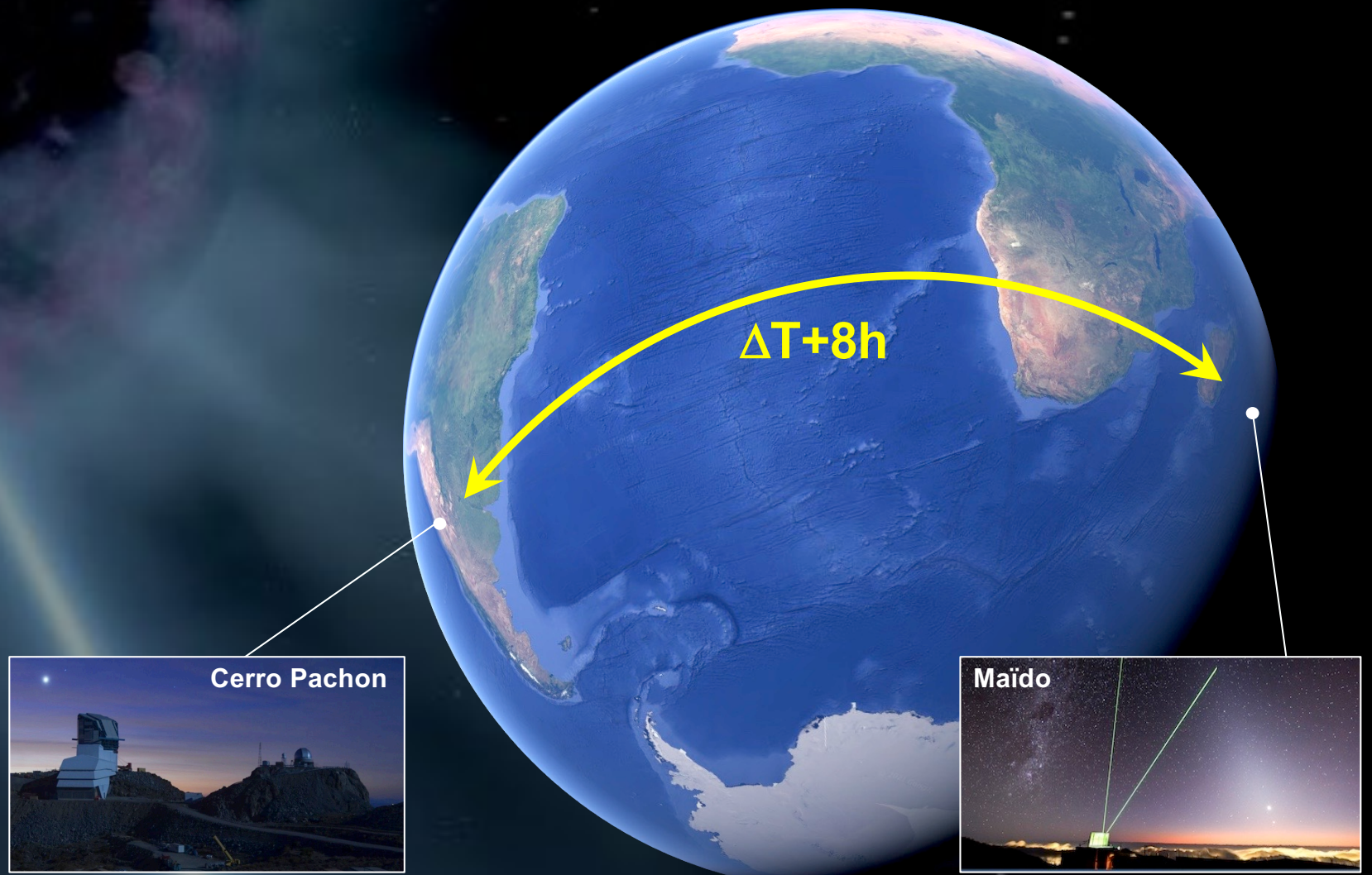
Probing the early phase of the brightest LSST transients

A possible dynamic survey preceding the LSST visits and performed from the Indian Ocean

Emeric Le Floc'h (CEA-Saclay, AIM)



Probing the early phase of the brightest LSST transients

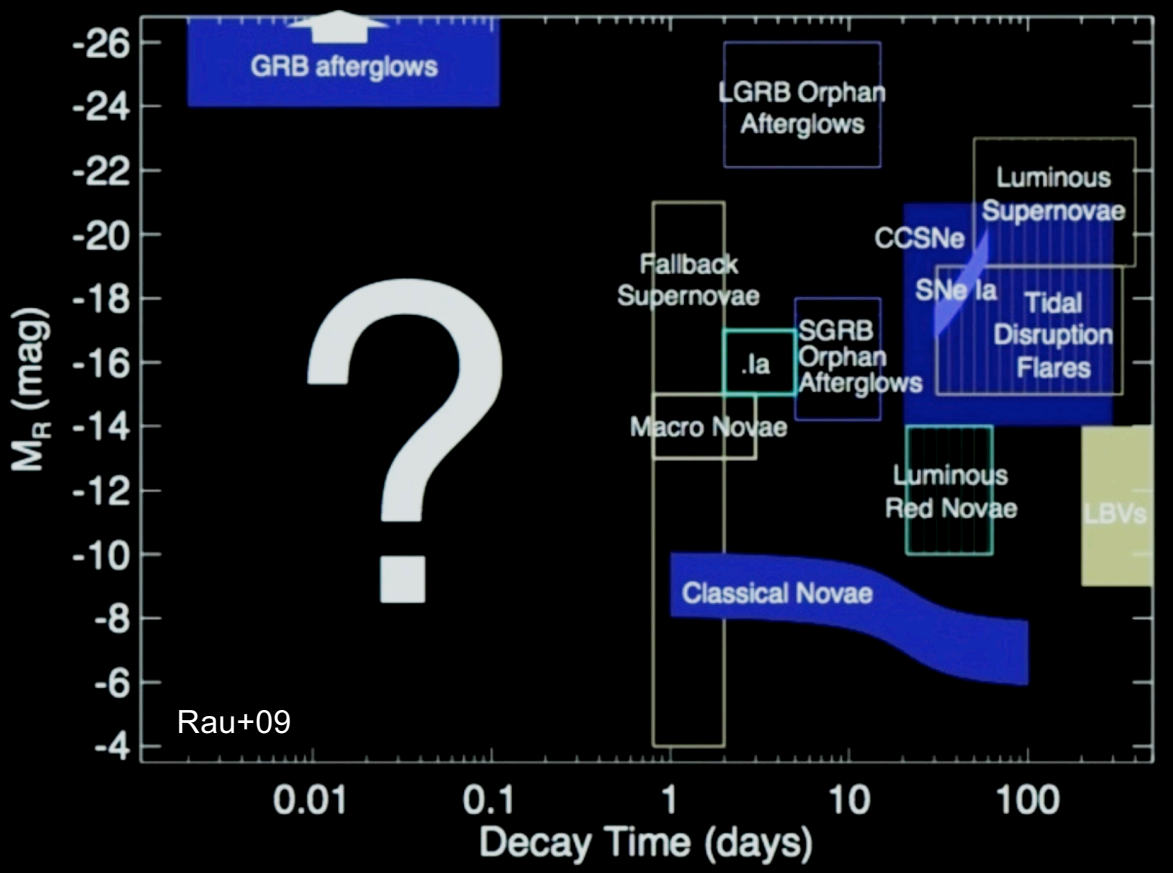
A possible dynamic survey preceding the LSST visits and performed from the Indian Ocean

Emeric Le Floc'h (CEA-Saclay, AIM)

and

- P. Gallais, S. Ronayette, D.Turpin, C. Gouiffès, S. Chaty (AIM)
- M. Renaud, G. Vasileiadis, E. Nuss (LUPM)
- A. Klotz, O. Godet (IRAP)
- F. Schüssler (CEA/DPhP)
- S. Basa (LAM)
- J. Peloton (IJCLab)
- E. Ishida (LPC)
- A. Möller (Swinburne Univ.)
- A. Coleiro, C. Lachaud (APC)
- D. Horan, S. Fegan (LLR)
- P. Maggi (Obs. de Strasbourg)
- S. Vergani (GEPI)
- M. Boër (OCA)
- Y. Hello & J.-P. Cammas (OSU-Réunion)

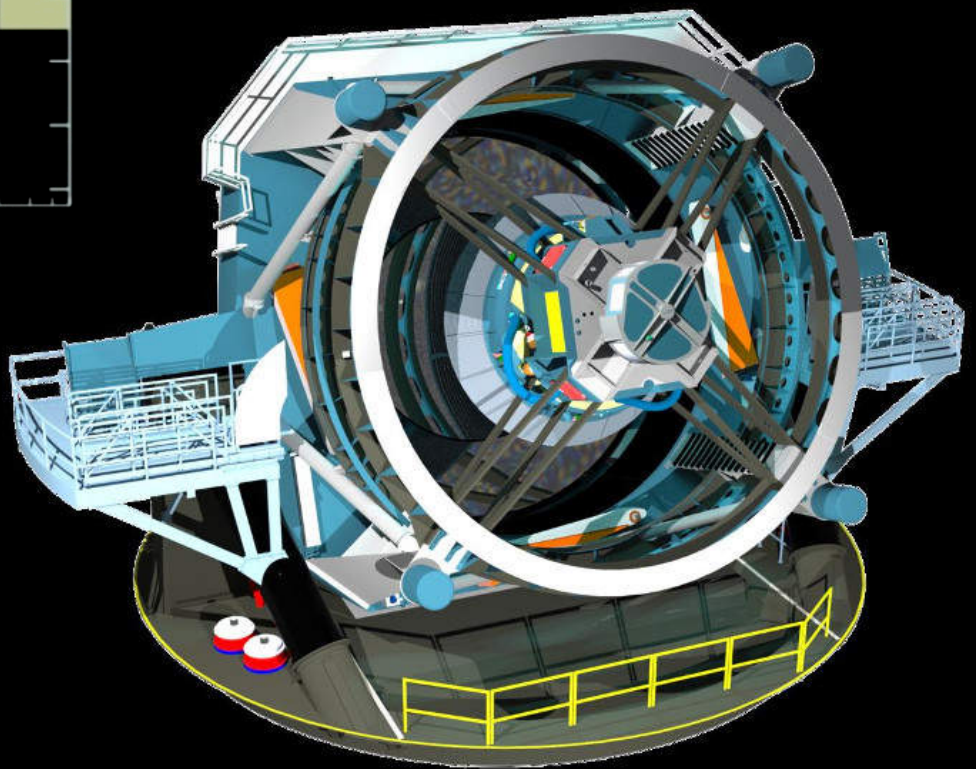
LSST: a revolution for the transient sky



