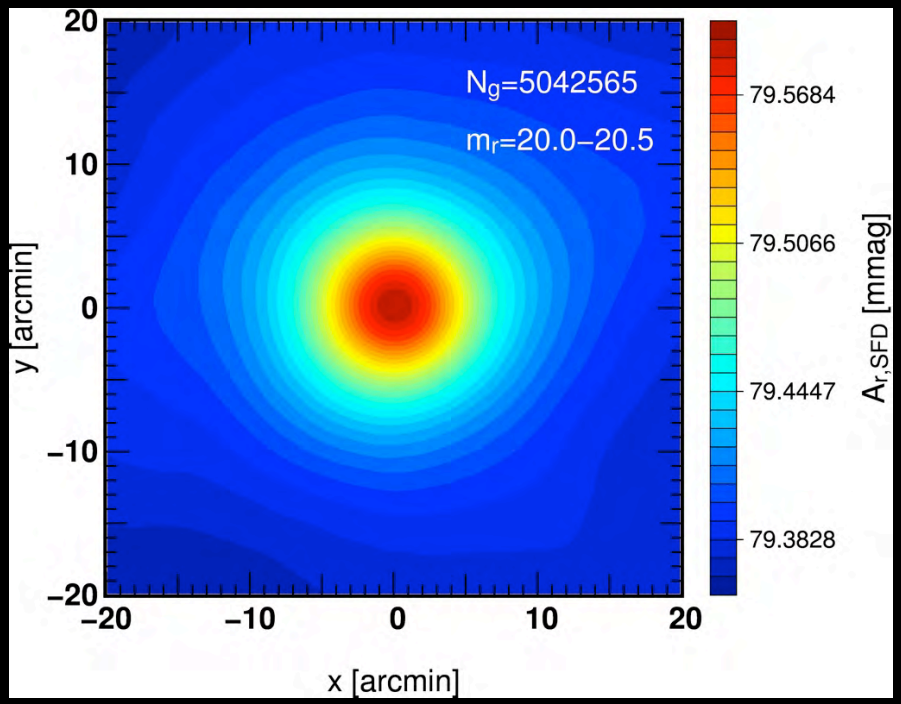
Detection of Far Infrared Emission from SDSS Galaxies in the SFD Galactic Extinction Map



Yasushi Suto *Department of Physics, The University of Tokyo*
& Global scholar, Dept. of Astrophysical Sci., Princeton University

11:20-11:50 November 1, 2012: The 5th KIAS Workshop on *COSMOLOGY AND STRUCTURE FORMATION*

This talk is based on

- *Detection of Far Infrared Emission from Galaxies and Quasars in the Galactic Extinction Map by Stacking Analysis*
  - **T.Kashiwagi,** K.Yahata & YS
  - Publ.Astron.Soc.Japan (2012), submitted
- *The effect of FIR emission from SDSS galaxies on the SFD Galactic extinction map*
  - K.Yahata, A.Yonehara, YS, E.L.Turner, T.Broadhurst, & D.P. Finkbeiner
  - Publ.Astron.Soc.Japan 59(2007)205

Korea House (October 22, 2006)

Kansas: *Dust in the wind (1977)*

Don't hang on
Nothing lasts forever, but the earth and sky
It slips away.
And all your money won't another minute buy
Dust in the wind
All we are is dust in the wind
Dust in the wind
Everything is dust in the wind

平家物語（1240？）

祇園精舎の鐘の聲
　　諸行無常の響き有り
沙羅雙樹の花の色
　　盛者必衰の理を顯す
驕れる者も久しからず
　　唯春の夜の夢の如し
猛き者も遂には滅びぬ
　　偏に風の前の塵に同じ

The Tale of the Heike (from Wikipedia)

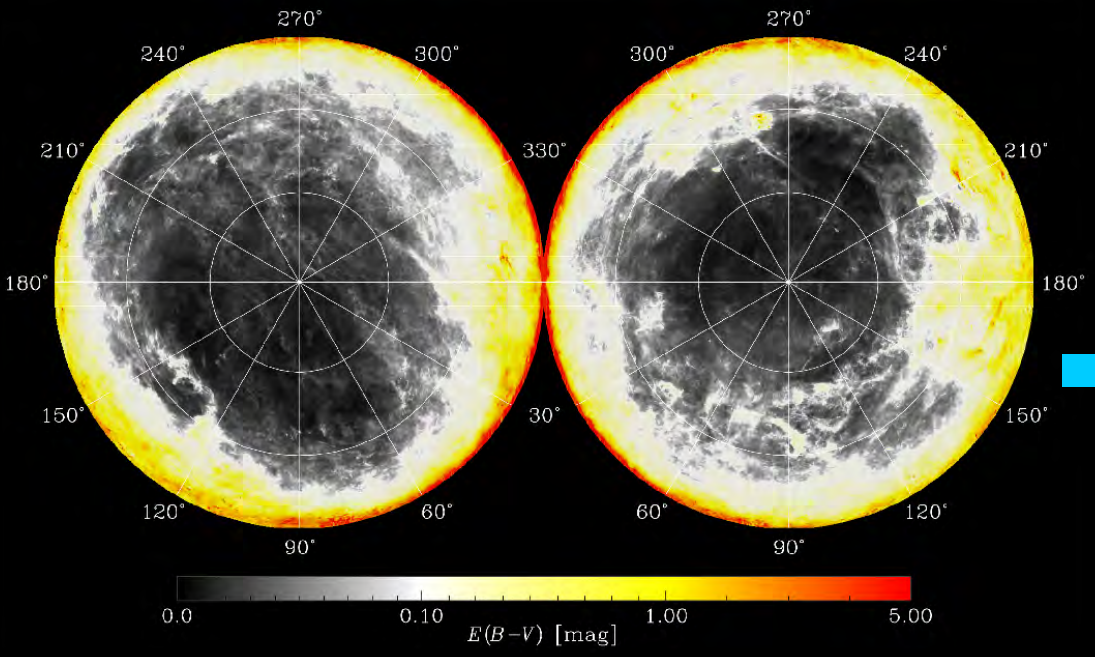
The sound of the Gion Shōja bells echoes the impermanence of all things; the color of the sāla flowers reveals the truth that the prosperous must decline.

The proud do not endure, they are like a dream on a spring night; the mighty fall at last, they are as dust before the wind.

