Peculiar Velocities with Type Ia Supernovae

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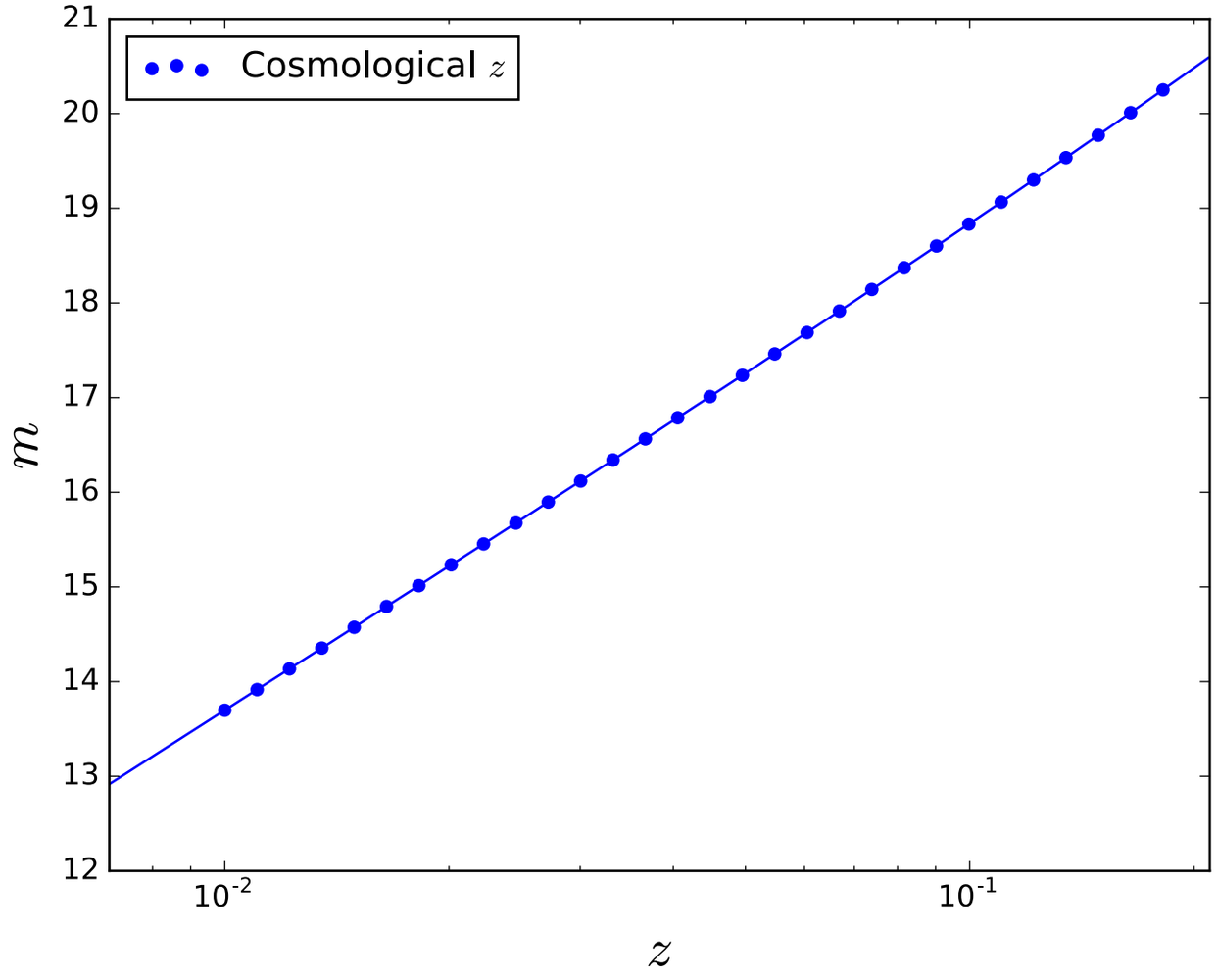
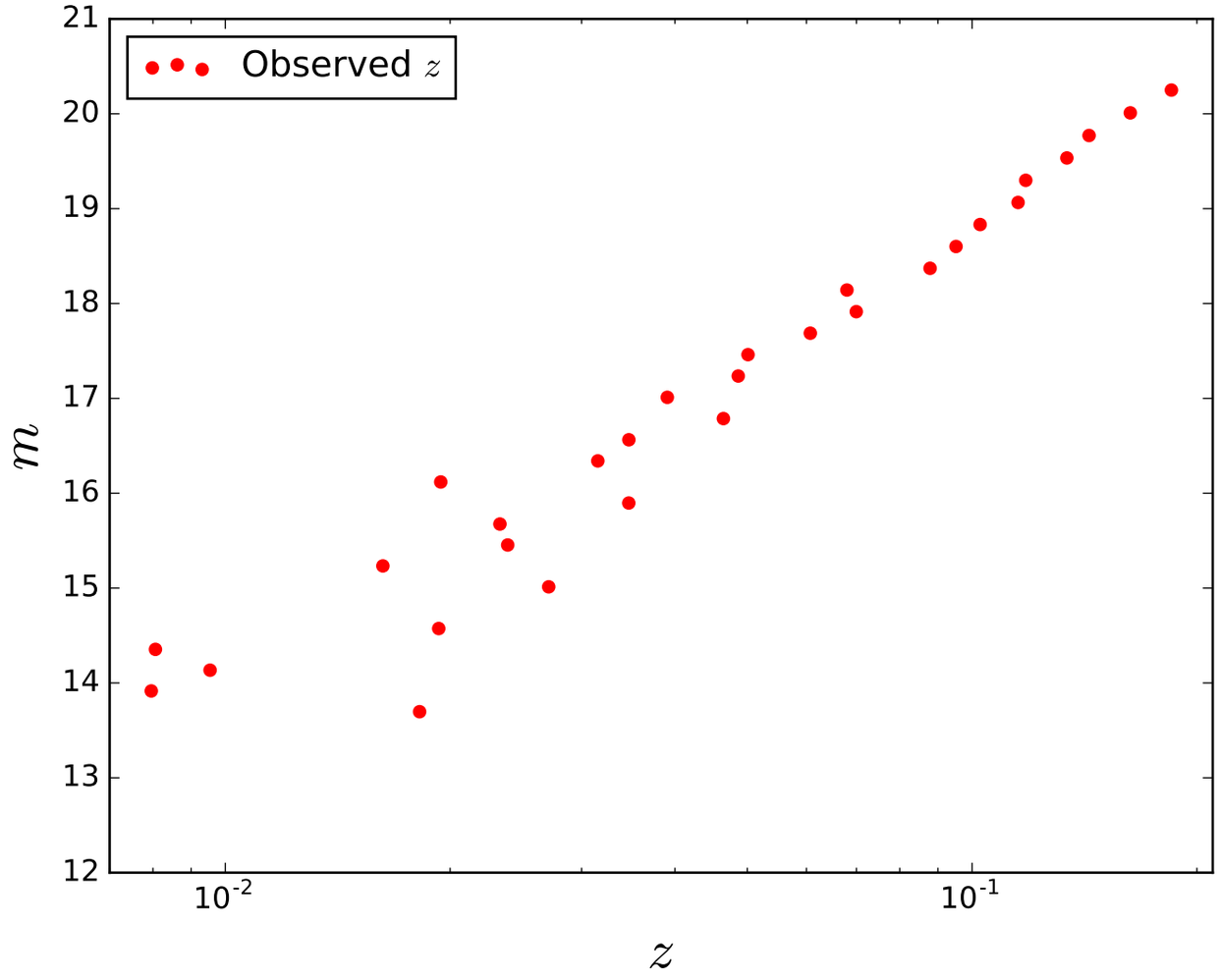
Hubble Diagram: Cosmological Redshift



