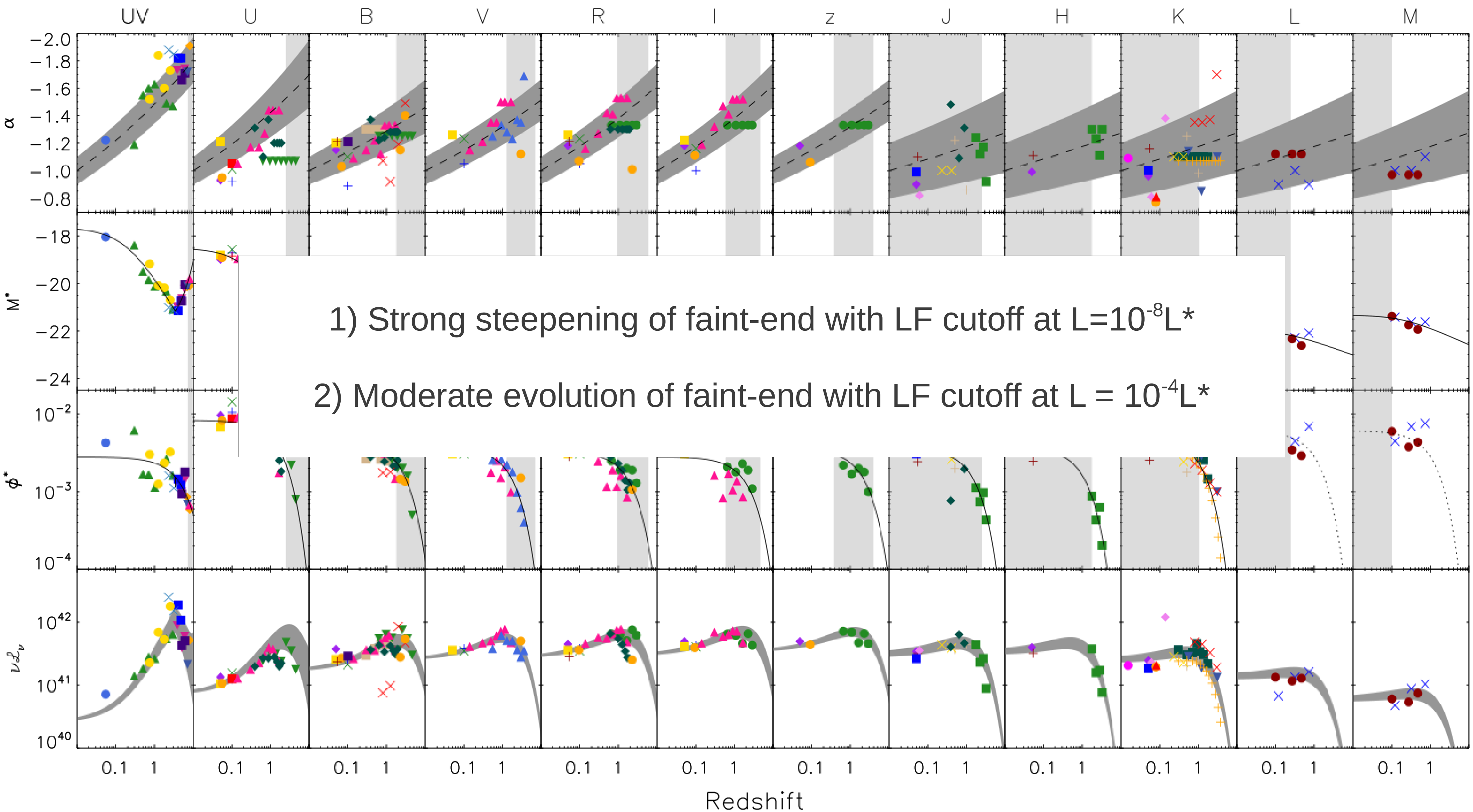
Probing the redshift cone



Luminosity Functions

Reference	Rest-frame band	Redshift z	Sample N_{gal}	Selection $m_{lim}(AB)$	Survey Catalog / Field
Arnouts et al. (2005)	1500Å	0.2-1.2	1039	NUV<24.5	GALEX/VVDS
		1.75-3.4		F450&F606<27	HDF
Wyder et al. (2005)	NUV, FUV	0.055	896,1124	$m_{UV}<20$	GALEX/2dF
Oesch et al. (2010)	1500Å	0.5-2.5	284-403	$\lesssim$26	HST ERS
Oesch et al. (2012)	1500Å	~8	70	$H<27.5$	CANDLES/HUDF09/ERS
Reddy et al. (2008)	1700Å	1.9-3.4	~15,000	$\mathcal{R}<25.5$	[a]
Yoshida et al. (2006)	1500Å	~4,5	3808,539	$\lesssim$26-27	Subaru Deep Field
McLure et al. (2009)	1500Å	~5,6	~1500	$z'\lesssim26$	SXDS/UKIDSS
Ouchi et al. (2009)	1500Å	7	22	$\lesssim$26	SDF/GOODS-N
Bouwens et al. (2007)	1600Å,1350Å	~4,5,6	4671,1416,627	$\lesssim$29	HUDF/GOODS
Bouwens et al. (2011)	1600Å,1750Å	~7,8	73,59	$\lesssim$26-29.4	HUDF09
Gabasch et al. (2004)	$u'g'$	0.45-5	5558	$I<26.8$	FORS Deep Field
Baldry et al. (2005)	$^{0.1}u$	<0.3	43223	u<20.5	SDSS
Faber et al. (2007)	B	0.2-1.2	~34000	$R\lesssim24$	DEEP2/COMBO-17
Norberg et al. (2002)	b_j	<0.2	110500	<19.45	2dFGRS
Blanton et al. (2003b)	$^{0.1}ugriz$	0.1	147986	<16.5-18.3	SDSS
Montero-Dorta & Prada (2009)	$^{0.1}ugriz$	$\lesssim$0.2	947053	<17-19	SDSS
Loveday et al. (2012)	$^{0.1}ugriz$	0.002-0.5	8647-12860	$r<19.8$	GAMA
Ilbert et al. (2005)	$UBVRI$	0.05-2.0	11034	$I<24$	VIMOS-VLT Deep Survey
Gabasch et al. (2006)	$i'z'r'$	0.45-3.8	5558	$I<26.8$	FDF