(Chapter 1.1, translated by Helen Craig McCullough)

From
Dust in the wind
to
Dust in the world

SFD Galactic extinction map



Galactic extinction E(B-V) map (Schlegel, Finkbeiner & Davis 1998; SFD)

- The most fundamental dataset for any astronomical observation
- True large-scale structures revealed only after the extinction correction
- Its reliability is of vital importance in precision cosmology

Most cited papers among all refereed astronomy journal articles published in 1800-2012 (ADS)

1	1998ApJ...500..525S	7647.000 06/1998 A E F X R C S U H	
	Schlegel, David J.; Finkbeiner, Douglas P.; Davis, Marc	Maps of Dust Infrared Emission for Use in Estimation of Reddening and Cosmic Microwave Background Radiation Foregrounds	
2	2003ApJS..148..175S	6991.000 09/2003 A E F X D R C S N U H	
	Spergel, D. N.; Verde, L.; Peiris, H. V.; Komatsu, E.; Nolta, M. R.; Bennett, C. L.; Halpern, M.; Hinshaw, G.; Jarosik, N.; Kogut, A.; and 7 coauthors	First-Year Wilkinson Microwave Anisotropy Probe (WMAP) Observations: Determination of Cosmological Parameters	

Top cited papers: 1st-5th

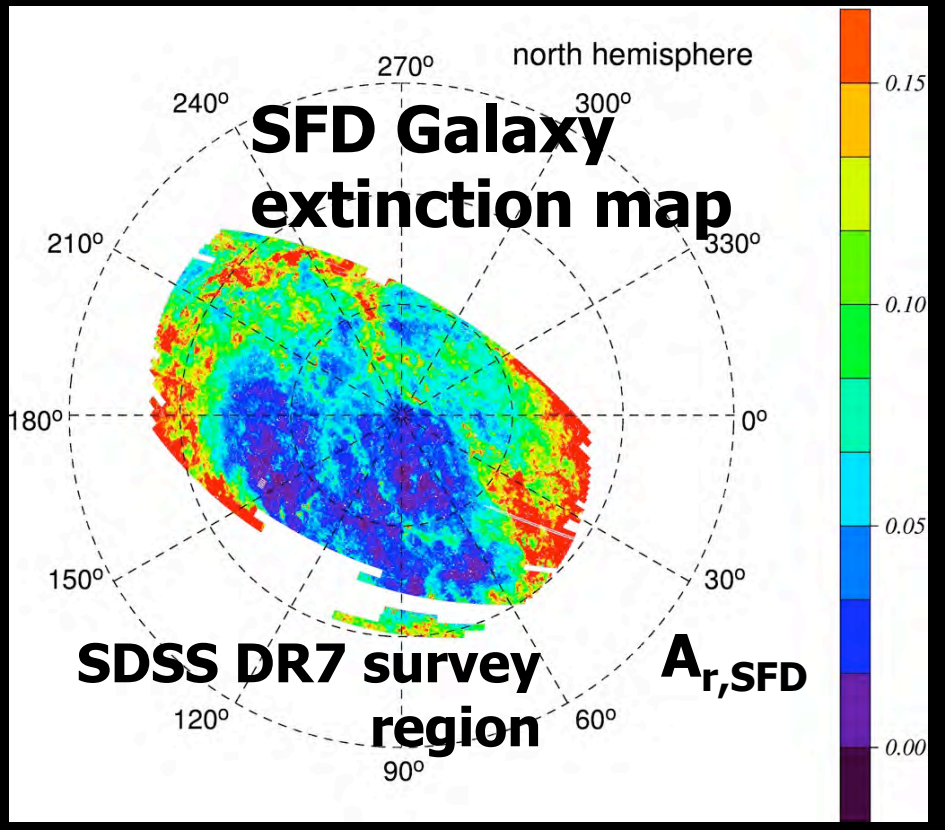
	authors	citation	title
1	Schlegel, Finkbeiner & Davis (1998)	7647	Maps of Dust Infrared Emission for Use in Estimation of Reddening and Cosmic Microwave Background Radiation Foregrounds
2	Spergel et al. (2003)	6991	First-Year Wilkinson Microwave Anisotropy Probe (WMAP) Observations: Determination of Cosmological Parameters
3	Perdew & Zunger (1981)	6872	Self-interaction correction to density-functional approximations for many-electron systems
4	Perlmutter et al. (1999)	6671	Measurements of Omega and Lambda from 42 High-Redshift Supernovae
5	Riess et al. (1998)	6564	Observational Evidence from Supernovae for an Accelerating Universe and a Cosmological Constant

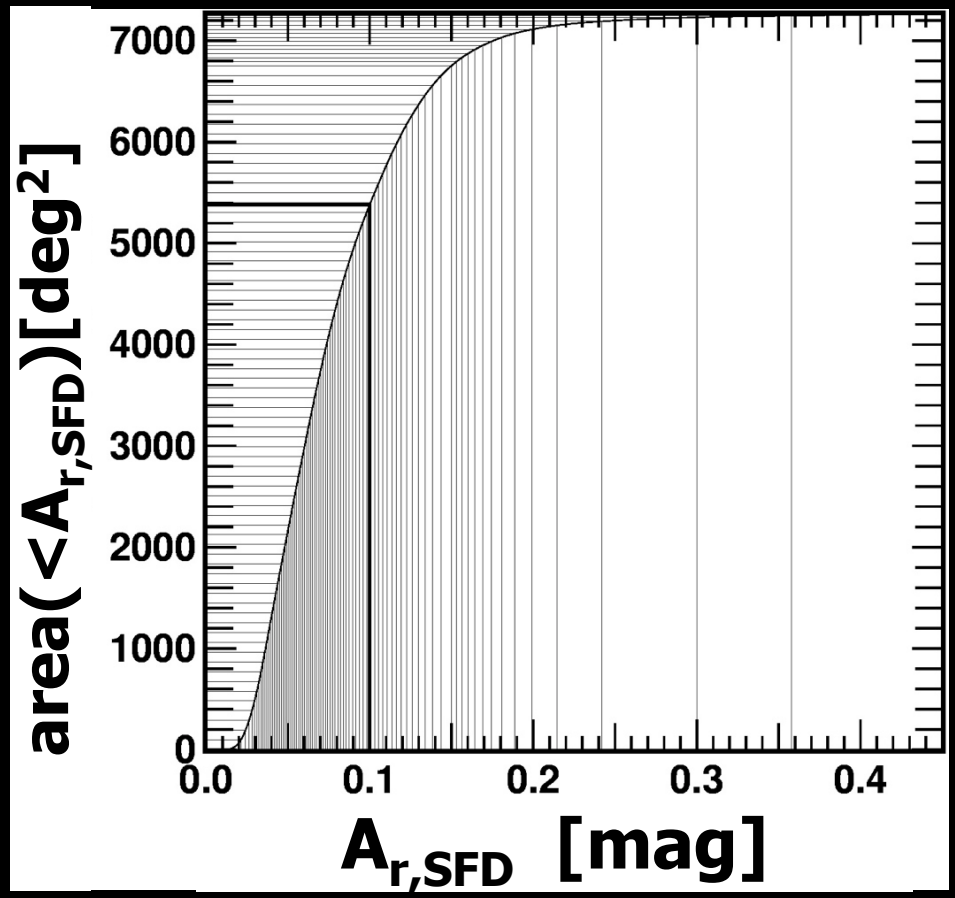
Top cited papers: 6th-10th

	paper	citation	title
6	Shakura & Sunyaev (1973)	5741	Black holes in binary systems. Observational appearance
7	Spergel et al. (2007)	5300	Three-Year Wilkinson Microwave Anisotropy Probe (WMAP) Observations: Implications for Cosmology
8	Anders & Grevesse (1989)	5265	Abundances of the elements - Meteoritic and solar
9	Randall & Sundrum (1999)	4764	Large Mass Hierarchy from a Small Extra Dimension
10	Cardelli, Clayton & Mathis (1989)	4630	The relationship between infrared, optical, and ultraviolet extinction

