Swift- and γ-ray Follow-Up of neutrinos (XFU / GFU)

Andreas Homeier

Realtime Astroparticle Physics

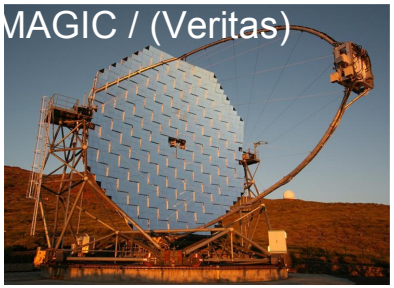
Bonn

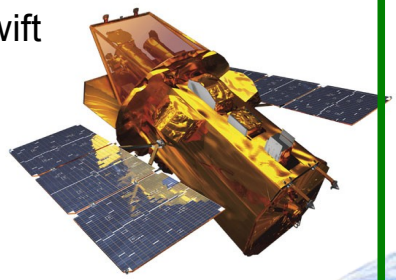
February, 4th – 6th 2012

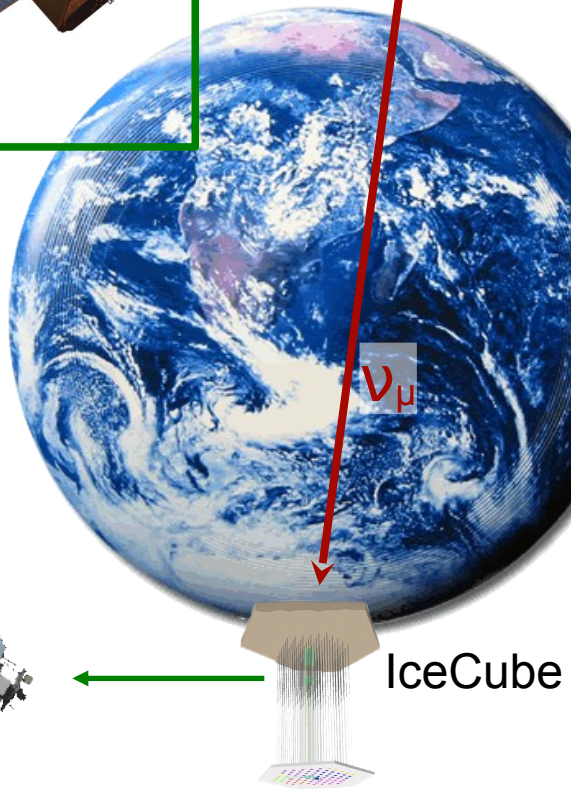
Overview

transient event (SN,GRB,…)

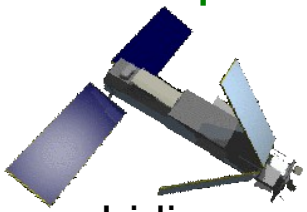
See talk by Markus Voge







northern hemisphere institute



Scientific Motivation

IceCube event / alert selection

Follow - Up

Gamma Ray Bursts

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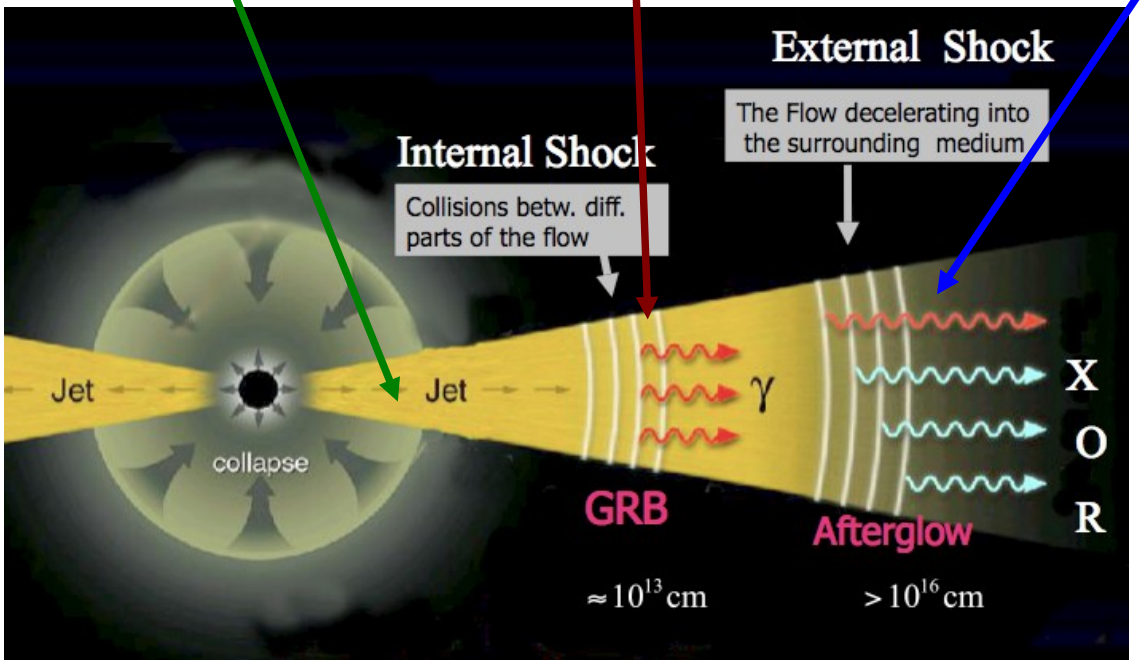
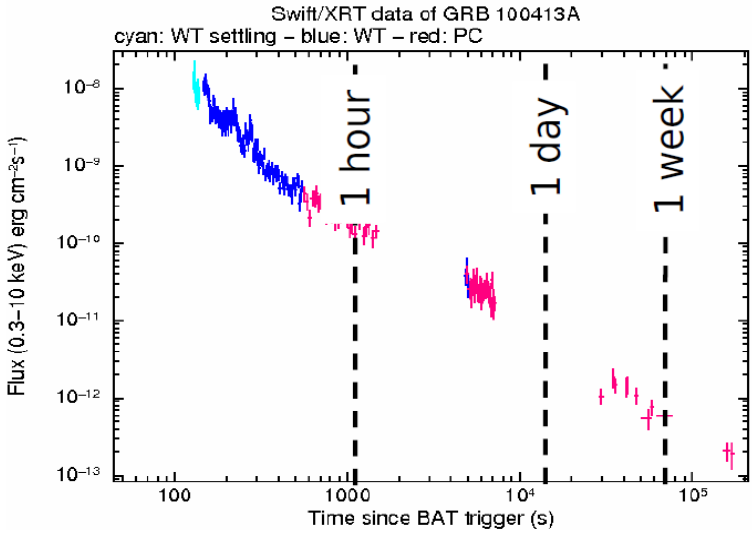
TeV neutrinos from inside the star (precursor)
[Meszaros & Waxman, 2001]
[Razzaque et al. 2003]

PeV Neutrinos from internal Shocks (prompt)
[Waxman & Bahcall 1997]
[Gupta & Zhang, 2006]
[Murase & Nagataki 2006]

EeV Neutrinos from external Shocks (afterglow)
[Dermer 2001]
[Waxman & Bahcall, 2000]



