Marek Kowalski
DESY&HU

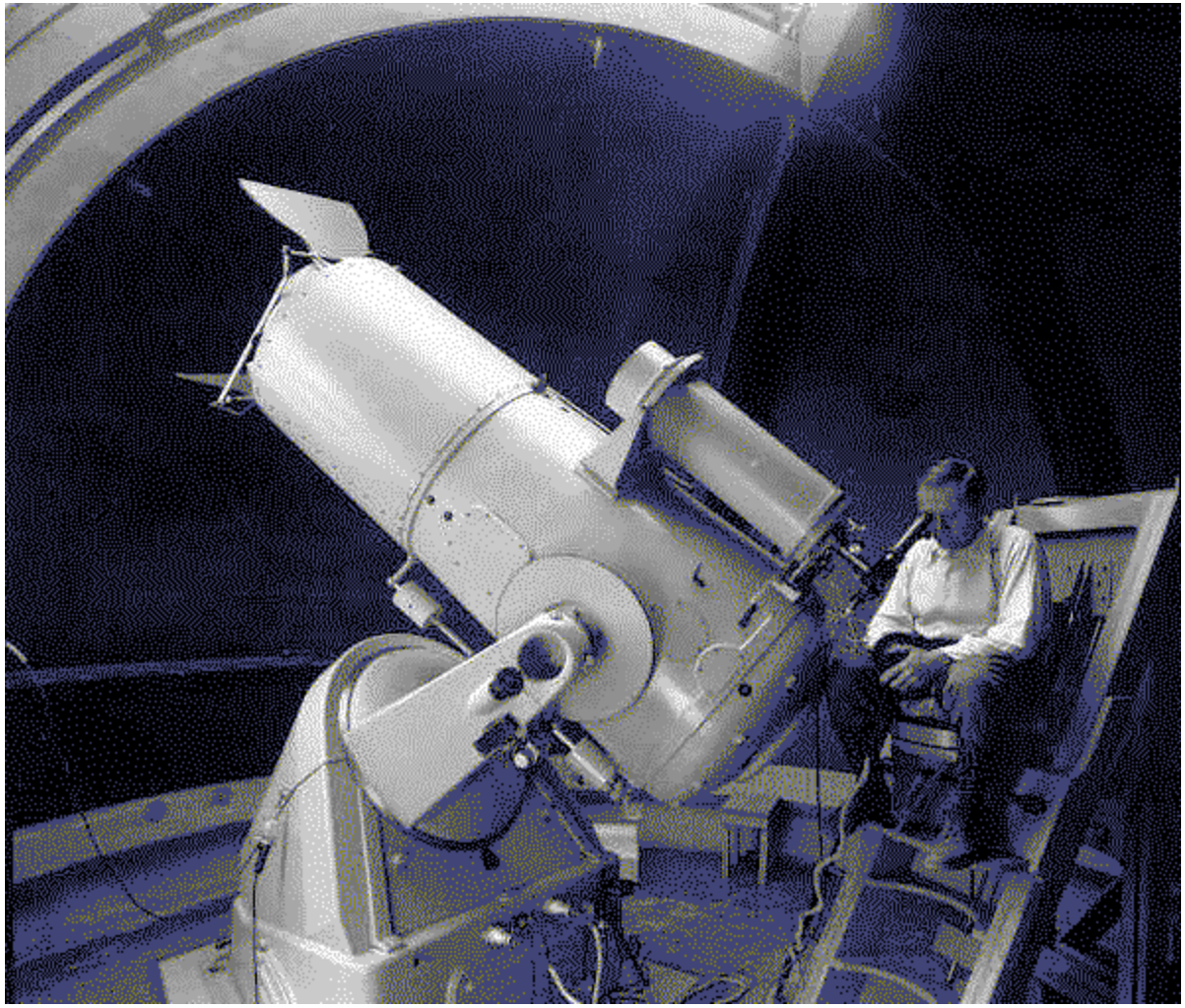
DESY-Seminar
21.10.2014

The Zwicky Transient Facility – wide field imaging at DESY

Content

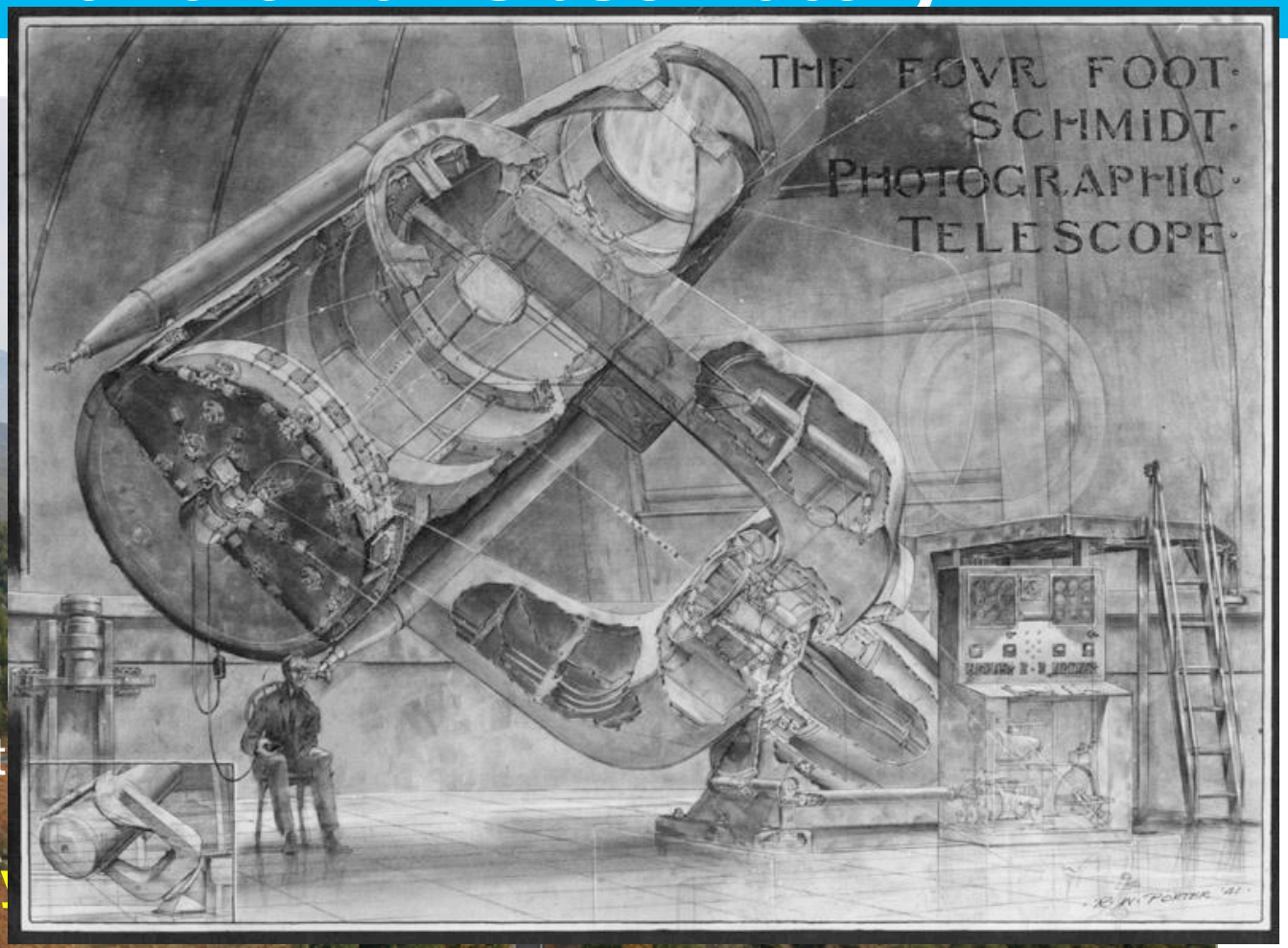
- Introduction
- Cosmology with nearby Supernovae Ia
- Hunting the sources of cosmic neutrinos
- The next step: Zwicky Transient Facility

Fritz Zwicky (1898-1974)



Mount Palomar Observatory

Mount Palomar Observatory

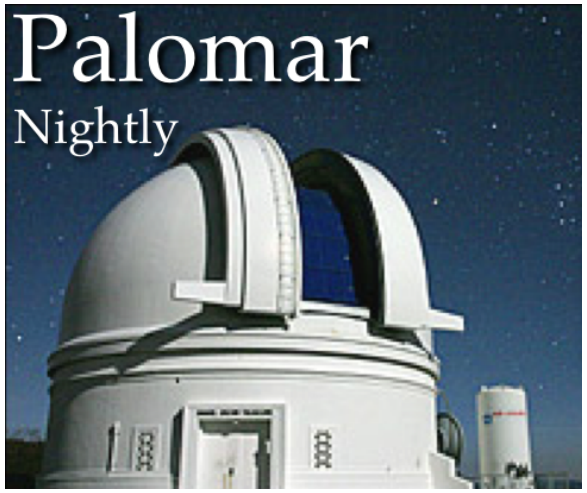


120 cm Schmidt t

The heart of the

Transient Facilit

Detecting & Observing Supernovae

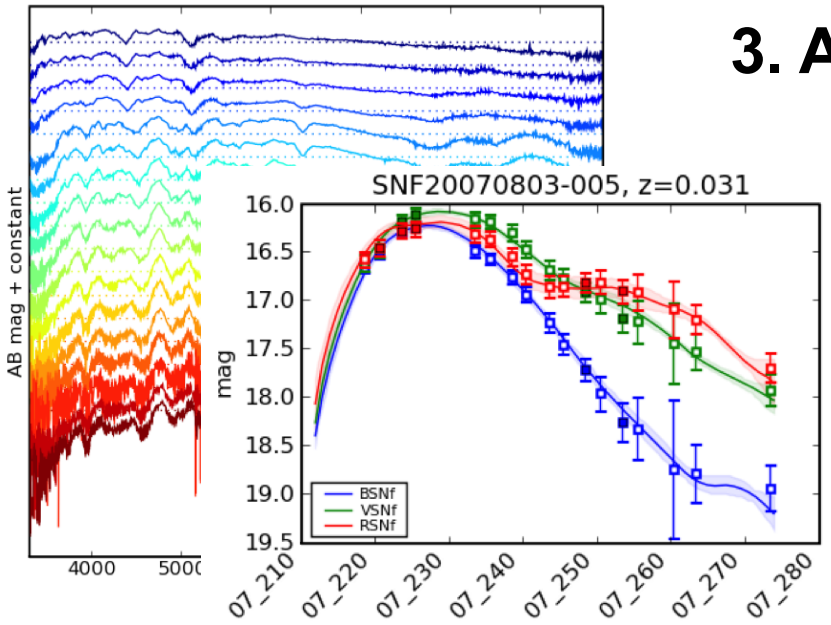


1. Discover

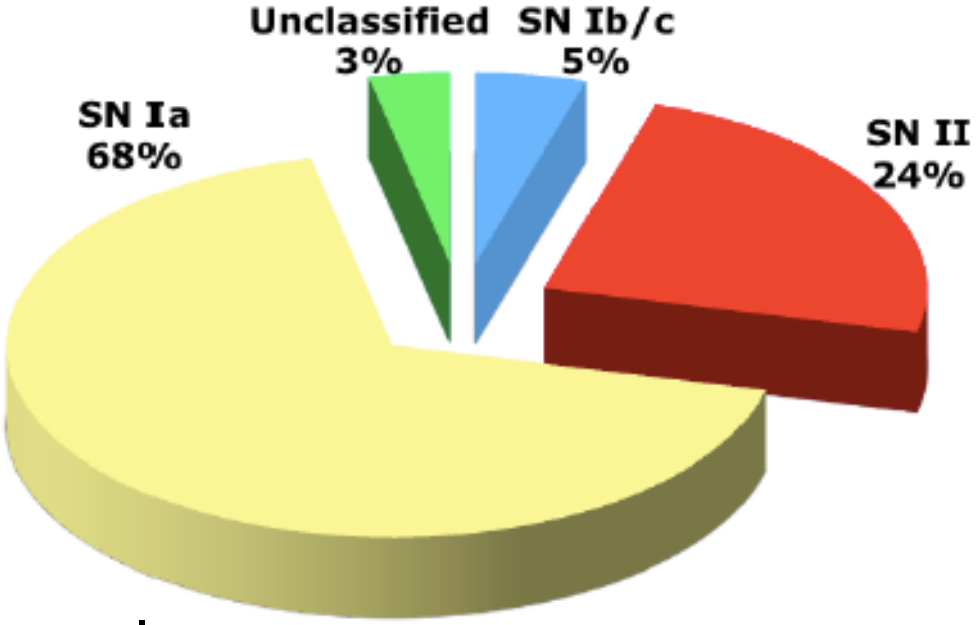
2. Observe

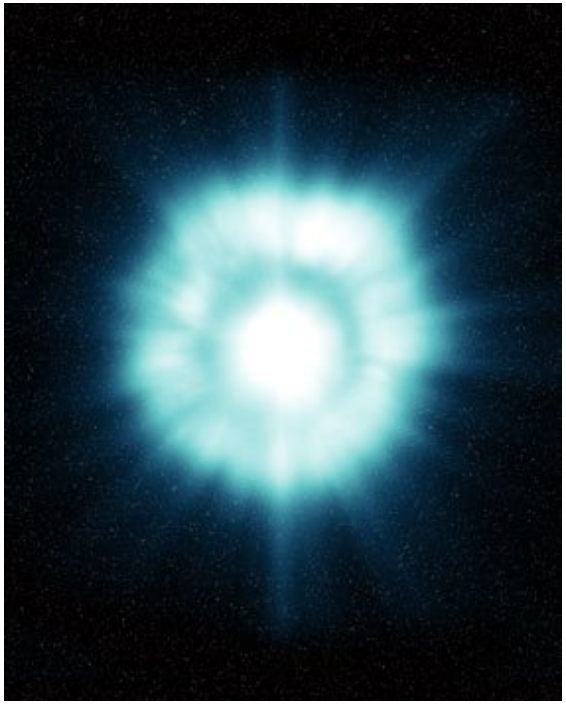
SNIFS: Custom spectrograph for nearby SN observations

3. Analyses



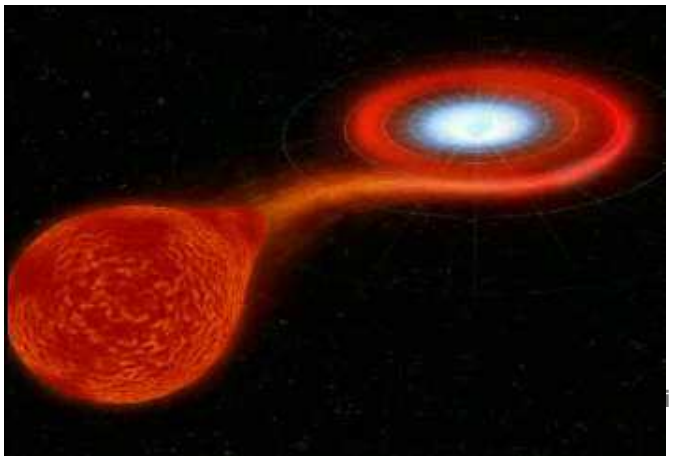
Detecting & Observing Supernovae





Core collapse SNe

Supernova Ia



~3000 SNe in total so far from Palomar Transient Factory and the Supernova Factory

