The ZTF SNIa program

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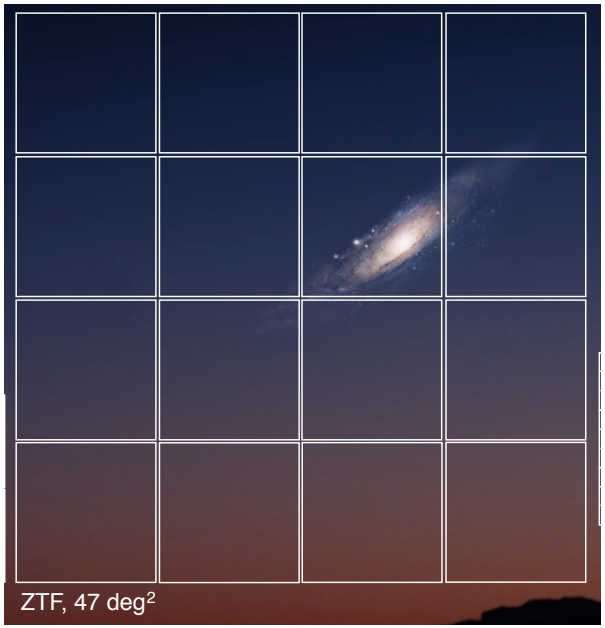

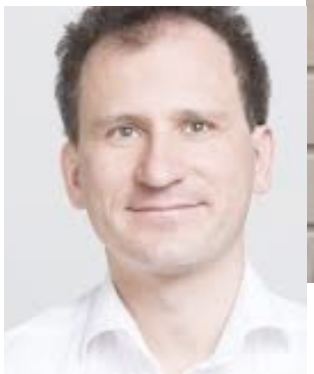

+ PhD students in Berlin and OKC

ZTF SNIa science goals

- Cosmological sample: new low-z anchoring set
- Set uncertinty floor for LSST, WFIRST: Host galaxy environment dependencies, dust
- Local anisotropies measurement
- Sample to trigger Near-IR SNIa Hubble diagram (Baron-Nugent+12, ...)
- Extragalactic extinction (Amanullah+14,15, Johansson+14)
- Interaction w. companion, CSM and surface radioactivity, dark phase of SNIa (first 4 days) (Nugent +11,Goobar+14,15,Cao+15, Kromer+16, ...)
- Late time lightcurves and spectra to understand nebular physics and interaction (>100 d).
- High-resolution spectroscopy: CSM and ISM studies. (Maguire+14,Ferretti+16...)
- Diversity in SNIa properties (Maguire+14, ...)
- Feasibility of photometric ID for e.g., LSST
- Lensed SNe?

(selected PTF/iPTF papers on the subject)

ZTF SNIa science goals

- Cosmology: challenge the ΛCDM paradigm

This talk!

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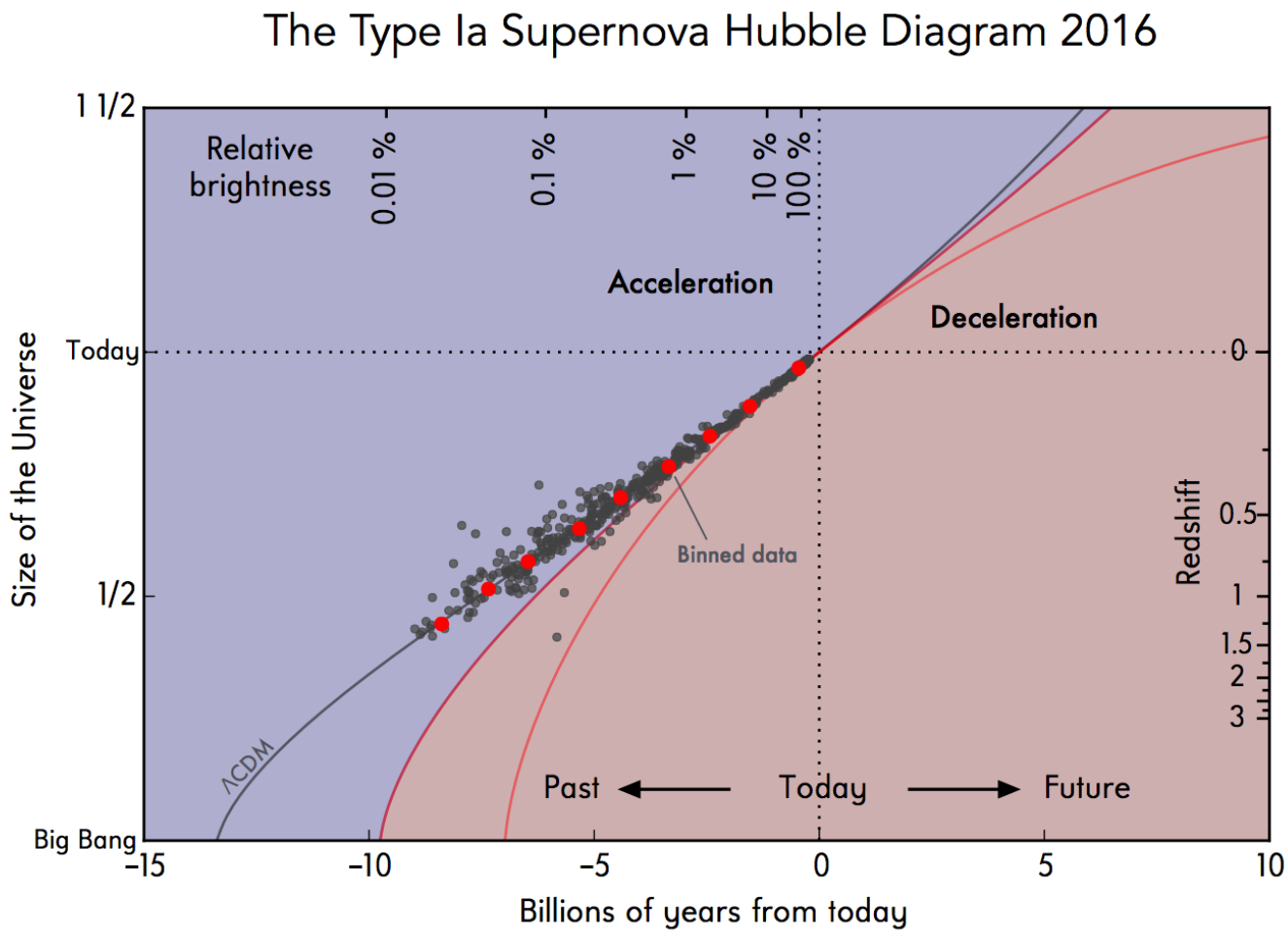
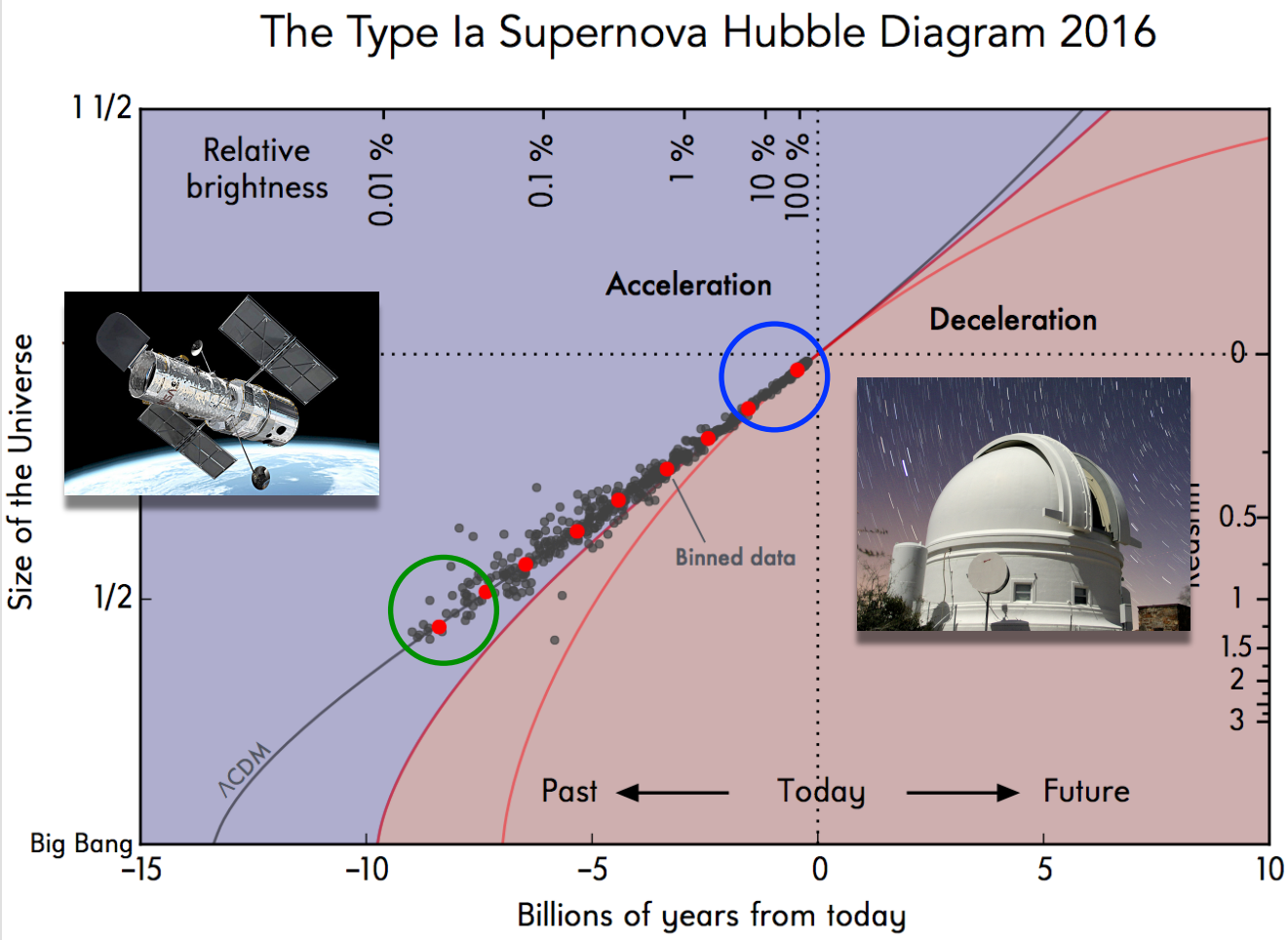
What is the origin of the accelerated cosmic expansion?



