Distances with Supernovae

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on behalf of a community of others

SN Ia Data at the Beginning of the LSST Era

High-redshift: 5,000

- DES
- PS-1/PS-2
- SNLS
- SDSS-II
- ESSENCE

Low-redshift: 2,000

- SNfactory
- Palomar Transient Factory
- La Silla Supernova Search
- Carnegie Supernova Program
- Center for Astrophysics
- KAIT/LOSS survey
- NOAO/WIYN NIR SNeIa
- SkyMapper
- Zwicky Transient Factory
- YUFSS (Your Unjustly Forgotten Supernova Survey)

Optical+NIR Spectra

High-z:

Confirmation

Evolution studies

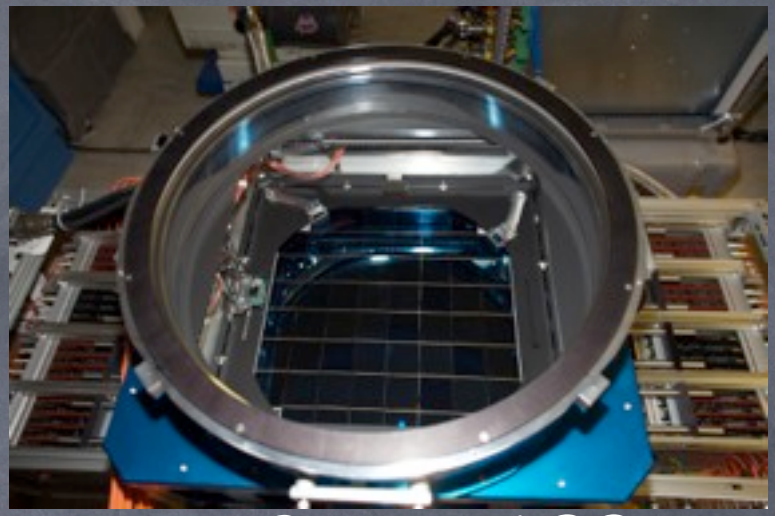
Low-z:

Indepth UV-NIR Spectrophotometry

Current and Future SN Surveys

Dark Energy Survey

photo: Rich Talcott



Pan-STARRS 1

photo: John Tonry

+SkyMapper, DES, KAIT, PTF, ...

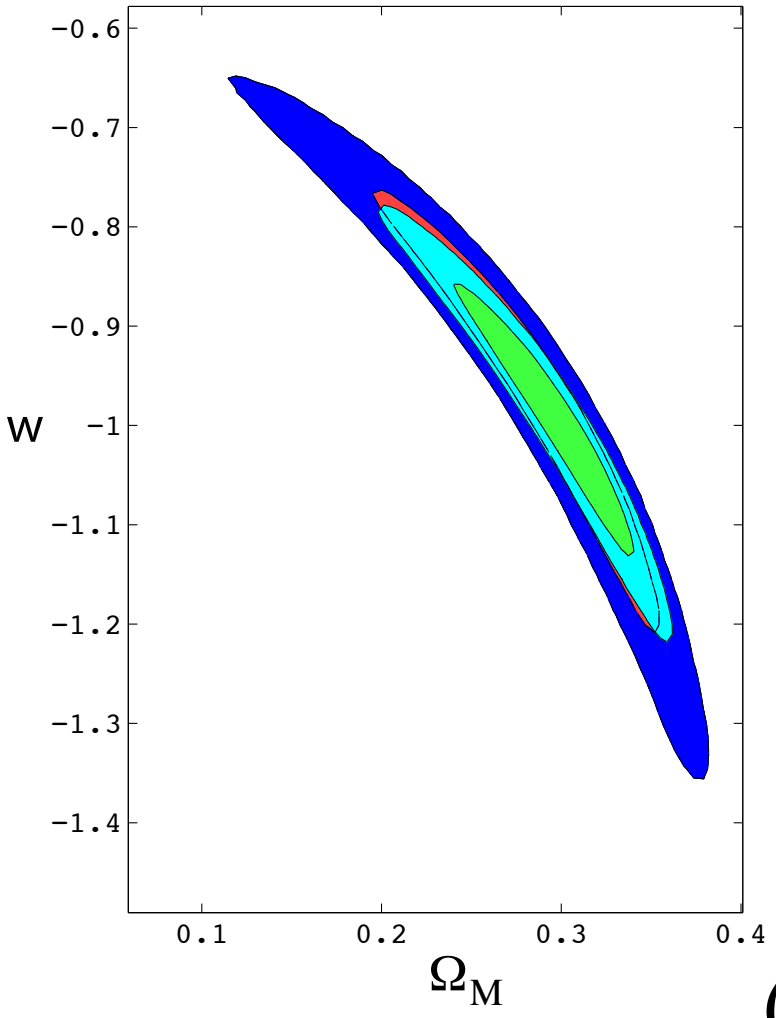
SuperNova Legacy Survey

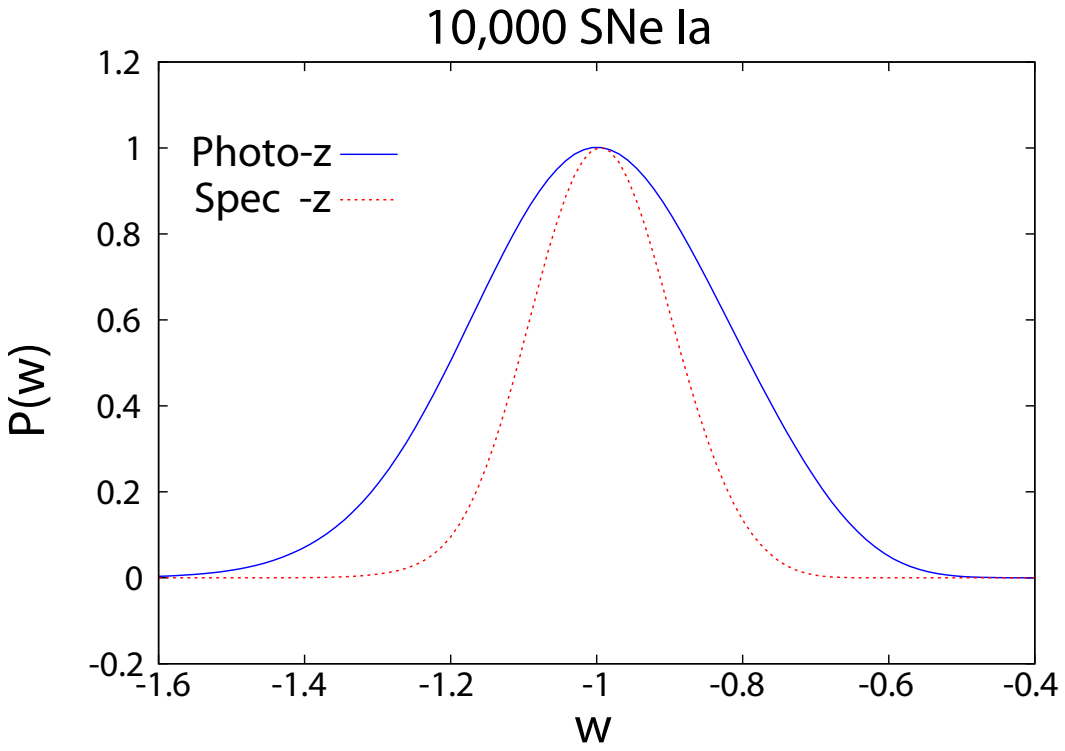
photo: Tom Kerr

LSST

photo: LSST Corporation

Taking pictures is sufficient for measuring w in an ideal world.