Cosmology

Cosmology Group @ Humboldt-University

Ulrich Feindt

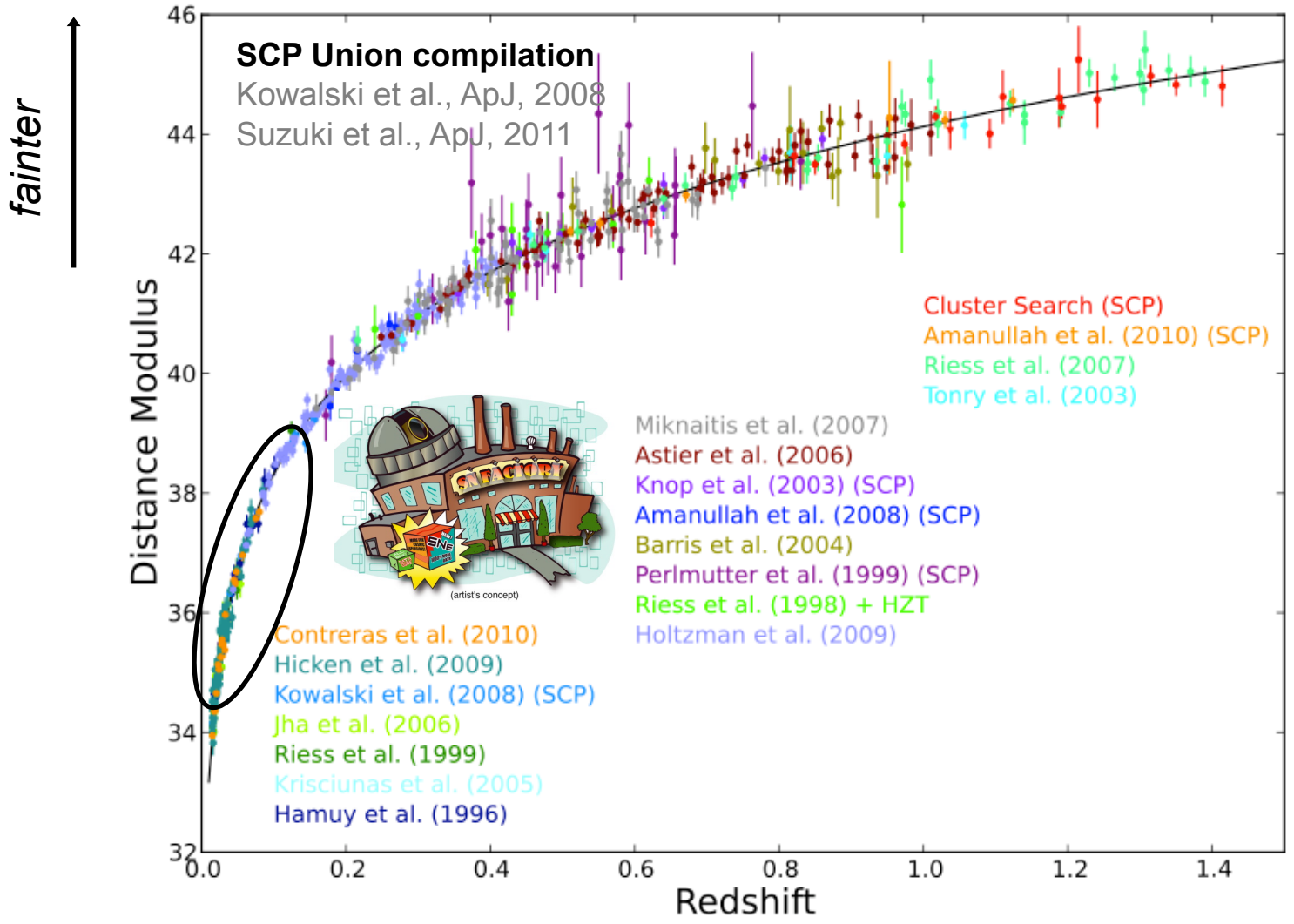
Dr. Mickael Rigault

Dr. Jakob Nordin

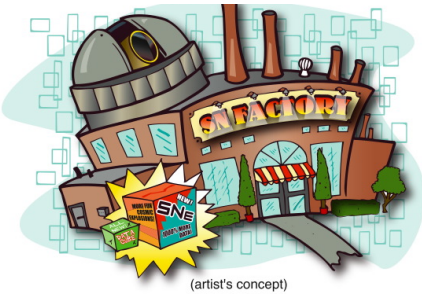
Daniel Küster

Simona Lombardo

A modern SNe Ia Hubble Diagram



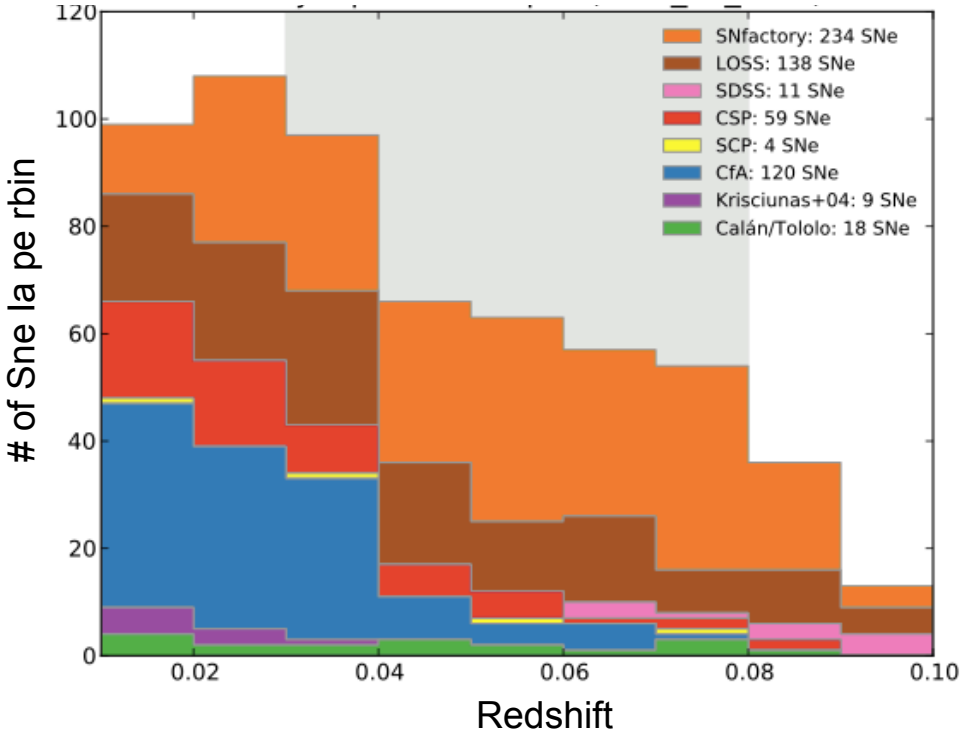
Supernova Factory

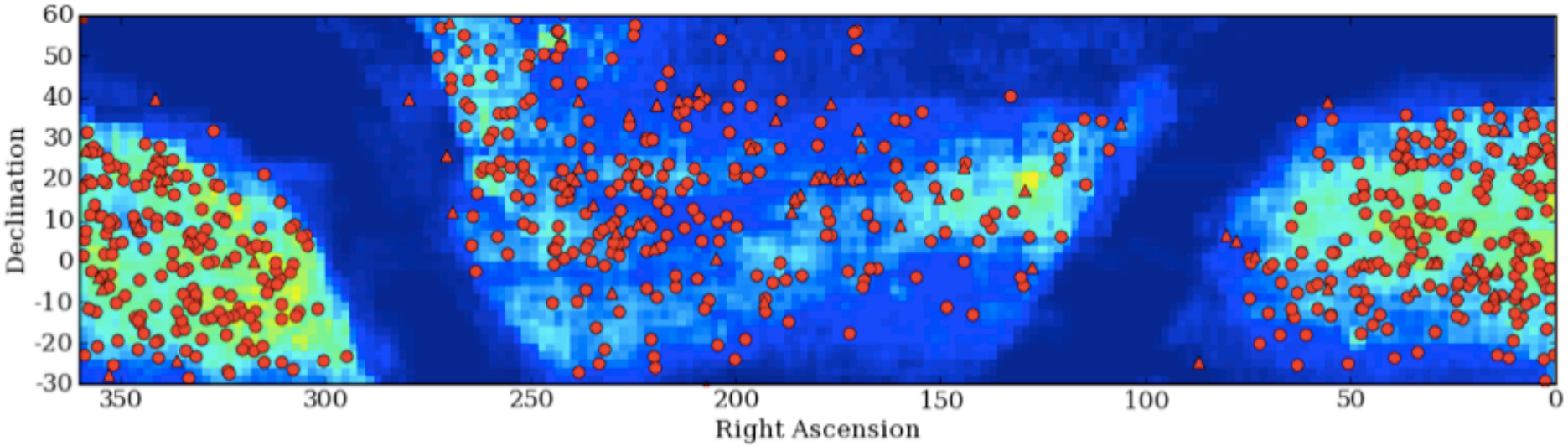


LBNL, LPNHE-Paris, IPNL-Lyon, CRAL-Lyon, Humboldt-U.
Yale U, Tsinguha U., (Bejing), MPA (Garchingen)

Supernova Factory

- Untargeted wide-field search (3000 sqdeg) using the Palomar 48-in telescope & QUEST II camera
- Follow-up with custom-build SNIFS spectrograph on the University Hawaii 2.2m telescope





The Hubble Constant

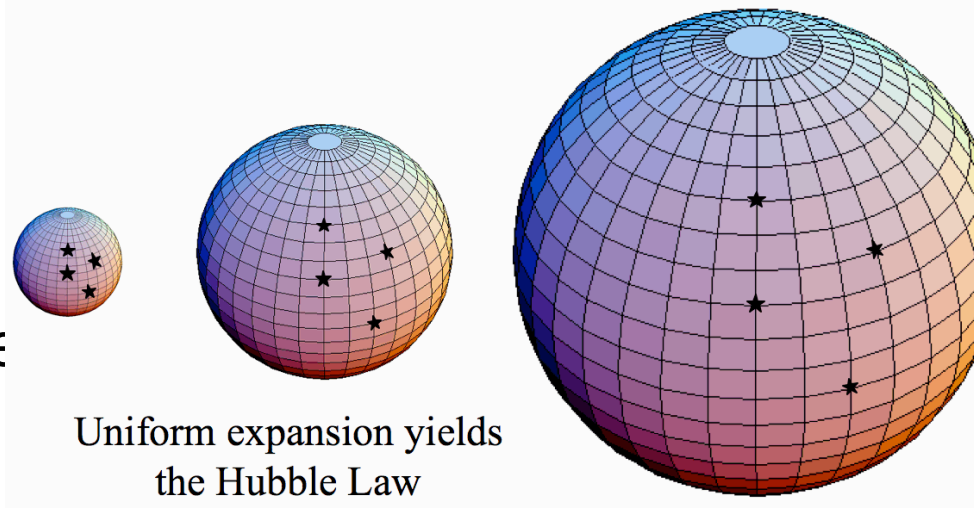
Friedmann eq. governing expansion rate of Universe

$$H^2 = \left(\frac{\dot{a}}{a}\right) = \frac{8\pi G}{3}\left(\rho_m + \rho_r + \rho_\Lambda + \rho_k\right)$$

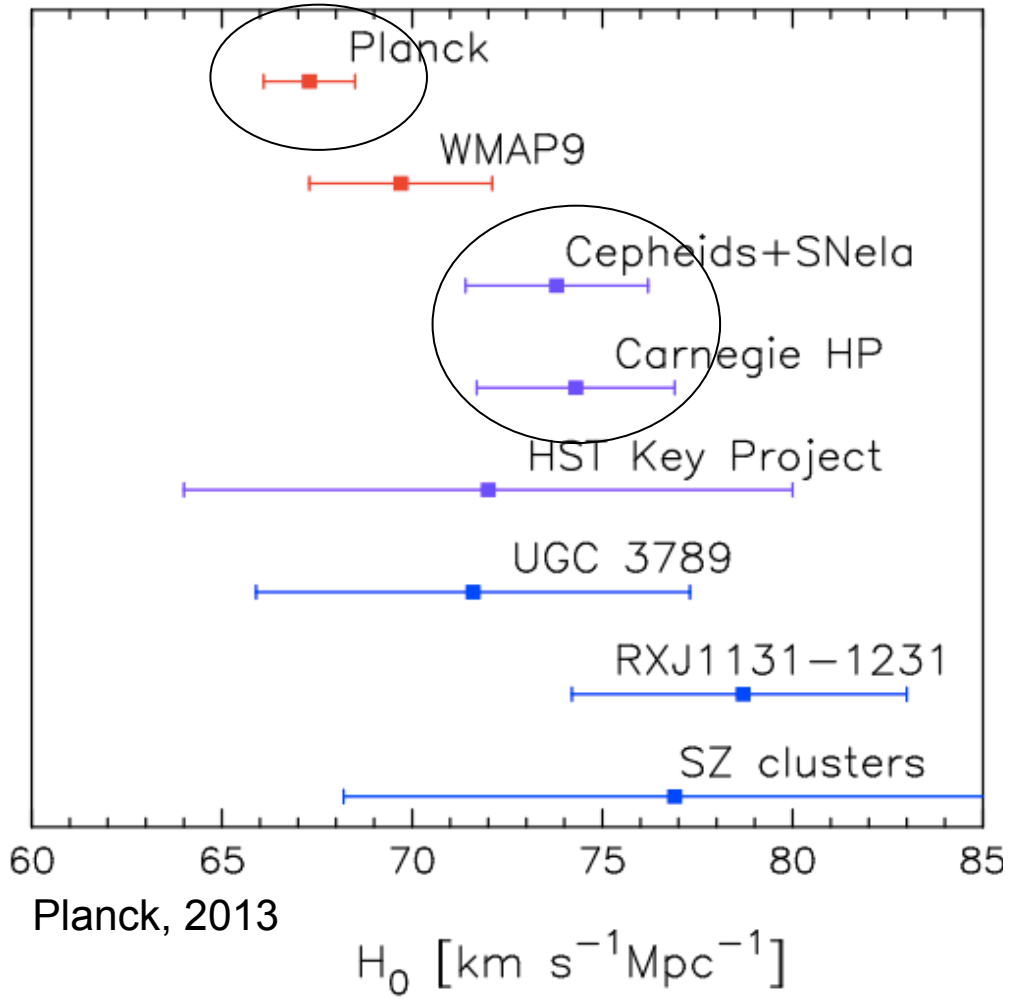
Hubble constant central parameter in cosmology, e.g.

⇒Dark energy equation of state

⇒Number of neutrino flavors



The Hubble Constant

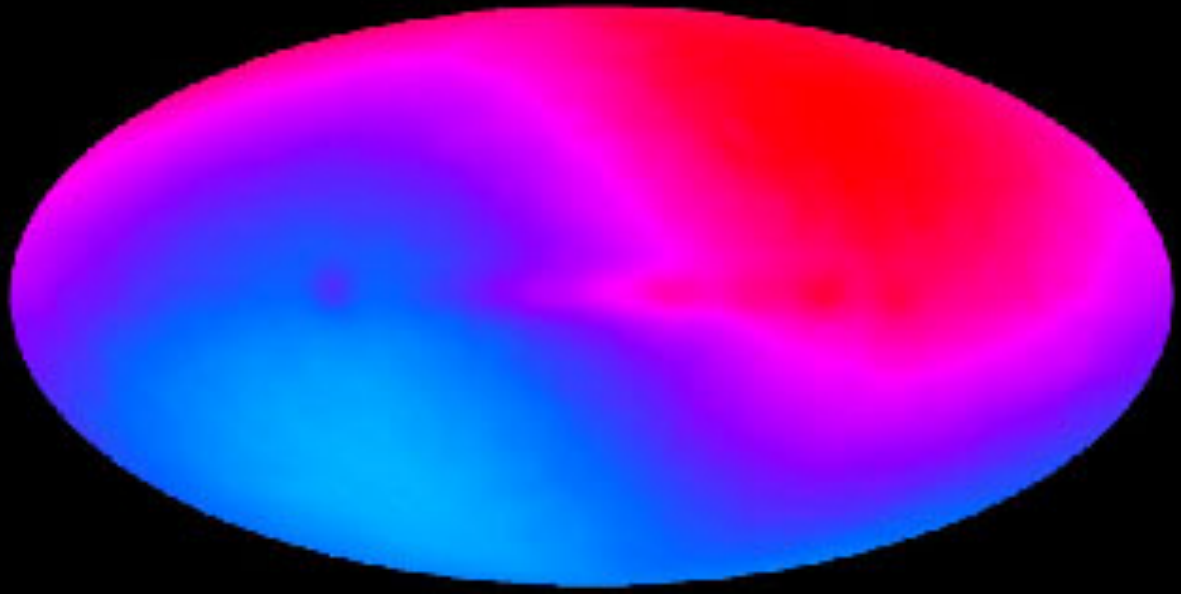


Planck, 2013

2-2.4 σ tension in the Hubble constant between CMB and SNe

- Systematic uncertainties underestimated?
- Mismatch between CMB and local H_o measurement due local matter under/ over densities?