What is the origin of the accelerated cosmic expansion?
- challenging Λ

- Cosmological constant (Λ), consistent with *existing* data but is 10^{60}-10^{120} times lower than the expected vacuum energy density
- **Completely new physics?**
- *Combined studies of low- and high-redshift SNe provides the key for testing models for the cosmic acceleration: time-evolution*
- High-z, HST programs now; WFIRST in the future
- ZTF: can provide critical low-z sample



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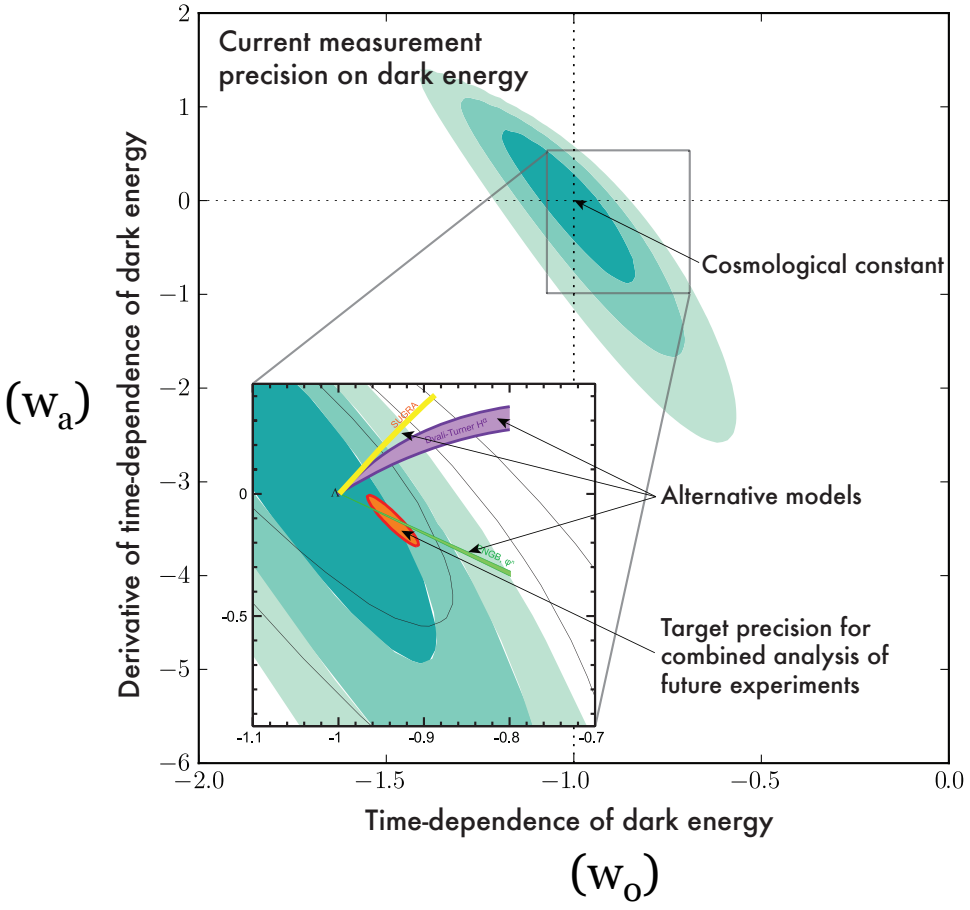
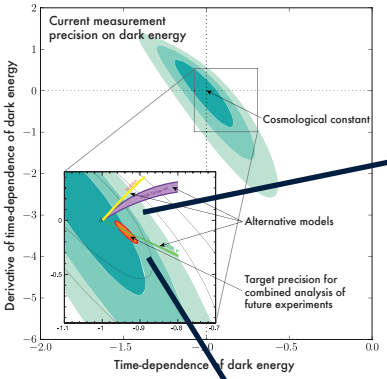


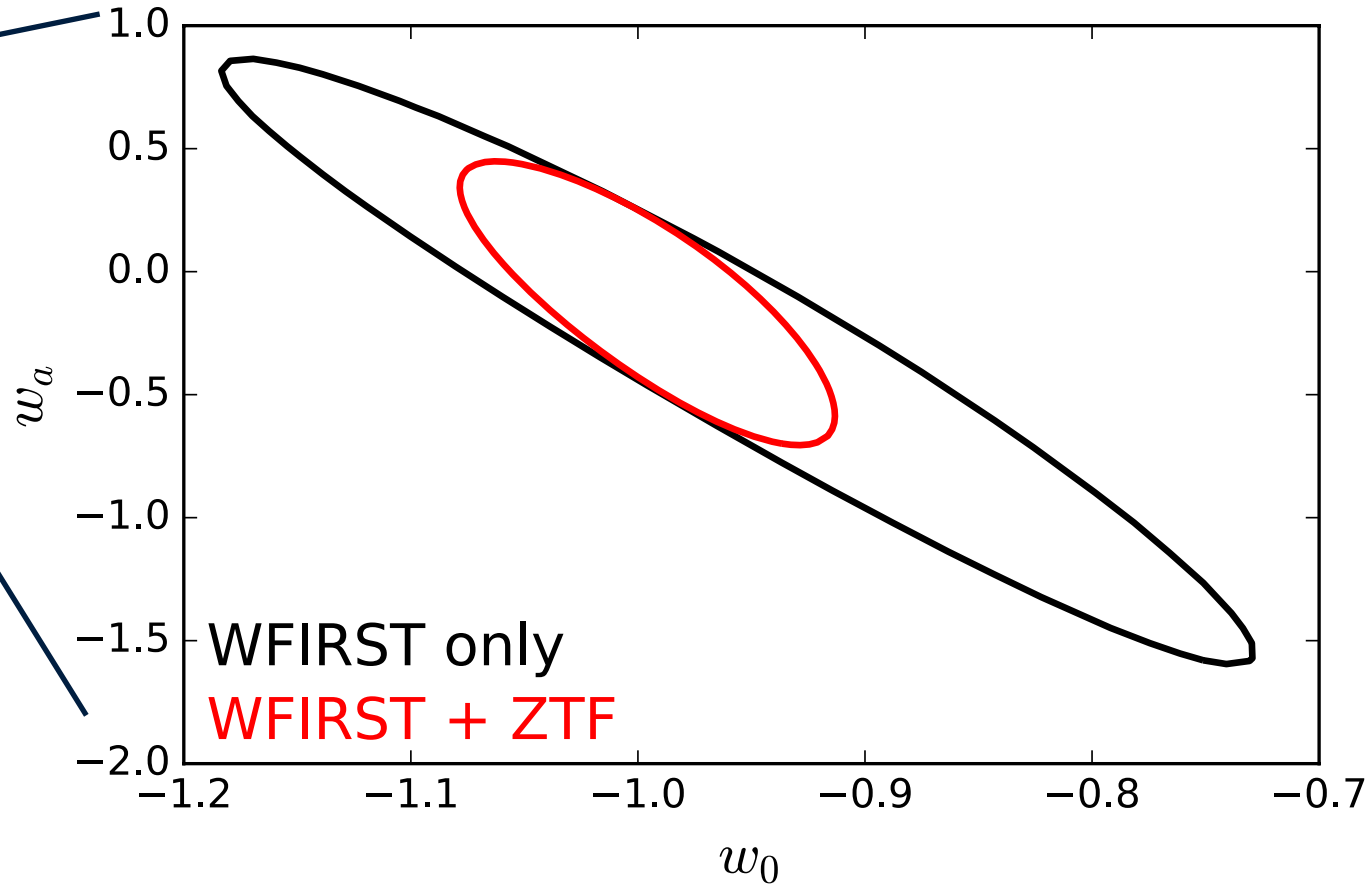
$$\rho_{DE} = \rho_{DE}^{0} a^{-3(1+w)}; w = w_0 + w_a(1-a)$$