A_{SFD} map in SDSS DR7 survey region

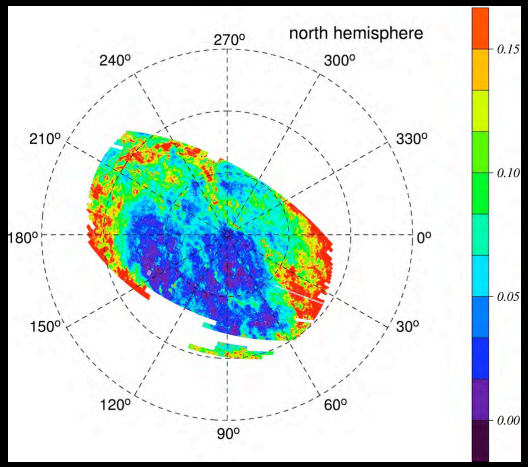
3.6x10^6 galaxies (17.5<r<19.4) in 7270 deg^2 from SDSS DR7 photometric catalog

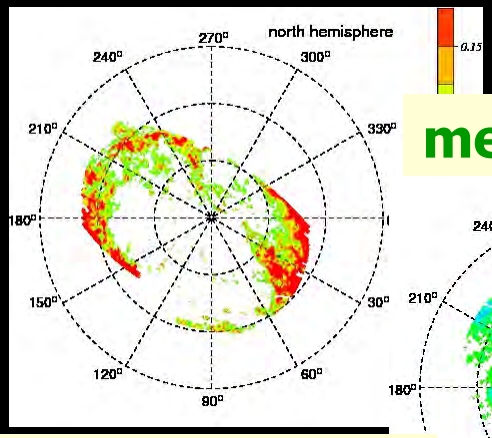




Estimating Galactic extinction from SDSS galaxy surface density

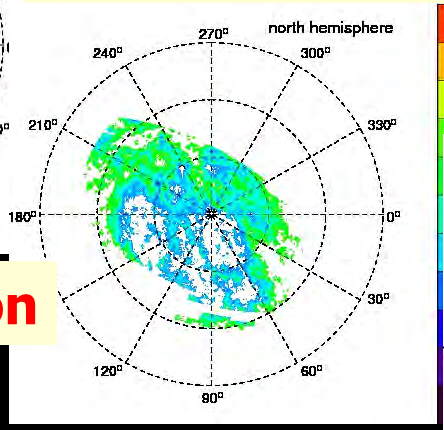
SDSS DR7 survey area (color coded according to A_{SFD})



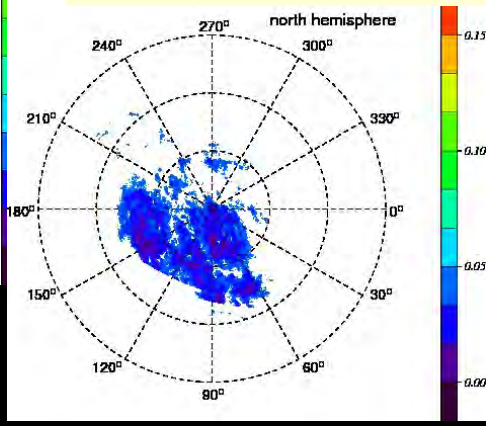


high extinction

medium extinction



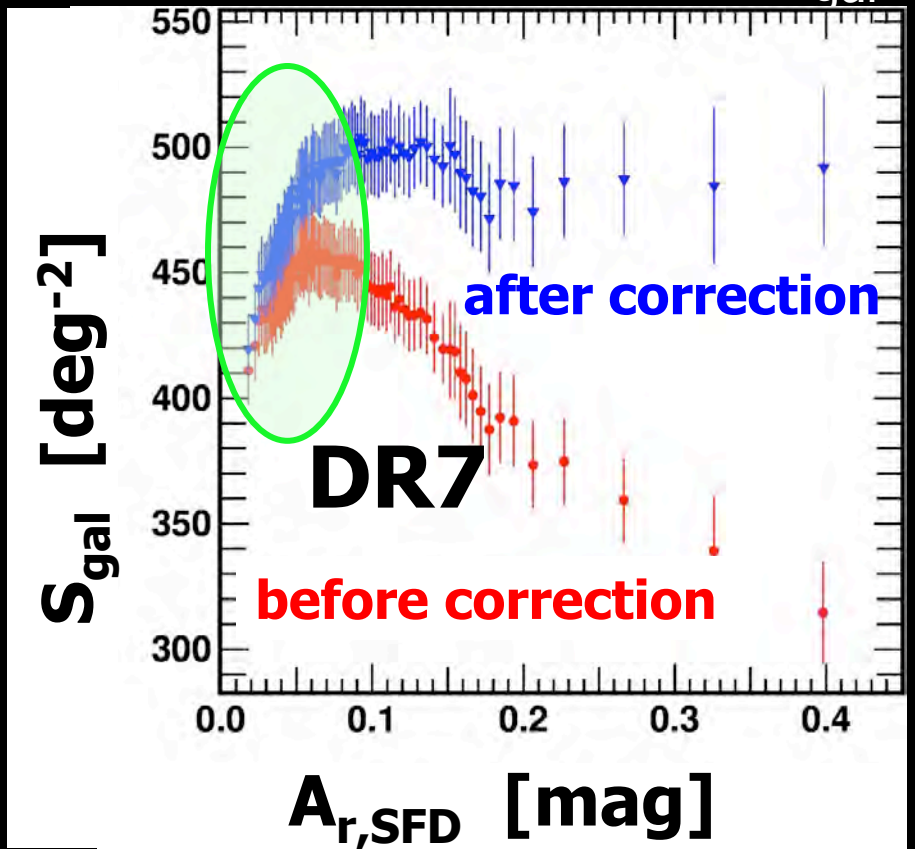
low extinction



- divide the SDSS DR7 survey area into many small regions according to A_{SFD}
- combine those un-contiguous regions into 84 bins with ~100 deg^2 each
- compare the galaxy number density S_{gal} for those bins

Anomalous behavior of SDSS galaxy surface density S_{gal} as a function of A_{SFD}

- ***If A_{SFD} is perfect, we expect that***
  - Before correction: S_{gal} should monotonically decrease as a function of A_{SFD}
  - After correction: S_{gal} should be constant