CMB temperature map: $\Delta T \sim 10^{-3}$ K

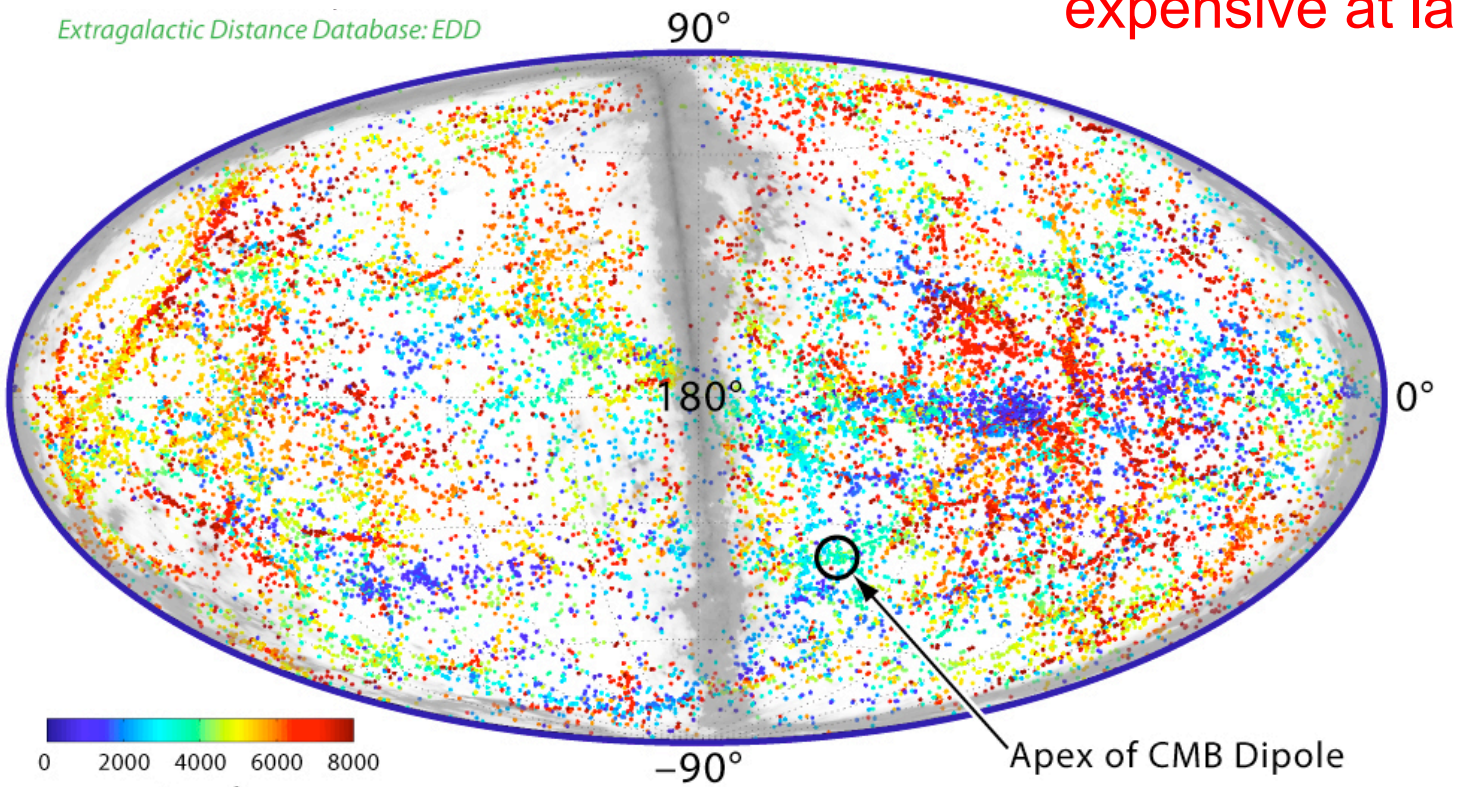


CMB Dipole due relative volicity of Local Group of 627±22 km/s (Kogut et al. 1993)

What is draging us trough space?

Resolving the Bulk flows: Galaxies vs SNe

Galaxies:
large statistics
expensive at large z

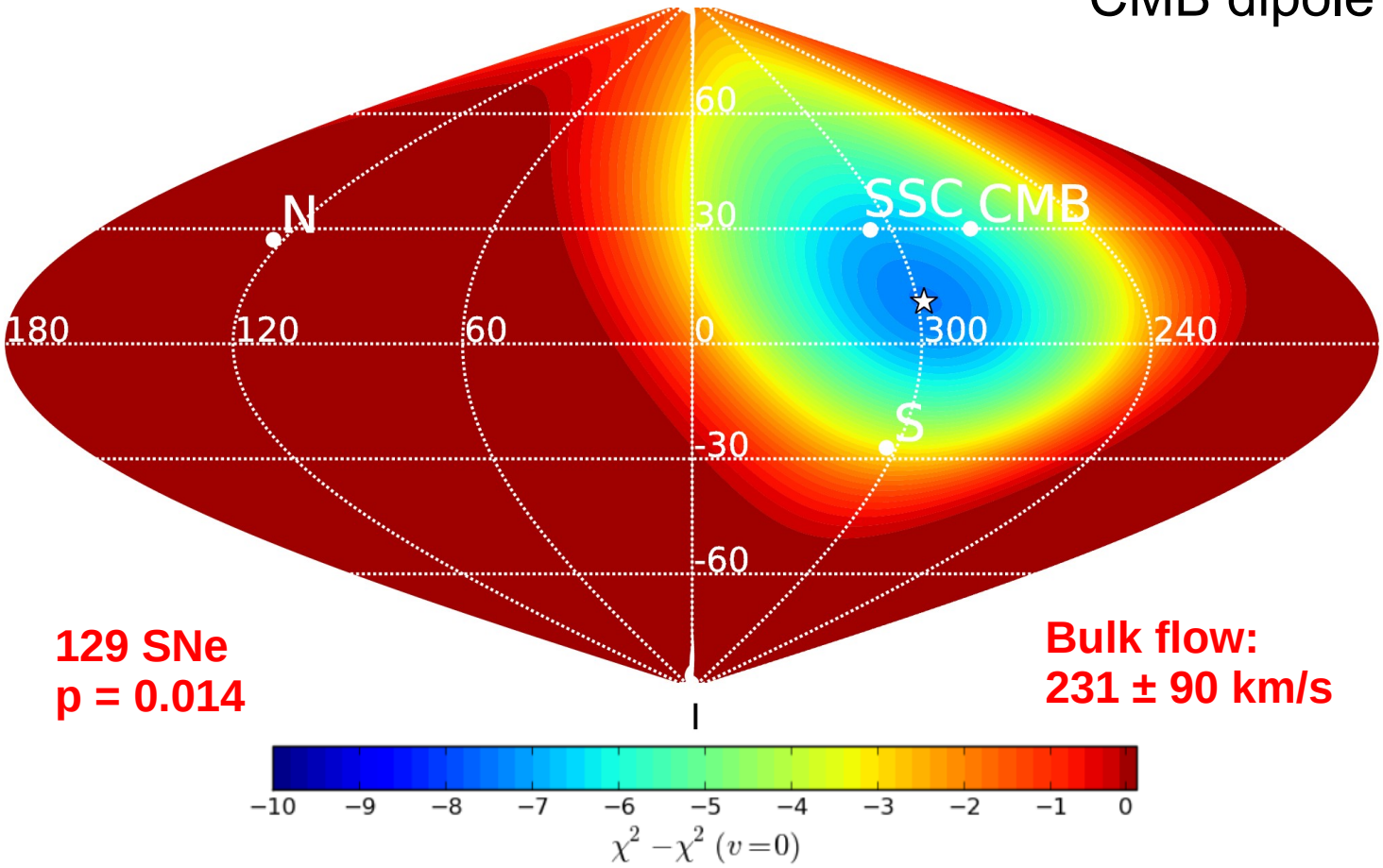


Supernovae:
small (but growing) statistics
easy to observe at larger z

Supernovae as velocity tracers

- redshift shell: 0.015 < z < 0.034

- Best fit direction consistent with CMB dipole

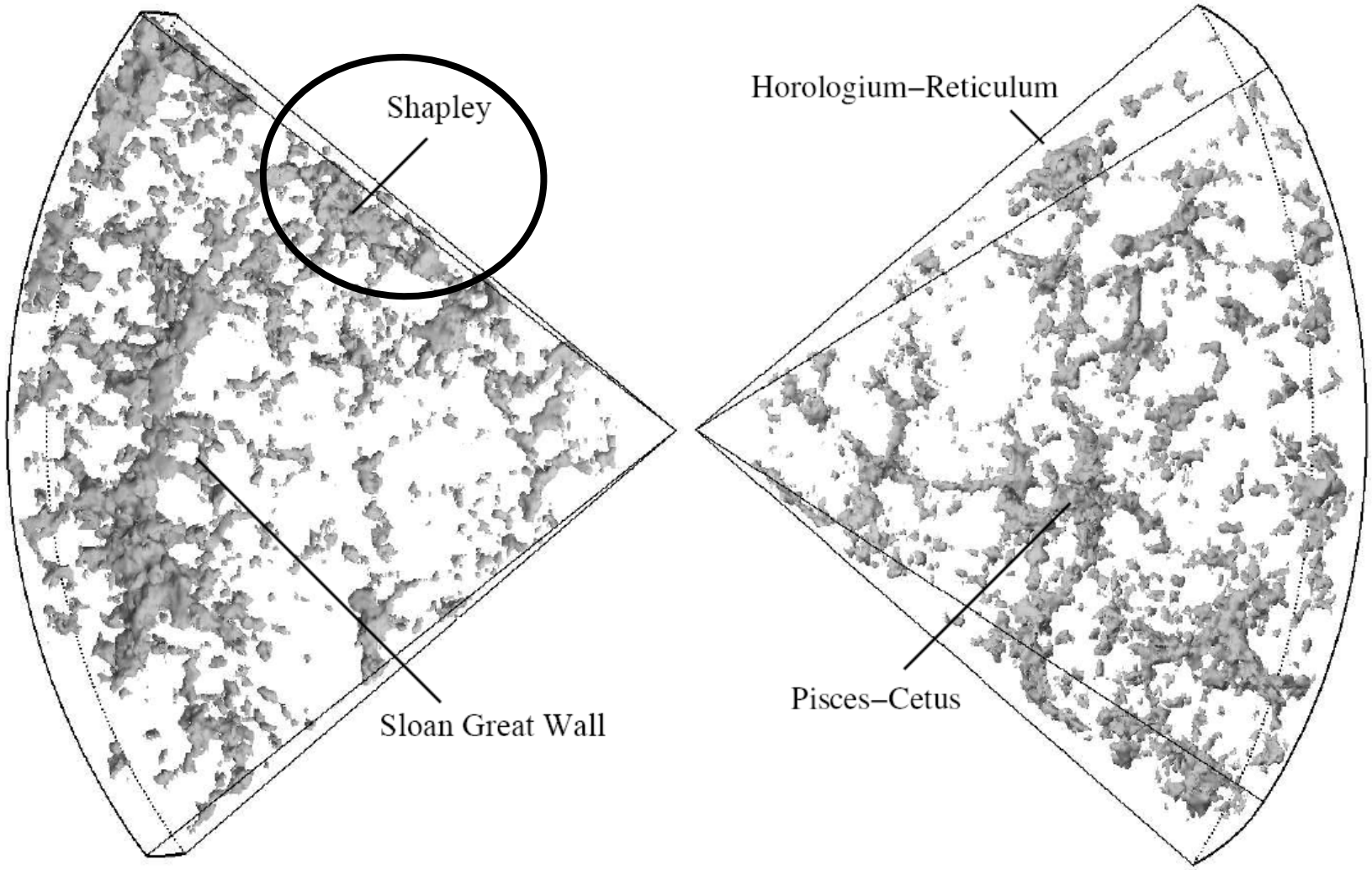


129 SNe
p = 0.014

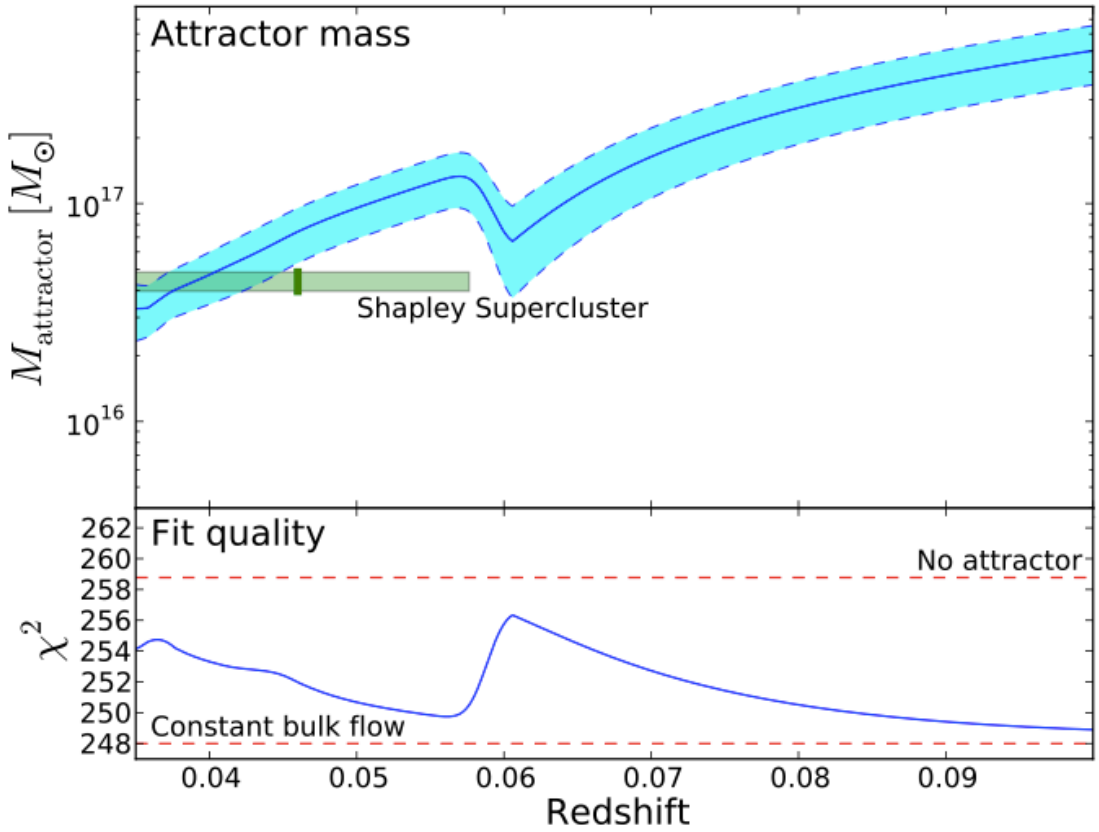
Bulk flow:
231 ± 90 km/s

Feindt et al., SNfactory, A&A, 2013

Identifying the attractors?



Identifying the attractors?