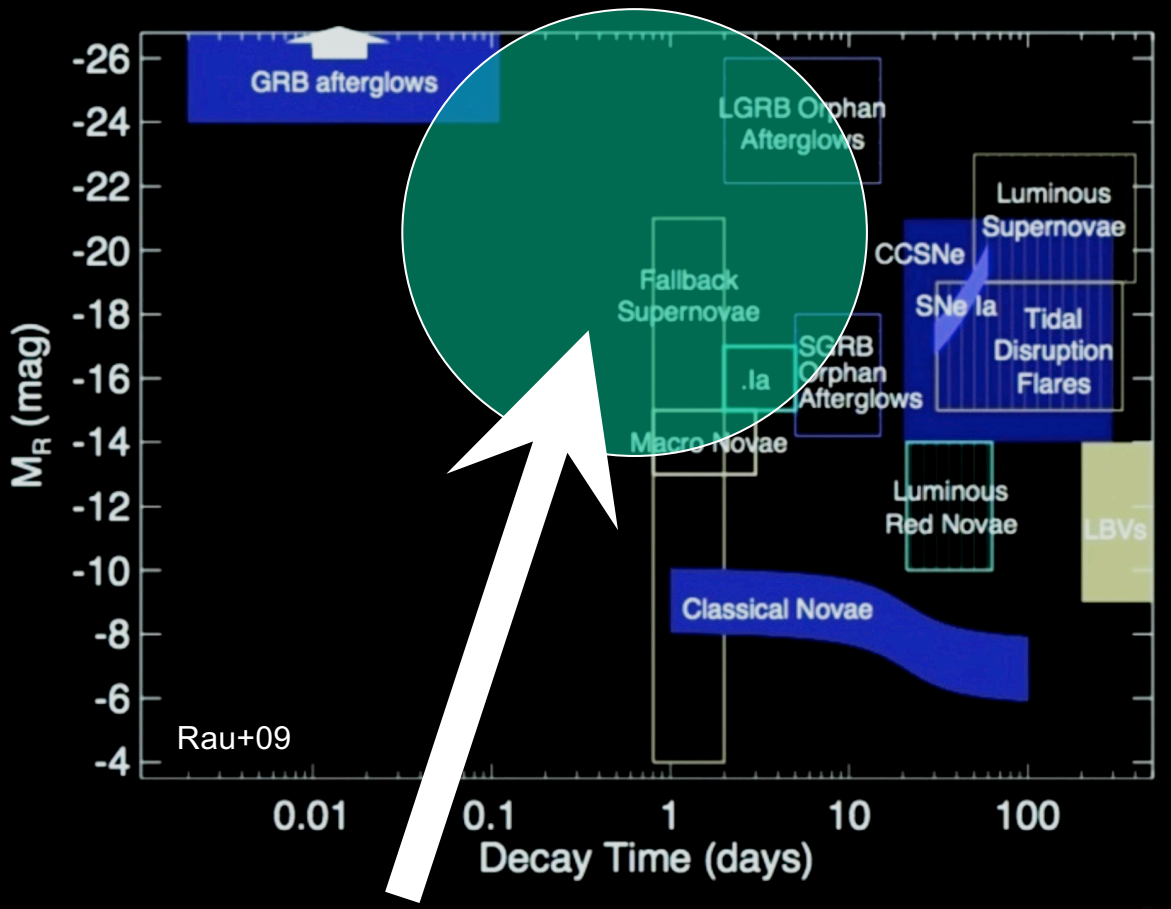
LSST alerts (illustrative numbers per visit, i.e.~30s)

- Variable stars : ~7200
- SN : ~200
- AGN : ~70
- Moving sources : ~3000

(Graham+, DMTN-102, 2020-03-06)



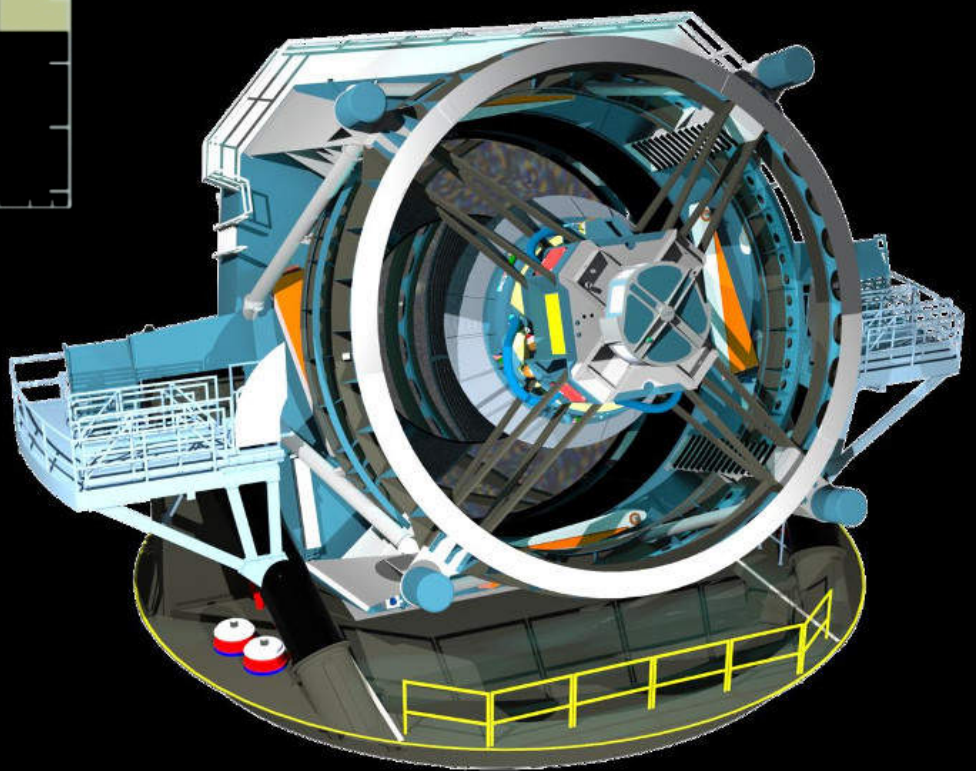
LSST: a revolution for the transient sky



LSST alerts (illustrative numbers per visit, i.e.~30s)

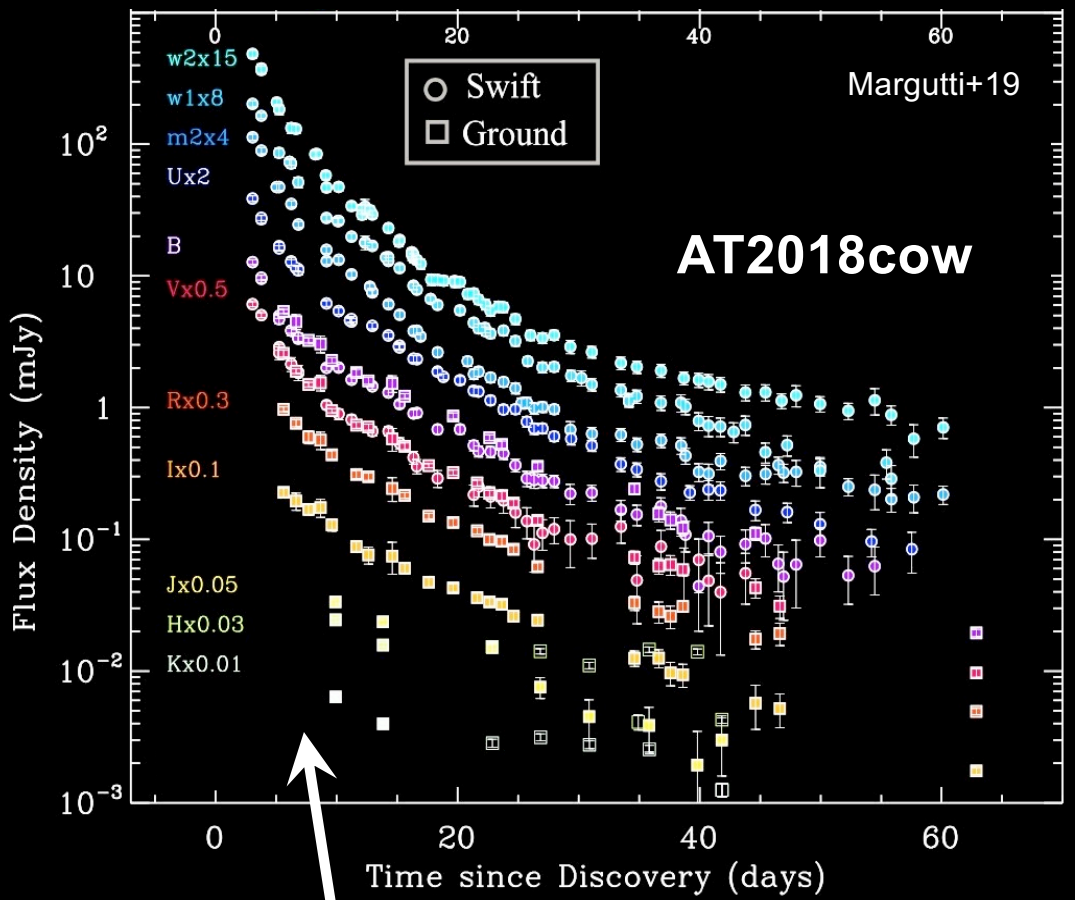
- Variable stars : ~7200
- SN : ~200
- AGN : ~70
- Moving sources : ~3000

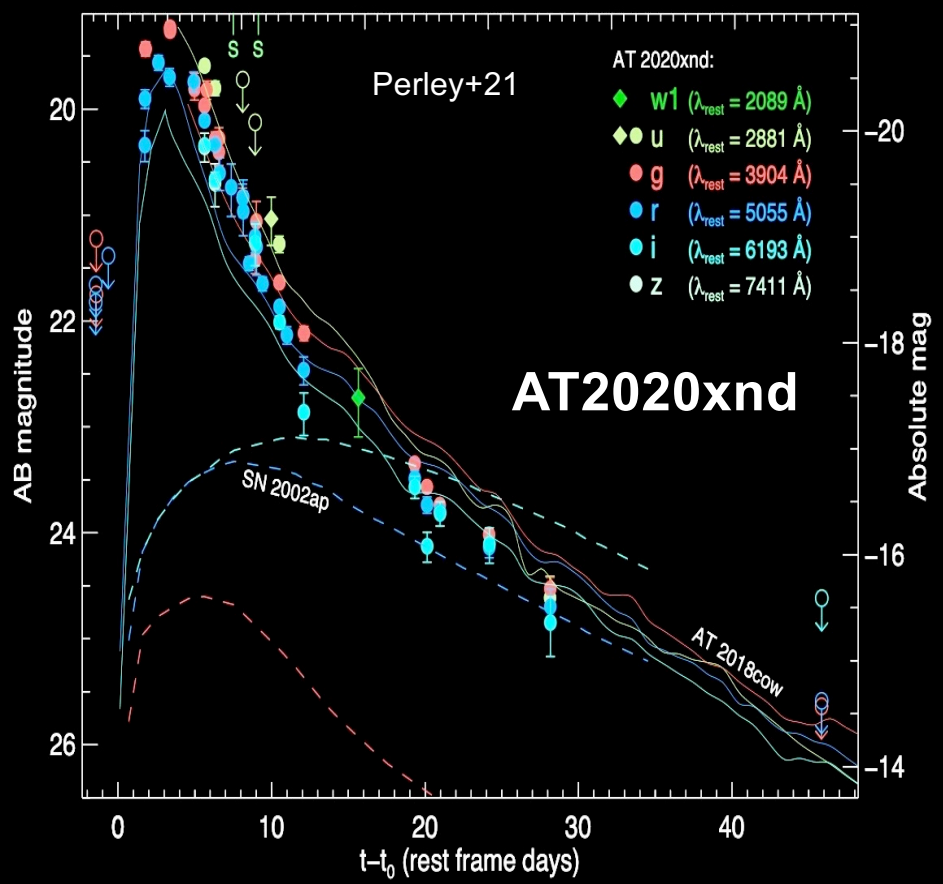
(Graham+, DMTN-102, 2020-03-06)

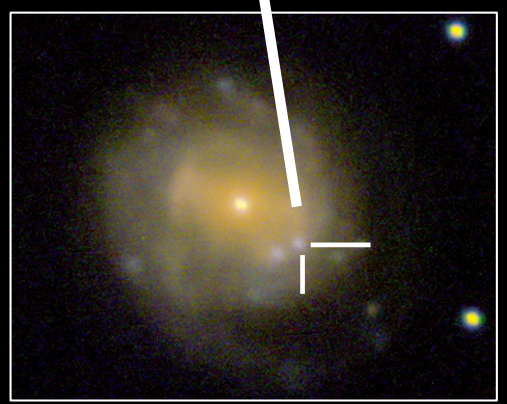


This talk is about the most luminous and fast evolving transients that Vera Rubin will catch !

