

Title: Three Years of Cosmology with SNLS

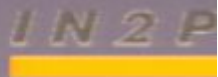
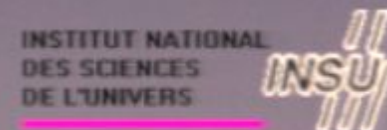
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Abstract:

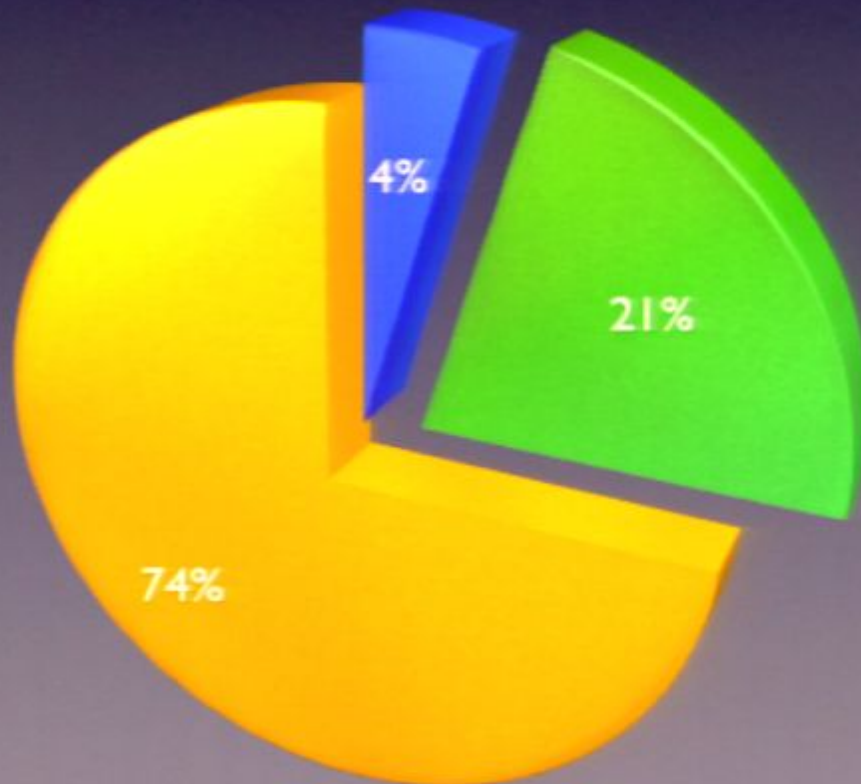
Three years of cosmology with SNLS

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What in the world is Dark Energy?

- Baryons
- Dark Matter
- Dark Energy



- Cosmological constant?
- New theory of gravity? (Extra dimensions, etc.)
- Scalar field?
- Why are they about equal?
- We know almost nothing

How can we figure it out?

$$H^2 = \left(\frac{\dot{a}}{a} \right)^2 = H_0^2 \left[\Omega_m a^{-3} + \Omega_r a^{-4} + \Omega_k a^{-3} + \Omega_{DE} a^{-3(1+w)} \right]$$

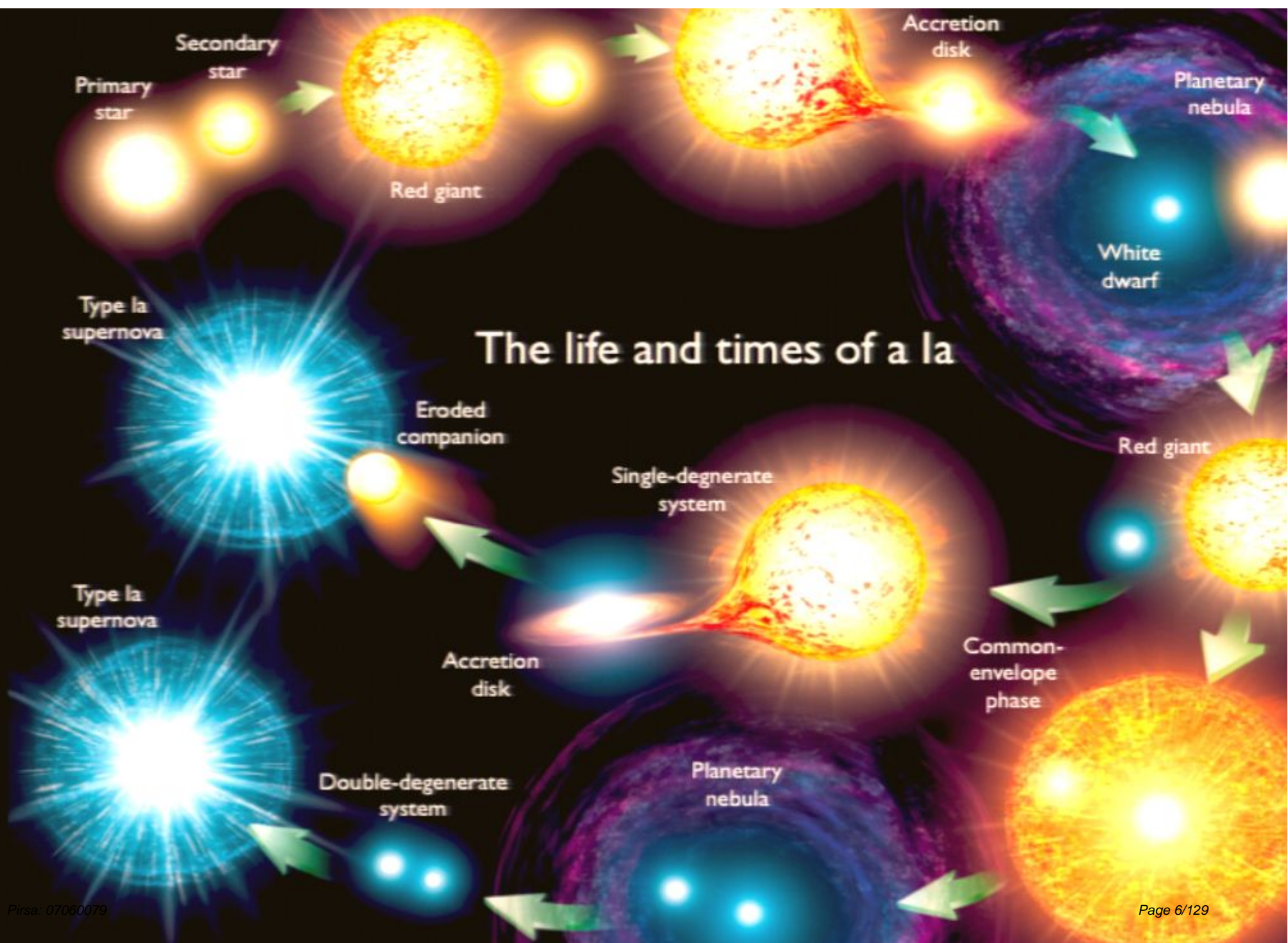
- Use expansion history
- The equation of state of dark energy:
 $w = P/\rho$
- $w = 1/3$ rad, 0 matter, -1 cosmological constant
- If w is not -1, then we have something exciting
- If w is changing, that's even better

Tools

- Type Ia (thermonuclear) supernovae are the best (bright) standard candles we know of
- Made even better by correcting for colour and light-curve shape



The life and times of a Ia



The Supernova Legacy Survey

- Massive amount of imaging using CFHT to find SN and get light-curves (griz) -- 202 nights/5 years
- All SN candidate discoveries immediately available to anyone
- Huge amount of spectroscopy to make sure we have the right type of SNe
- About 1000-2000 SNe discovered



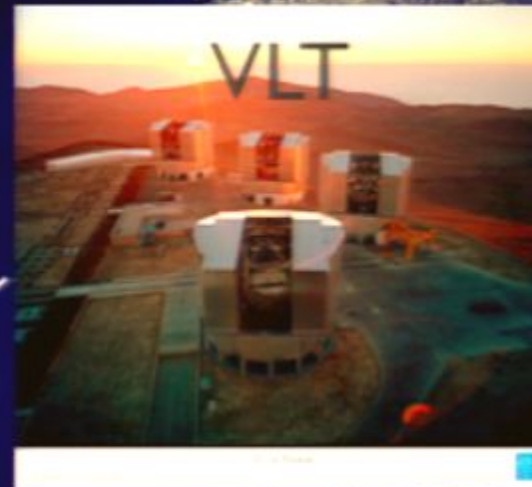
SNLS facilities and people



SNLS facilities and people



SNLS facilities and people



Important aspects of SNLS

- One instrument, so well understood
- Data set is larger *and* higher quality than previous samples
- This allows us to test our standard candles

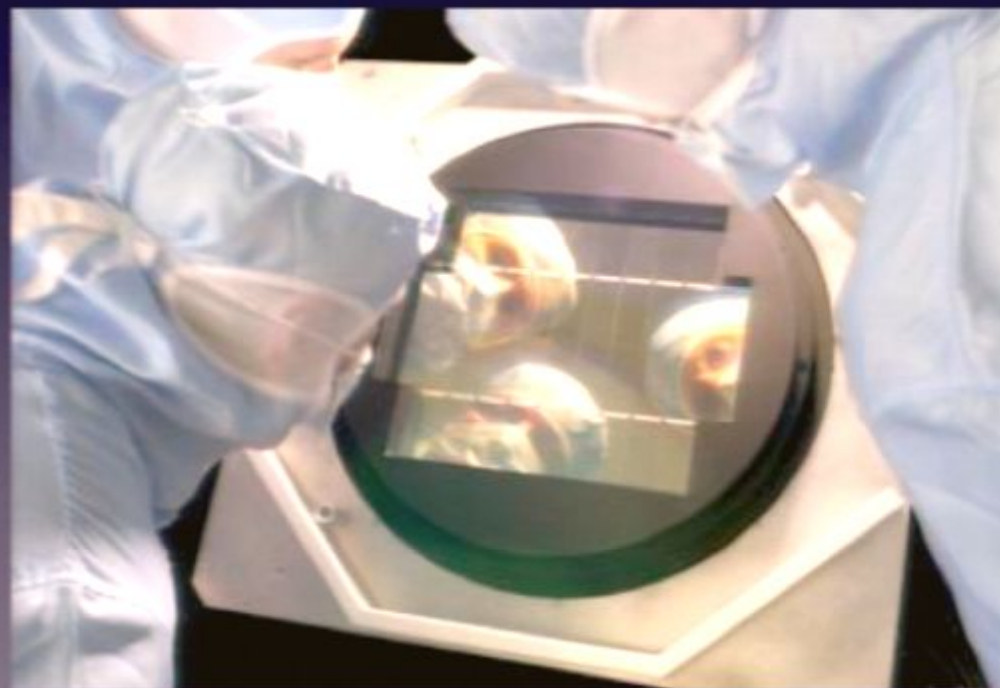
MegaCam

- New front end for CFHT w/ 4 element prime focus corrector
- 36 (40) CCDs, 1 sq. degree FOV.
- 324 million pixels, 700 MB raw
- Median i' IQ 0.7 arcsec