Marchesini et al. (2007)	BVR	2.0-3.5	989	$K_s\lesssim25$	MUSYC/FIRES/GOODS/EIS
Marchesini et al. (2012)	V	0.4-4.0	19403	$H<27.8, K<25.6$	[a]
Hill et al. (2010)	$ugriz$	0.0033-0.1	2437-3267	<18-21	MGC/UKIDSS/SDSS
	$YJHK$		1589-1798	<17.5-18	
Dahlen et al. (2005)	UBR	0.1-2	18381	$R<24.5$	GOODS-HST/CTIO/ESO
	J	0.1-1	2768	$K_s<23.2$	
Jones et al. (2006)	$b_j r_f$	<0.2	138226	$b_j r_f<15.6, 16.8$	6dFGS/2MASS
	JHK			$JHK<14.7$	/SuperCOSMOS
Bell et al. (2003)	$ugriz$	< 0.1	22679	$r<17.5$	SDSS
	K		6282	$K<15.5$	2MASS
Kashikawa et al. (2003)	BK'	0.6-3.5	439	$K'<24$	Subaru Deep Survey
Stefanon & Marchesini (2011)	JH	1.5-3.5	3496	$K_s<22.7$-25.5	MUSYC/FIRES/FIREWORKS
Pozzetti et al. (2003)	JK_s	0.2-1.3	489	$K_s<20$	K20 Survey
Feulner et al. (2003)	JK'	0.1-0.6	500	$K'<19.4$-20.9	MUNICS
Eke et al. (2005)	JK_s	0.01-0.12	16922,15664	$JK_s\lesssim15.5$	2dFGRS/2MASS
Cole et al. (2001)	JK_s	0.005-0.2	7081,5683	$JK_s\lesssim15.5$	2dFGRS/2MASS
Smith et al. (2009)	K	0.01-0.3	40111	$K<17.9, r<17.6$	UKIDSS-LAS/SDSS
Saracco et al. (2006)	K_s	0.001-4	285	$Ks<24.9$	HDFS/FIRES
Kochanek et al. (2001)	K_s	0.003-0.03	4192	$K_{20}<13.35$	2MASS/CfA2/UZC
Huang et al. (2003)	K	0.001-0.57	1056	$K<15$	2dF/AAO
Arnouts et al. (2007)	K	0.2-2	21200	$m_{3.6mic}<21.5$	SWIRE/VVDS
					/UKIDSS/CFHTLS
Cirasuolo et al. (2010)	K	0.2-4	~50000	$K<23$	UKIDSS/SXDS
Babbedge et al. (2006)	$L_{3.6\mu m}M_{4.5\mu m}$	0.01-0.6	34281	<20.2	SWIRE/INT WFS
Dai et al. (2009)	$L_{3.6\mu m}M_{4.5\mu m}$	0.01-0.6	4905,5847	$LM<19, I<20.4$	IRAC-SS/AGES





