Damien TURPIN
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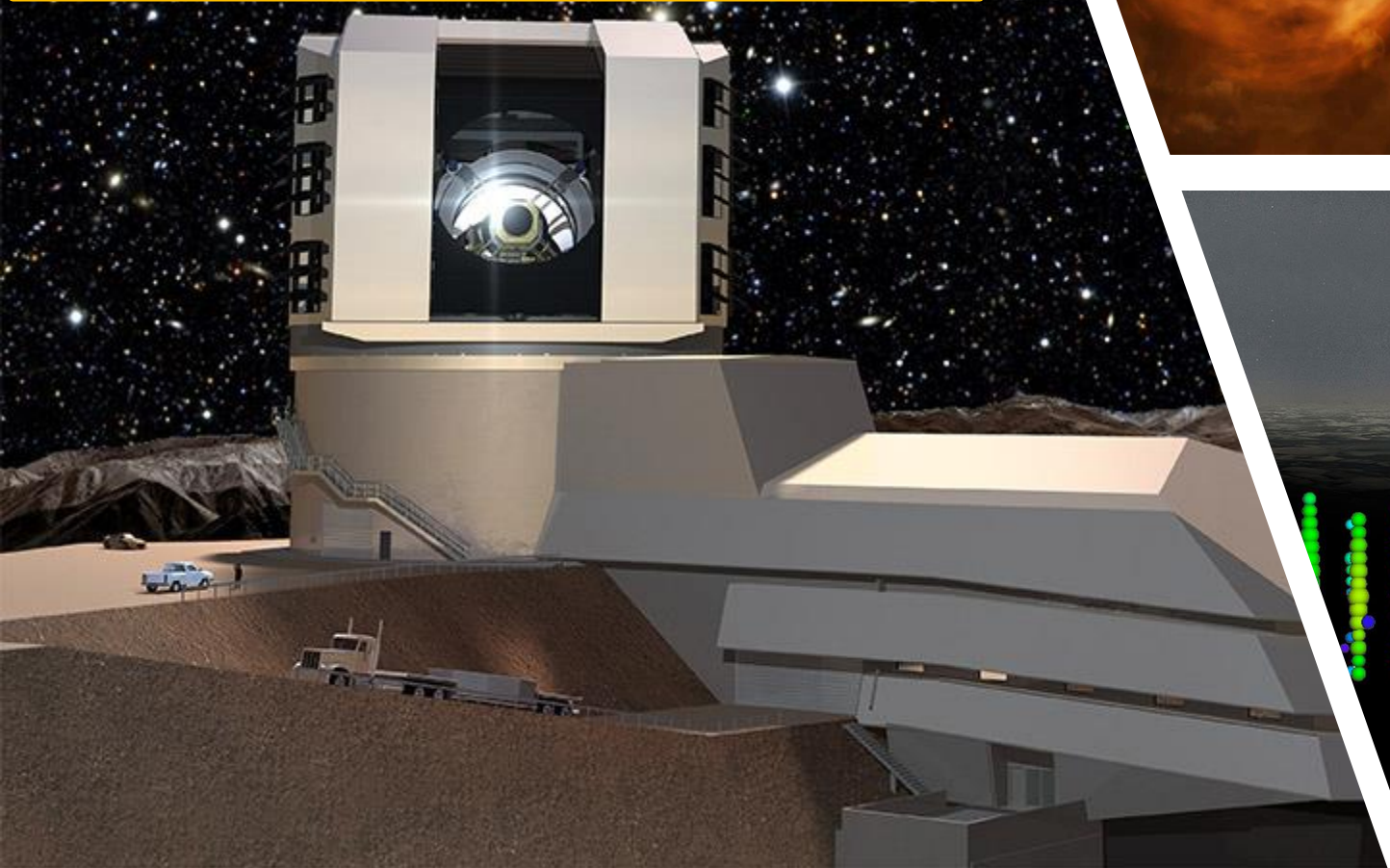
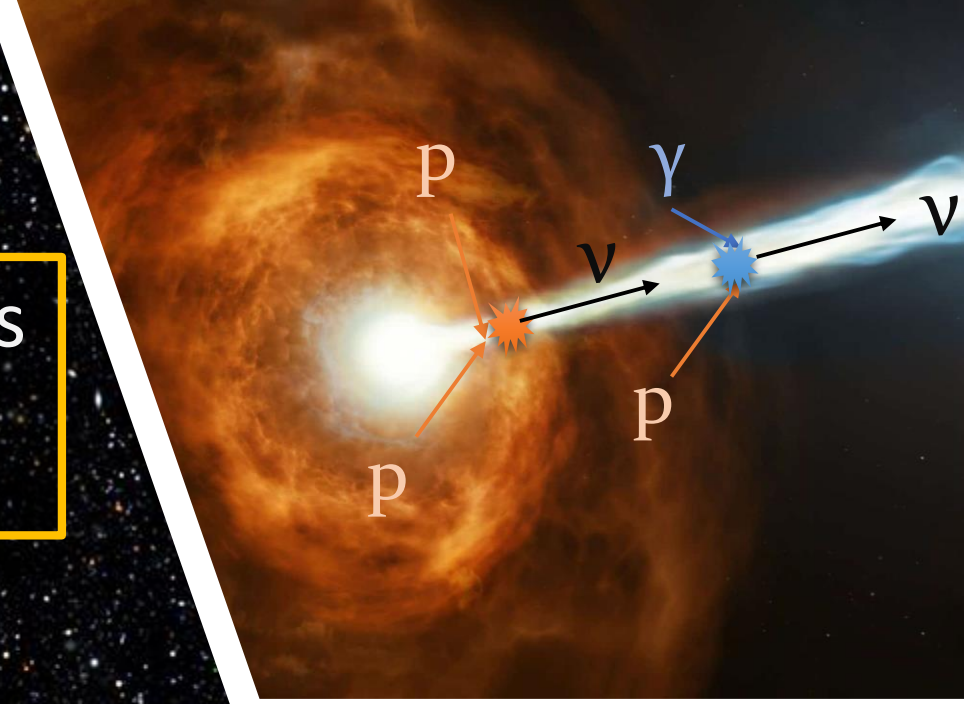
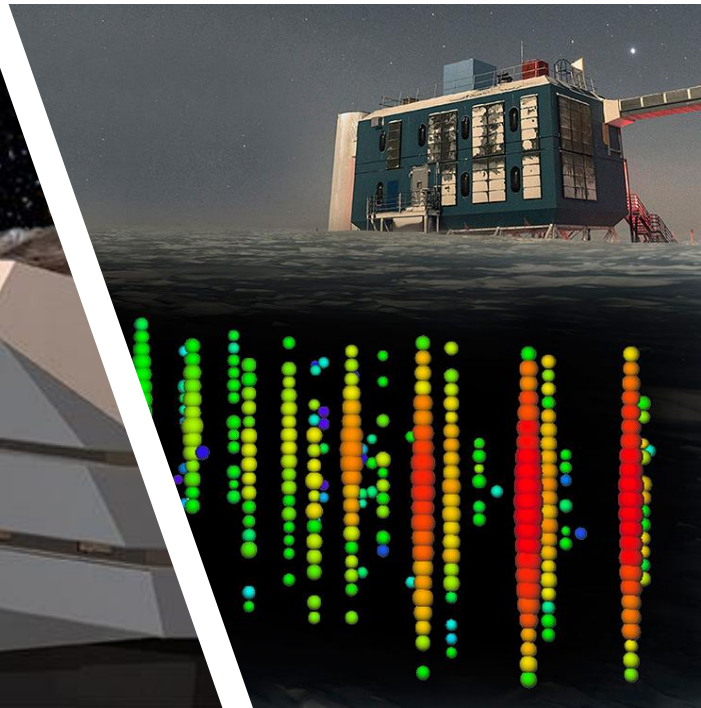
Some slides are from A. Coleiro (APC)