$$\rightarrow w = -1 \text{ makes } \rho_{DE} \text{ constant}$$

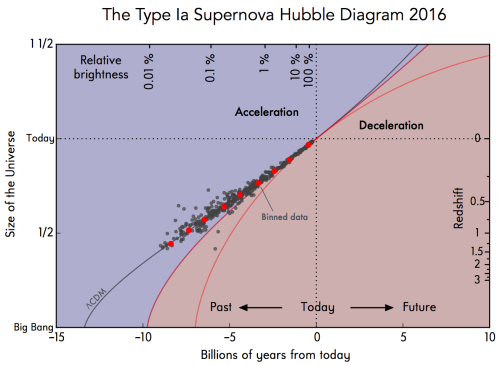
Anchoring the Hubble diagram

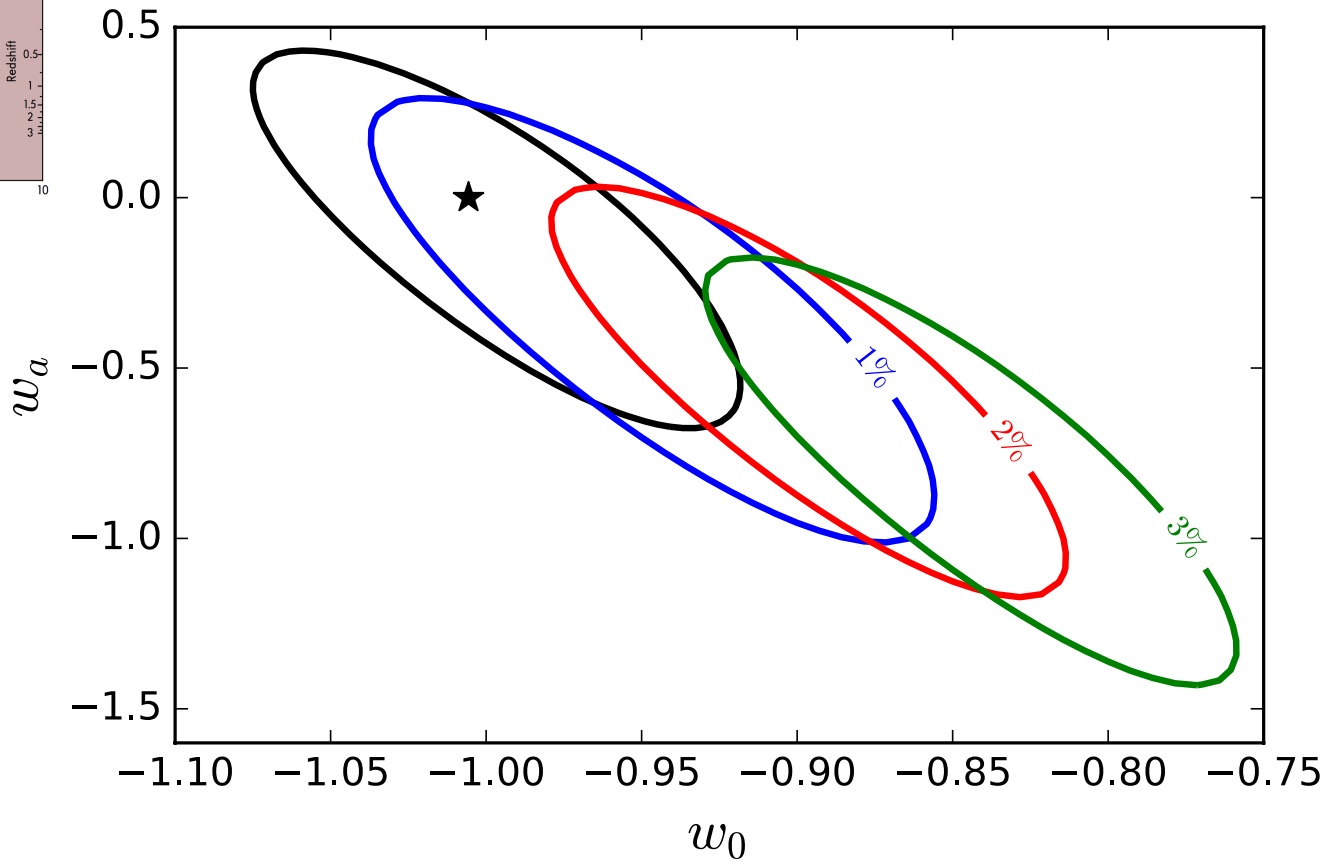
DE FoM significantely improved with ~2000 SNe Ia @ z≤0.1





Calibration requirements
– impact of photometric bias





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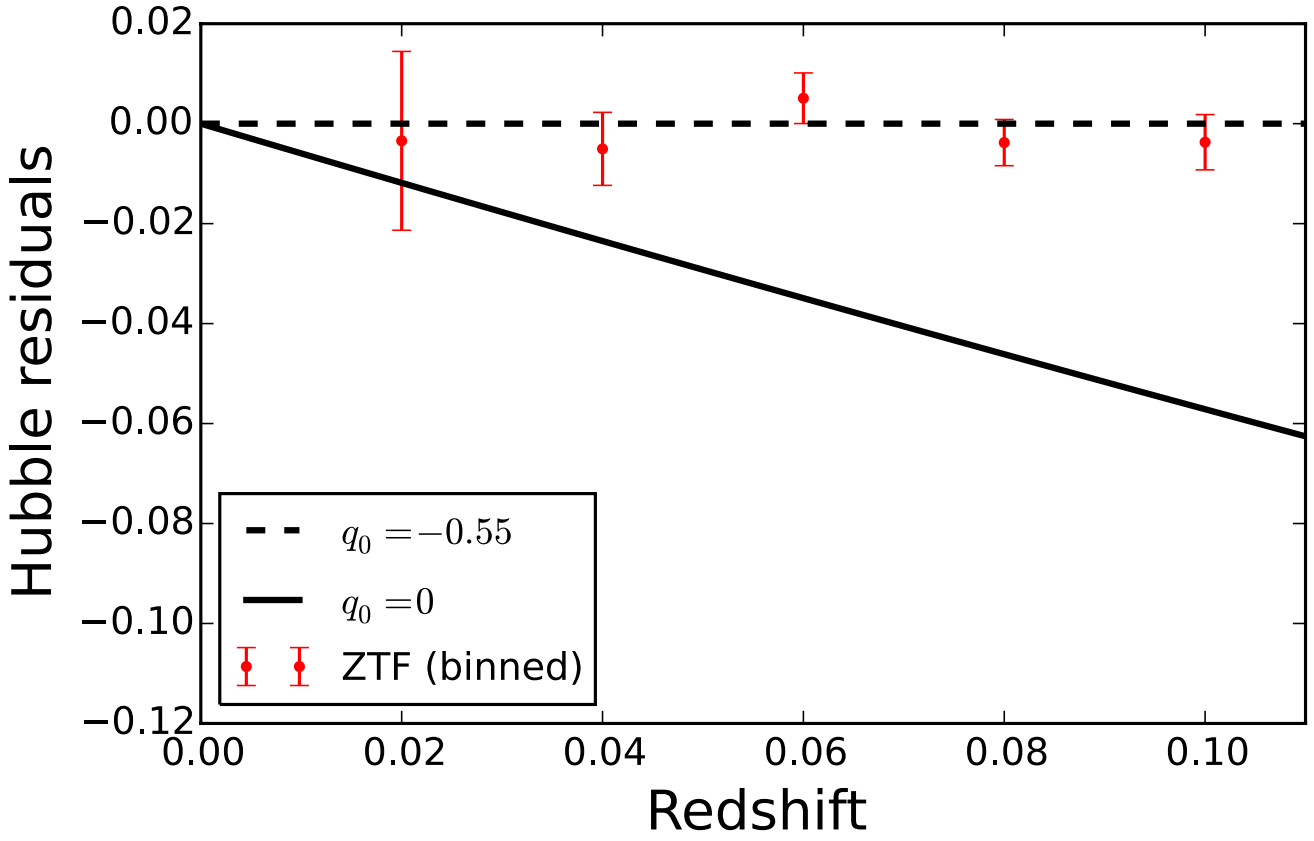
ZTF data alone sensitive to cosmic acceleration



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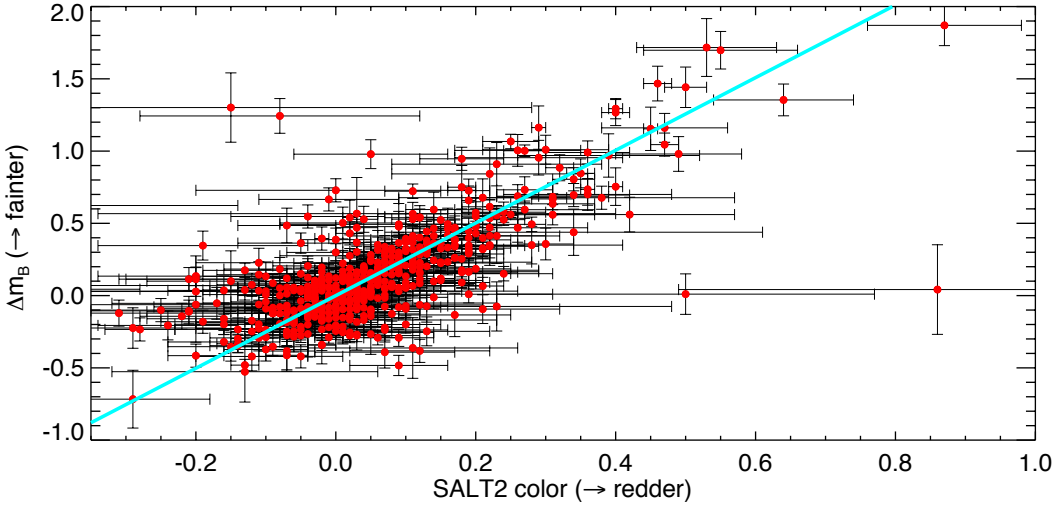
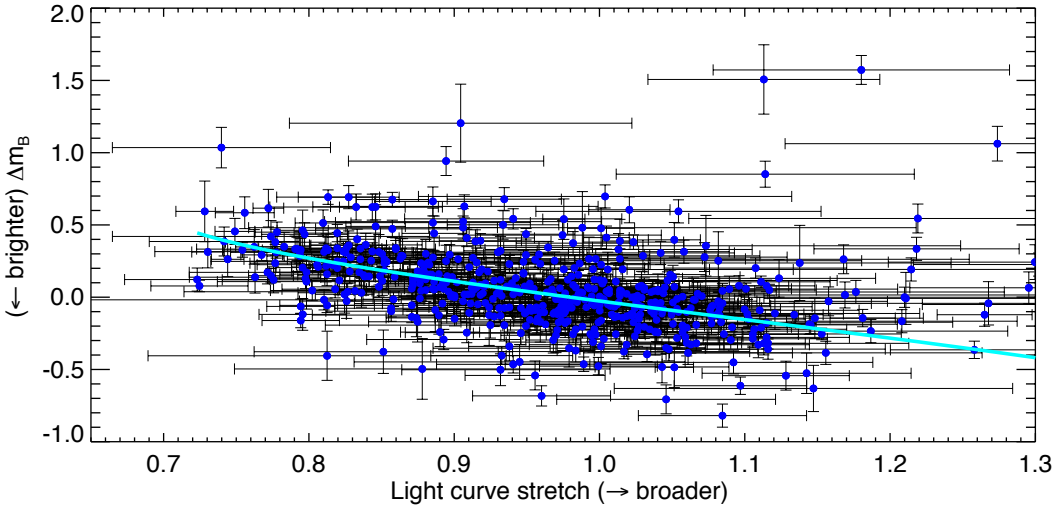
But(!) requires 2 bands for necessary color corrections



