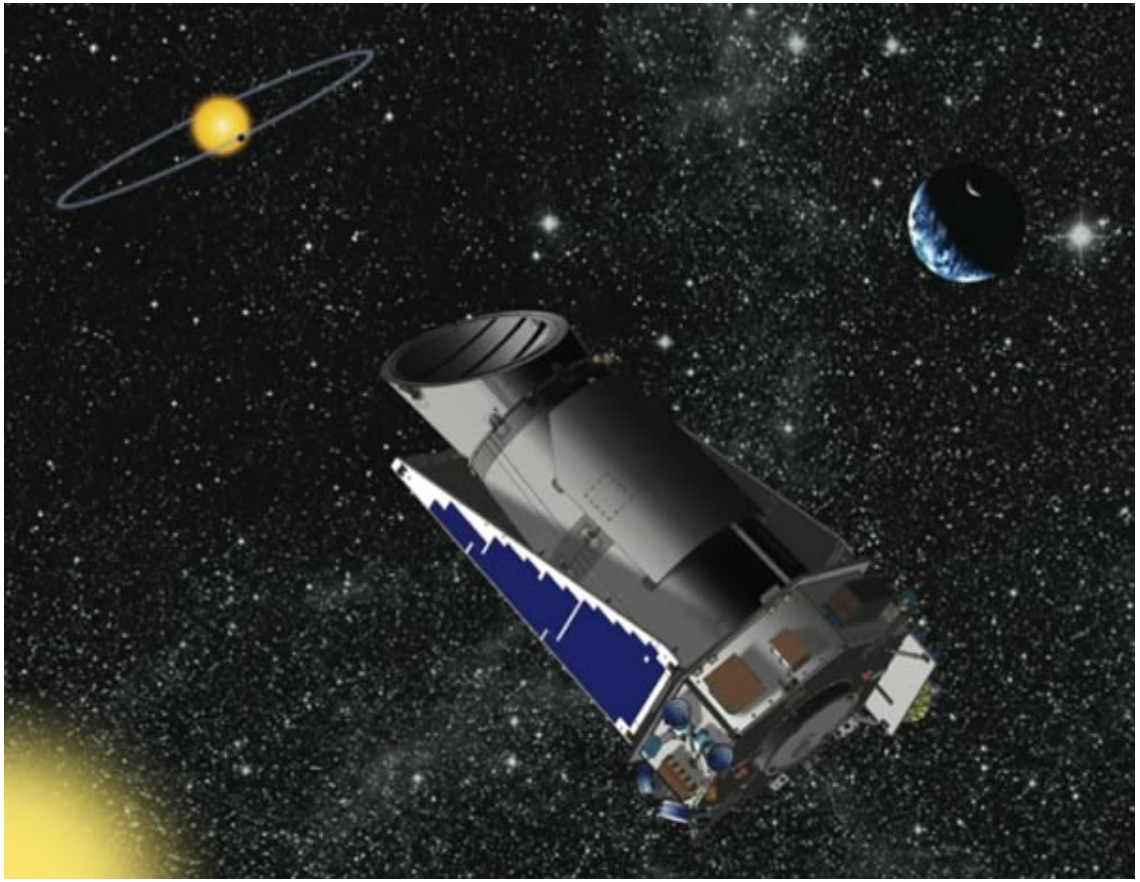
The Early Rise and Search for Shocks in Kepler Light Curves of SNe Ia



Peter Garnavich
University of Notre Dame

KEGS – Kepler Extra-Galactic Survey

The Kepler ExtraGalactic Survey (KEGS)

