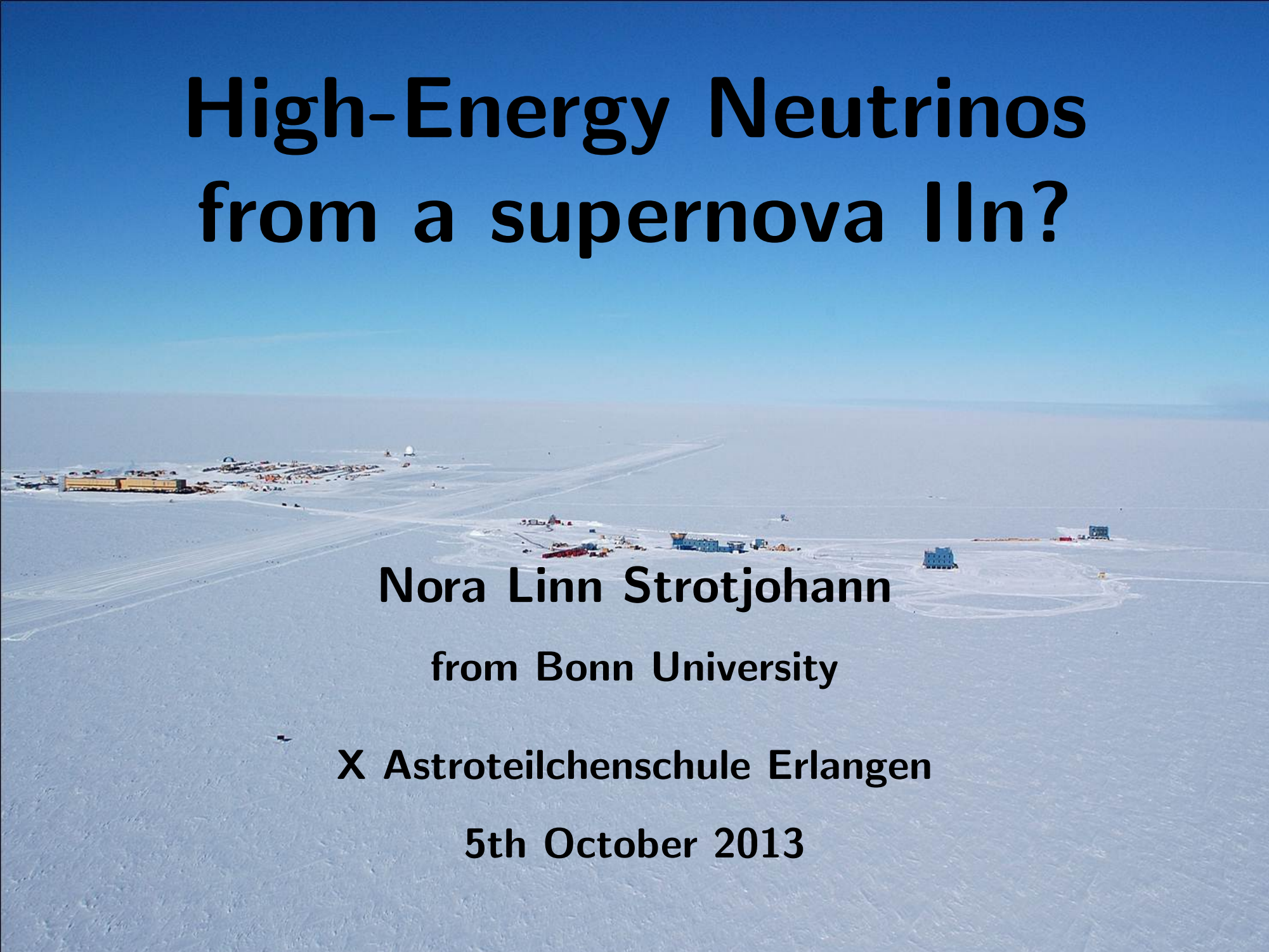
High-Energy Neutrinos from a supernova IIn?



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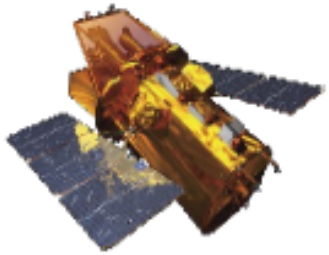
X Astroteilchenschule Erlangen

5th October 2013

The Online Follow-up program of IceCube



SN/GRB

ν

Operating since
Dec. 2008

ROTSE III
Network (optical)

PTF (optical)

Operating since
Aug. 2010

Swift (X-ray)