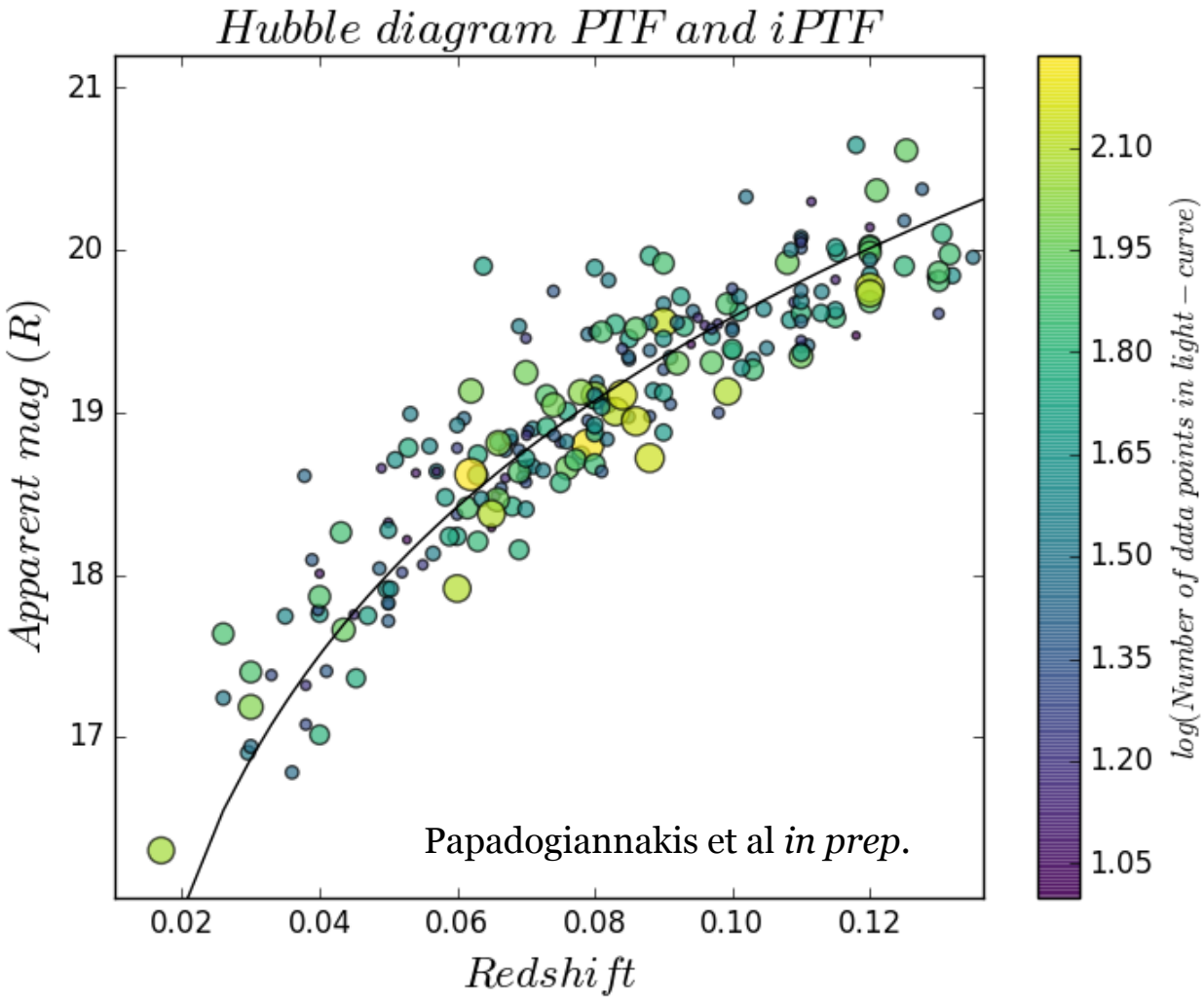


Cosmology accuracy improvement with **color data+statistics:** PTF ➔ ZTF

$$\sigma_\mu(z) \propto \frac{\sigma_m}{\sqrt{N}} \approx \frac{1/3}{\sqrt{10}} \Rightarrow \frac{\sigma_\mu^{ZTF}}{\sigma_\mu^{PTF}} \sim 0.1$$

Single band iPTF/ PTF Hubble has large scatter (no color corrections are possible)

$$\Delta m_B = A_B = (R_v + 1) \cdot E(B-V)$$



Potential concern: Diversity in color correction, R_V

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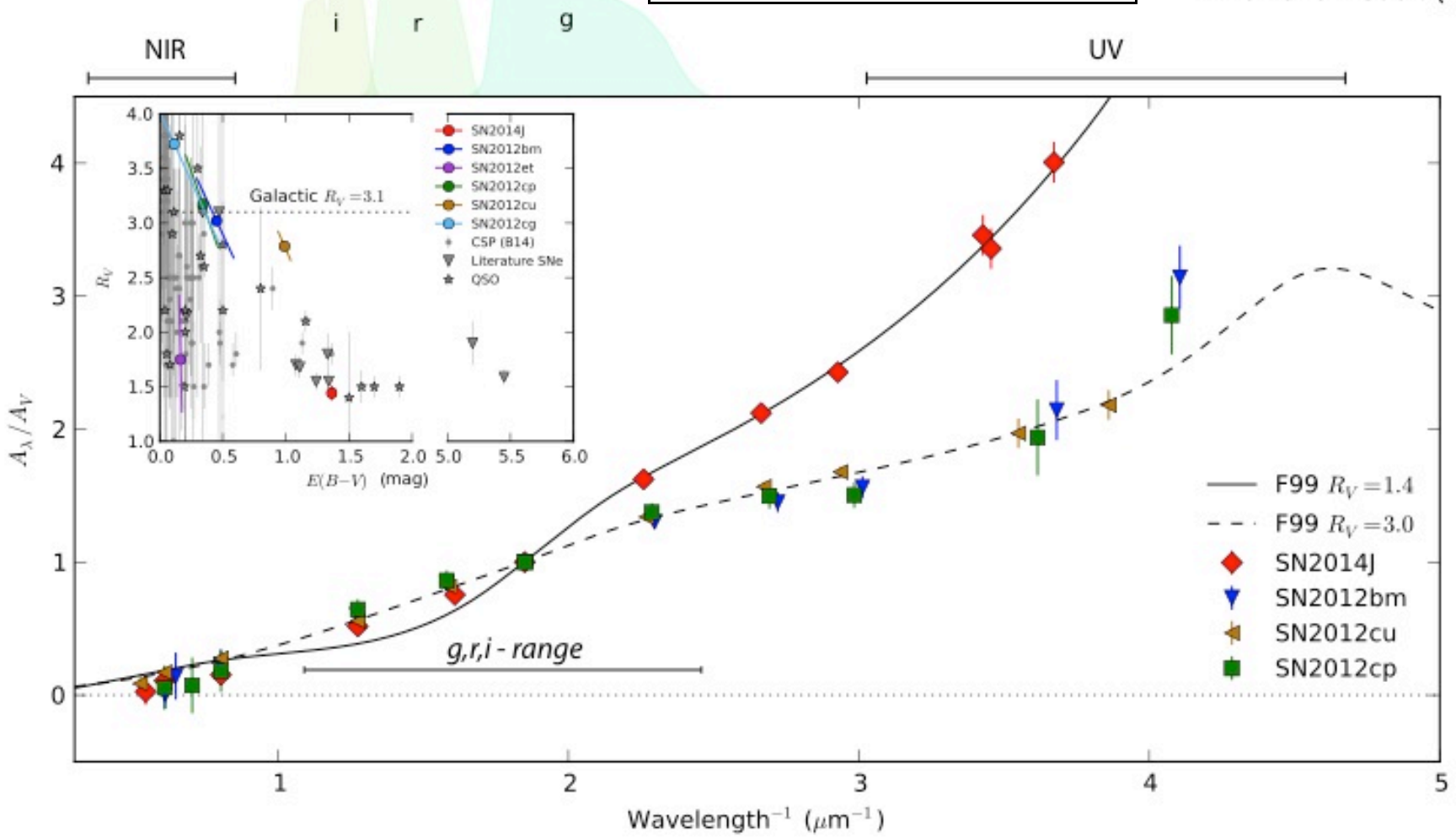
Amanullah et al. (2015)