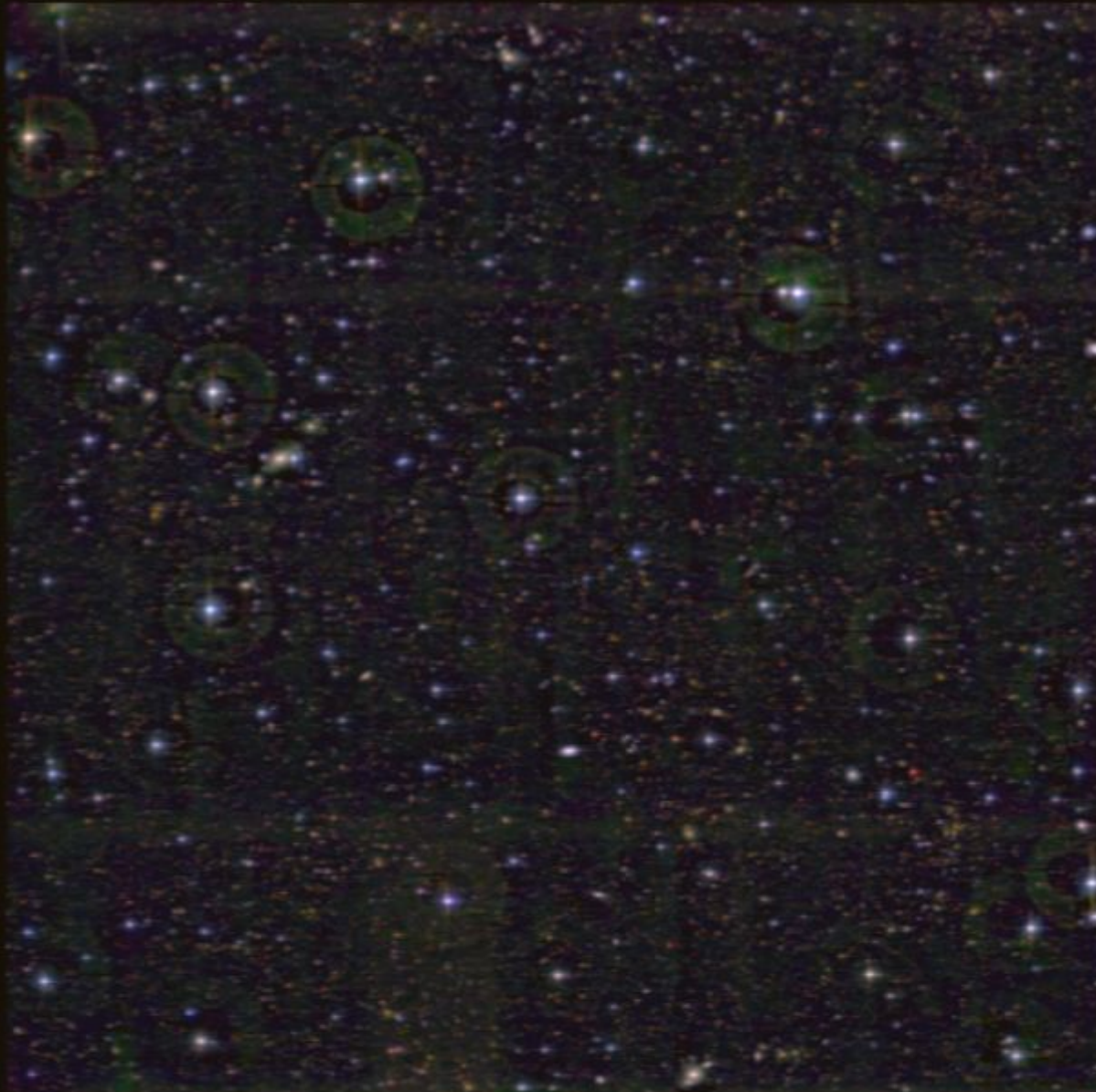


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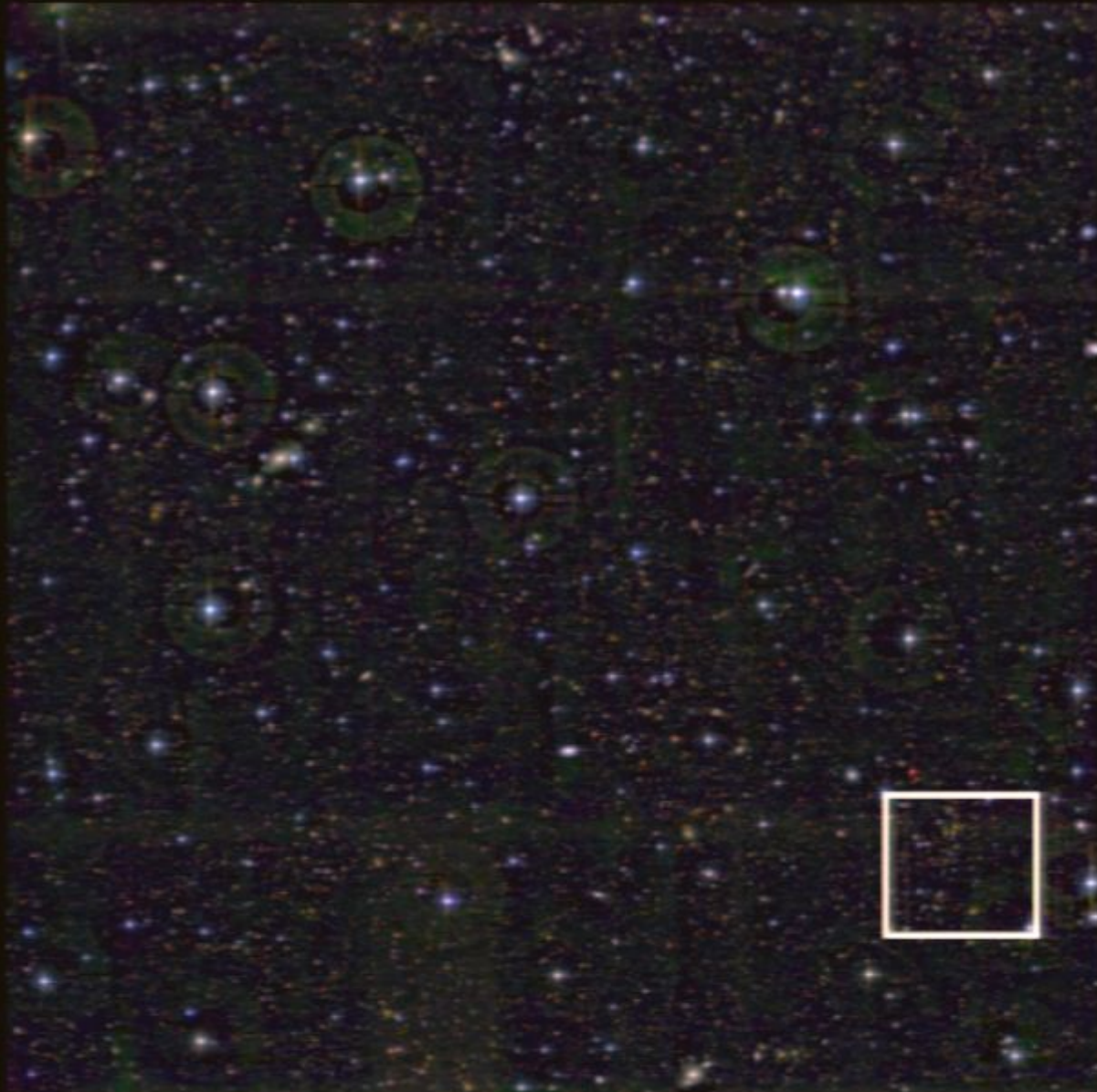
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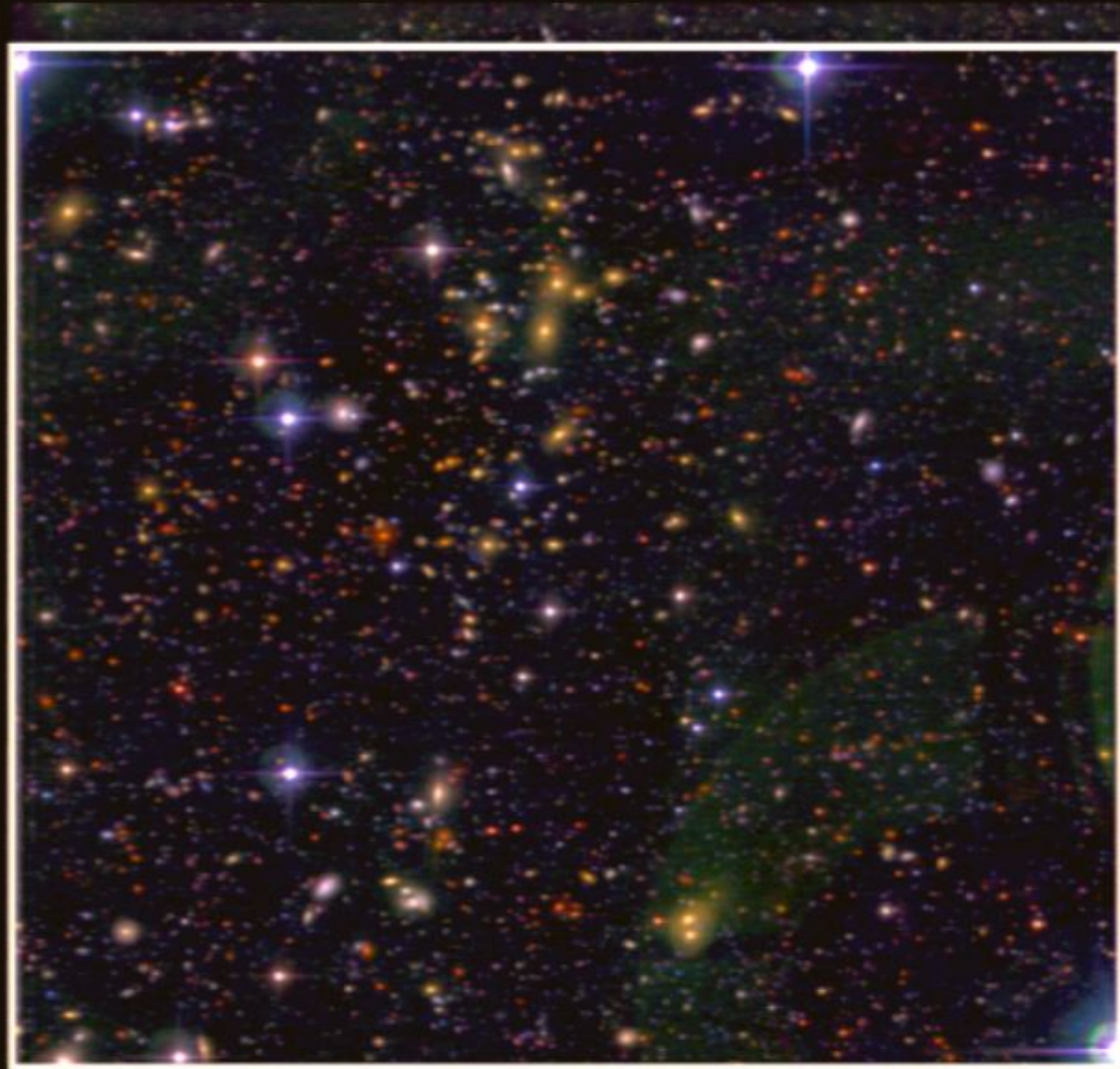
SNLS D I