1) Strong steepening of faint-end with LF cutoff at L=10^{-8}L*

2) Moderate evolution of faint-end with LF cutoff at L = 10^{-4}L*

233 Measured Luminosity Functions

Helgason, Ricotti & Kashlinsky 2012

Populating and projecting the lightcones

$$\Phi_i(M|z_i) = 0.4\ln(10)\phi^\star(z_i)\left(10^{0.4(M\star(z_i)-M)}\right)^{\alpha(z_i)+1} \times \exp\left(-10^{0.4(M^\star(z_i)-M)}\right)$$

Distance modulus

Evolution

$$m = M + DM(z) + K(z) + E(z) + A_b(l,b)$$

k-correction

Extinction

Number Counts

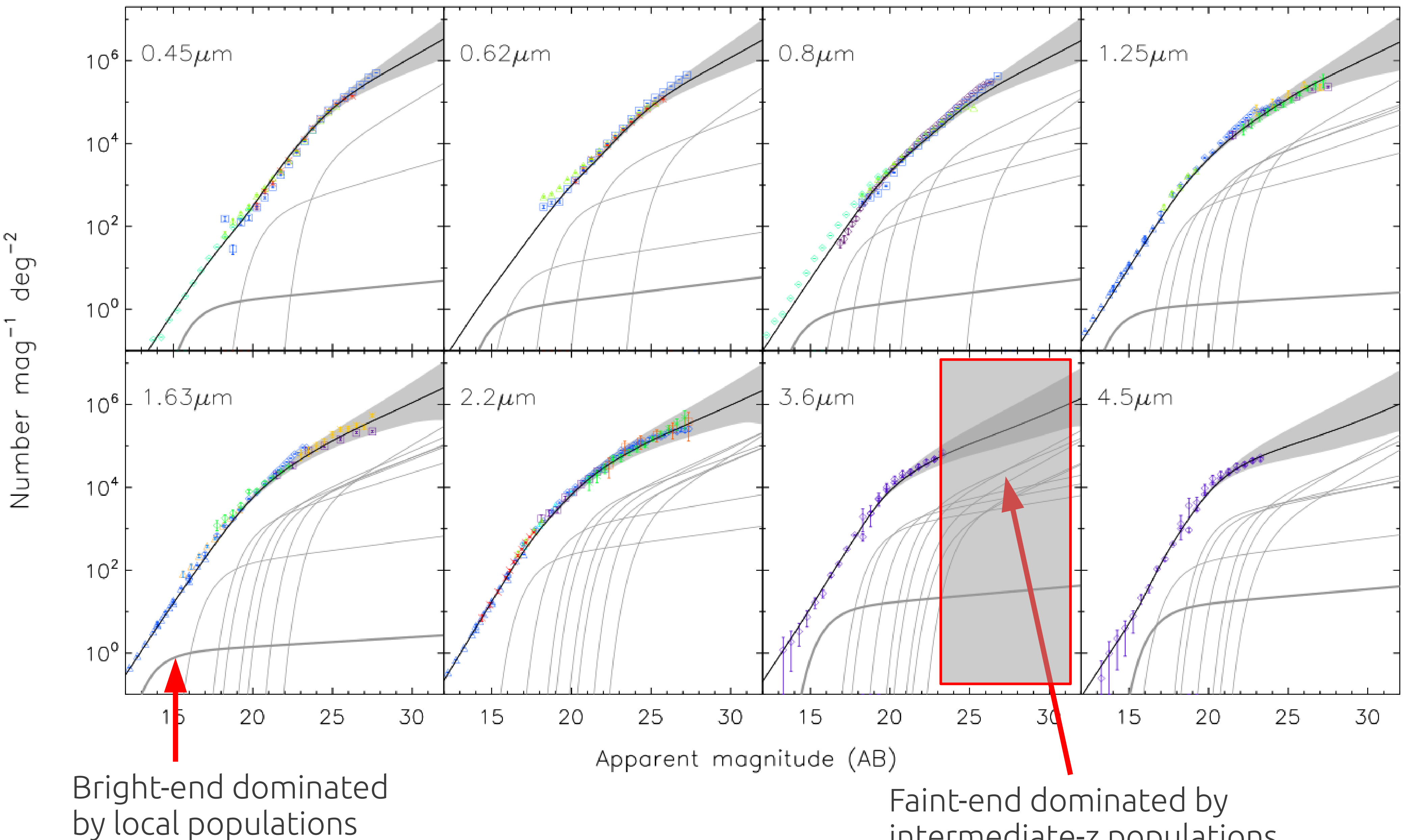
$$N(m) = \int \Phi(m|z)\frac{dV}{dzd\Omega}dz$$