Feindt et al. (Snfactory) A&A 2013

Modeling the attractor

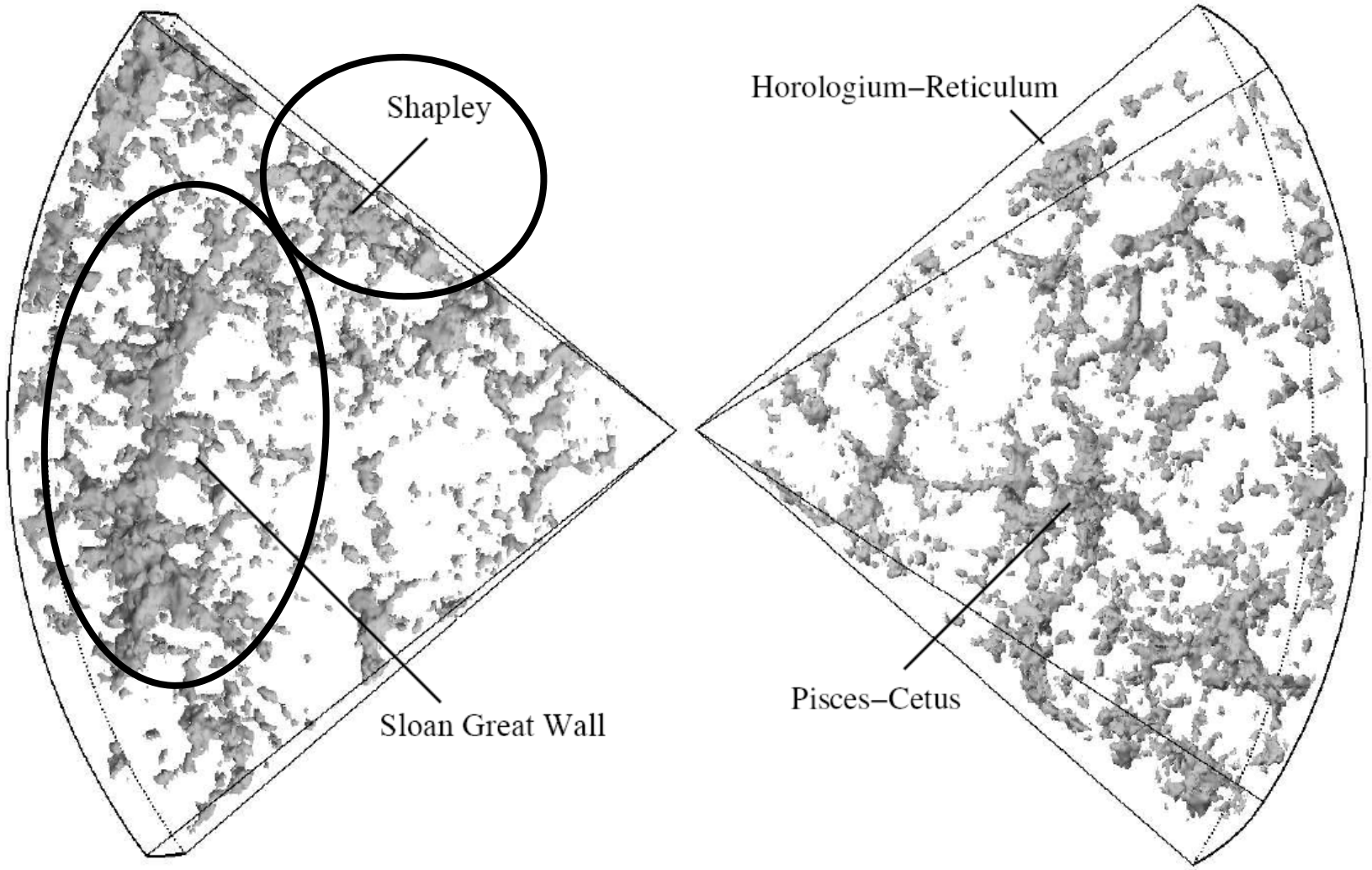
$$M_{\mathrm{attractor}} = \frac{4\pi R^3}{3}\rho_c \Omega_M (1+\delta)$$

$$\vec{v}_p(\delta) = \frac{afH}{4\pi}\int \frac{\vec{y}-\vec{x}}{|\vec{y}-\vec{x}|^3}\delta(\vec{y})\mathrm{d}^3\vec{y}$$

At distance of the SSC required mass is two to three times higher

SSC disfavored at 2σ compared to constant bulk flow independent of mass

Identifying the attractors?



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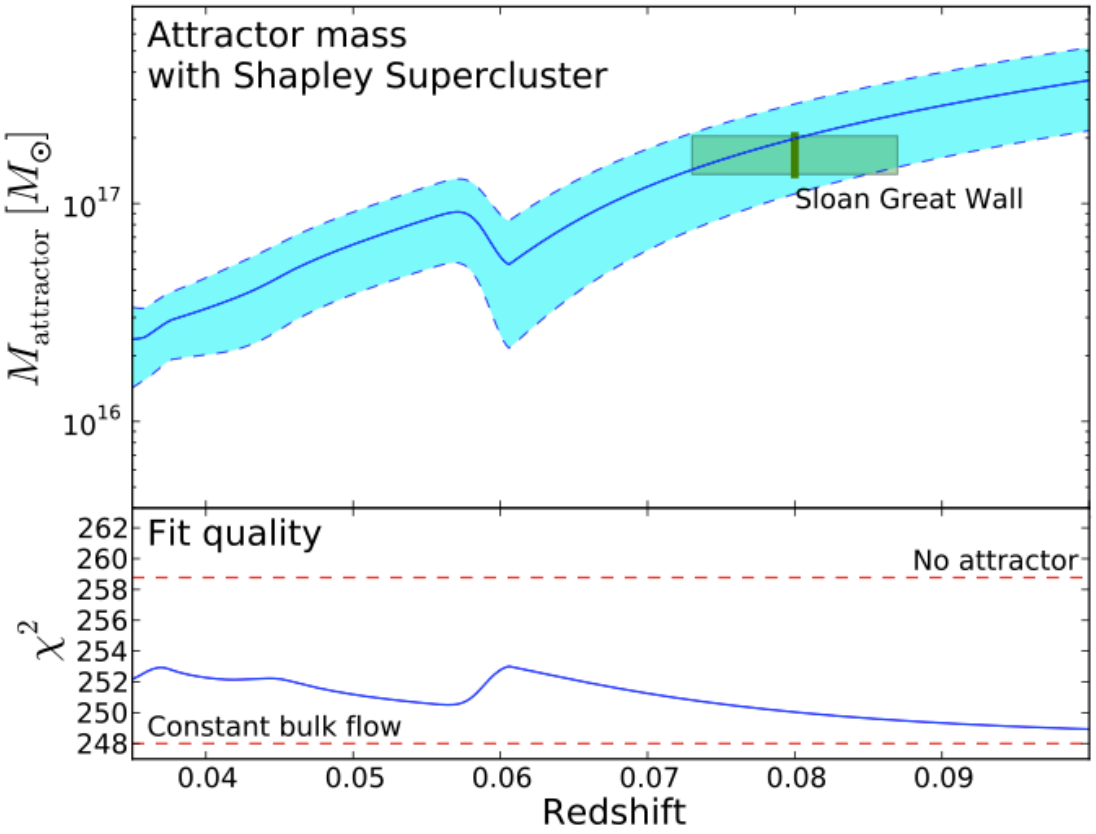

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$$\vec{v}_p(\delta) = \frac{afH}{4\pi}\int \frac{\vec{y}-\vec{x}}{|\vec{y}-\vec{x}|^3}\delta(\vec{y})\mathrm{d}^3\vec{y}$$

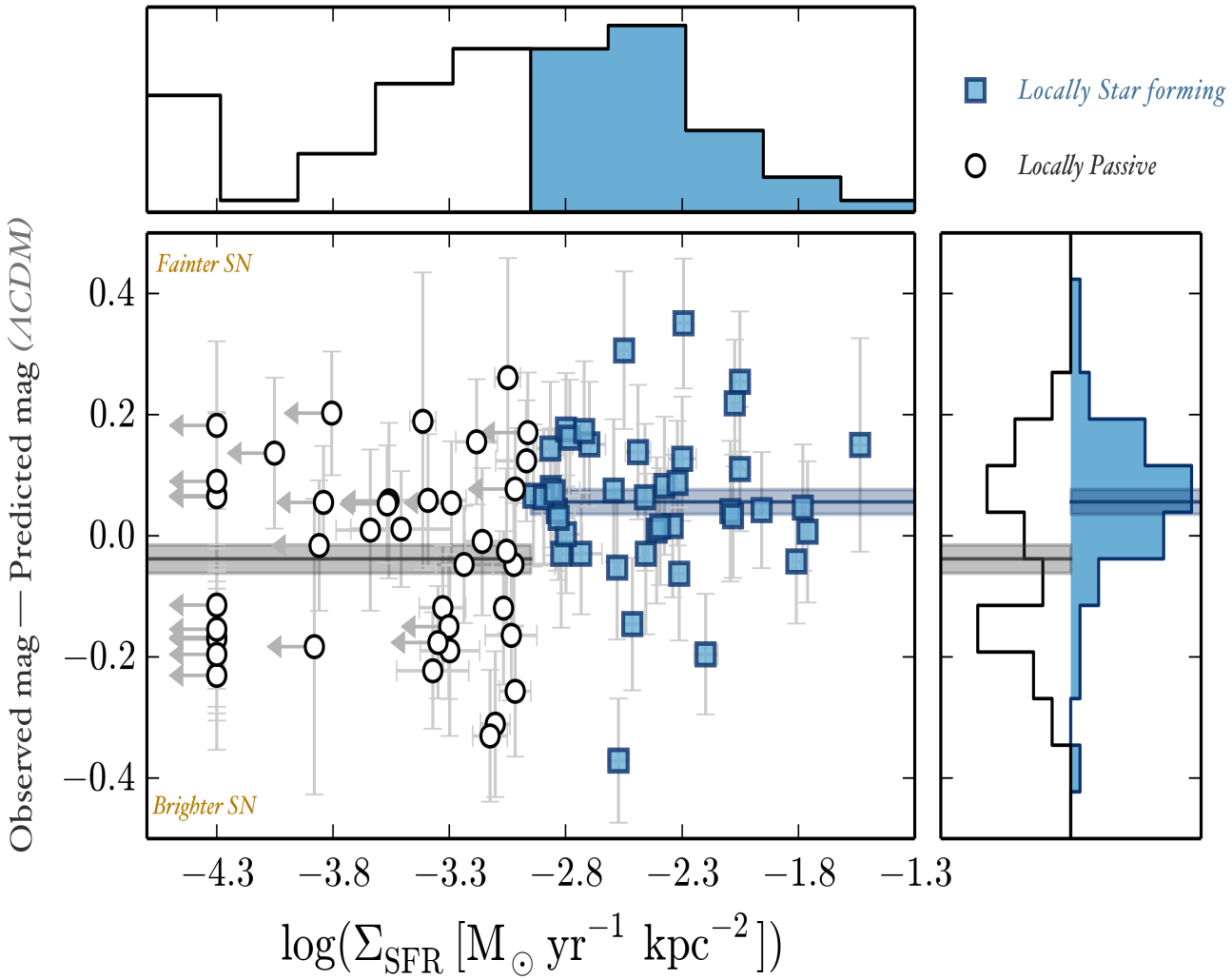
Sloan Great Wall + SSC provides sufficient mass!

Impact on Hubble constant due additional masses < 1%

Feindt et al. (SNfactory) A&A 2013

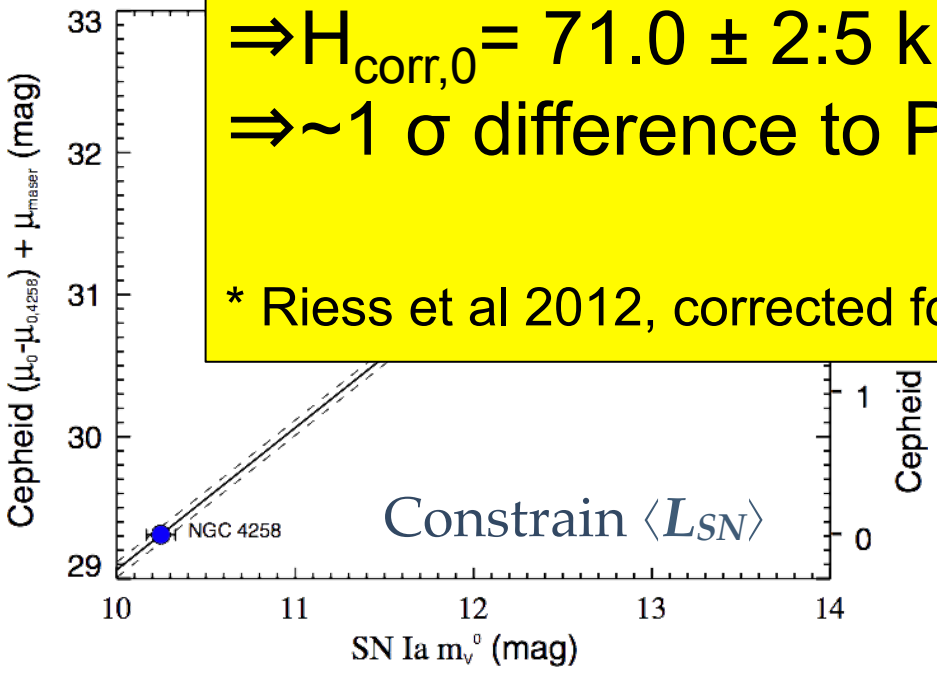
Hubble constant - a bias in the measurement

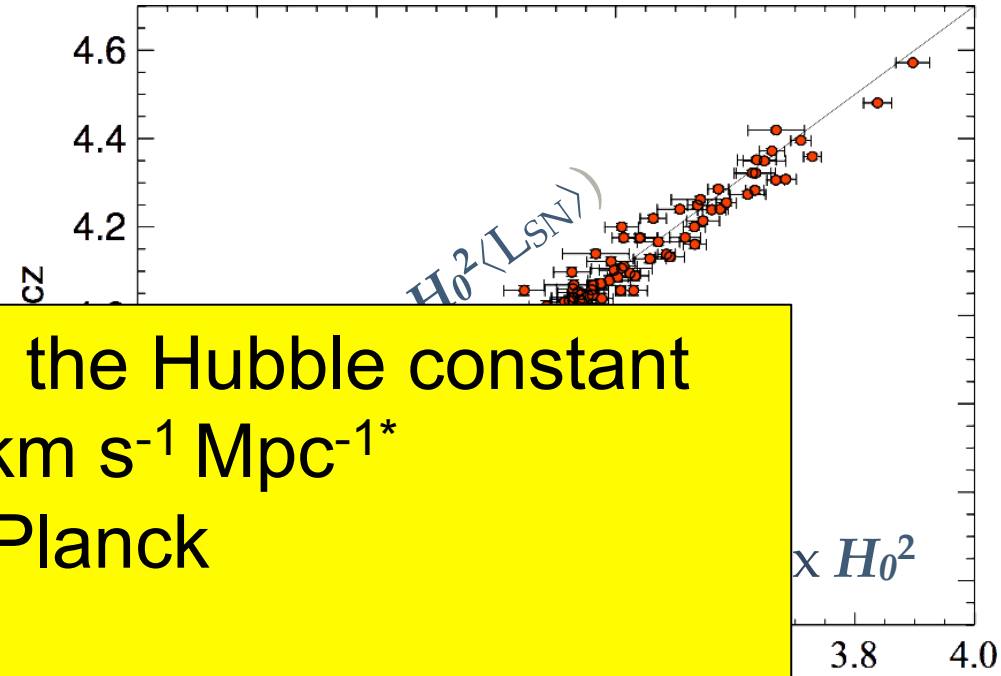
SN Ia brightness depends on the star formation activity in its local environment (Rigault, ApJ 2013)