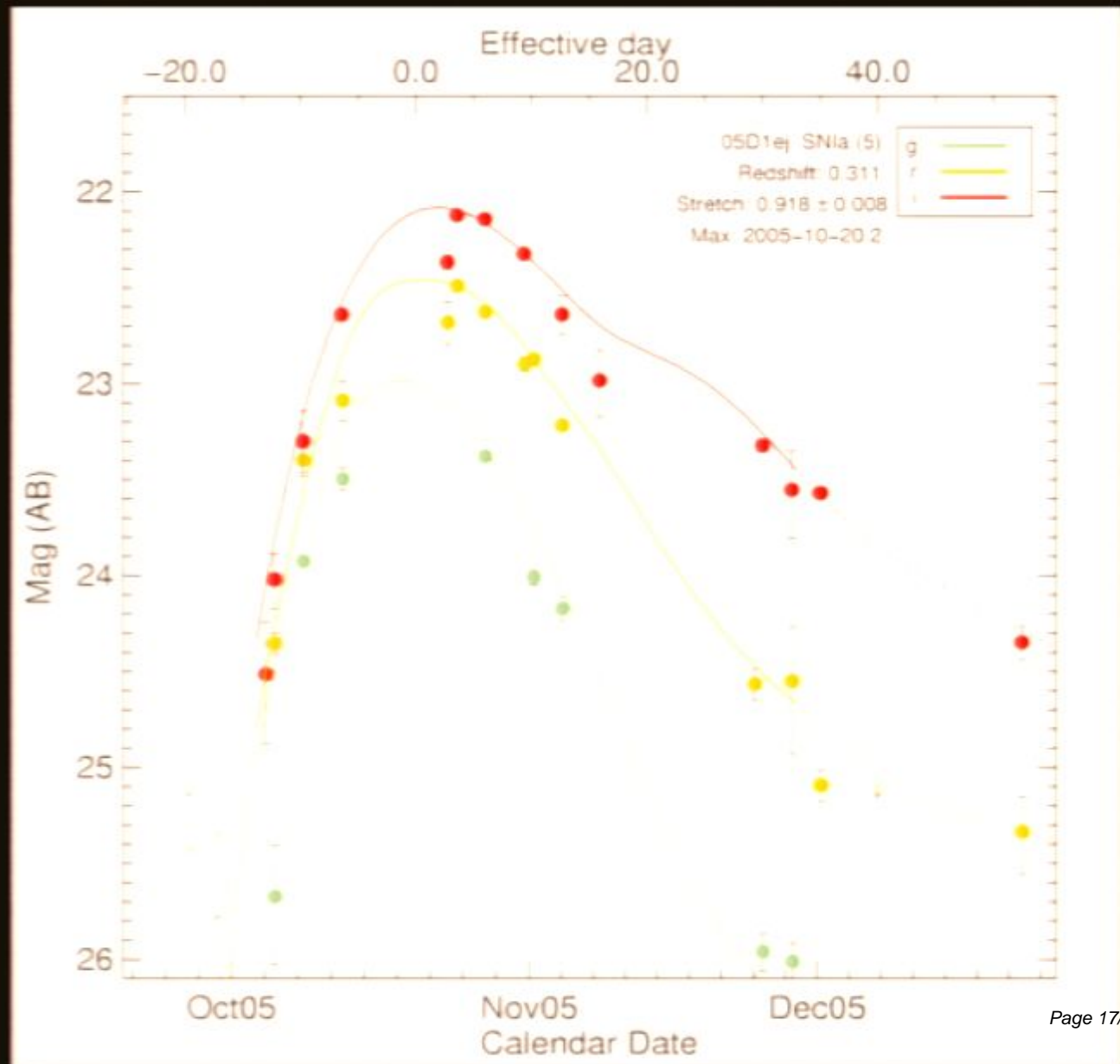


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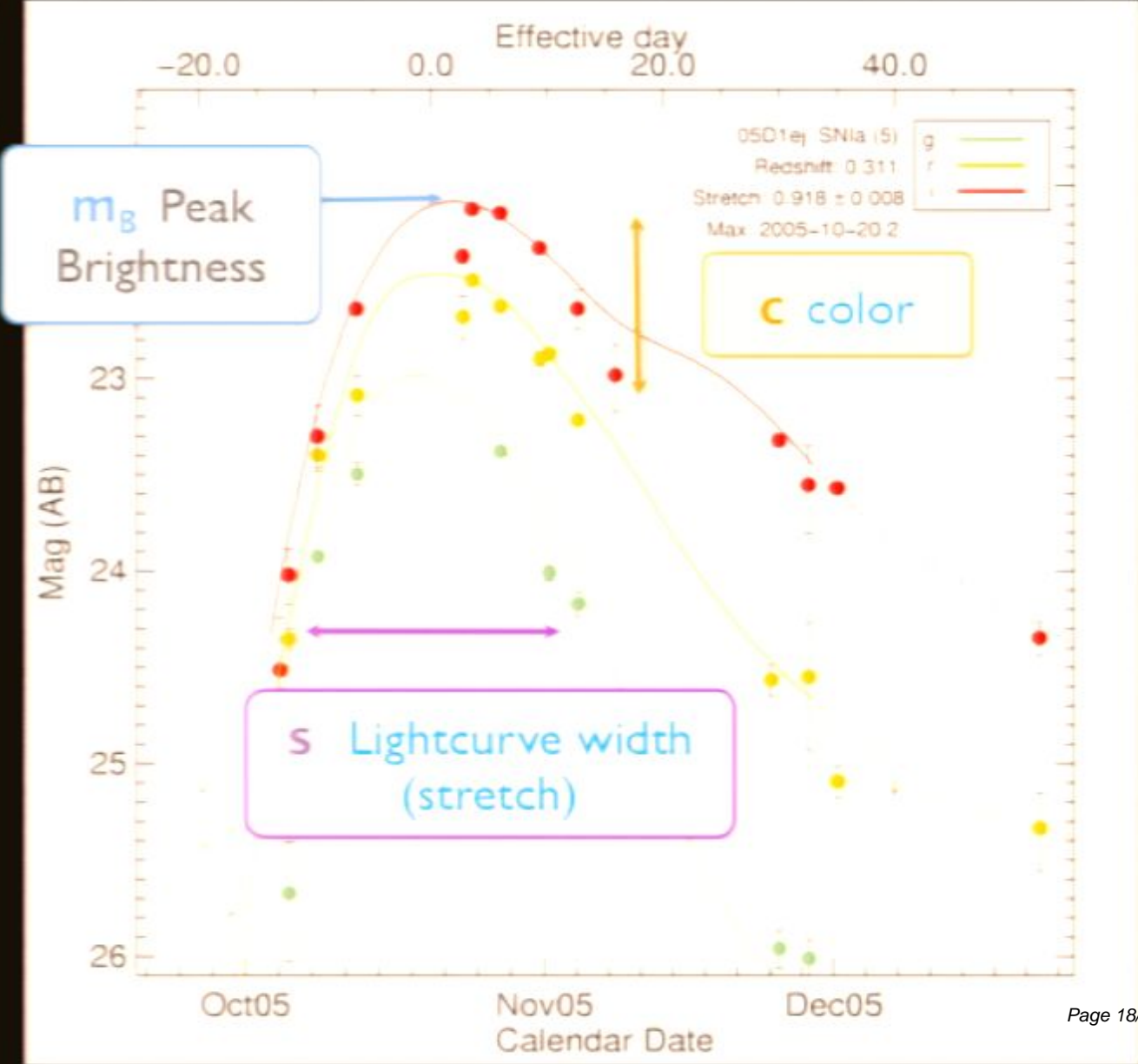
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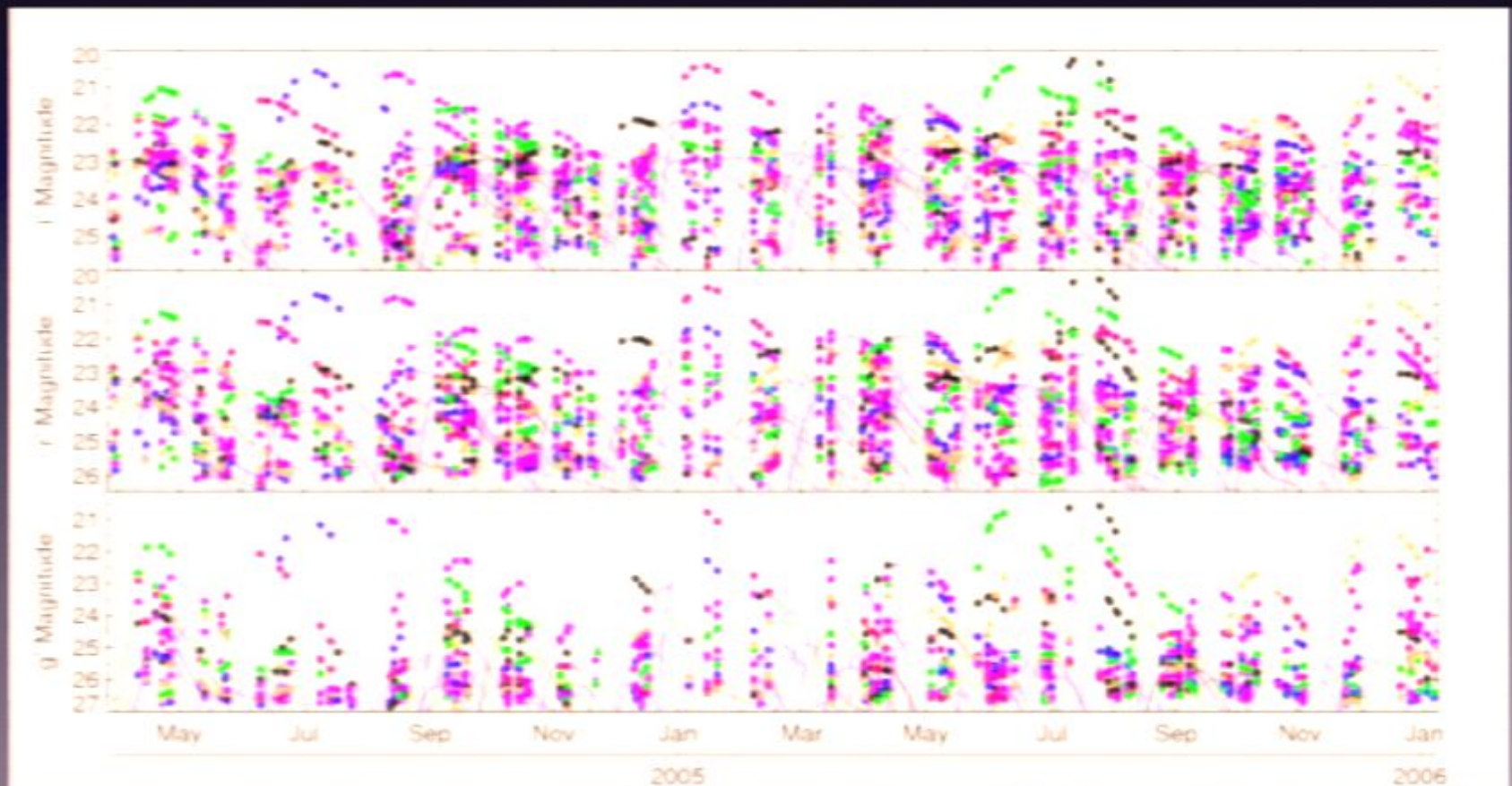