- OK for A_{SFD} >0.1, but *quite the opposite for A_{SFD} <0.1*
  - ~70% of the SDSS survey area has A_{SFD} <0.1 !
- First pointed out by Yahata et al. (2007) for DR4, and confirmed by Kashiwagi (2011) for DR7

The SFD procedure to construct the Galactic extinction map

- COBE 100 μm+240 μm maps (0.7deg.pixel)
  - Remove zodiacal light and cosmic infrared background
  - Dust temperature map ⇒ temperature-dependent emissivity corrected 100 μm map
- Calibration of higher angular-resolution IRAS 100 μm map (5 arcmin. pixel)
- Assume

  $E(B-V)=p\times(\text{IRAS 100}\,\mu\text{m flux})^T$; p∼0.0184, T∼1

  at each region and determine p and T from the data
- Convert E(B-V) to A_{band} adopting SED of ellipticals and $R_V=A_V/E(B-V)=3.1$

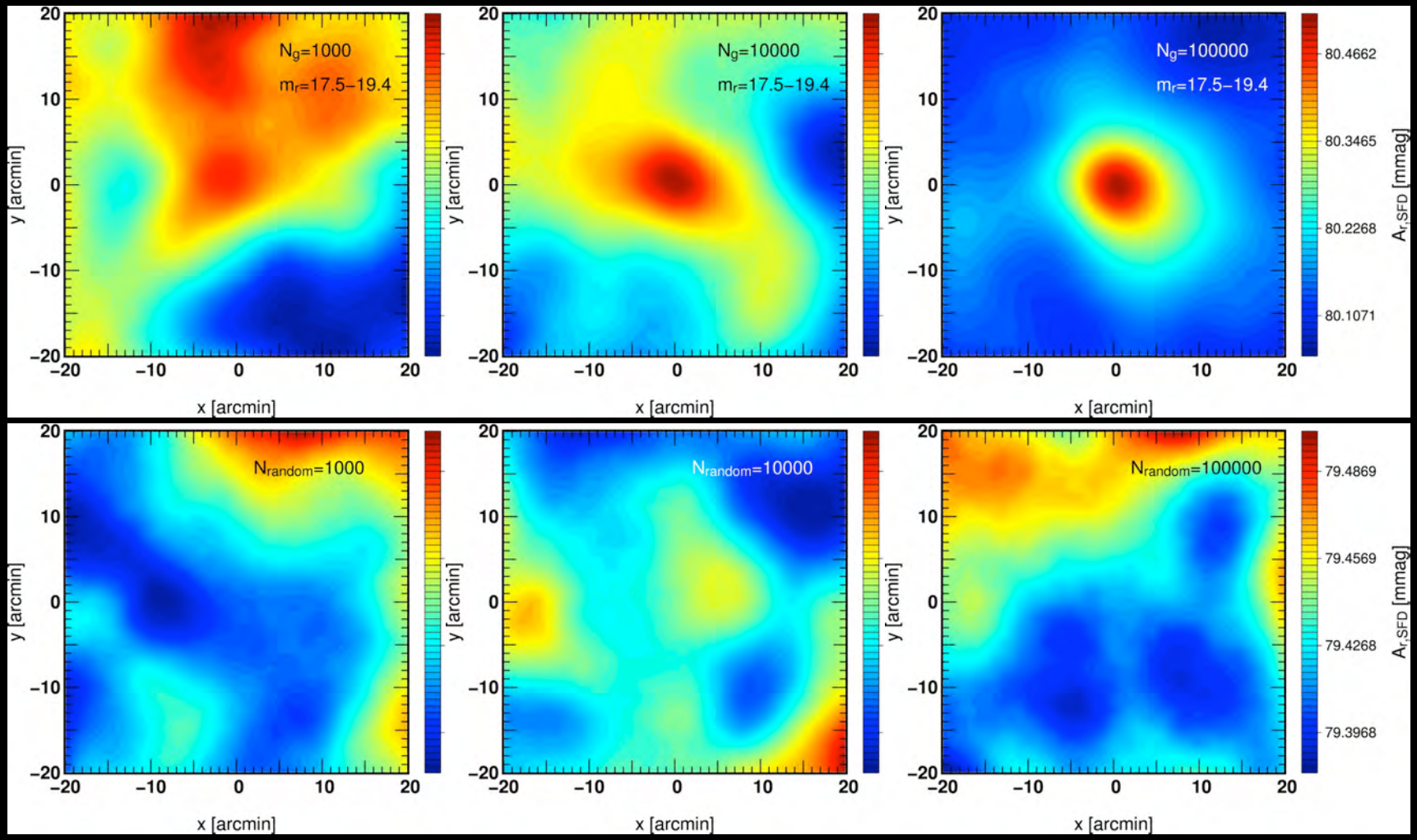
Origin of the anomaly

- A_{SFD} is estimated assuming that the reddening is proportional to the FIR emission flux (100 μ m)
  - the anomaly indicates the positive correlation between galaxy surface density and the FIR flux at least where the real extinction is small
- 100 μ m flux = Galactic dust + galaxies
  - contamination by the FIR emission from galaxies proposed by Yahata et al. (2007)