Flux production

$$\frac{d\mathcal{F}}{dz} = \int_{m_{lim}}^{\infty} dm f(m)\frac{dN(m|z)}{dz}$$

Number Counts

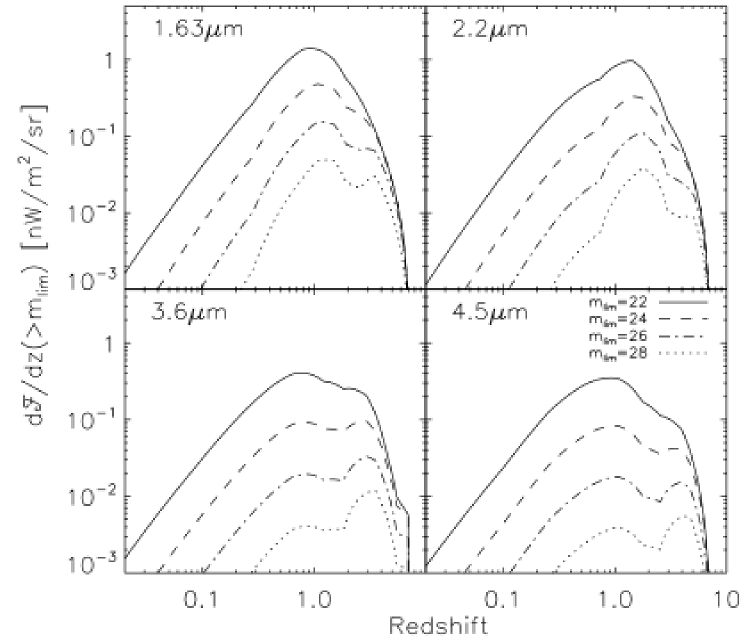
$$N(m) = \int \Phi(m|z) \frac{dV}{dz d\Omega} dz$$