LSST scientific perspectives

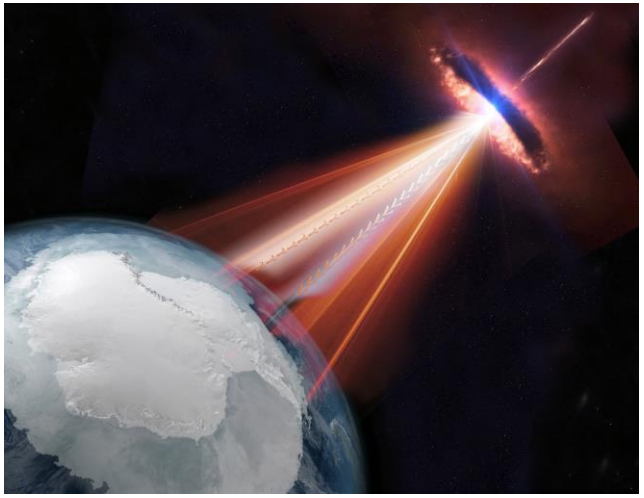
Identification of the high-energy neutrino transient sources

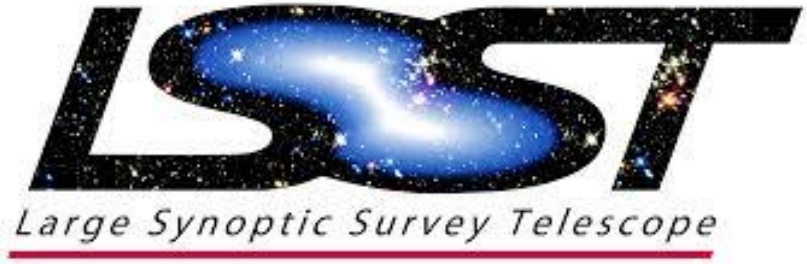






Outlines





I

Scientific objectives and current status of the neutrino astronomy

Probing the astrophysical origin of the UHECR and the high-energy neutrinos

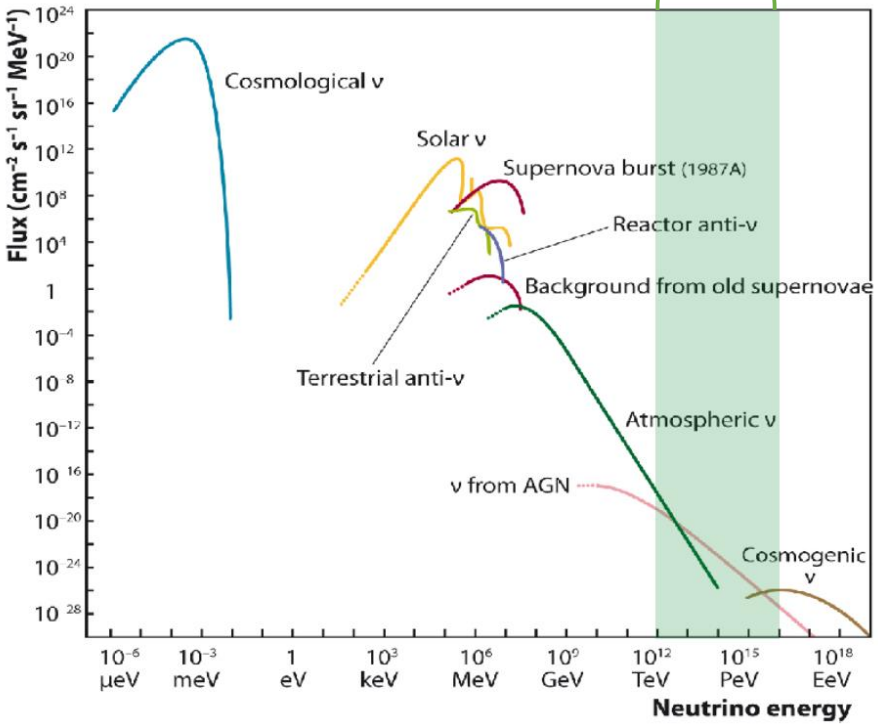
II

LSST synergies with astroparticle physics

How LSST can play a significant role in this multi-messenger quest?