Rob Olling

Ed Shaya

Richard Mushostsky

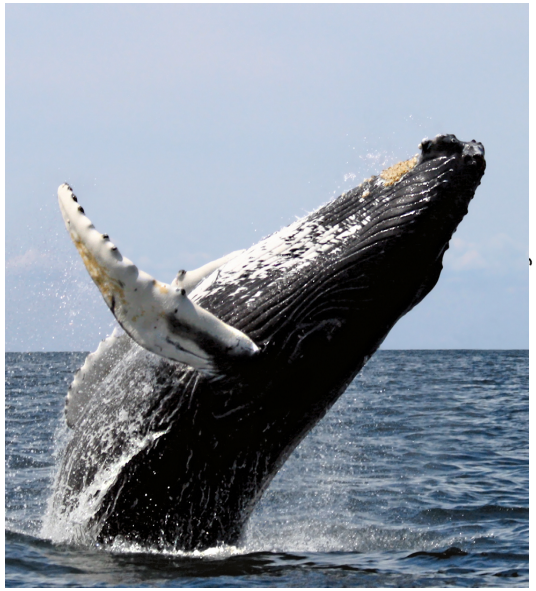
Armin Rest

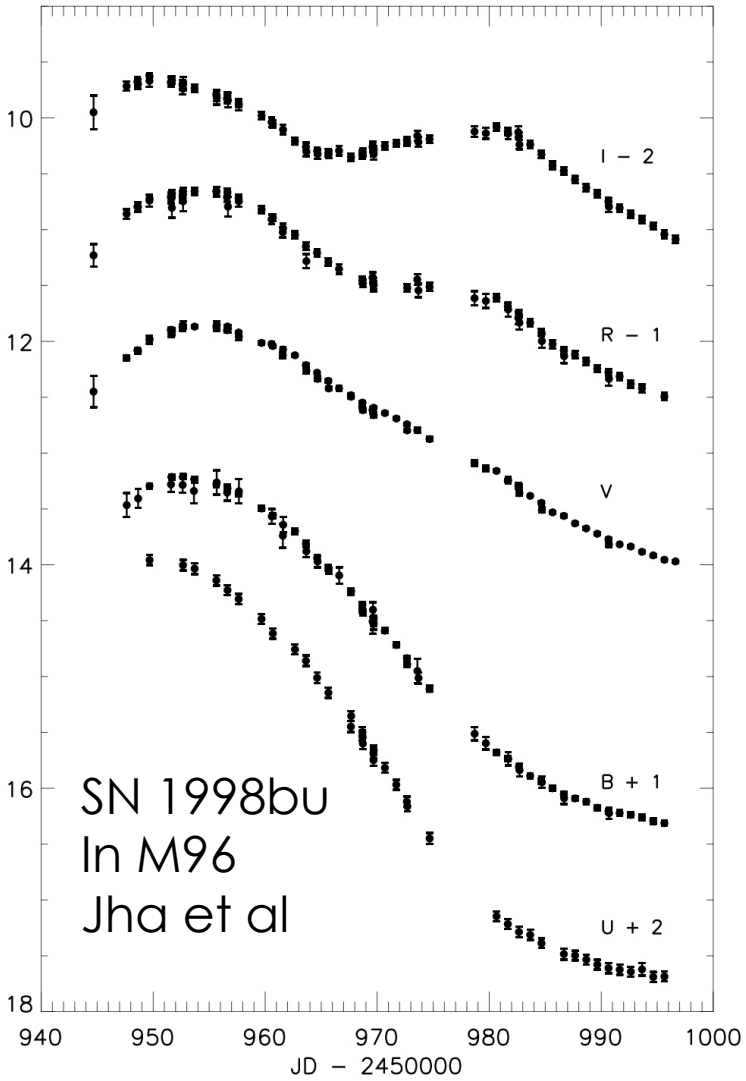
Peter Garnavich

Dan Kasen

Brad Tucker

Catching SNIa on the Rise





Cadence Improving

SDSS-II SN Survey

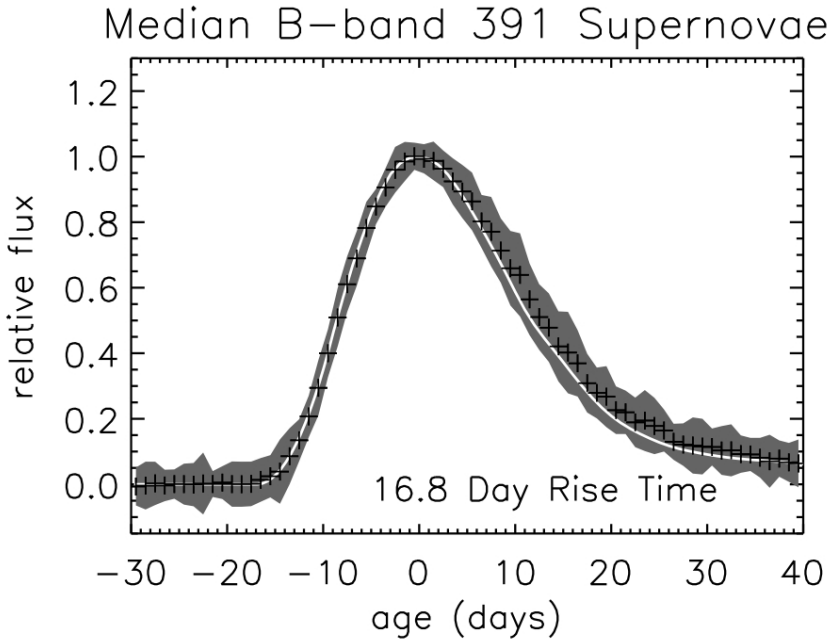
2 day Cadence

But with weather 4 days

Measure rise time

Measure rise power-law

Look for shocks

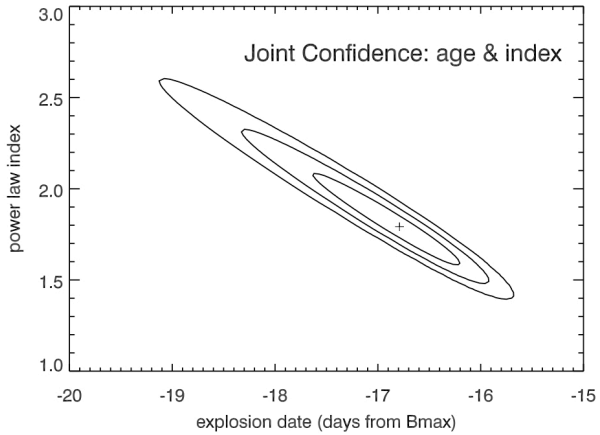


Hayden et al. 2010

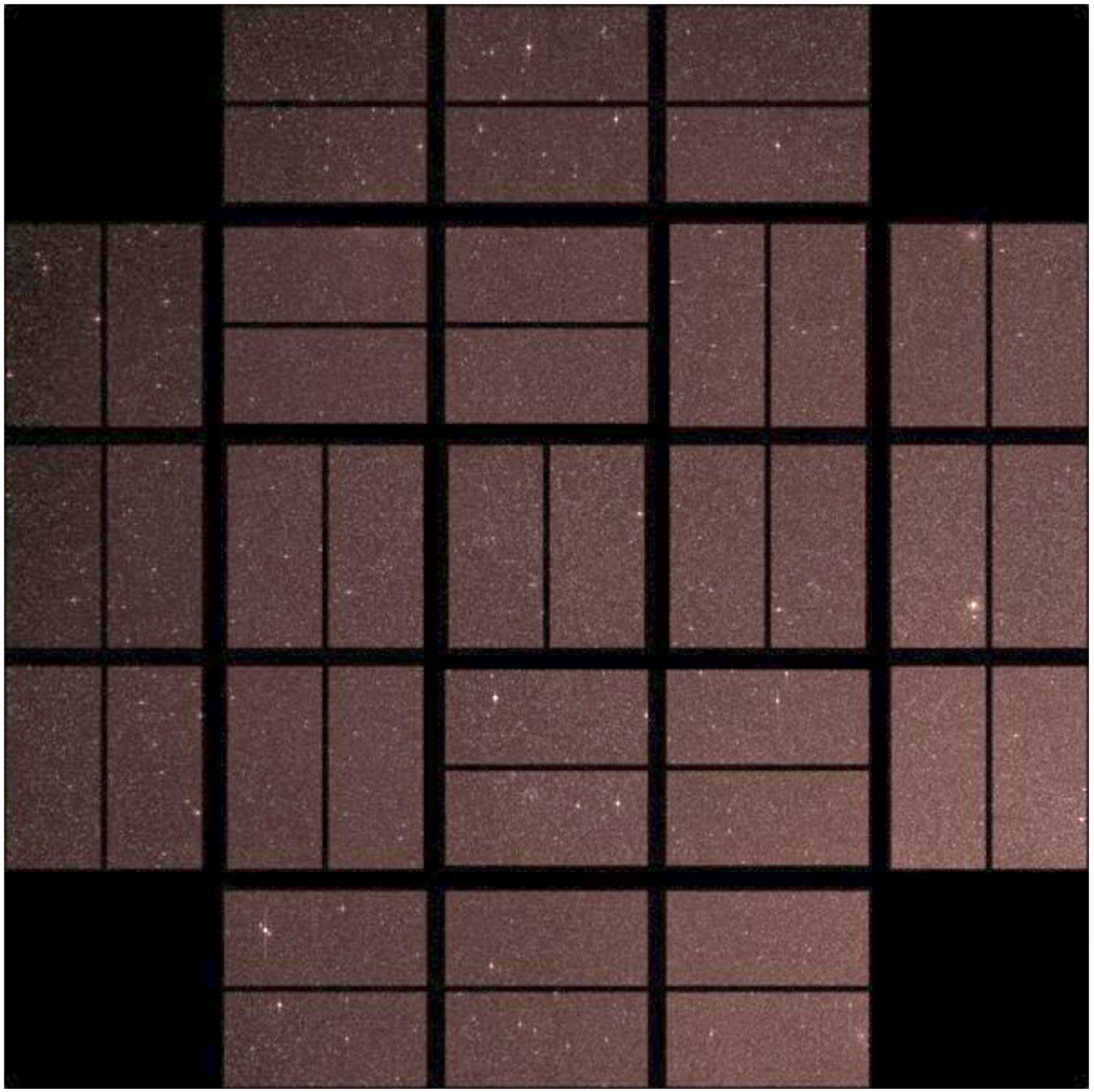
Flux ~ $(t-t_0)^{\alpha}$

Power-law index α about 2.0

Rise time (B) 17 days



Original Kepler – stares at the same spot



Transiting planets around bright stars

105 sq. degree field in Lyra/Cygnus

~100K targets (~3k GO)

1 min + 30 min cadences

Data downloaded ~ 3months (~40 GB data)

Only selected pixels downloaded

Three years of GO programs looking at ~500 galaxies

Kepler Did and Will Observe Supernovae

3 type Ia's (Olling et al. 2015)