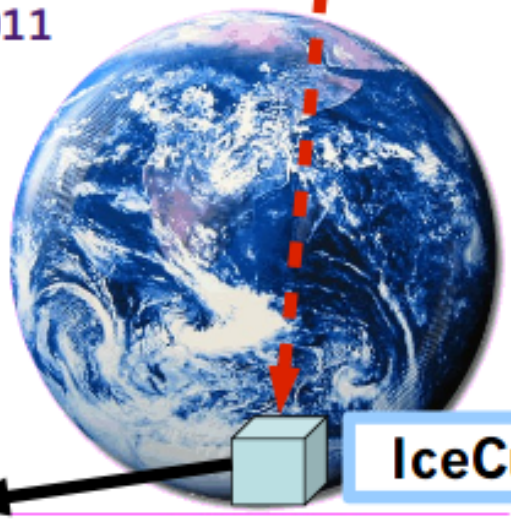
Operating since
Feb. 2011

ROTSE alerts

Subset

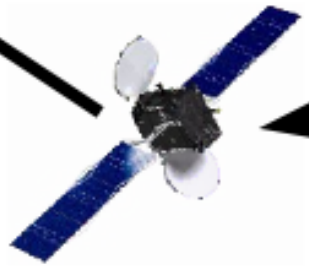
Subset

Madison/Bonn



IceCube

Iridium

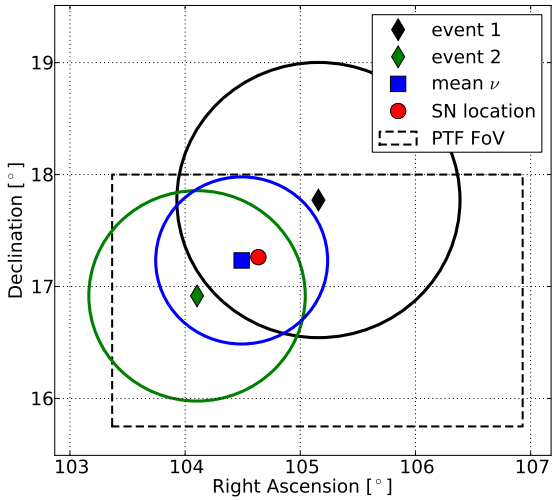


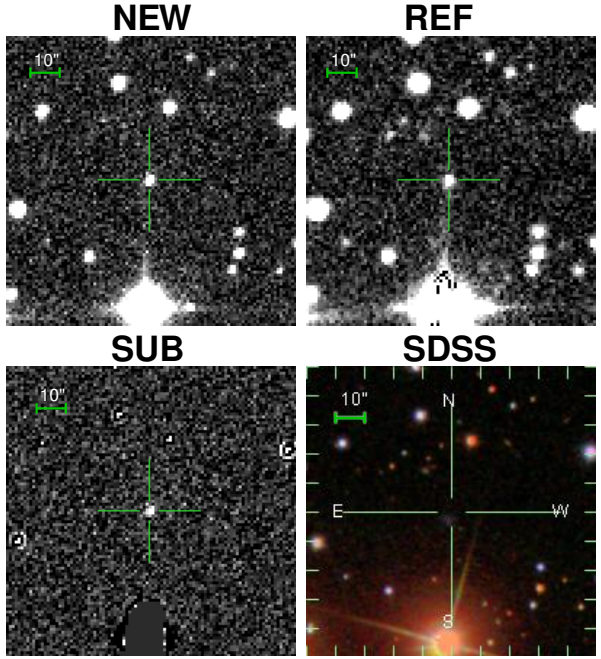
Alert:
2 (muon) neutrinos
within 100s
reconstructed direction
within 3.5°

Alert in March 2012

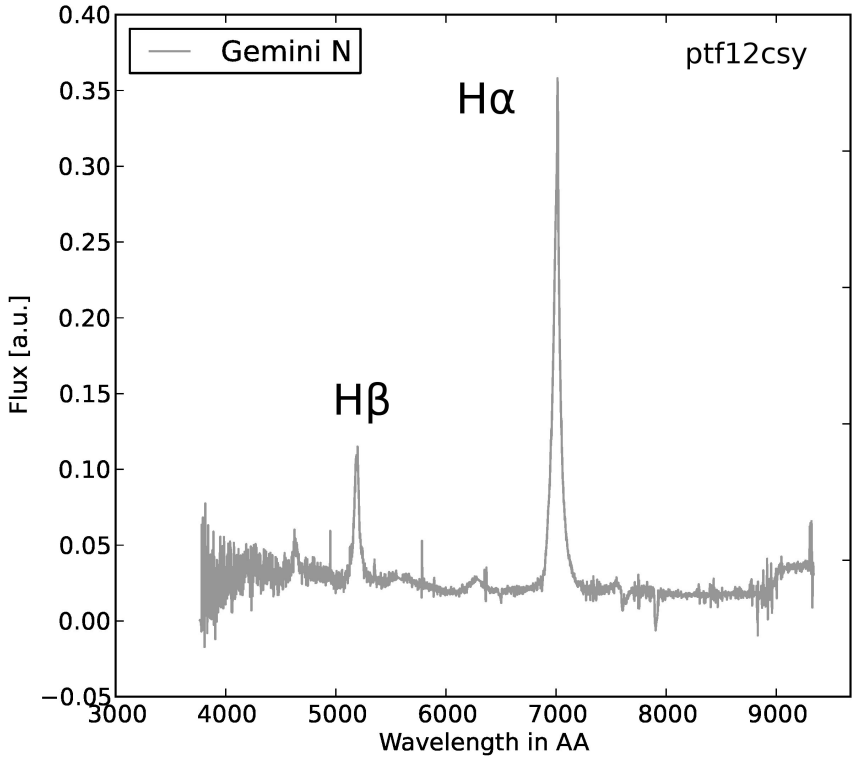
- most significant alert up to now
- 2 neutrinos (1 and 3 TeV) within 1.7 s
- significance of the neutrino signal: 13.9% within IC 86-I season (∼50% since Follow-up is working)