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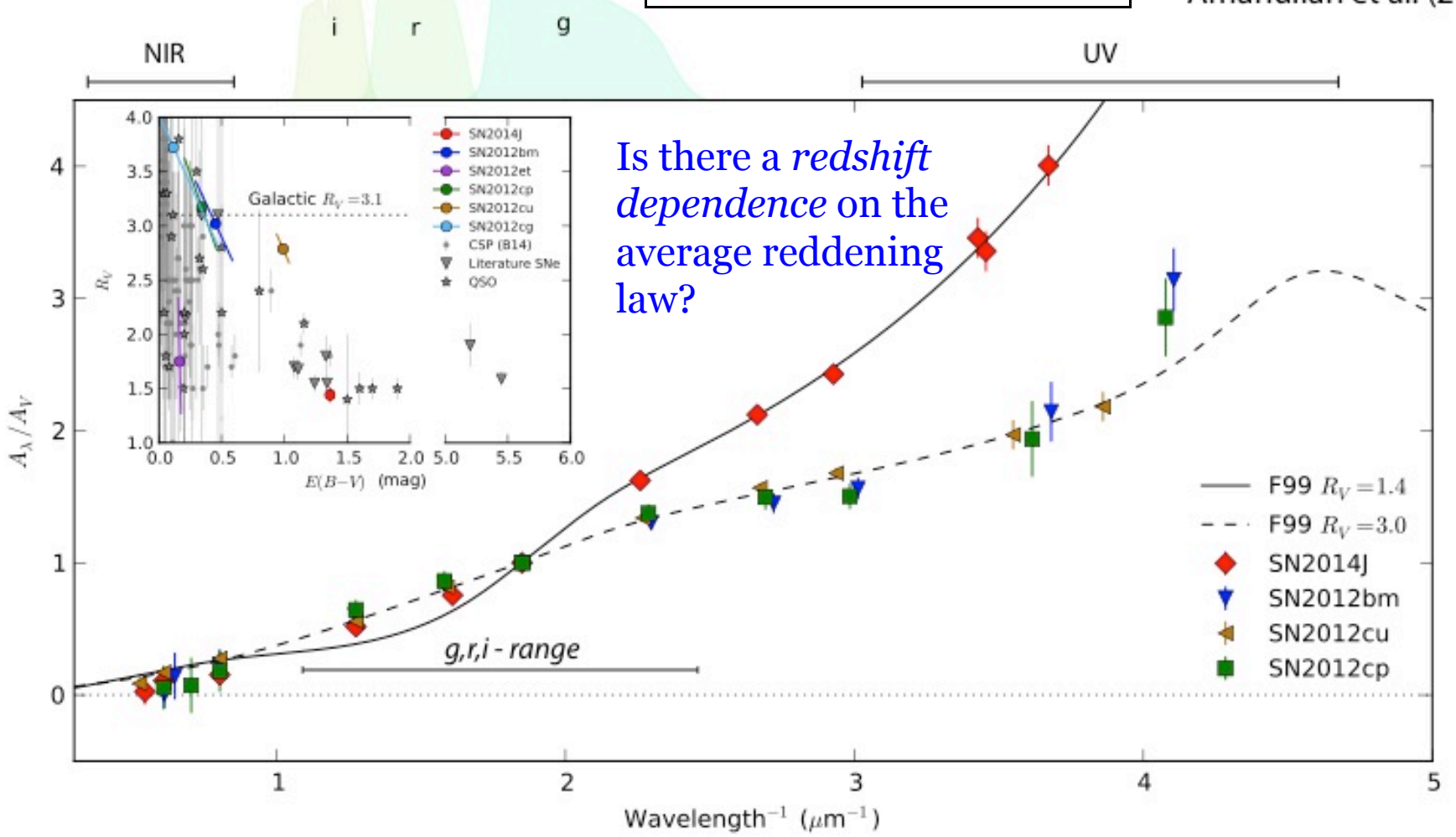
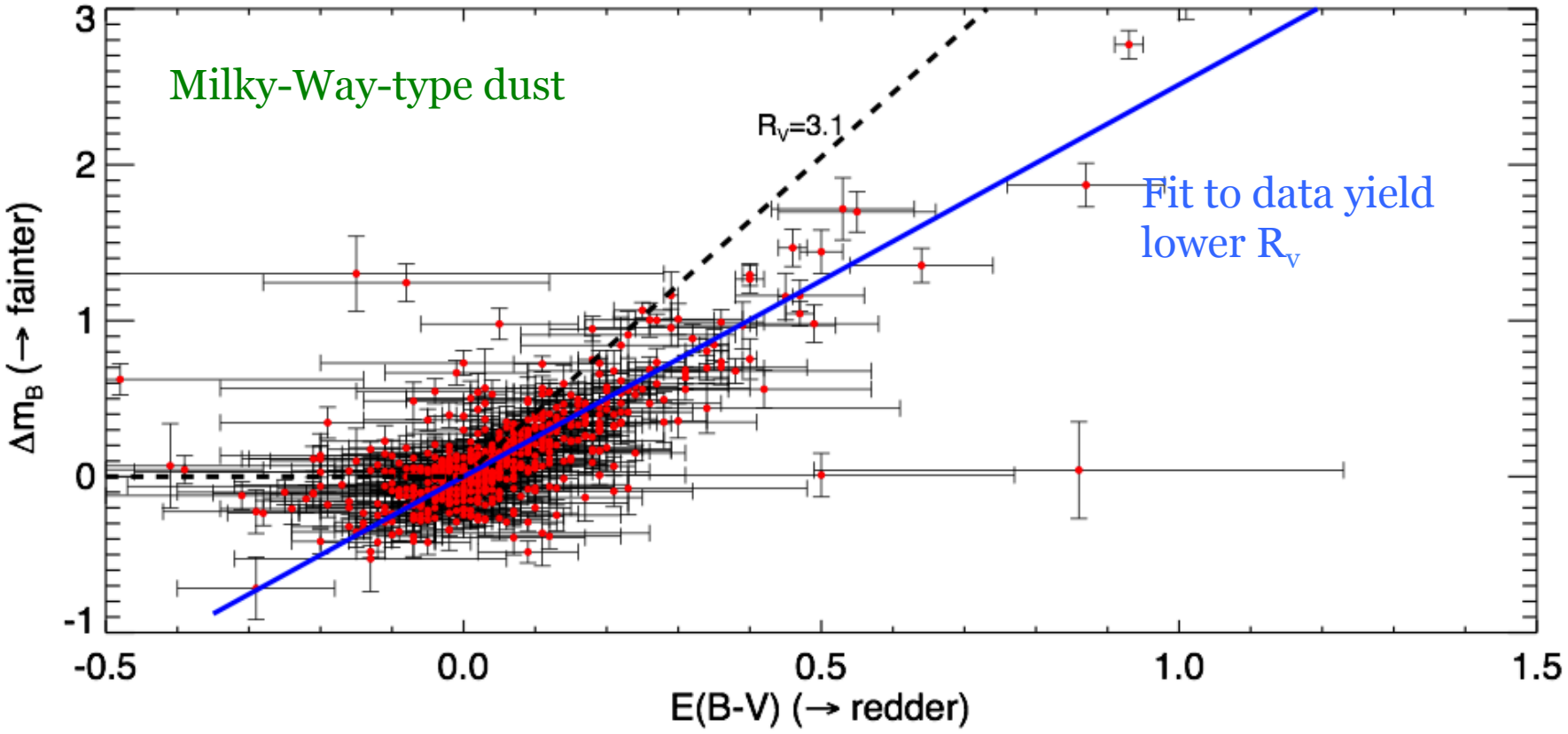
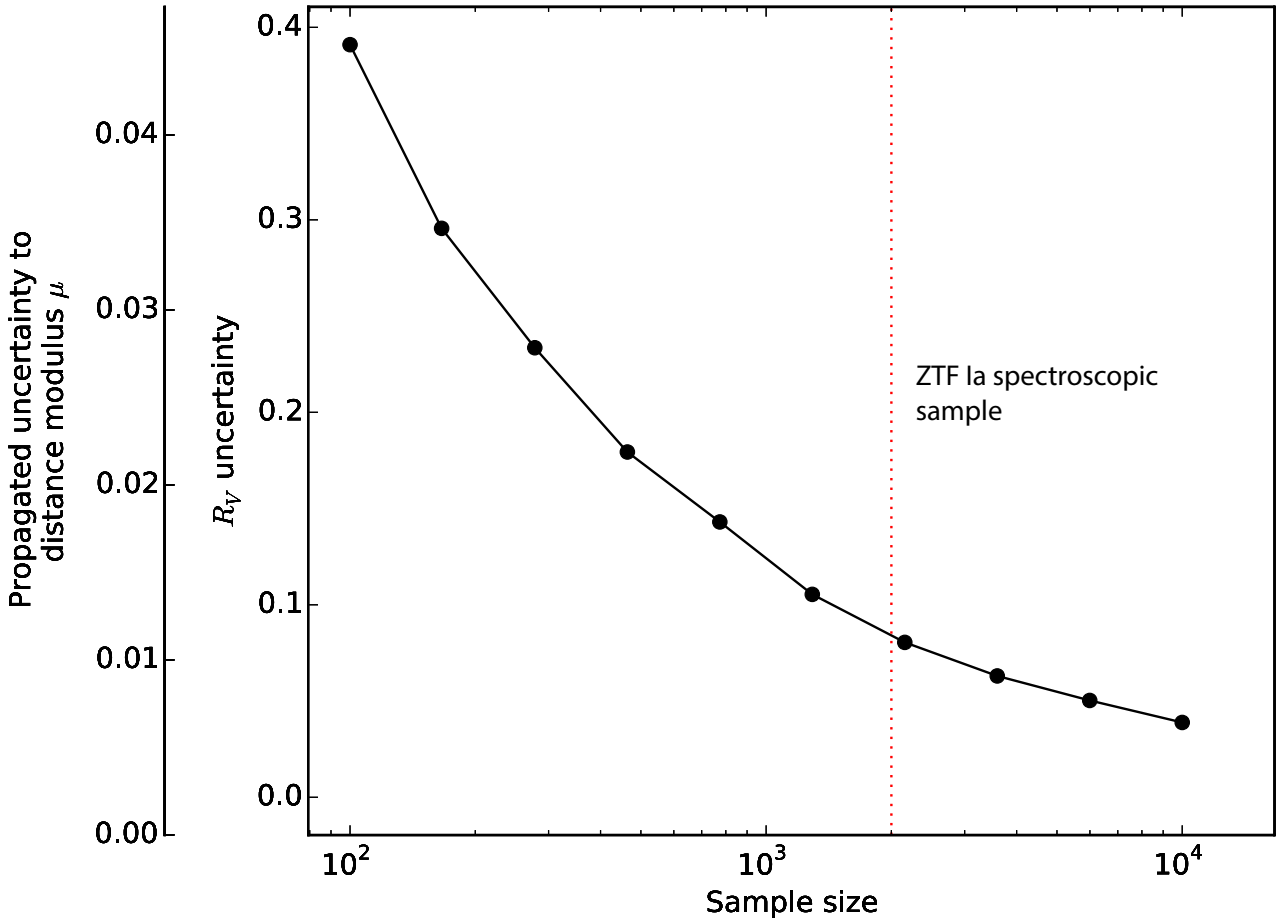


