

INFRARED PHOTOMETRIC UNCERTAINTIES WITH THE PAIRITEL 1.3M TELESCOPE

Andrew Friedman

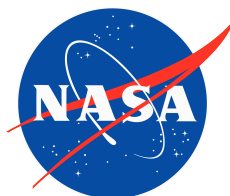
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www.cfa.harvard.edu/pairitel

www.pairitel.org

web.mit.edu/asf/www/

asf@mit.edu



Fred Lawrence Whipple Observatory

OUTLINE:

INFRARED PHOTOMETRIC UNCERTAINTIES WITH THE PAIRITEL 1.3M TELESCOPE

1. Data: PAIRITEL Supernova Project

Wood-Vasey, Friedman+08
Friedman+13 in prep.

2. Photometry Tests

Friedman+13 in prep.

3. Galaxy Subtraction Tests

Friedman+13 in prep.

SCIENTIFIC GOALS

- Study NIR properties of large, homogeneous, ground-based, low-z, bright SN Ia data set
- NIR+Optical → more accurate & precise distances
- Understand dust in other galaxies
- High-z cosmology (HST, JWST, EUCLID, WFIRST)
- Thesis: (Friedman+13)
- Largest homogeneous NIR SN Ia sample
~double published NIR SN Ia LCs ($\sim 120 \rightarrow \sim 200$)
~more than triple # of observations



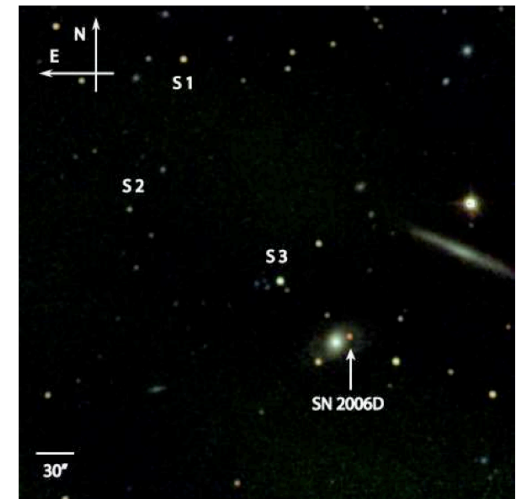
Peters Automated InfraRed Imaging TELEscope

- PAIRITEL 1.3m: 2MASS telescope
- Roboticized in 2004: **(Bloom+06)**
- Autonomous queue scheduled obs
- 20+ science projects + SN follow-up



PAIRITEL SN Project

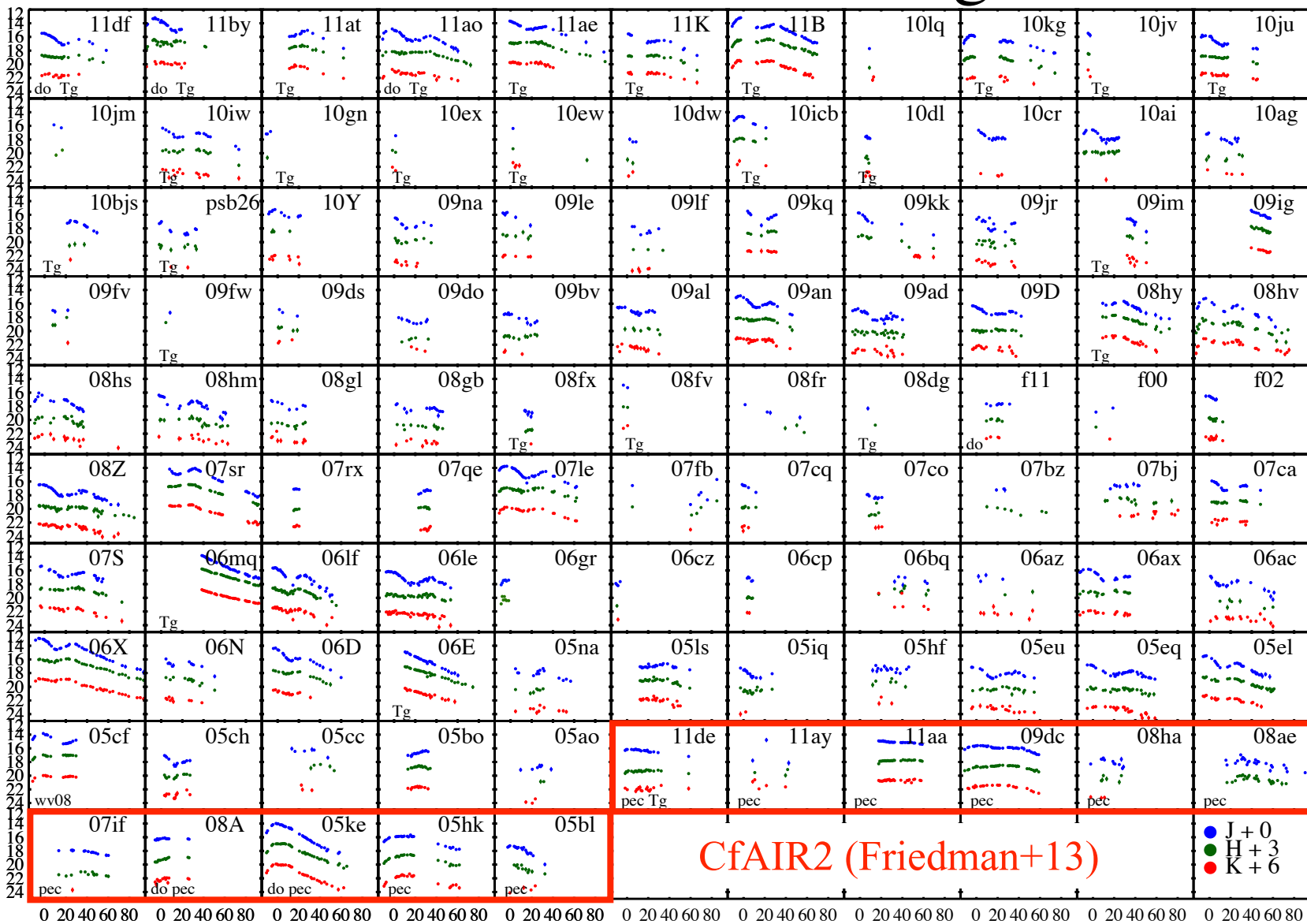
- ~30% time since 2005
- Homogeneous data set, tested camera
- Simultaneous JHK, ~nightly cadence
- Photometric calibration → 2MASS
- Optical Phot, Spectra (1.2m, 1.5m)



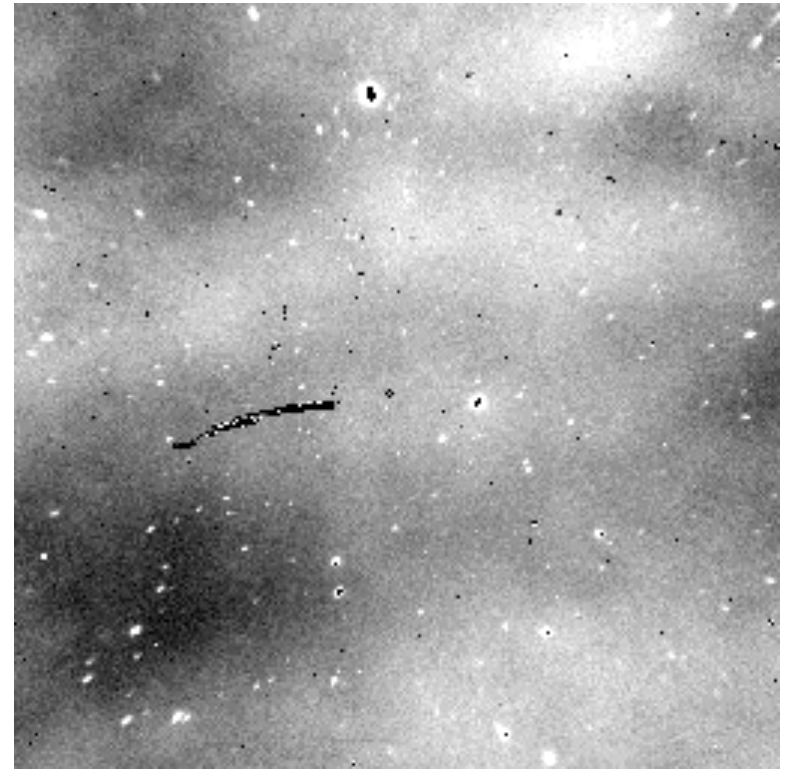
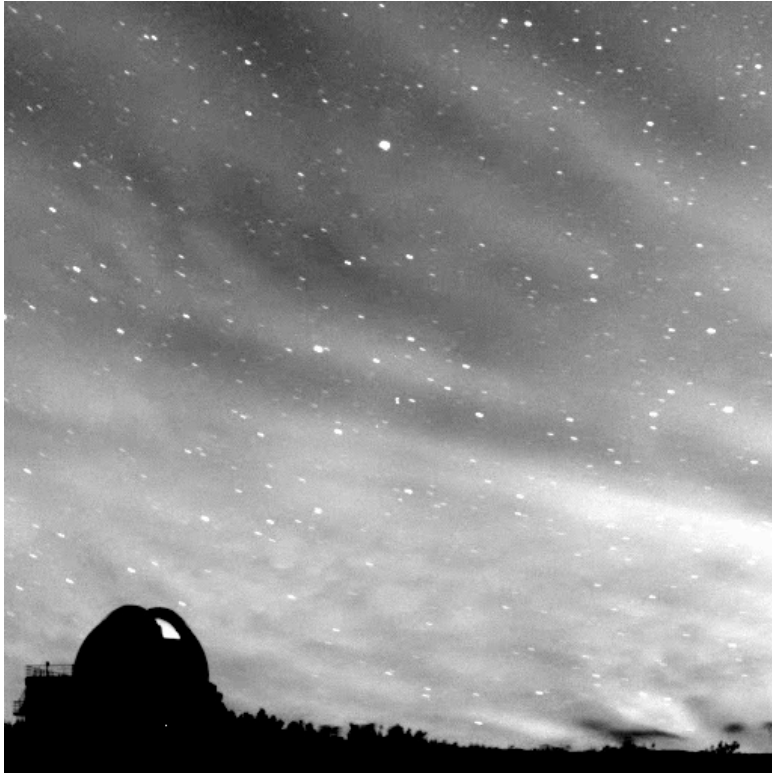
PAIRITEL JHKs: SN2006D
Wood-Vasey, Friedman+2008 (FIG 1)

104 PAIRITEL SN Ia JHK Light Curves

Apparent Magnitude + constant



THE DARK SIDE OF THE BRIGHT IR SKY



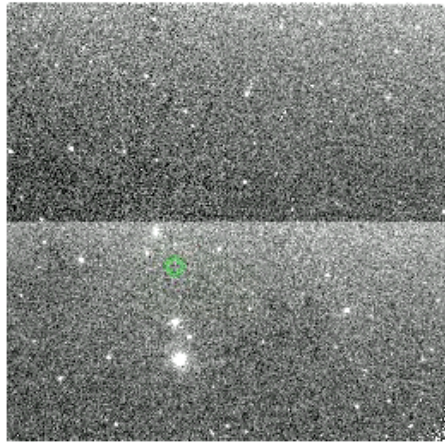
Observatoire de Haute-Provence

2MASS H-Band (FLWO)

INFRARED AIRGLOW FROM
THE NIGHT SKY. AT NIGHT!