Fast Blue Optical Transients (FBOTs)



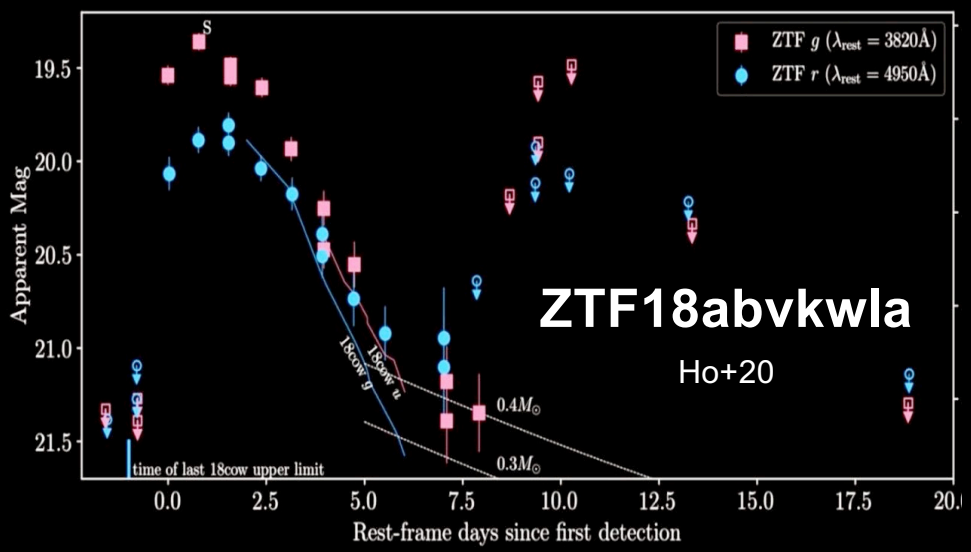




- Fast optical rise (~1 day)
- High photospheric temperature → blue color
- Luminous in X-rays, radio and millimeter wavelengths
- Dwarf / low-mass host galaxy

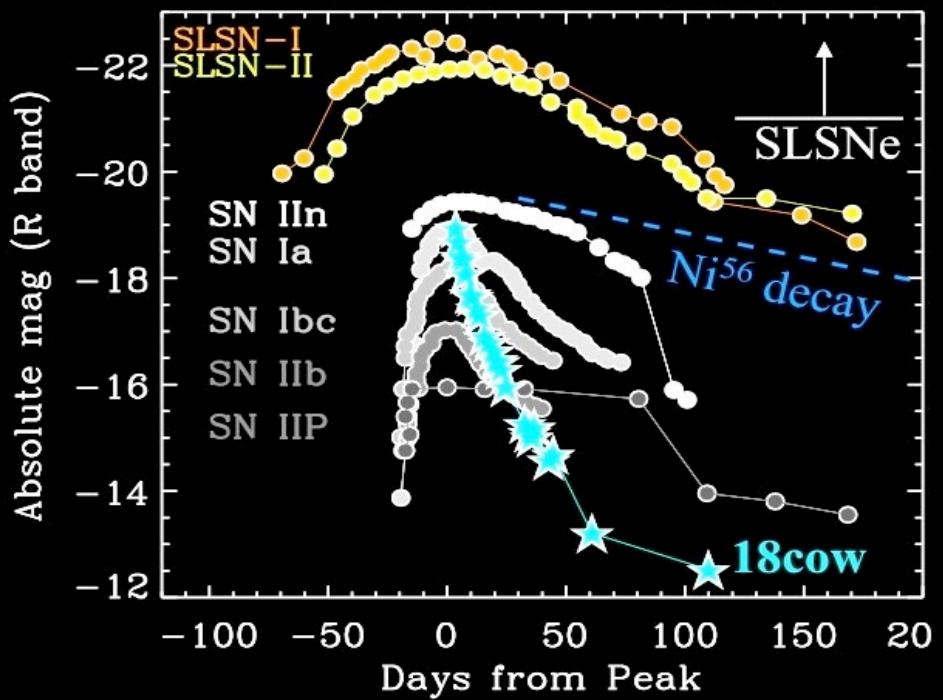
… also RETs (Rapidly Evolving Transients), FELTs (Fast Evolving Luminous Transients)…

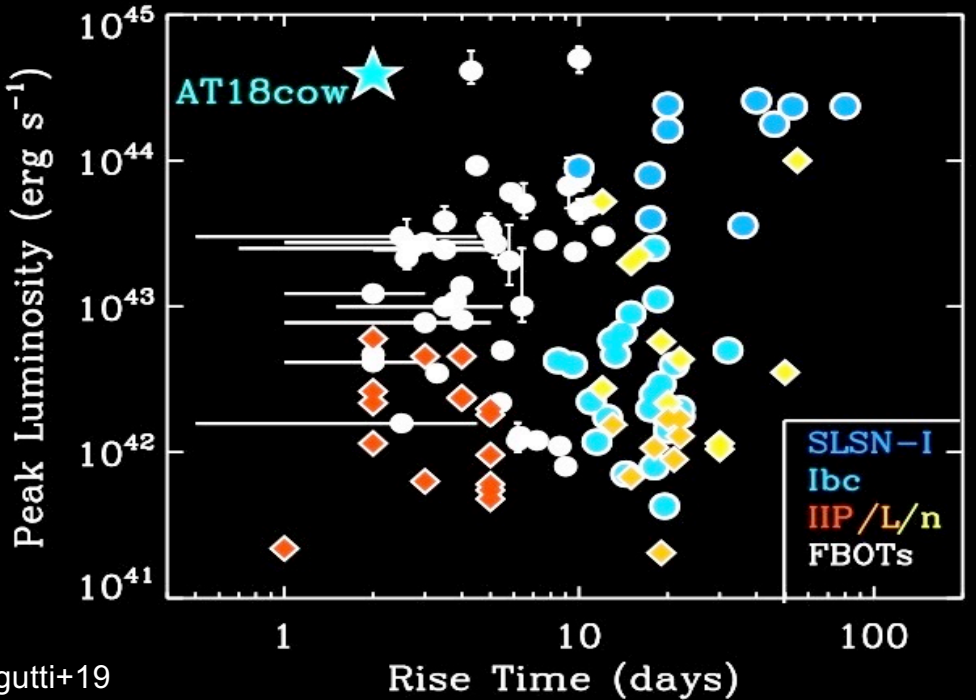
Fast Blue Optical Transients (FBOTs)



- Nature still debated but distinct from "classical" SNe (i.e. distinct progenitor and/or central engine)
- Blast wave from fast-moving ejecta → radio
- Shock interaction with a dense and compact circumstellar medium → optical

… consistent with the presence of a relativistic jet powered by accretion after the formation of a BH