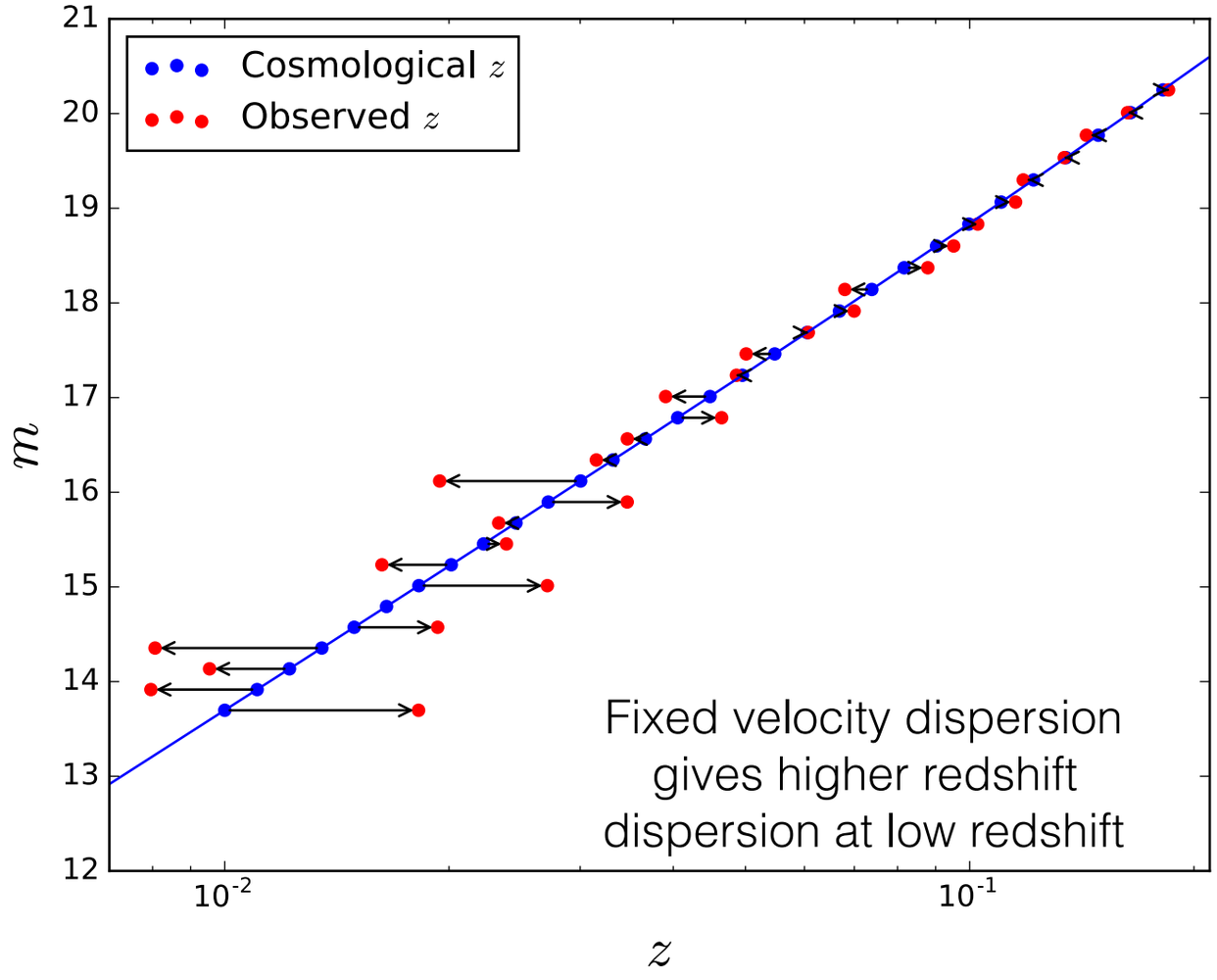
- Perfect standard candles lie on nominal distance-redshift relationship (e.g. Hubble law) when using the cosmological redshift