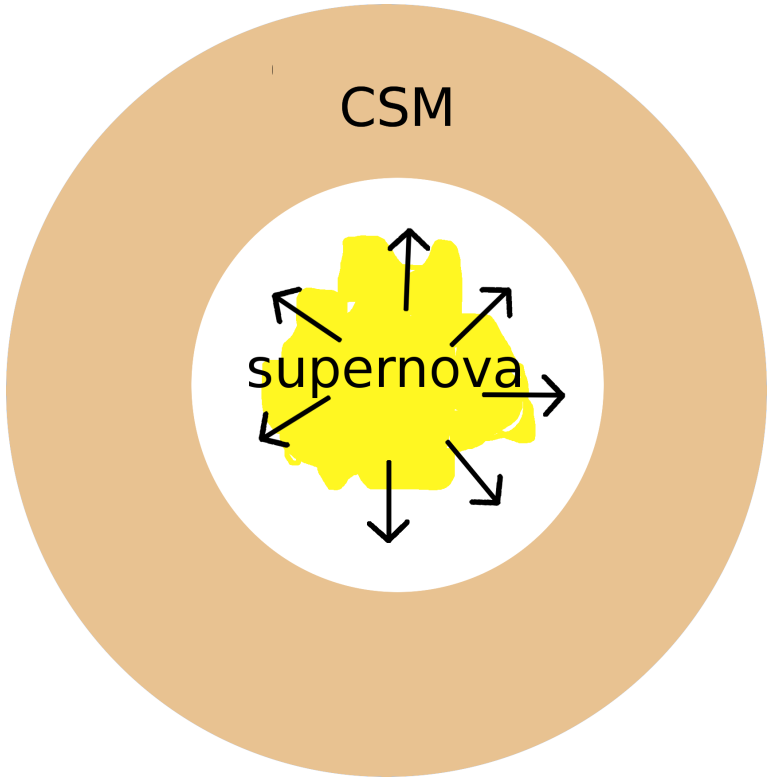
- PTF found a supernova IIn! (ptf12csy)
- significance of ν signal and SN: 1.6% (2.4σ)
- 300 Mpc away, >169 days old





Supernovae type IIn





- "n" for narrow emission lines
- progenitor star looses material during years before SN
- SN takes place within a dense circumstellar medium (CSM)
- SN ejecta crash into CSM: kinetic energy is transfered to radiation within ∼100 days (a "fast motion SN remnant")

Neutrino Model for SN IIn

SN IIn emit high energy (up to PeV) neutrinos during ∼100 days (Murase+ 2011)

Neutrino signal depends on:

- distance → from redshift of spectrum
- total energy of SN → estimate bolometric luminosity (requires light curve and spectral energy distribution)
- optically thickness of CSM → light curve evolution

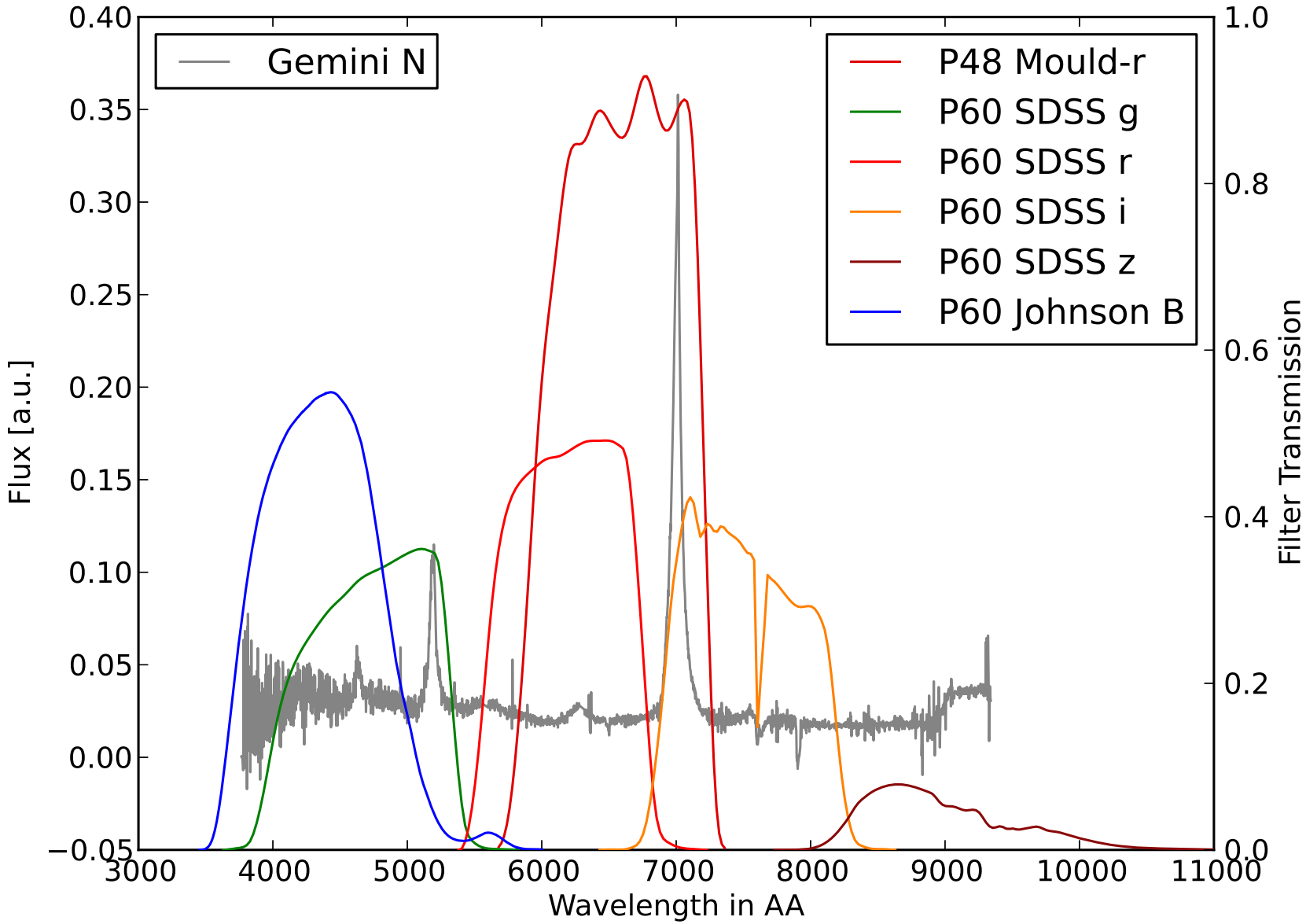
- mass of CSM and ejecta
- geometry of CSM
- strength of magnetic fields