I
Scientific objectives of the neutrino astronomy

Neutrino spectrum

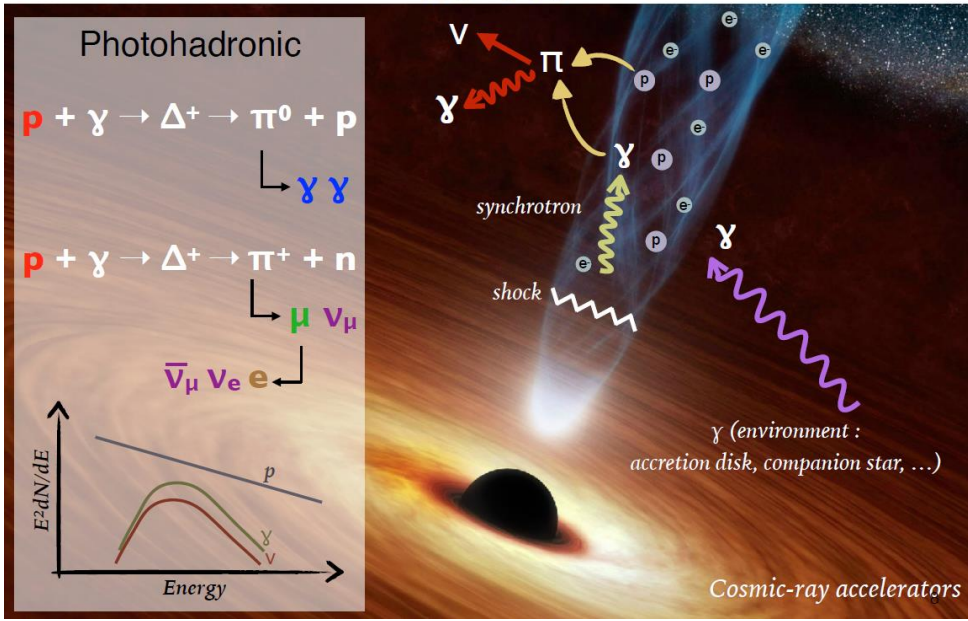


HEN probe the acceleration processes of ultra high energy cosmic rays >EeV energies

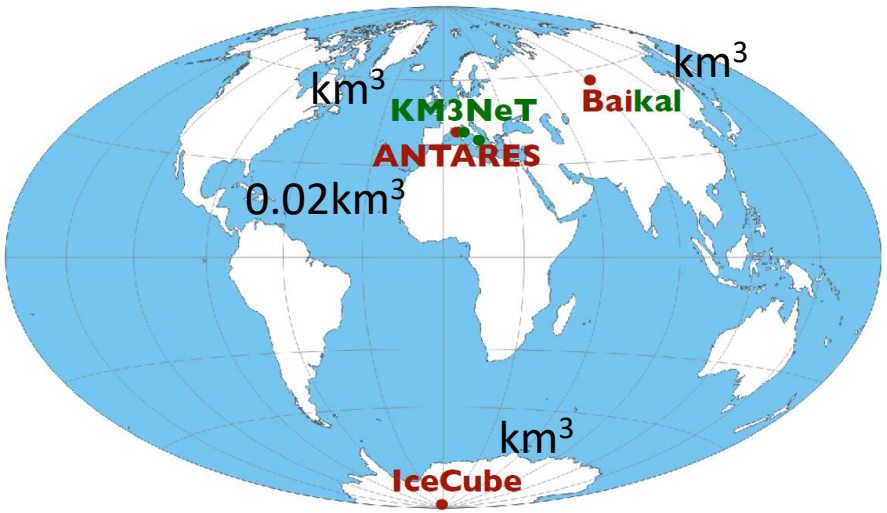
TeV-PeV neutrinos are produced by cosmic accelerators and/or in the viscinity of their environment