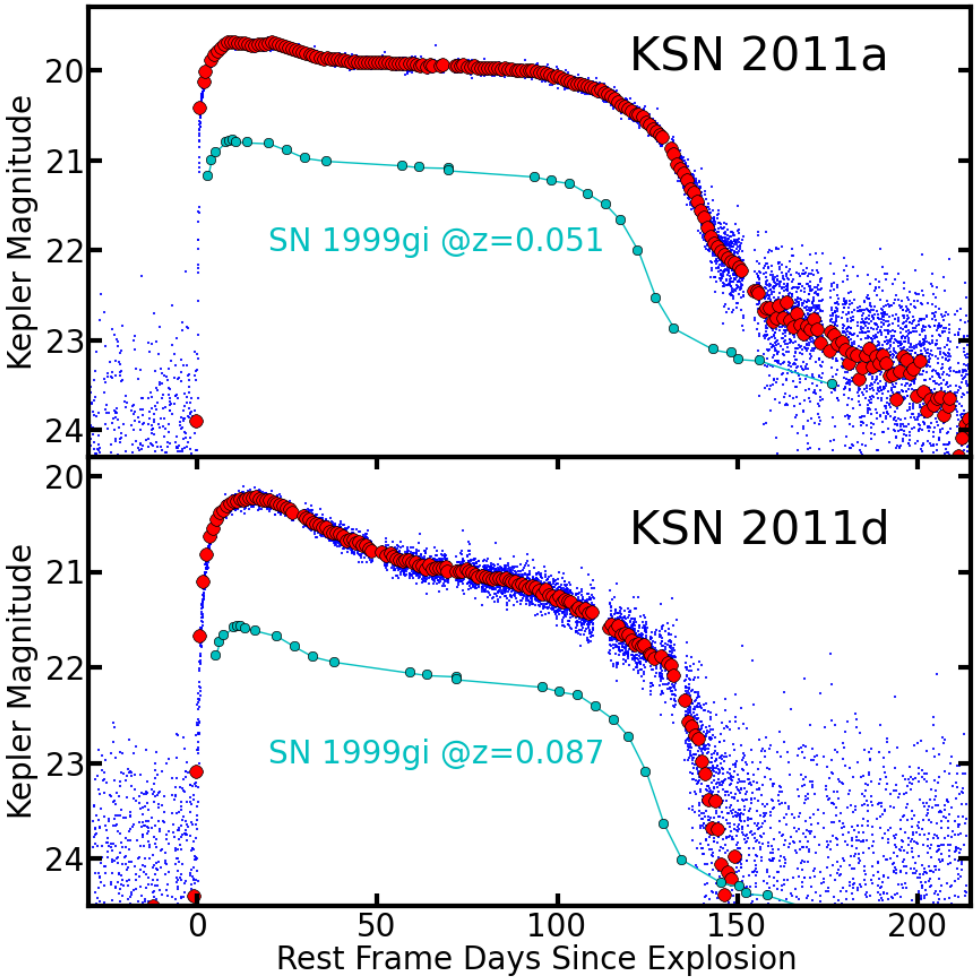
2 type II-P (Tucker et al. 2015)

1 type IIn (Garnavich et al. 2016)

AGN studies (Shaya et al. 2015)

On-going monitoring program with "K2"

Type II-P



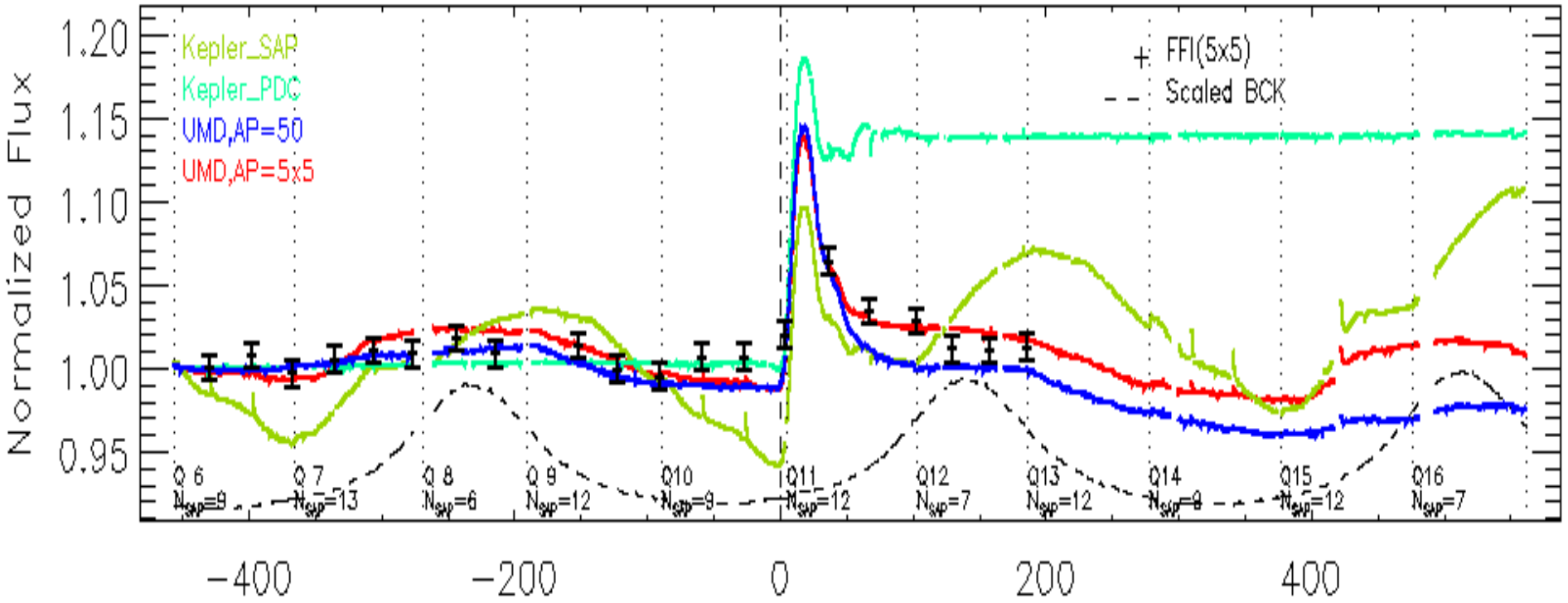
Tucker+ (2015)

Supernovae with Kepler – Not Ideal

Kepler does very high precision photometry – on short timescales

On long timescales: background variations and telescope shifts

UMD folks have figured out how to get good long-term photometry



Really Nice Light Curves

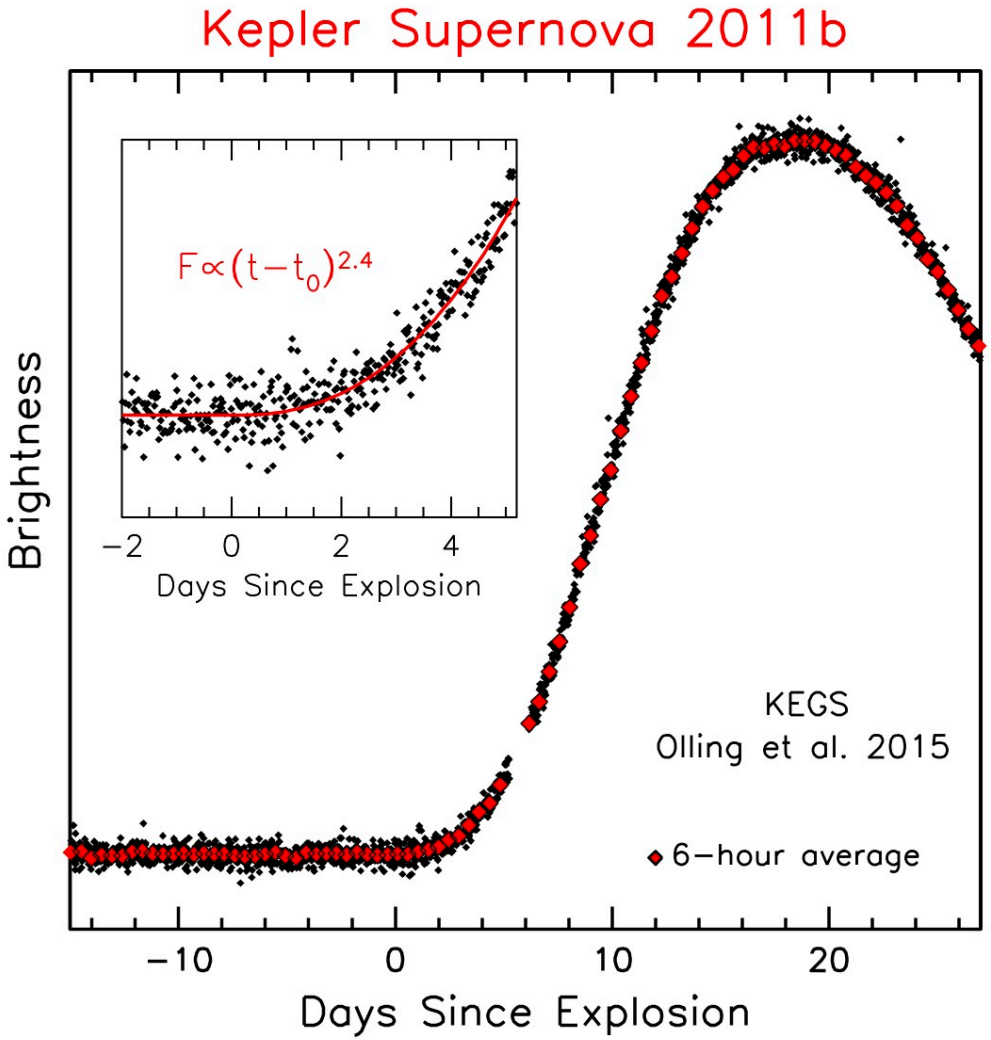
30 Minute Cadence!!!