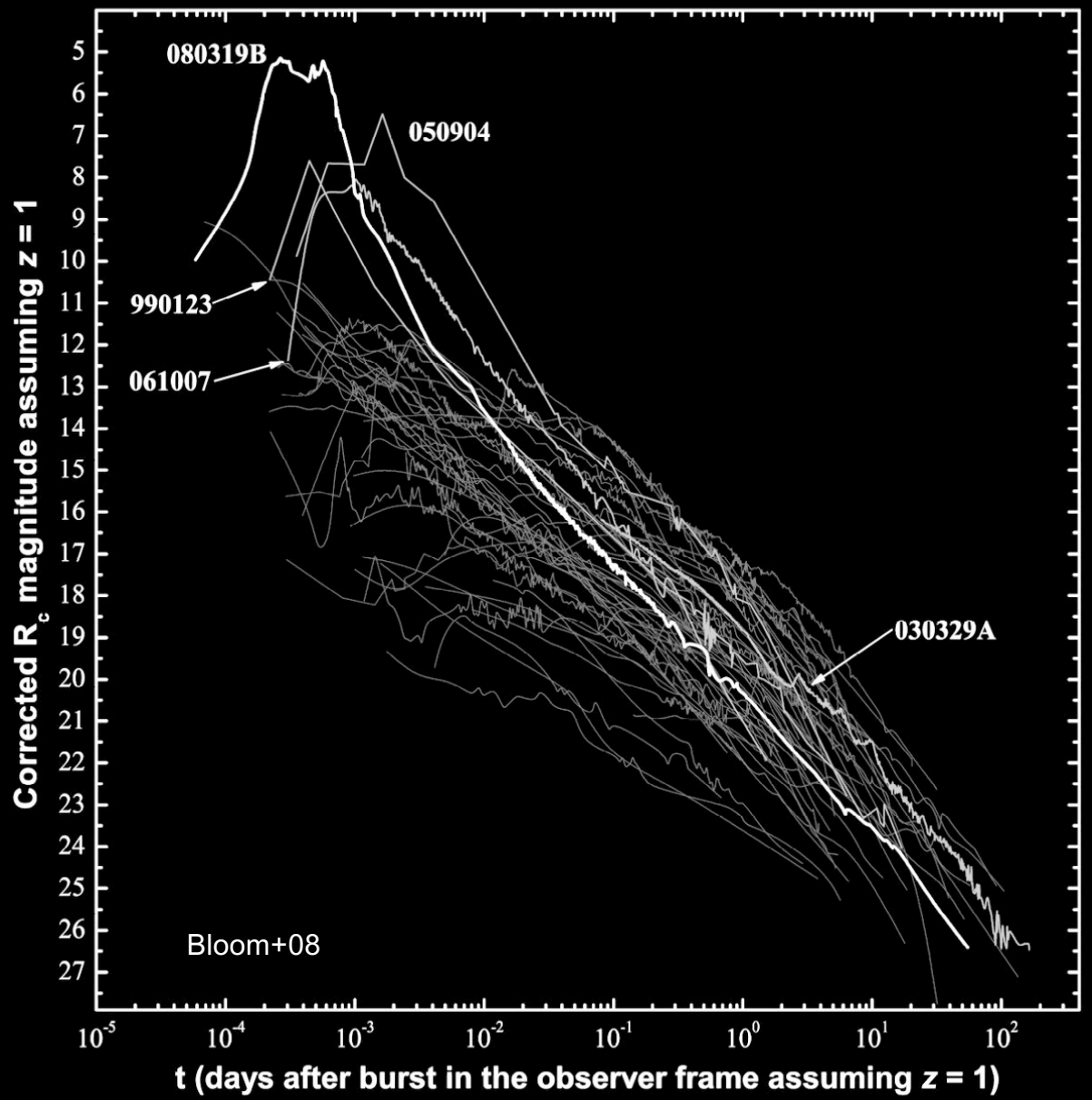




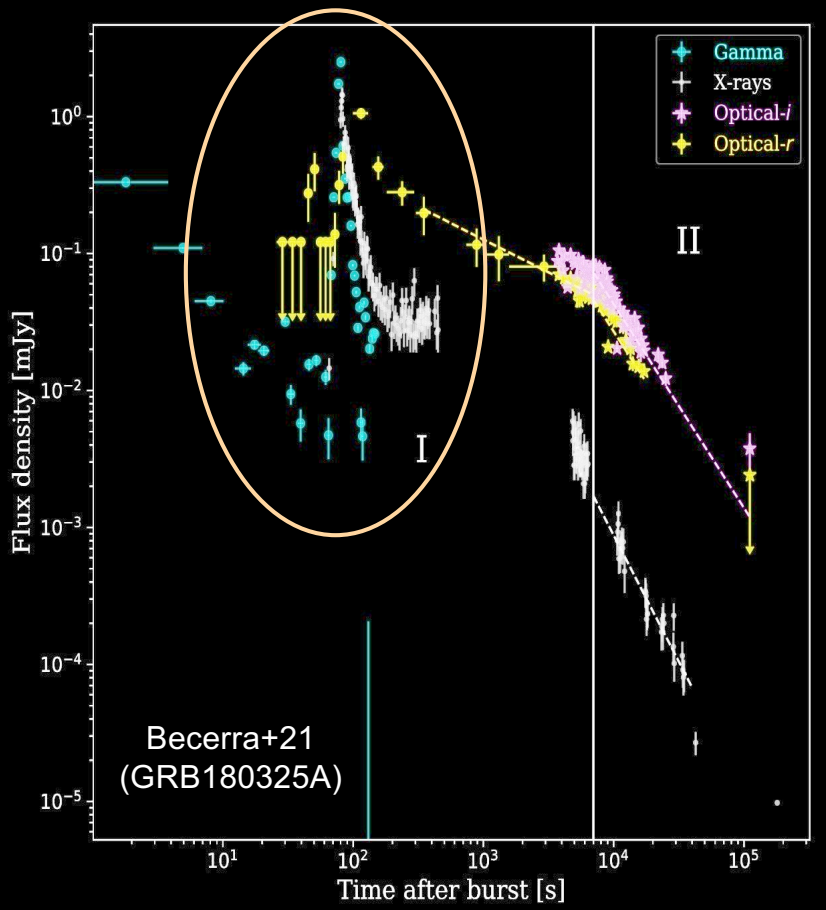
Margutti+19

GRB optical emission at early time

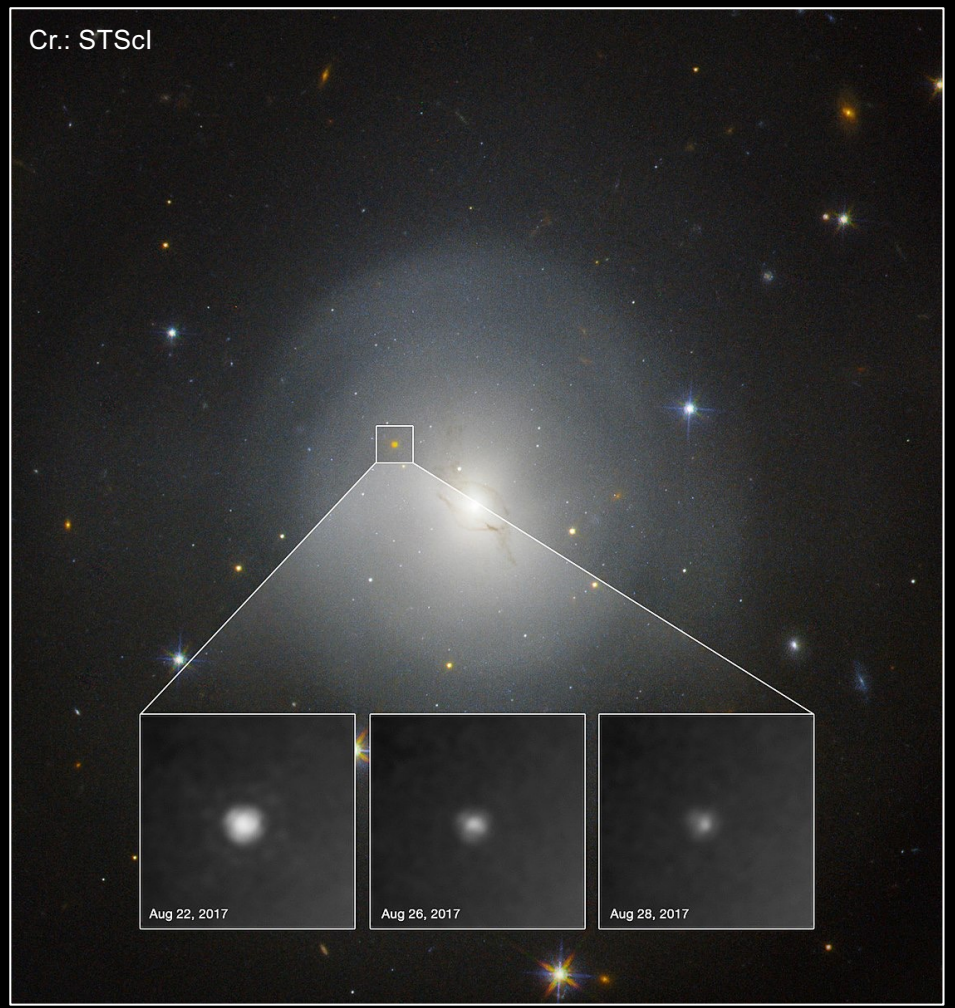
- Extremely fast decay as soon as the first hours after trigger



- Afterglow produced by external shocks with the ISM
- Optical pulses due to the reverse shock

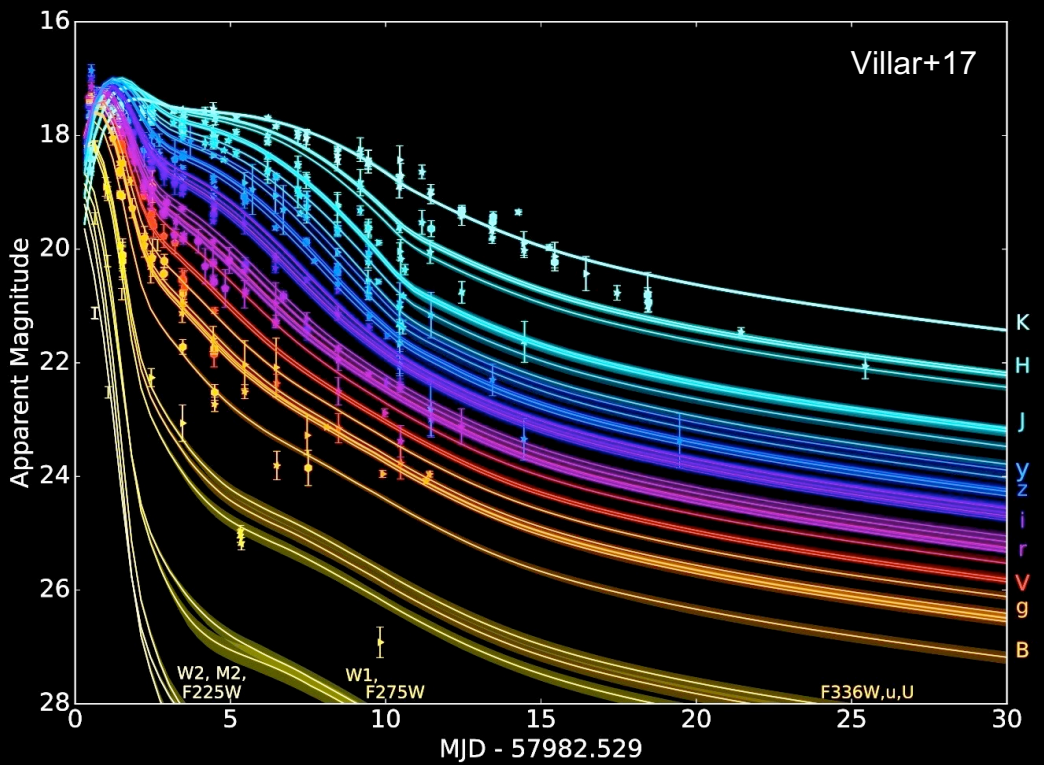


Kilonovae

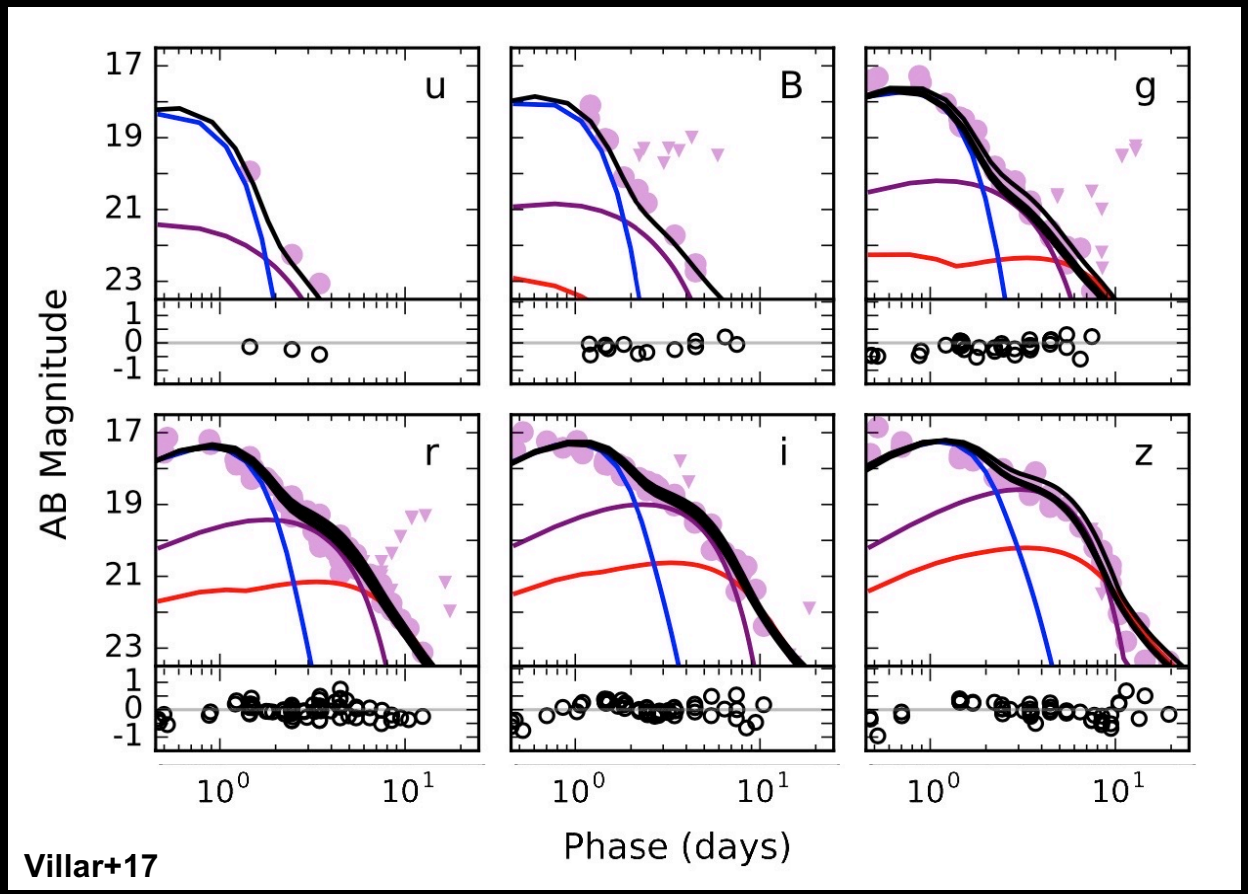


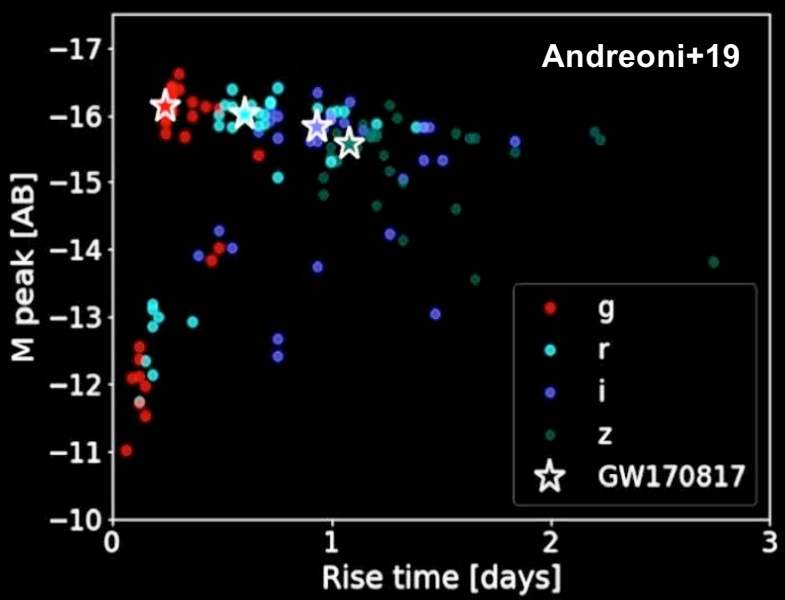
- Distance : 40 Mpc (z=0.01), in NGC 4993