Neutrino production

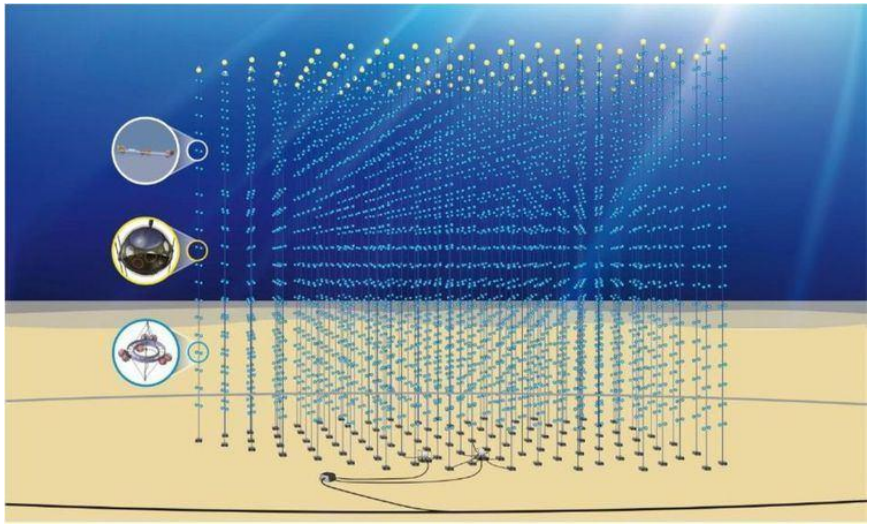
TeV - PeV



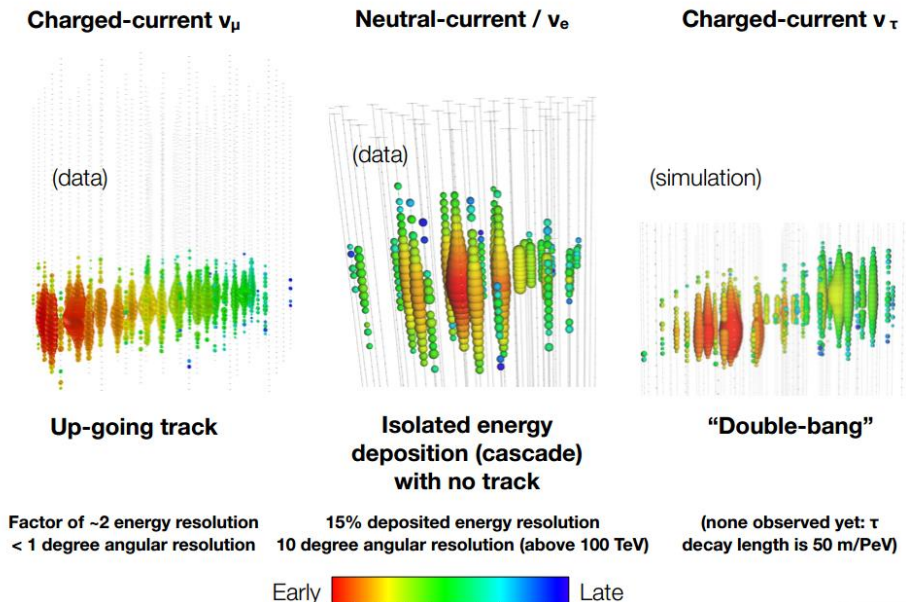
I
Scientific objectives of the neutrino astronomy



Earth distribution of the large-scaled neutrino detectors



KM3Net detector configuration



Depending on the neutrino flavor, you will expect to get different accuracies on the reconstructed neutrino **direction** and **energy**

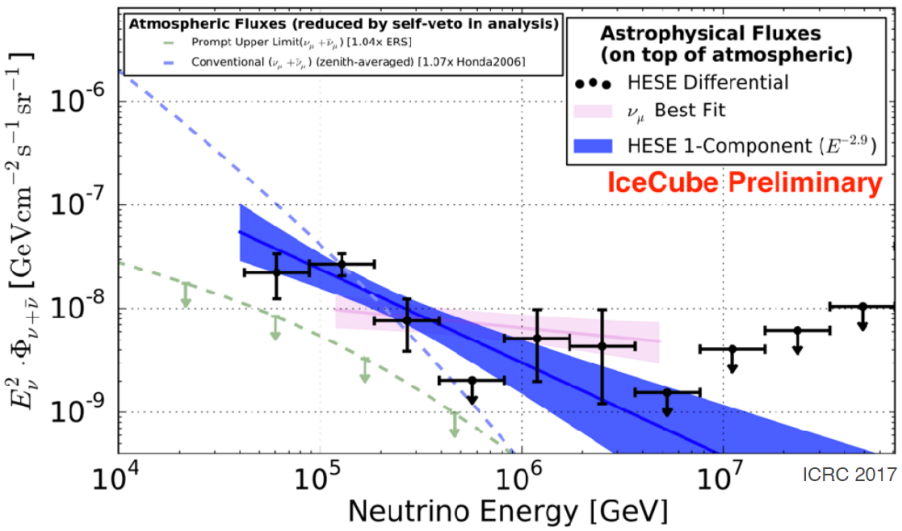
I
Scientific objectives of the neutrino astronomy

A neutrino diffuse flux at TeV-PeV energies

A diffuse flux of astrophysical neutrinos

15

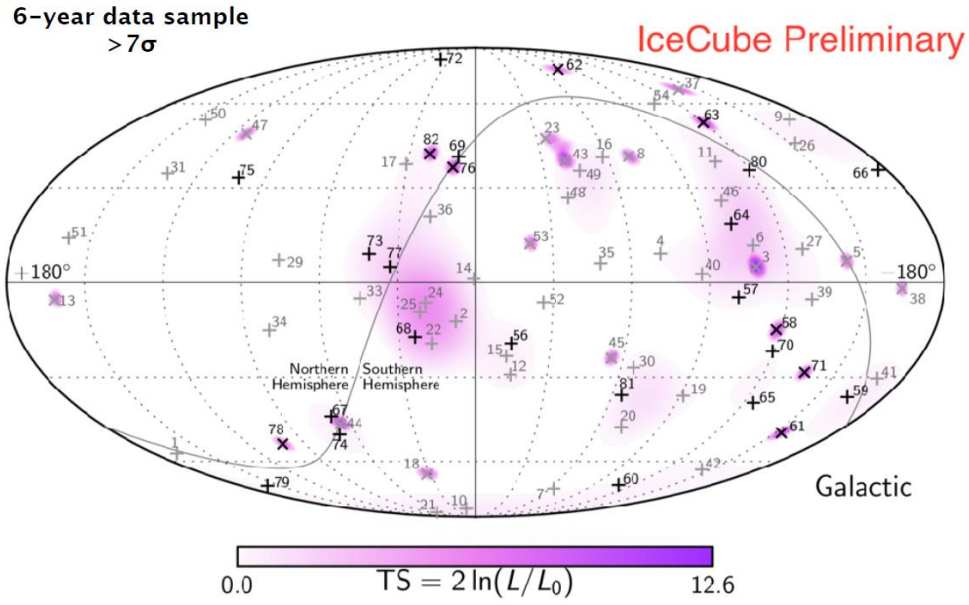
Different samples / different spectra



A collection of cosmological sources are indeed producing TeV-PeV neutrinos across the all sky

A diffuse flux of astrophysical neutrinos

14



IceCube coll., ICRC 2017

Golden question:
Which astrophysical sources ?