} use theoretical values

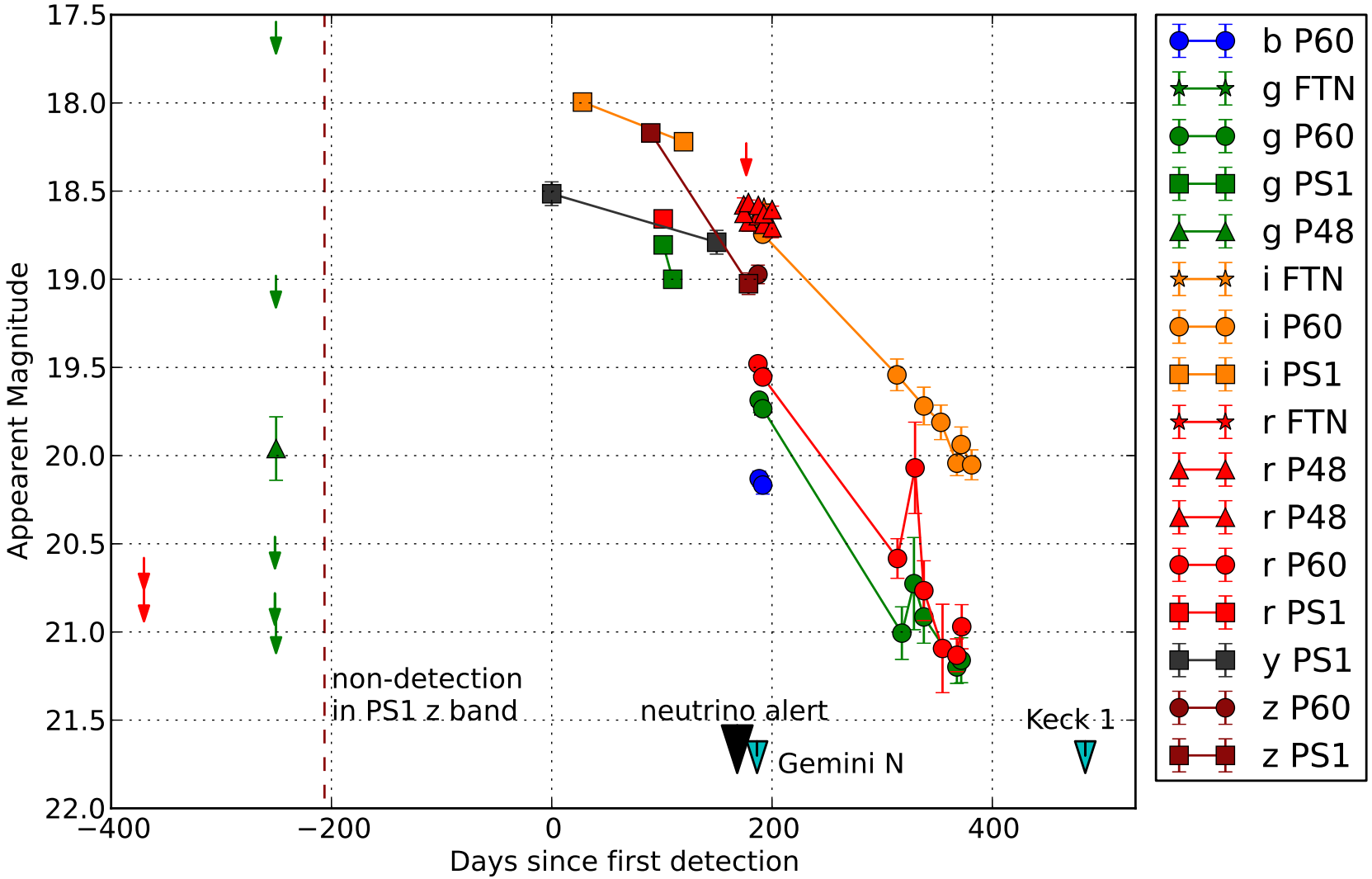
- shock velocity in CSM
- breakout radius