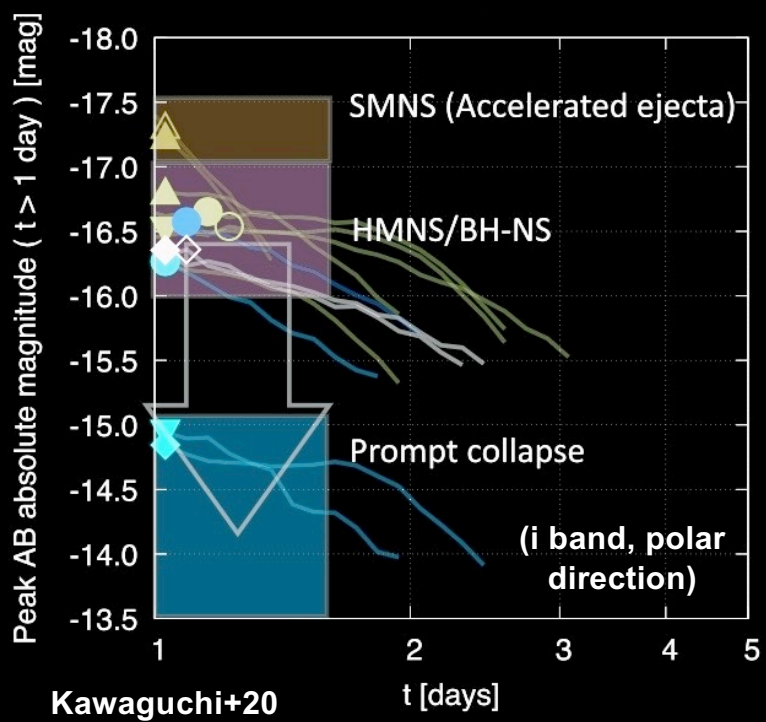
- AT2017gfo: optical counterpart associated with GW170817
- Light-curve consistent with r-process heating in a kilonova
- Fast evolution: $\Delta g > 5$mag, $\Delta T \sim 6000$K in the first week



Kilonovae

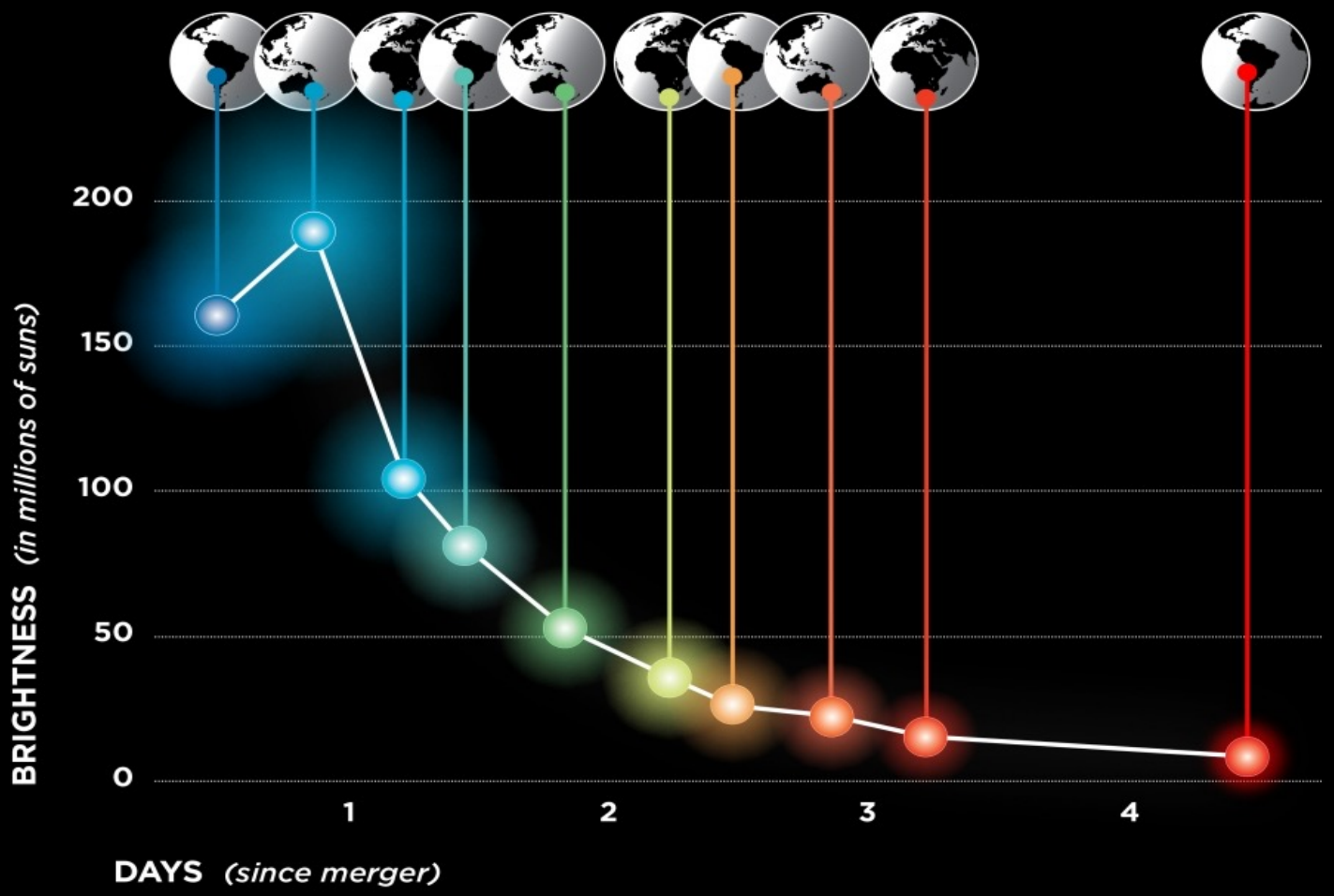






- GW170817 KN: blue component associated with lanthanide-free polar dynamical ejecta + redder components revealing a delayed lanthanide-rich outflow from the accretion disk of the BNS merger
- Peak brightness and time correlated with ejecta properties (mass, energy injection, …)

A need for world-wide follow-up



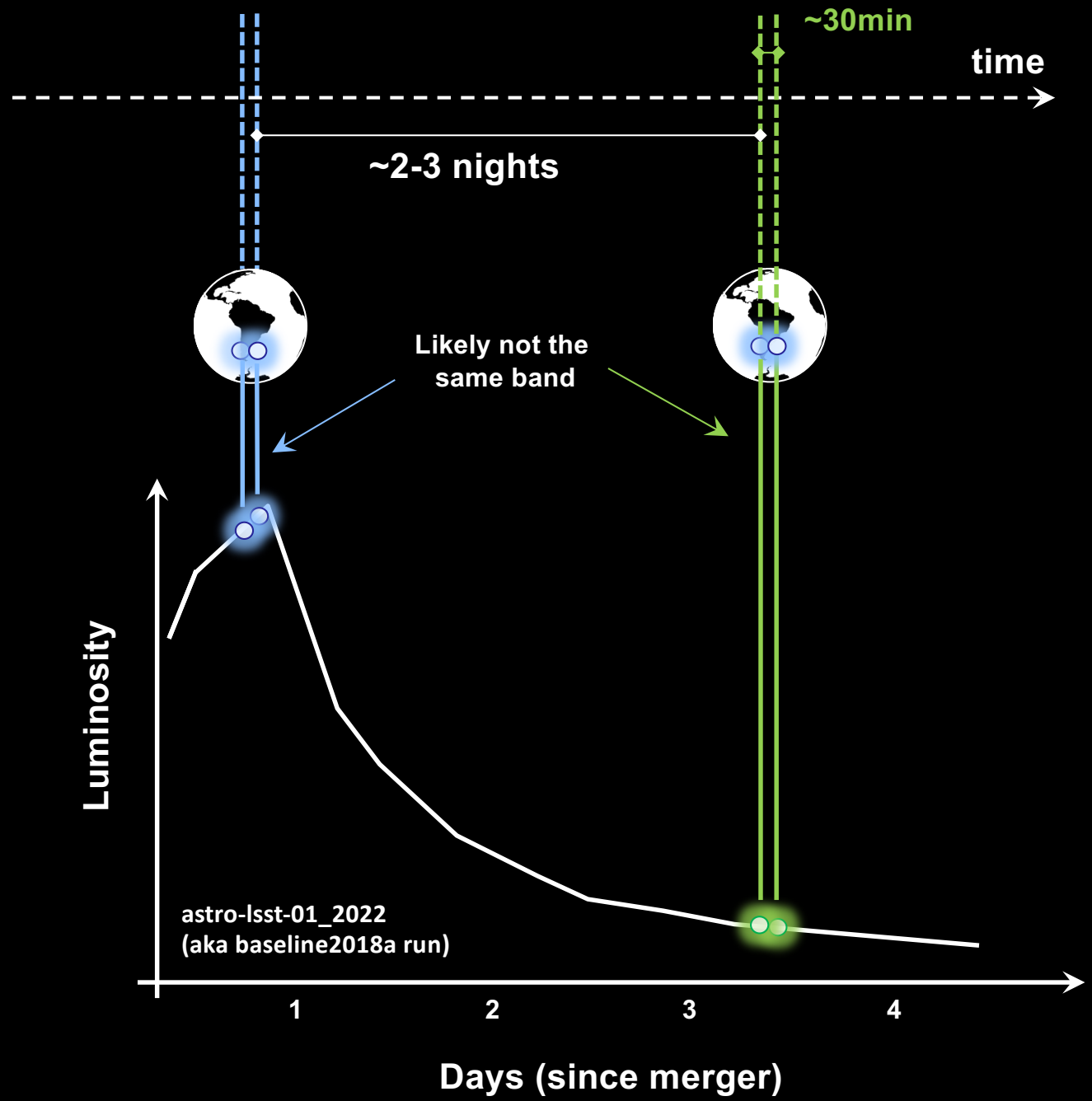
Las Cumbres Observatory LCO

Arcavi et al., 2017

- Requires coordinated observations spread world-wide (LCO, GRANDMA, GROWTH, …)
- Doable on case-by-case basis (e.g., GW170817 counterpart)

→ won't be feasible for the million of LSST transients

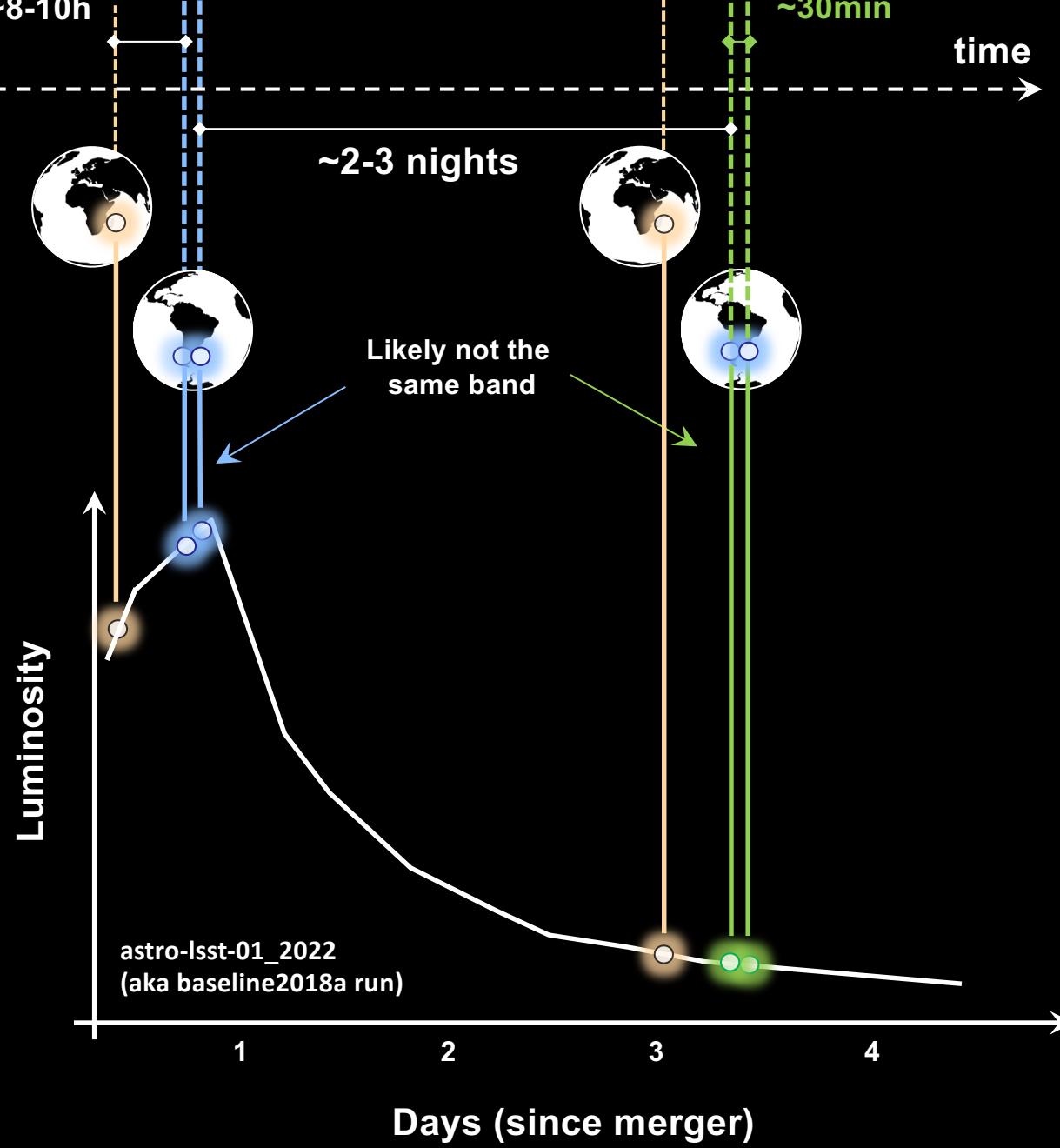
LSST cadence design



LSST cadence design

+

?