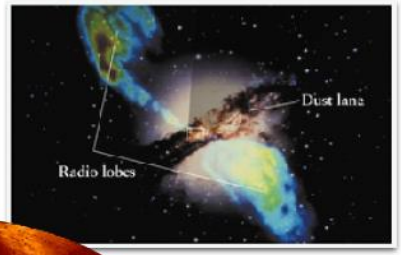
I
Scientific objectives of the neutrino astronomy

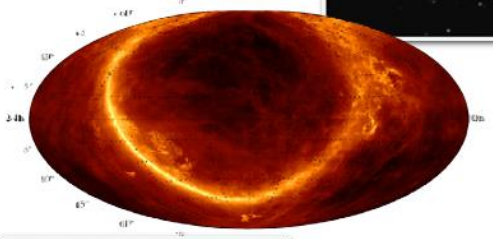
Transient sources !

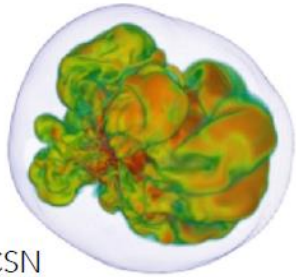
Astrophysical sources

Cosmic-ray reservoirs

- radiogalaxies
- diffuse Galactic emission
- star-forming galaxies
- galaxy clusters

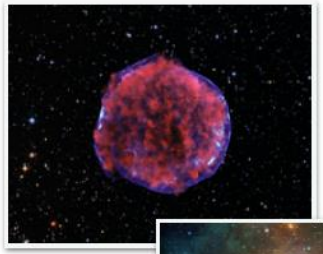






- CCSN

Cosmic-ray accelerators

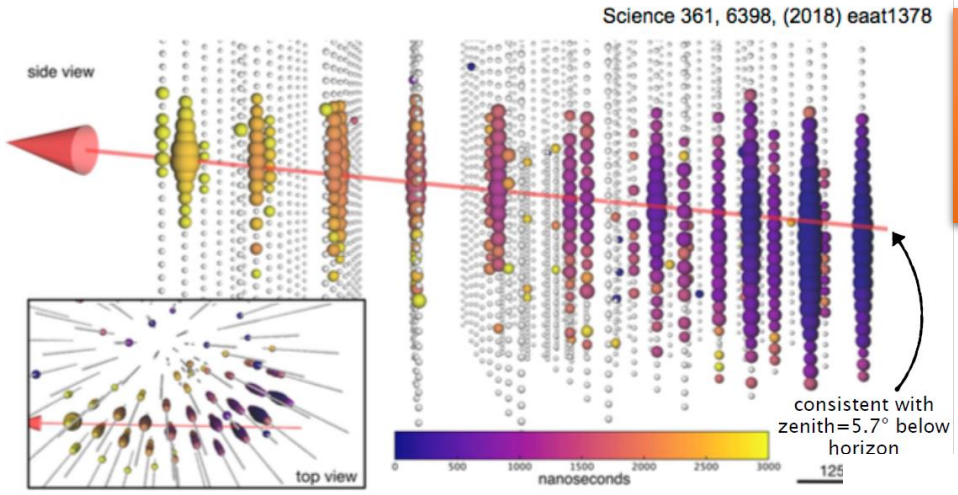


- SNR
- AGN / Blazars
- microquasars
- GRB
- Sgr A*

I
Scientific objectives of the neutrino astronomy

Clue 1: TXS 0506+056 the most credible individual HEN source so far

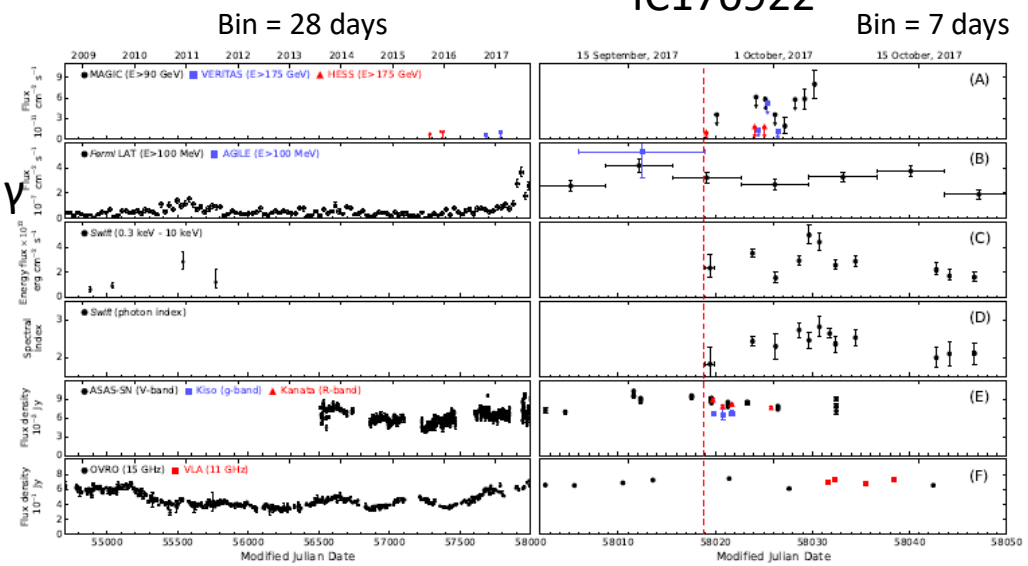
22 september 2017 (latency = 43 sec)
Deposited energy = 23.7 ± 2.8 TeV → 290 TeV (90% CL lower limit of 183 TeV)
Signalness = 56.5% → need of electromagnetic counterpart to confirm astro. origin.