Hubble constant - a bias in the measurement

Cepheid-SN: ~100% Star forming



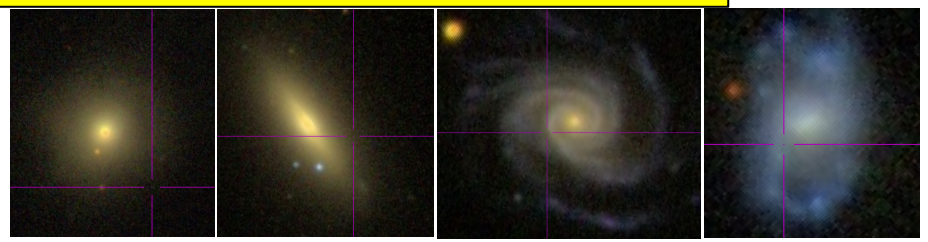


⇒(2.8 ±0.4)% bias in the Hubble constant

⇒$H_{corr,0}$= 71.0 ± 2:5 km s^{-1} Mpc^{-1}*

⇒~1 σ difference to Planck

* Riess et al 2012, corrected for bias



Field-SN: ~50% Star forming

Rigault, in prep, 2014

Multi-Messenger

Neutrino Astronomy with IceCube

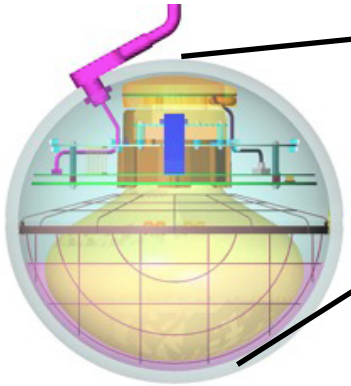
The IceCube Neutrino Observatory

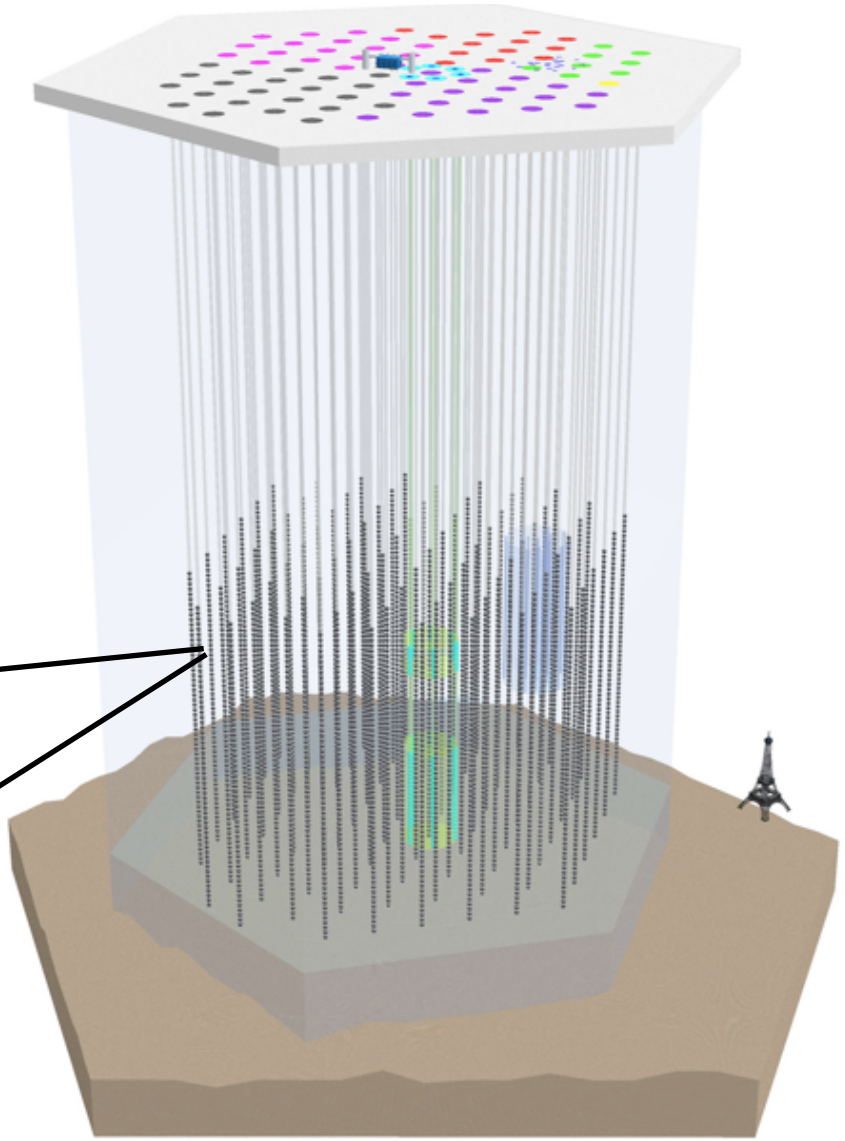
IceCube

- 86 Strings, 5360 DOMs
- $E_{thresh} \sim 100$ GeV

➔ astrophysical neutrinos

digital optical module (DOM)
housing 10 inch PMT



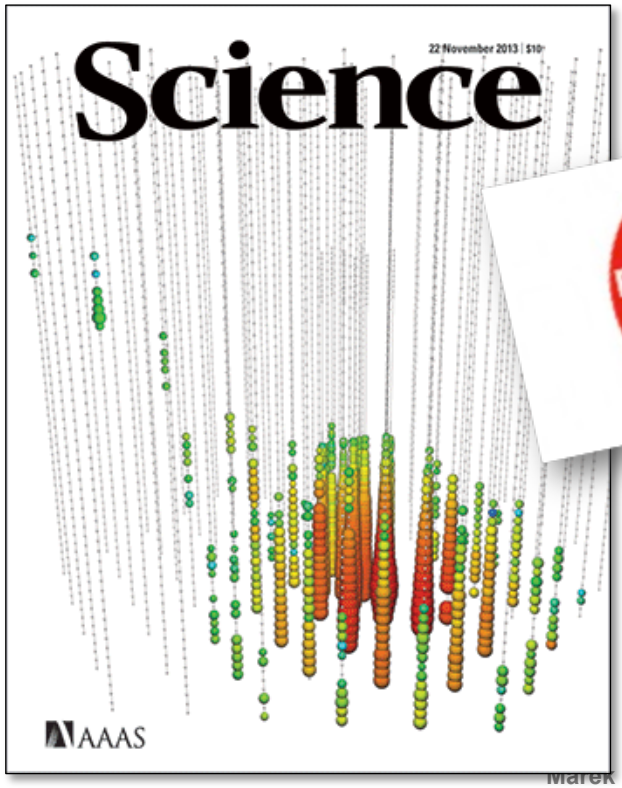


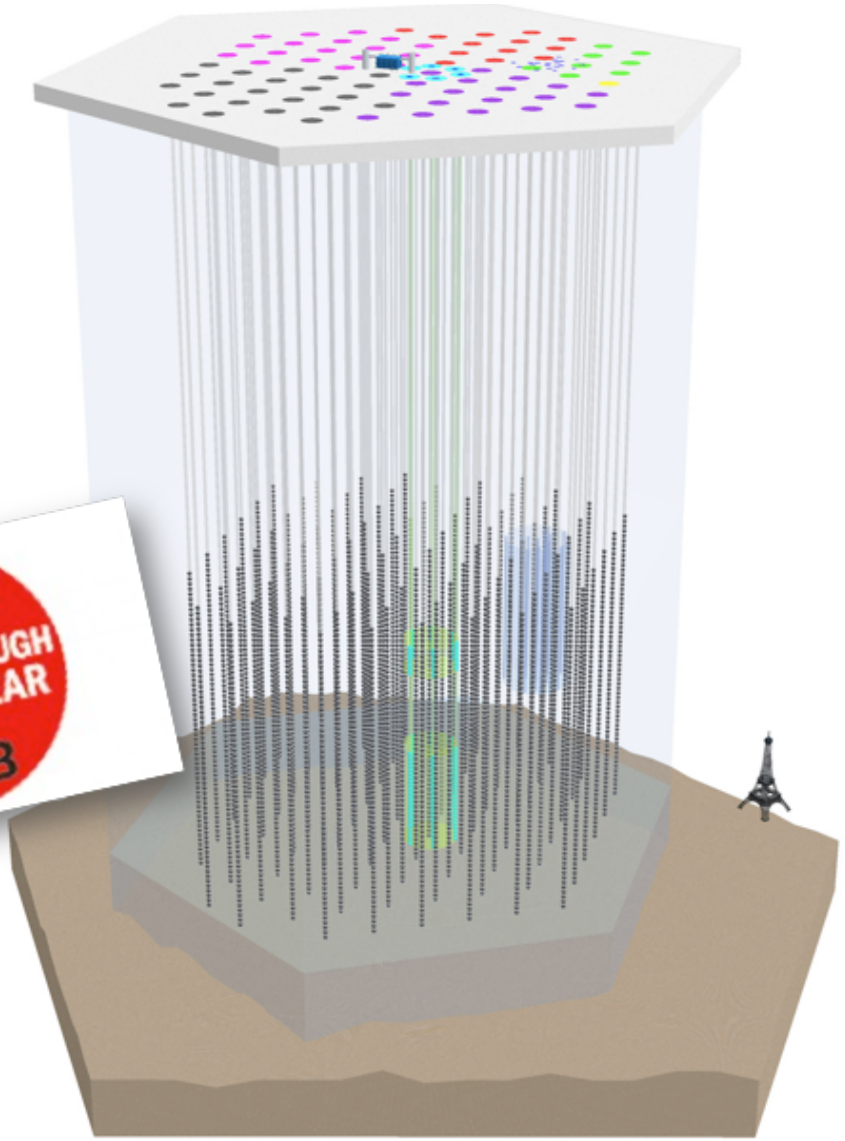
The IceCube Neutrino Observatory

IceCube

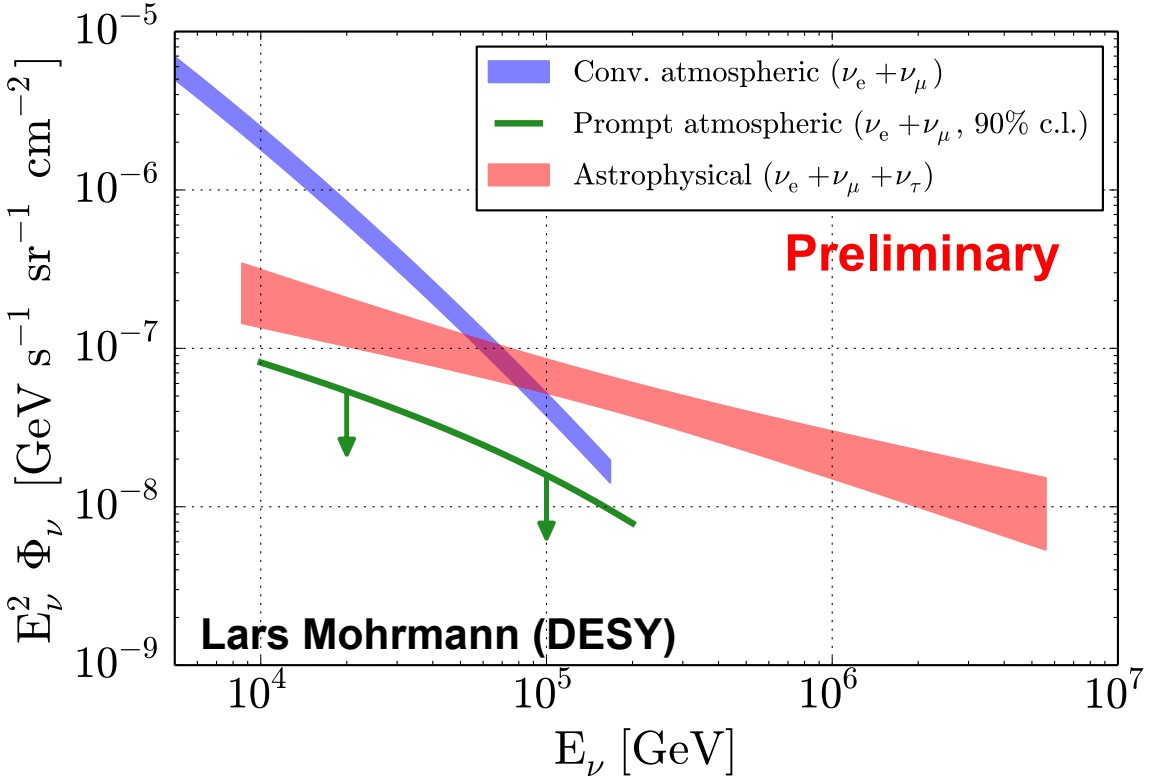
- 86 Strings, 5360 DOMs
- E_{thresh} ~ 100 GeV

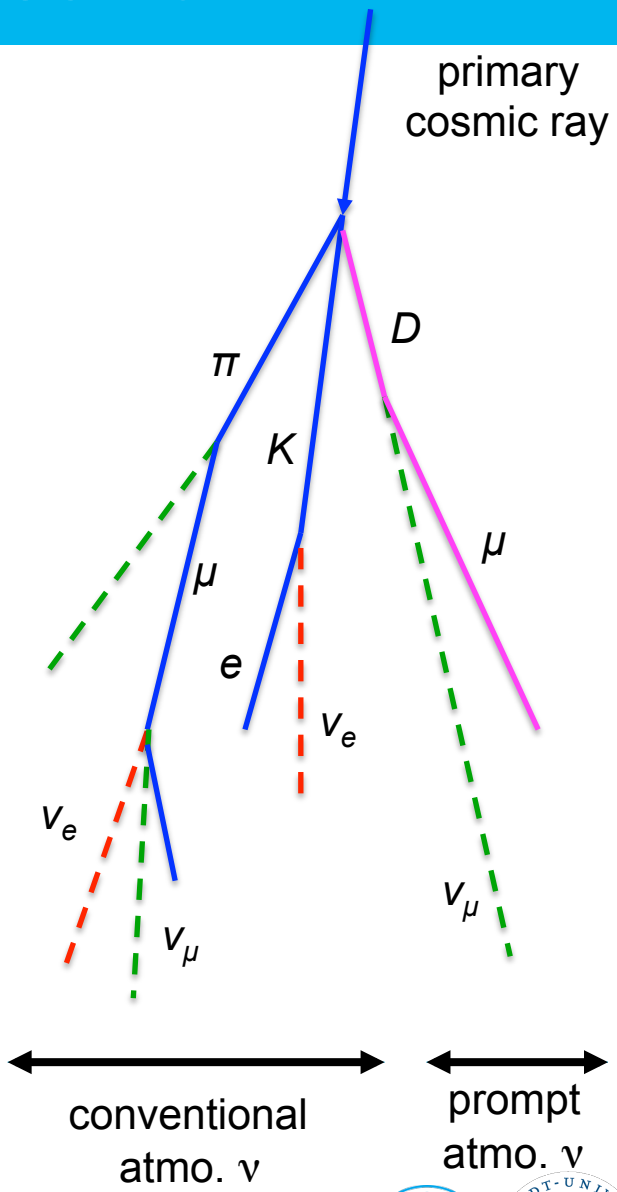
➔ astrophysical neutrinos





Current constraints on the diffuse flux

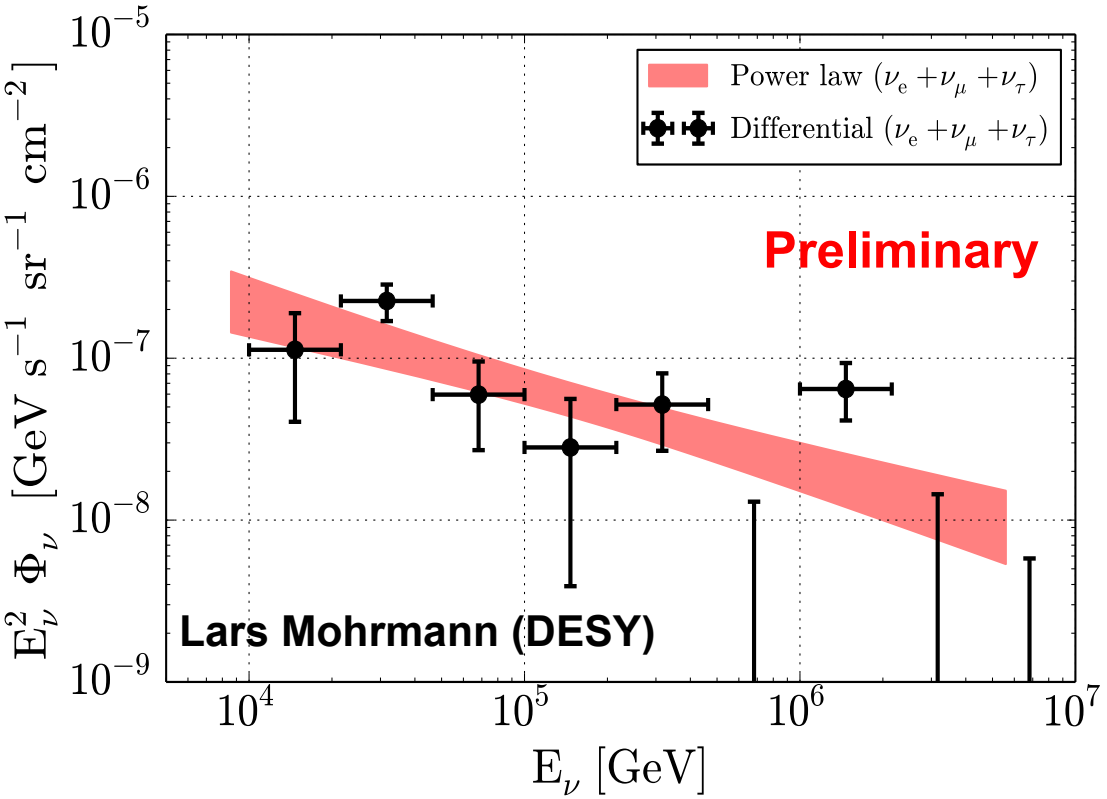


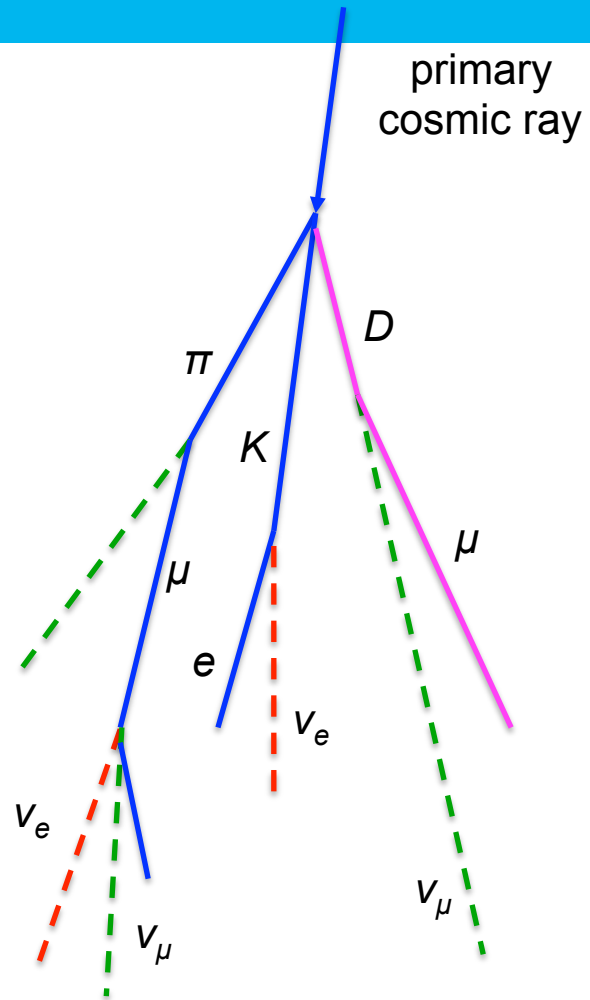


Combined analysis of 6 IceCube data sets

- ϕ = (2.29±0.36) x (E/100 TeV)$^{-\gamma}$ x 10^{-18} GeV^{-1} s^{-1} sr^{-1} cm^{-2} with sprectral index γ=2.50±0.08
- Charmed meson (prompt) component < 1.5 x pCCQ model