$$\mu_B = m_B - M_B + \alpha(s-1) - \beta c$$

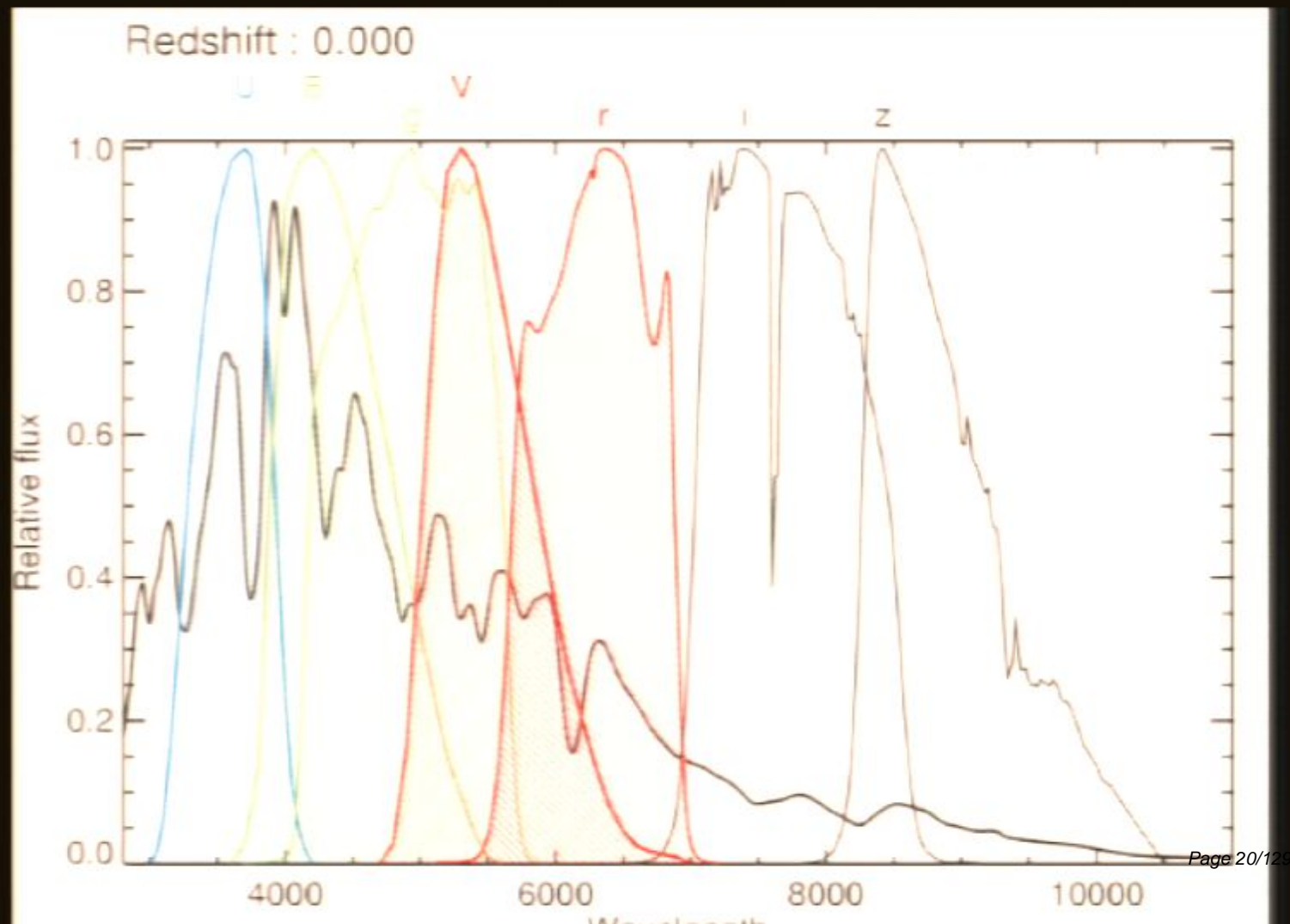


Rolling Search

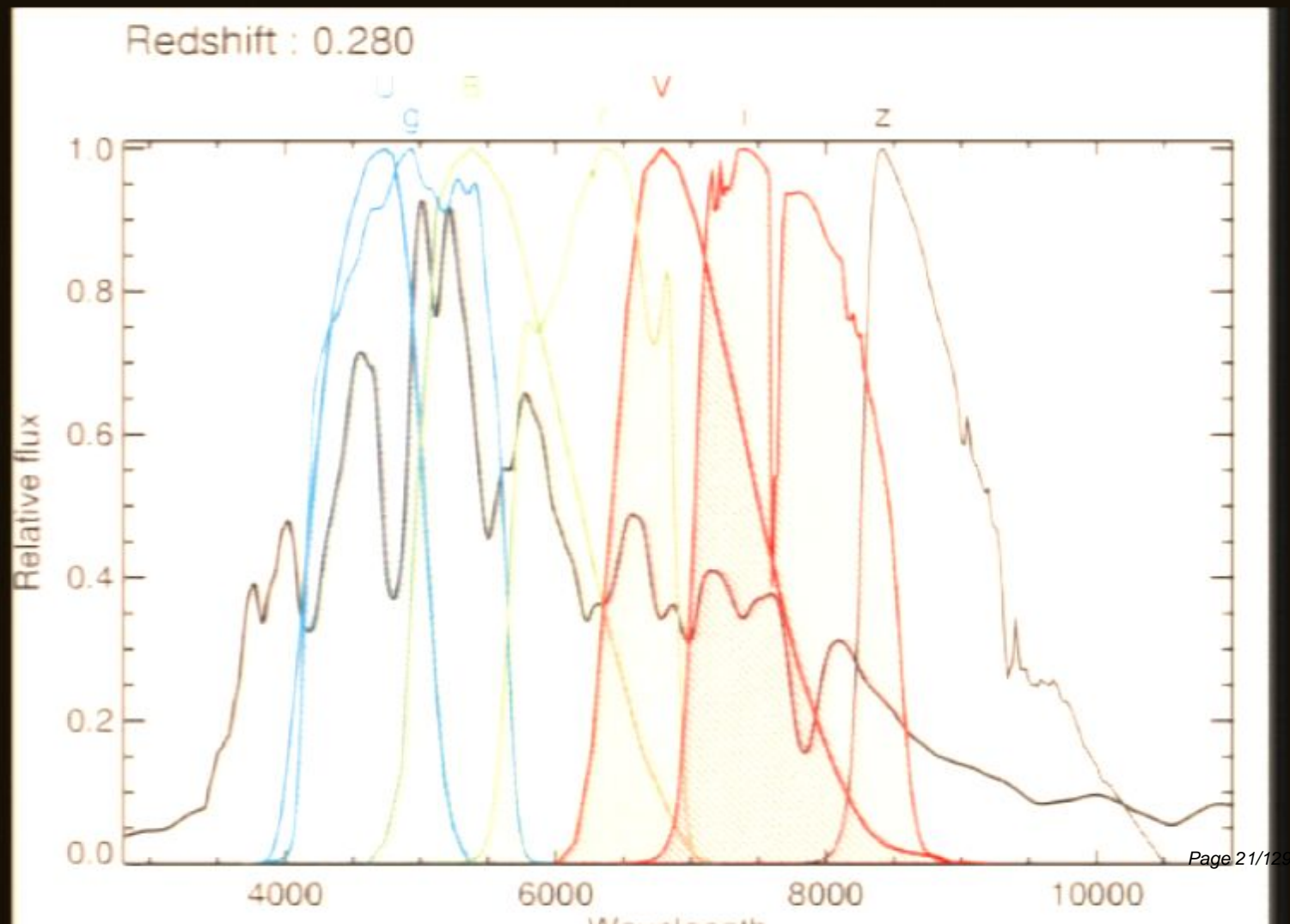


Find new SN and follow them with the same telescope simultaneously

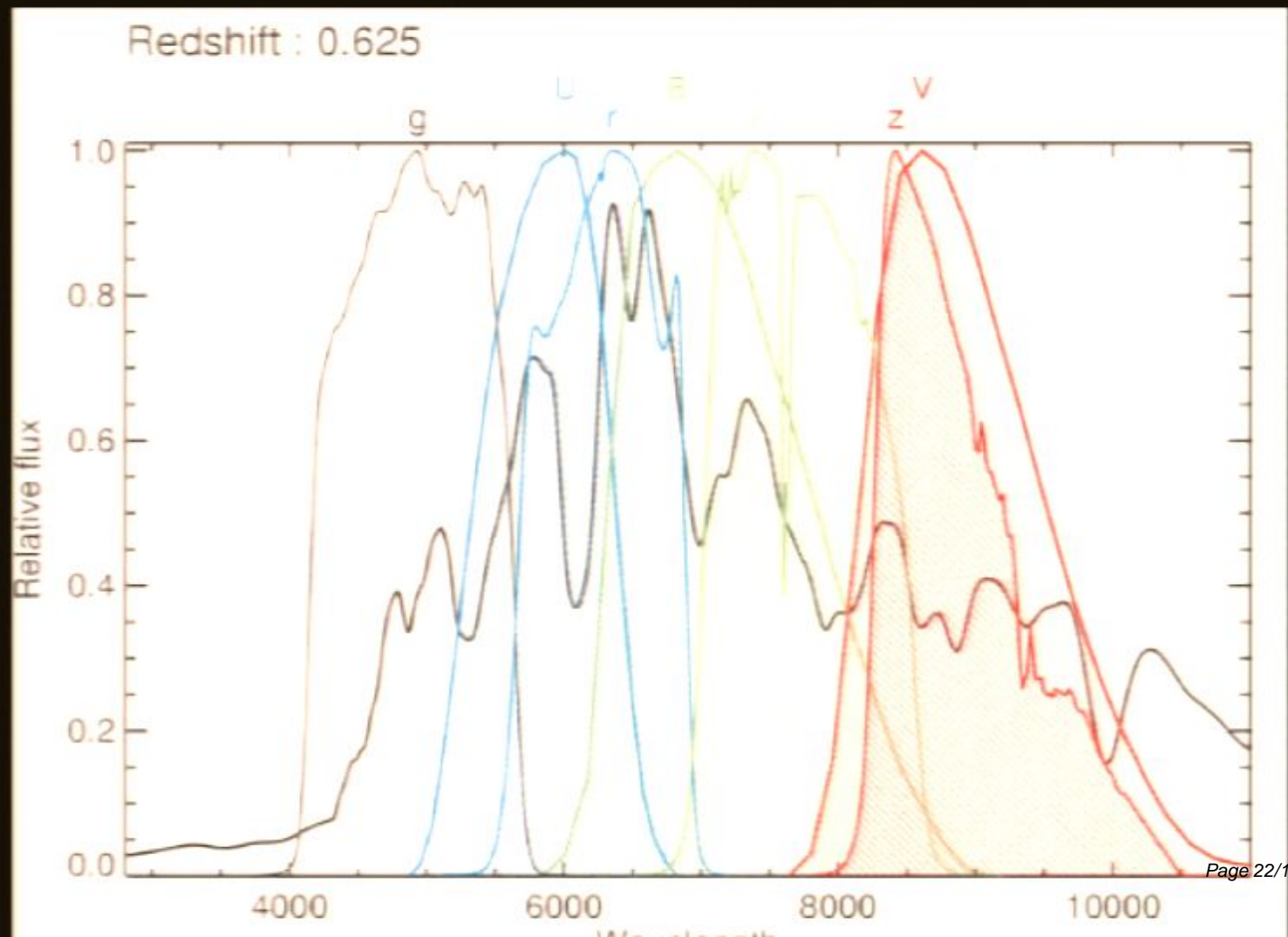
Multiple passbands = colours at all redshifts



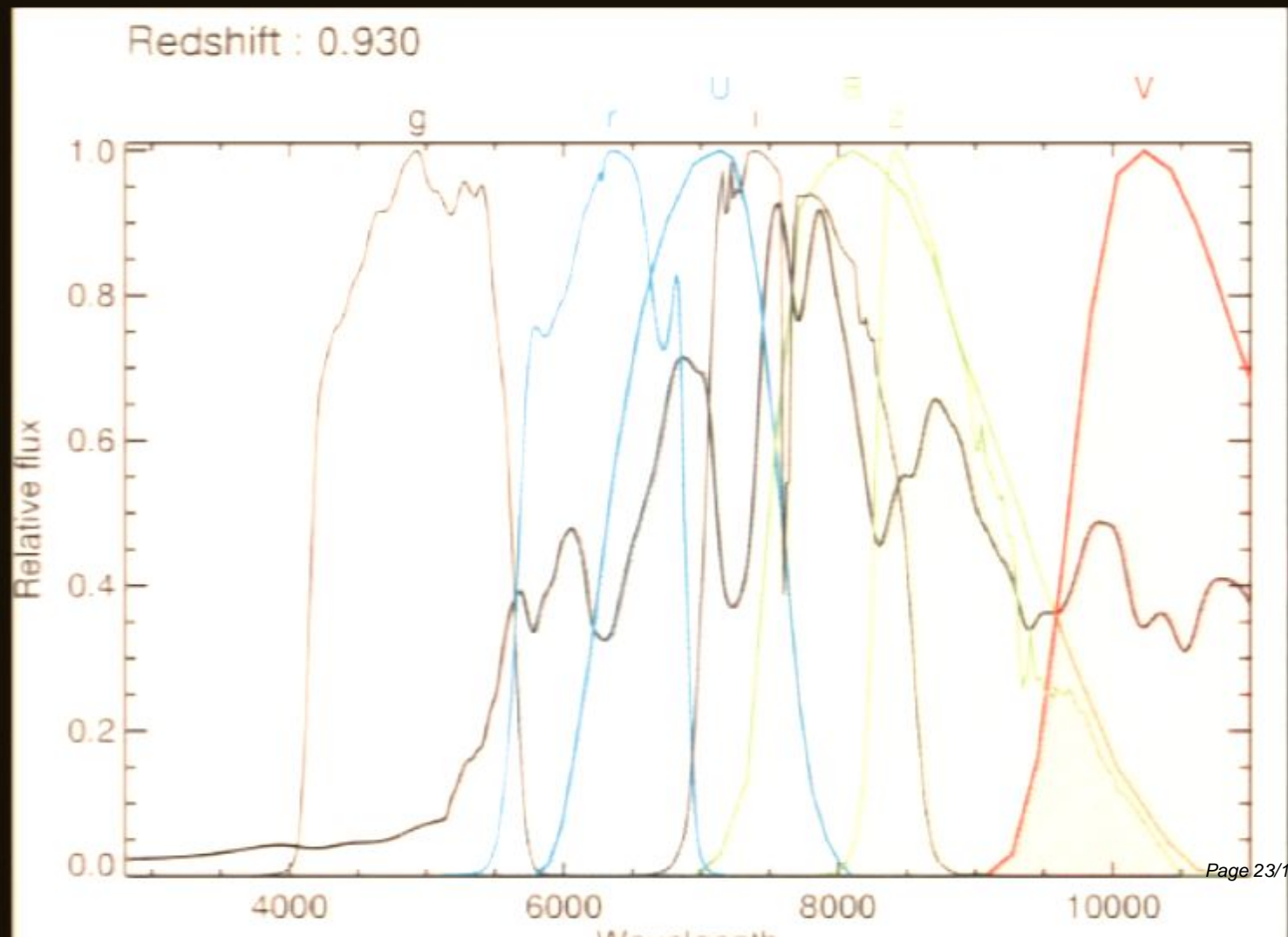
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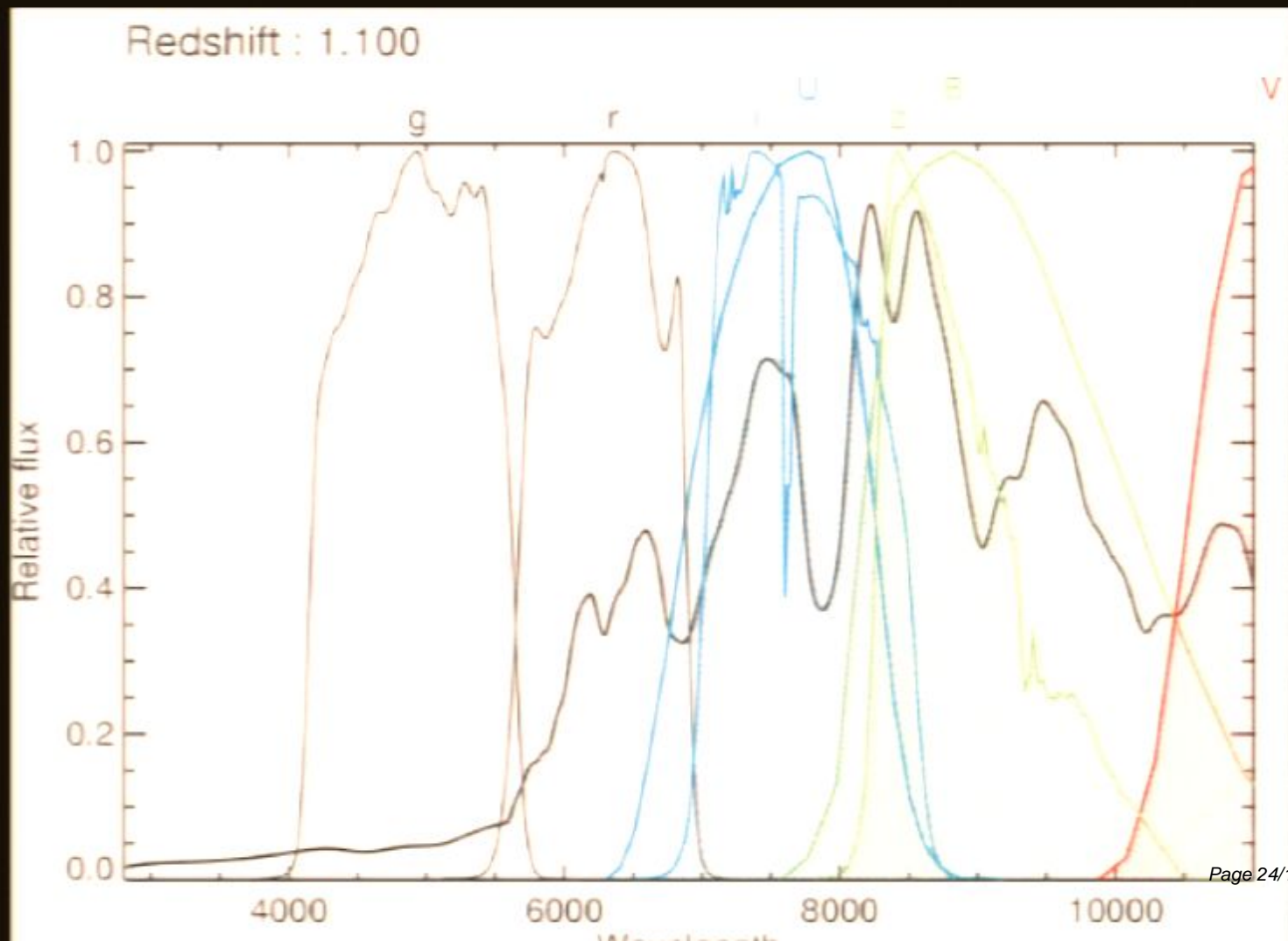
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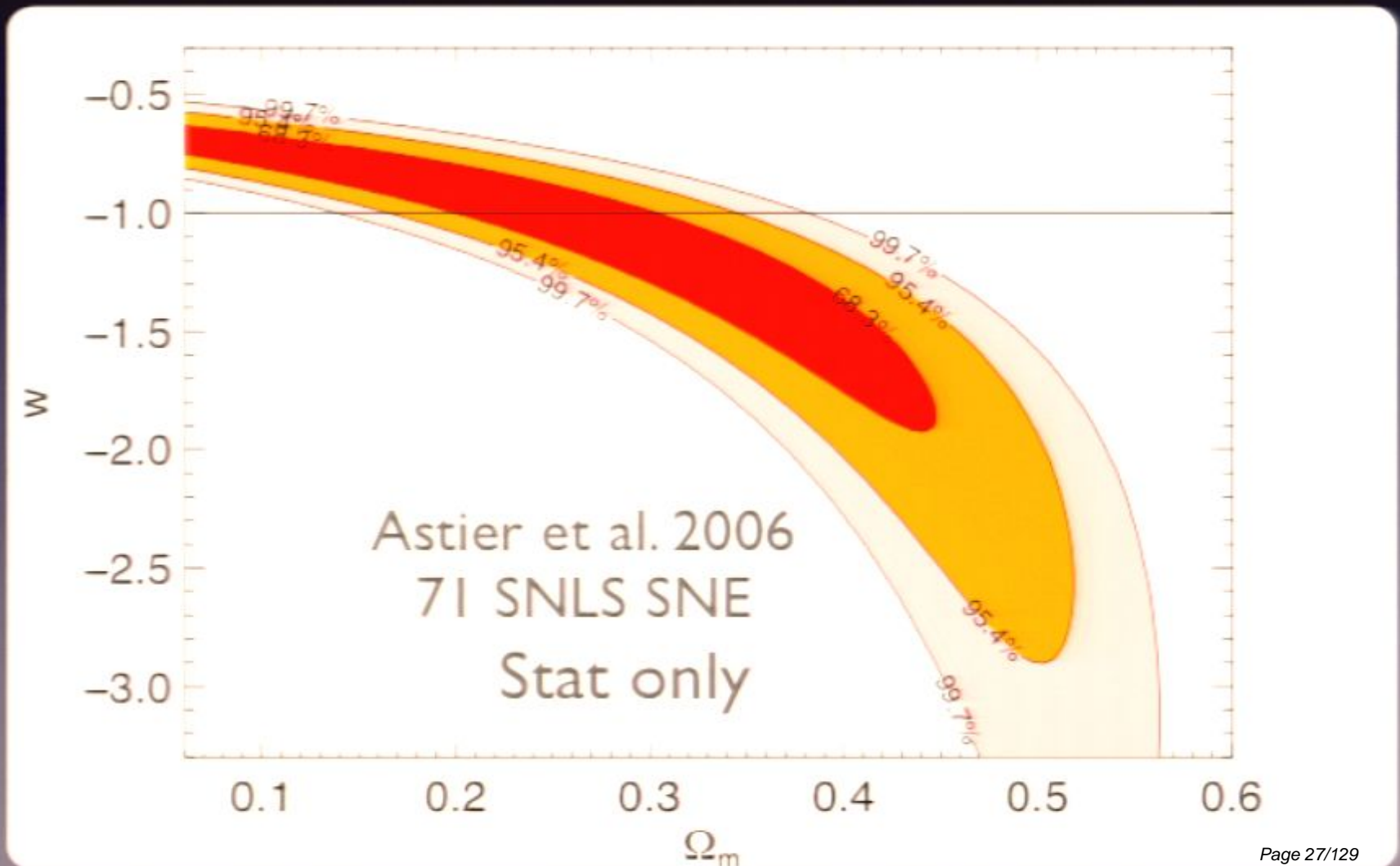
State of Play

- First year paper in 2006 (Astier et al.)
- SNLS ends June 11th
- 3rd year analysis coming soon
- Nearby, comparison, SN sample has not changed much

What's new from 1st year?