Stacking analysis of SDSS galaxies on the SFD map

galaxy

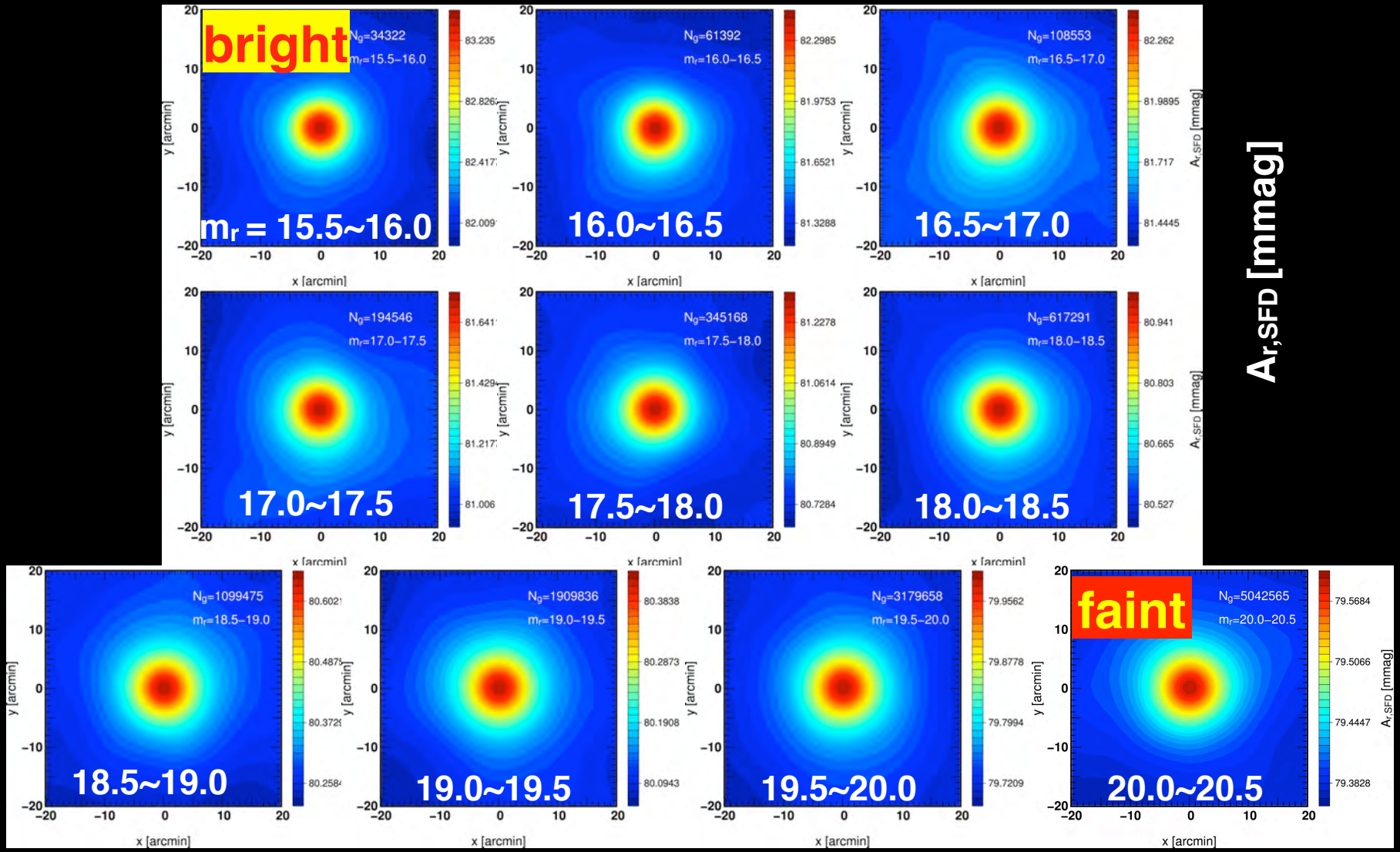
random



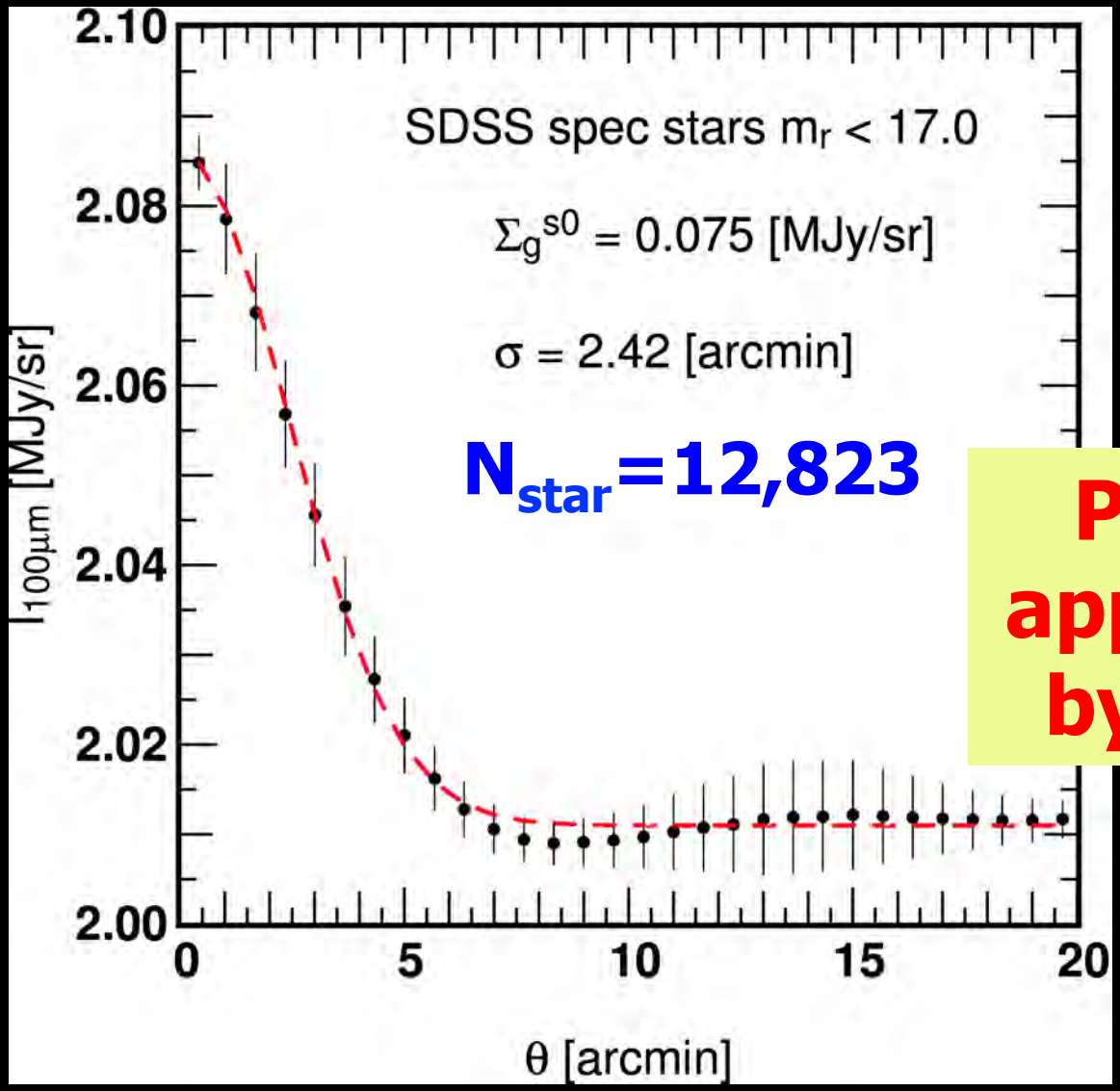
$N = 10^3$ $N = 10^4$ $N = 10^5$

Magnitude dependence

Stacking SDSS galaxies ($15.5 < m_r < 20.5$) over SFD map according to their r-band magnitude ($\Delta m_r = 0.5$)