A flaring blazar consistent with the neutrino trigger time and position at ~3σ !!

Science Vol. 361, Issue 6398, eaat1378

IC170922



- A flaring blazar = moderately low variable source (day/week timescale)
- Rather bright in optical (here it was R=13-14 at z=0.34)

I
The current status of the neutrino astronomy

Alert rate and localization

Public (GCN) and private alerts (AMON alert system)

2016: 1 public alert
2017: 3 public alerts (including IC170922A)
2018: 3 public alerts
2019: 18 public alerts
2020: 3 public alerts

Typical localizations

Muon track event: 0.5° - 1.5° (energy dependent)

Electron cascade event: 5-10°

- Low neutrino alert rate per year
- The localization of the events are rather compatible with the LSST FoV.
- 1 LSST image covers the error boxes of almost all the neutrino alerts

II
LSST synergies with astroparticle physics

Two ways to work

Detected 1 Any EM transient ?

ν — Multi-wavelength follow-up campaign → γ LSST Large Synoptic Survey Telescope

Any neutrino flare? 2 Detected

ν — Multi-messenger follow-up campaign → γ LSST Large Synoptic Survey Telescope

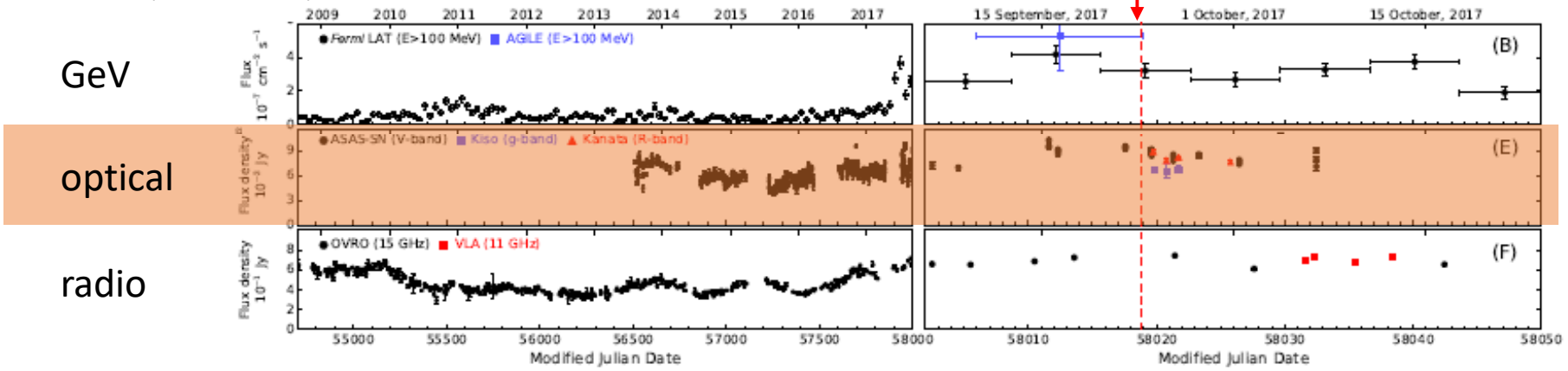
There is almost no neutrino astronomy without synergies with EM facilities

II
LSST synergies with astroparticle physics

LSST and the AGN/blazar neutrino candidates

Example TXS 0506+056 and IC170922A

Science Vol. 361, Issue 6398, eaat1378



Need to monitor the AGN/blazar fluxes over years to estimate the flaring/high state periods

Need to monitor at daily (3 days) timescales the AGN/blazar fluxes to well sample the variable/flare emission