- Lots more SNe (from 71 to 250), allowing better subsample and SN physics studies
- Substantial calibration improvements
- Improved SN empirical models incorporating UV data: RMS from 0.19 to 0.16 mag
- Much better treatment of systematic errors

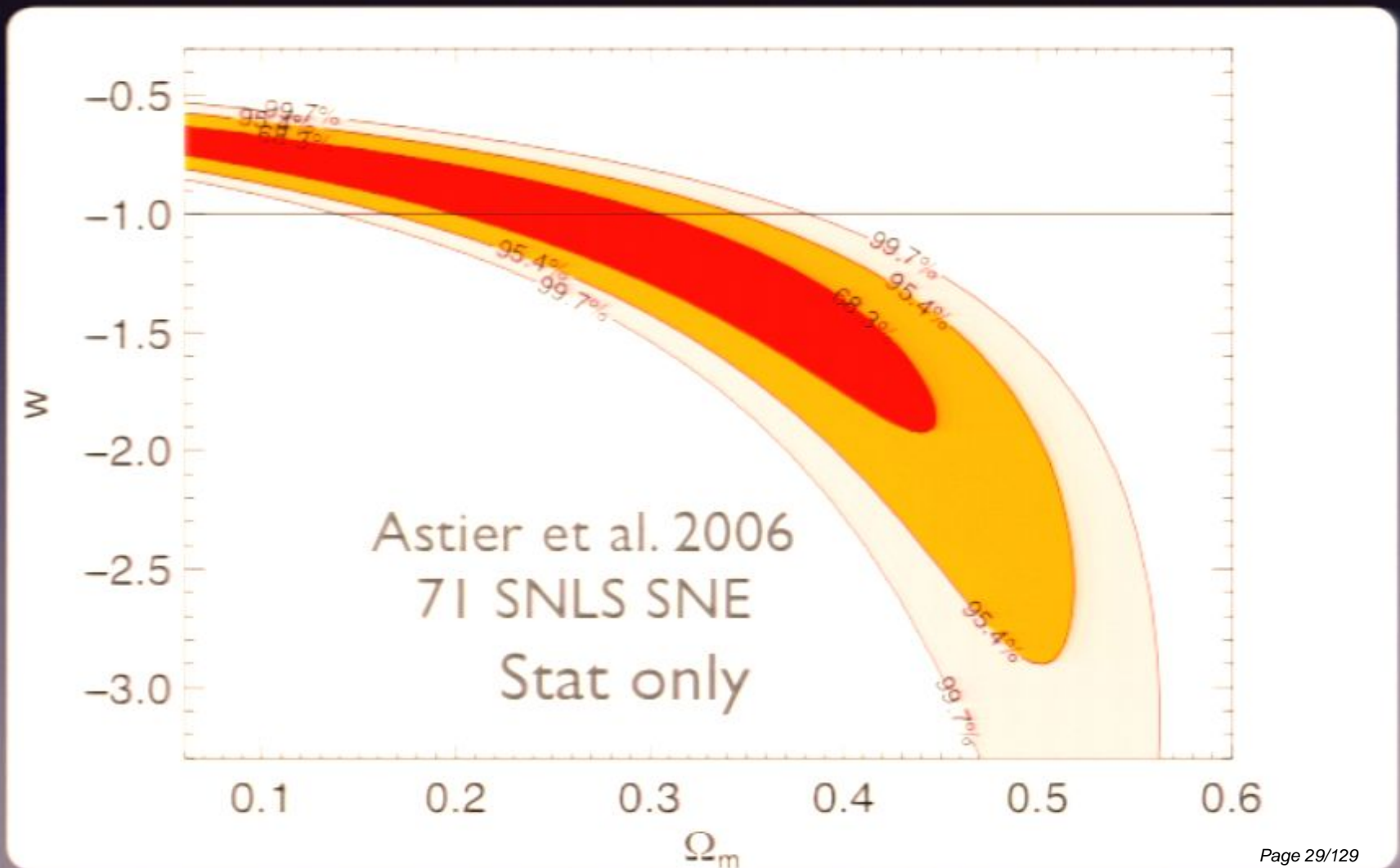
Cosmological Results



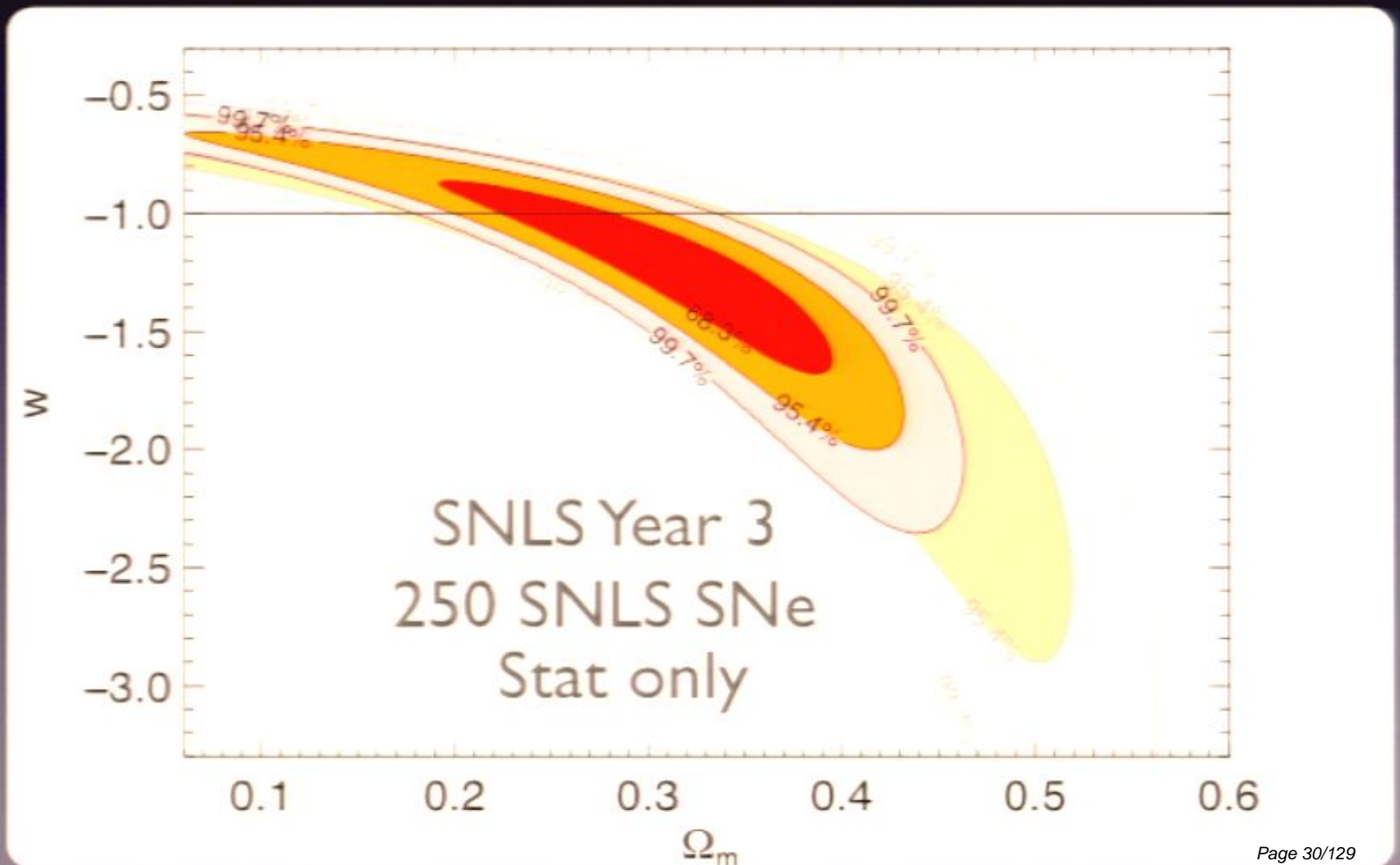
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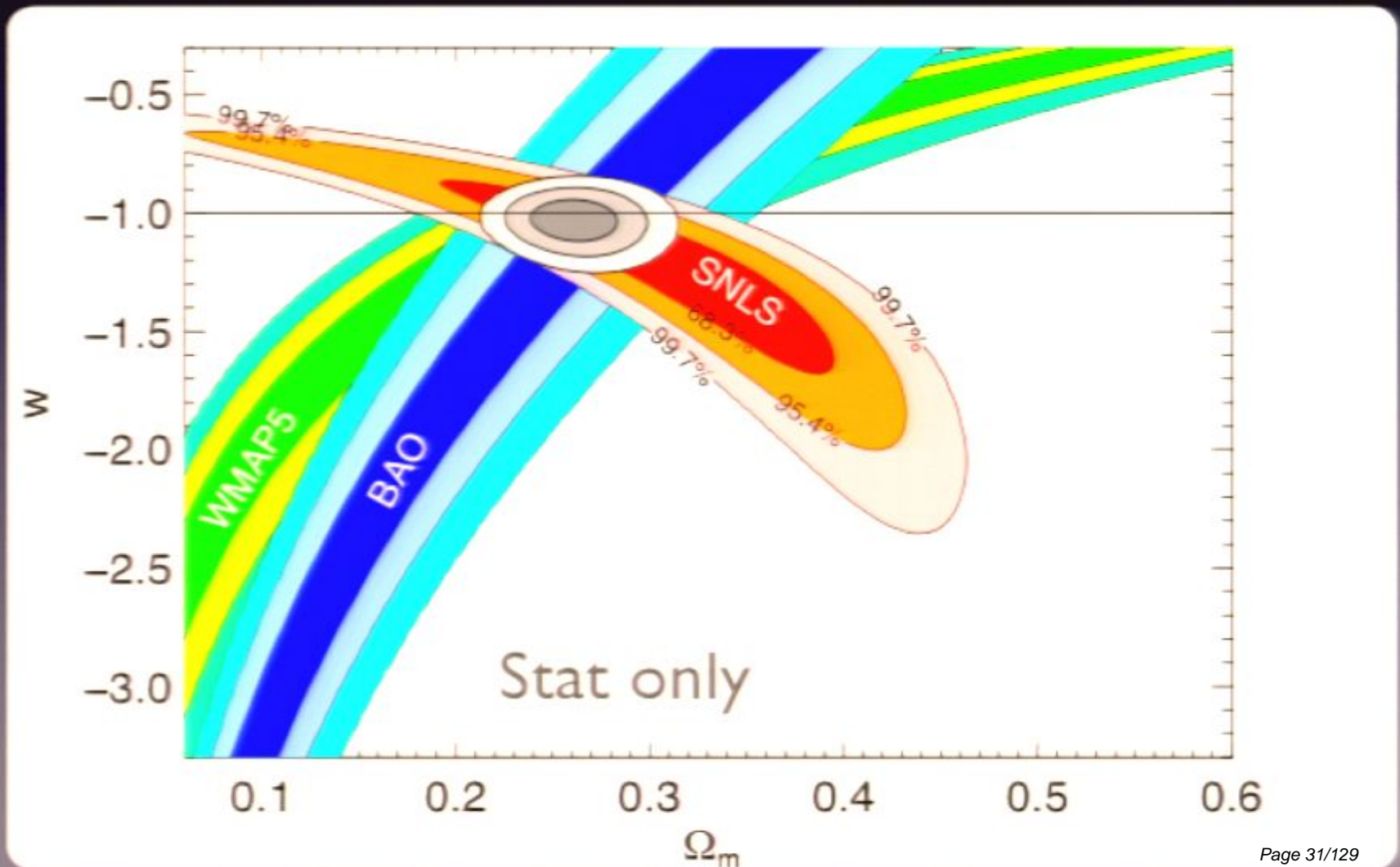
Cosmological Results