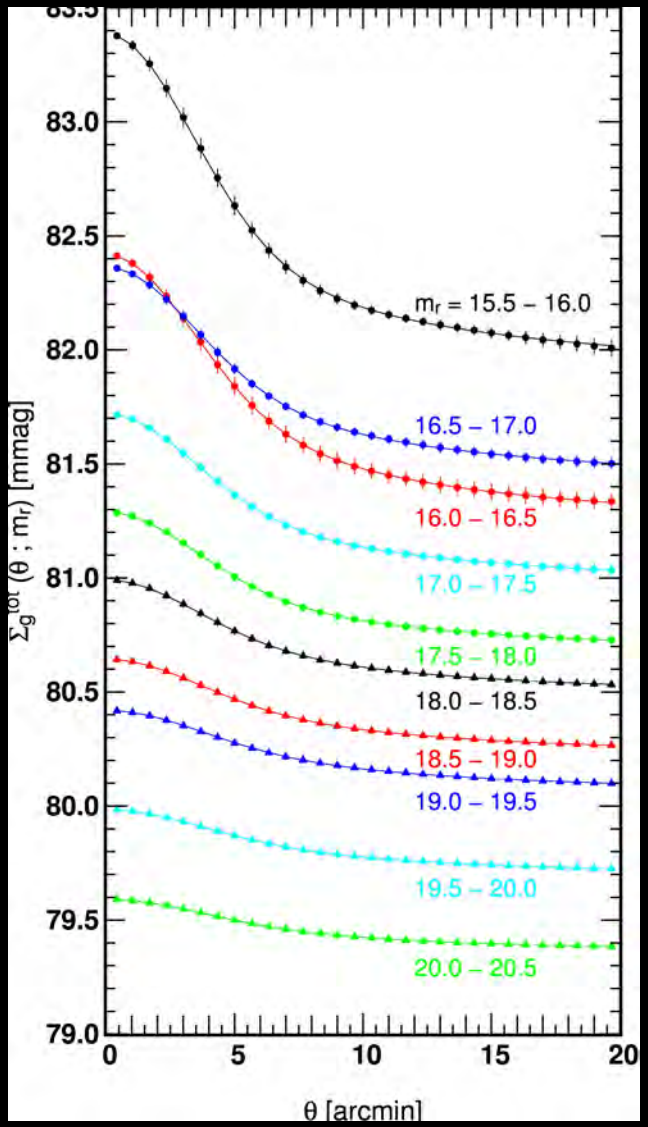


Point spread function of IRAS



PSF is well approximated by Gaussian

Decompositions into single galaxy and clustering terms



$$\Sigma_{\rm g}^{\rm tot}(\boldsymbol{\theta};m_r)=\Sigma_{\rm g}^{\rm s}(\boldsymbol{\theta};m_r)+\Sigma_{\rm g}^{\rm c}(\boldsymbol{\theta};m_r)+C$$

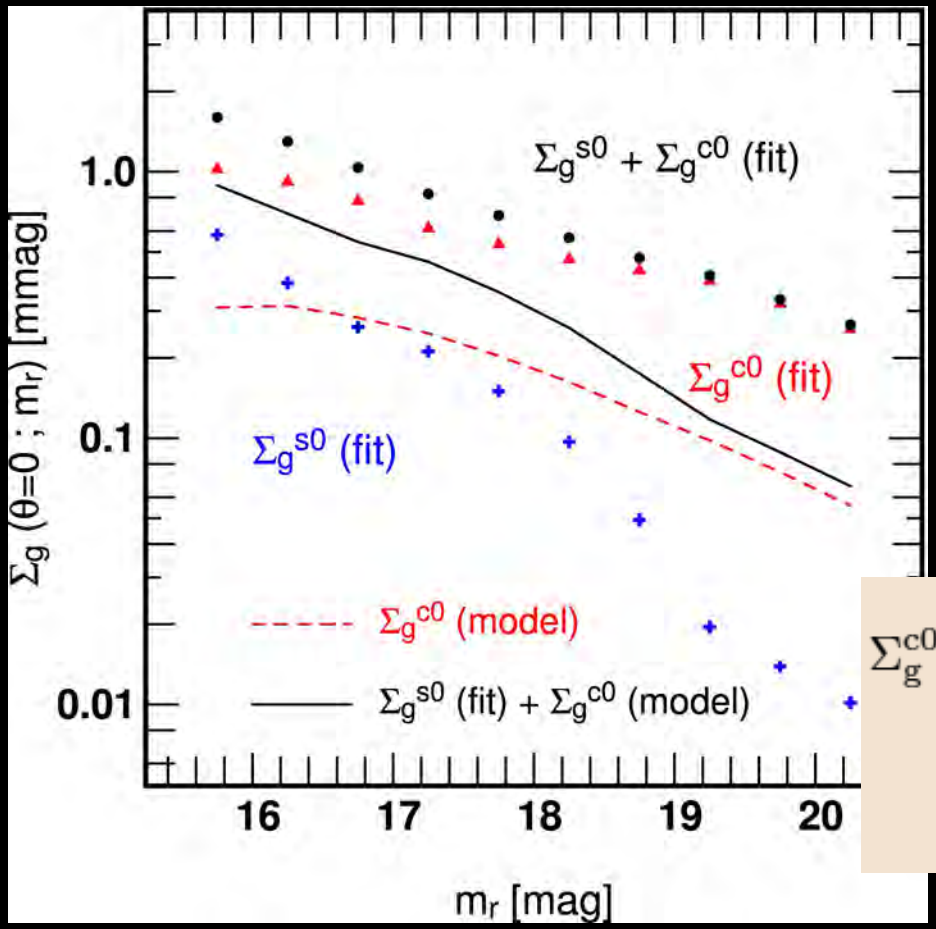
$$\Sigma_{\rm g}^{\rm s}(\boldsymbol{\theta};m_r)=\Sigma_{\rm g}^{\rm s0}(m_r)\exp\left(-\frac{\theta^2}{2\sigma^2}\right)$$

$$\Sigma_{\rm g}^{\rm c}(\boldsymbol{\theta};m_r)=\iint dm'd\boldsymbol{\varphi}\;\Sigma_{\rm g}^{\rm s}(\boldsymbol{\theta}-\boldsymbol{\varphi};m')\times w_{\rm g}(\boldsymbol{\varphi};m',m_r)\frac{dN_{\rm g}(m')}{dm'}$$

$$w_{\rm g}(\boldsymbol{\varphi};m',m_r)=K(m',m_r)(\varphi/\varphi_0)^{-\gamma},$$

$$\Sigma_{\rm g}^{\rm c}(\boldsymbol{\theta};m_r)=\Sigma_{\rm g}^{\rm c0}(m_r)\exp\left(-\frac{\theta^2}{2\sigma^2}\right)\times{}_1F_1\left(1-\frac{\gamma}{2};1;\frac{\theta^2}{2\sigma^2}\right)$$