} free parameters

The optical light curve - Used filters

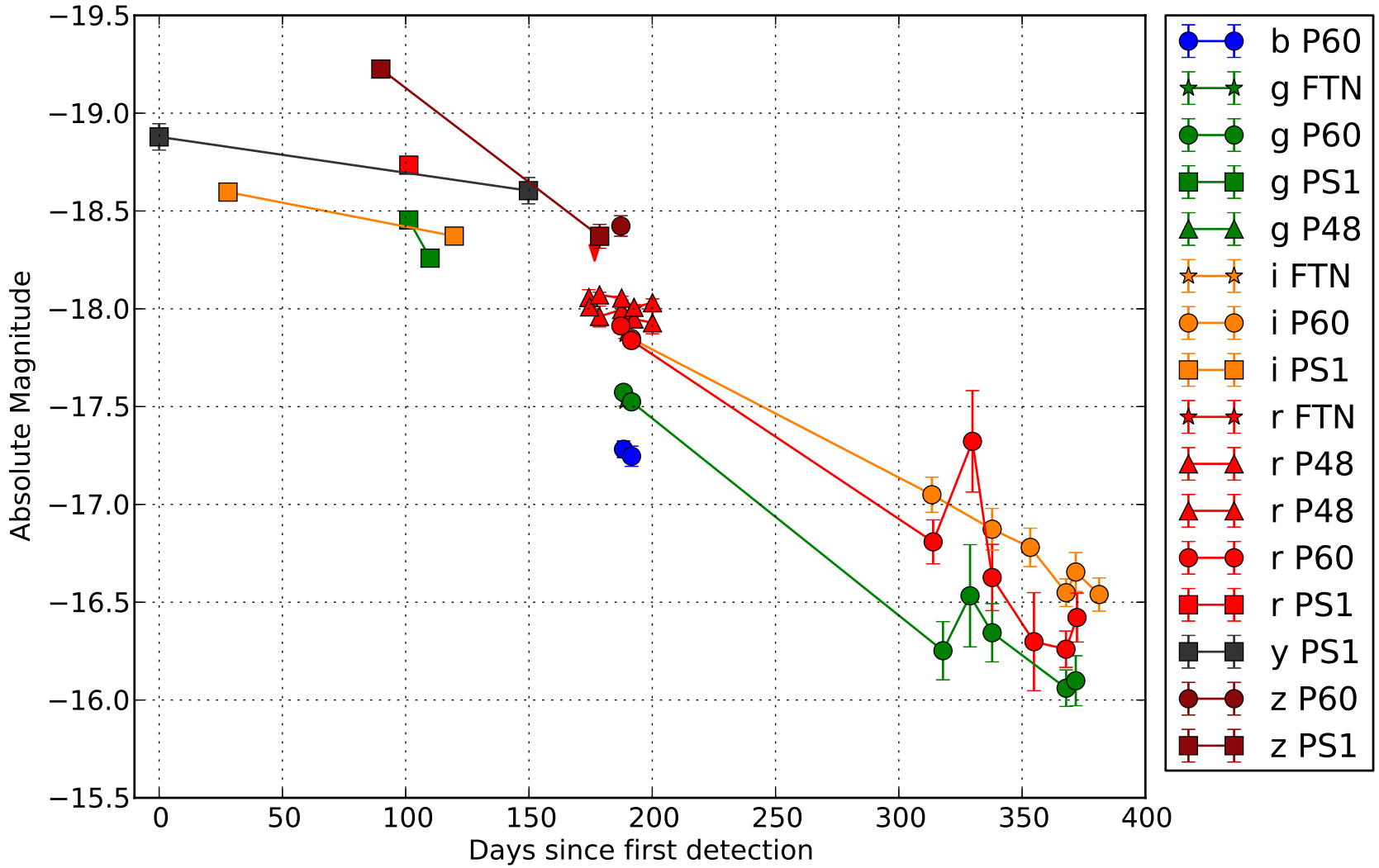


The light curve - Apparent Magnitudes



The light curve - Absolute Magnitudes

After correcting for emission lines, extinction in the Milky Way and converting to absolute magnitudes:



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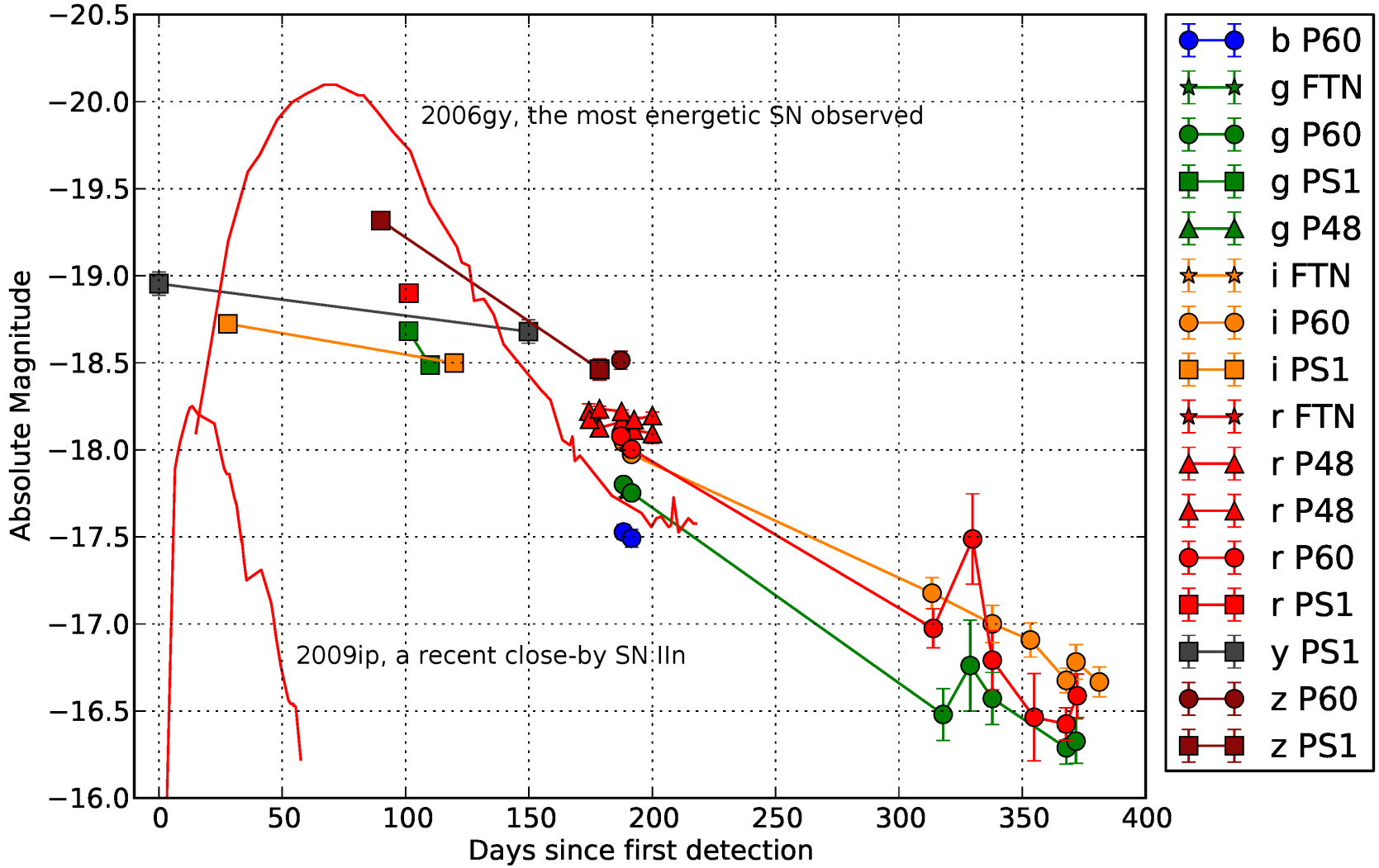