<http://www.obs-besancon.fr/nirsky/>,
<http://www.astro.virginia.edu/~mfs4n/2mass/airglow/adams/airglowpage.html>

IR MOSAICS DITHER PATTERN



each 8.5 x 8.5 arcmin FOV

12 x 12 arcmin FOV

TARGET: Sn2010iq

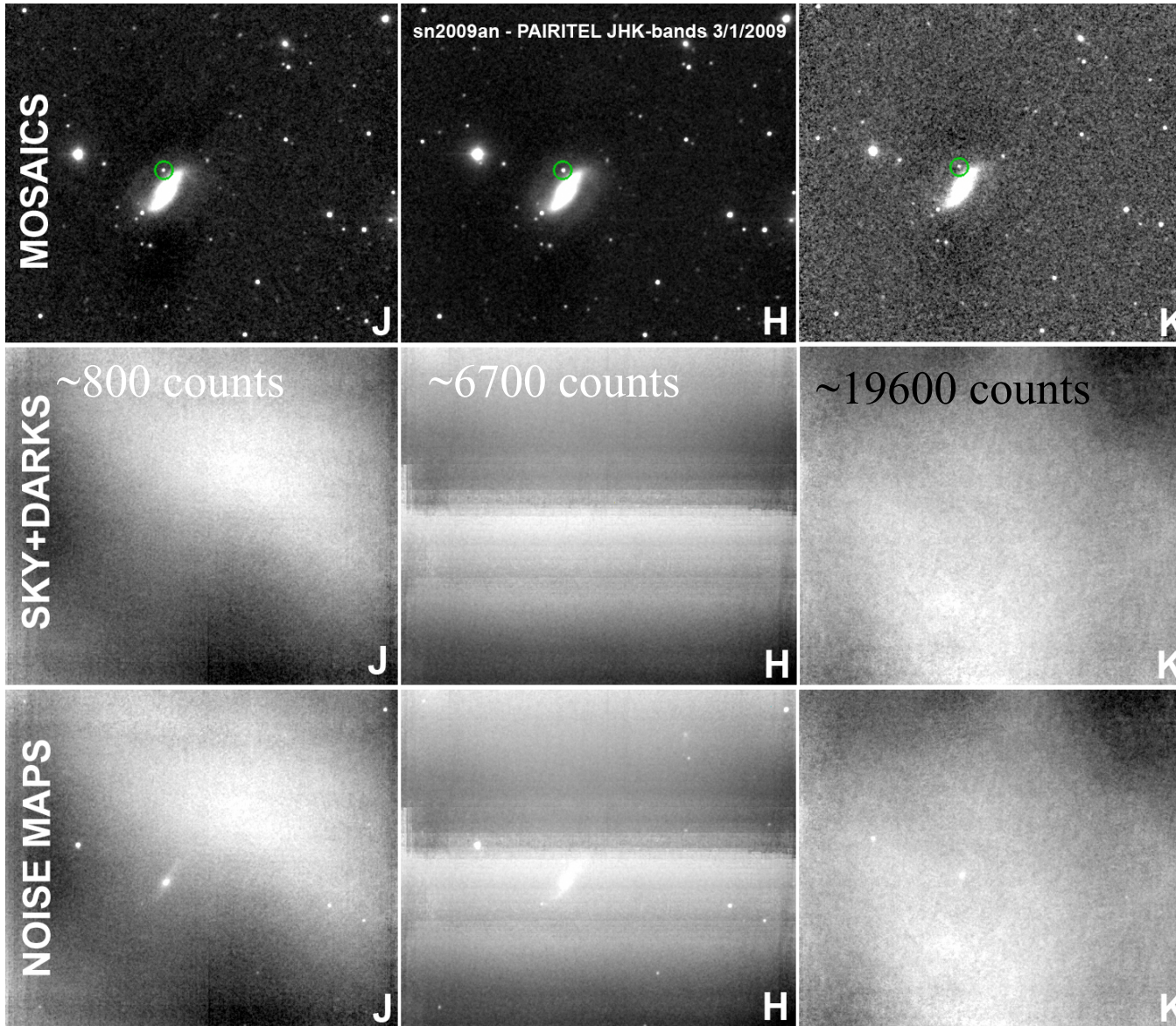
MOSAIC CENTER

Final Mosaic

[PAIRITEL Mosaic Code](#): Automated Reductions @ Berkeley, CfA

- p1.0-p3.5: Josh Bloom, Cullen Blake, Dan Starr, Chris Klein (Berkeley)
- p3.6: Andrew Friedman, Bill Wyatt (Harvard/CfA)

THE INFRARED SKY IS EVIL



MOSAICS
Sky+dark
subtracted

SKARKS
sky+dark maps
(constant value
assumed: p2.0)

NOISE MAPS
Noise/pixel in
mosaic from
source, sky, dark,
etc...

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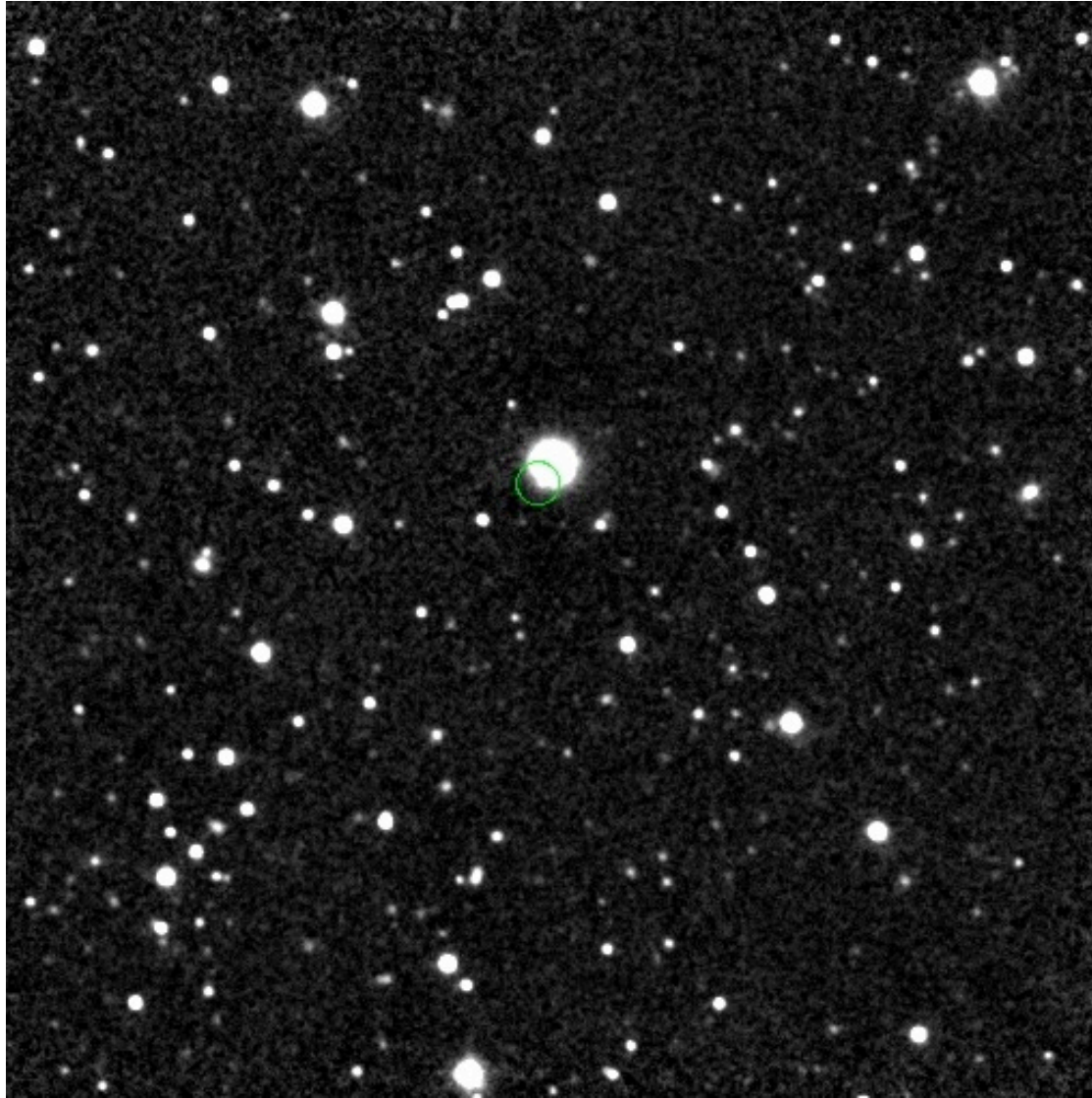
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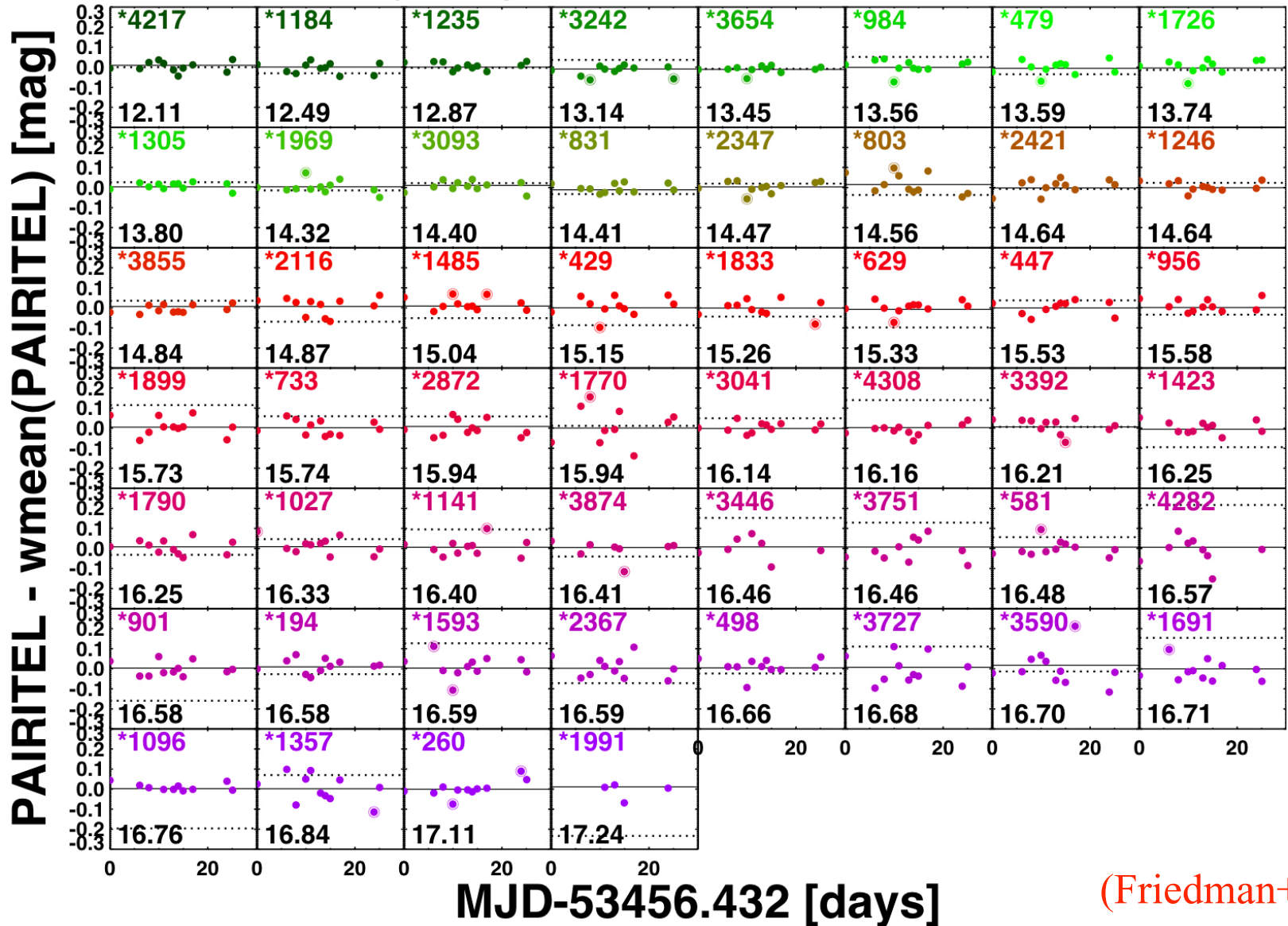
PHOTOMETRIC PRECISION TESTS