Hubble Diagram Observed Redshift



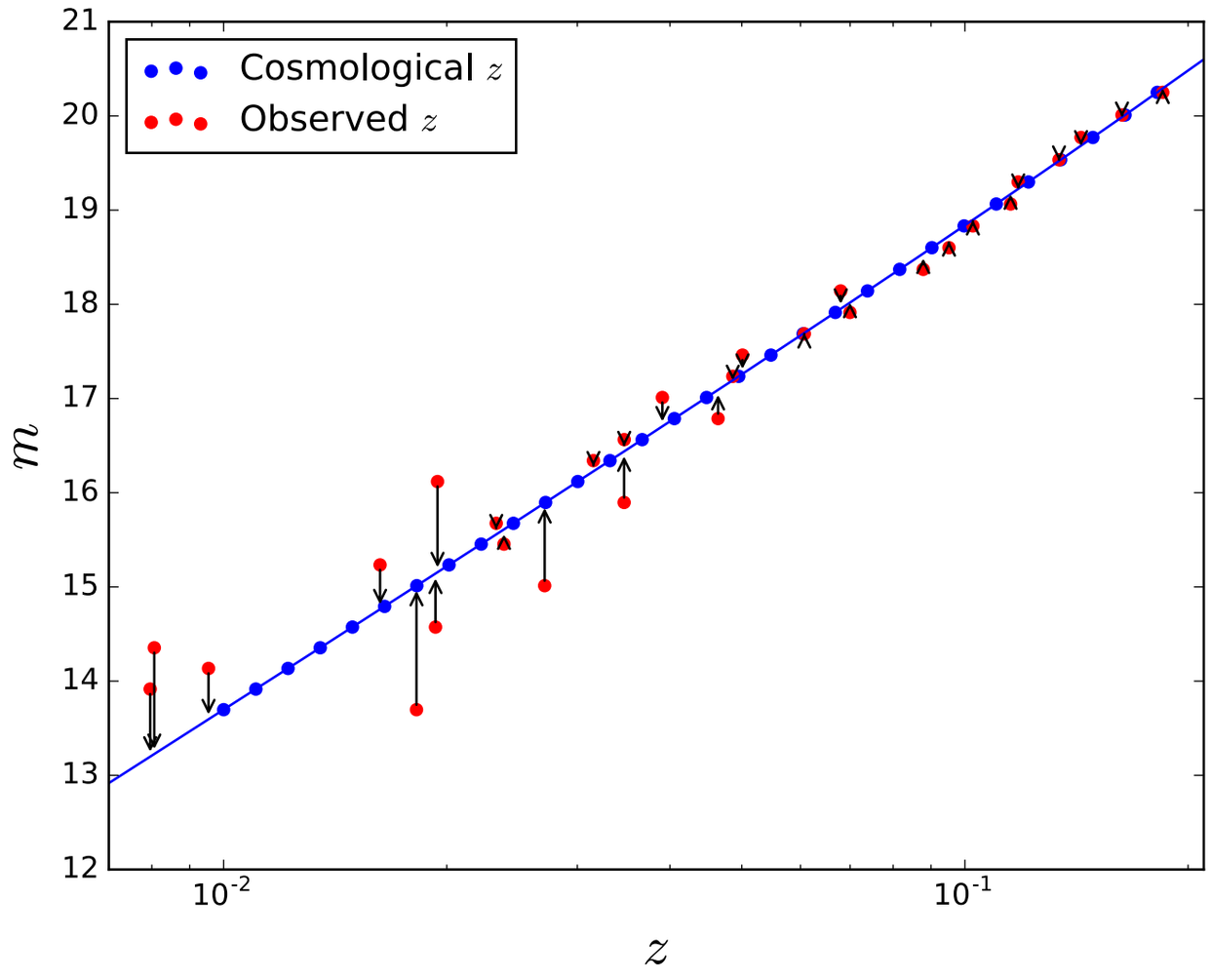
- Don’t actually observe a clean straight line
- Peculiar velocity!

Hubble Diagram: Observed Redshift Due to Peculiar Velocity



- Perfect standard candles with motion relative to the Hubble flow do not lie on nominal distance-redshift relationship when using the observed redshift