Minimum 2 bands - and at least 3 to also fit R_V

$$\Delta m_B = A_B = (R_v + 1) \cdot E(B-V)$$

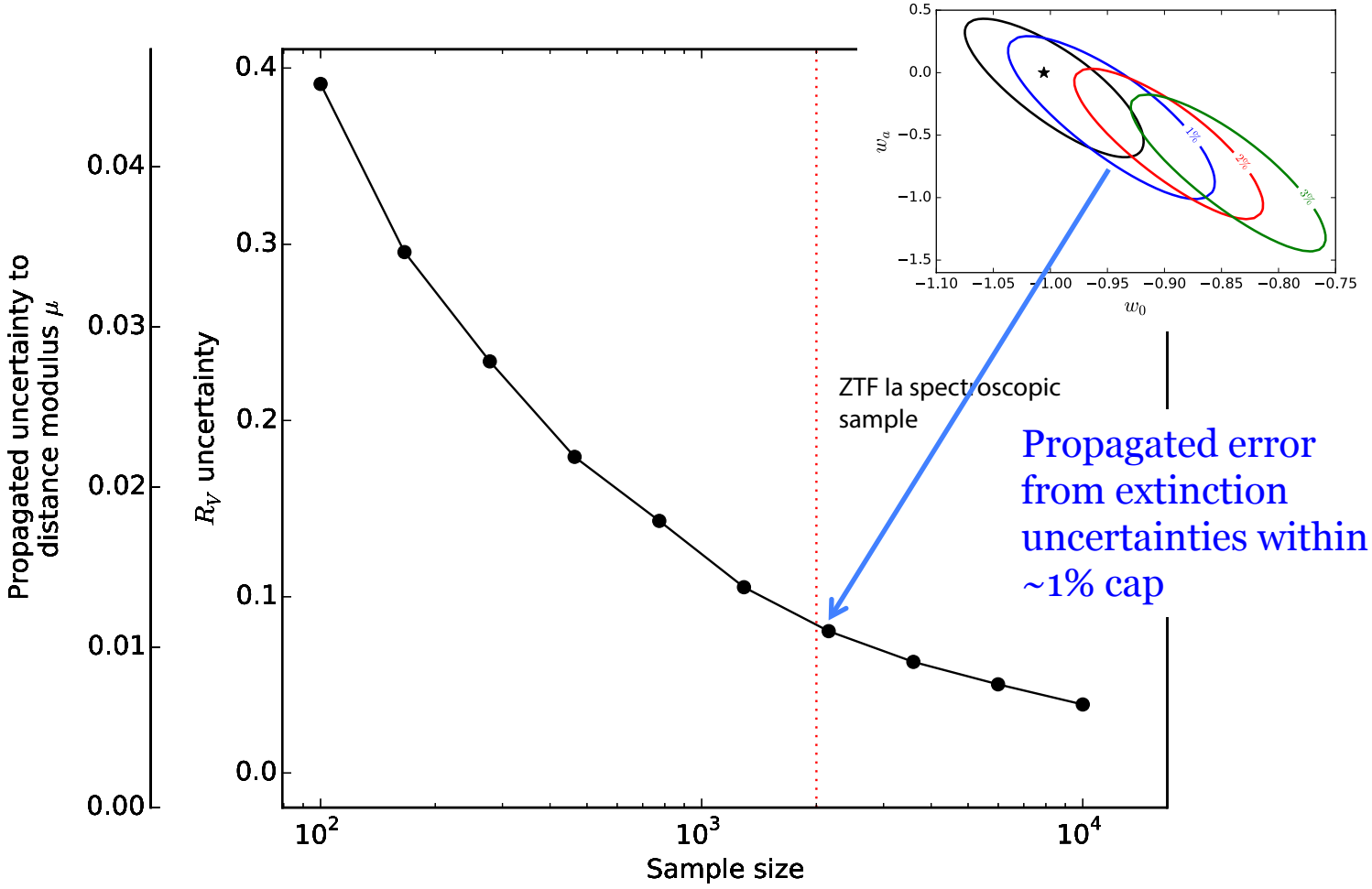


Prospects of also measuring *average* R_V with gri



Monte-Carlo study using low-z reddening and R_v distributions

Prospects of also measuring *average* R_V with gri

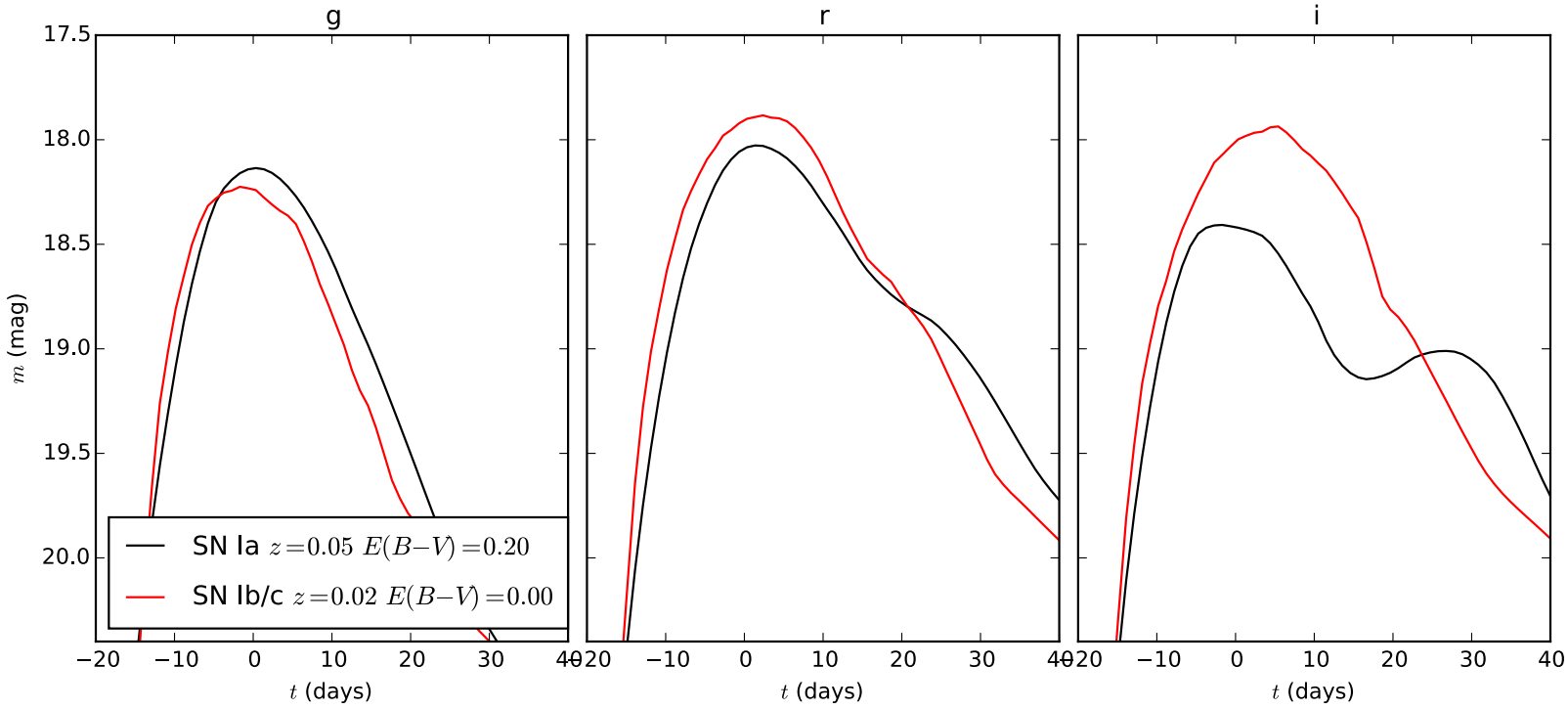


Target SNIa sample

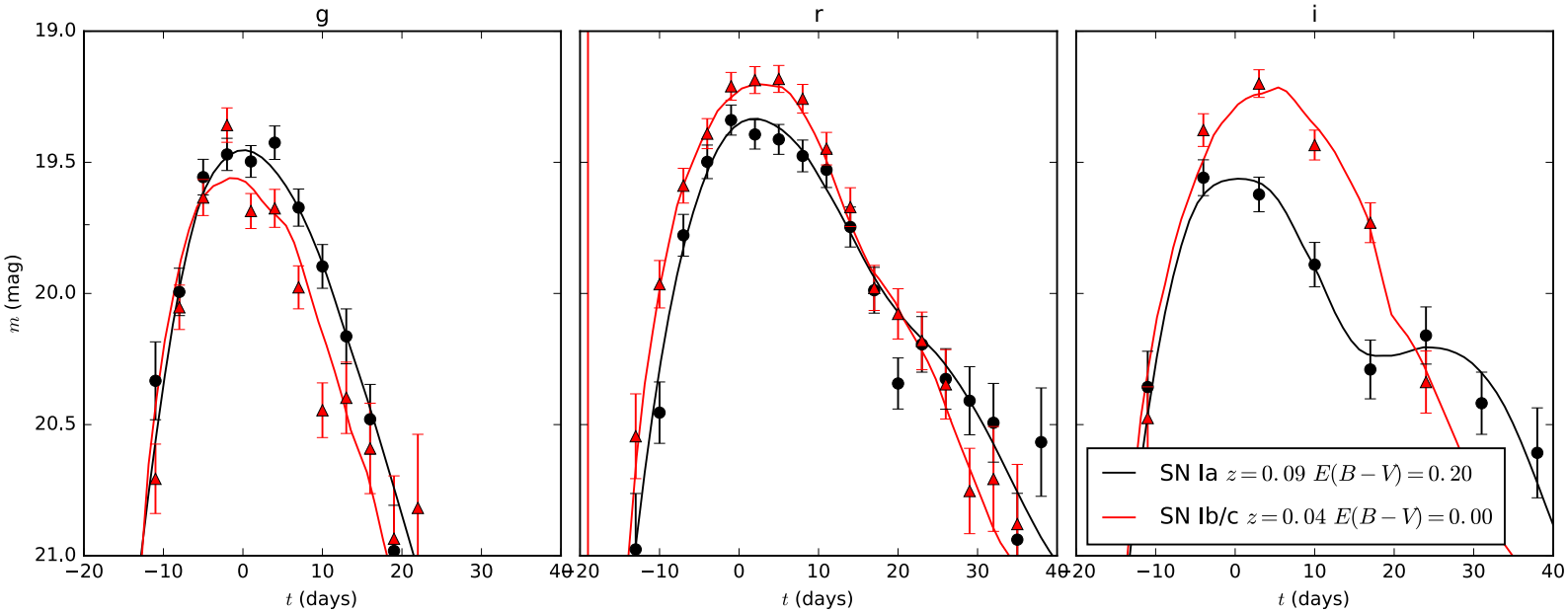
SNIa rates: 3-4000 Sne Ia/year within FoV and redshift range of interest

- 1800 spectroscopicaly ID:ed SNe Ia in galaxies (ideally in the DESI footprint) and within PTF Hα survey.