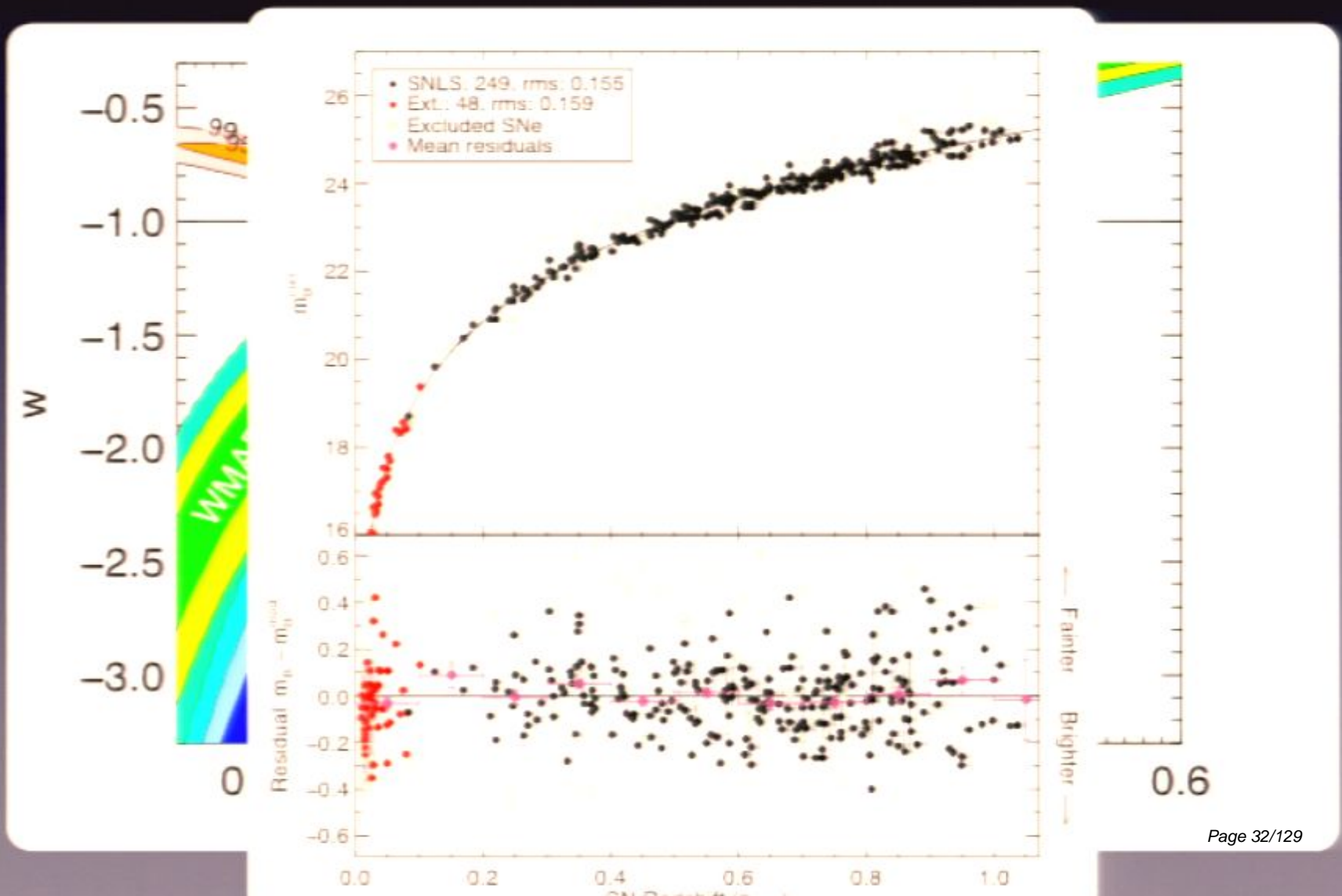
Cosmological Results



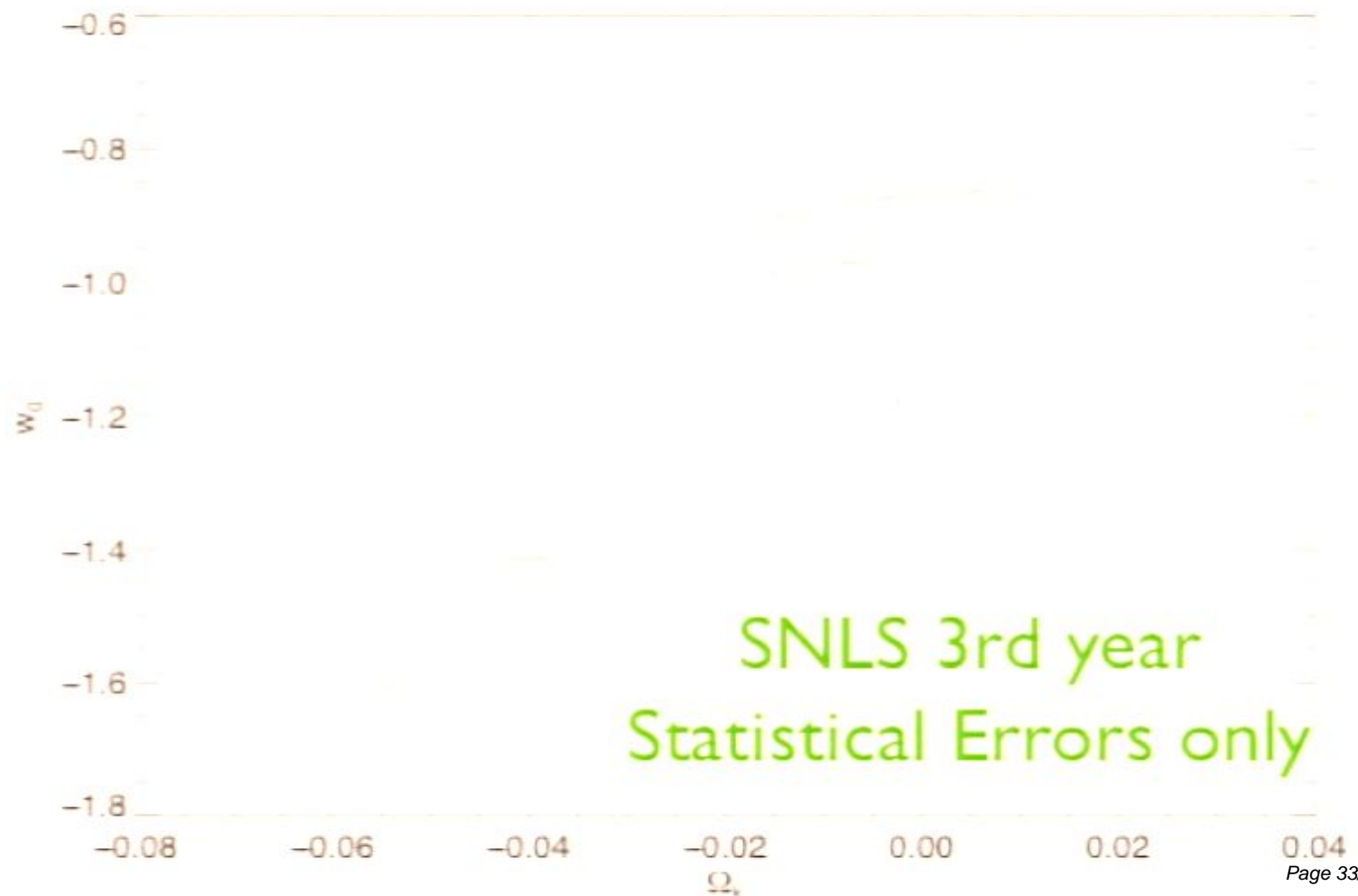
Cosmological Results



Cosmological Results



Non-flat Universe



Systematics matter

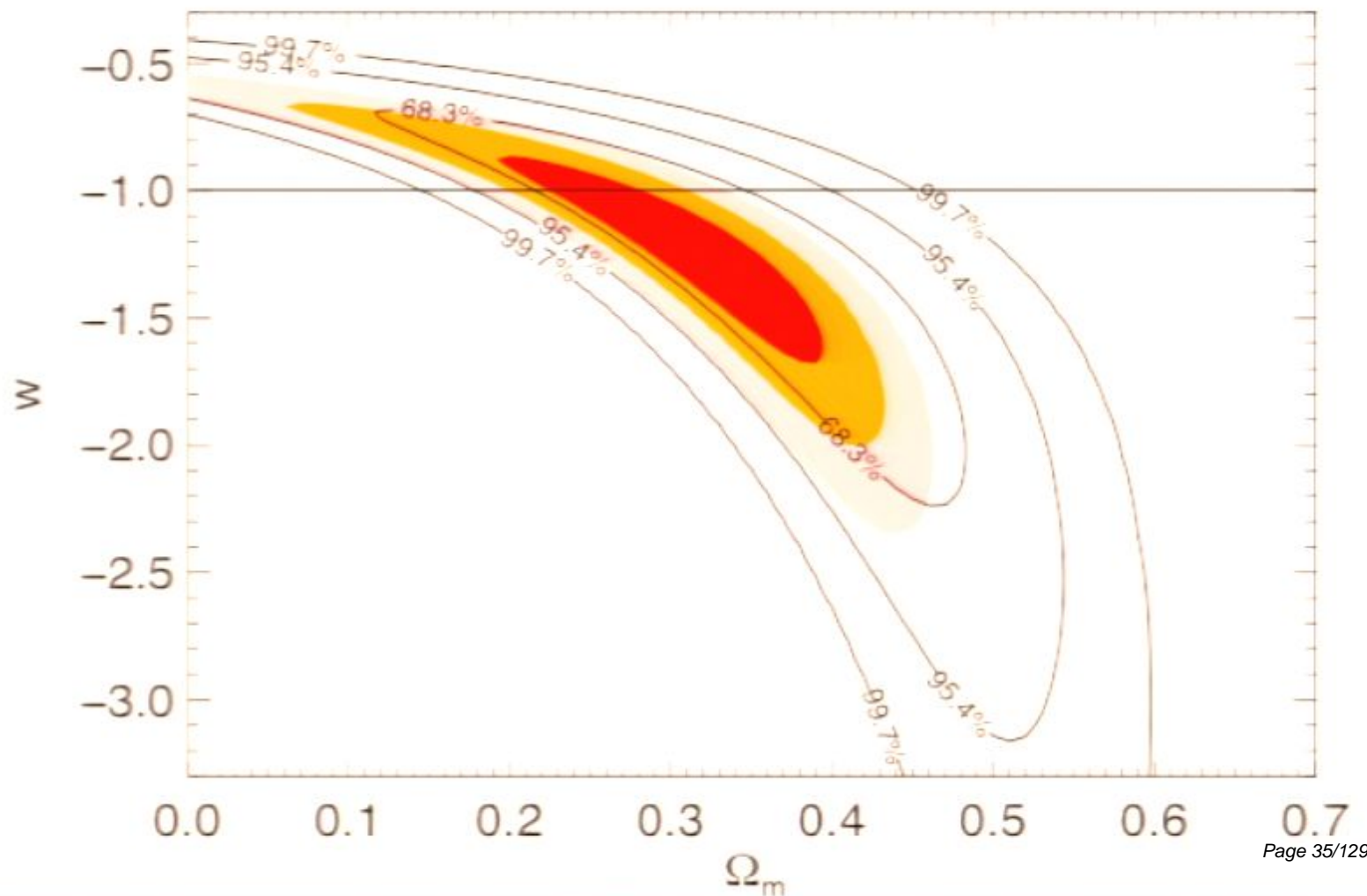
- Calibration systematics (zeropoints, Landolt system, detector response)
- Non-SN systematics (pec. velocities, lensing)
- SN model uncertainties
- Extinction/colours of SNe
- Demographic shifts with lookback time
- Evolution of SN with redshift

Less SN physics



More SN physics

Results with Systematic Errors

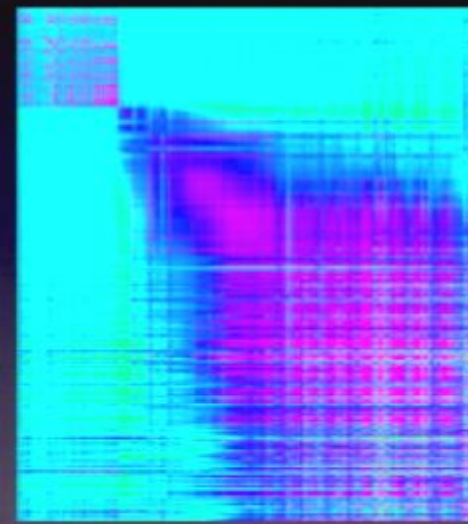


Most of our papers are about 'systematics'

| | | | |
|--|--|---|--|
| Calibration, photometry, Malmquist bias | Minimized by spectroscopic typing | UV behavior, dispersion of spectra | Peculiar velocities Hubble bubble |
| Perrett et al. 2008 Regnault et al. 2008 | Howell et al. 2005 | Hsiao et al. 2007 Ellis et al. 2008 Guy et al. 2007 Conley et al. 2008 | Neill et al. 2007 Conley et al. 2007 |
| Experimental Systematics | Non-Ia contamination | K-corrections | Non-SNe effects |
| Intrinsic vs extrinsic SN colors | Population drift | Lightcurves, luminosities | SNe which don't correct normally |
| Conley et al. 2007 Guy et al. 2005 Guy et al. 2007 | Sullivan et al. 2006 Howell et al. 2007 | Conley et al. 2006 Ellis et al. 2007 Bronder et al. 2007 | Howell et al. 2006 |
| Extinction Corrections | Population demographics | Evolution in SN properties | Unusual SNe |

Some Numbers

| Systematic | w Error |
|--|---------|
| Colour of Vega on Landolt system | 0.0277 |
| SNLS zeropoints | 0.0217 |
| SNLS bandpasses | 0.0250 |
| SN model | 0.0290 |
| Evolution in colour-luminosity (β) | 0.0242 |
| Landolt bandpasses | 0.0146 |
| Local flows | 0.0137 |
| SED of Vega | 0.0150 |

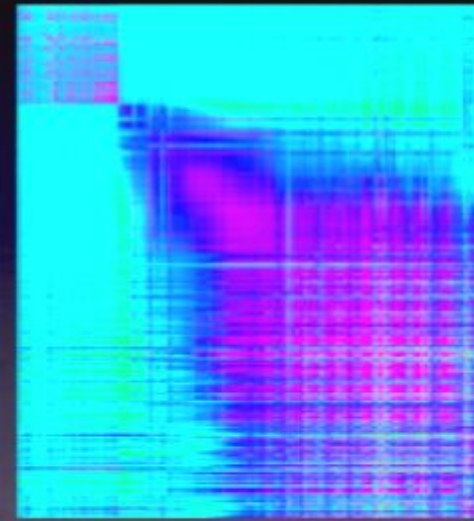


Our systematics covariance matrix

Stat plus systematic error on w is about 9%

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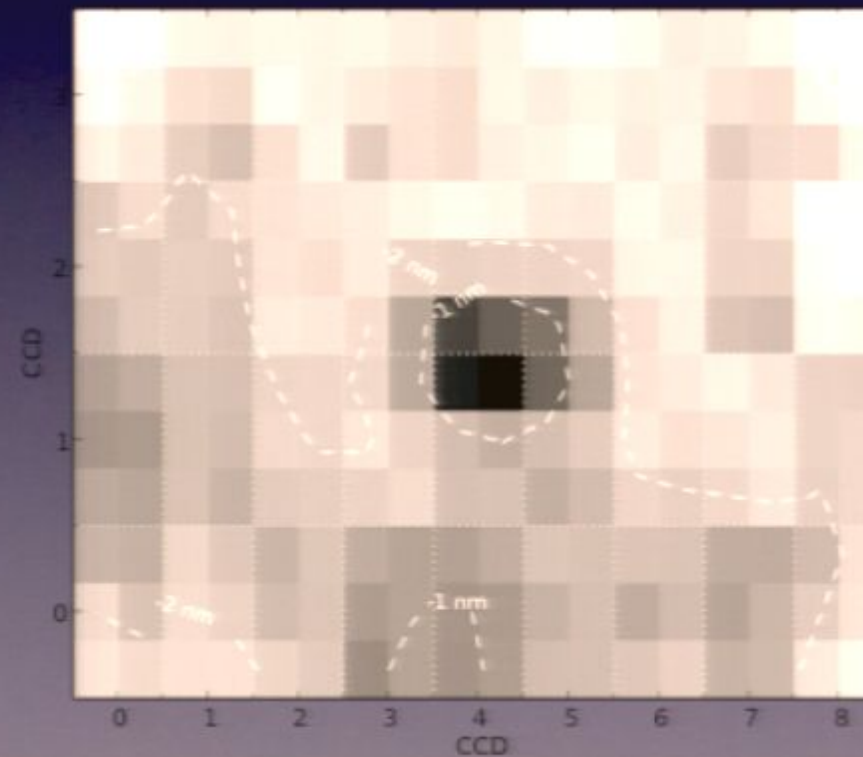
Improved by new low-z sample