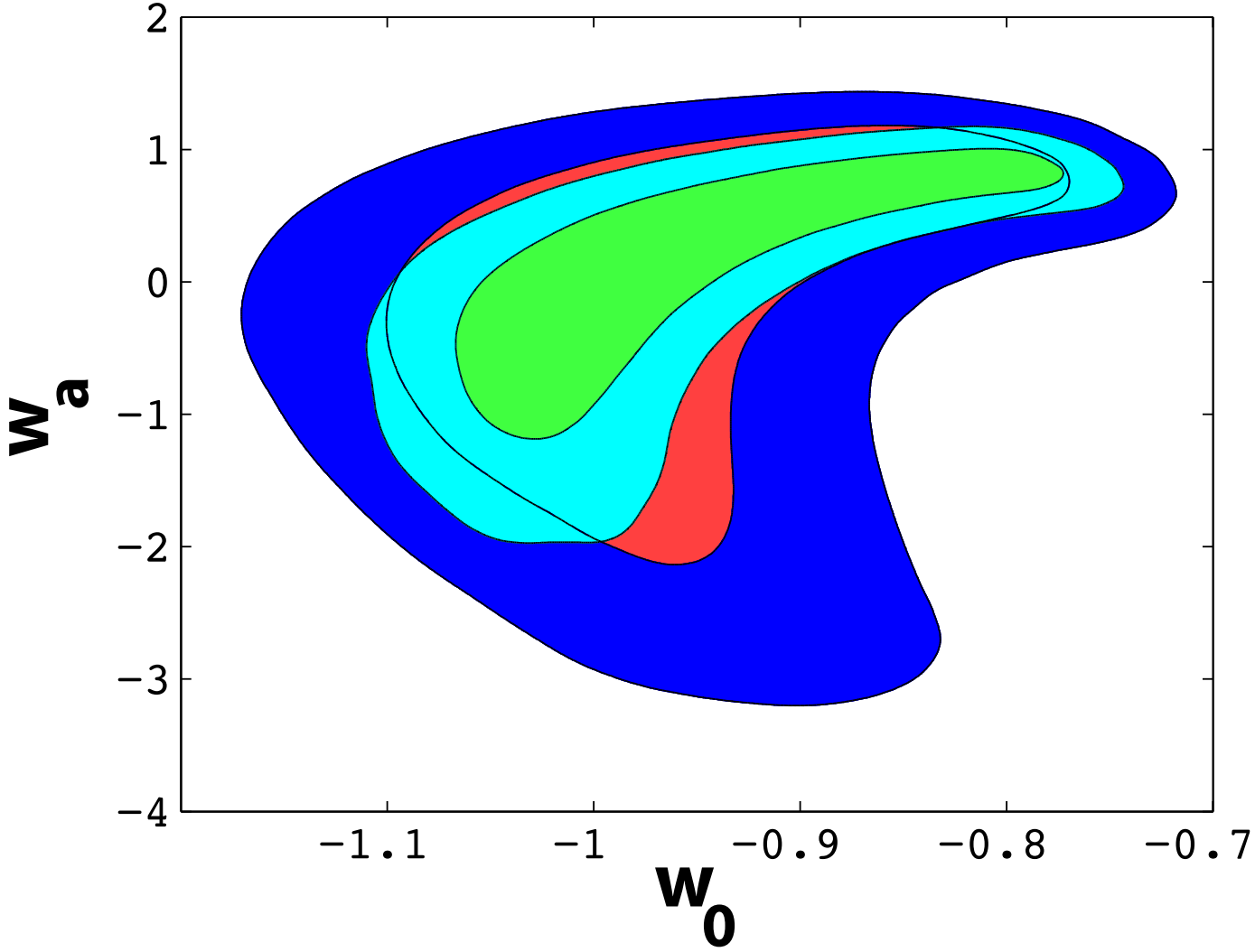




LSST SNeIa alone constrain constant w in a flat Universe

(LSST Science Book arXiv:0912.0201)

50,000 SNela Constrain Evolving w in a Flat, Kind Universe



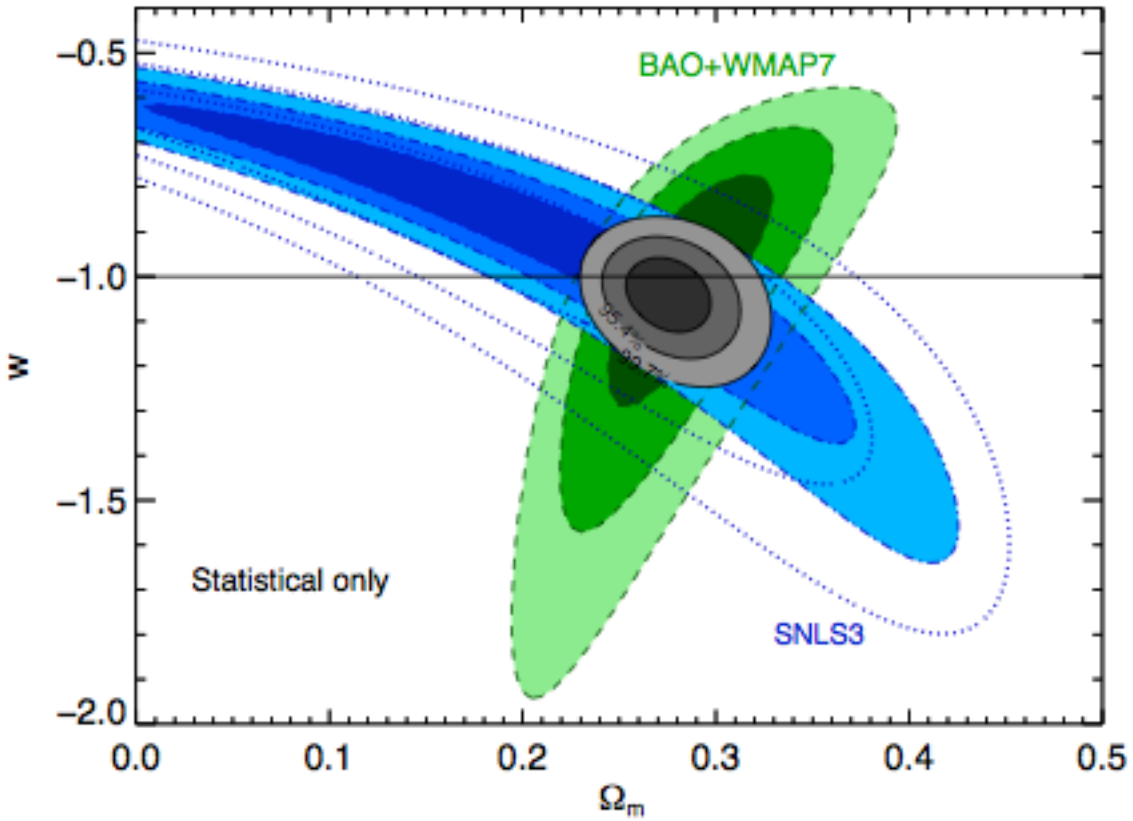
(LSST Science Book arXiv:0912.0201)

What Do We Need to Achieve LSST Projection

The three challenges are all focused on reducing systematics:

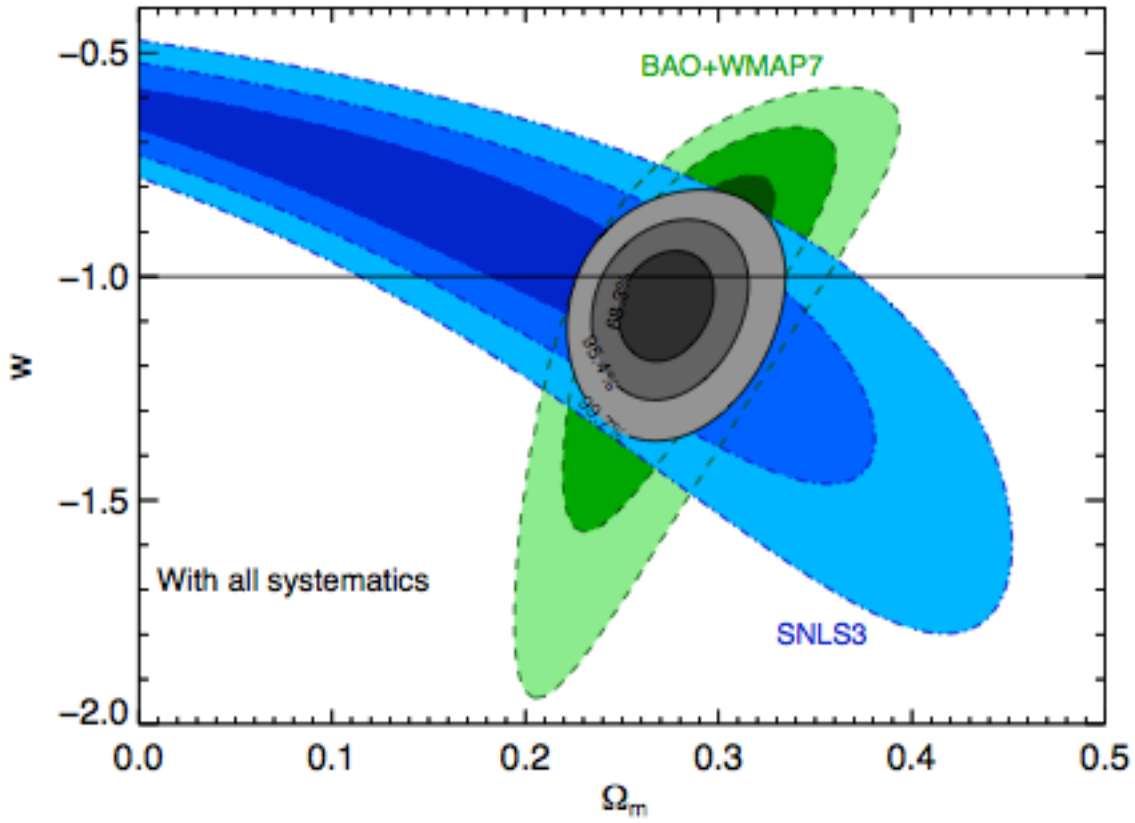
- **Photometric Calibration** – largest limiting factor in the use of SNe Ia today as cosmological probes.
  80% of w-OM systematics area
- **Supernova Ia Calibration** – determine the best way (smallest statistical and systematic errors) to use SNe Ia to measure distances.
- **Spectroscopy** – eliminate and constrain non-SN Ia contamination. Learn physics.