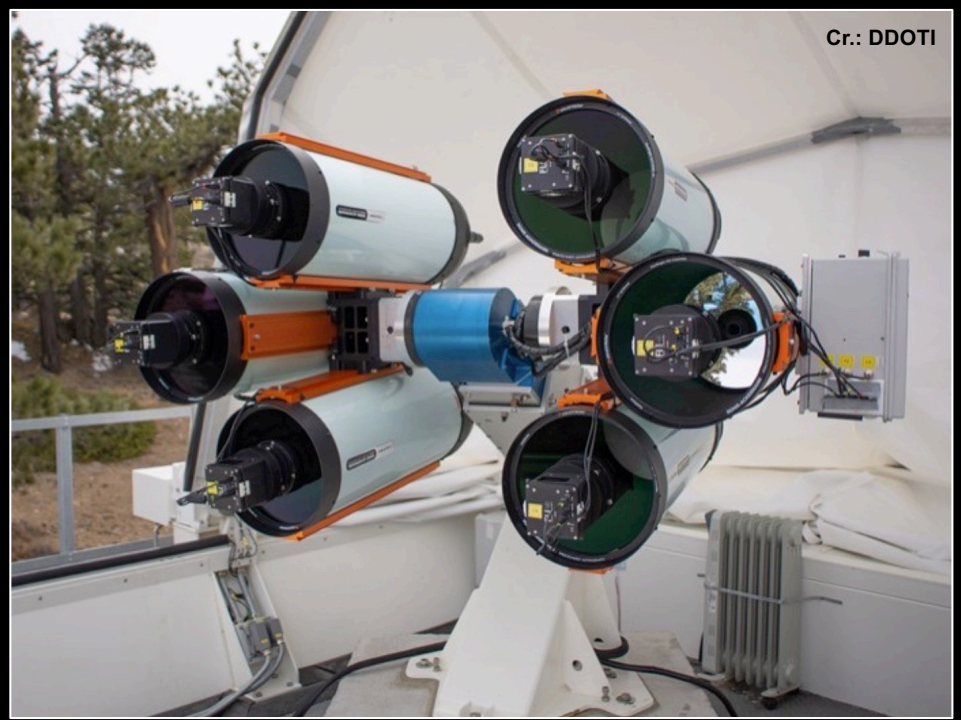


Wide-field robotic telescopes

A revolution in the field of wide surveys with small robotic telescopes, thanks to new high-quality astrographs at moderate cost

- “Rowe-Ackermann Schmidt Astrograph” (RASA) : optical design optimized for high quality imaging at large FOV
- New CMOS detectors with sizeable chips

e.g., DDOTI (« Deca-Degree Optical Transient Imager »), GOTO (« Gravitational-wave Optical Transient Observer »)


Cr.: DDOTI

Cr.: GOTO

Matching the LSST field of view

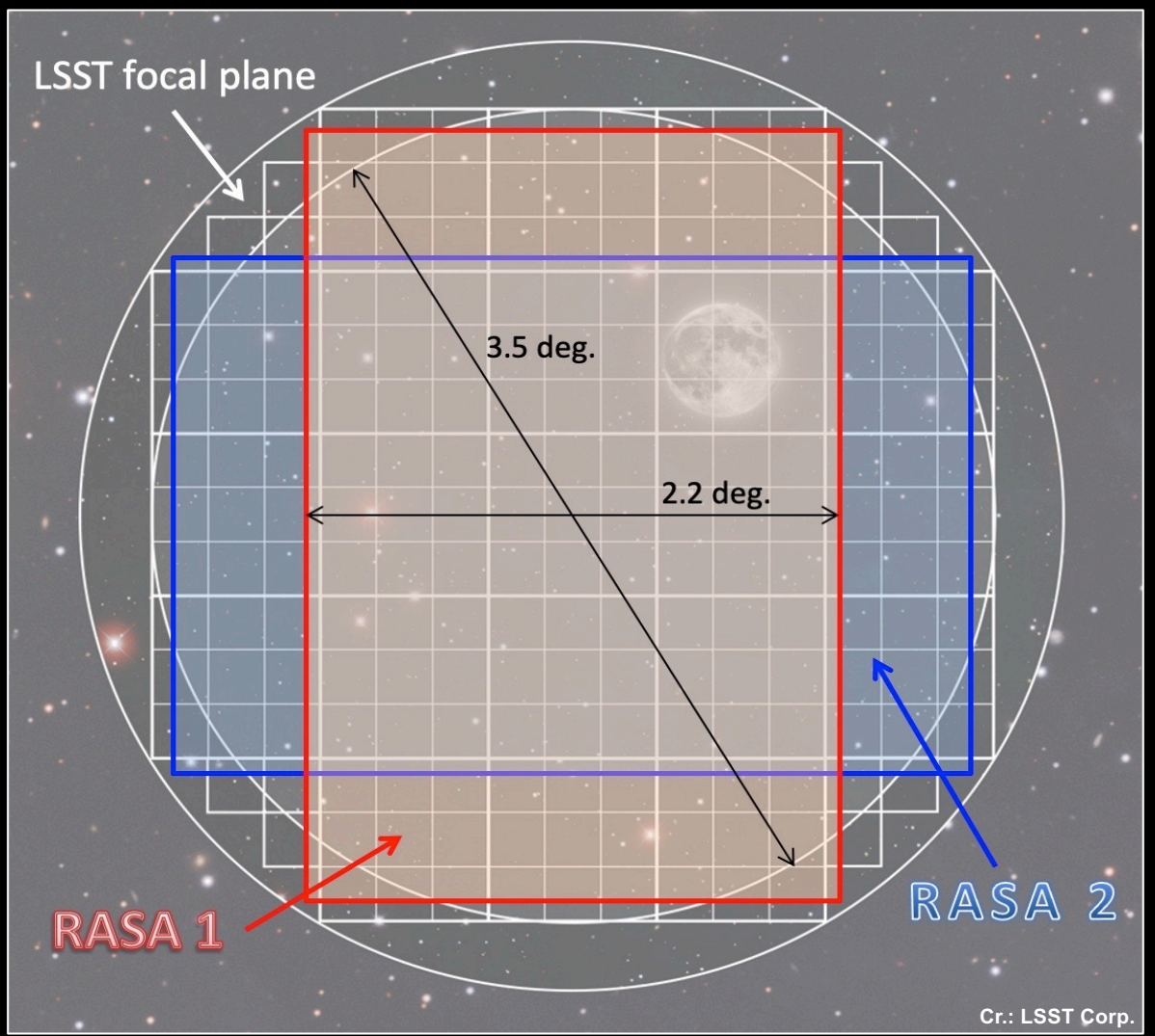
Commercial astrographs with small aperture have short focal lengths
→ large FOV (with detector at prime focus), but single filter

RASA C11 + 24x36mm CMOS
(QE~90%, 61MPx) :

- Diameter: 280mm
- FOV: 7.3 deg^2
- 1.2”/px
- R ~ 20mag in 5min (5σ)

2 RASA units with perpendicular orientation would cover most of the LSST FOV

(Optics + detectors: <20kEuros)

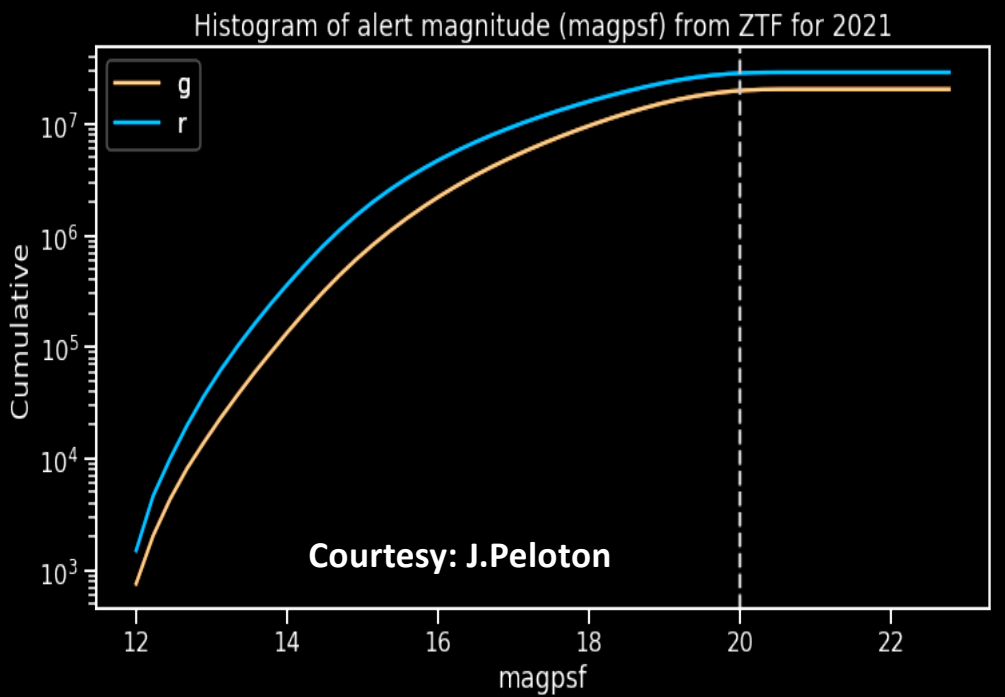


Pointing strategy and detection rate

- LSST visits covered ~8-10h in advance up to R~20mag
- Limited sensitivity imposes 5min of integration time to reach mag requirement
  - → Cadence 5x longer than LSST
  - → Not all LSST fields to be observed every night