Continuous monitoring

Pre-Explosion

4000 Data Points per SN!

Photometry ~0.01 mag (week timescale)



3 Type Ia in "Original" Kepler

KSN2012a z=0.086
KSN2011b z=0.052
KSN2011c z=0.144

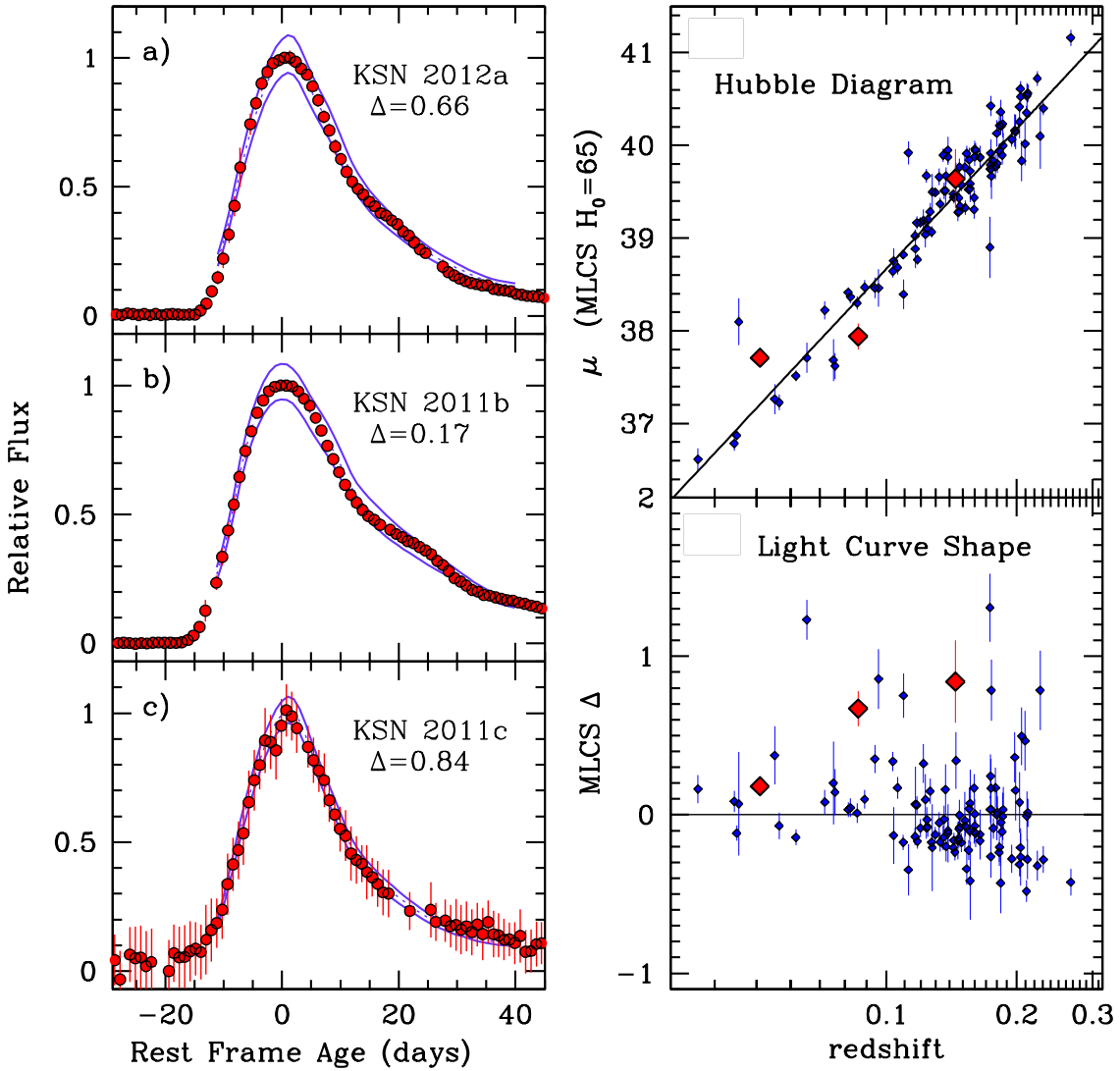
MLCS2k2 fits consistent with type Ia

Second bump - SNIa

Bias toward fast-decliners (2MASS galaxy selection)

No color information, so no dust correction

Hubble scatter consistent with SDSS SNIa fit with r light curve



Olling+ (2015)