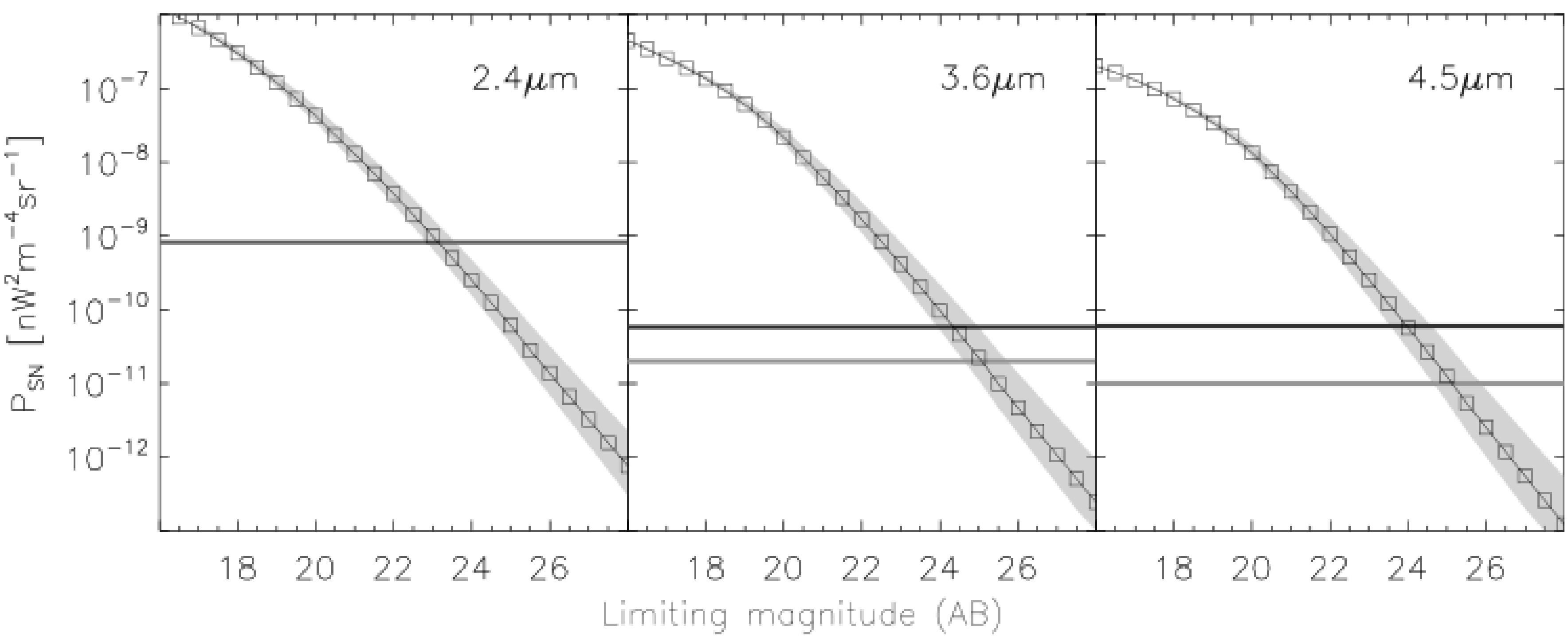


Flux & Shot Noise

$$\frac{d\mathcal{F}}{dz} = \int_{m_{lim}}^{\infty} dm f(m) \frac{dN(m|z)}{dz}$$

$$P_{SN} = \int_{m_{\rm lim}}^{\infty} f^2(m) \frac{dN}{dm} dm$$