SN 2005ao PAIRITEL J-band, 4/9/2005

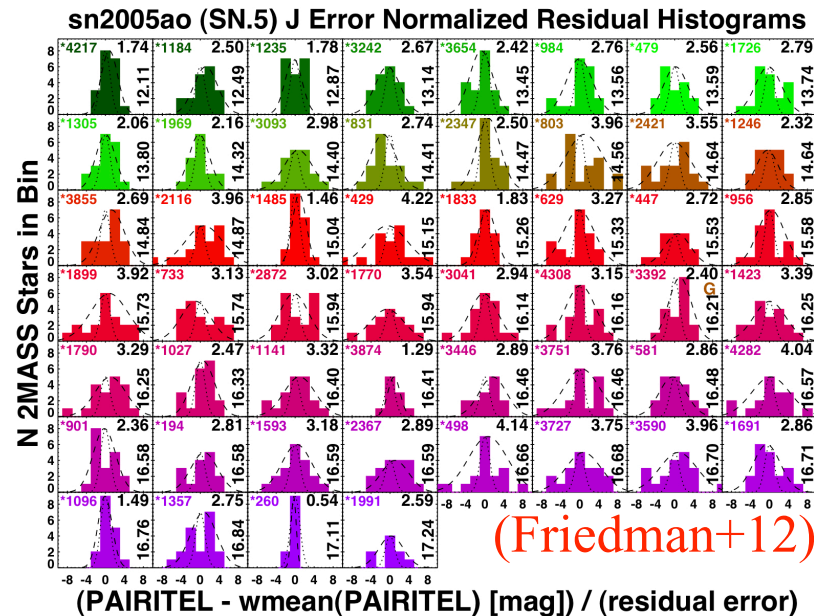
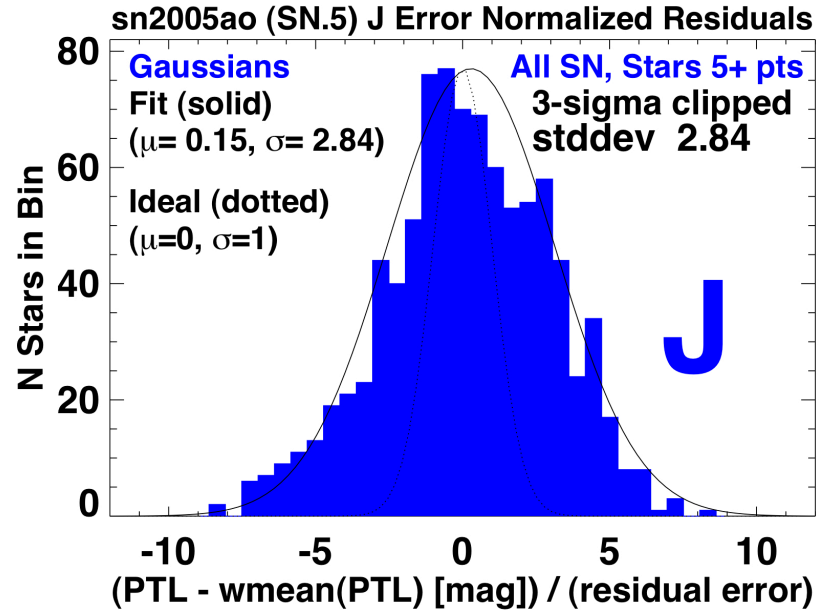
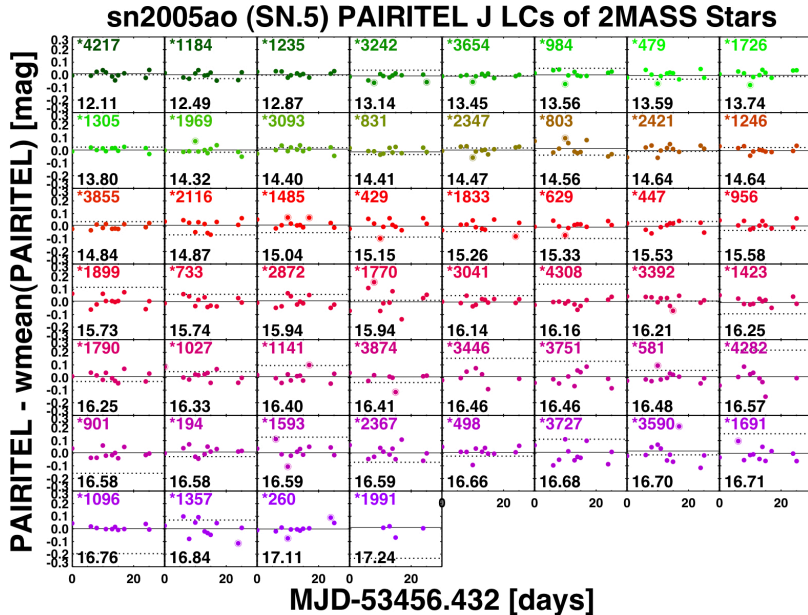
PHOTOMETRIC PRECISION TESTS

sn2005ao (SN.5) PAIRITEL J LCs of 2MASS Stars



(Friedman+13)

PHOTOMETRIC PRECISION TESTS



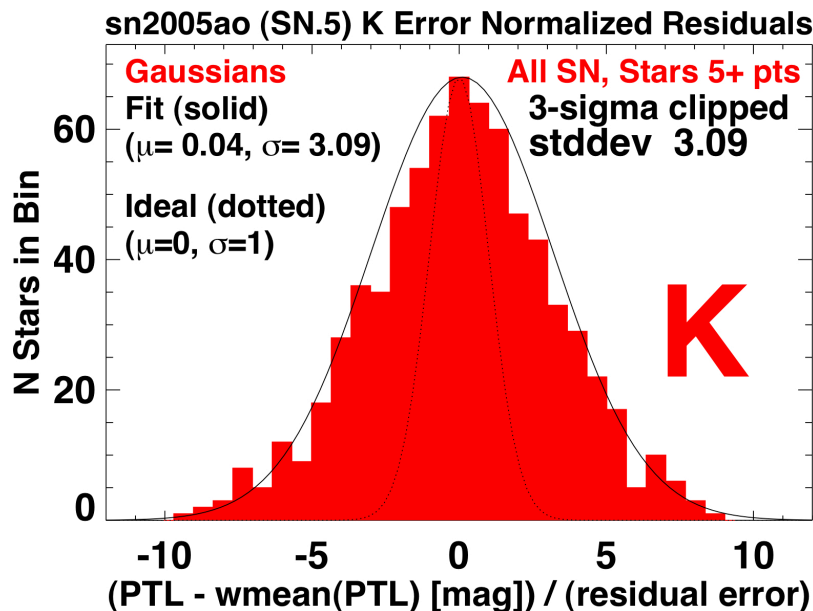
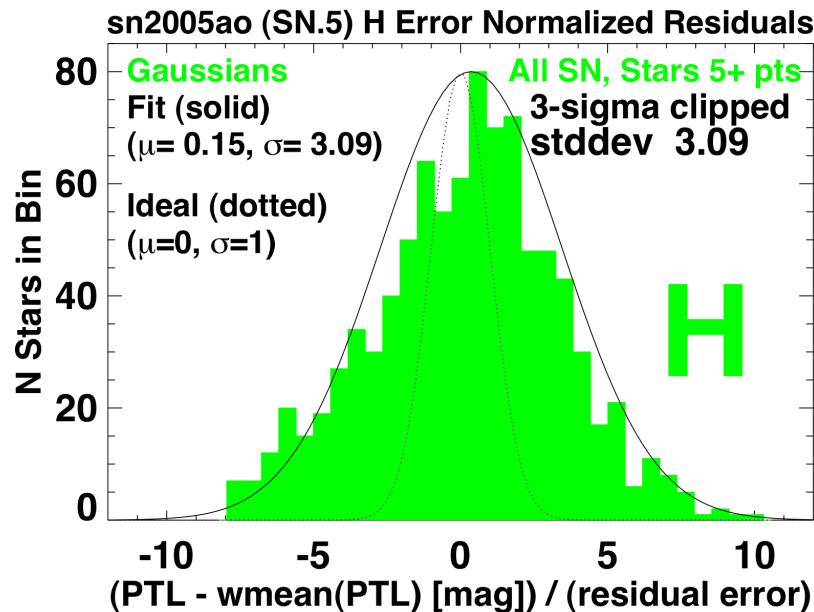
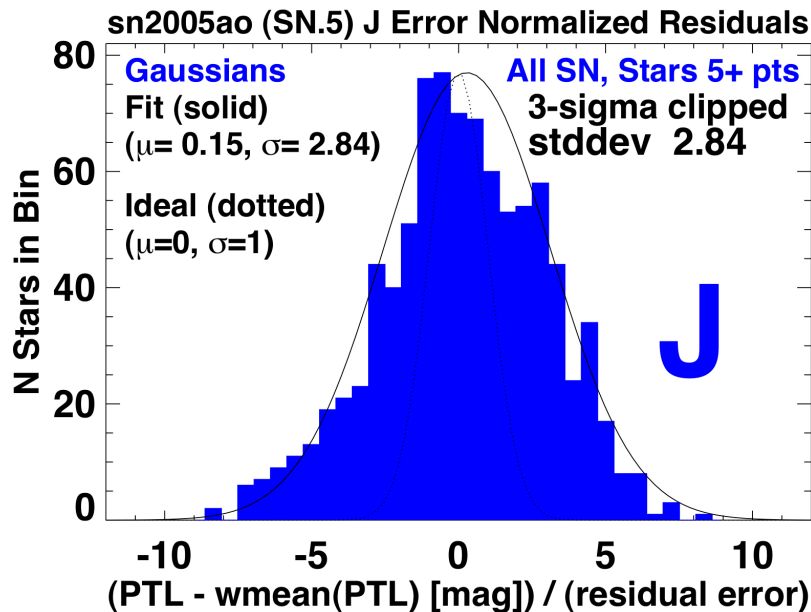
(Friedman+12)

Field of SN 2005ao (J-band)

Error normalized residuals
Stddev = 2.84 → DoPHOT
errors underestimated by ~3

Noise maps don't perfectly
model all noise (e.g. sky)