Current State of SN Ia Cosmology



SNLS: Conley et al. (2011); Sullivan et al. (2011)

Current State of SN Ia Cosmology



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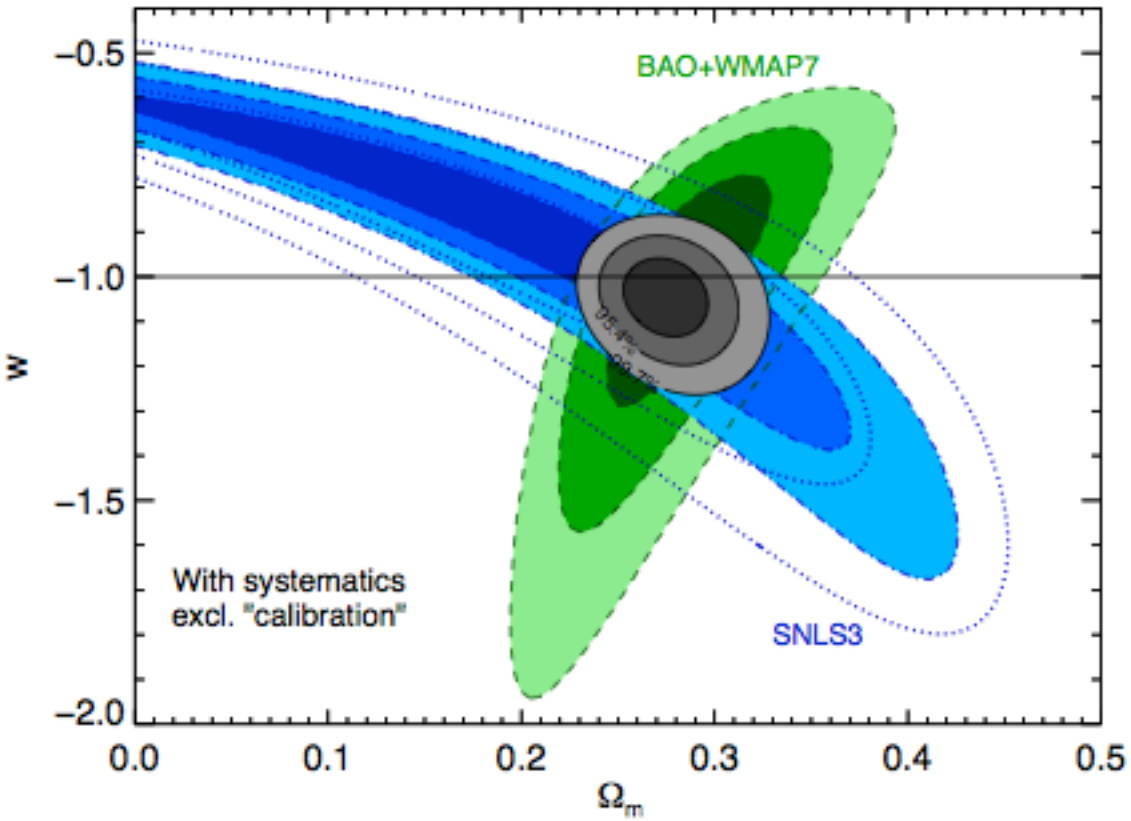
Current State of SN Ia Cosmology



SNLS: Conley et al. (2011); Sullivan et al. (2011)

Astronomical Calibration

Extinction above the atmosphere

$$\phi(i,j) = \sum_{sources} \int S(\lambda)A(\lambda)G(\lambda)T(\lambda)\, d\lambda$$

Source **Atmosphere** **Instrumental transmission**

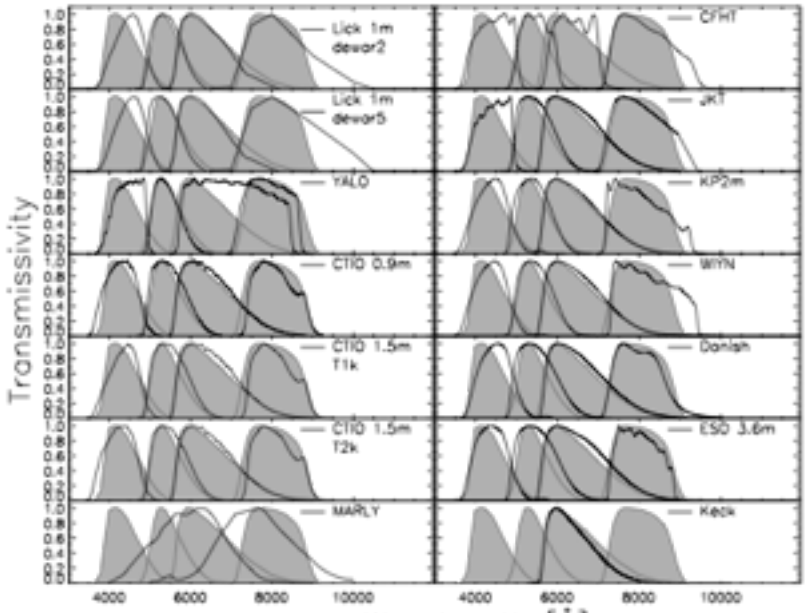
"Metrology and Meteorology"

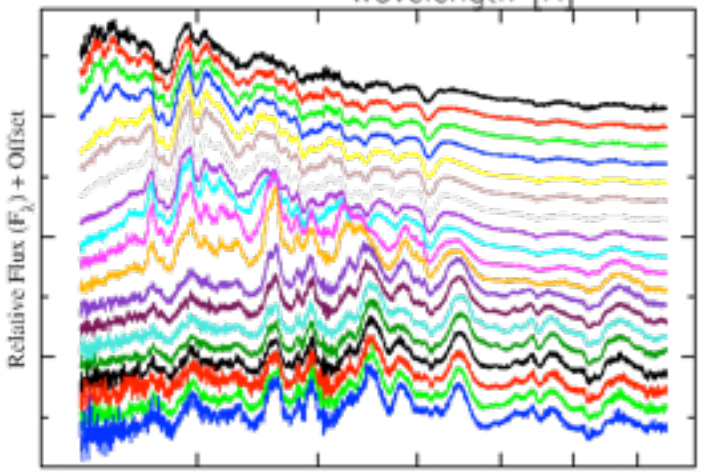
Historical Integral-constraint-approach insufficient
Must now separately determine each component

(Chris Stubbs)

Spectrophotometry is Ideal: S(λ)

S-corrections





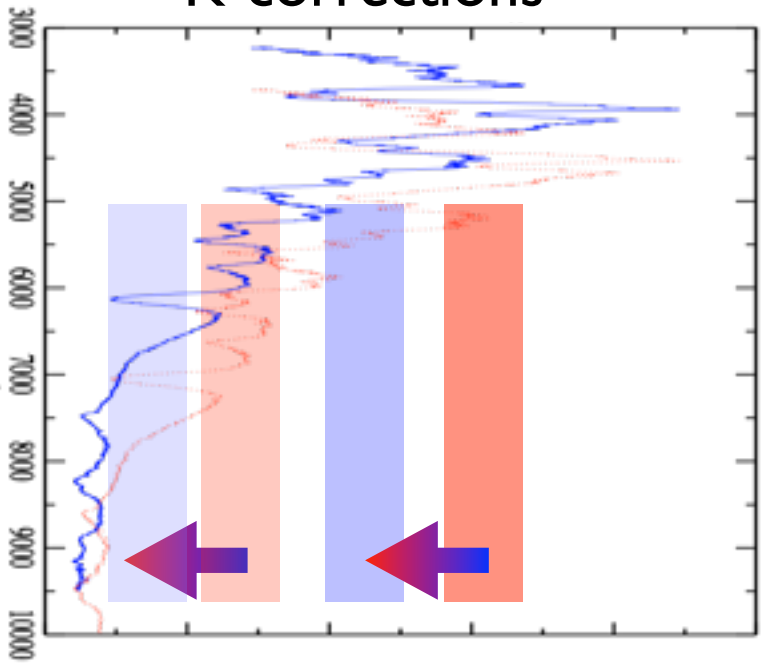
Wavelength ⟶

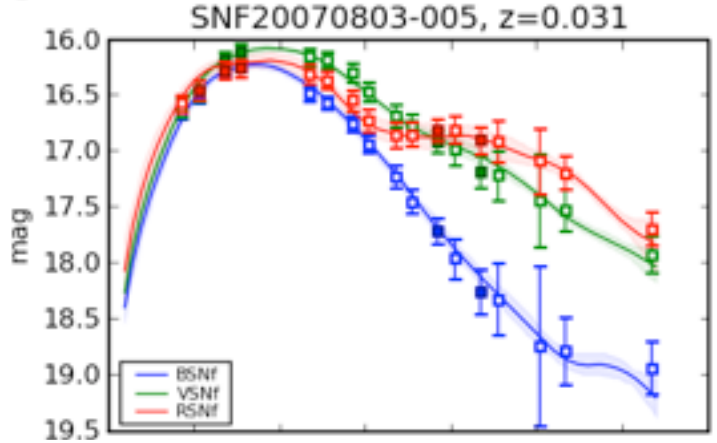
Date ⟶

(SNfactory)