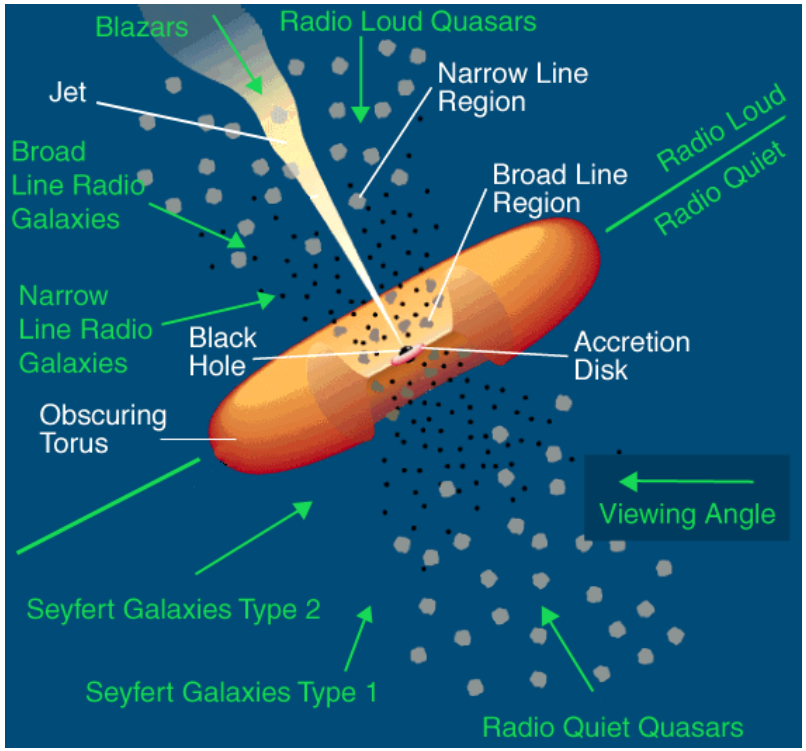
- Short bursts
- Fast decaying afterglow

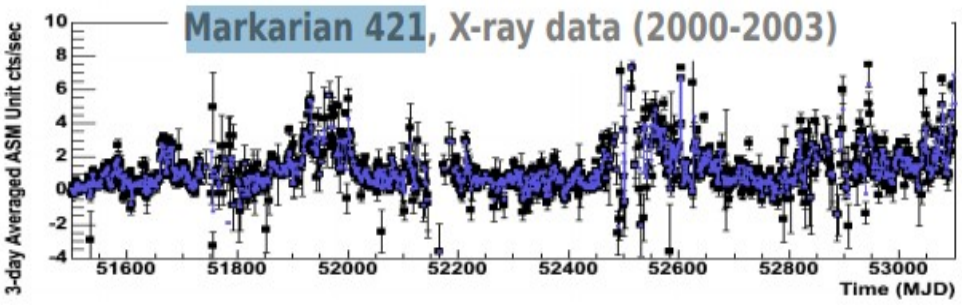


Active Galactic Nuclei

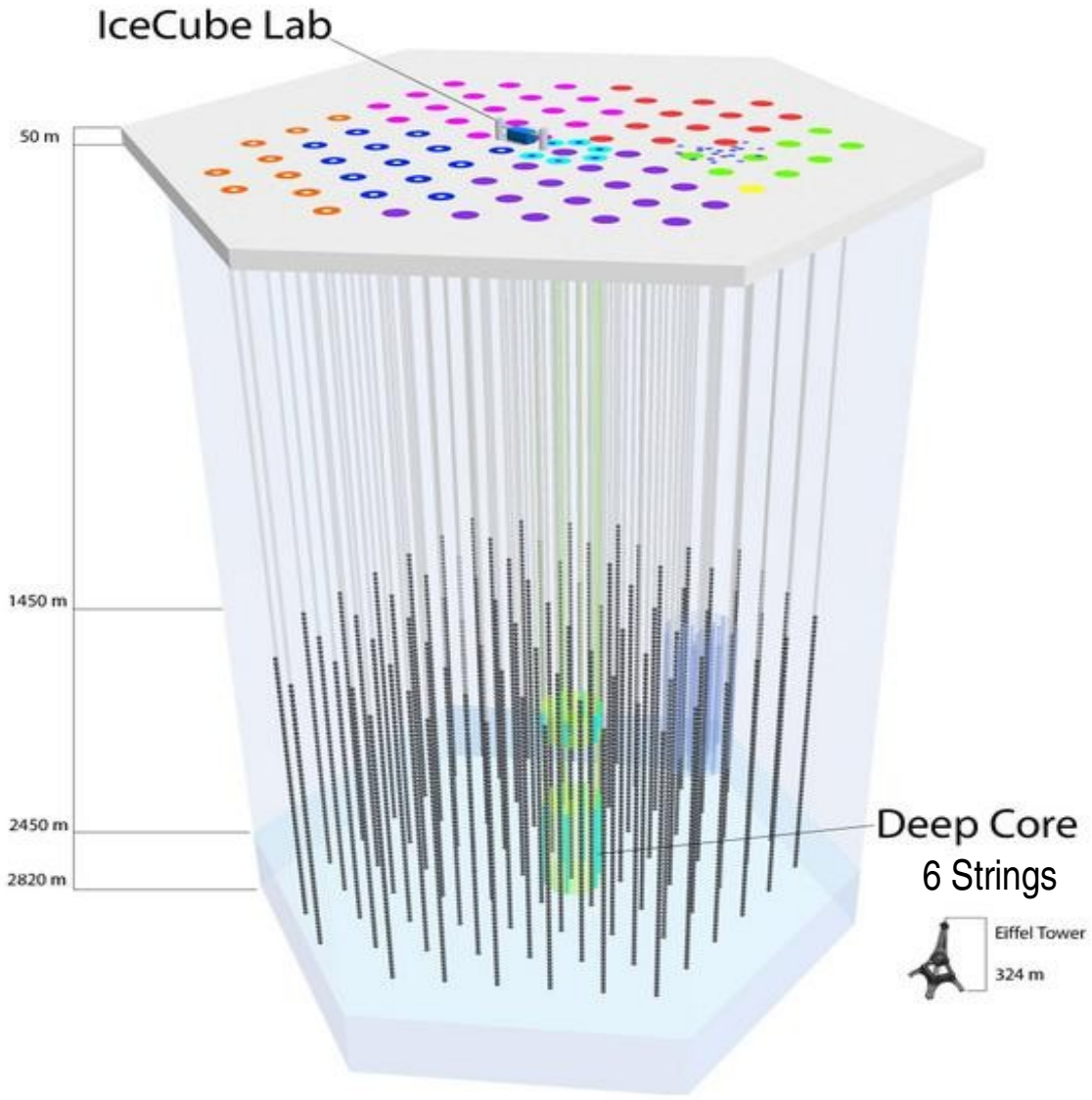
Active Galactic Nuclei

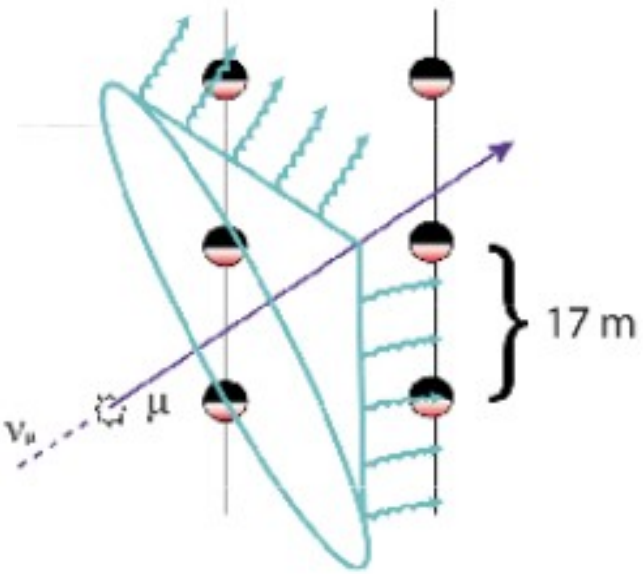
- massive central black hole (10^8 M_0)
- relativistic jets
  - Neutrinos → hadronic acceleration
- emission from radio to TeV
- high variability
- **flare duration up to weeks**





IceCube Neutrino Detector





Facts

- construction completed 2011
- 86 strings, 5160 optical modules
- 1km^3 instrumented volume
- most sensitive for Tev – PeV neutrinos