PHOTOMETRIC PRECISION TESTS



Field of SN 2005ao (**JHK**)

Error normalized residuals

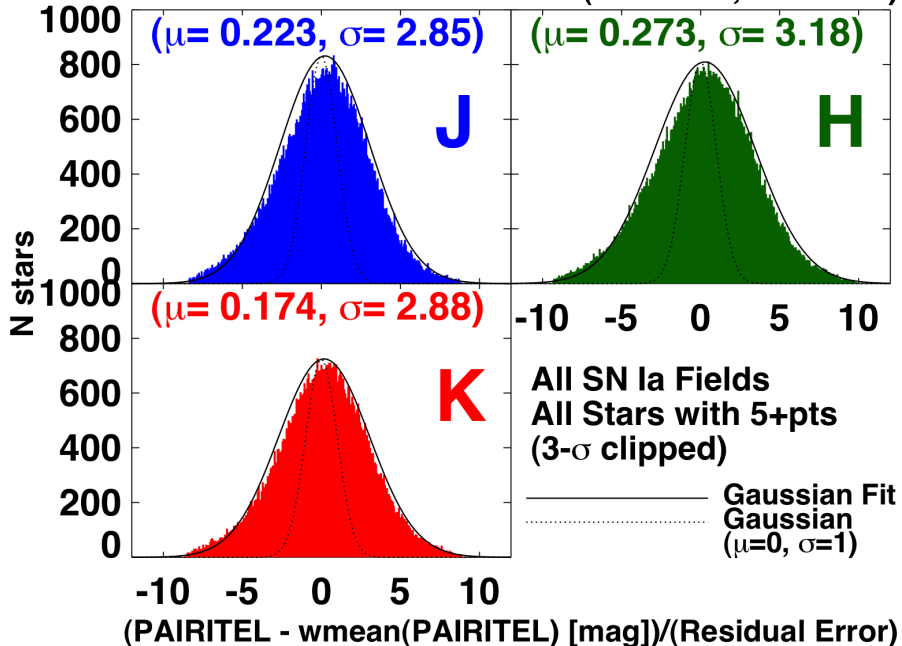
Stddevs = 2.84, 3.09, 3.09

DoPHOT **JHK** errors
underestimated by ~ 3

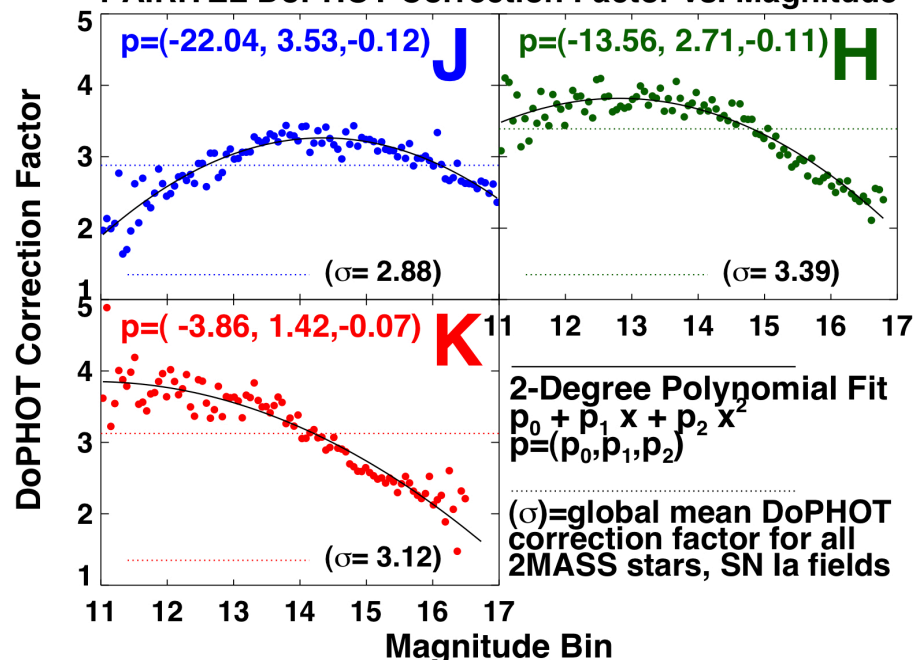
(Friedman+13)

PHOTOMETRIC PRECISION TESTS

Error Normalized Residuals (All Stars, Ia Fields)



PAIRITEL DoPHOT Correction Factor vs. Magnitude



Aggregate All Stars, Ia Fields

Error normalized residuals

Global Stddevs = 2.85, 3.18, 2.88

DoPHOT JHK errors underestimated by ~ 3

...But Depends on Star mag!

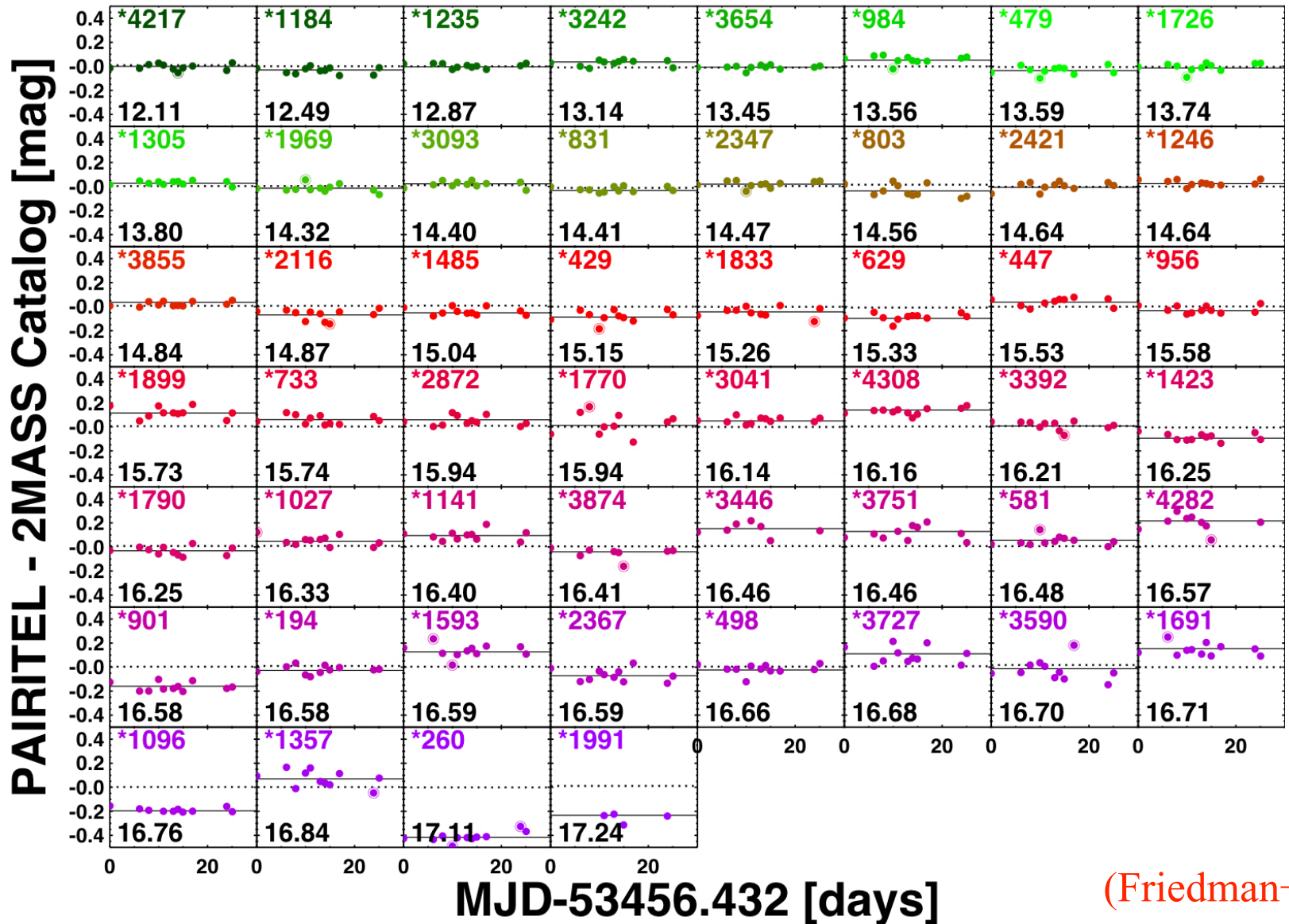
Source & sky noise \sim equal at turnover (14.5, 13, 11 mag)

Correct SN Ia LC errors by mag & band-dependent factor

(Friedman+13)

PHOTOMETRIC ACCURACY TESTS

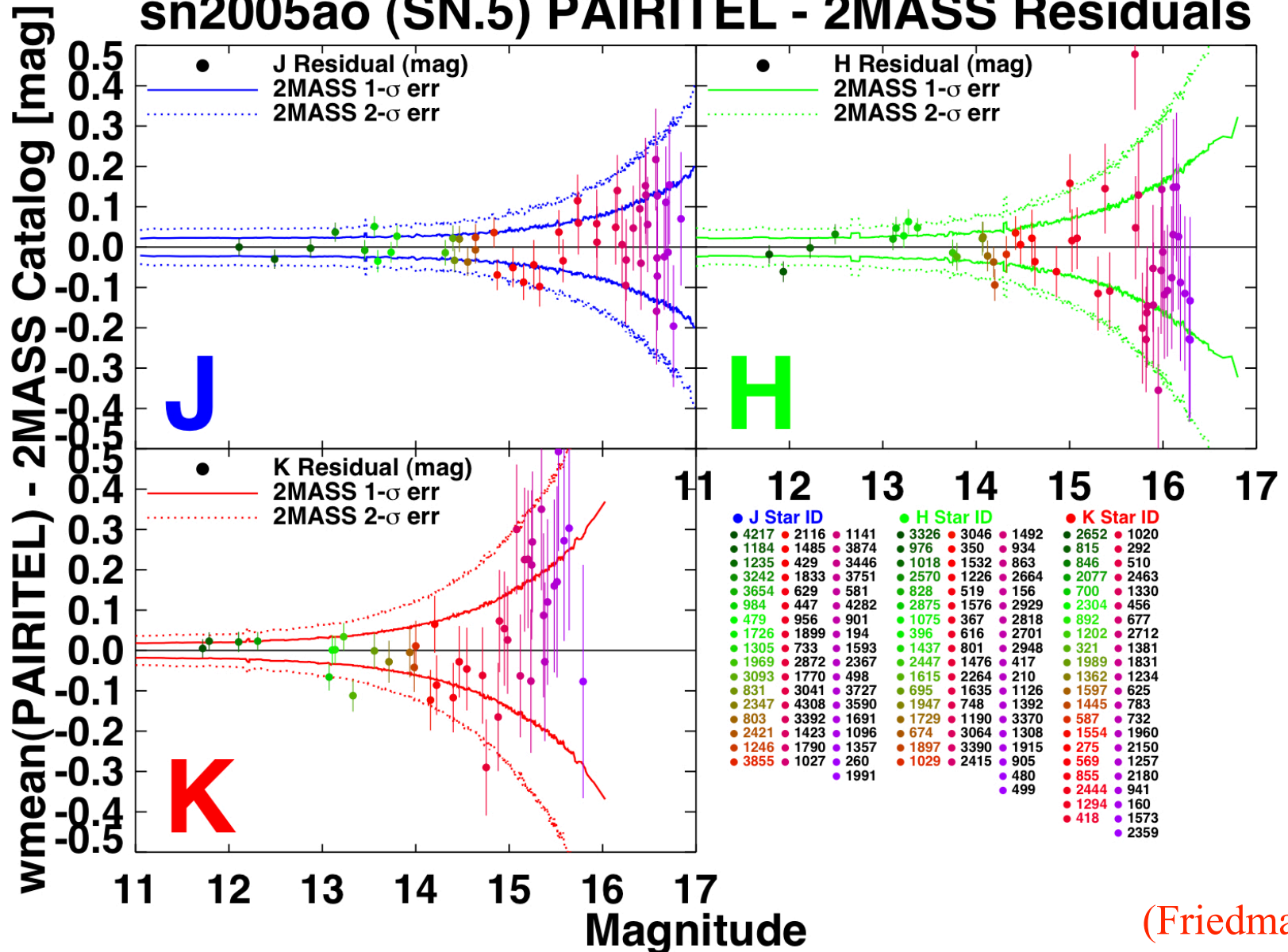
sn2005ao (SN.5) PAIRITEL J LCs of 2MASS Stars