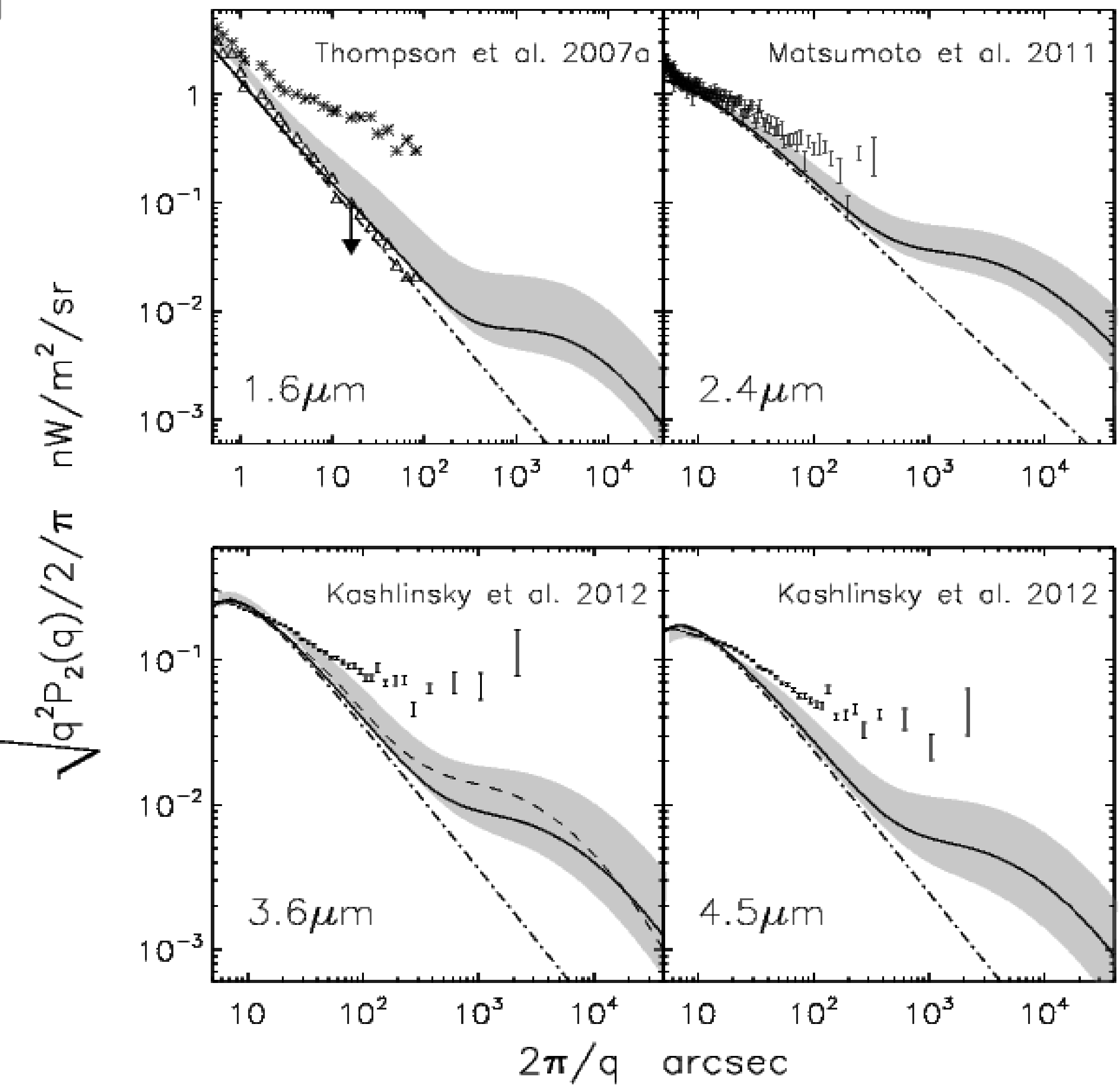
2D Angular Power Spectrum

$$P_{SN} = \int_{m_{\lim}}^{\infty} f^2(m) \frac{dN}{dm} dm$$

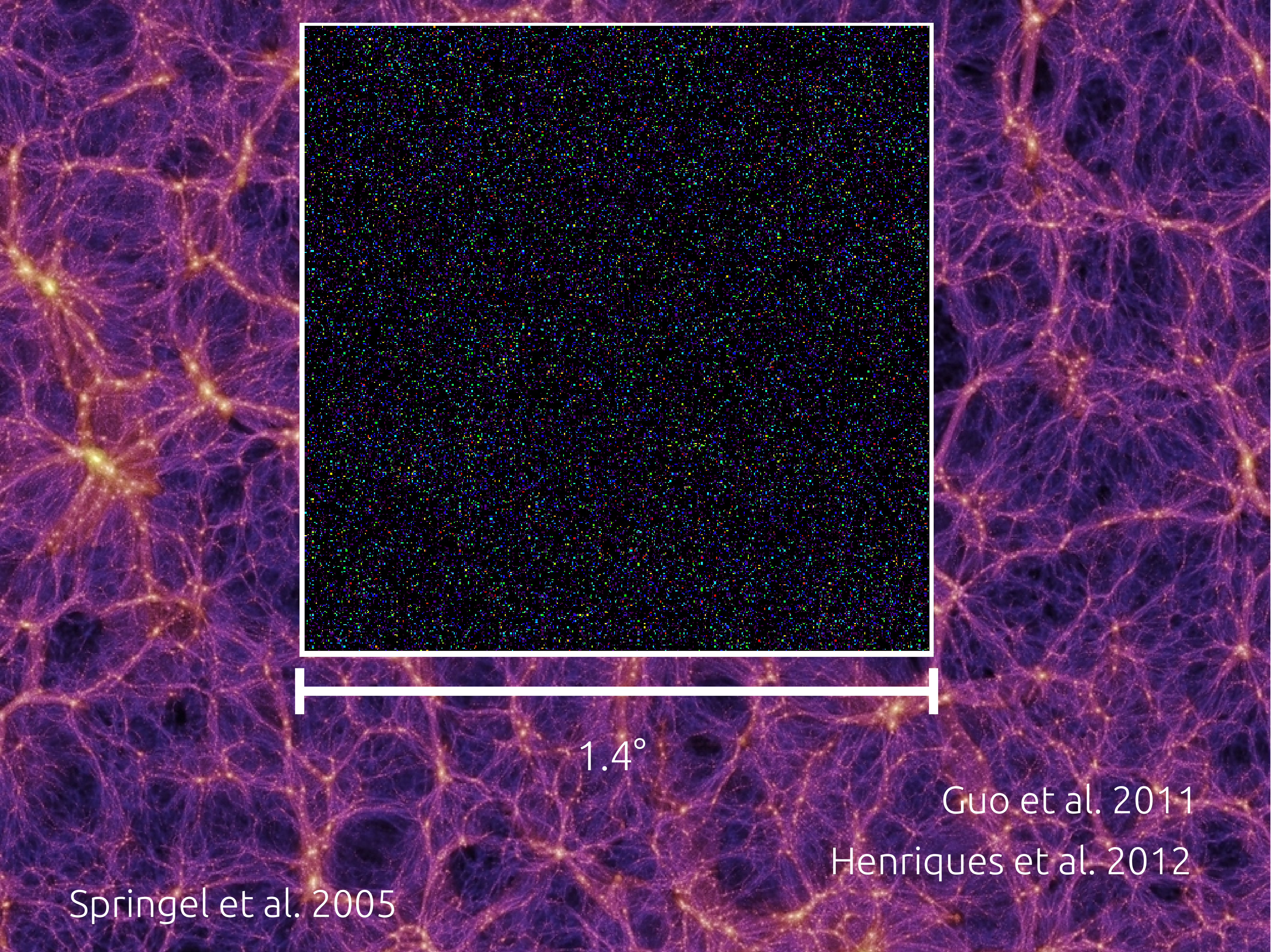