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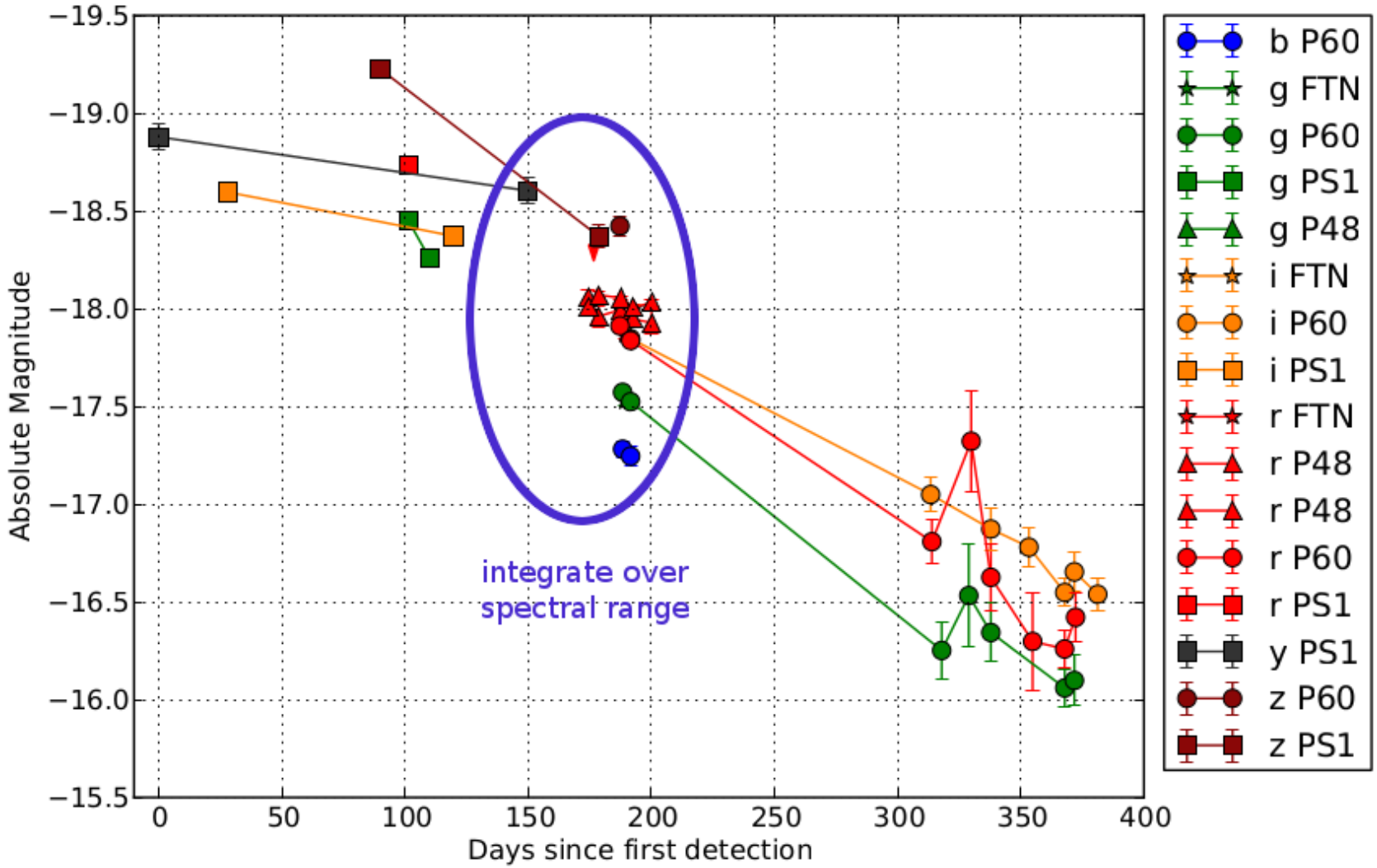
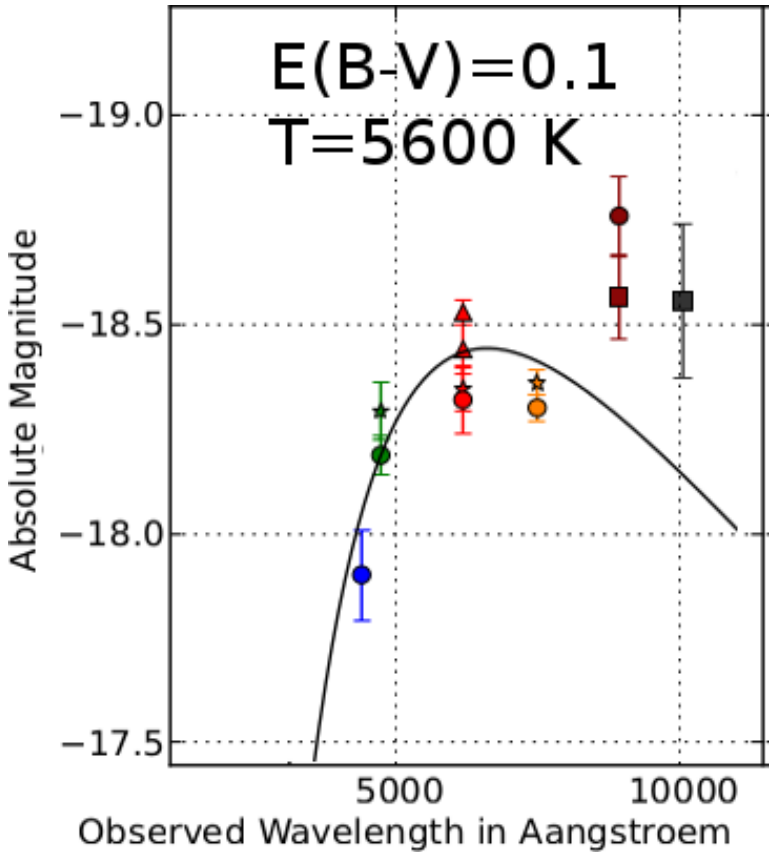
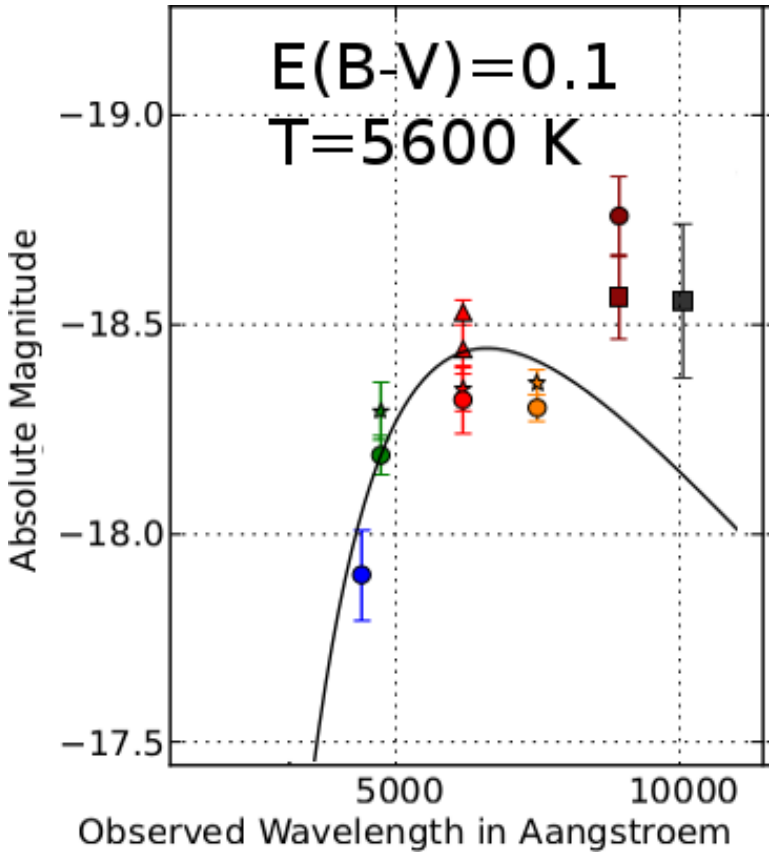