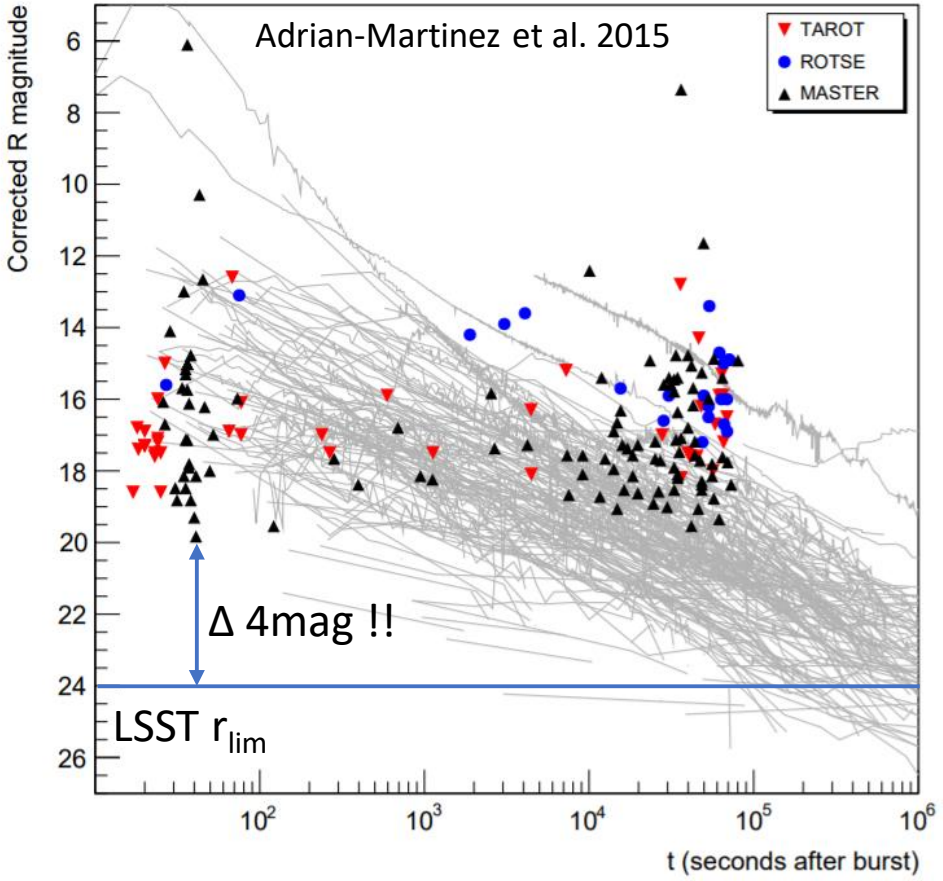
Large Synoptic Survey Telescope

Can « easily » manage this task for a lots of AGN/Blazars (very useful for neutrinos astronomy !)

II
LSST synergies with astroparticle physics

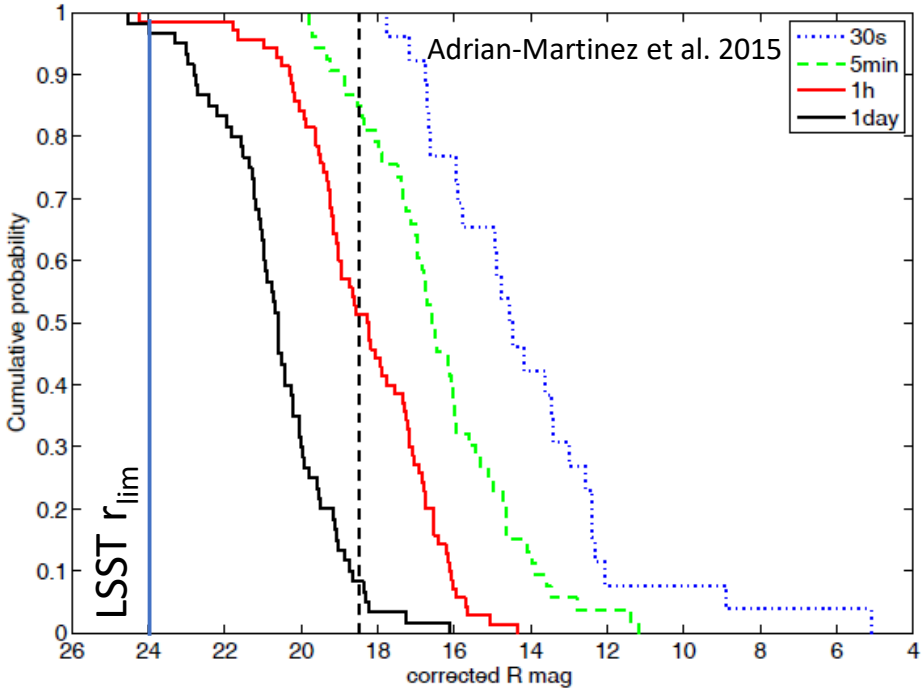
LSST and the GRB neutrino candidates

U.L. on the GRB optical afterglow brightnesses potentially associated with ANTARES neutrinos (TAToO ANTARES MM program)



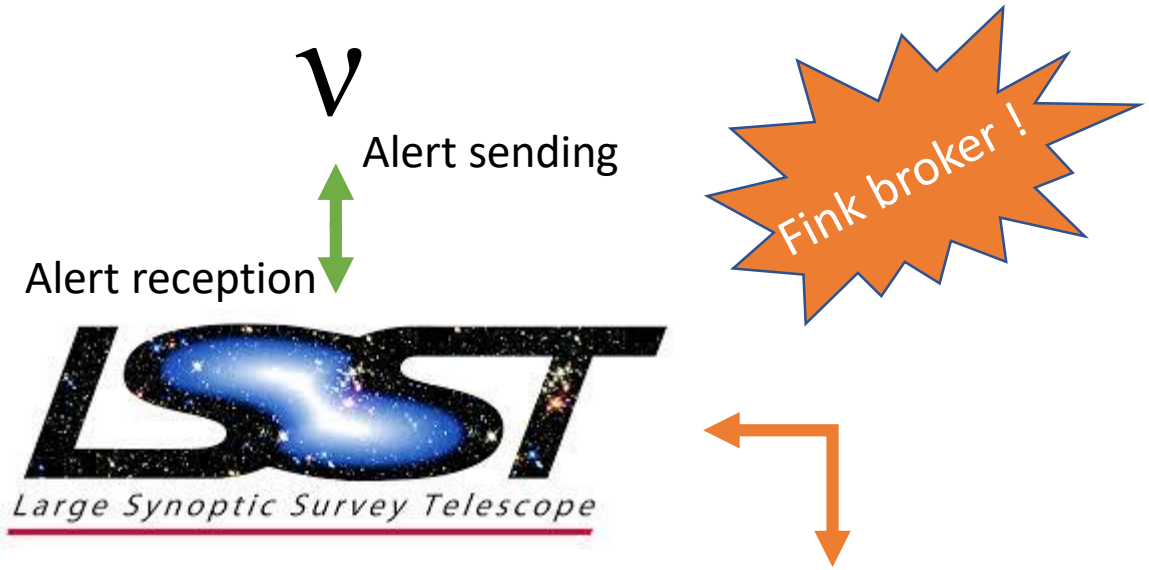
Great sensitivity to quickly reject the GRB-ν association