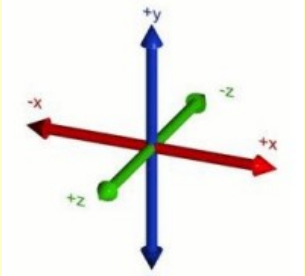
Event selection

XFU

Neutrino Level

Multiplets

$\Delta t \leq 100$ s



$\Delta\Psi \leq 3.5°$

Likelihood: 7 most significant alerts / year

Event selection

Neutrino Level

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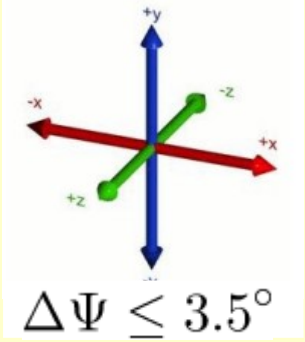
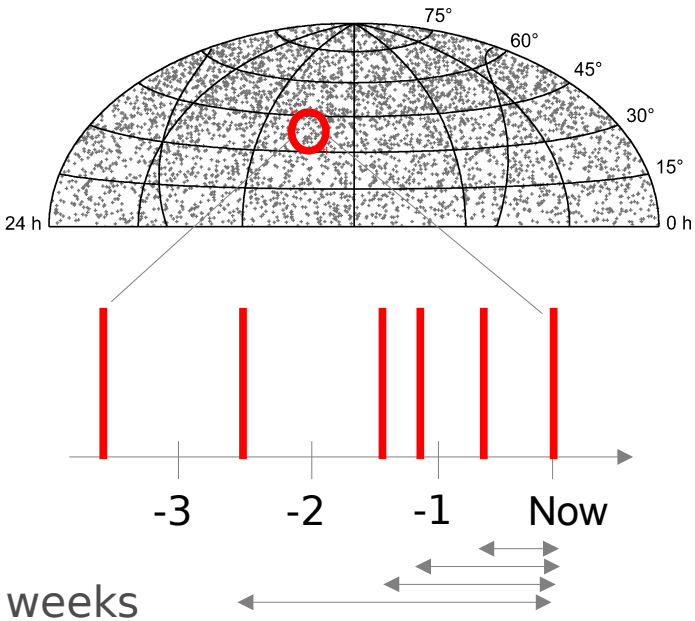


$\Delta\Psi \leq 3.5°$

Likelihood: 7 most significant alerts / year

GFU

Catalog of 109 established sources



Time-scale for cluster search: seconds to ~3 weeks

Gamma-ray follow-up with MAGIC & Veritas

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Operation

- Started Feb, 2012
- Running stable; alerts are being sent

Latency

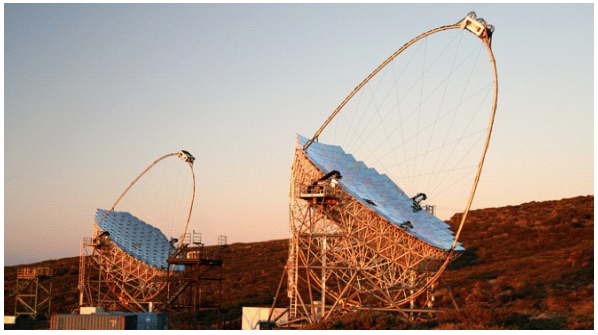
- IceCube: ~5 min
- MAGIC / Veritas: daytime dependent

Resources

- Alerts per year: MAGIC 5; Veritas 1
- Trigger threshold: MAGIC 3.2 σ; Veritas 3.5 σ

Results

- No results yet
- Will cover additional source in IceCube's follow-up program



X-ray follow-up with Swift

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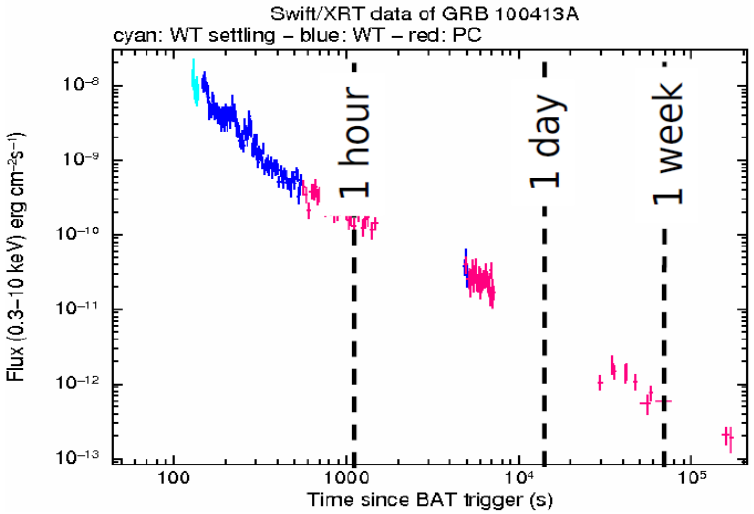
Latency

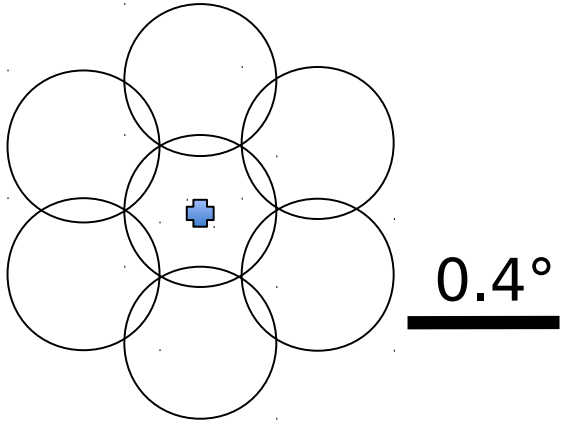
- IceCube latency: 5 minutes
- Swift latency: 1 – 4 hours