Stat plus systematic error on w is about 9%

MegaCam Calibration

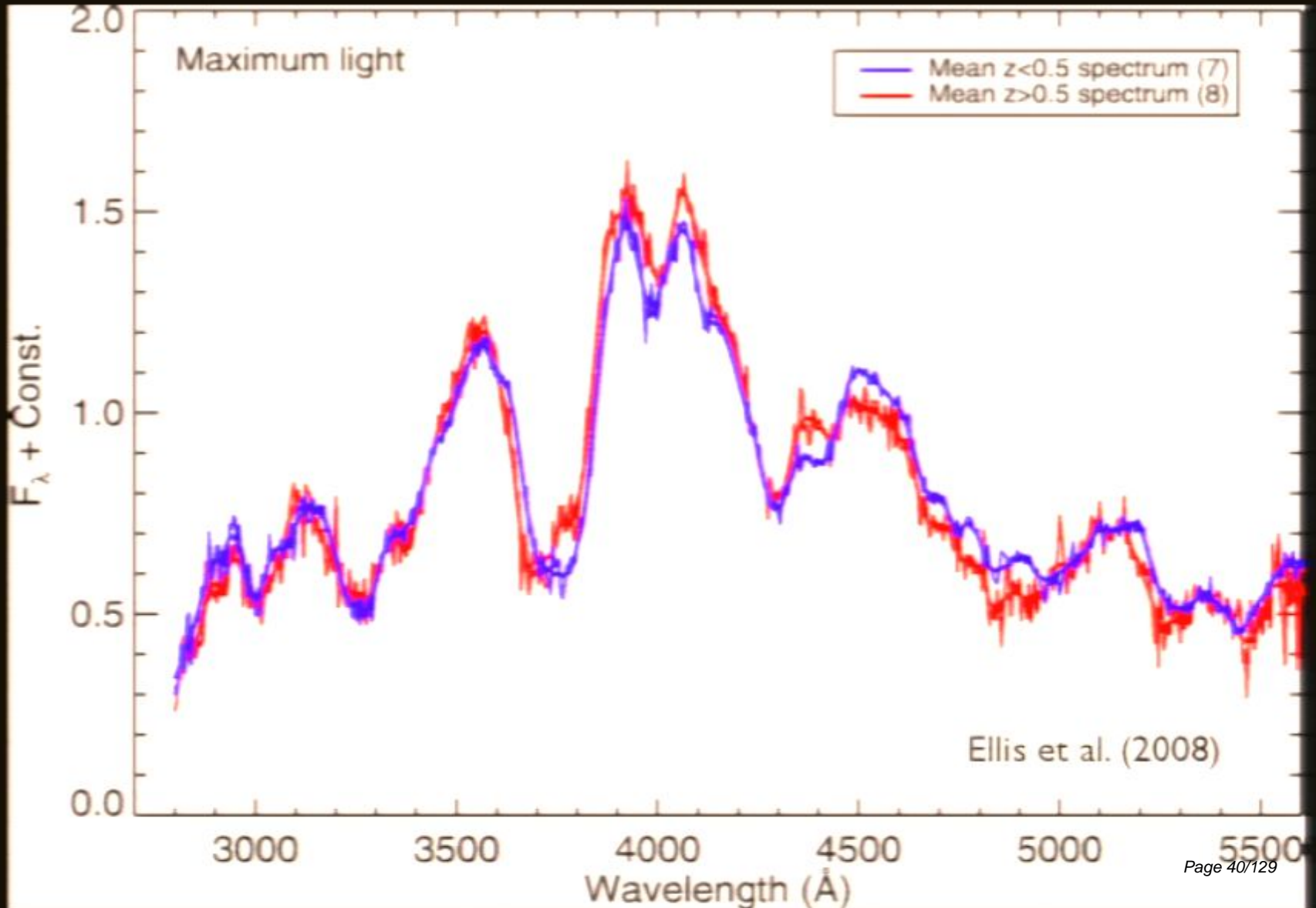
- Filters have non-uniform spatial response at 1-2% level
- Discovered in our data, then confirmed by filter scans
- Real issue is now the definition of the standard system

g' colour uniformity

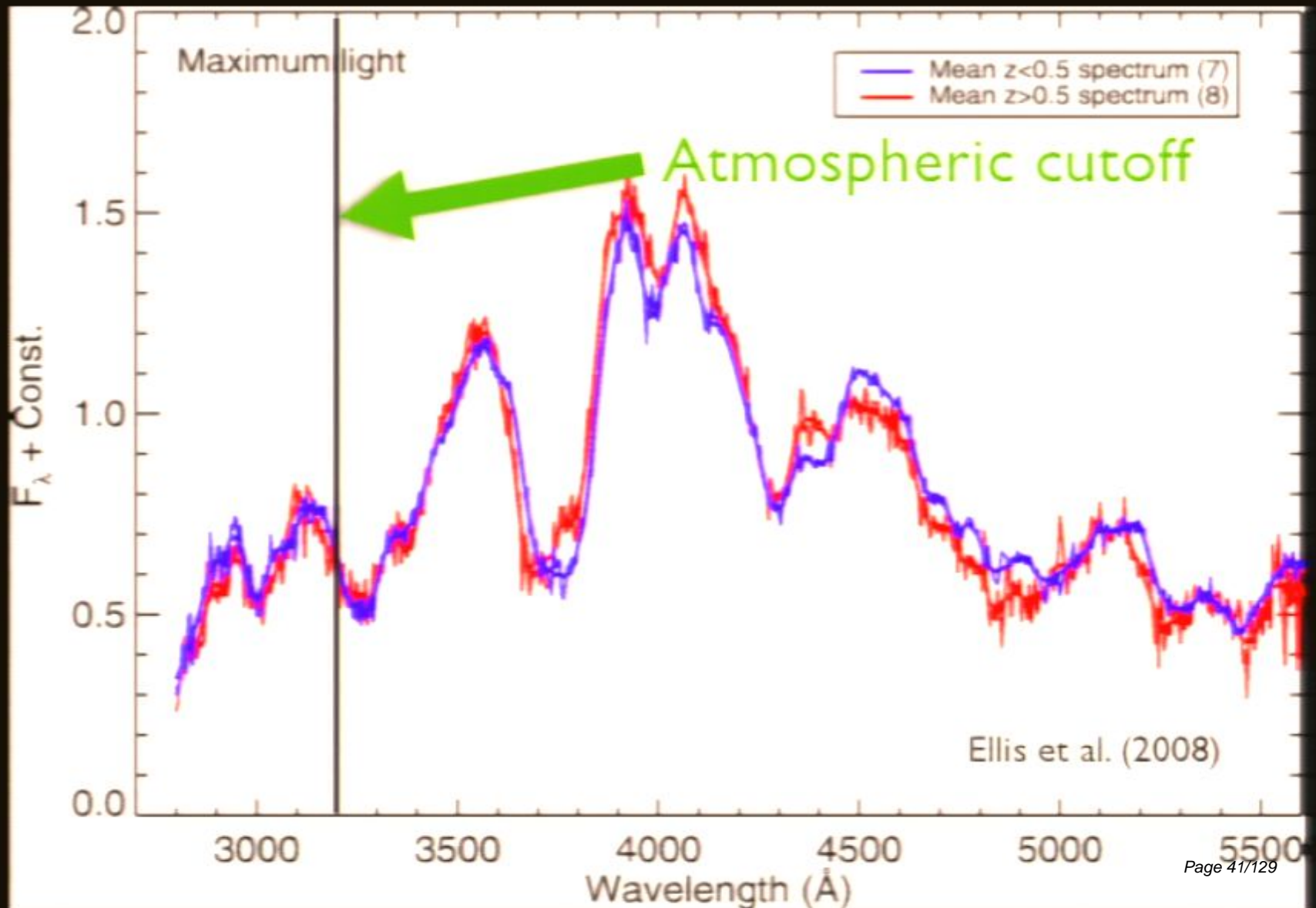


Regnault et al., in prep

Studying the near UV



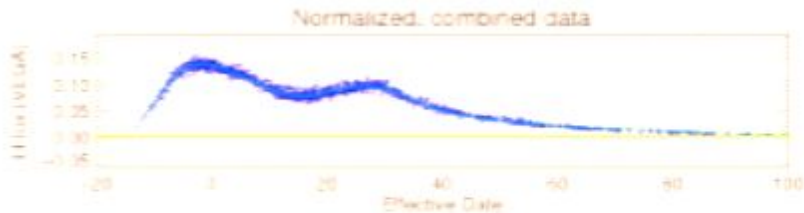
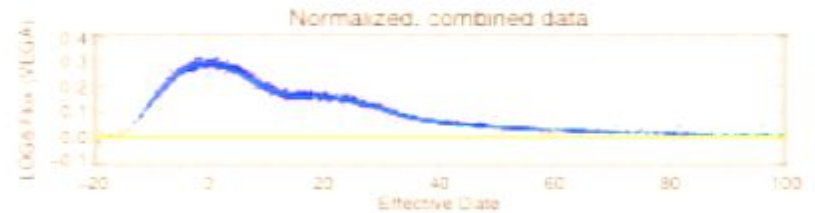
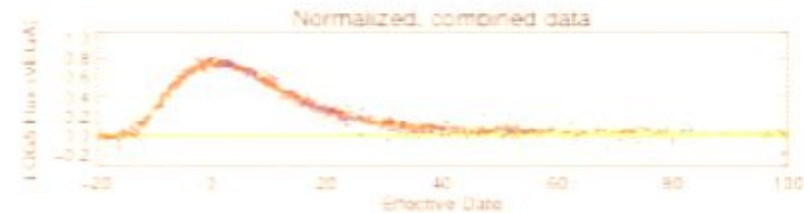
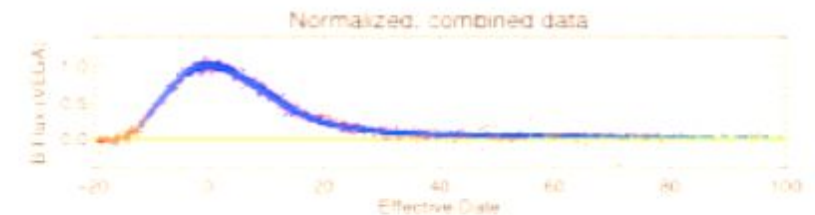
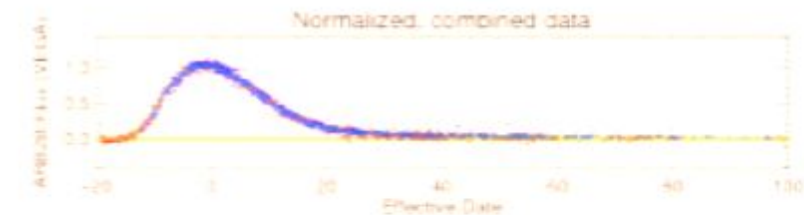
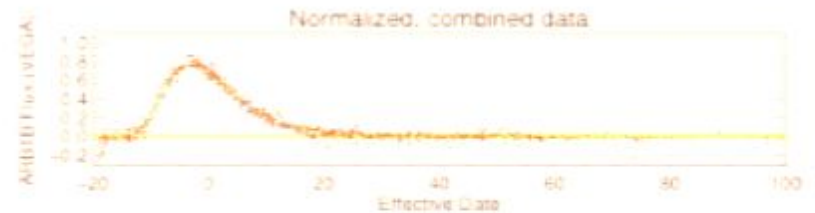
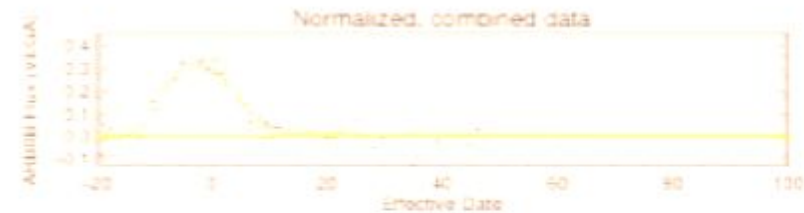
Studying the near UV