(Friedman+13)

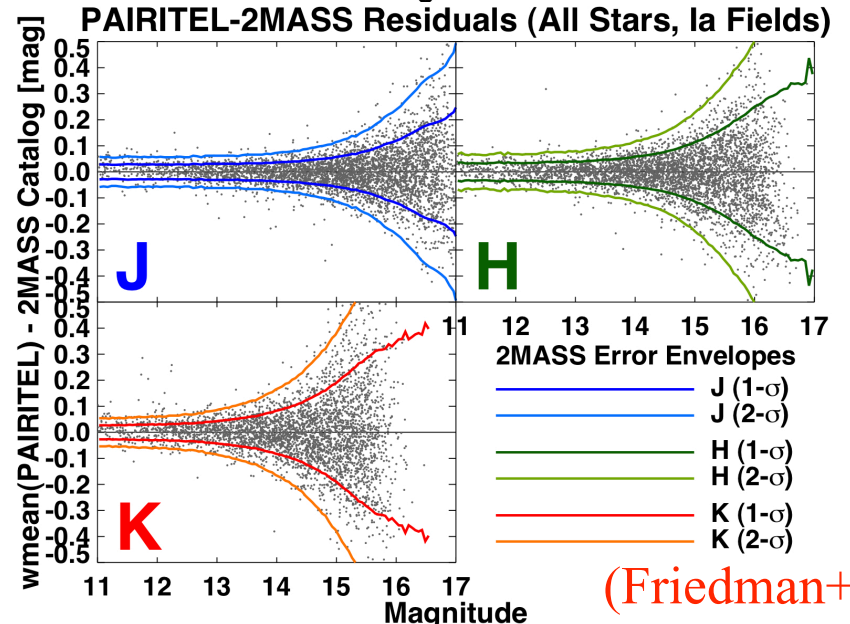
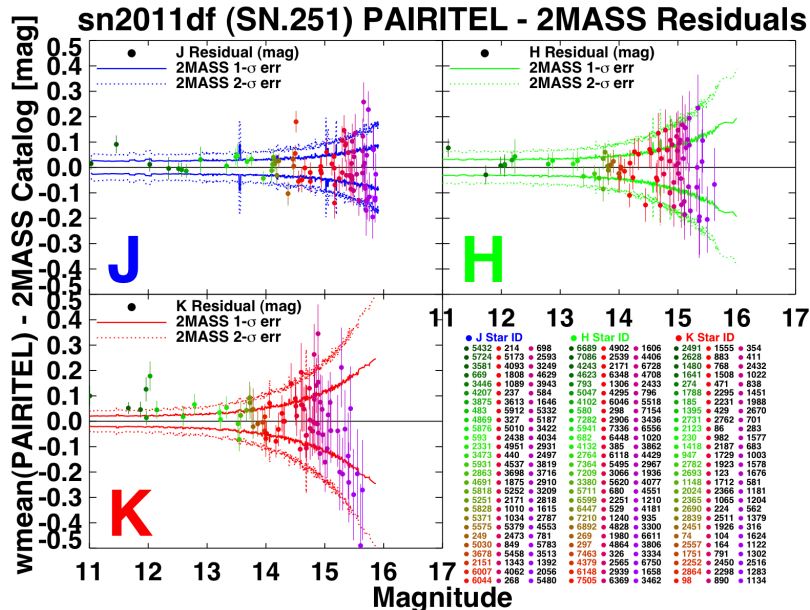
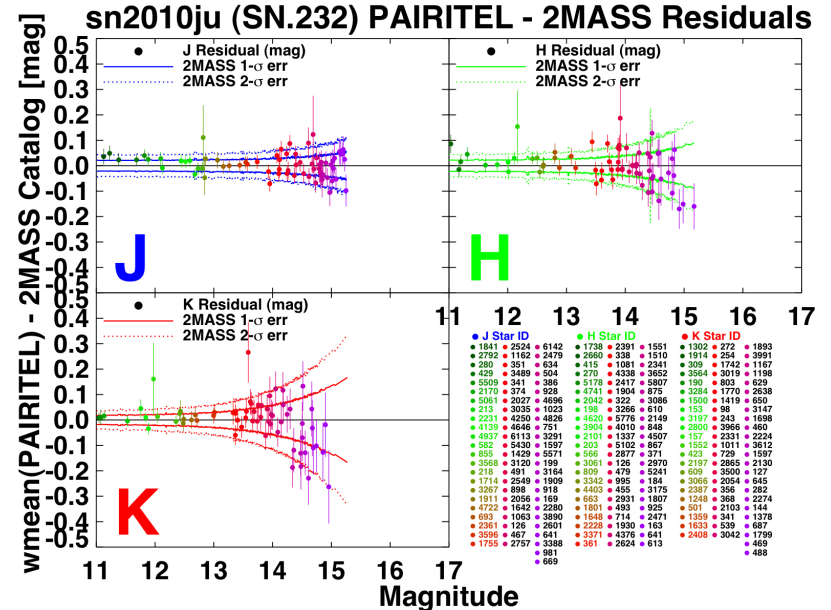
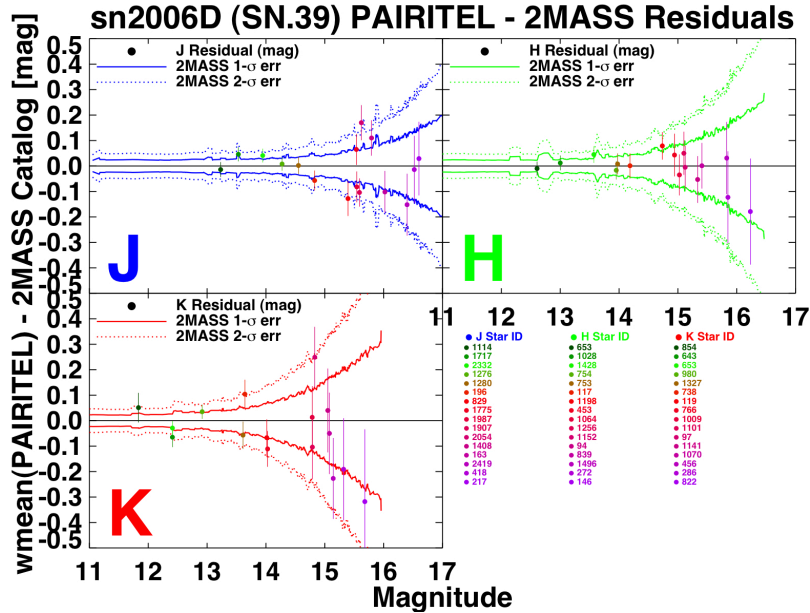
PHOTOMETRIC ACCURACY TESTS

sn2005ao (SN.5) PAIRITEL - 2MASS Residuals



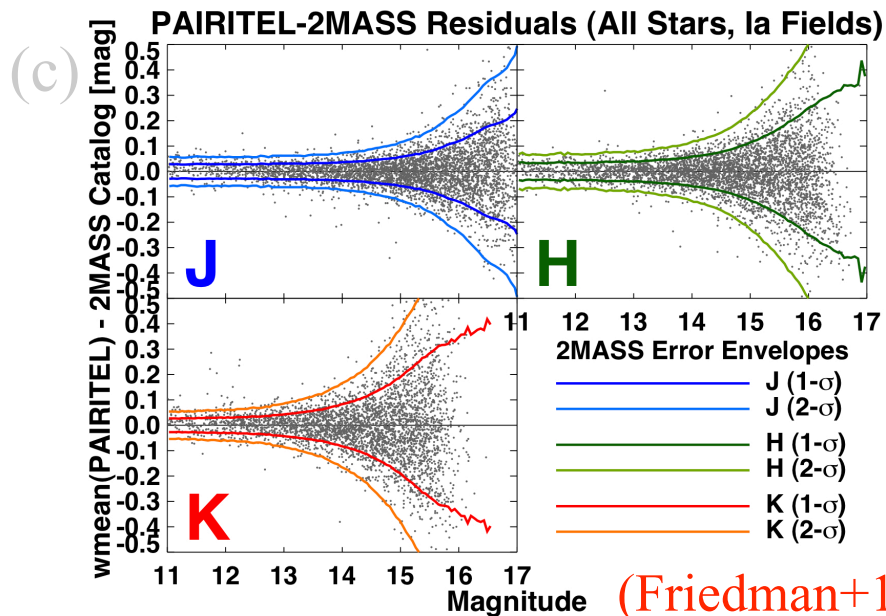
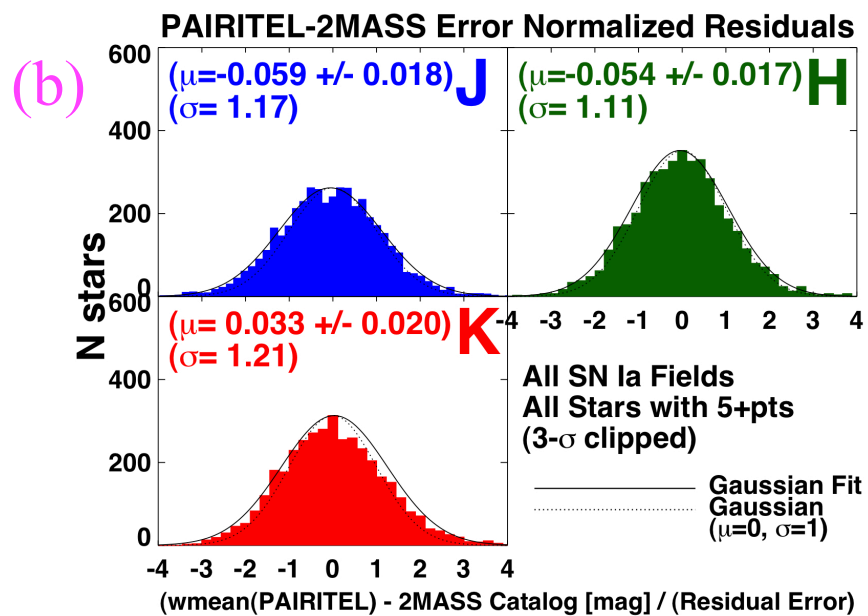
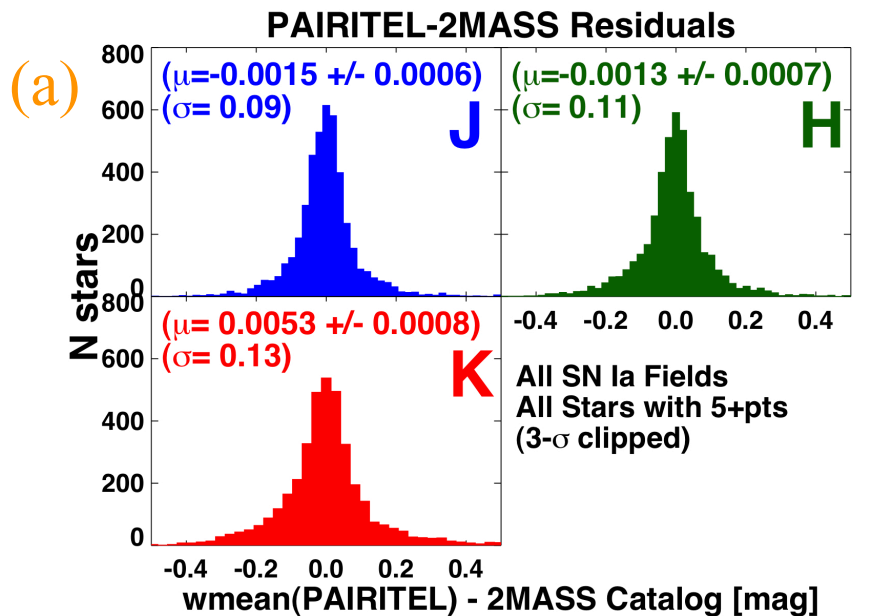
(Friedman+13)