Early Rise Shape

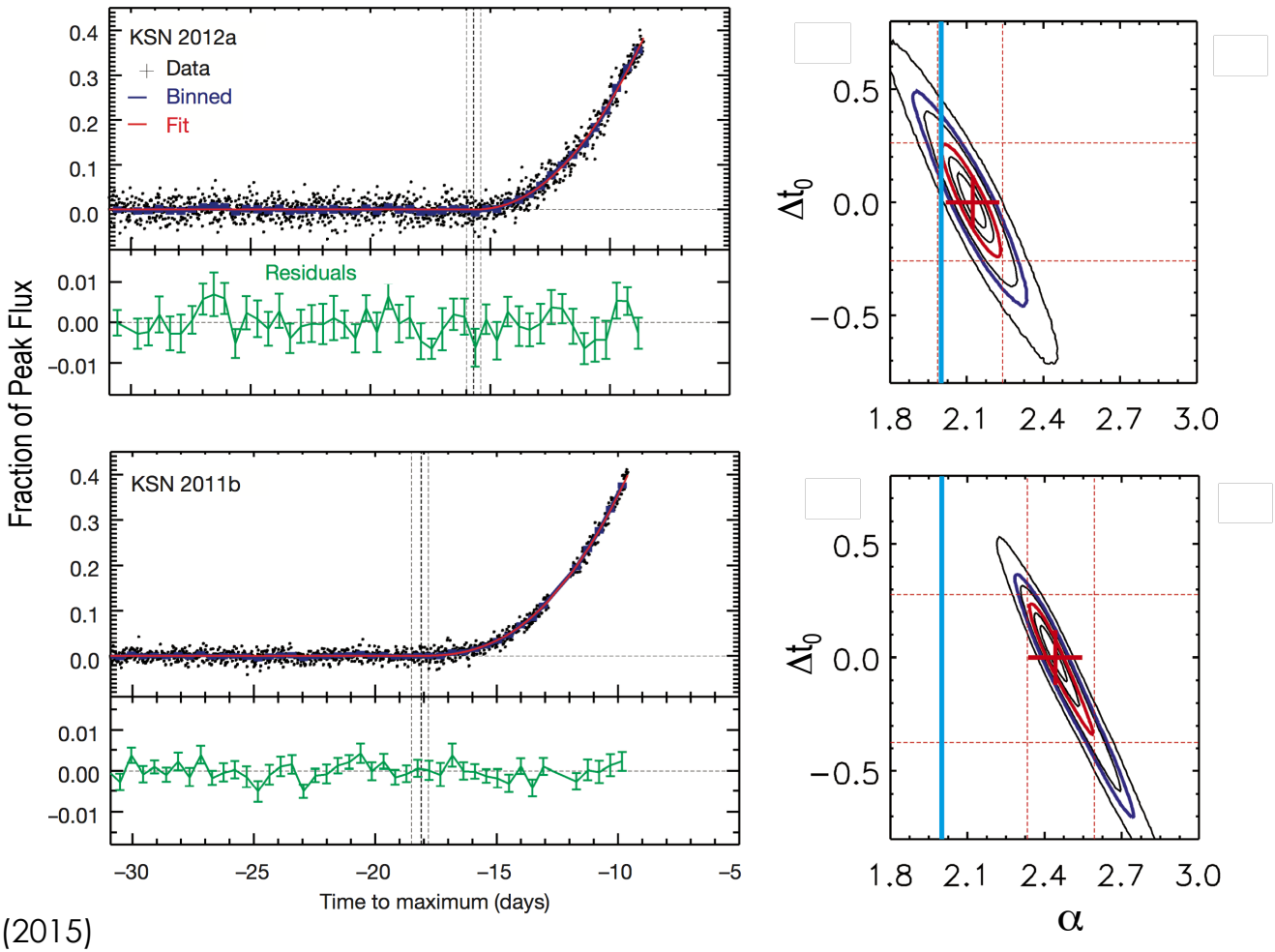
Fit flux function $F=C(t-t_0)^{\alpha}$

t_0 => "time of explosion" (assume no dark phase)

α=2 is simple "fireball model"

Measured α:
2.12+/-0.14
2.44+/-0.15
2.58+/-0.33

Simple model fits to 0.5% of peak on time scales of hours



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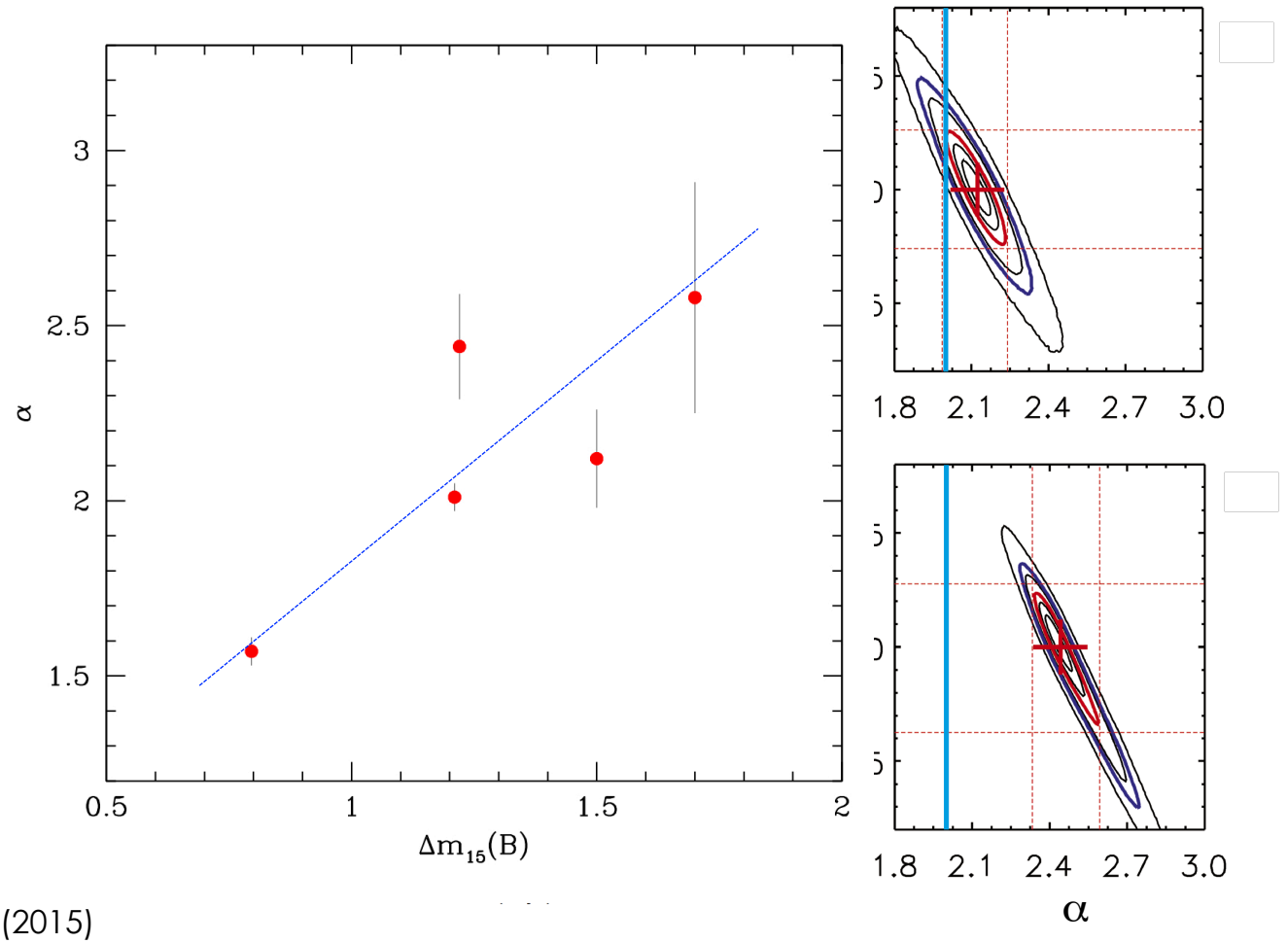
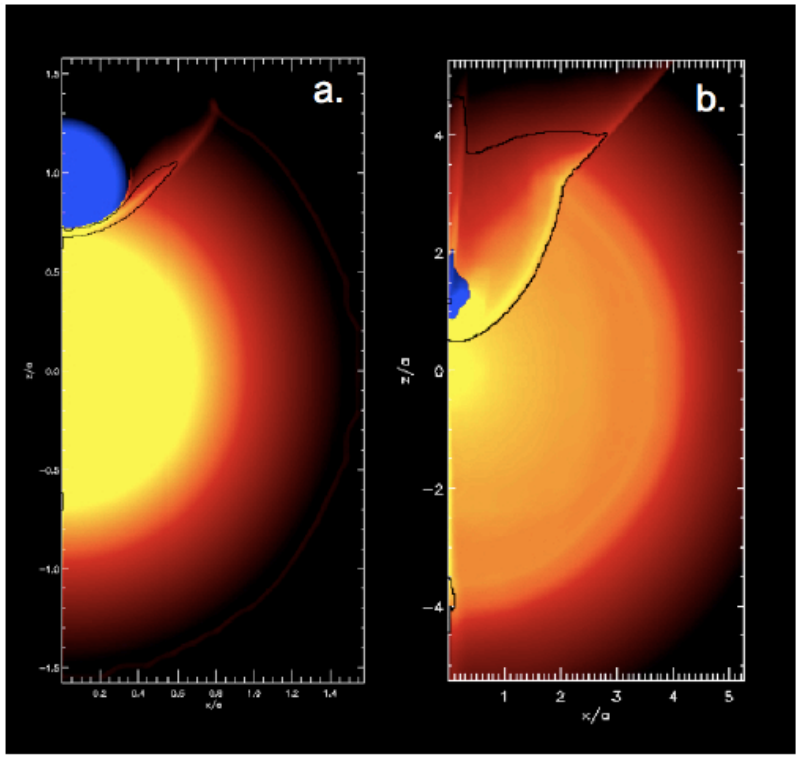


Olling+ (2015)

Early Shock Emission from SNIa?