K-corrections

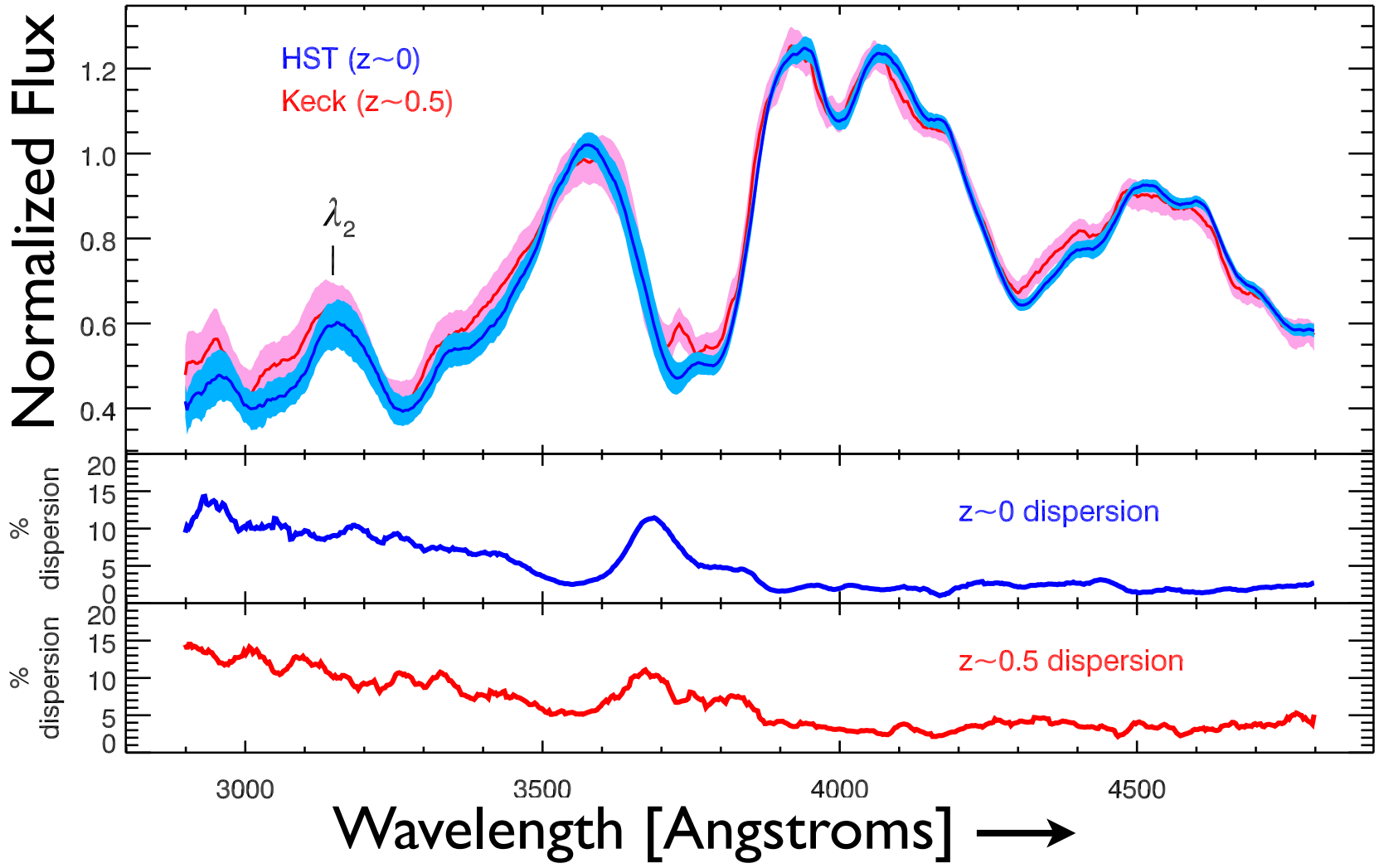
Wavelength ⟶





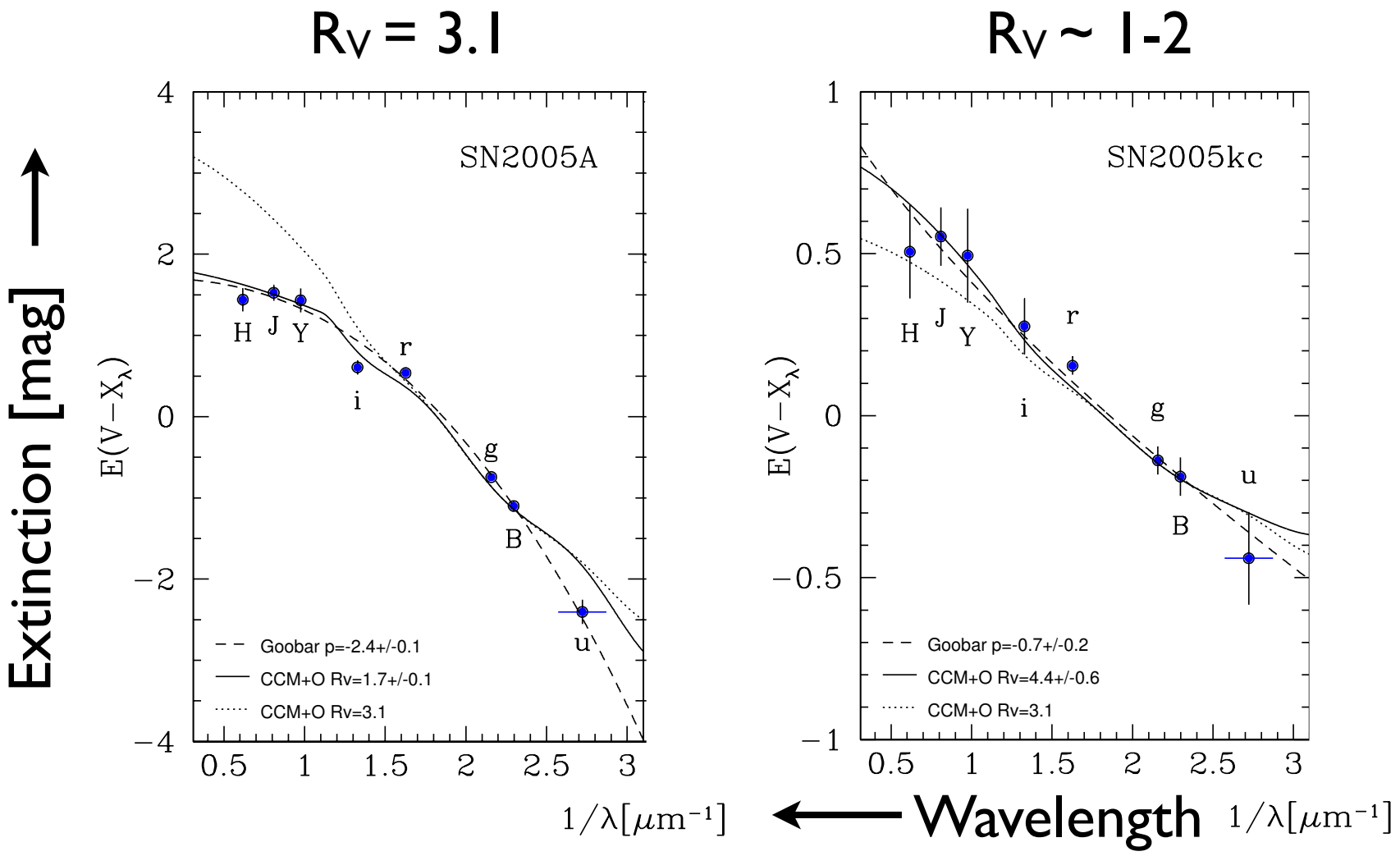
Date ⟶

Spectra Test z Evolution of S(λ)