Resources

- 7 alerts per year
- 7 tilings needed
  - ~70% efficiency
- 2 ks per field

  → intensive follow-up if fixed criteria are met





X-ray follow-up with Swift

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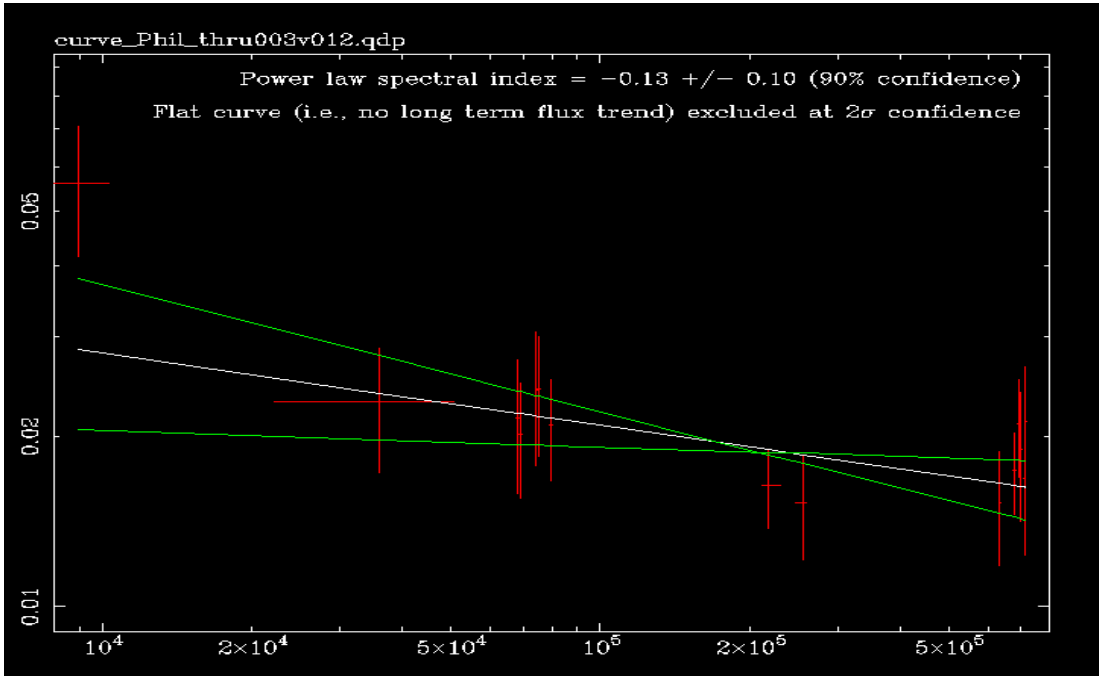
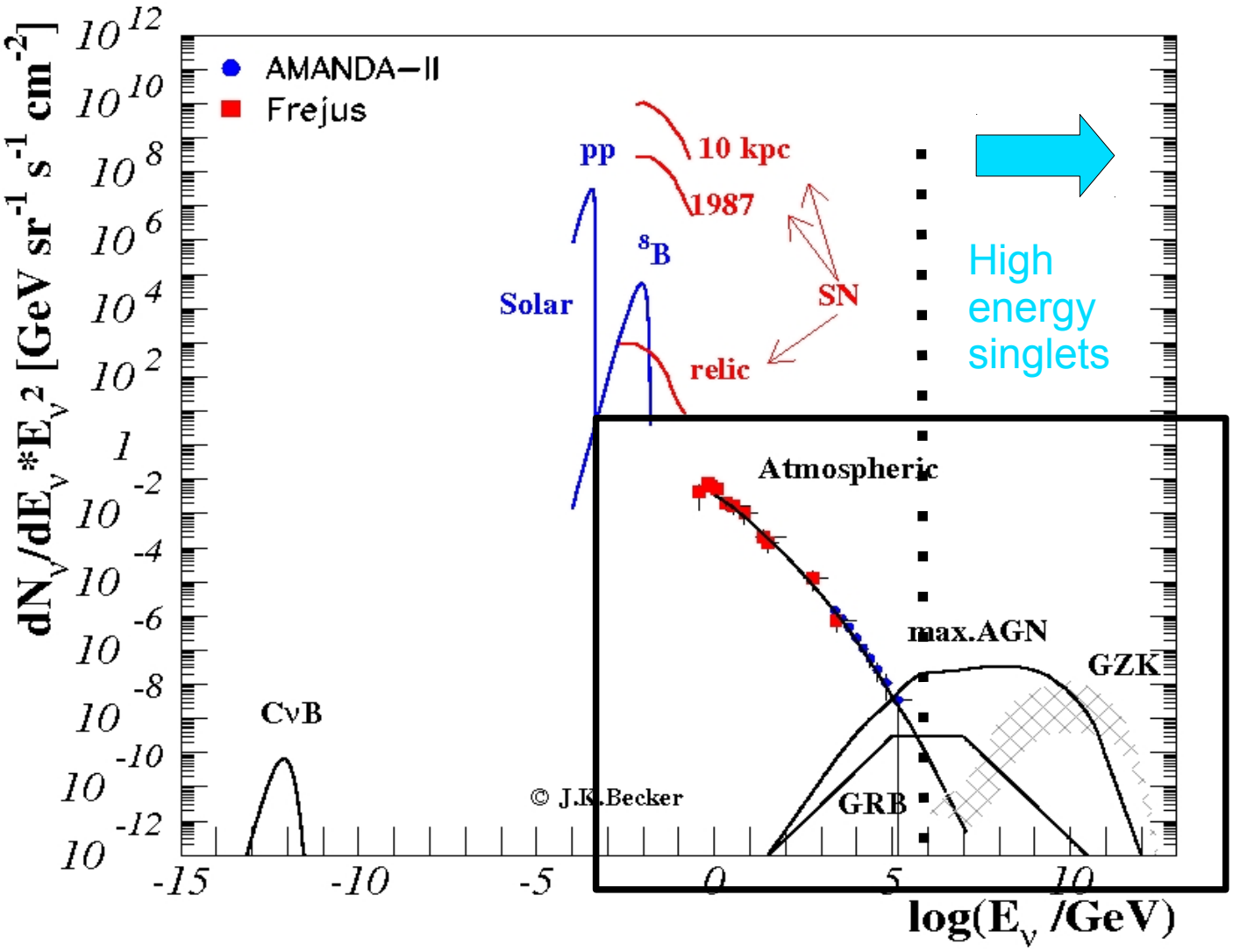
Operating since Feb. 2011

- 14 alerts sent to Swift
- No intensive follow-up
- How can we increase our sensitivity?



In development: high energy singlets



Singlet vs Doublet Stream

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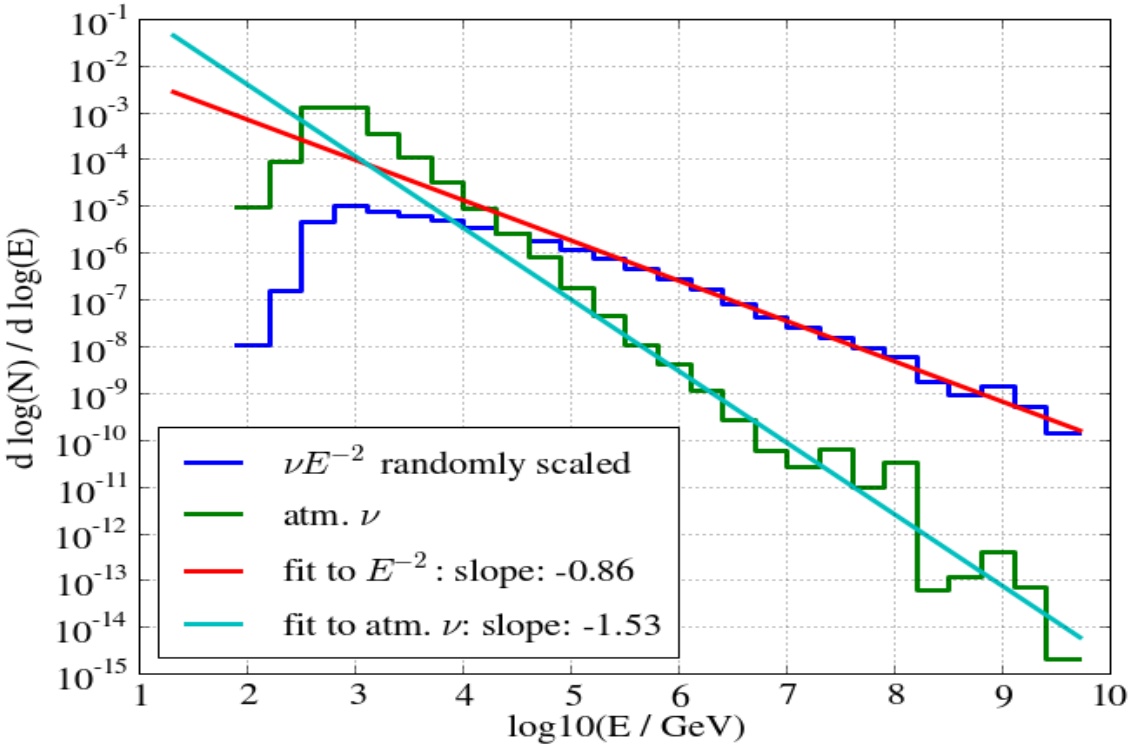

Toy model

- Measured muon spectrum
  - Background: $E^{-2.5}$
  - Signal: $E^{-1.9}$
- Optimization Parameter
  - Energy threshold E_{th}
  - Opening angle Ψ_{th} between doublets
  - Fixed alert number

Detection probability

$$P = P(E > E_{th}|n = 1) \cdot P(n = 1) + P(\Psi < \Psi_{th}|n = 2) \cdot P(n = 2)$$