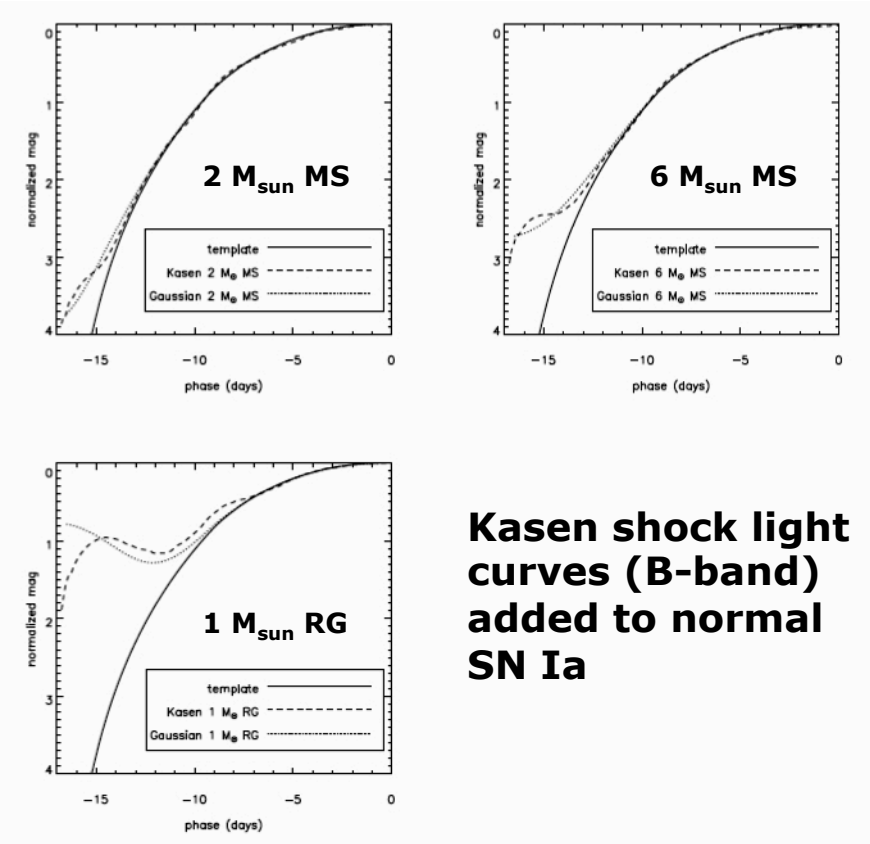
Companion of single degenerate progenitor will shock ejecta. **Test between DD & SD**



Kasen 2010

Strong viewing angle dependence.

Shock brightness depends on size of secondary…Red Giants easy



Kasen shock light curves (B-band) added to normal SN Ia

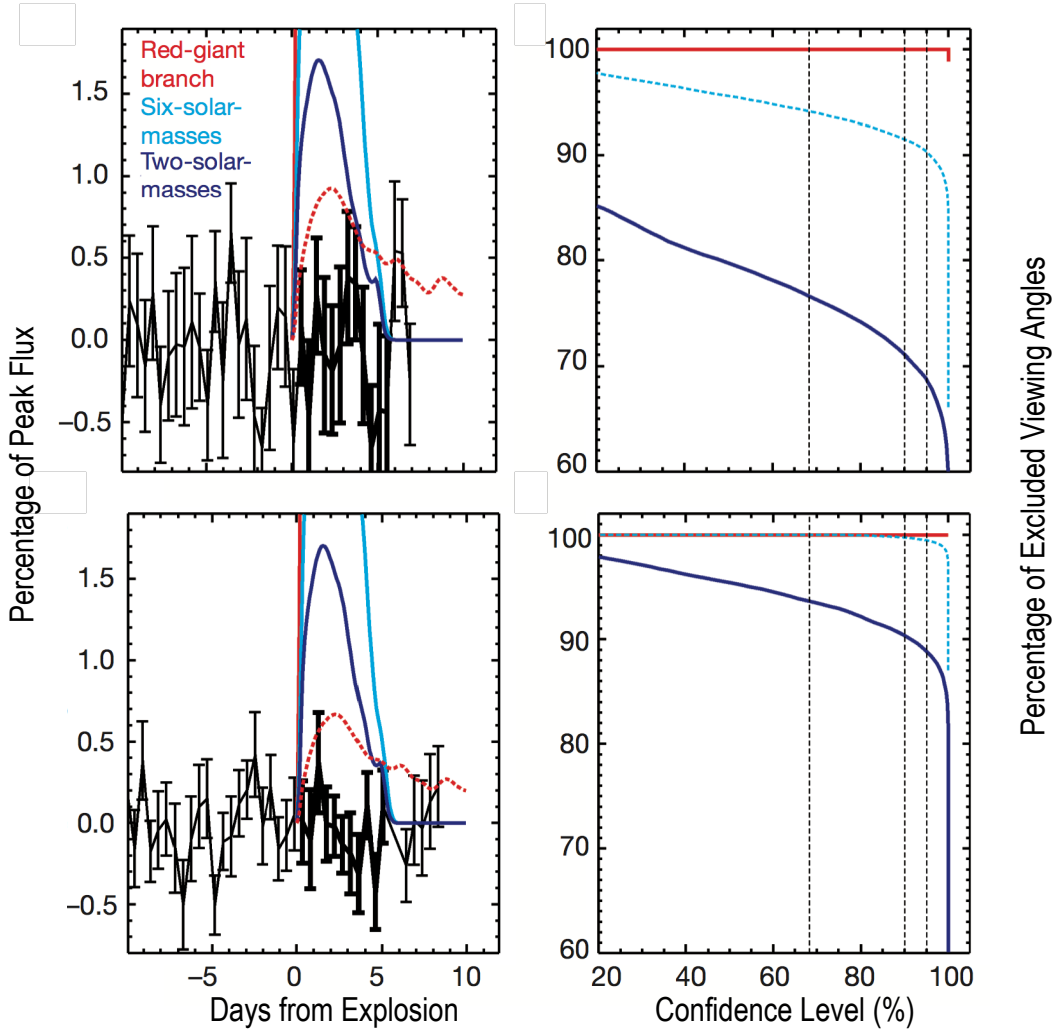
Don’t See No Shocks

Limit amplitude of any initial shock using Kasen models

Light Curves consistent with no shocks

KSN2012a – 2 M_{sun} companion ruled out for 70% of viewing angles

KSN2011b – 2 M_{sun} companion ruled out for 90% of viewing angles



Olling+ (2015)

Kepler Can Catch Shocks

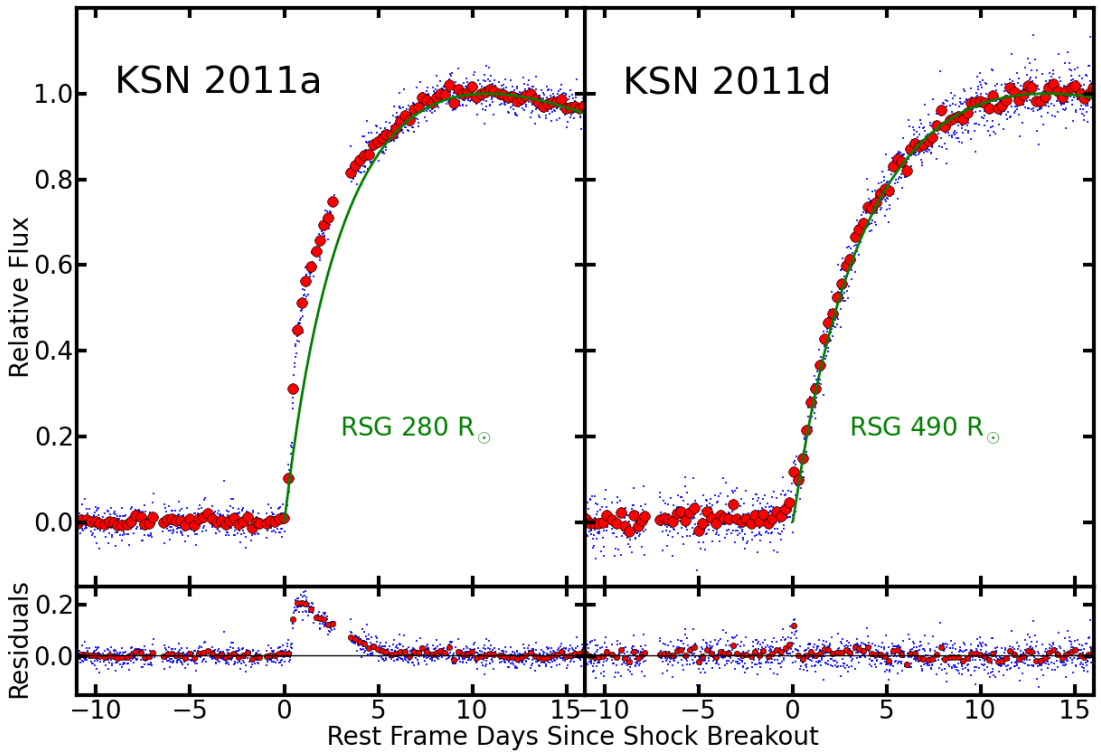
KSN2011a shows a circumstellar interaction