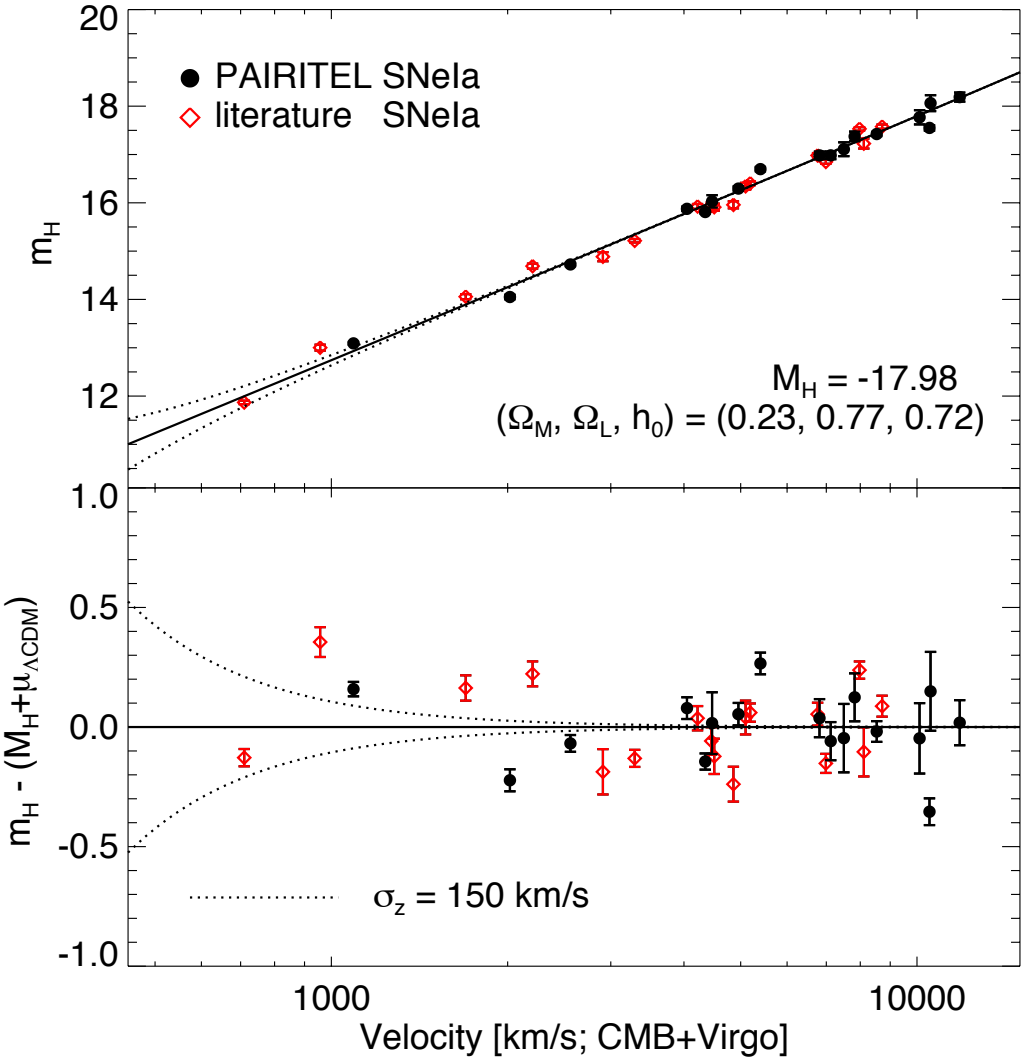
(Ellis et al 2008; Maguire et al 2012; also Foley et al. 2008

NIR Helps Measure Dust: G(λ)

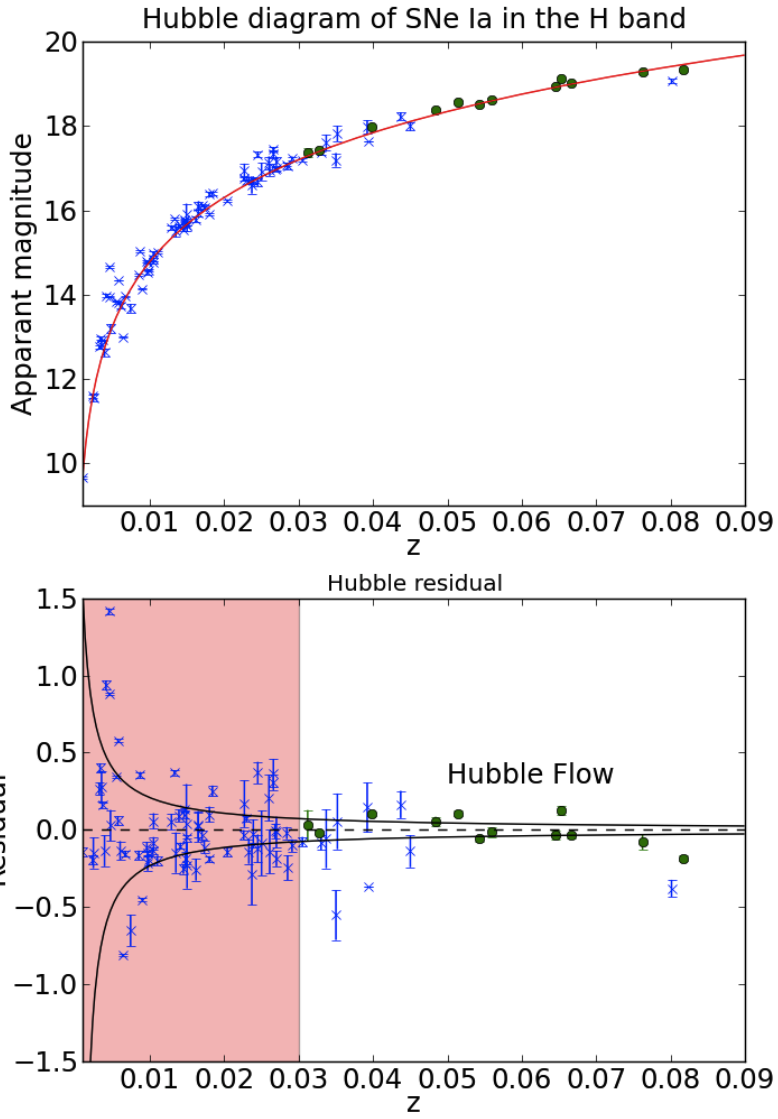


(Folatelli et al. (2010); also Goobar 2008; Amanullah & Goobar 2011)

NIR SNela measure Distance to 5%

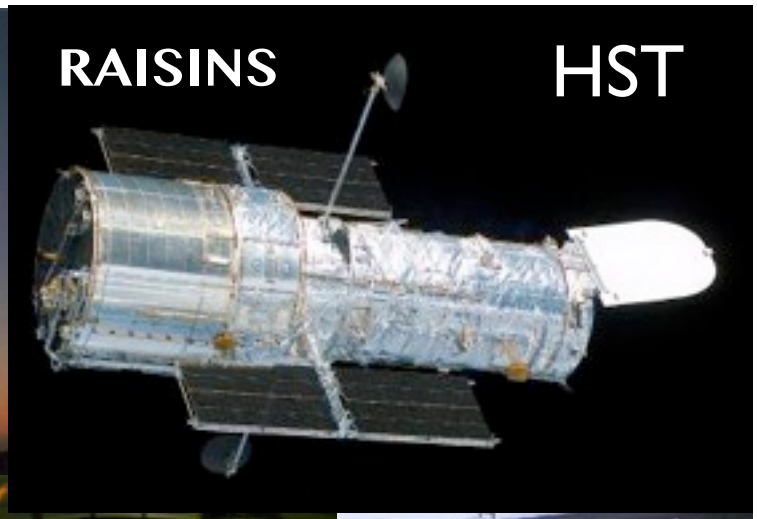


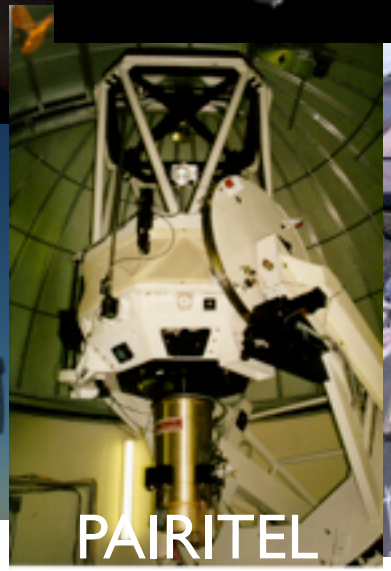
Wood-Vasey et al. (2008)



Barone-Nugent et al. (2012)