$$\frac{P(n = 2)}{P(n = 1)} = \frac{< n >}{2}$$

$< n >$: average number of expected neutrinos per GRB in IceCube

Singlet vs Doublet Stream

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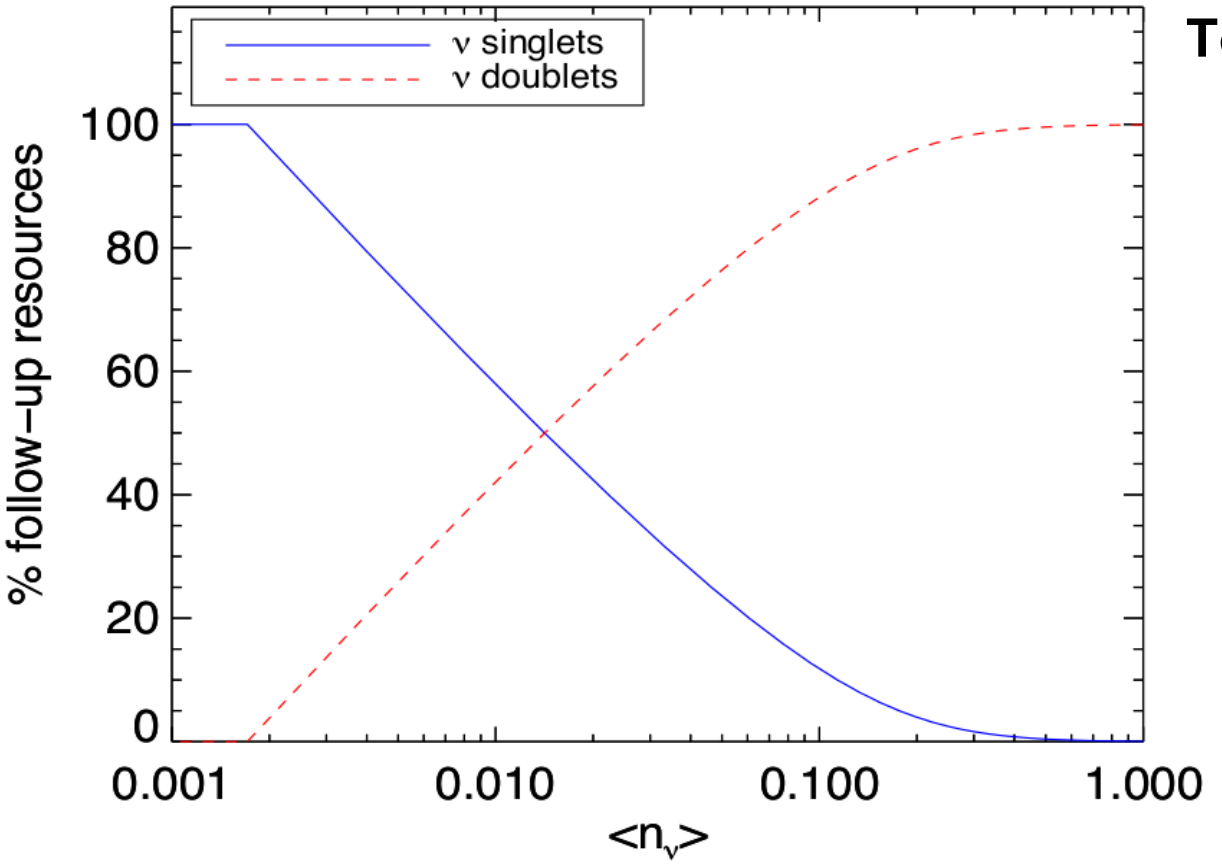

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Event selection (XFU): Singlet vs Doublet Stream

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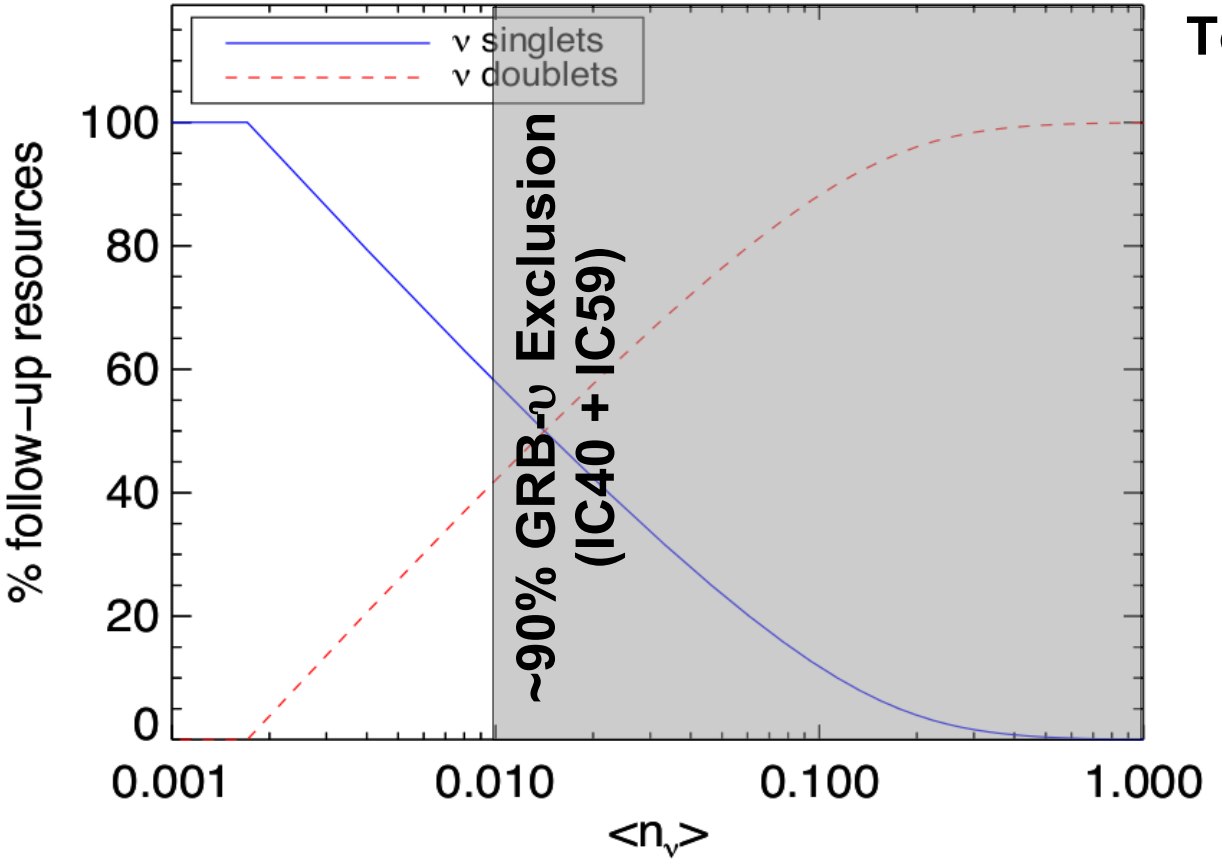

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Conclusion

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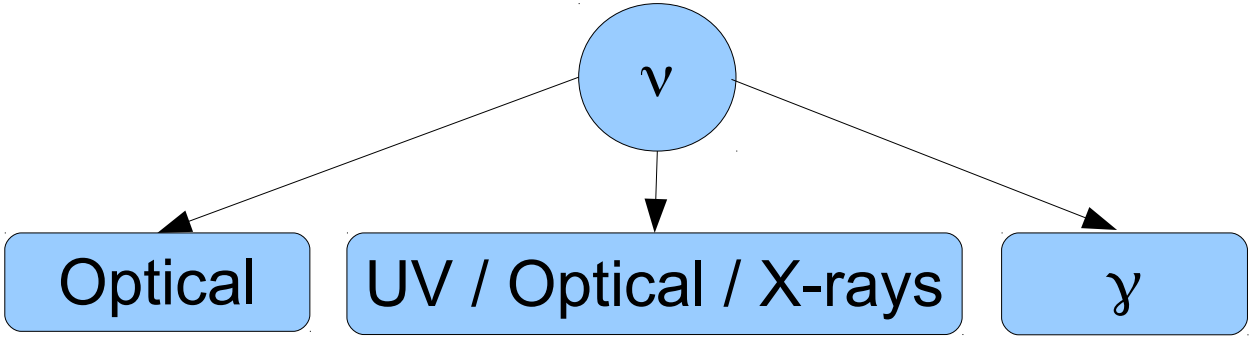
Multimessenger

- Important strategy for the future
- Neutrinos: Smoking gun for hadronic acceleration

IceCube follow-up programs

- No discoveries, yet
- Trying to improve
  - High energy singlets → 4π coverage
- Covering SNe (choked GRBs), GRBs, AGNs
- Covering wide range of electromagnetic bandwidth




Questions?