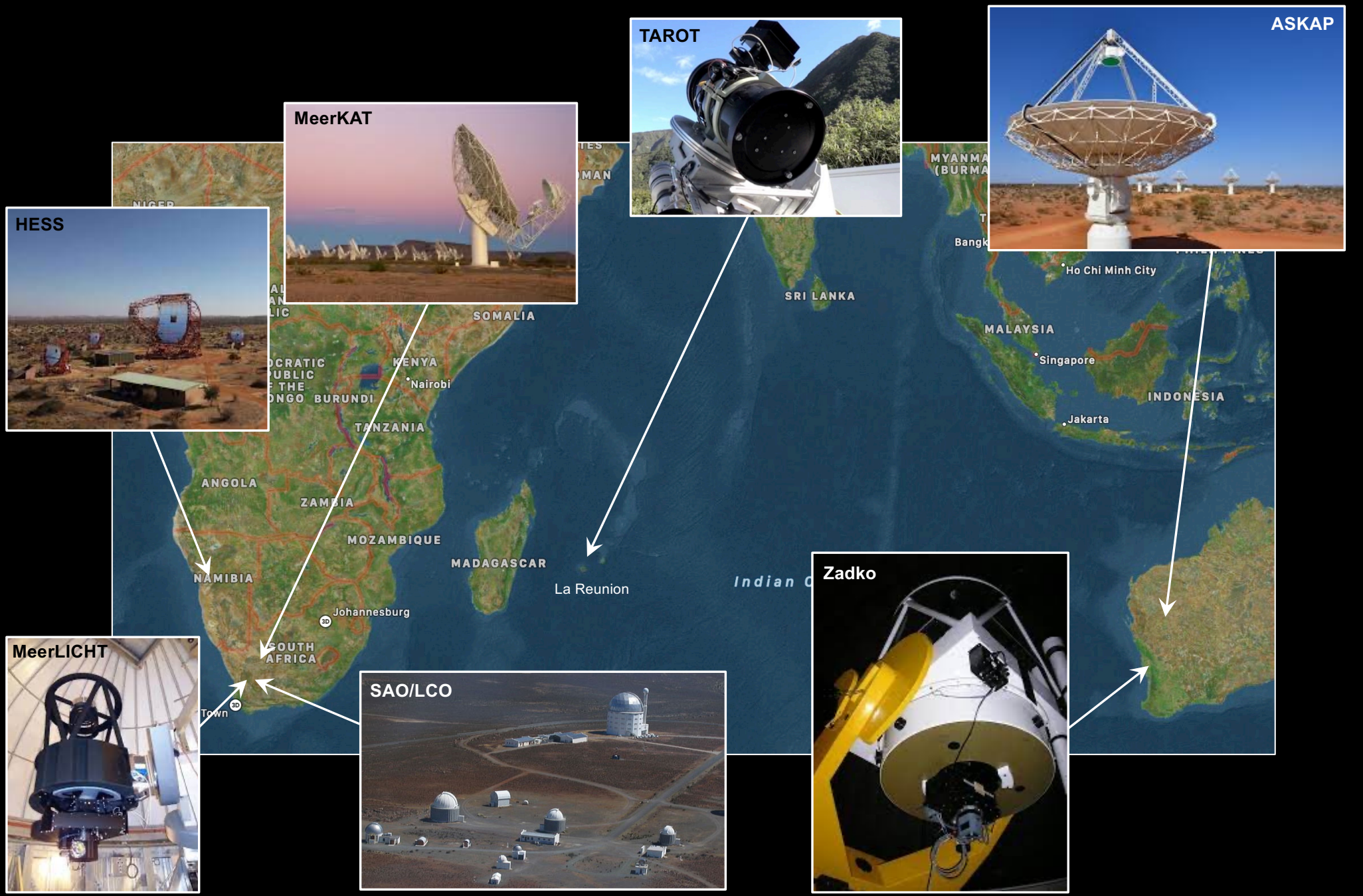
- Rough estimate of LSST transients to be detected up to R~20mag with our pointing strategy :

  x1000 - x10 000 per night, based on current rate of alerts reported by Zwicky Transient Factory



- Data to be processed in real-time and articulated with the FINK full-stream alert broker (Möller, Ishida, Peloton+)
- Will also trigger follow-up of VOEvents like GWs, GRBs, neutrino alerts, …

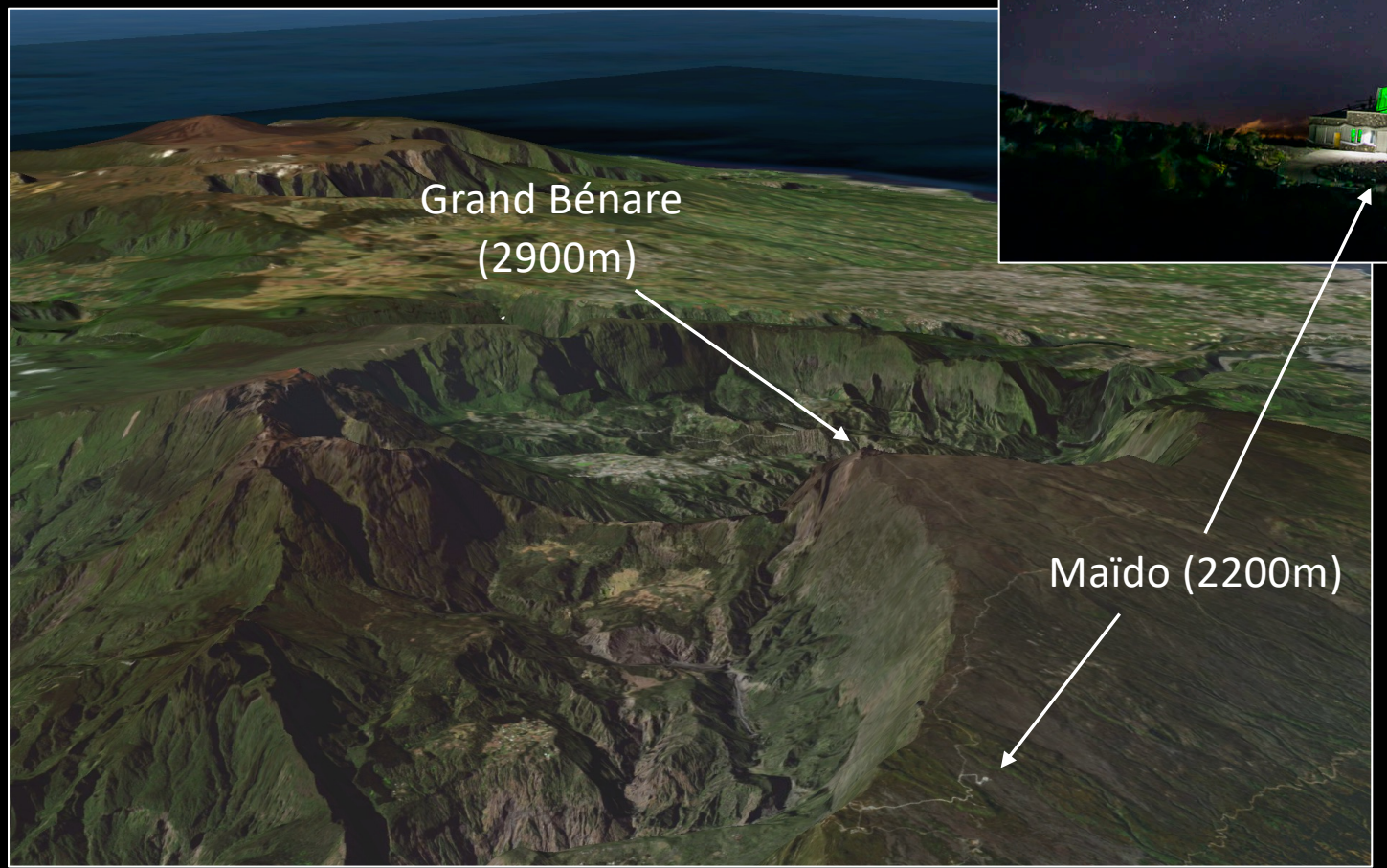
A location ~8-10h ahead of Chile

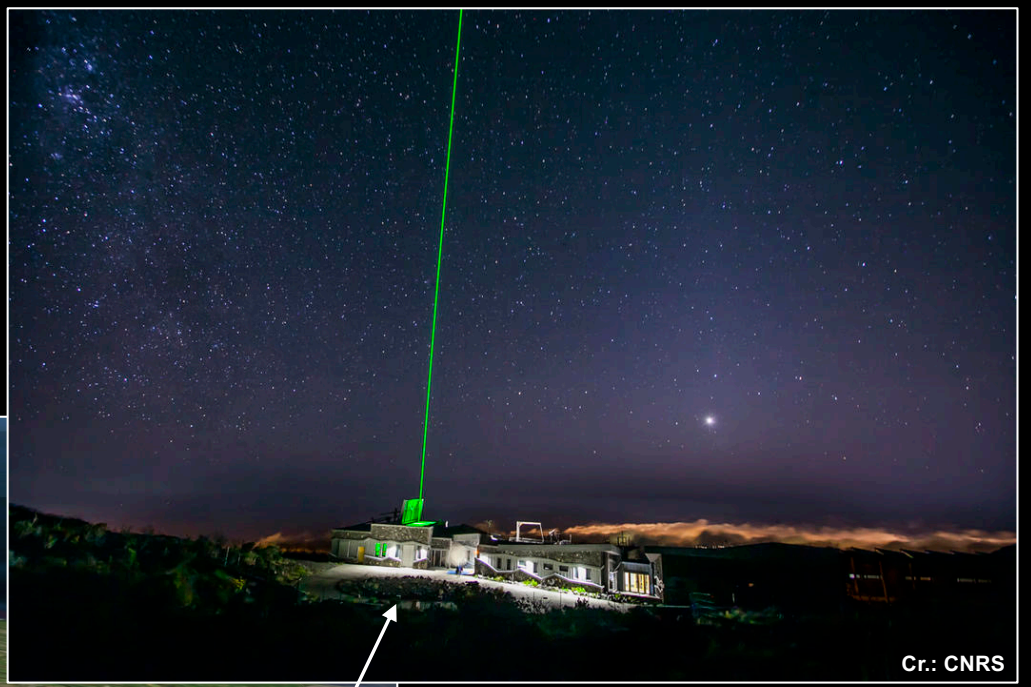


Astronomical sites on Reunion island

- Grand Bénare (2900m): ESO pre-selection for VLT, site testing in 1986-1987 (INSU)

- “Les Makes” (1000m): stargazing observatory, TAROT + T60 (IMCCE)