Fraction of GRB afterglows detected by LSST



II
LSST synergies with astroparticle physics

Probing the origin of the high-energy neutrinos with LSST



Searches into archive (very important)

- ✓ History of AGN or Blazars fluxes
- ✓ Supernovae records
- ✓ History of transients in galaxies

Real-time search for transients

- ✓ Fast fading GRB afterglows (2-3 days max)
- ✓ « Slow » variable AGN/blazars (week)
- ✓ Long transient Supernovae (weeks/months)

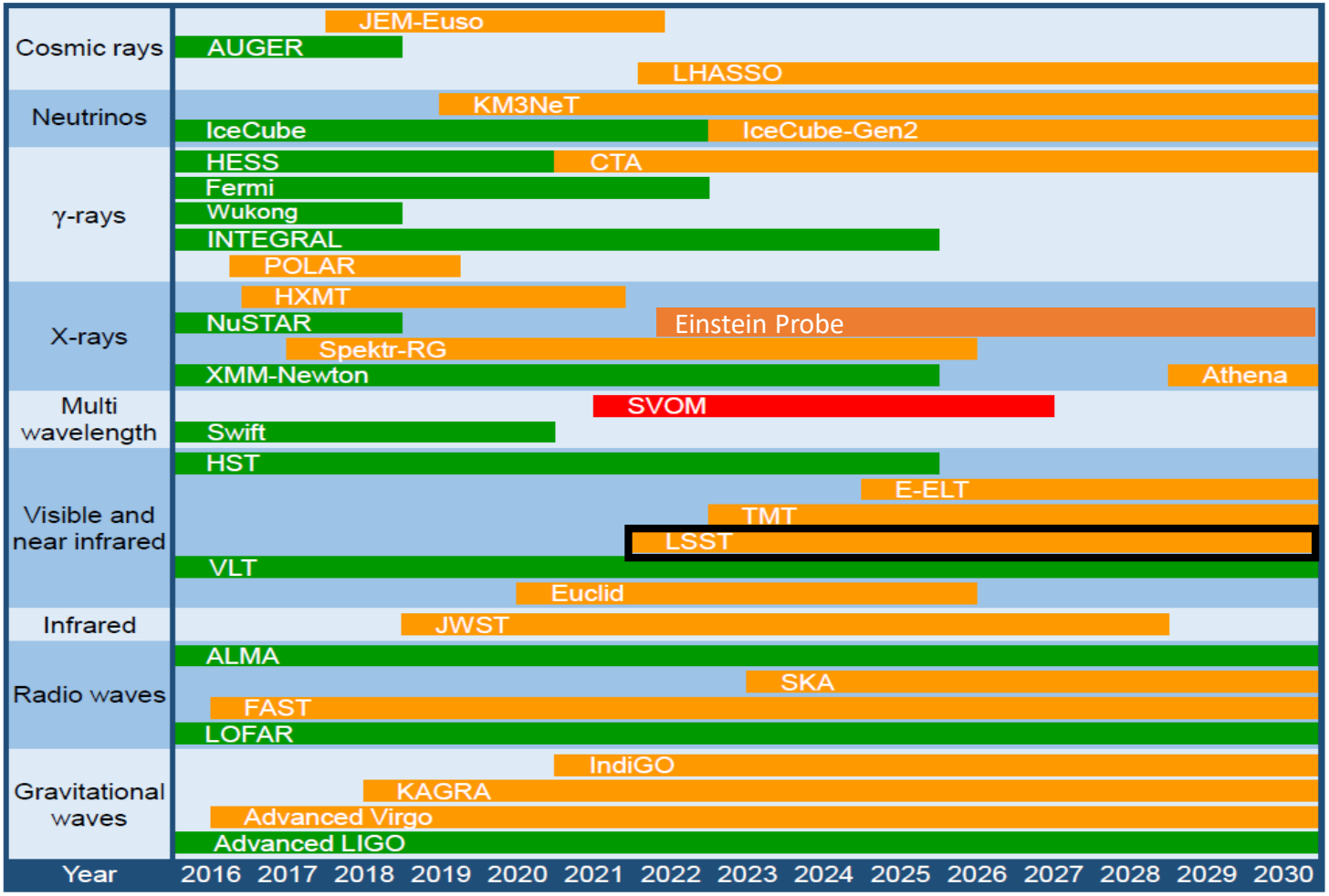
Quick vetting of the unrelated transients found by other groups

(No) Transient candidate associated with the neutrino alert

II
LSST synergies with astroparticle physics

The muti-messenger era of the next decade: 2021-2030

The best sky coverage and sensitivity ever achieved at any energy !



Conclusions

The high-energy neutrino astronomy is an exciting topic !
It will allow us to probe the origin of the greatest particle accelerators in the Universe

LSST will be of great help to identify the sources of the HEN thanks to:

- Its great sensitivity to hunt for the faintest transient sources and the most distant ones
  -> very useful to put stringent constraints on the GRB-neutrino association

- Its survey strategy to monitor the transient sky at daily timescales
  -> very useful for SNe and identifying flaring activities of Blazars/AGN, promising sources of HEN
  -> very useful to quikly vet the optical transient candidates detected by other groups (like ZTF and PanSTARRS actually do but at much lower sensitivity)

To make this possible, LSST need a tool to:

Fink broker !

- Quickly search archive data of potentially interesting sources into a given sky field
- « Quickly » identify flaring state of Blazars/AGN
- Broadcast LSST alerts with key criteria to classify the transients (GRB, SNe, TDE, etc.) so that MM follow-ûp campaign can be triggered