- Redshift range z≤ 0.1; with up to 1 mag reddening discovered >1 mag below peak.
- High galactic latitude, $E(B-V)_{MW} < 0.1$
- **P48 photometric coverage**: gr + ideally i-band (1 week cadence, reddening + *typing*)
- 2-filter lightcurves (gr) with 3-day cadence, SNR>10 (TBD), ≥15 points. Coverage to day +40
- High-cadence sample, single band (~2000 sq.deg), for *very early* discoveries
- Multi-band (+ spectroscopy) follow-up highly desireable

Photometric typing (I)



Photometric typing (II)



Cadences in gri = (3,3,7)

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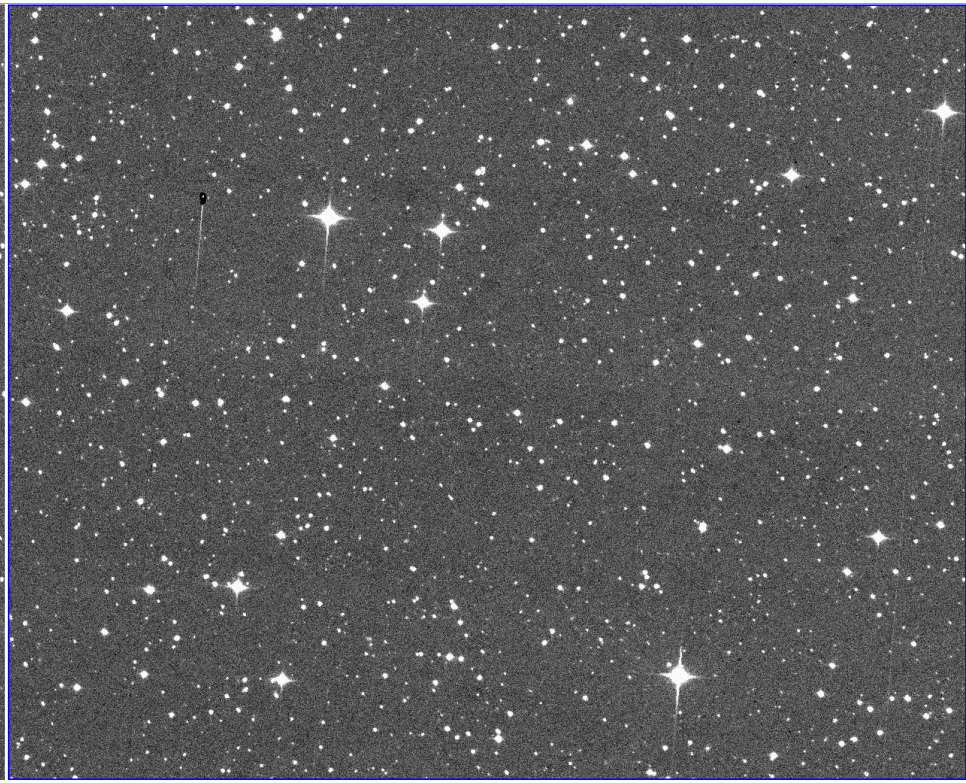
First look at i-band P48 data