KSN2011d shows a shock breakout

10% to 20% of supernova peak

Shocks corresponds to absolute magnitudes of -15.5

Shock breakout consistent with model predictions

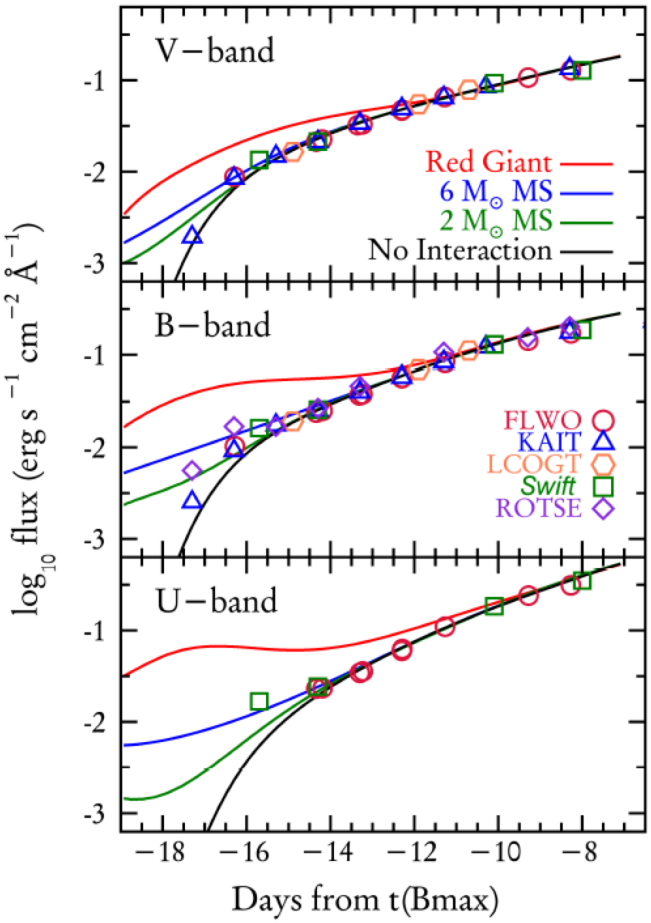


Companion Shock in Type Ia Seen?

Cao et al. (2015), but not a normal type Ia

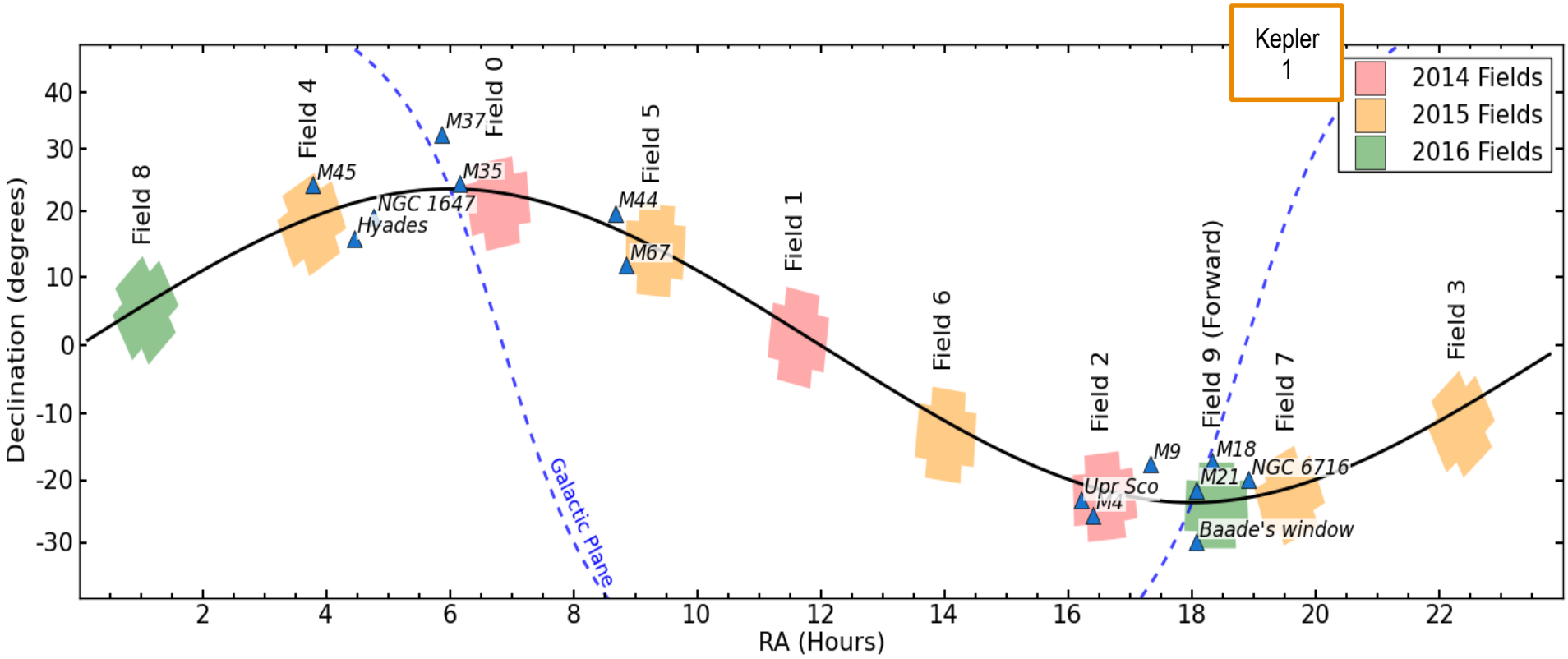
SN 2012cg (Marion et al) is strong evidence for shock from a ~6 M_{sun} companion