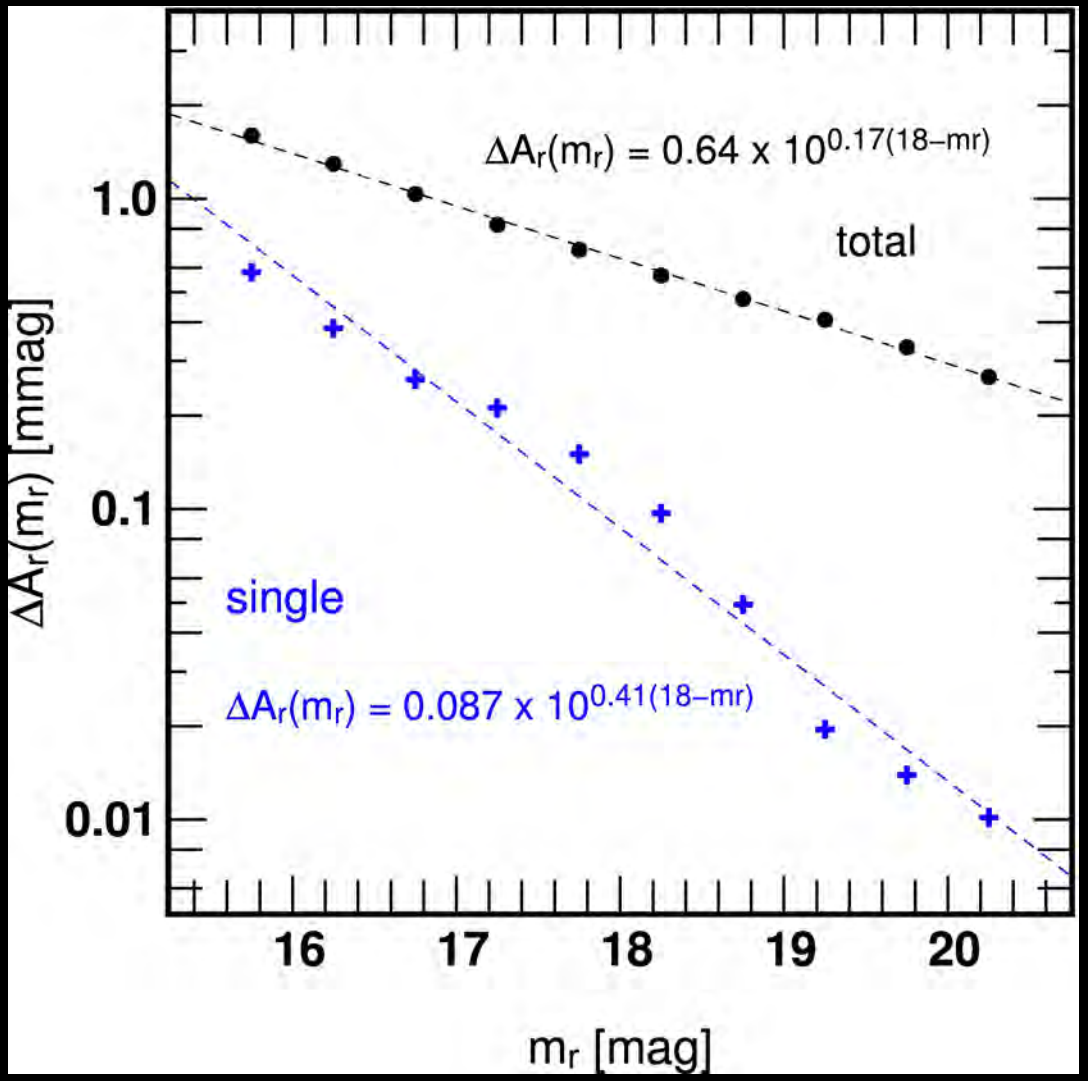
Extended dust emission around the halo hosting the central galaxy and/or contribution from unresolved galaxies ?



- The fitted clustering term is a factor of 2-3 larger than that expected from the measured angular correlation functions of resolved SDSS galaxies

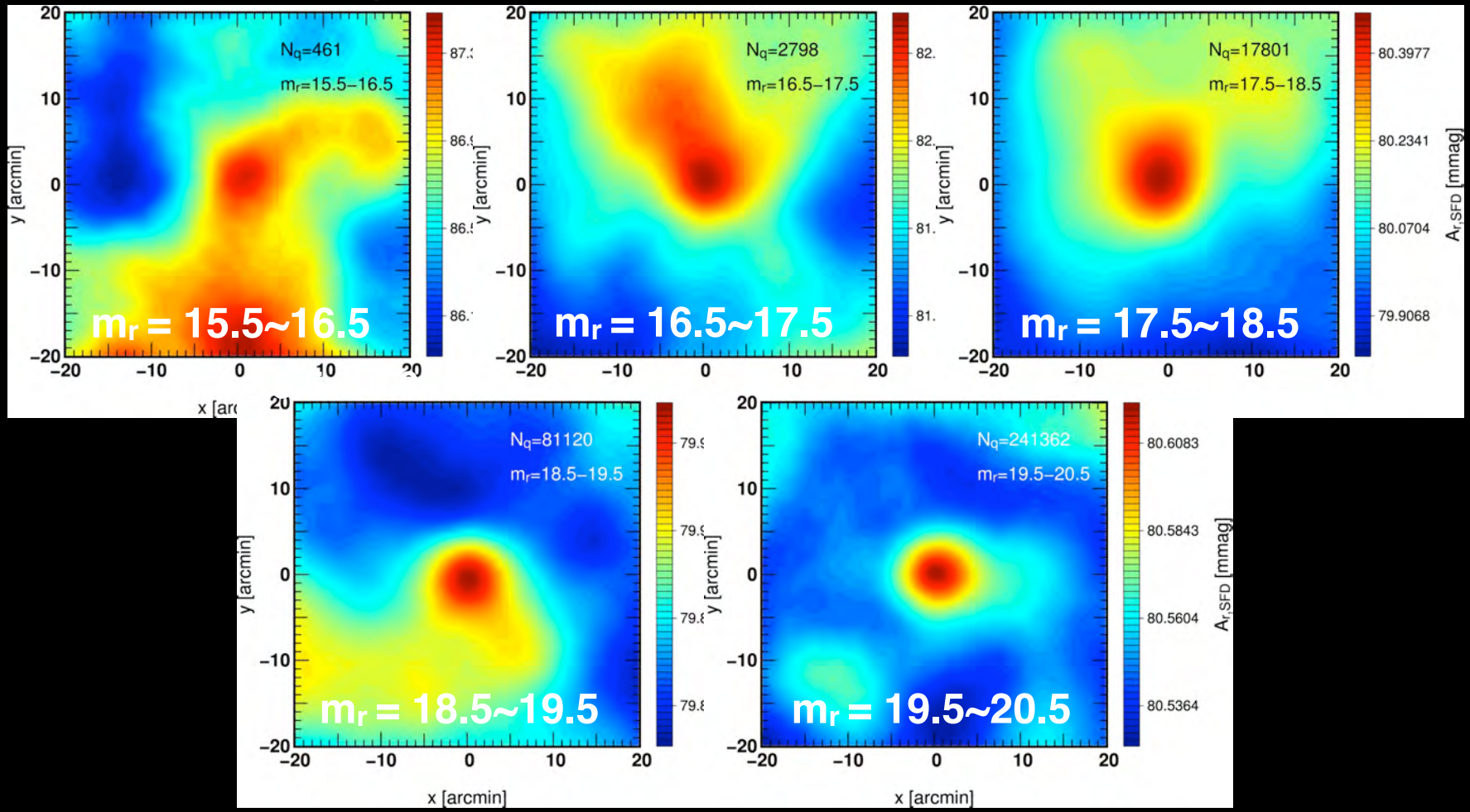
$$\Sigma_{\rm g}^{\rm c0}(m_r) = 2\pi\sigma^2 \left(\frac{\varphi_0}{\sqrt{2}\sigma}\right)^{\gamma} \Gamma\left(1-\frac{\gamma}{2}\right) \times \int dm' \Sigma_{\rm g}^{\rm s0}(m') K(m', m_r) \frac{dN_{\rm g}(m')}{dm'}$$