PHOTOMETRIC ACCURACY TESTS



(Friedman+13)

PHOTOMETRIC ACCURACY TESTS



(a) PAIRITEL & 2MASS global mean residuals agree:
 ~ 0.001 mag **JH**, ~ 0.006 mag **K**

(b) Error normalized residuals
 Stddevs: **1.17**, **1.11**, **1.21** (10-20%)

(c) 68%, 95%, 99% star residuals consistent with 0 to 1, 2, 3- σ

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GALAXY SUBTRACTION



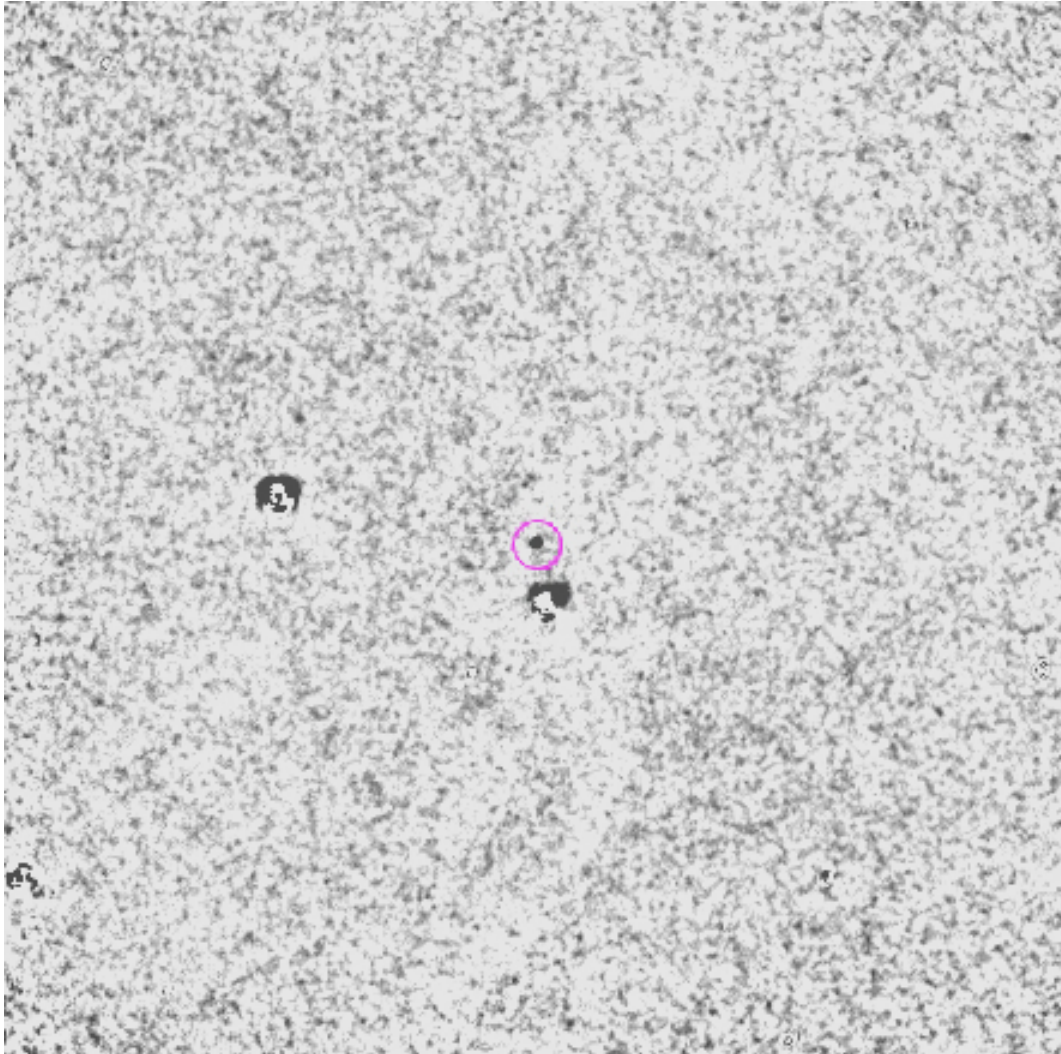
**SEND
THE GALAXY
FAR FAR AWAY!**

PAIRITEL H-Band Images

GALAXY SUBTRACTION



**SEND
THE GALAXY
FAR FAR AWAY!**



PAIRITEL H-Band Images

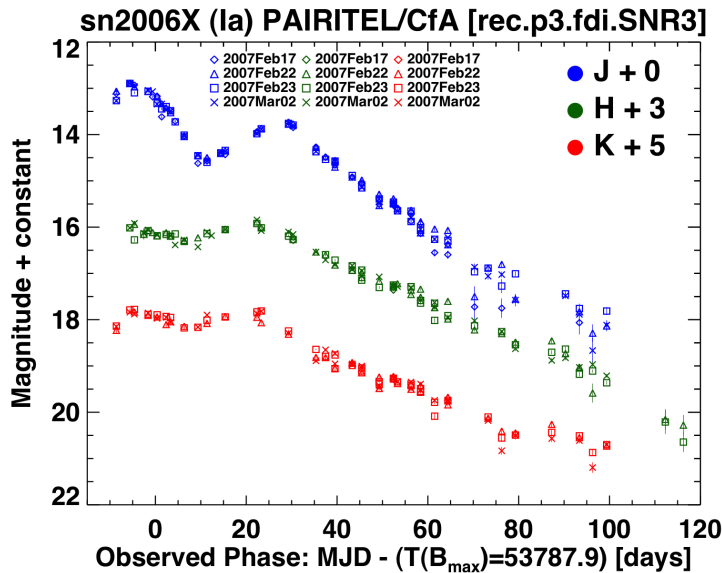
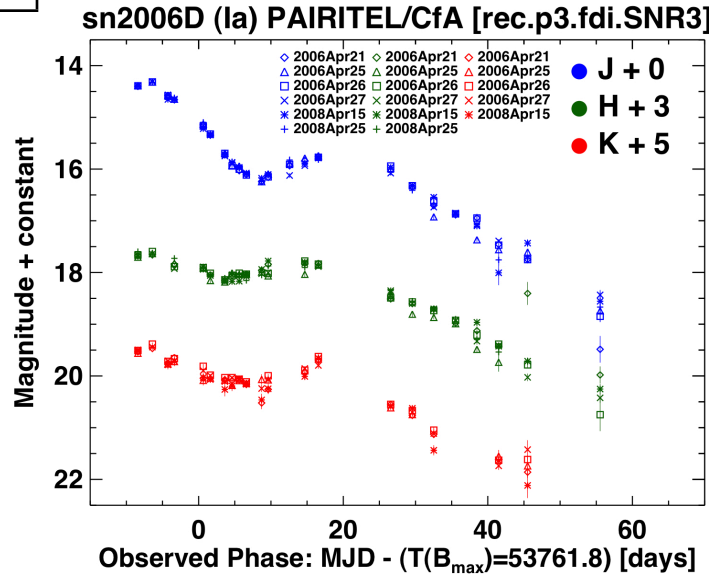
Difference Image
SN - SNTEMP

N~2-10
host galaxy
SNTMP
images

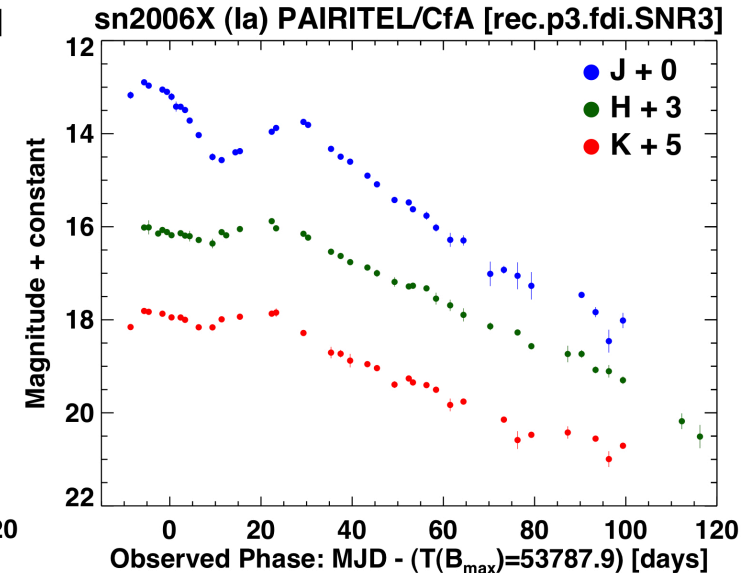
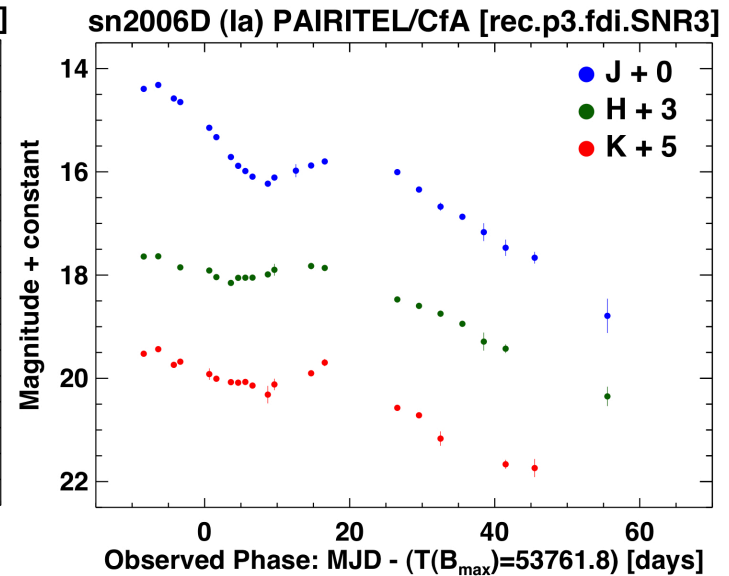
N LCs: One
for each
subtraction