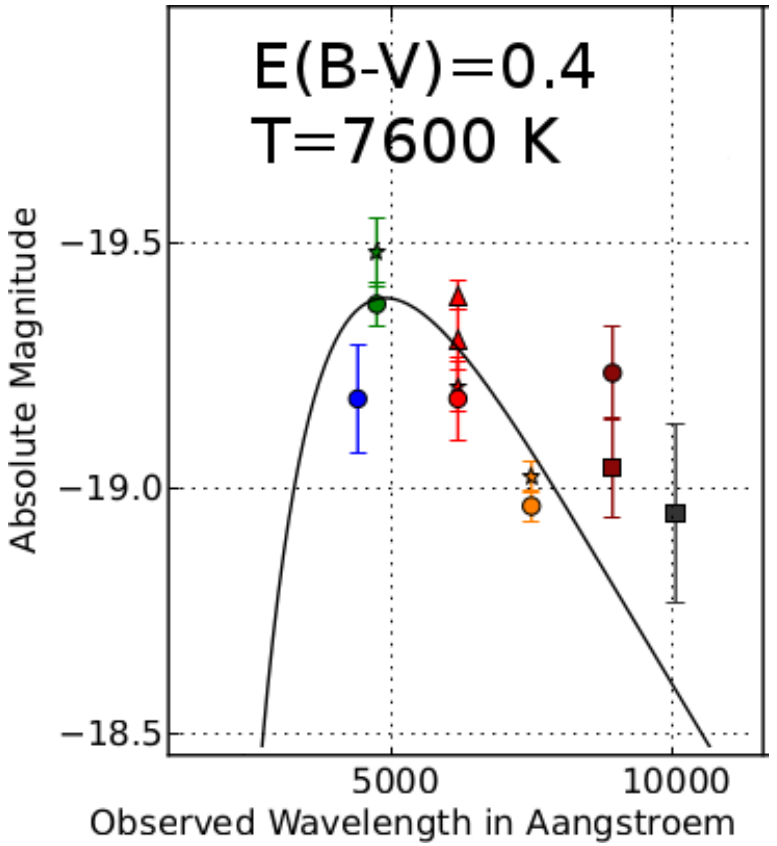
The Spectral Energy Distribution



- spectrum of an optically thick SN has a black body shape
- extinction in host galaxy unknown

The Spectral Energy Distribution





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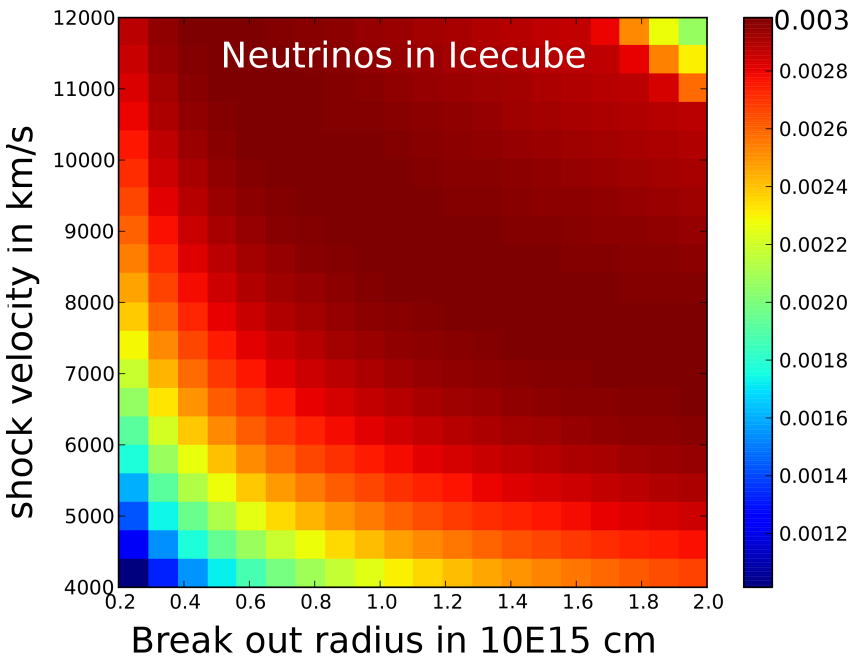
The Spectral Energy Distribution

$E(B-V)_{\text{host}}$	T_{bb} in K	$E_{\text{bol.}}$ in erg
0.0	5200	$9.5 \cdot 10^{49}$
0.1	5600	$1.3 \cdot 10^{50}$
0.4	7600	$3.6 \cdot 10^{50}$

- assume a constant temperature for complete light curve
- bolometric luminosity used as lower limit for total energy
- assume that $\sim$10% of total energy are emitted in cosmic rays

Expected neutrino signal



Expect to see up to 0.003 ν with IceCube, emitted within 100 days.

$\Rightarrow$ due to uncertainties a higher flux of $\sim$0.03 ν is possible

Uncertainties:

- explosion date of SN
- host extintion: E(B-V)=0.4 $\Rightarrow$ 3 times more ν
- total energy, total cosmic ray energy
- CSM and ejecta mass

$\Rightarrow$ **can not explain detected neutrino doublet!**

Atmospheric neutrinos and coincidental supernova? (1.6% probability)

Summary

- the Follow-up program of IceCube searches in real-time for transient neutrinos sources
- a doublet of TeV neutrinos lead to the discovery of a bright SN IIn
- a model for SN IIn predicts:
  - emission of neutrinos up to PeV
  - the signal is at most 0.03 ν in IceCube
  - emission time $\sim$100 days

$\Rightarrow$ unclear whether neutrino signal and supernova are related

Future Plans:

- search for additional ν within a time interval of 100 days
- do a stacked analysis for a catalogue of 40 SN IIn