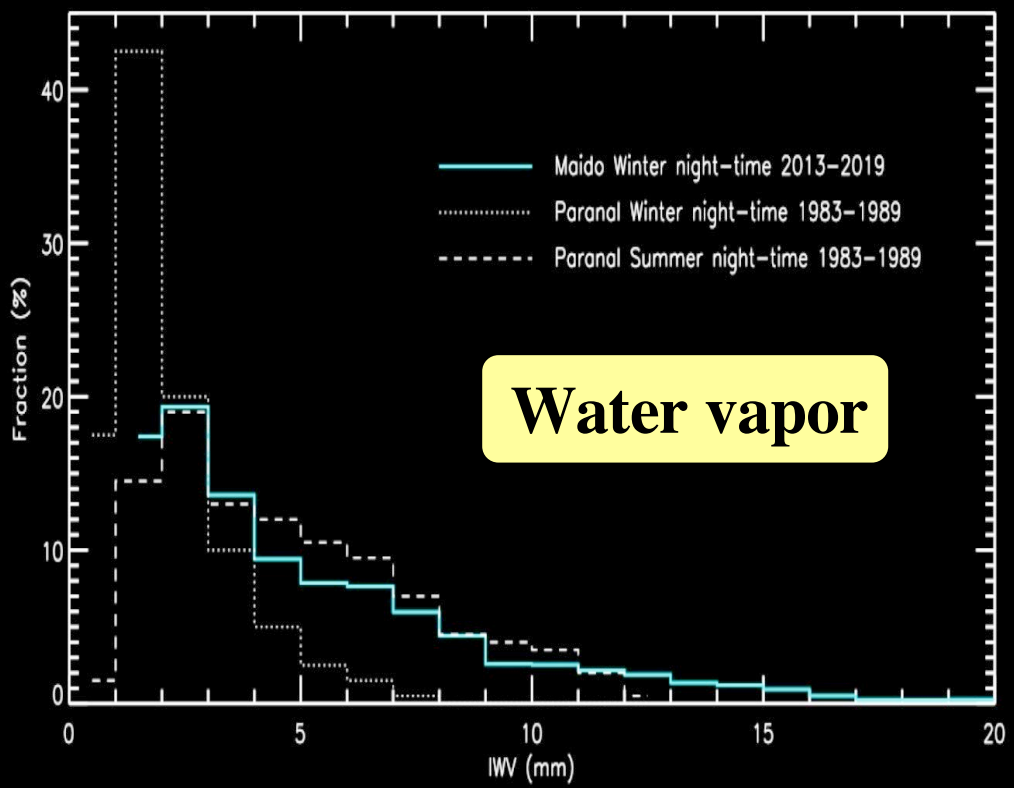


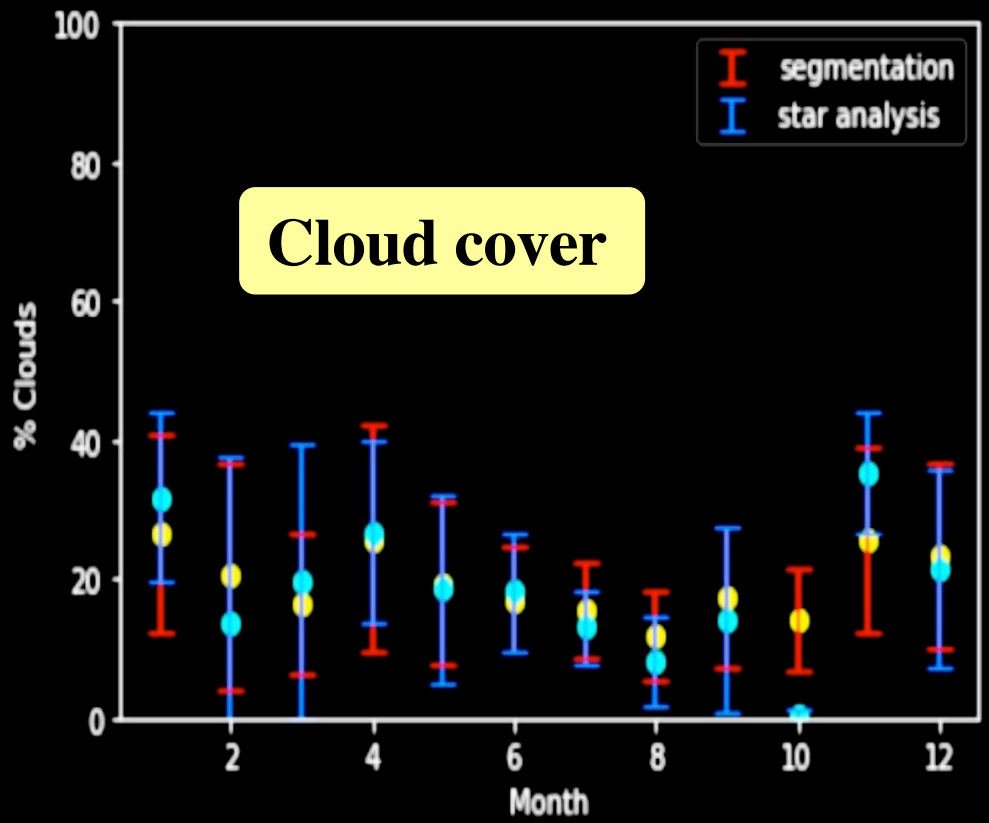
- Maïdo (2200m): Atmospheric Sciences observatory, built in 2012, operated by CNRS (INSU-OA)

Current site testing at Maïdo Observatory

- Meteorological conditions : FTIR station running from 2013 (temperature, humidity, wind, …)
- GNSS : integrated water vapor
- Cloudiness : all-sky camera
- Seeing, extinction coefficients : to be done in 2022 (LF, Renaud, et al. + LUPM)

→ excellent conditions, especially in southern winter time (e.g., IWV comparable to Paranal in summer time)





Spec. overview

- 2 parallel telescopes (each with 280mm primary mirror) on a single robotic mount
- CMOS detectors at prime focus, 1.2”/px, 61MPx each
- Total FOV : 9.7 deg^2
- R~20 mag in 5 min (5σ)
- Location: Maïdo obs. (Reunion)

- Default pointing strategy : survey preceding the LSST visits, ~8-10h ahead of Chile

Science

- **Fast evolving high-energy transients**

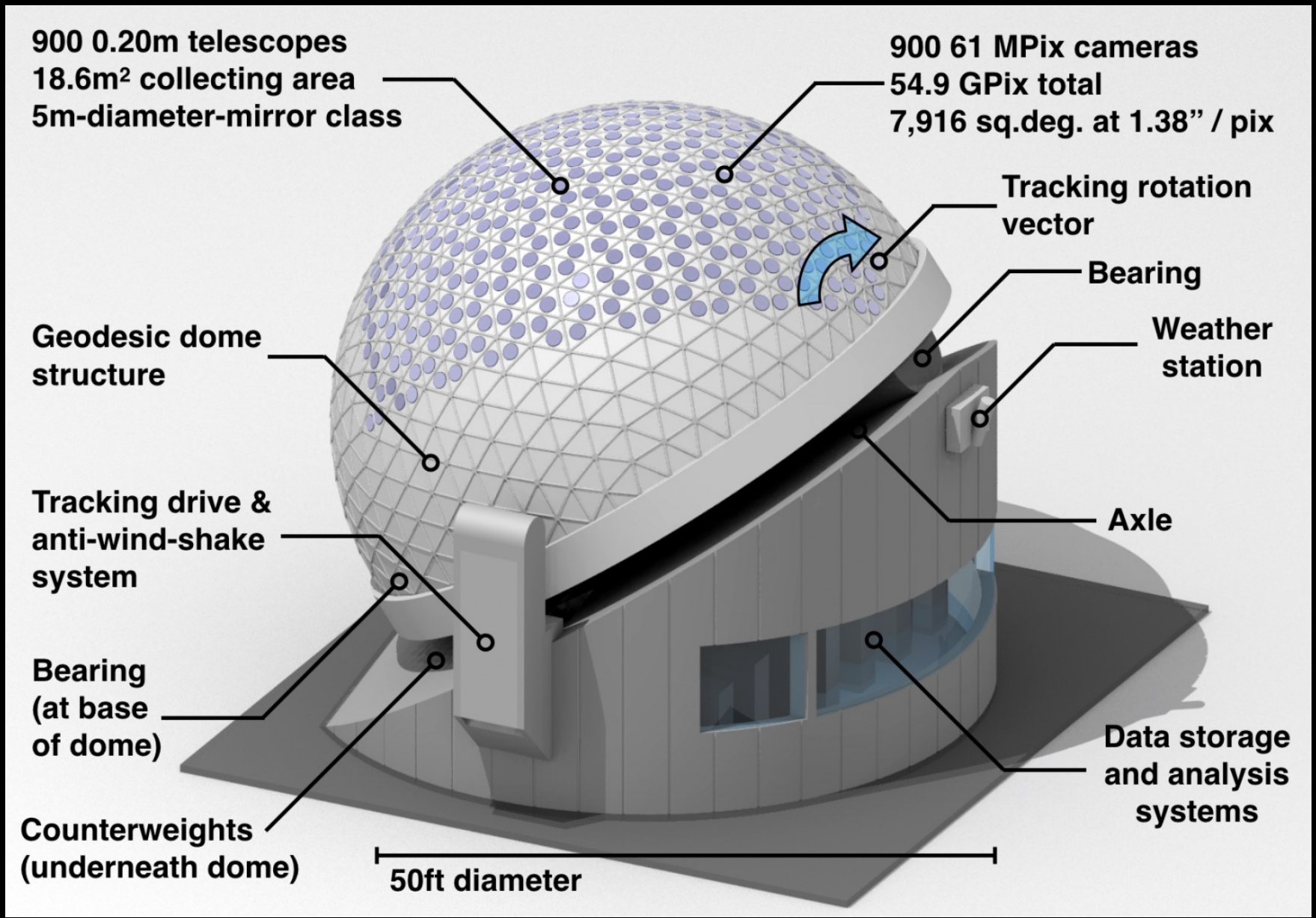
- Moving sources ??
- Other SNe ??

Fully open project :

Please join us !!!

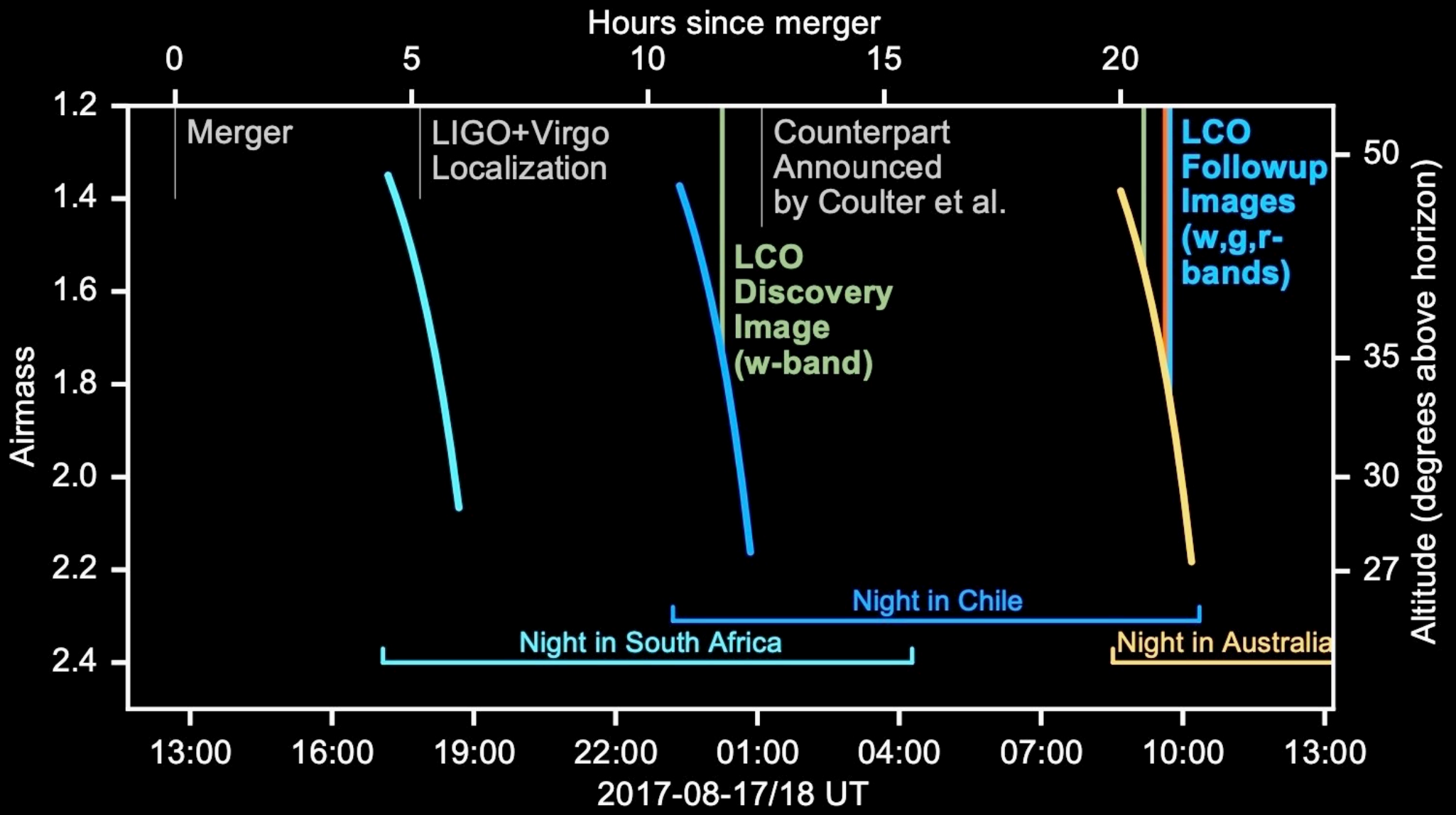
(Cr.: CNRS phototeque)

The Argus Telescope Array



Law et al. 2021

Back-up slide



Arcavi+17, Nature (LCO detection of GW170817 optical counterpart)