Current constraints on the diffuse flux





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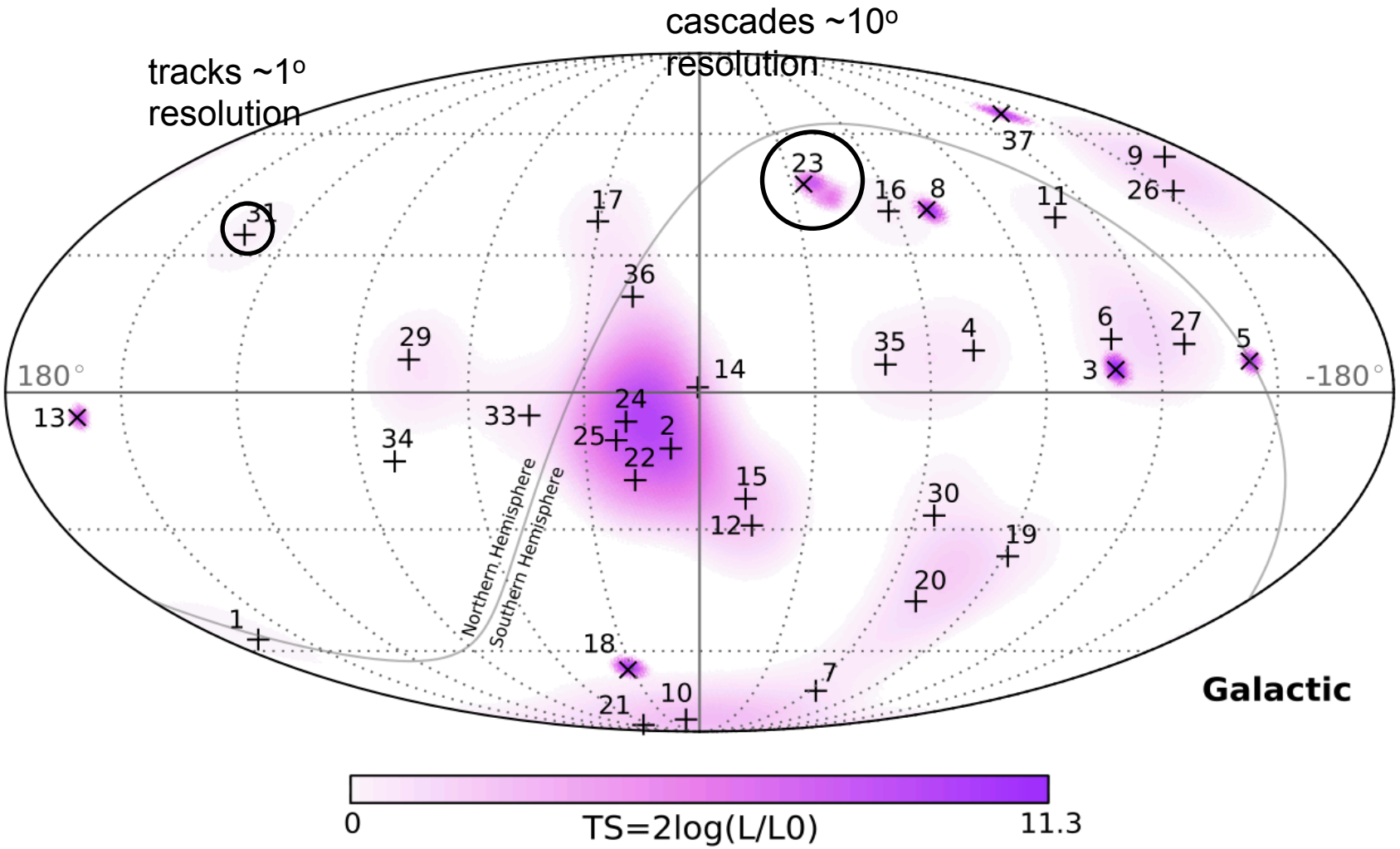
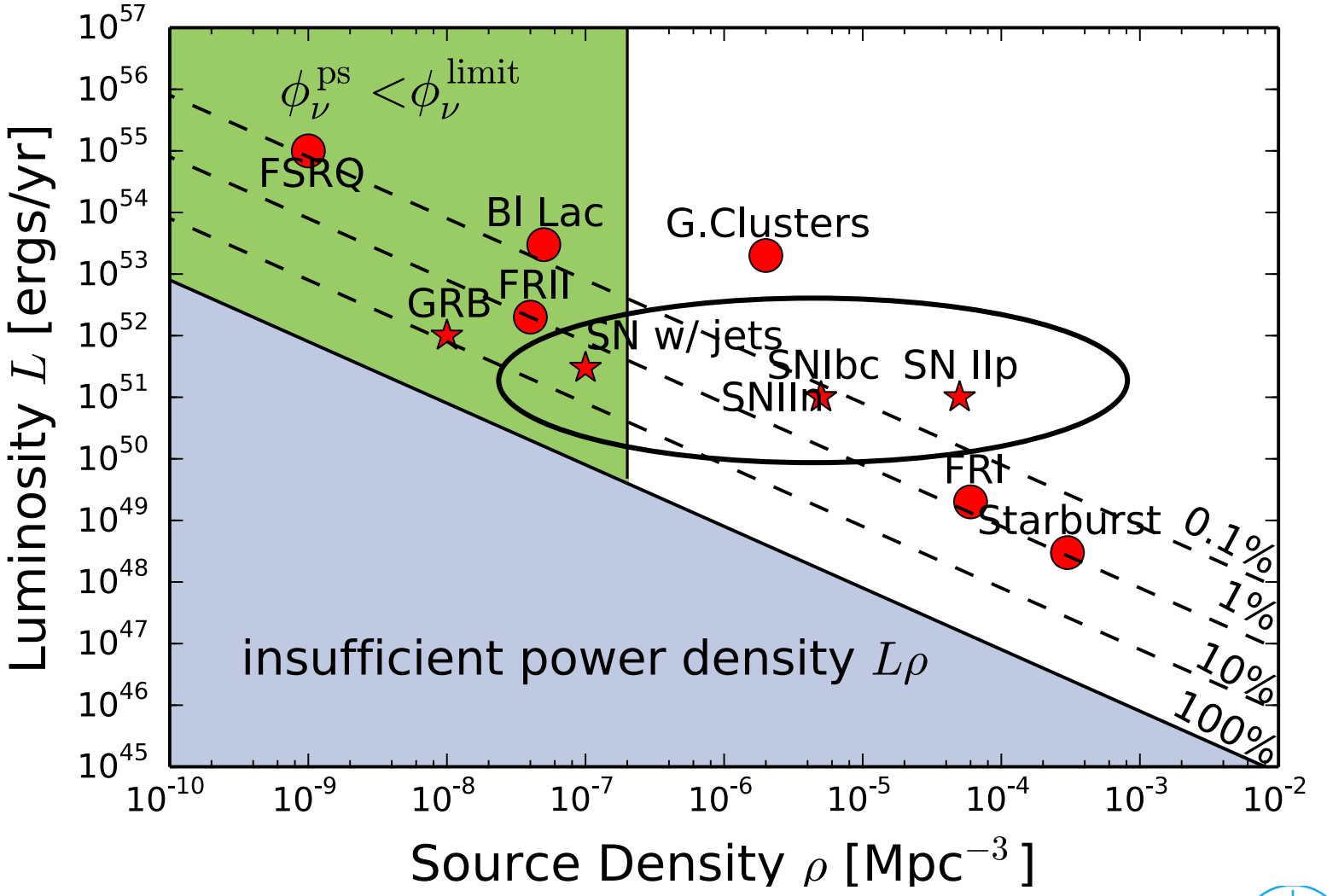
- Charmed meson (prompt) component < 1.5 x pCCQ model

Extragalatic origin!



Possible sources of the diffuse flux



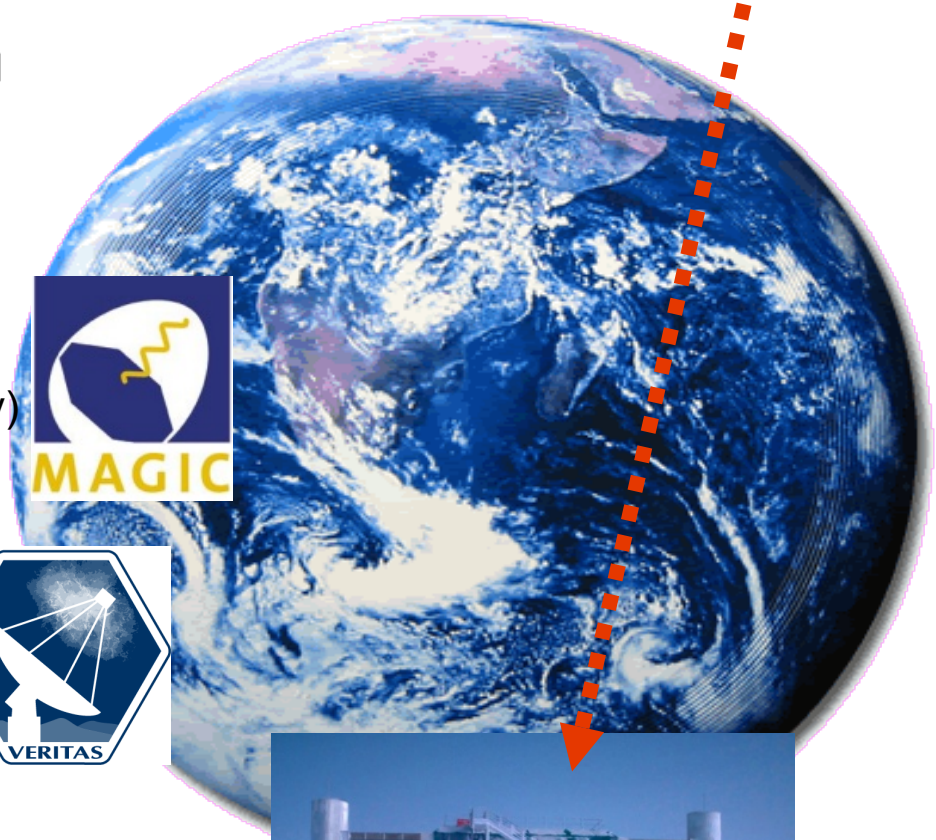
IceCube neutrino follow-up

AGN/SN/GRB

Swift (X-Ray)

PTF (optical)

PALOMAR TRANSIENT FACTORY



MAGIC

(Gamma-Ray)

MAGIC

DESY

VERITAS

(Gamma-Ray)