We are Obtaining more SNIa NIR



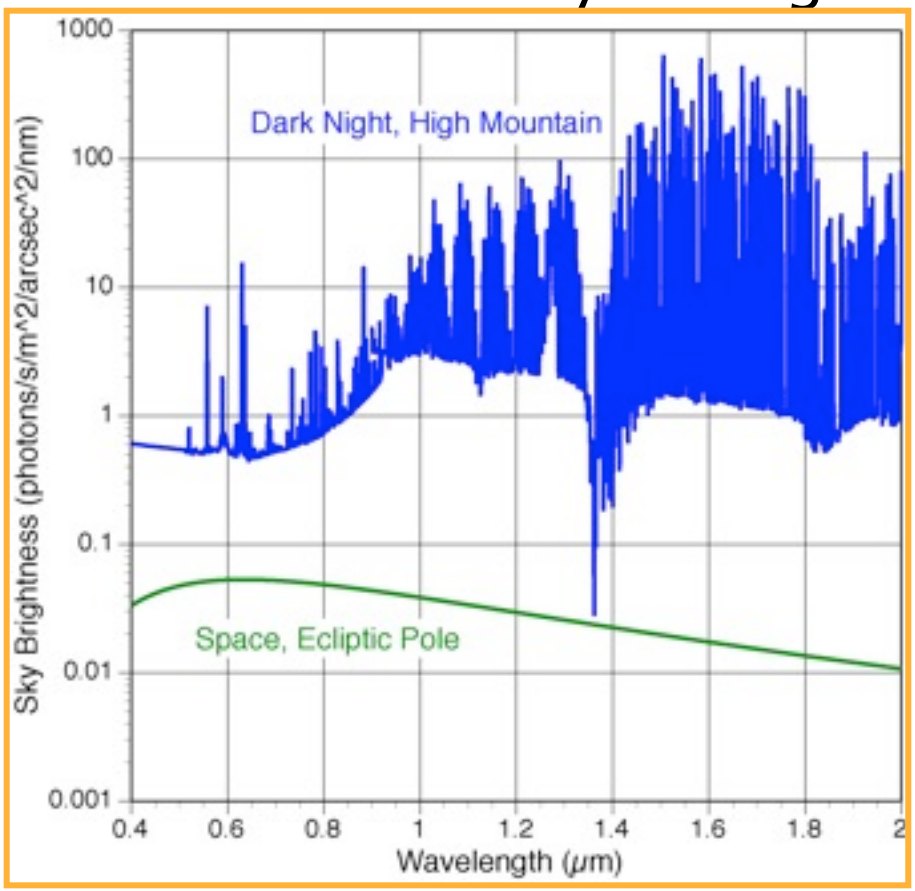


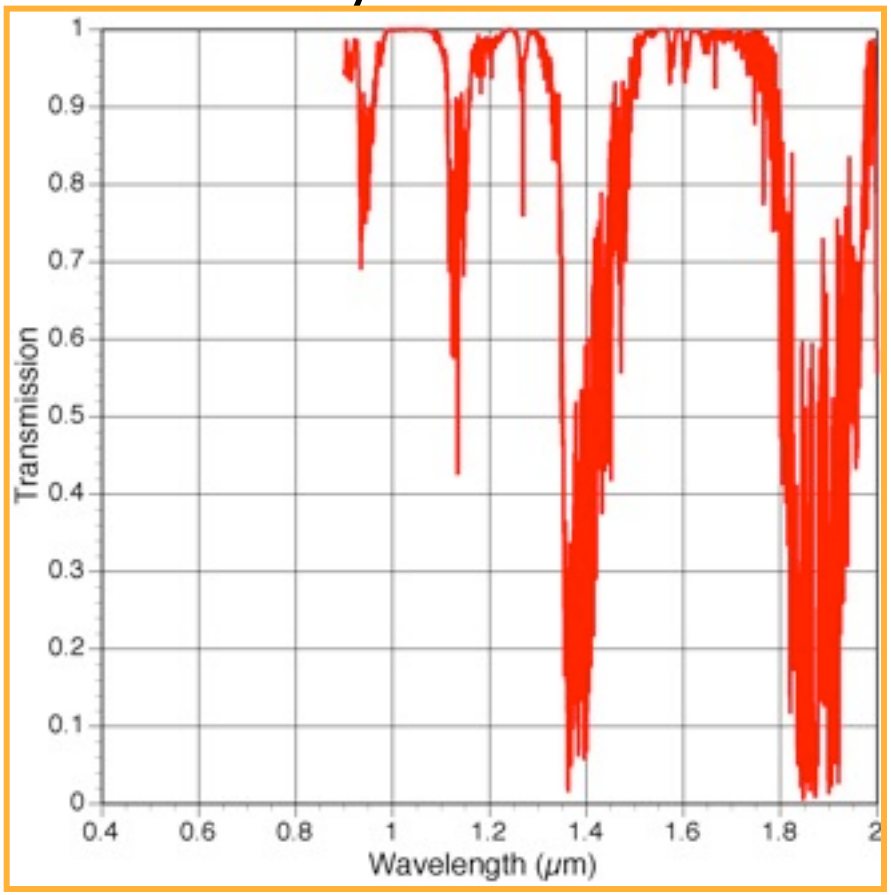
Going to z>0.1 requires space[*]

z~1 NIR SNeIa Requires Space With Current Technology

Ground Sky is 100x brighter than Space in NIR:

Ground Sky is not transparent in NIR: absorption due to water is very strong and extremely variable



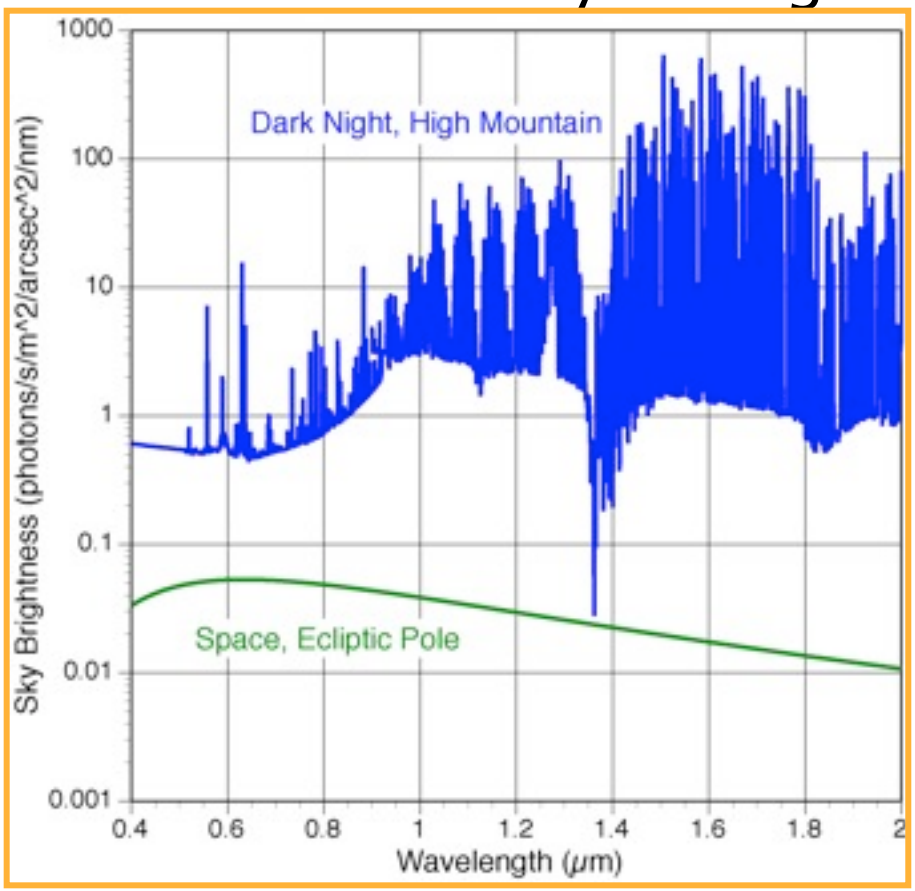


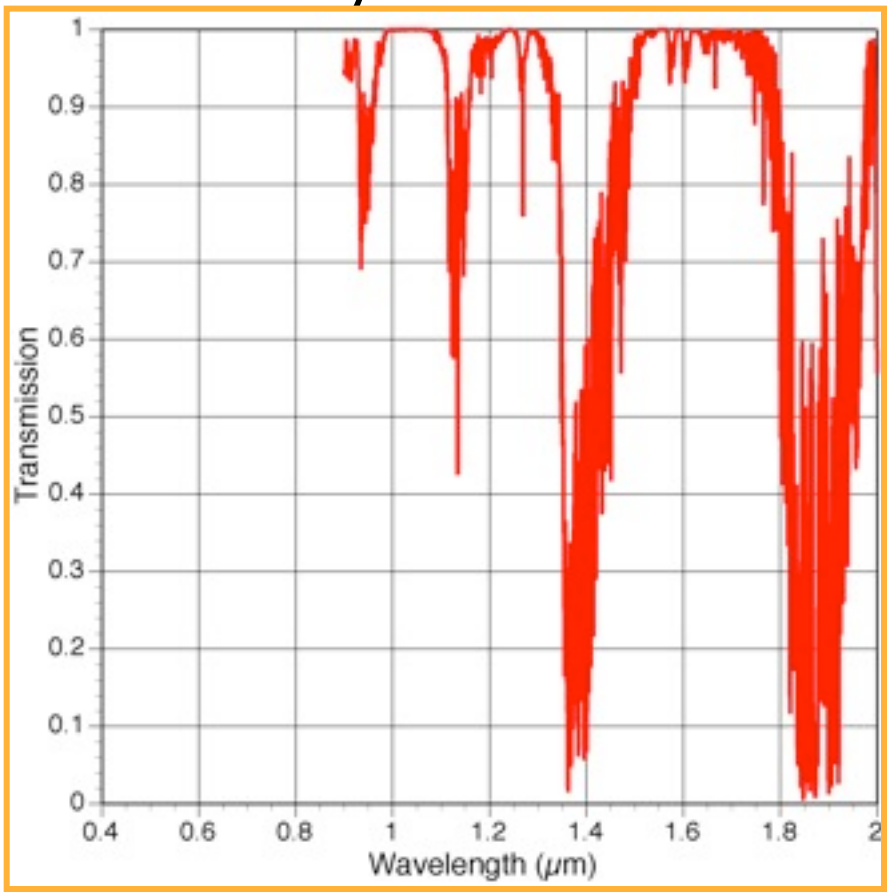
(Courtesy Bob Kirshner)

z~1 NIR SNeIa Requires WFIRST

Ground Sky is 100x brighter than Space in NIR:

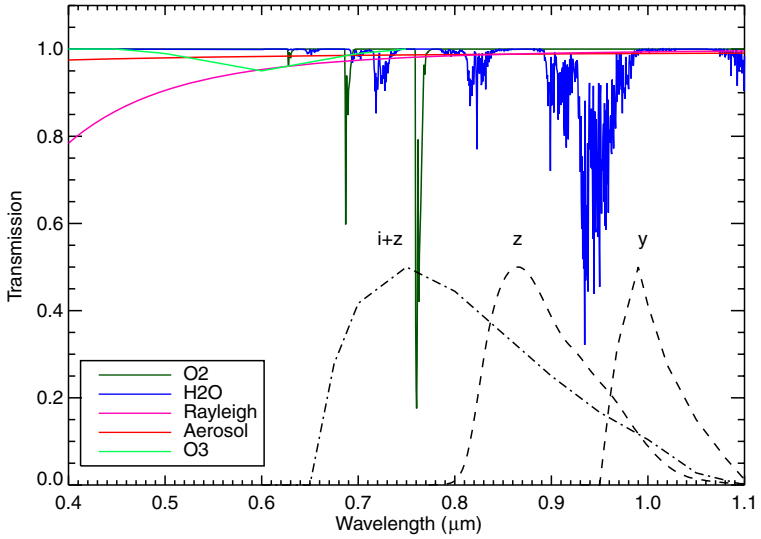
Ground Sky is not transparent in NIR: absorption due to water is very strong and extremely variable

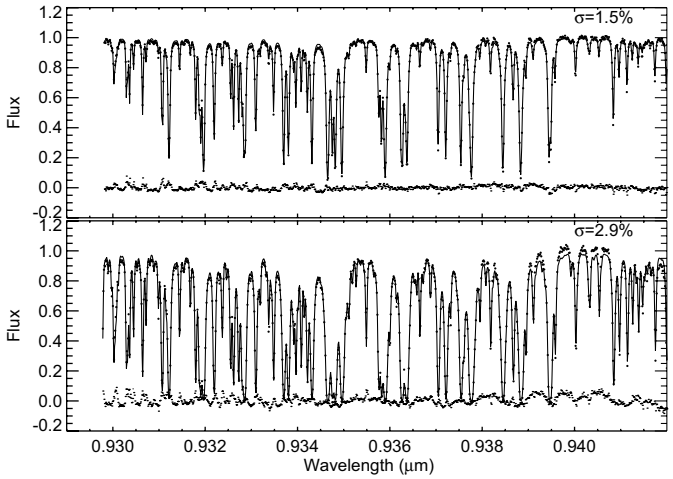


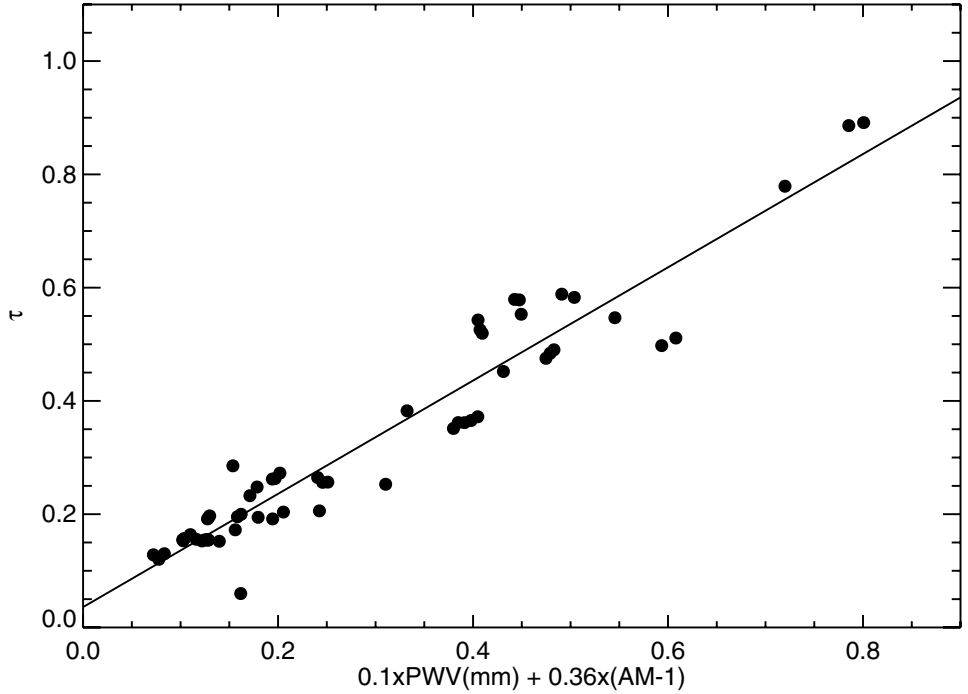


(Courtesy Bob Kirshner)

Calibrate Atmosphere with GPS



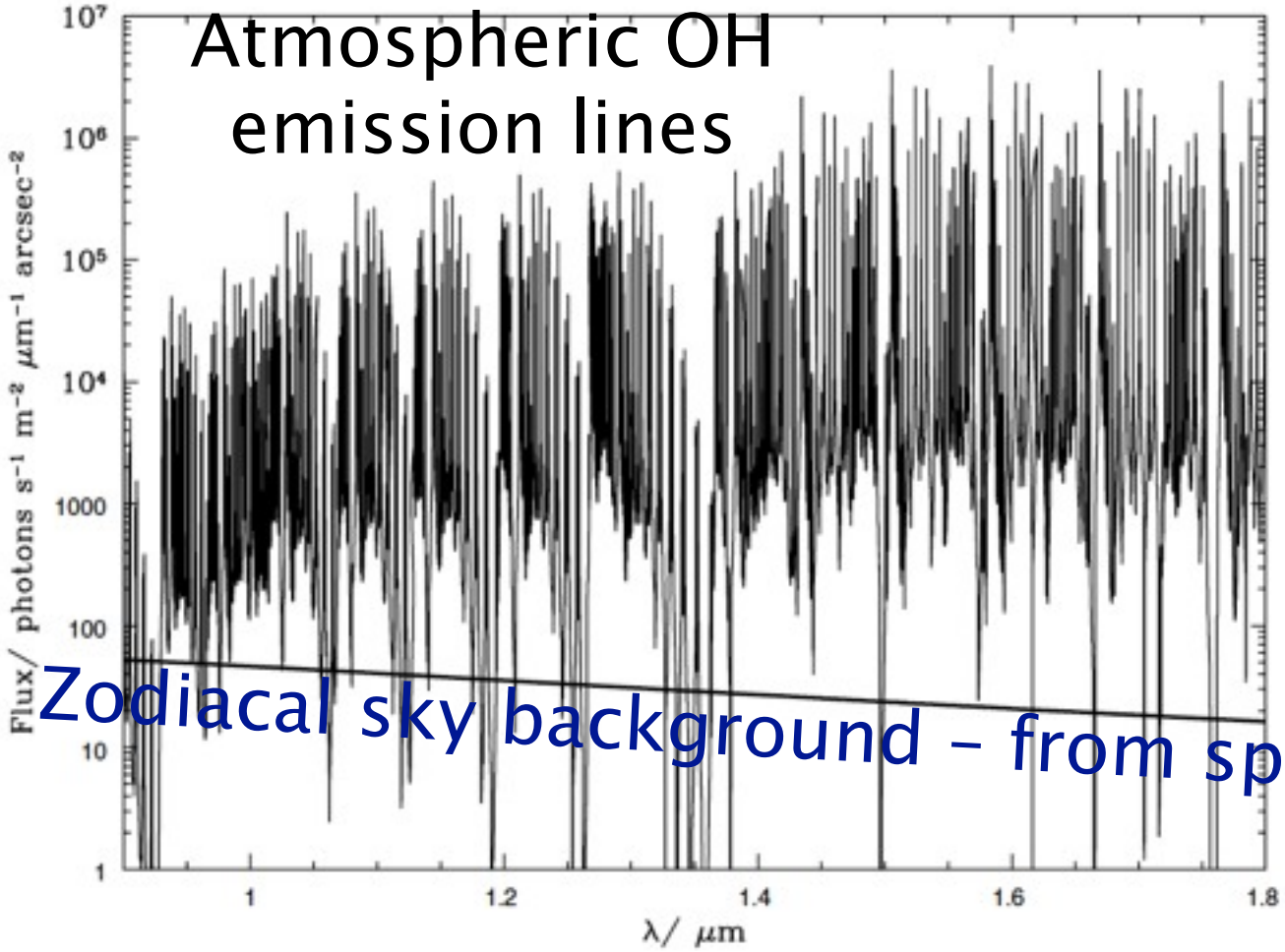




Blake and Shaw (2011)