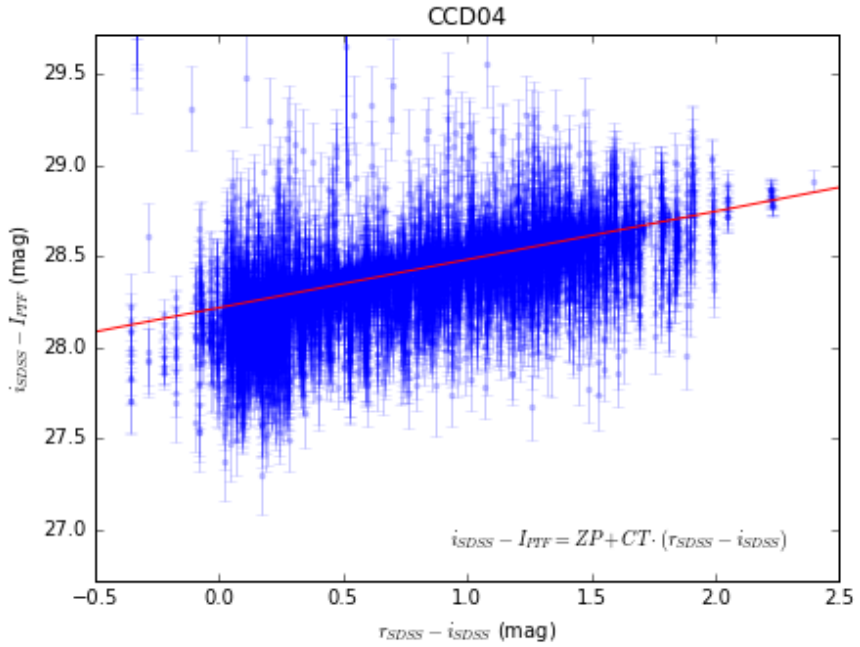
R-band

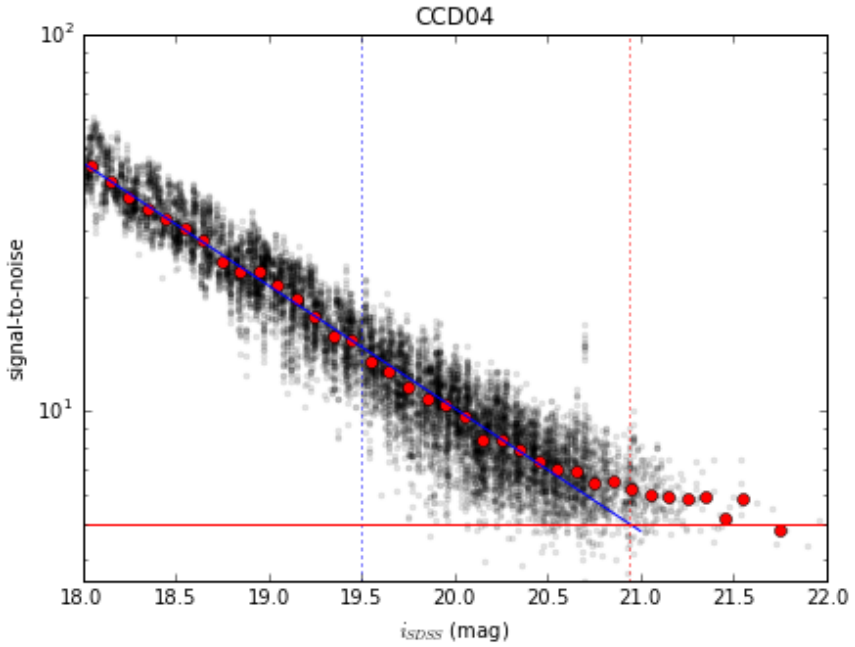
i-band



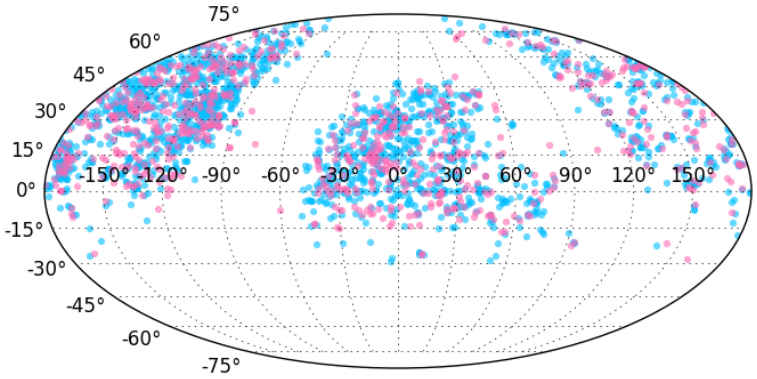
First look at i-band P48 data

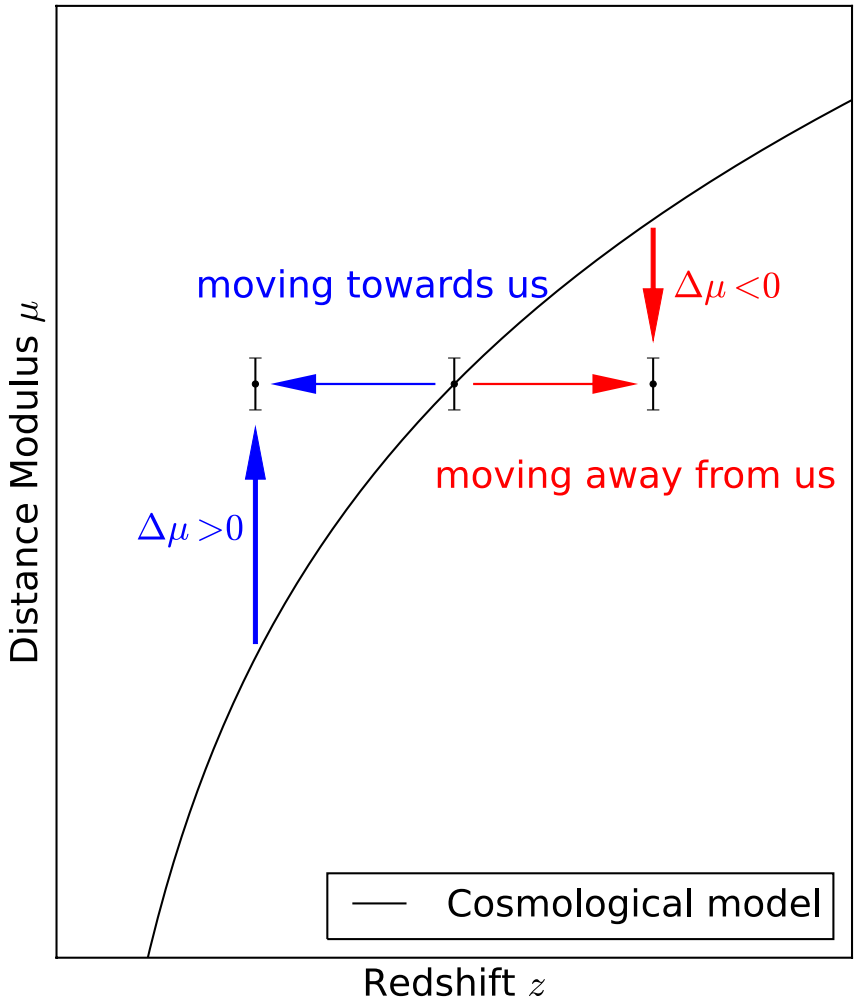
CCD=00 I=20.4 CT=0.10	CCD=01 I=20.4 CT=0.11	CCD=02 I=20.5 CT=0.26	CCD=03	CCD=04 I=20.9 CT=0.26	CCD=05 I=21.0 CT=0.30
CCD=06 I=20.5 CT=0.23	CCD=07 I=20.4 CT=0.11	CCD=08 I=20.5 CT=0.26	CCD=09 I=20.7 CT=0.20	CCD=10 I=20.6 CT=0.20	CCD=11 I=20.5 CT=0.14



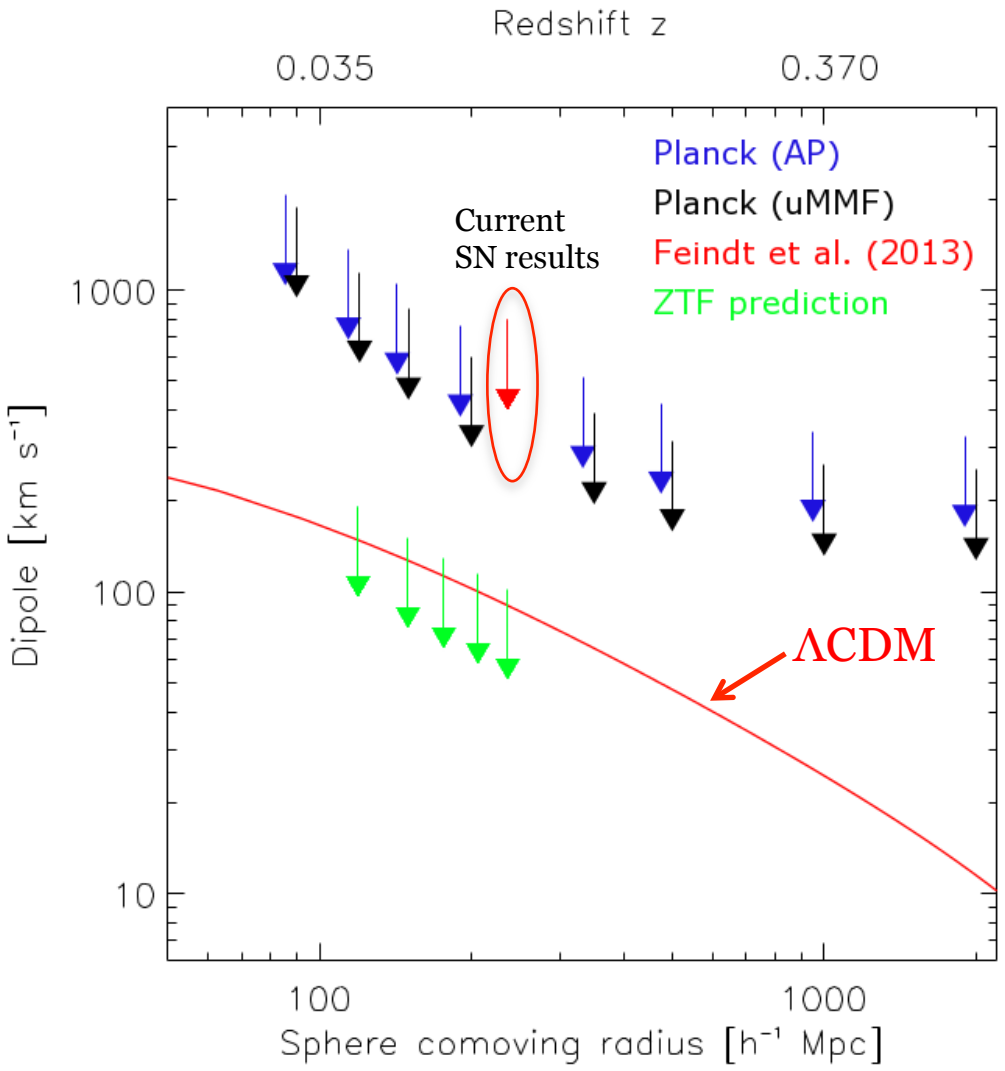


Angular dependent Hubble diagram: studying matter *distribution* from coherent motions: challenging CDM?





Dipole vs ΛCDM prediction:
ZTF in the right ballpark



Summary & Outlook

- ZTF excellent discovery machine for producing the low-z SNIa anchoring sample for precision cosmology to put ΛCDM to severe tests: great legacy value!
- Requirements: 2+1 bands and 1% calibration.
- Active working group: Stockholm-Berlin-Berkeley.
- Willing to collaborate/share tools with *other science* groups. Suggestion: lets use *same tools* to compare FoM of different survey modes for ZTF.