VERITAS

iridium

IceCube

SOUTH POLE NEUTRINO OBSERVATORY

IceCube online data processing pipeline

Farm for online reconstruction

Latency 2009: 4-8 hours
since 2010: ~5 minutes

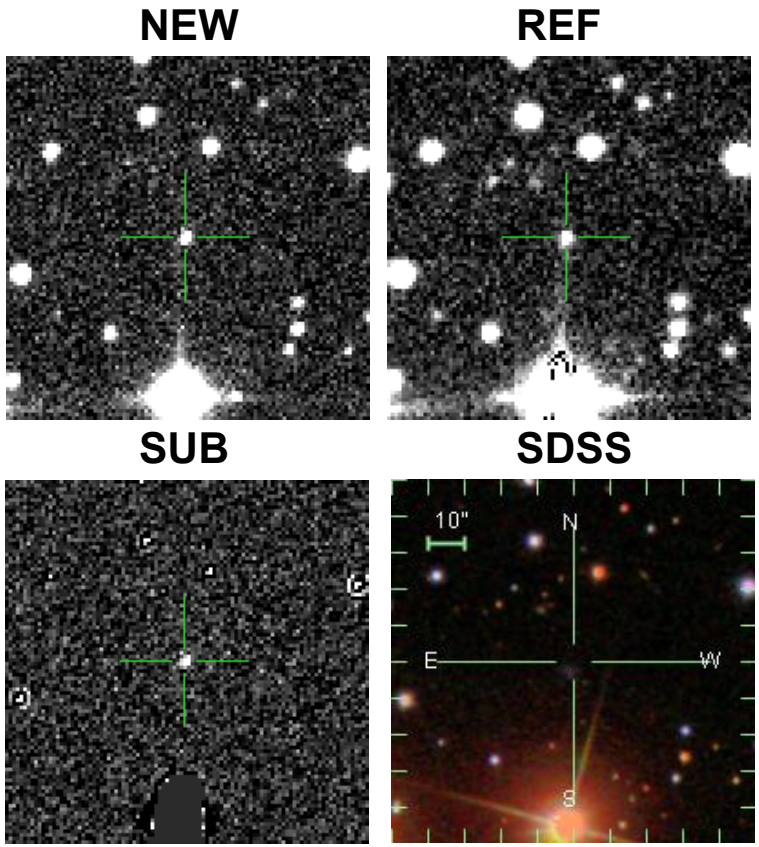
Trigger
2000 Hz

Level 1
30 Hz

Neutrino-
Level
0.002 Hz

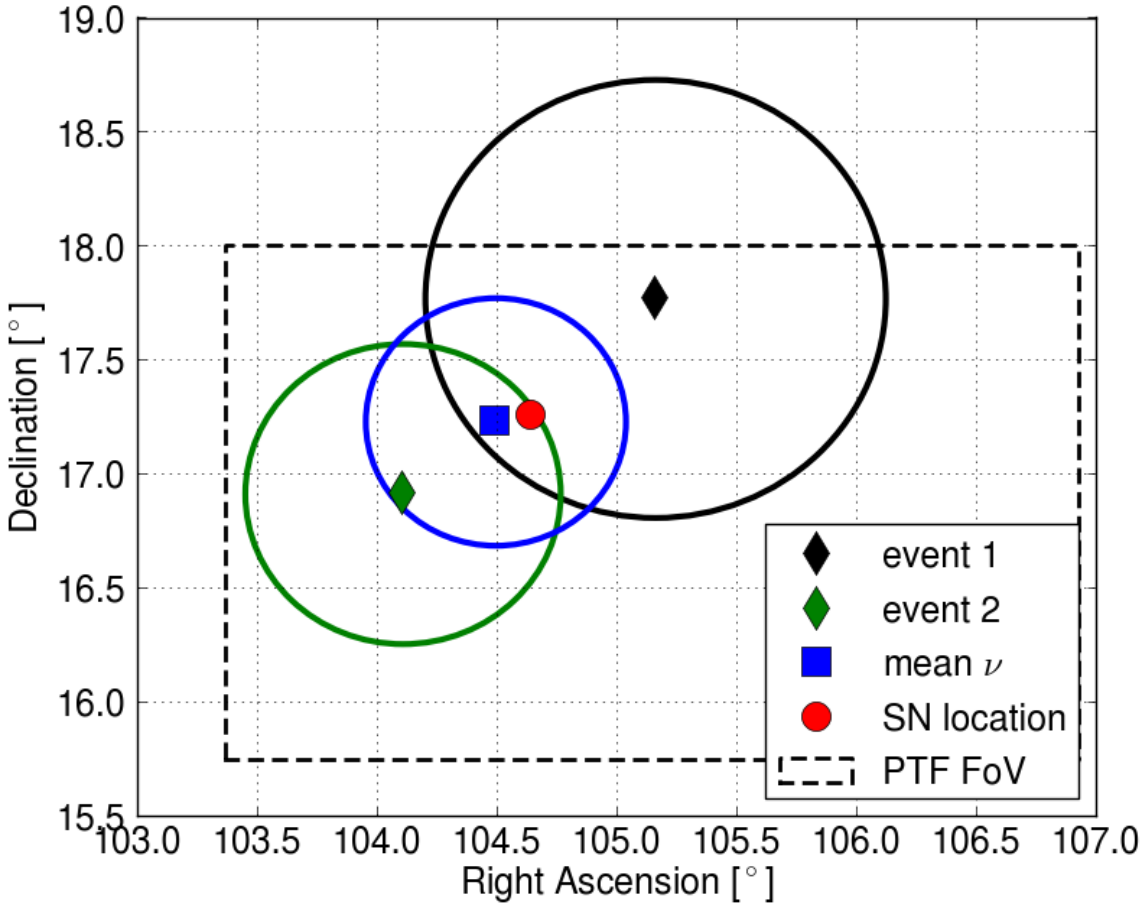
Neutrino-
Multiplets

IceCubes' first SN



PTF12csy

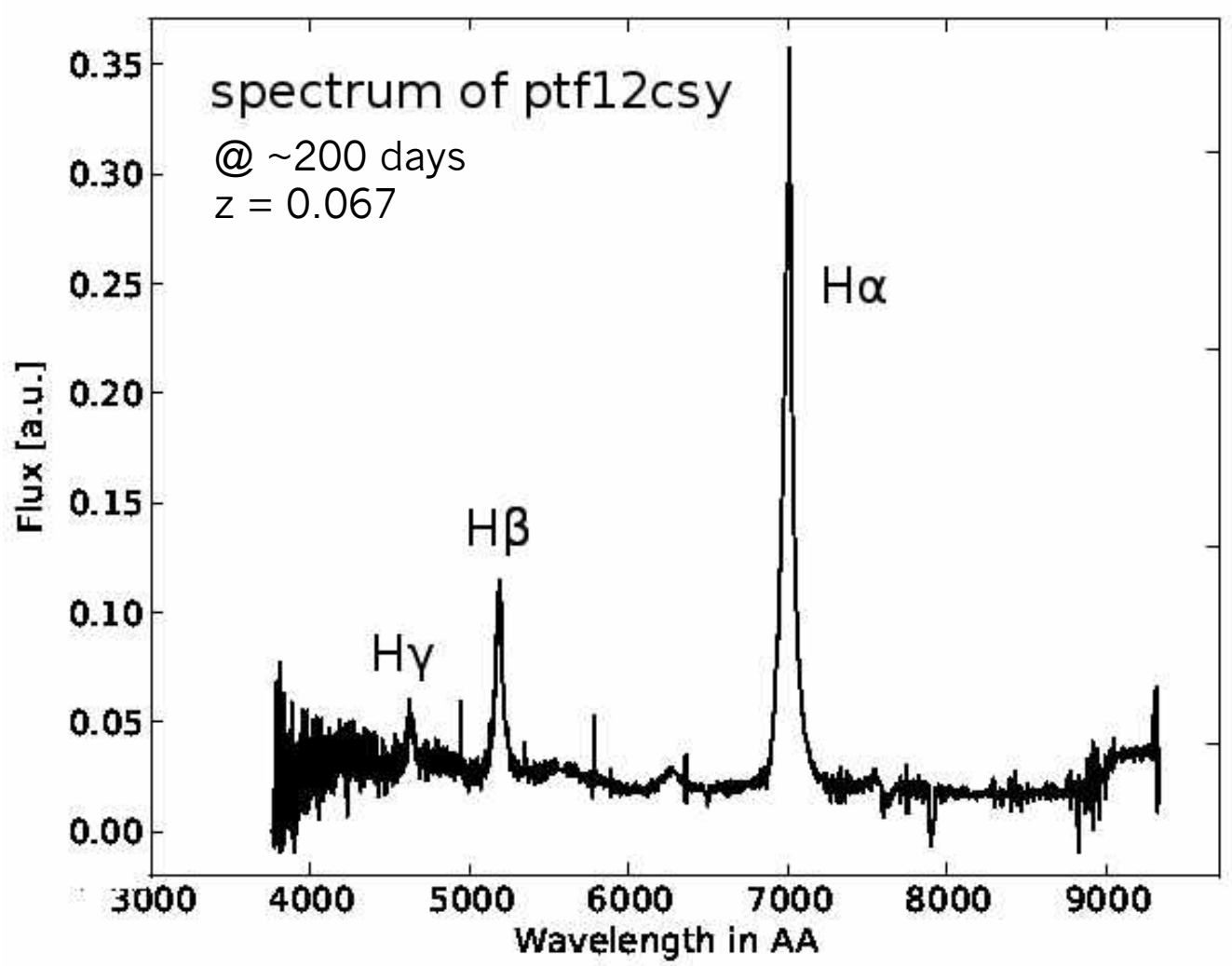
IceCubes' first SN



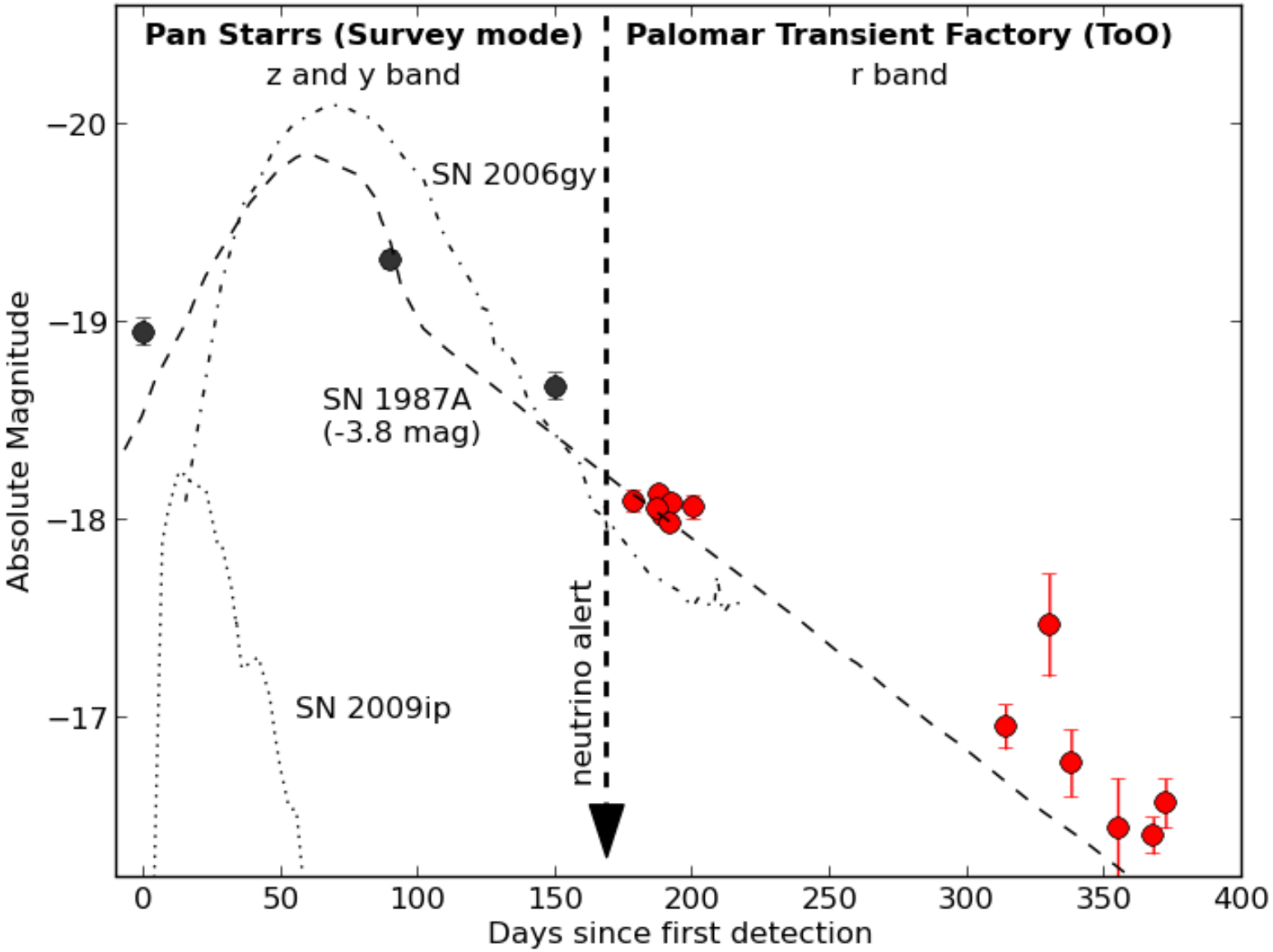
PTF12csy found very close to neutrino direction (0.14°)

IceCubes' first SN

its a Type IIn SN...but it was already old



IceCubes' first SN

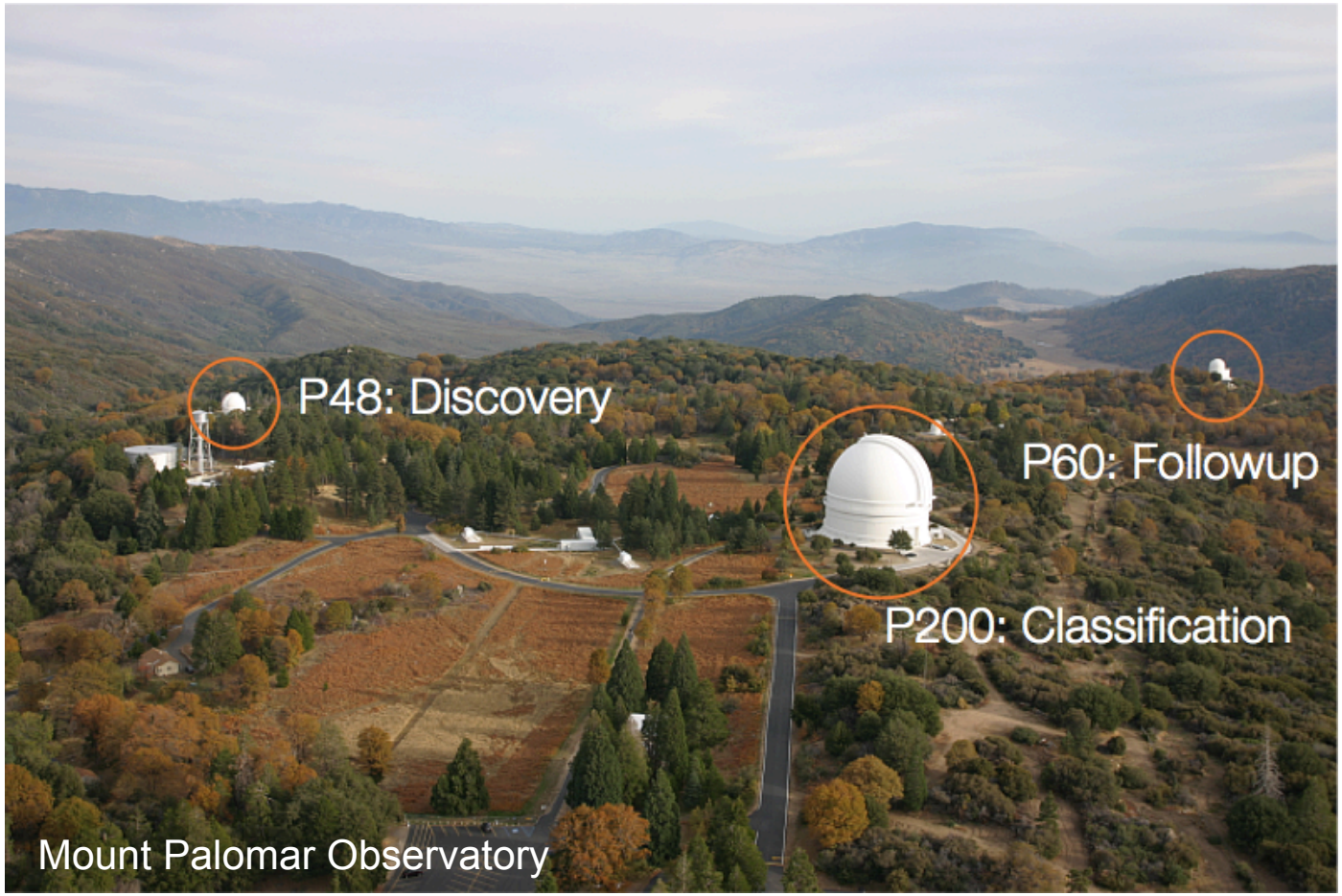


An a-posteriori p-value calculation for PTF12csy

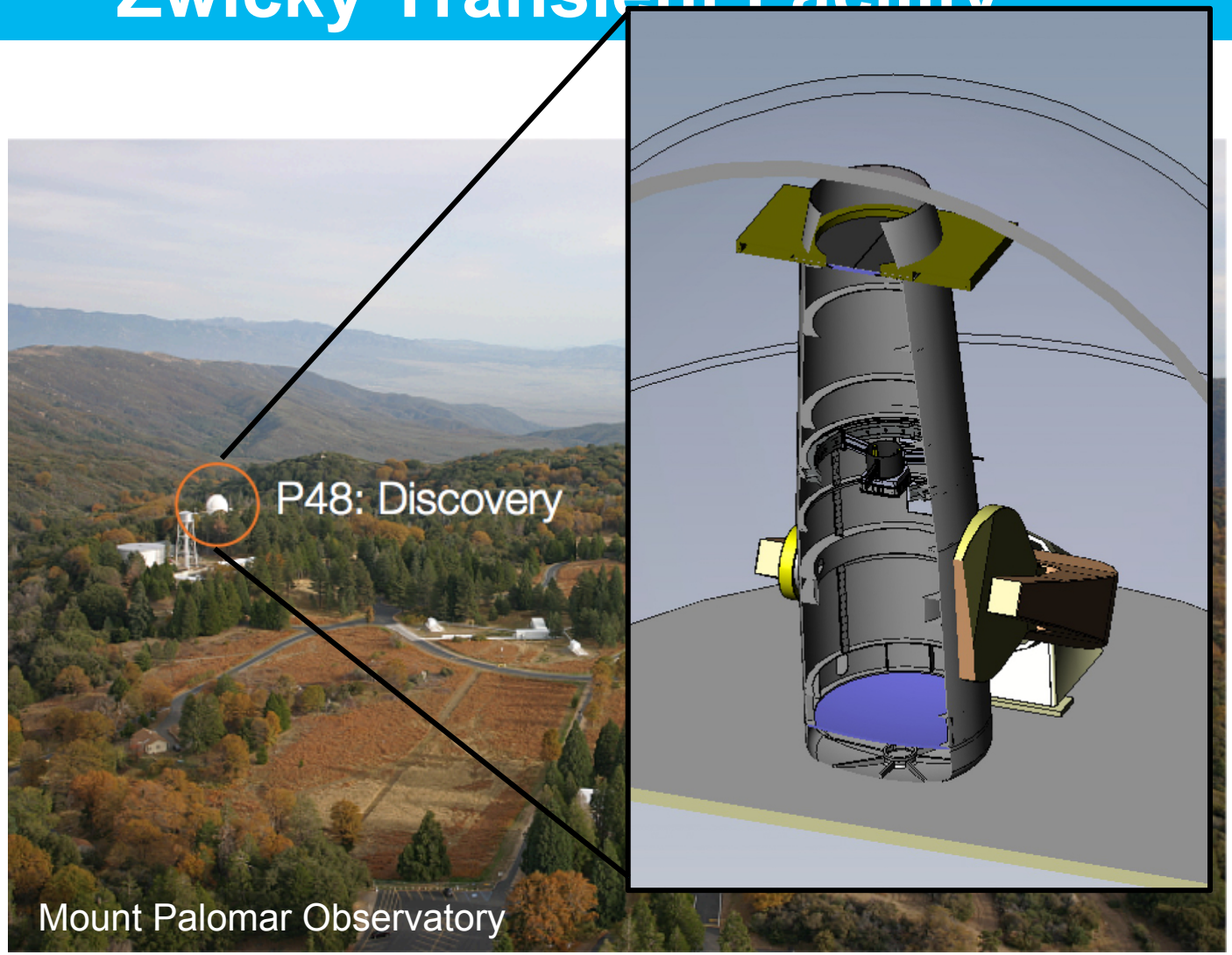
- **P_{alert}:** Probability for an alert with logLlh ≤ –18.1
- **P_{SN}:** Prob. to find any *CCSN* by chance, within error radius of the alert, within 300 Mpc
- **P_{comb}:** Using Fisher's method: Prob. for getting the alert *and* finding the SN in this alert