Average contribution to A_r from FIR emission of (SDSS) galaxies

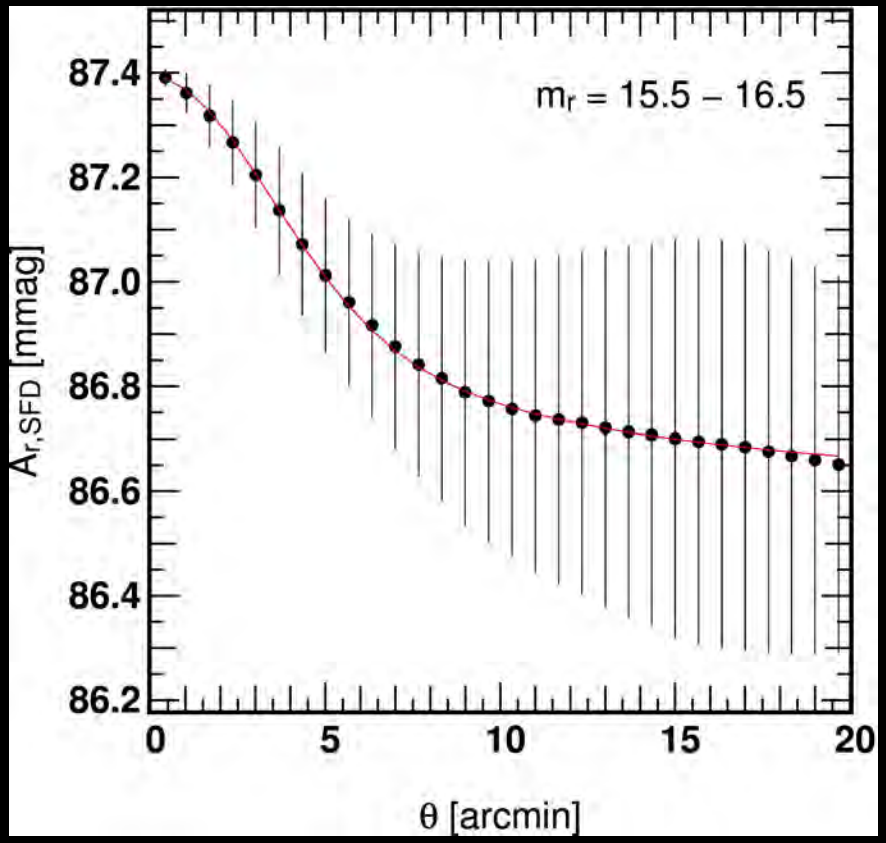


Stacking SDSS quasars

Similar stacking analysis of SDSS photometric quasar catalogue (Richards et al., 2009) indicates the FIR signals as well.

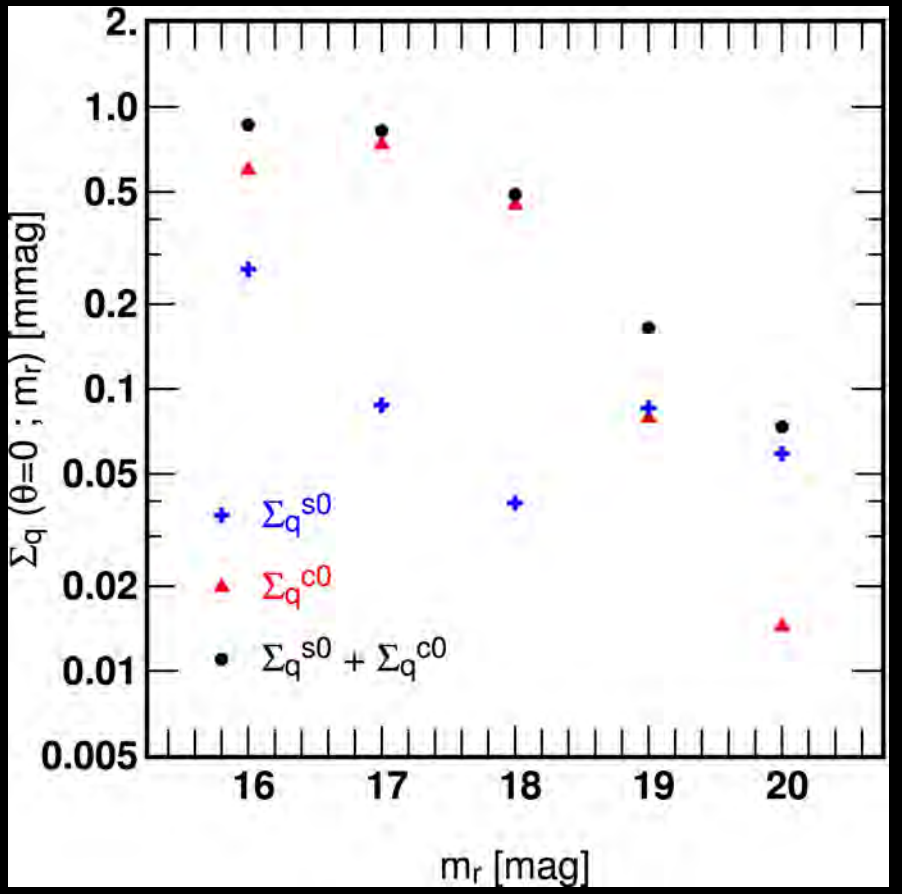


Profiles of stacked quasar images



Stacked quasar profile and its best-fit

Best-fit decomposition into the single and clustering terms



Summary

- Detection of FIR emission from SDSS galaxies (and quasars) by stacking analysis over the SFD map（～ IRAS　100 μ m map)
  - Correction to the SFD map and future Galactic extinction map with Planck
  - A new probe of unresolved (dusty) galaxy correlations or dust profile of the hosting halo
- Everything is **dust** in the wind (Kansas)
- 風前一笑世皆塵 (Korea House)
- The mighty fall at last, they are as **dust** before the wind (The Tale of The Heike)