SN 2012cg slow decliner



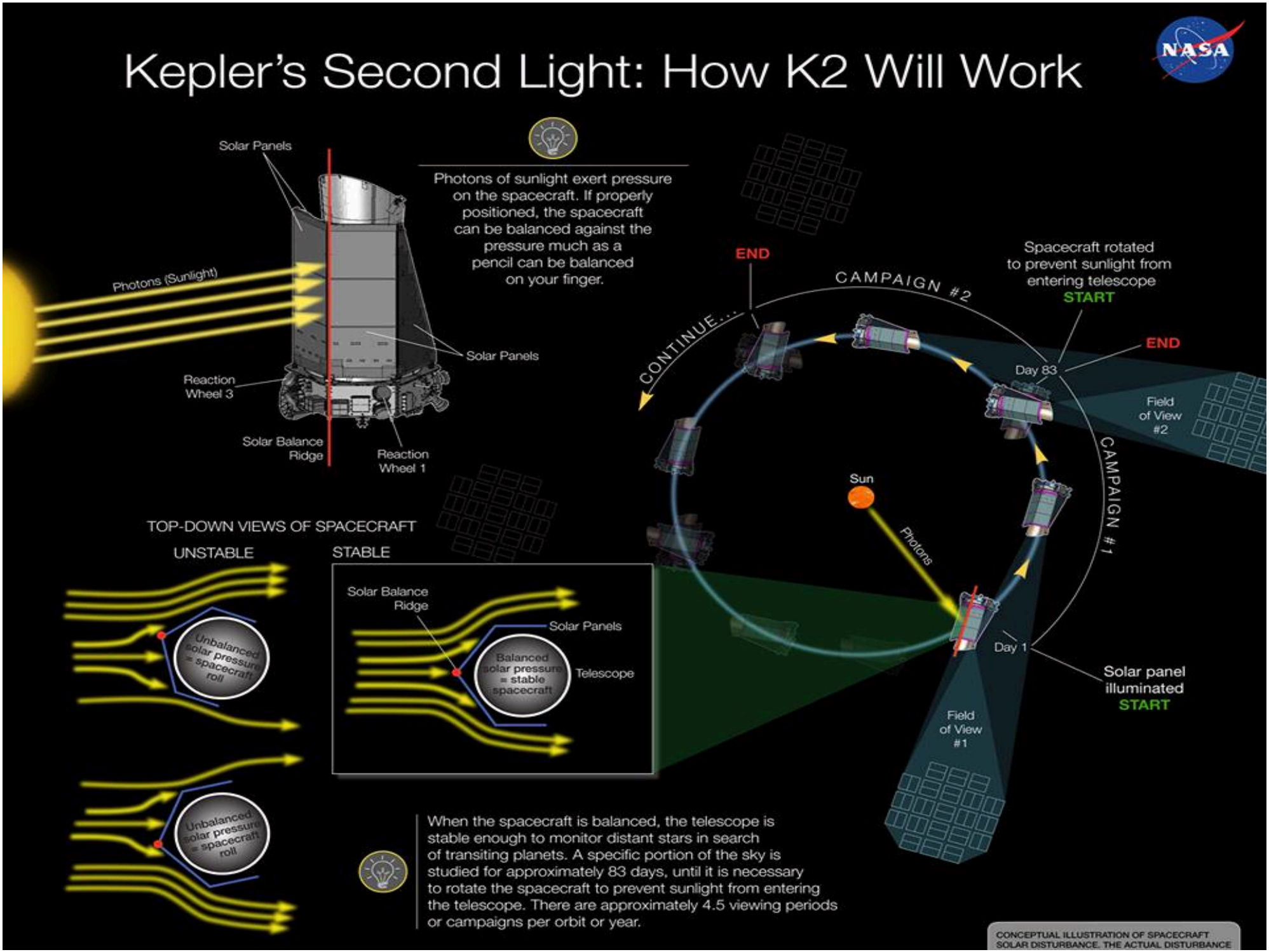
Marion et al (2015)

K2 – Another Chance at Kepler SNe



K2 Campaigns – 80 days on Ecliptic - more drift than Kepler
Position relative to Sun makes ground-based observations challenging

Kepler's Second Light: How K2 Will Work



K2 + Ground

K2 looking at a new patch of sky every 90 days

Data available three months after the “campaign”

KEGS proposing for thousands of galaxies each cycle

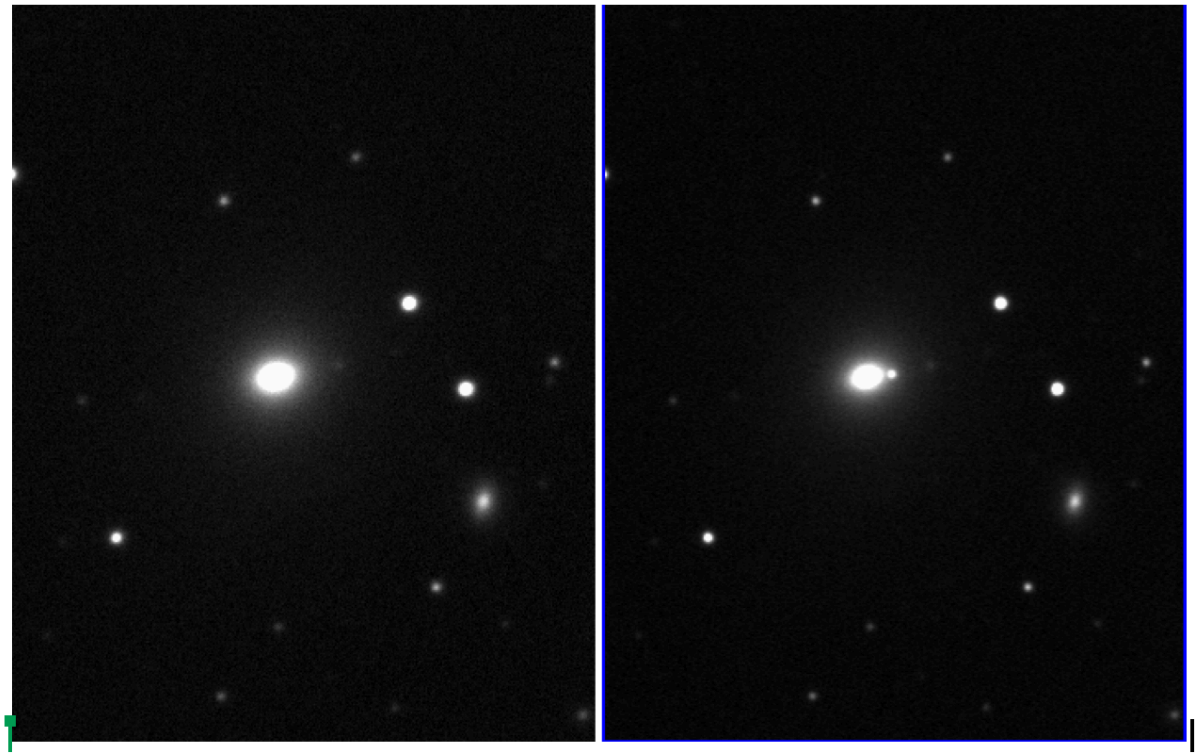
Armin & Brad organizing simultaneous ground search + follow-up

Fields close to Sun

Candidates already identified

KSN 2015a in K2 Campaign 5
found with DECam/CTIO 4m

z=0.03



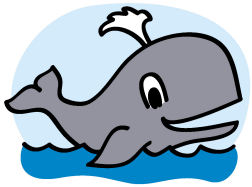
Zenteno et al (2015)

Summary

Kepler observed 6 supernovae in three years – 3 type Ia supernovae

Night & Day 30-minute cadence light curves are amazing!

Rise consistent with α>2 with no sign of shock



Companions less than 2 M_{sun} for most viewing angles

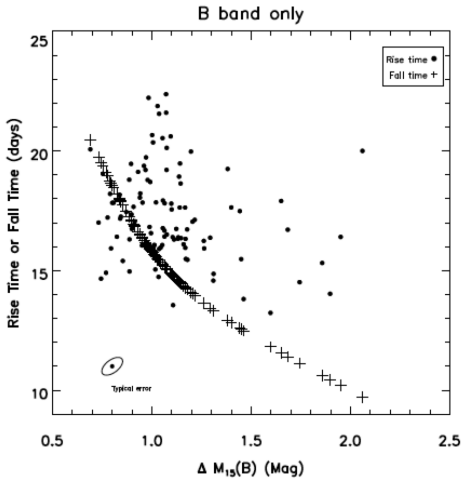
K2 will allow more SNe to be studied at extreme cadence

Could use ground-based help to get colors and spectra of K2 events

Questions

No shocks in most normal/fast decliners, “shock” in slow decliner: multiple progenitors in the Branch normal SNIa?

Might the early light from 12cg be a weak circumstellar interaction?



Slow decliners end to be fast risers