NNTEMP
Weighted
Average of
N LCs

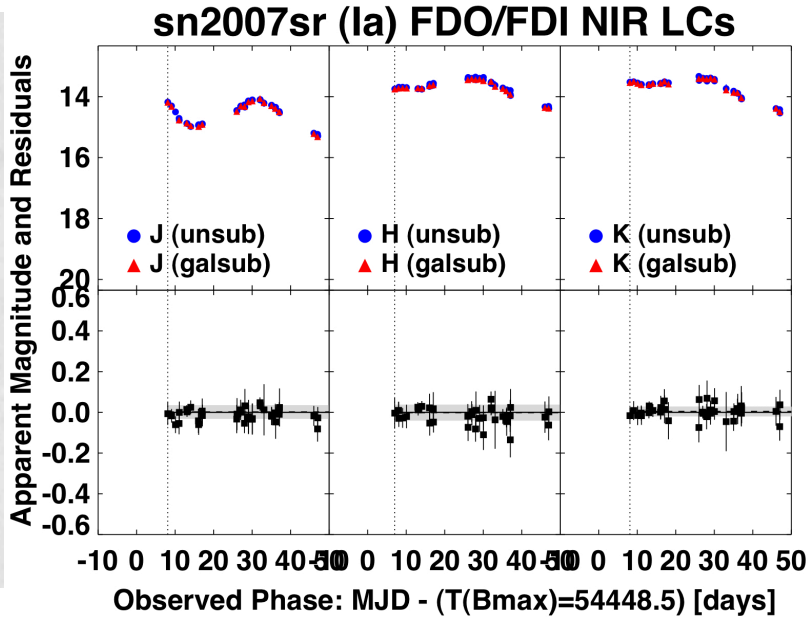
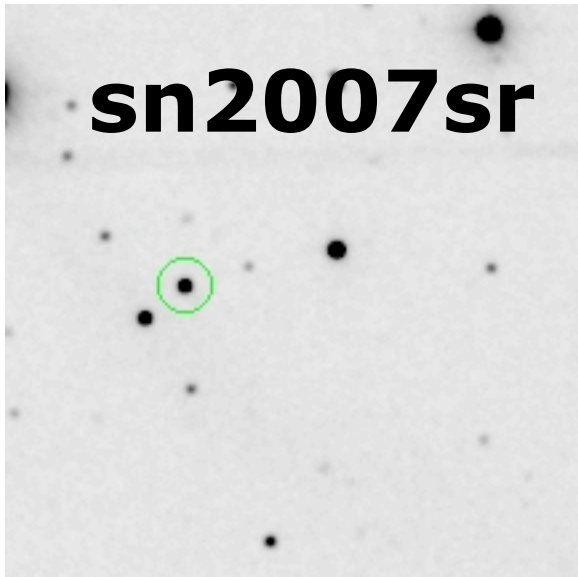
Before NNTEMP



After NNTEMP

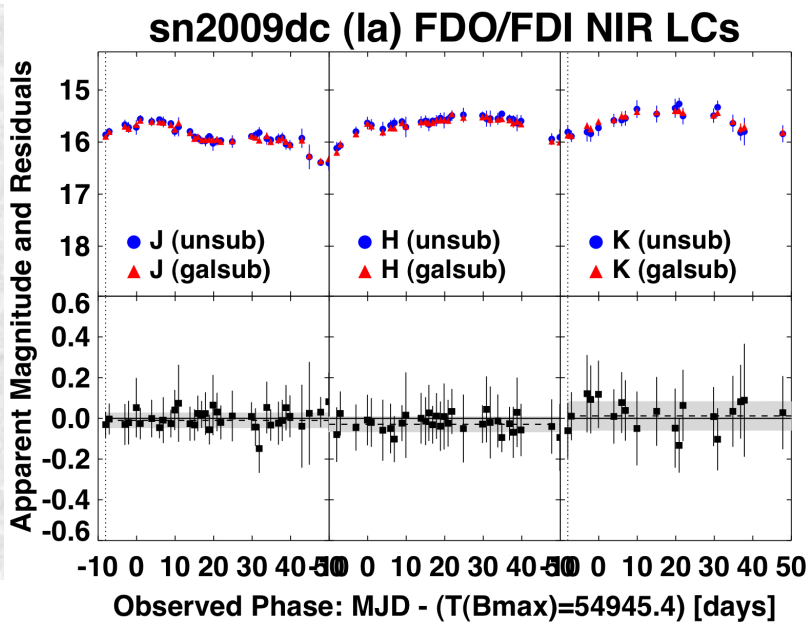
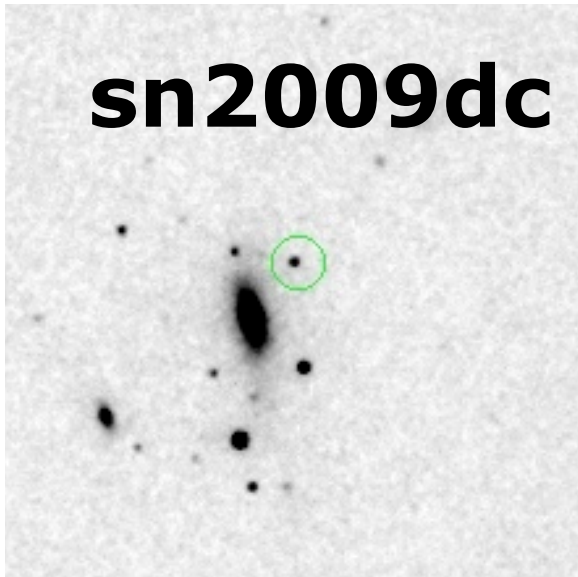


GALAXY SUBTRACTION TESTS



20 Bright, well isolated SN, little galaxy light

LCs with and without host galaxy sub



Mean residuals consistent with 0!

-0.0009 ± 0.0016

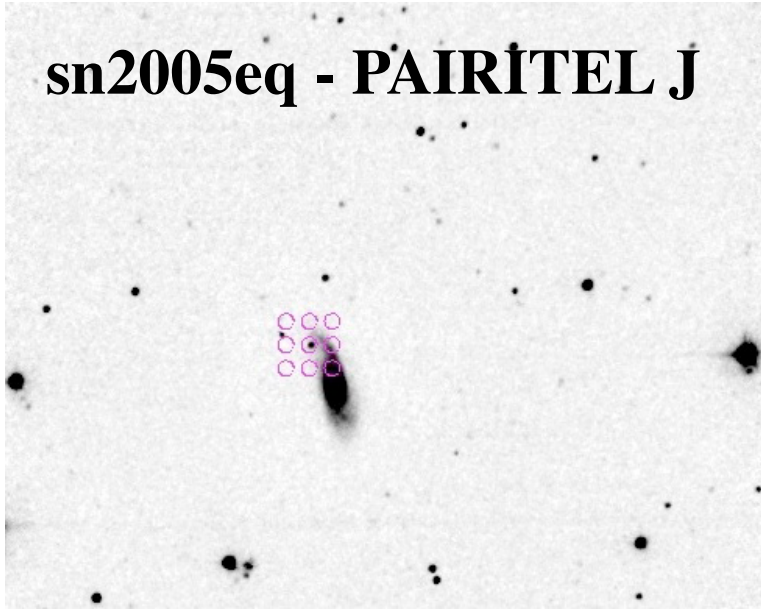
0.0006 ± 0.0019

0.0007 ± 0.0026

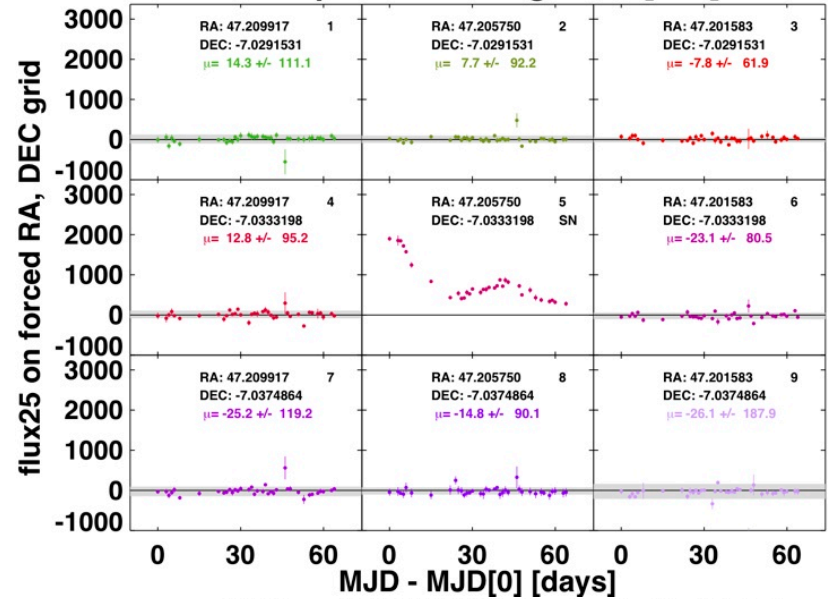
Agg scatter [mag]

0.072, 0.079, 0.138

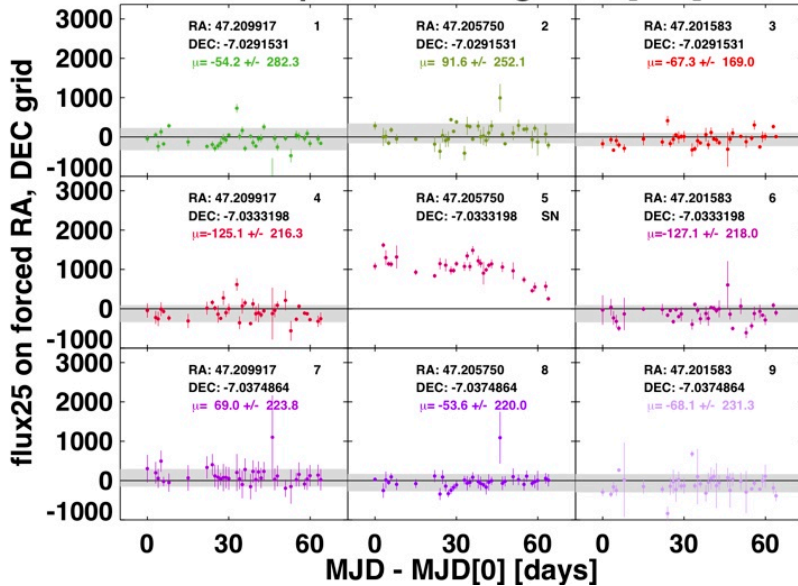
GALAXY SUBTRACTION TESTS



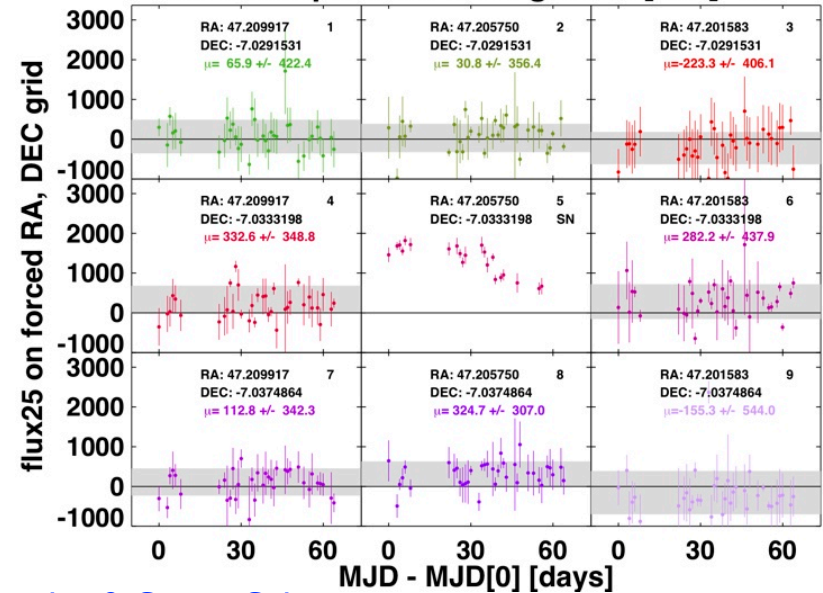
sn2005eq J fDiffPHOT galsub [3x3] 15"



sn2005eq H fDiffPHOT galsub [3x3] 15"