Participants

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Ice Cube

Doug Cowen

Ignacio Taboada

Anna Franckowiak

Andreas Homeier

Tyce DeYoung

Marek Kowalski

Peter Mezsaros

Sebastian Böser

Erik Blaufuss

University of Leicester

Phil Evans

Julian Osbourne

Swift GI

Derek Fox

Abe Falcone

Qirong Zhu

Swift ops

Miles Smith

Neil Gehrels (PI)

John Nousek

David Burrows

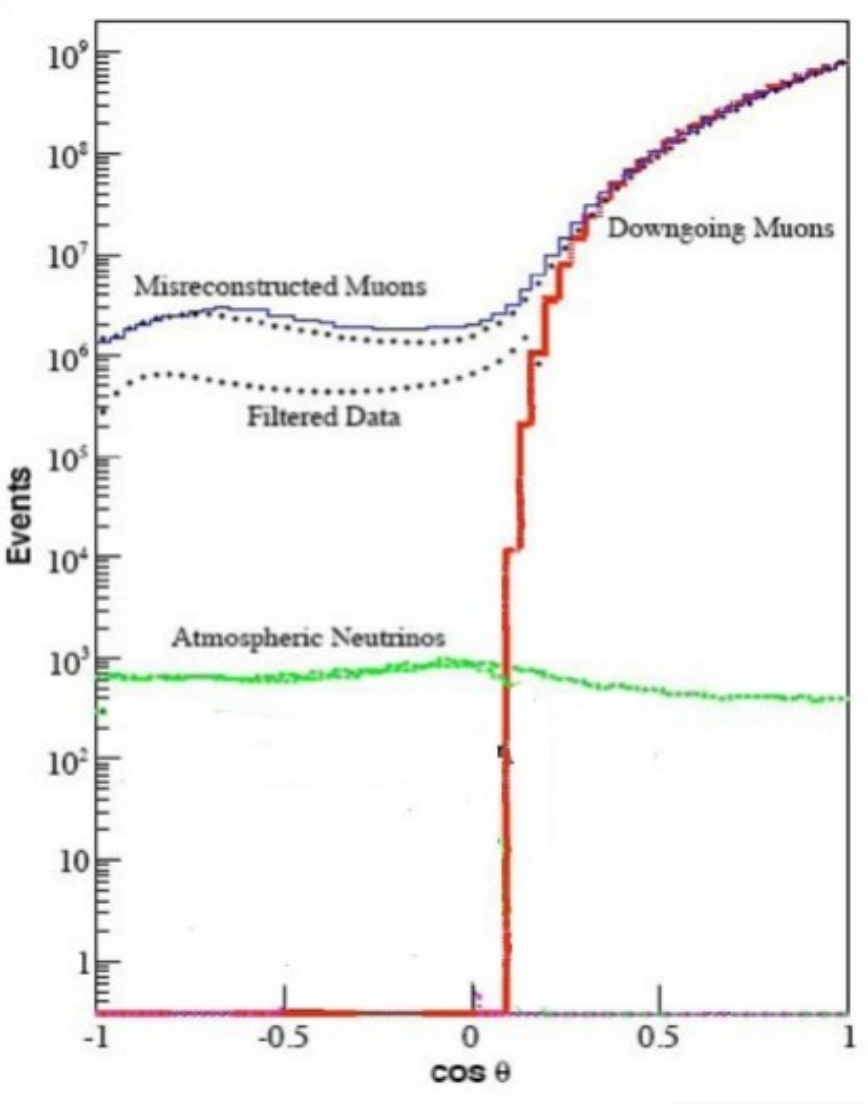
Jamie Kennea

Scott Barthelmy

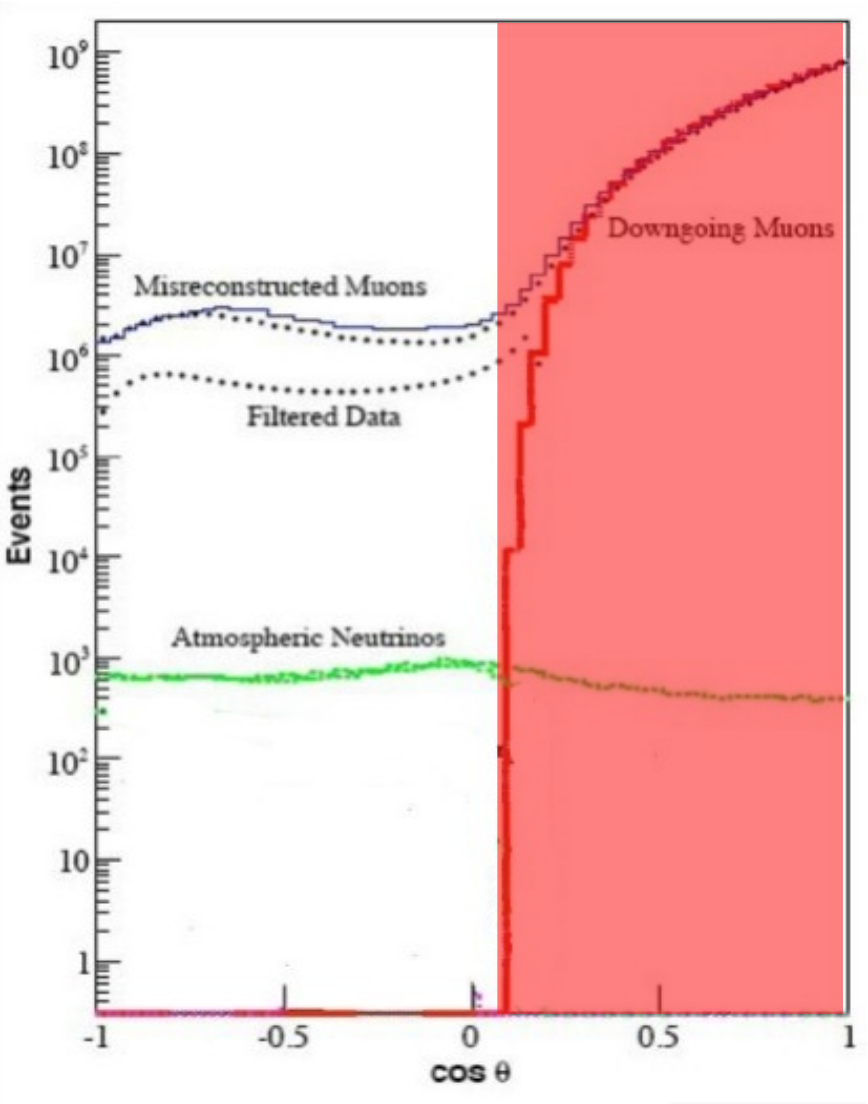
Jonathan Gelbord

Michael Stroh

Event selection



Event selection



Muon background

- Restrict to northern sky
- Quality parameter to identify missreconstructed muons

X-ray follow-up with Swift

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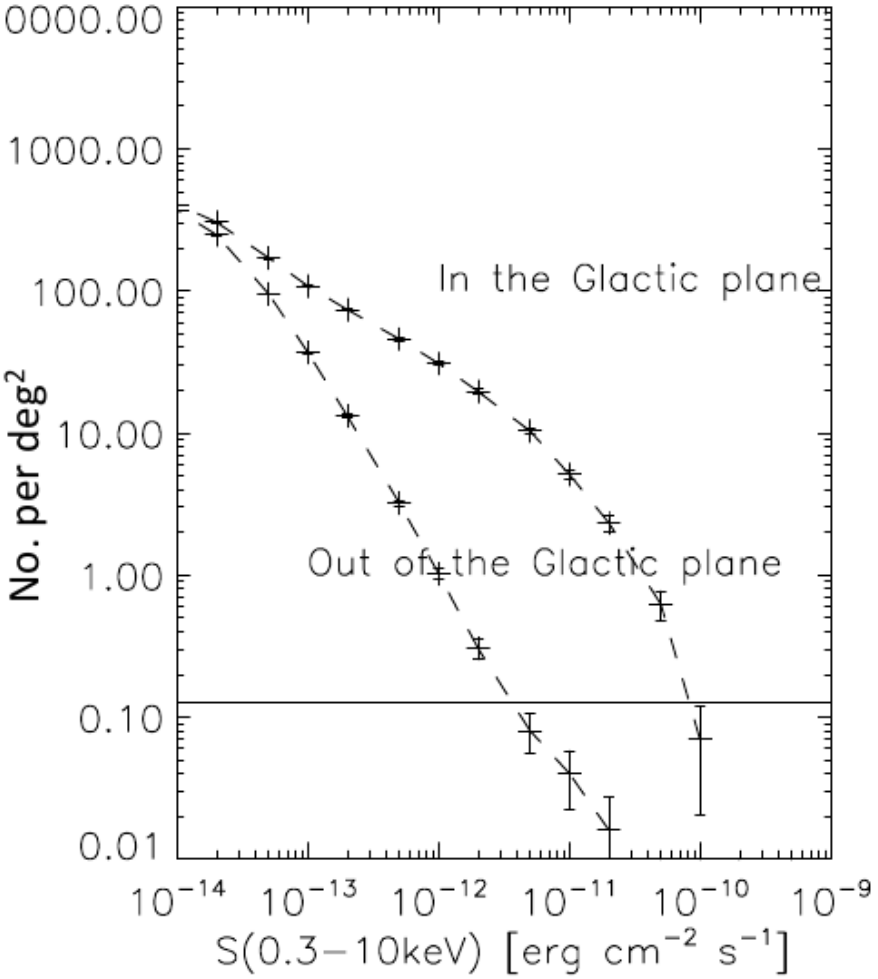
Study by Miles Smith, Qirong Zhu and Jonathan Gelbord