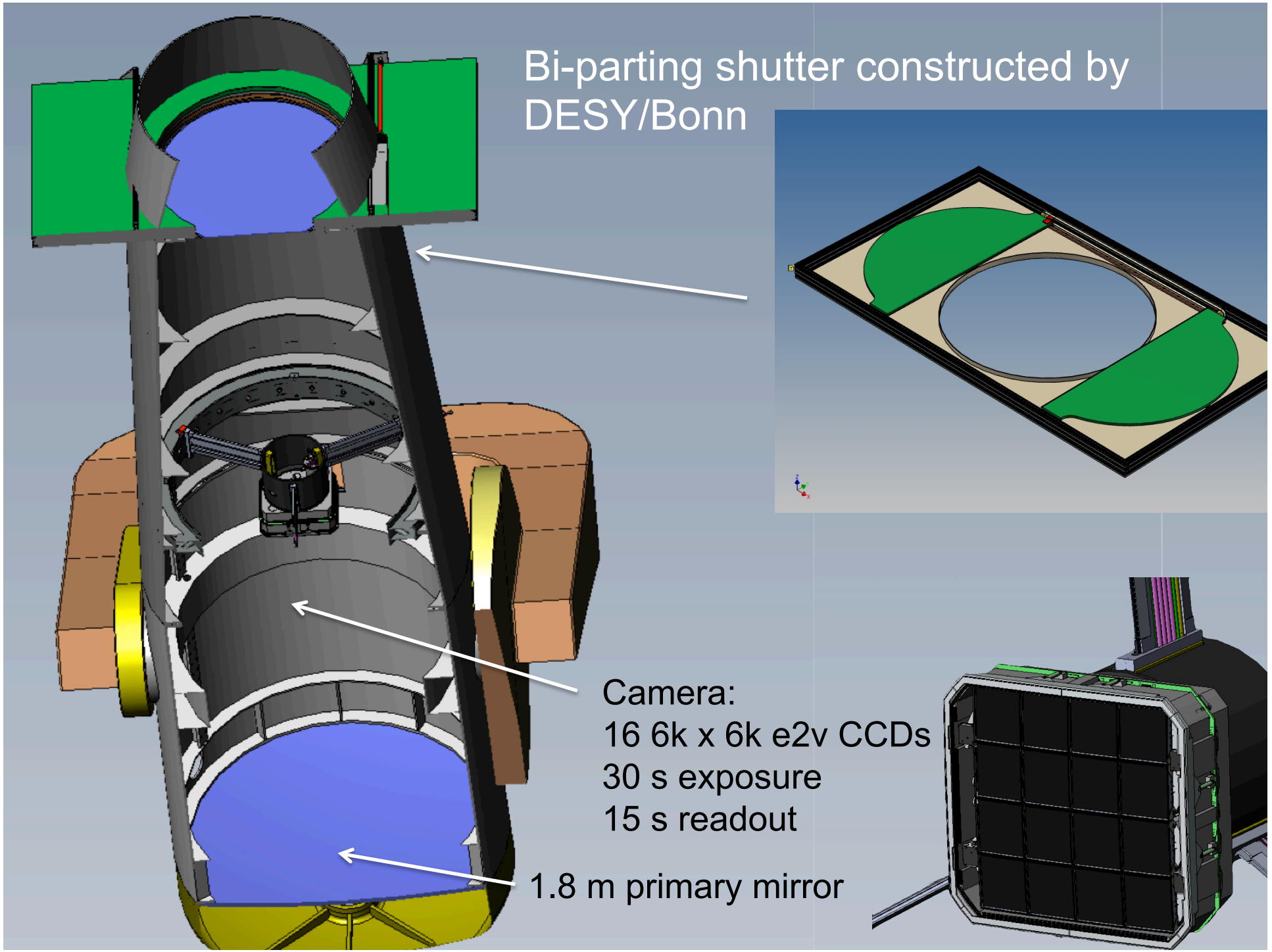
	P_{alert}	P_{SN}	P_{comb}
single year	13.9%	1.6%	**1.6% = 2.4 σ**
3 years	~46%	1.6%	**~4.3% = 2 σ**

Zwicky Transient Facility



Zwicky Transient Facility




Bi-parting shutter constructed by DESY/Bonn
Camera:
16 6k x 6k e2v CCDs
30 s exposure
15 s readout
1.8 m primary mirror

ZTF versus PTF

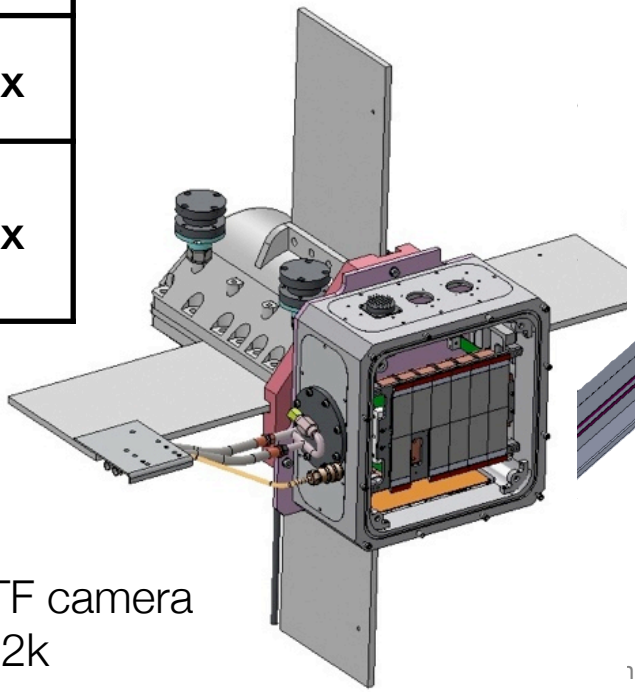
	PTF	ZTF
Active Area	7.26 deg^2	47 deg^2
Overhead Time	46 sec	<15 sec
Optimal Exposure Time	60 sec	30 sec
Relative Areal Survey Rate	1x	**14.7x**
Relative Volumetric Survey Rate	1x	**12.3x**

3750 deg^2/hour

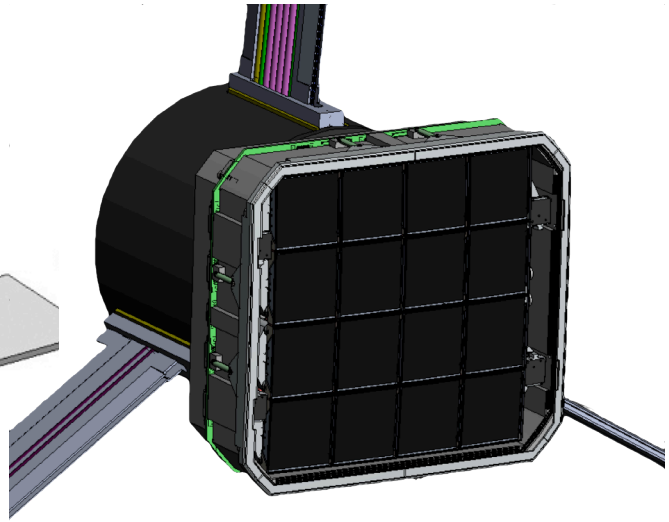
⇒ 3π survey in 8 hours

>250 observations/field/year

for uniform survey



Existing PTF camera
MOSAIC 12k



New ZTF camera:
16 6k x 6k e2v CCDs

ZTF versus other surveys

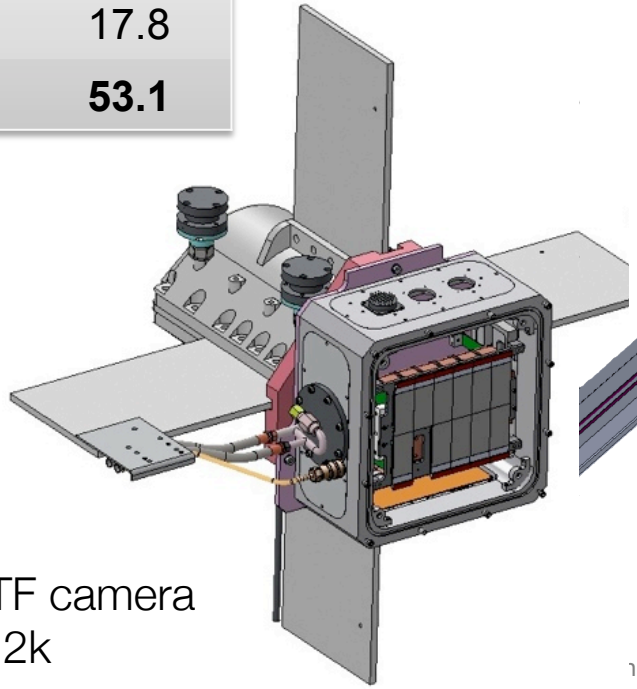
3750 deg²/hour

⇒ 3π survey in 8 hours

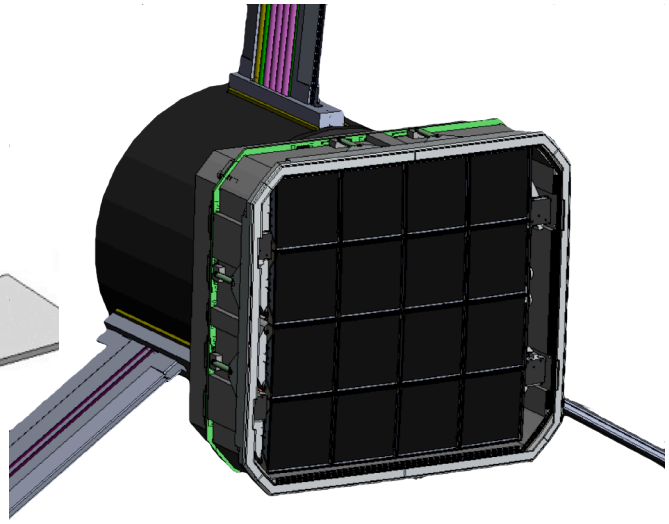
>250 observations/field/year

for uniform survey

Survey Camera	D (m)	Ω_{FoV} (deg²)	Etendue (m²deg²)
PTF	1.2	7.3	8.2
DECam	4.0	7.0	37.7
PS1	1.8	3.0	17.8
ZTF	**1.2**	**47**	**53.1**



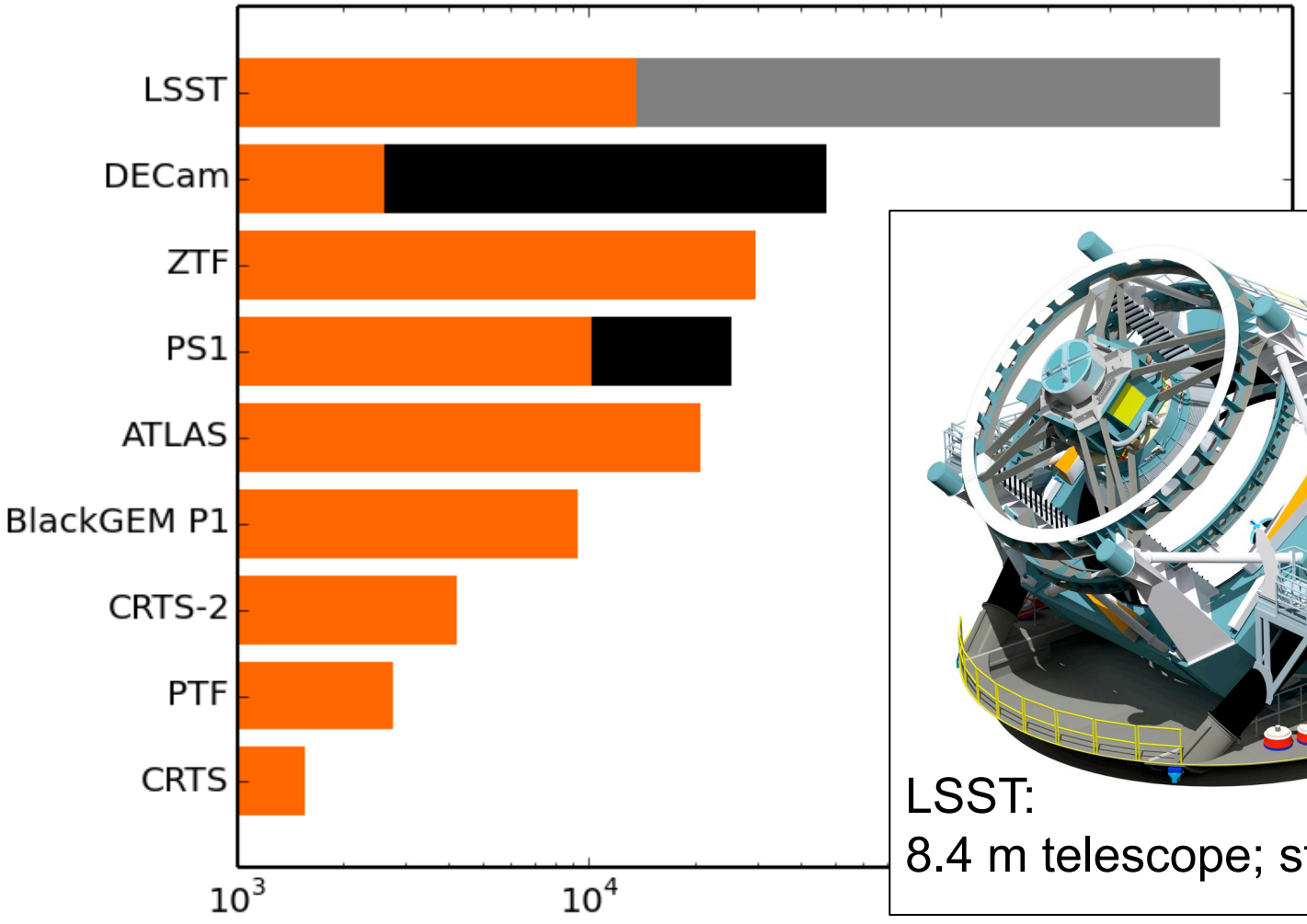
Existing PTF camera
MOSAIC 12k



New ZTF camera:
16 6k x 6k e2v CCDs

ZTF versus other surveys

ZTF will world-leading speed in finding spectroscopically-accessible transients.



LSST:
8.4 m telescope; start ~2022

Summary and Outlook

- Wide-field imagining provides access to transient Universe
- Measure expansion rate & local matter distribution
- Improve hunt for sources of cosmic neutrinos
- ZTF will improve statistics by a factor 10 over currently available data


ZTF is coming in 2017!