$$P_{tot} = P_{clust} + P_{noise}$$

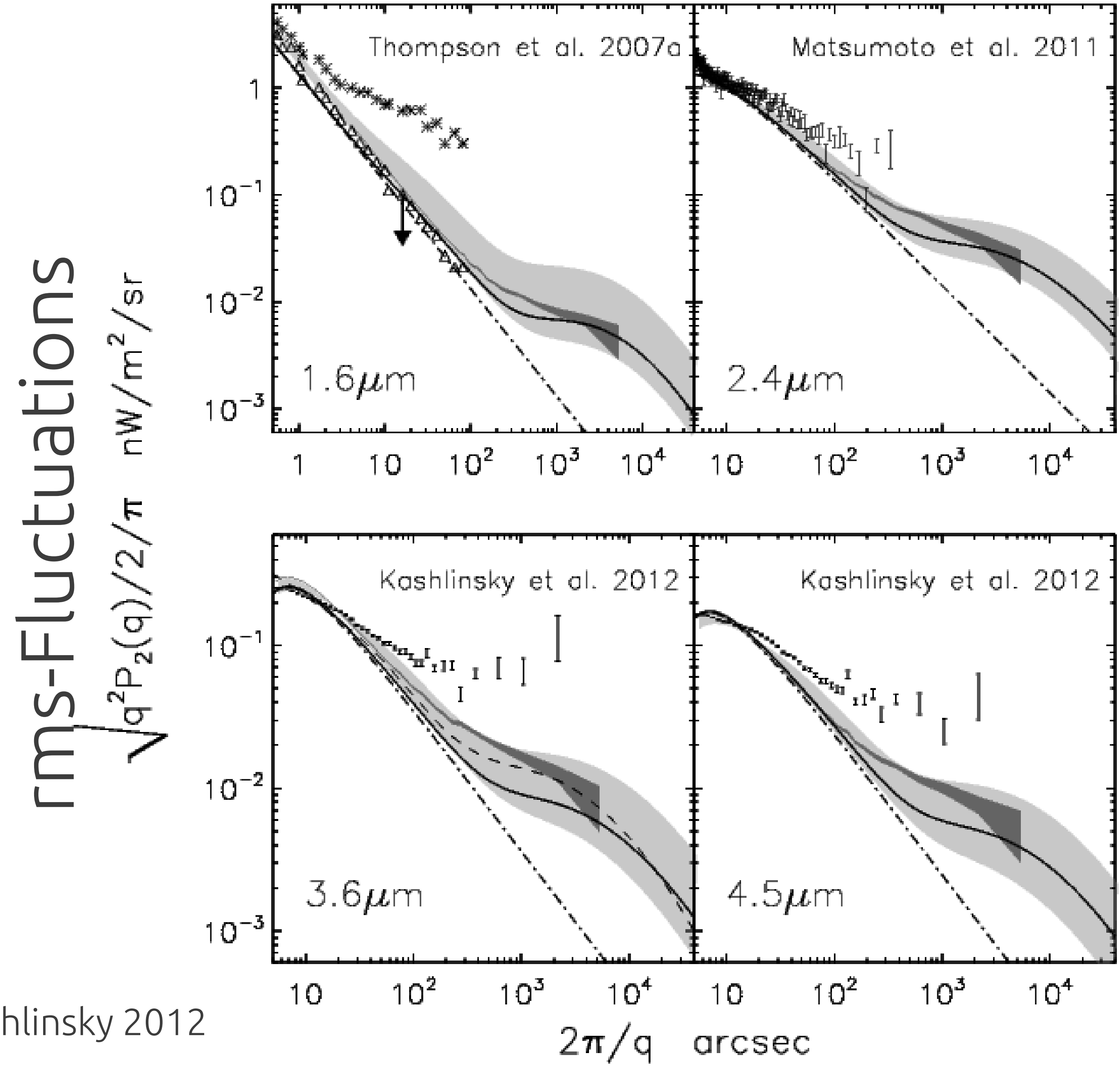
$$P(q) = \frac{1}{c} \int \left[\frac{d\mathcal{F}}{dz}\right]^2 \frac{P_3(q d_A^{-1}; z)}{\frac{dt}{dz} d_A^2(z)} \frac{dz}{1+z}$$