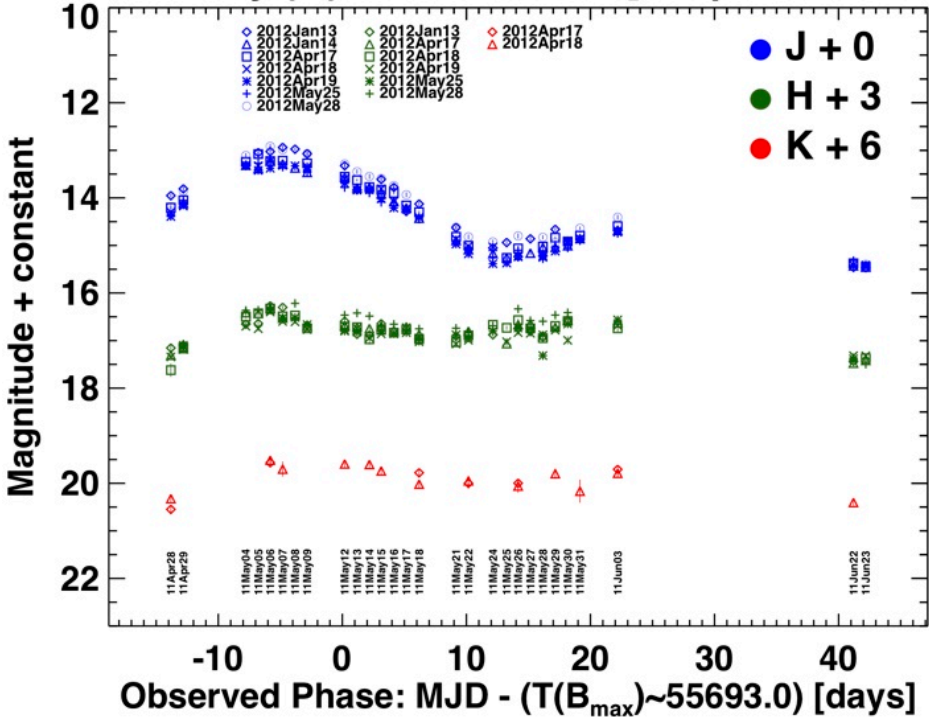


sn2005eq K fDiffPHOT galsub [3x3] 15"

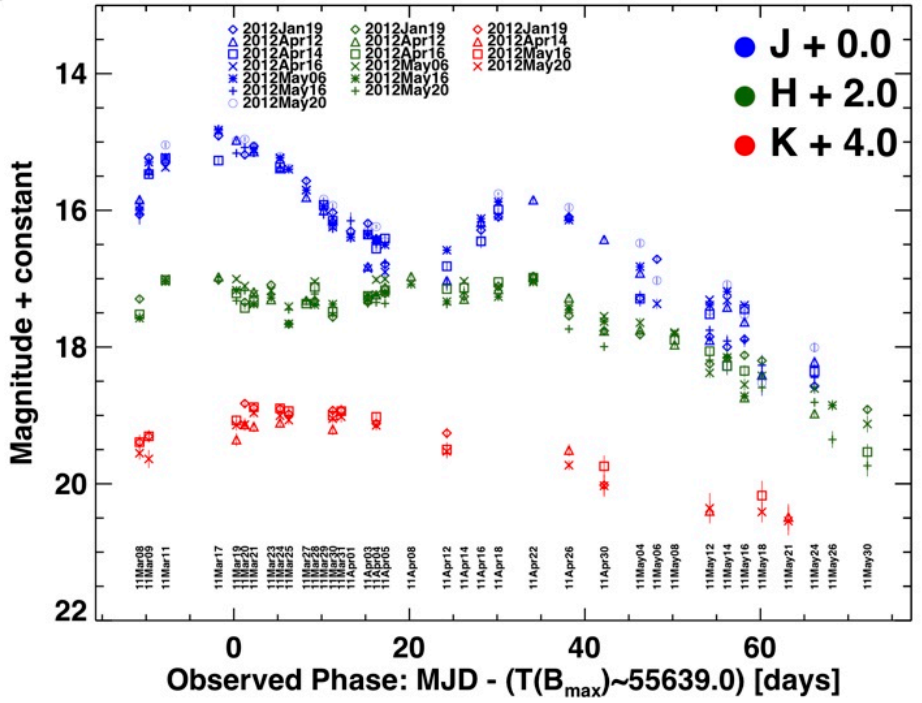


GALAXY SUBTRACTED LCS

sn2011by (la) PAIRITEL/CfA [rec.p3.fdi.SNR3]



sn2011ao (la) PAIRITEL/CfA (SN.244) [rec.p3.fdi.SNR3]



sn2011by - well sampled LC

sn2011ao - well sampled LC

Subtractions for a given template correlated across nights.

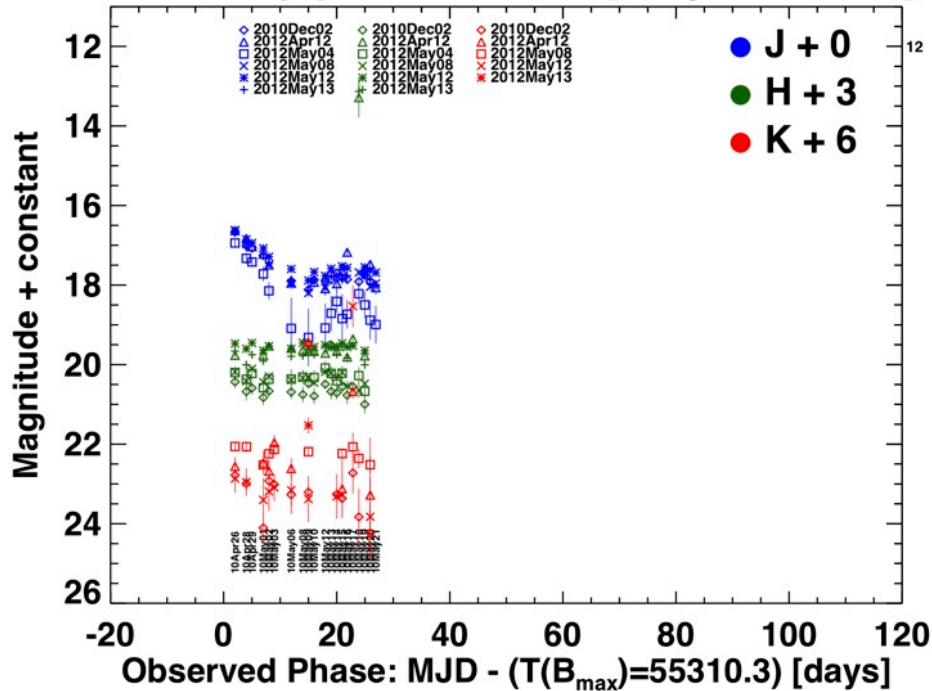
Subtractions for a given template correlated across nights.

Clearer as SN gets fainter.

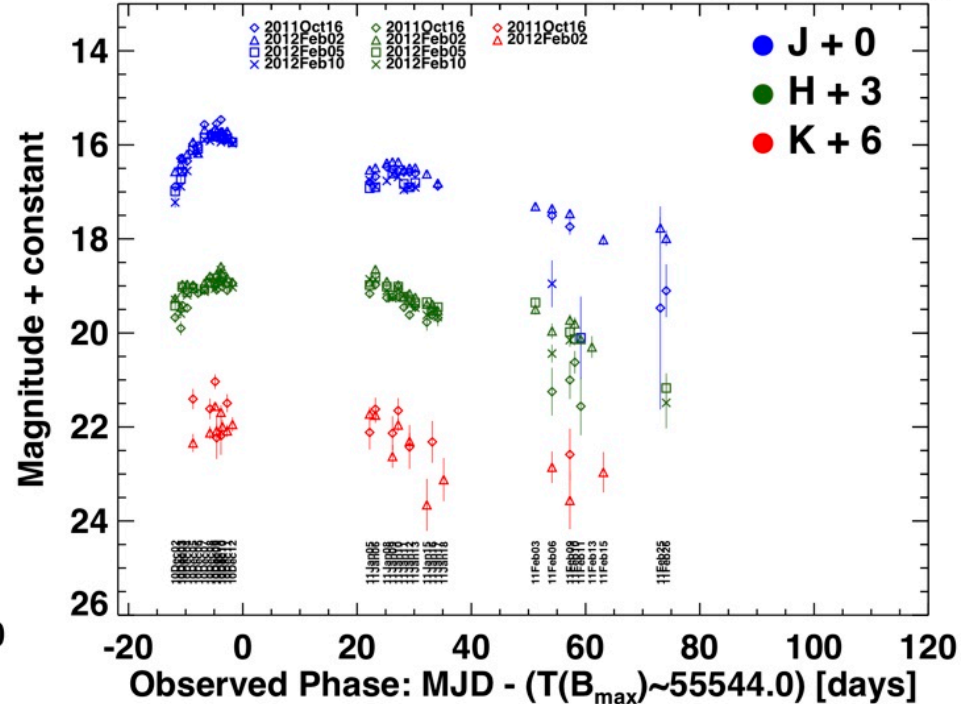
Less correlated than sn2011by

GALAXY SUBTRACTED LCS

sn2010cr (Ia) PAIRITEL/CfA [rec.p3.fdi.SNR3]



sn2010kg (Ia) PAIRITEL/CfA [rec.p3.fdi.SNR3]



sn2011cr - *good early sampling*

Large spread in LCs from different templates. Manually exclude all subtractions from specific bad templates, e.g. 2012May04 J band.

sn2011kg - *good early and late sampling with big gap*

J and H subtractions can be much better than K.

GALAXY SUBTRACTION ERRORS

Combine subtractions into final LCs + uncertainties

SIMPLE METHOD

(works for > 4-5 templates, well sampled LCs)

- **Flux = Weighted Mean of subtractions for each night**
- **Error = Standard deviation of all subtractions on each night**

BAYESIAN METHOD (K. Mandel)

(handles fewer templates, missing subtractions, missing LC points)

- **Model correlation across nights for subtractions from same galaxy template**
- **Account for missing subtractions**
- **Maximum likelihood estimates of flux and errors**