Intensive follow-up if source with high flux that

- Is decaying
- Is uncatalogued
- Is a brightened known sources

Automated System
(Leicester University)



Swift

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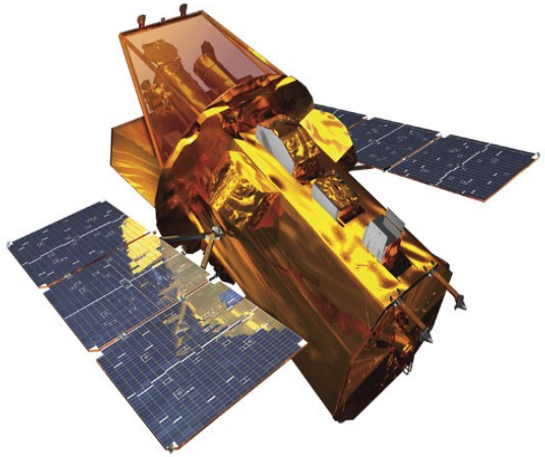
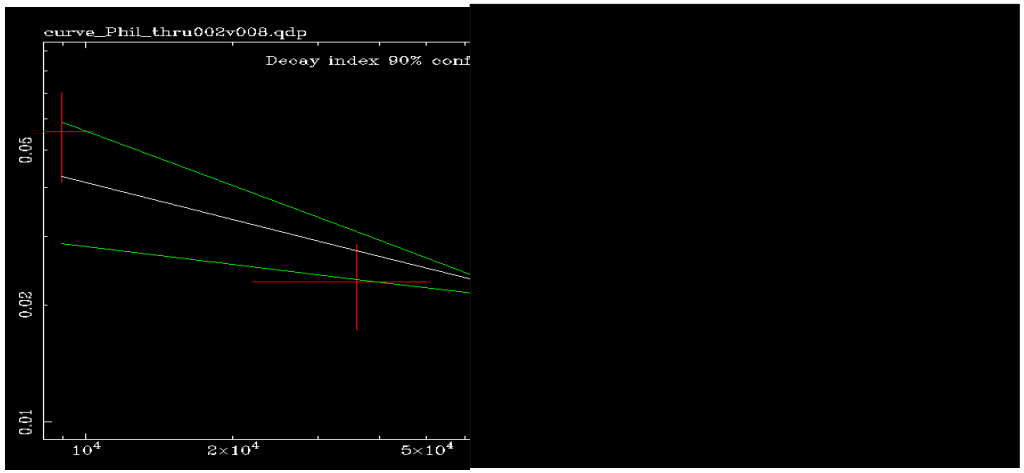
Relevant Swift Characteristics	
Instruments	1. BAT (γ-rays) 2. XRT (X-rays) 3. UVOT (UV/opt)
Normal operating mode	Pre-planned science timelines daily
Rapid response mode	Re-pointing in ~2min (Swift triggers) or 1-4 hours (non-Swift)
Visibility	25-45 min of a 96 min orbit
Prime instrument	XRT (this program)
XRT FOV	0.4 deg
XRT energy range	0.2 – 10 keV
XRT pos error	2.4 arcsec



Swift alert: Fading source?



First observations:

- Fast fading source found
- Just below Swift threshold for intensive follow-up → not part of analysis

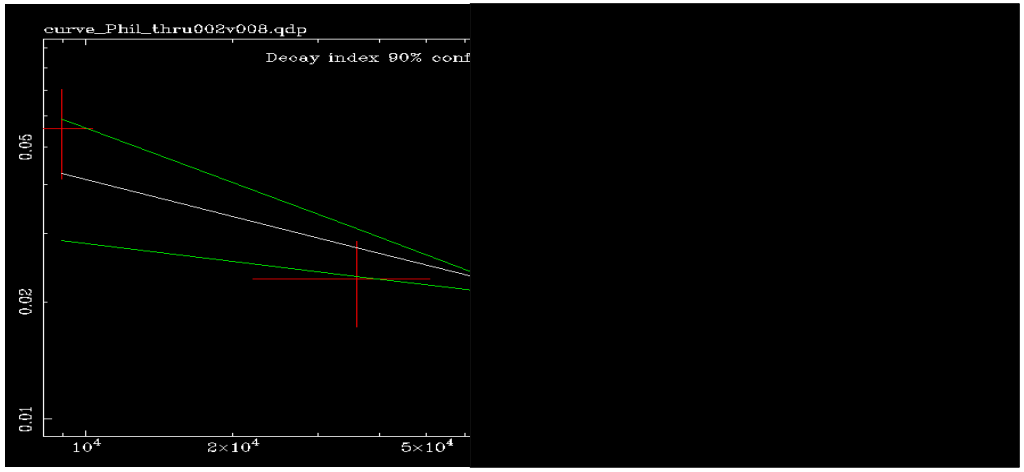
Swift decision: More observations

IceCube:

- Detector stability checks
- Everything ok, but nothing extraordinary

Swift alert: Fading source?

Alert from 2012-03-03:



First observations:

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IceCube:

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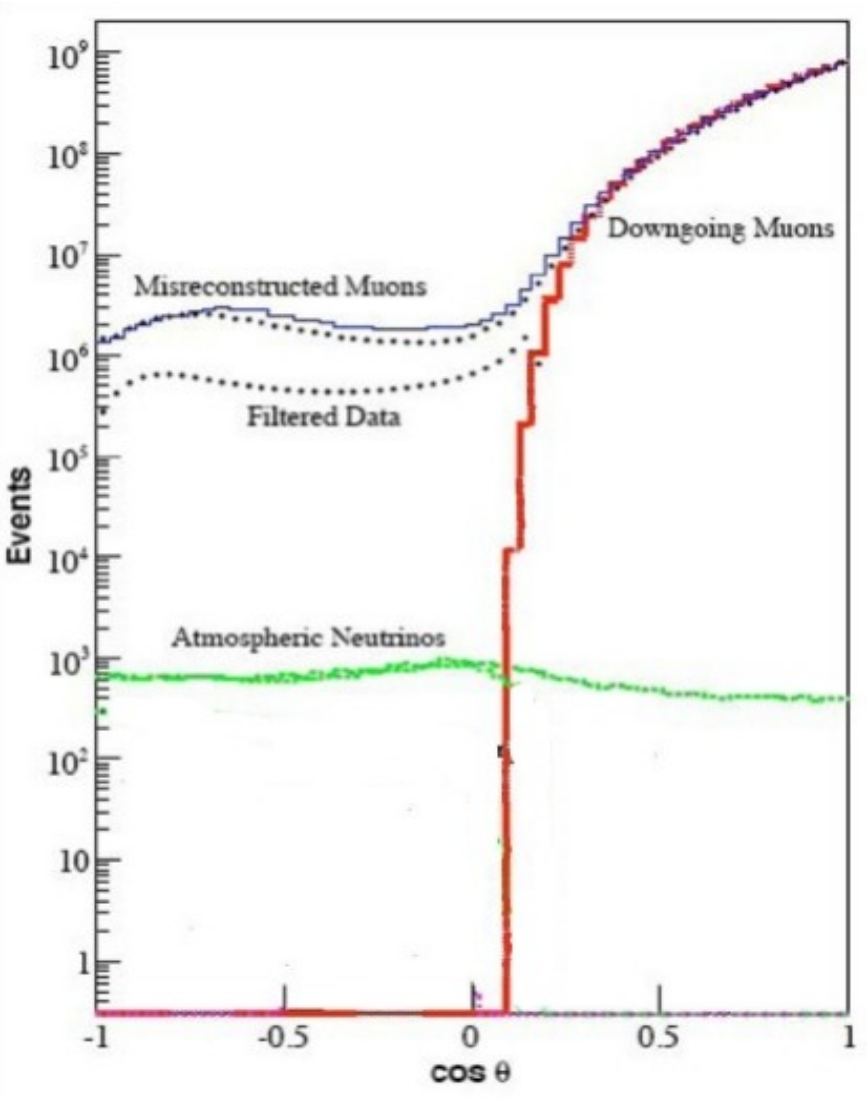
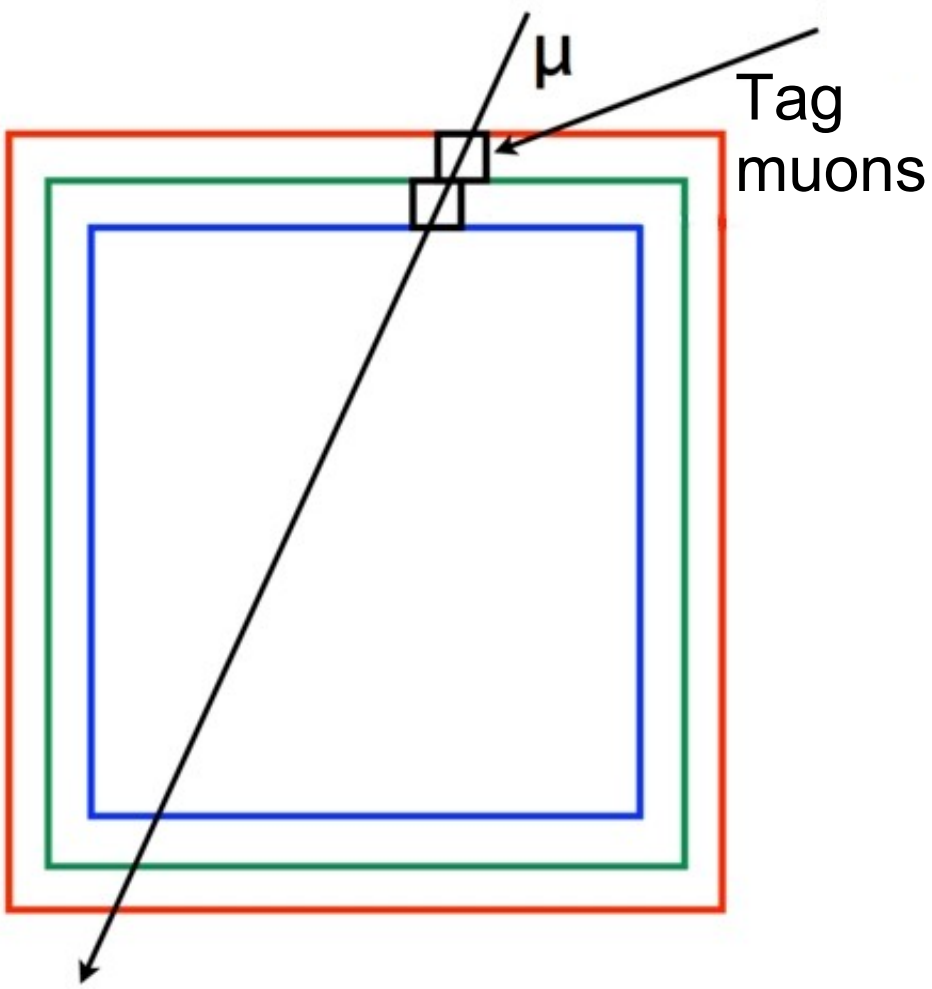
- Everything ok, but nothing extraordinary

Result: More observations with Swift show slow fading/variability. Probably background AGN

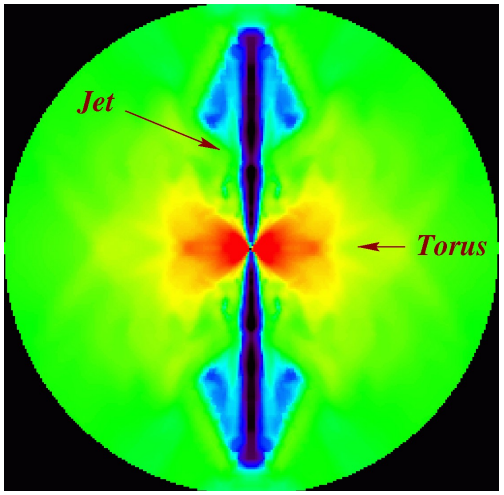
Future plans: Event selection



Starting Tracks

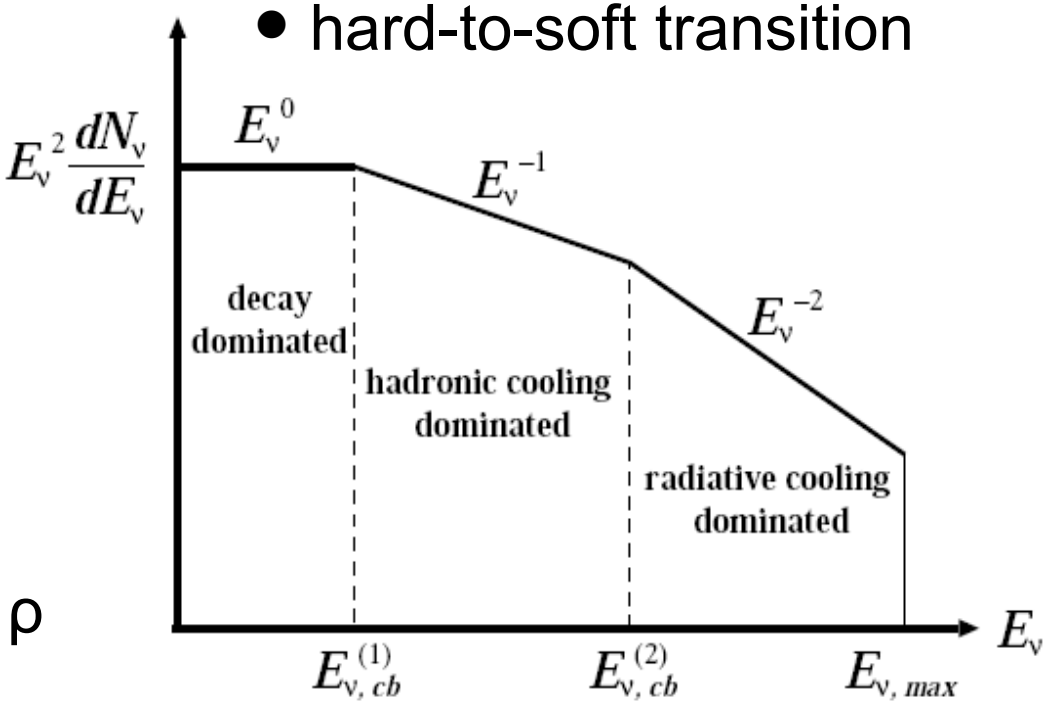


Model expectations



Neutrino flux spectrum

- calculated according to [Ando, Beacom (PRL 95, 2005]
- hard-to-soft transition



Model parameters

- jet boost factor Γ
- jet energy E_{jet}
- density of SNe with jets ρ

SN Neutrino energy spectrum