rms-Fluctuations

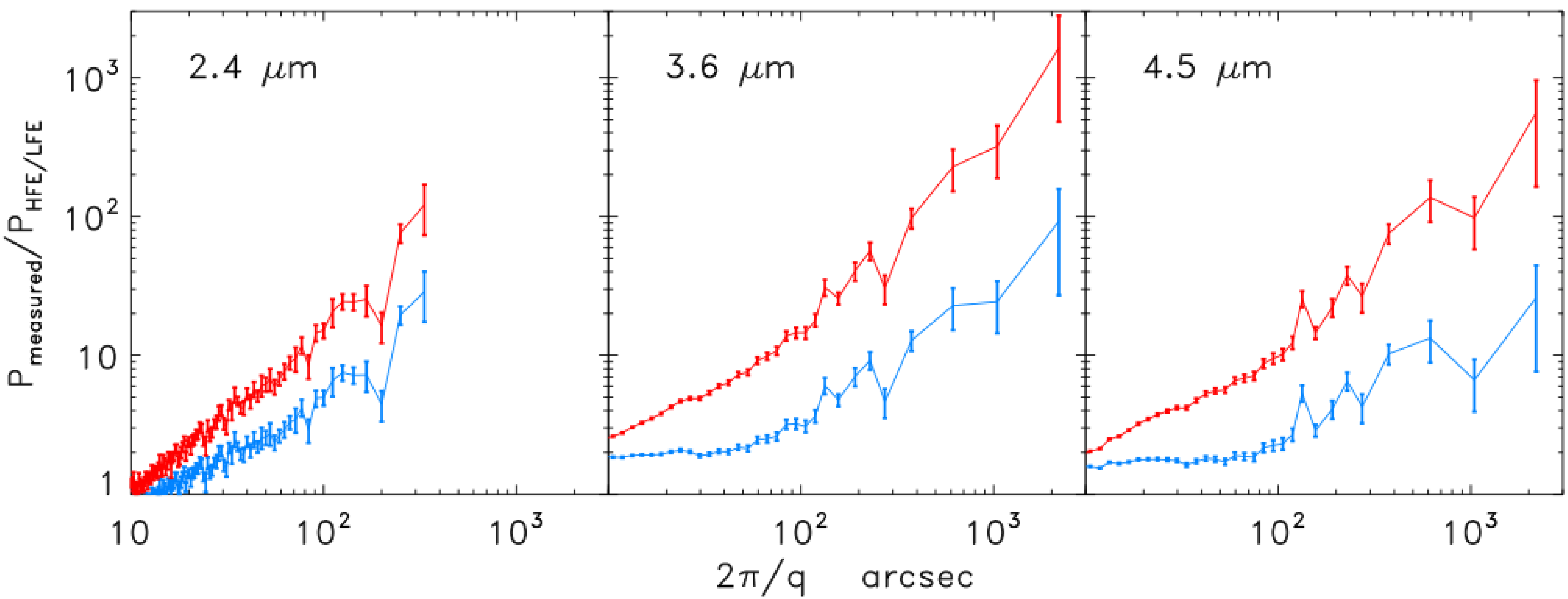


Helgason, Ricotti & Kashlinsky 2012


1.4°
Guo et al. 2011
Henriques et al. 2012
Springel et al. 2005



Helgason, Ricotti & Kashlinsky 2012



2.4 μm
3.6 μm
4.5 μm
P_measured/P_HFE/LFE
2π/q arcsec

Summary

- It is possible to empirically reconstruct the emission history of the Universe from known galaxy populations out to z~3-5 from UV to NIR
- This reconstruction matches both observed counts and integrated background light

- CIB fluctuations from known galaxy populations are unable to account for the measured power by factors >10
- There is strong evidence for *new* populations in the CIB fluctuations

- There are strong arguments for a high-z origin of the detected CIB fluctuation excess
- If so, these populations had to have high L/M, but the measurements cannot differentiate between the stellar emission and BH accretion
- If the sources lie at low(er) *z*, they would have to be new very faint populations evolving independently from normal galaxies AND remain undetected in deep ACS images