Interpreting Observed Redshift as Cosmological Redshift: Peculiar Magnitude

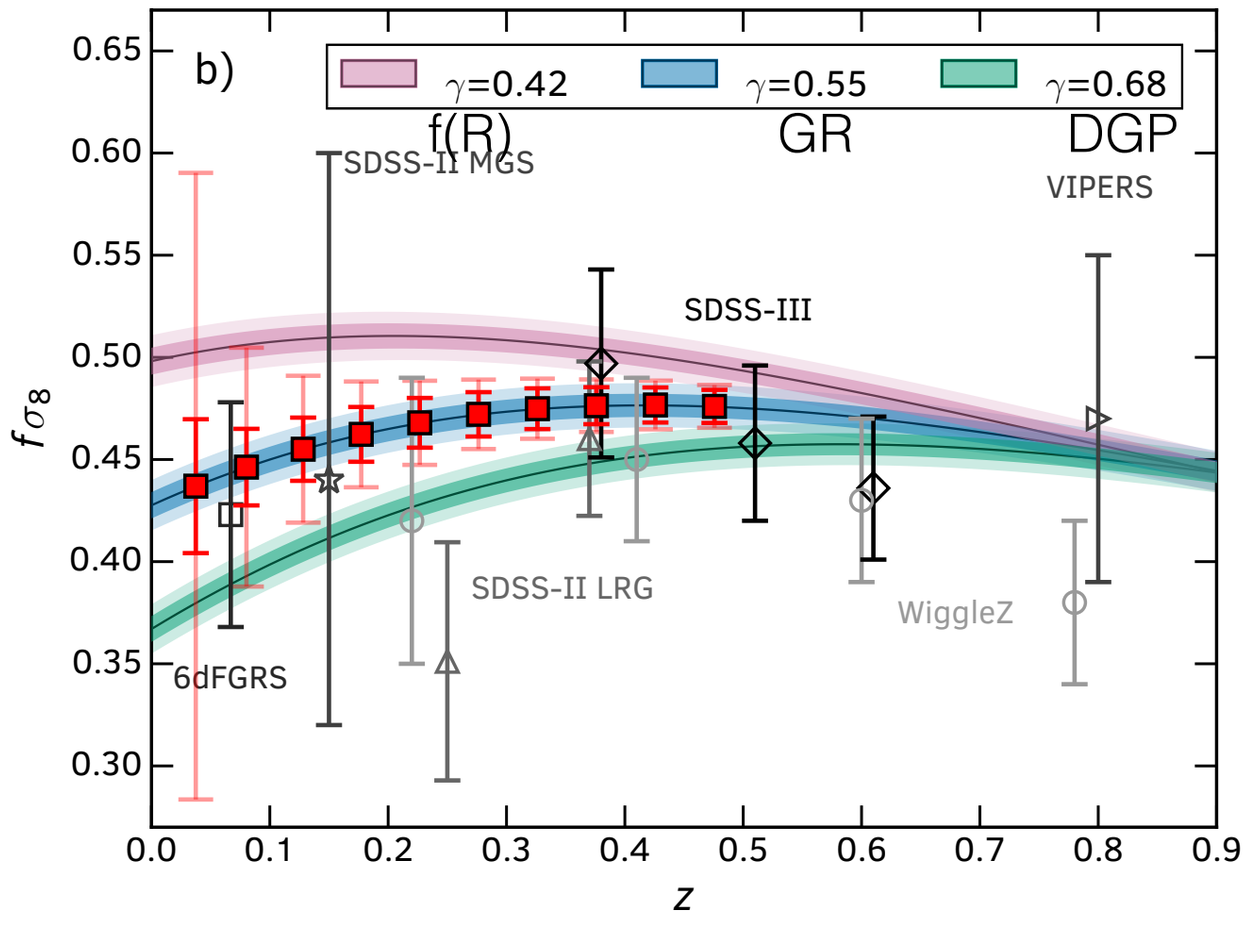


- Redshift offset can be equivalently described as a peculiar magnitude offset
- Best measured with a standard candle with small magnitude dispersion

Type Ia Supernovae Powerful Probes of Peculiar Velocity

- Low intrinsic-magnitude dispersion (after standardization):
  - Depending on data quality σ=0.08-0.12 mag
    - Translates to low peculiar velocity uncertainty
- Ongoing survey (ZTF) and future survey (LSST) provide large numbers of SNe Ia over a large solid angle
  - ~1000 SNe/year over 14000 square degrees

$f\sigma_8$ Measured with LSST SN Peculiar Velocities



Howlett, Robotham, Lagos, Kim (2017)

- Peculiar velocities of LSST-discovered SNe Ia tests GR and other gravity models

- Cross-correlation with galaxy surveys powerful

Type Ia Supernovae Versus Galaxies as a Probe of $f\sigma_8$

- Galaxy intrinsic magnitude dispersion ~4x larger than SN Ia
  - SN Ia low intrinsic dispersion means less room for systematics
  - 40,000 Taipan galaxies vs 5000 SNe Ia after 5 years
    - “Infinite” number of SNe to improve statistics for the patient
  - SNe have 2=16/8 variance advantage relative to galaxies
  - ZTF and LSST SN surveys have clean sample selection and photometric calibration

Need for Spectroscopy

- SN Classification (time-critical when SN is bright)
- Host-galaxy redshift (not time-critical)
- Small intrinsic magnitude dispersion
    - Photometric classification and redshifts come with larger uncertainties and systematics

What Kind of Spectroscopy?

- Active supernovae: 1/100/sq.deg. for m<20.5
    - (Not so much benefit for going deeper)
- Supernovae after three years of survey: 3/sq.deg. m<20.5
- Host-galaxy redshift measurement R~>1000
- SN classification R>75
- SN twinning (0.08 mag intrinsic dispersion)
    - Spectrophotometry

Desired Telescope and Instrument

- Small aperture telescope < 1-2 m
    - z<0.2 SNe are bright
- Small field of view, single object targeting
    - Low surface density of targets
- Moderate resolution spectroscopy
    - SN features broad, precise redshift
- BONUS IFU spectroscopy
    - SN features to calibrate the standardizable candle, reduce intrinsic dispersion

Non-PV Spectroscopy Science

- Magnitude-limited transient survey

- SN Ia properties