Building a better mousetrap

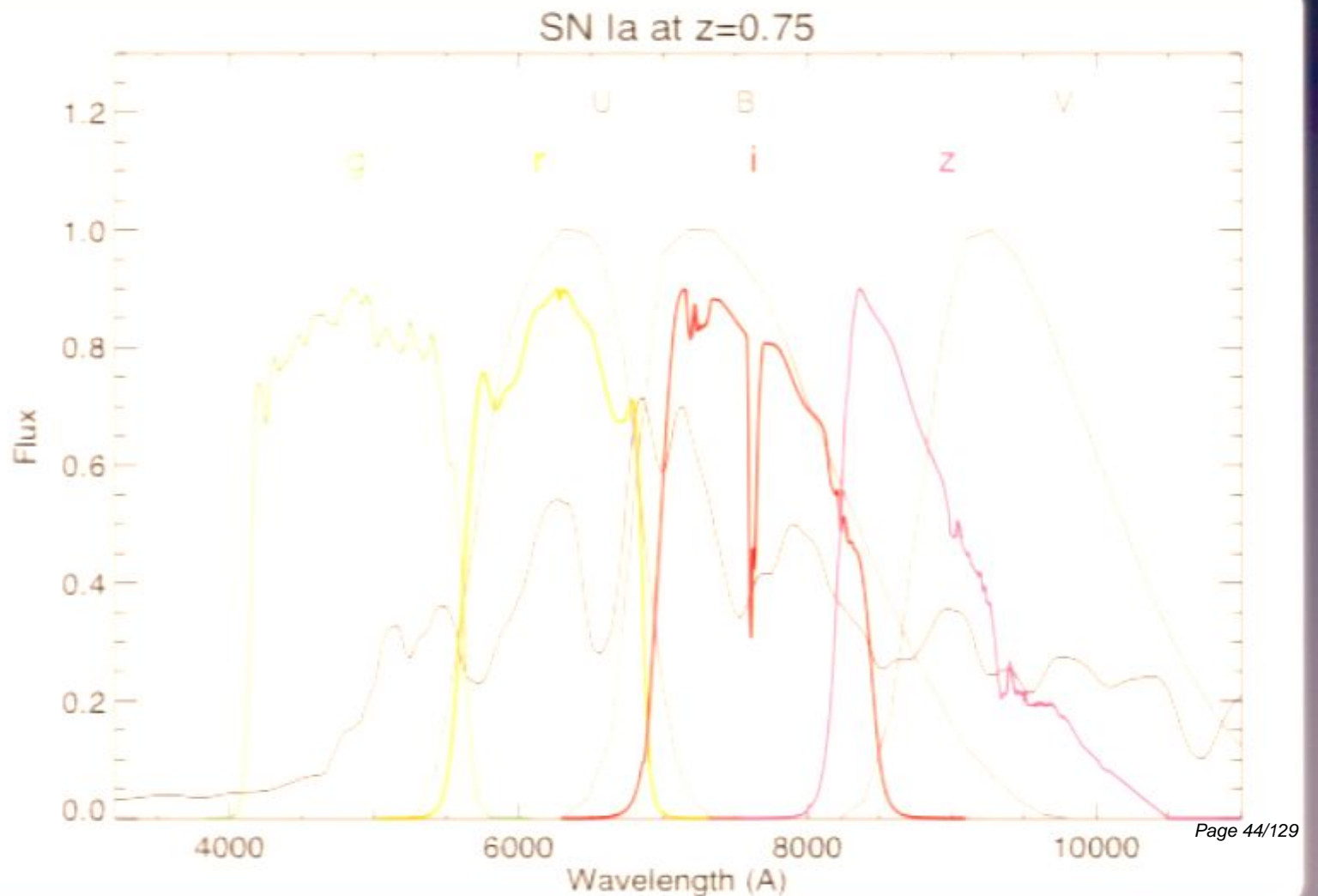
- Use our own data to improve our empirical model of SN Ia, especially in the near-UV
- Our new fitter is called SiFTO
- Also one developed in France: SALT(2), also goes blue
- Improve standardization of SN Ia from 0.2 mag to 0.16 mag

SN are quite homogenous



Conley et al. (2008)

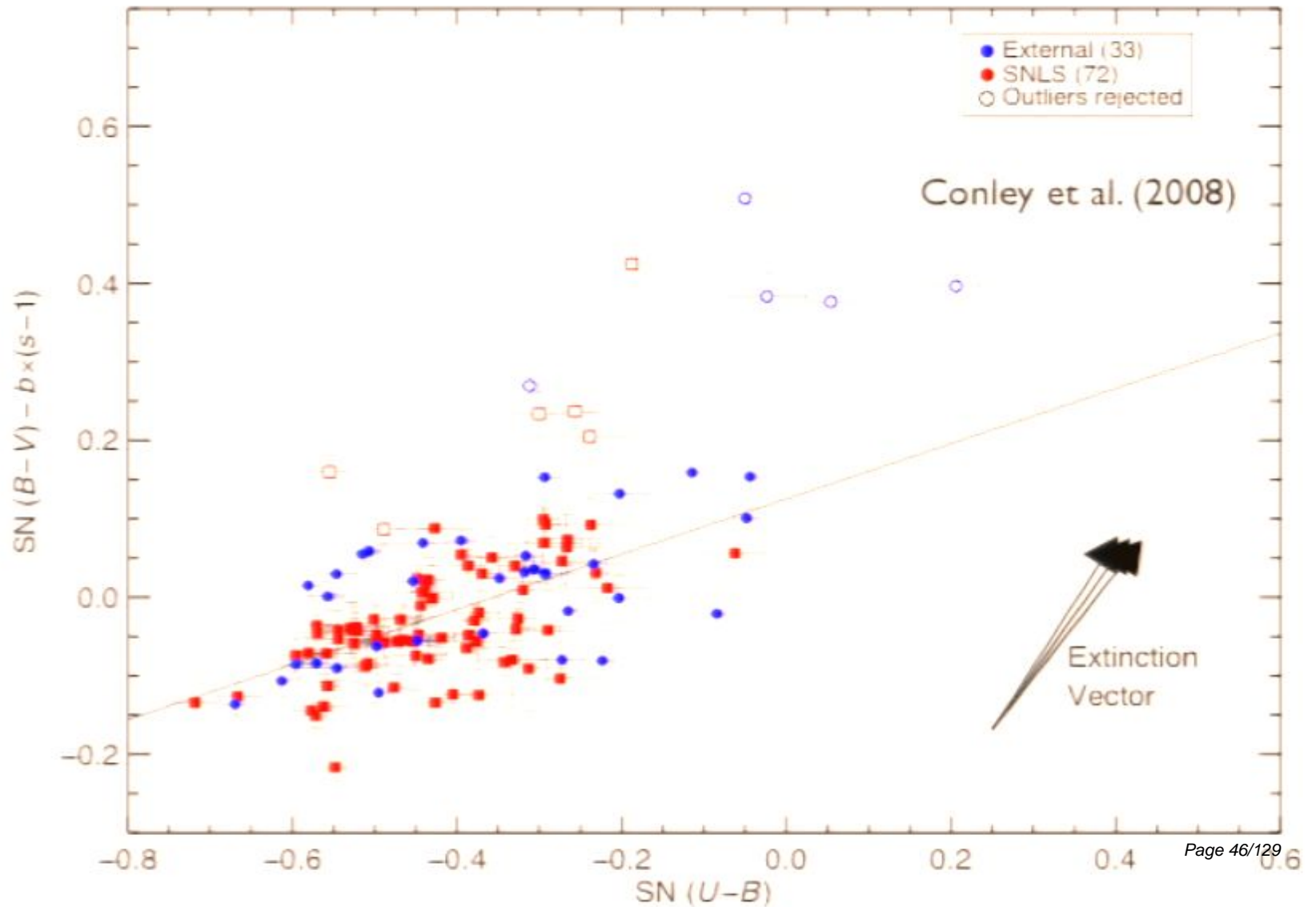
Go blue!



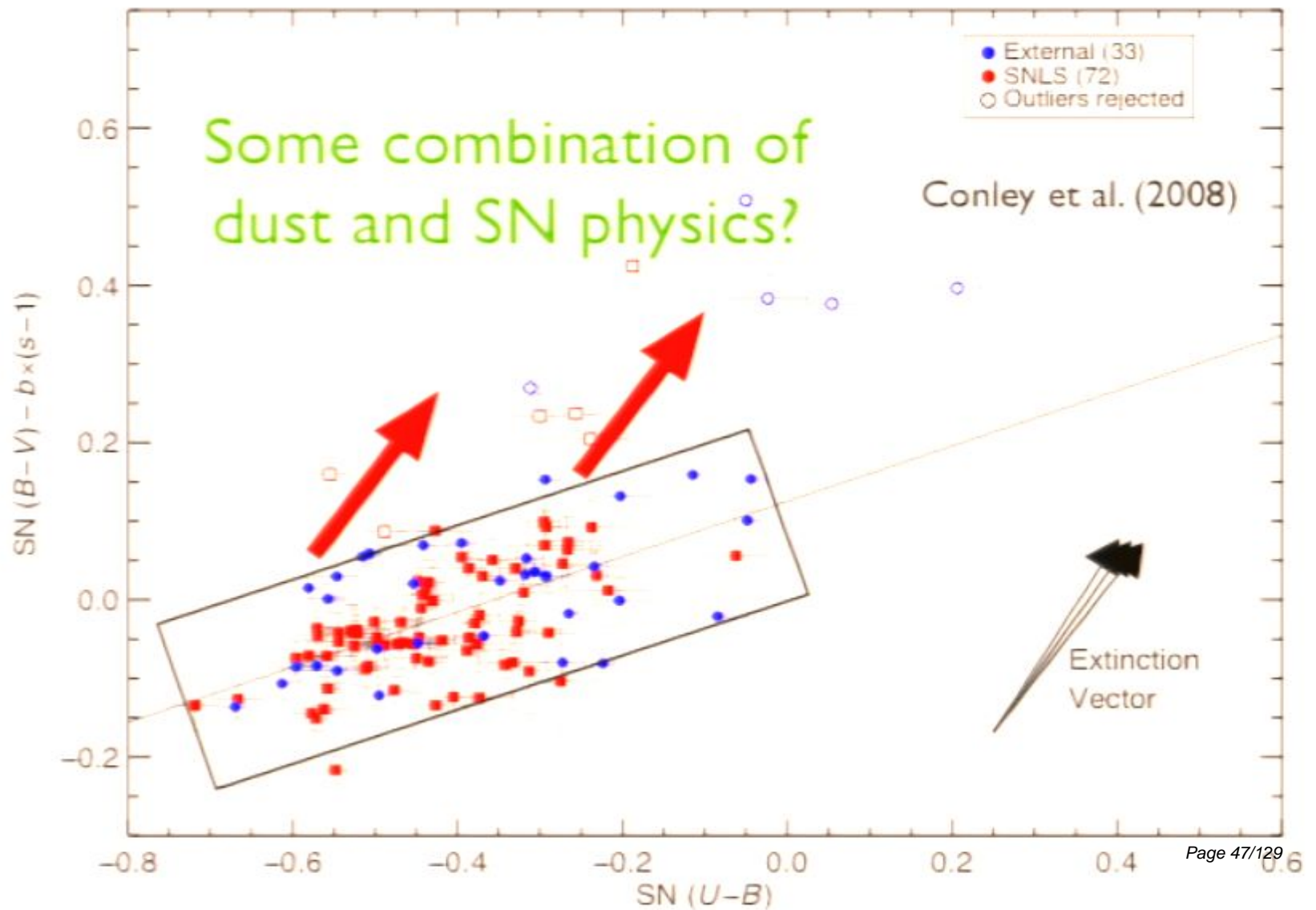
SN colours

- Redder SN are fainter
- We expect this from dust if nothing else
- But it doesn't seem to behave like only dust

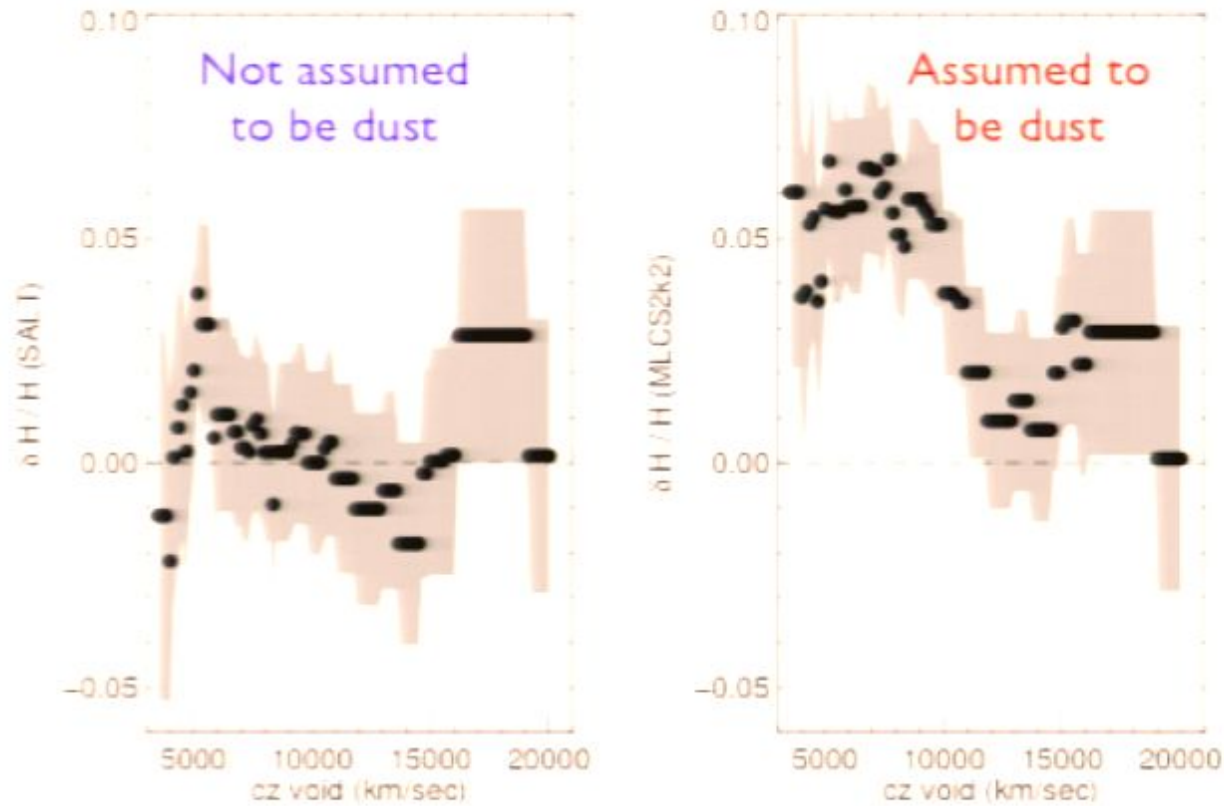
SN Ia colours



SN Ia colours



Assuming it is all dust gives you a Hubble bubble



Conley et al. (2007)

Other Science

- Rates of different SN types (progenitor clues) : Neill et al. (2006), Sullivan et al. (2006)
- Type IIP cosmology: Nugent et al. (2005)
- Developing reliable photometric typing
- The list goes on

Ensuring the Legacy Value

- 3rd year sample will raise the bar considerably for SN cosmology
- Real potential of data will be realized with new nearby SN samples
- Plug-in for CosmoMC so others can analyze their favourite cosmology
- More supernova science to come

Lessons of SNLS

- We need a better low- z sample to make progress
- Calibration is difficult
- Step after that requires improved understanding (colours, evolution, etc.)
- We need more high-quality data, not just more data

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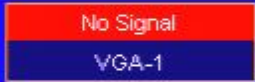
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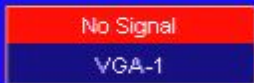
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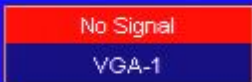
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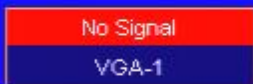






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