Can We Peer Through Atmosphere? OH-Suppression

Deserves Sigificant R&D



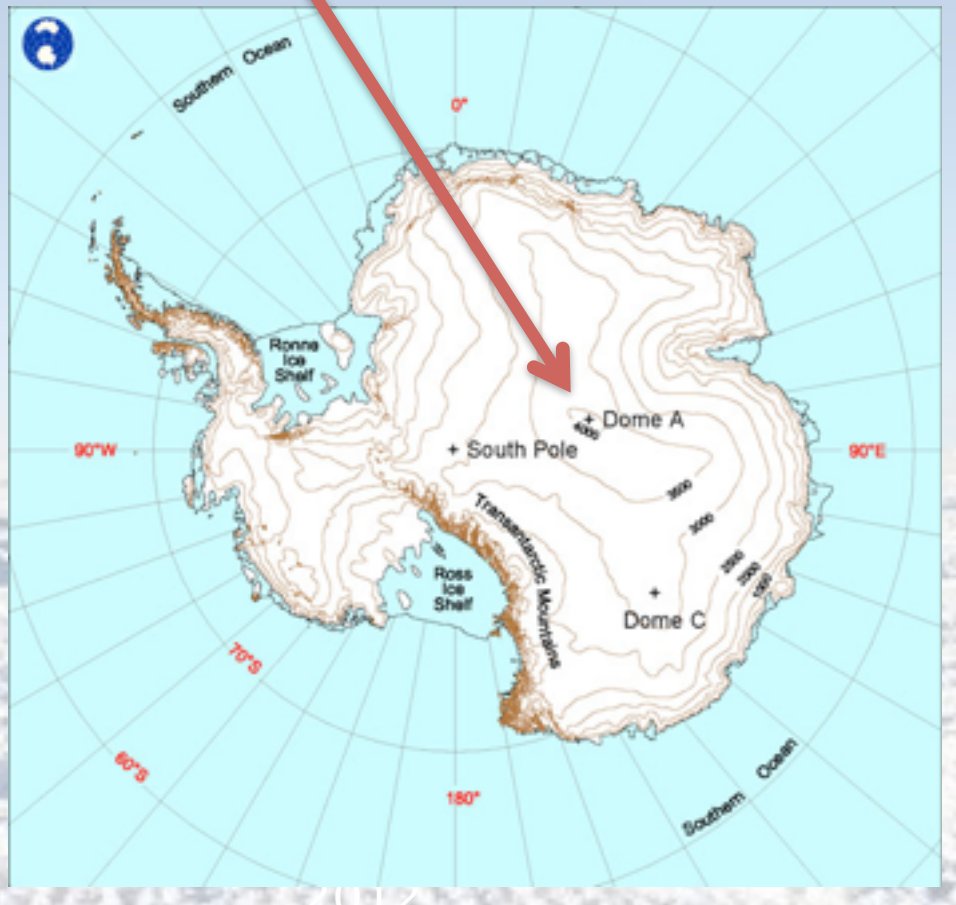
Ellis & Bland-Hawthorn, MNRAS (2008) (Courtesy Saul Perlmutter)

Kunlun Dark Universe Survey Telescope:

An Optical / IR Observatory on The Antarctic Plateau

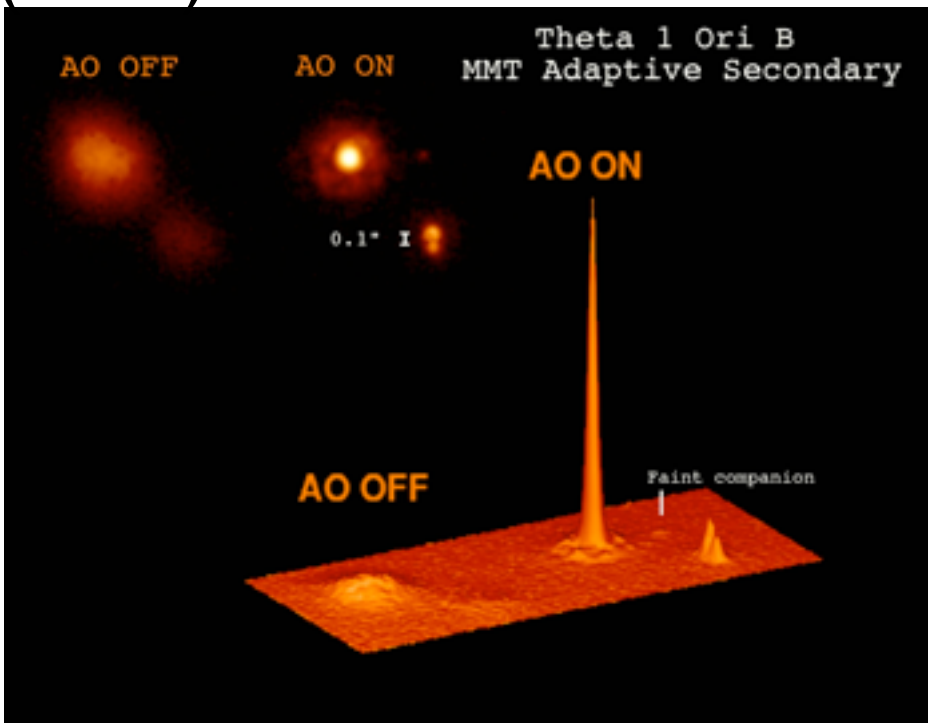
The Site:

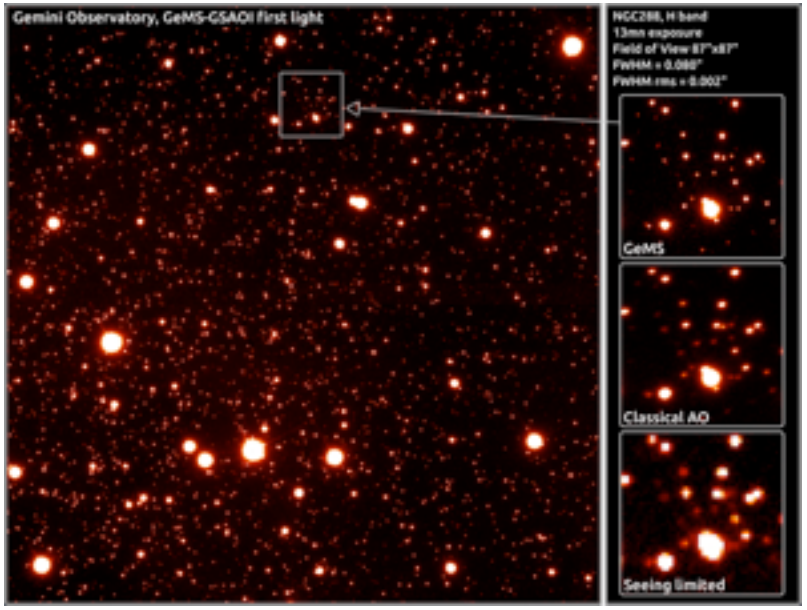
- Elevation: 4091 meters
- Turbulence Boundary Layer: 14.5 meters
- **Best Seeing**
  Free Atmospheric Seeing: 0.3”
- Low Scintillation Noise: 0.5 mmag ($m^{-2/3}$ $s^{-1/2}$)
- Observable Nights: > 90%
- **Coldest** Point on Earth:
  Lowest Thermal IR Background
- **Lowest** Precipitable Water Content



Can we Look at Less Atmosphere? Multi-Conjugate Adaptive Optics

(UofA)





(Gemini)

Can we do both
AO + OH-suppression?

Future of SNIa Cosmology

- 2010-2020
  - SNIa Astrophysics (optical-NIR)
  - Astronomical Calibration
  - Photometric-only analyses
- 2020-2030
  - LSST
  - +Euclid, +JWST
  - <1% metrology and meterology
- 2025-Beyond
  - Ground-based AO+OH suppression
  - Space-based restframe NIR
  - Fundamental limits to SNe Ia?