

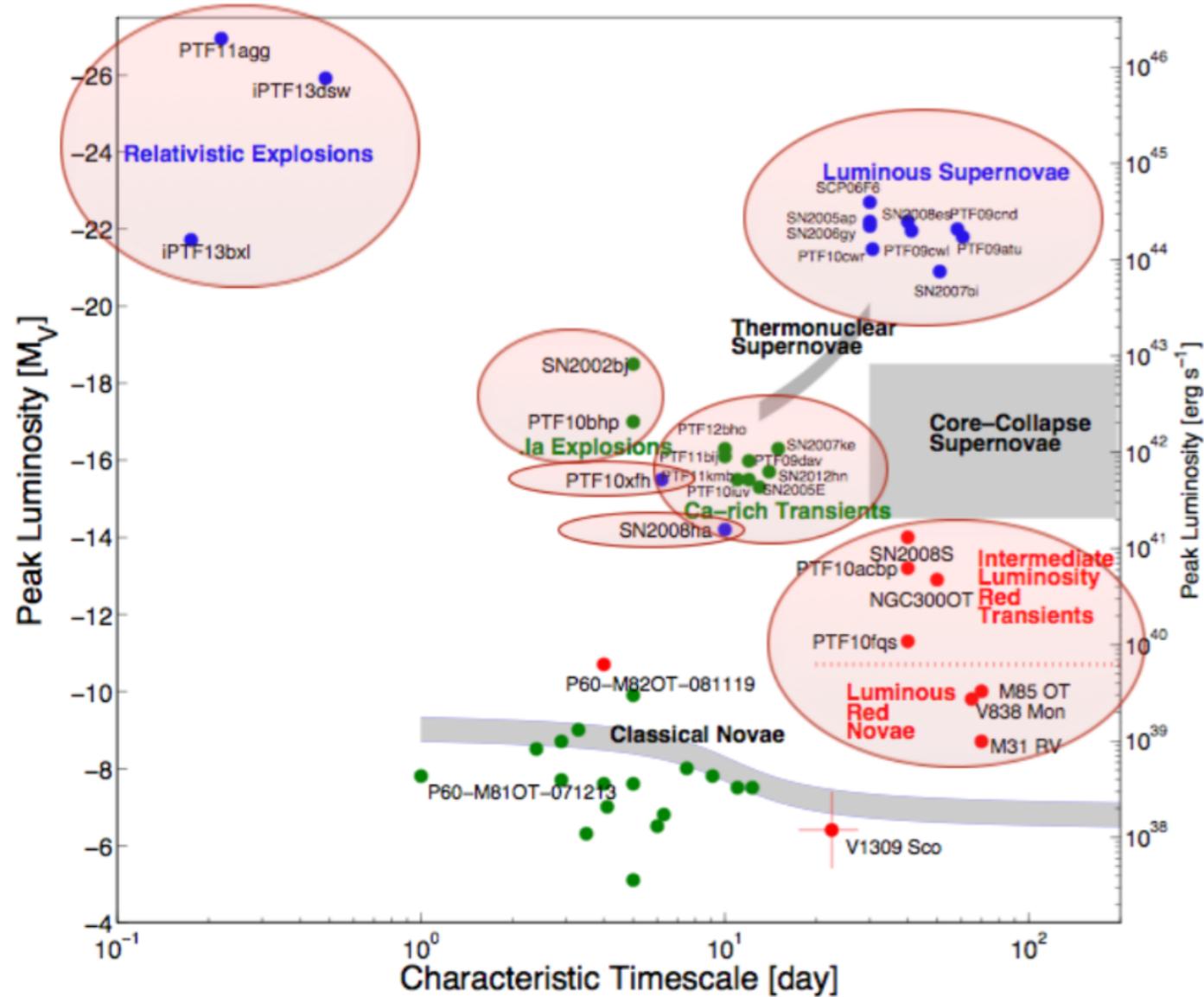
# Transients à LSST

Documents de référence:

- LDM151
- LSE-163\_DataProductsDefinitionDocumentDPDD

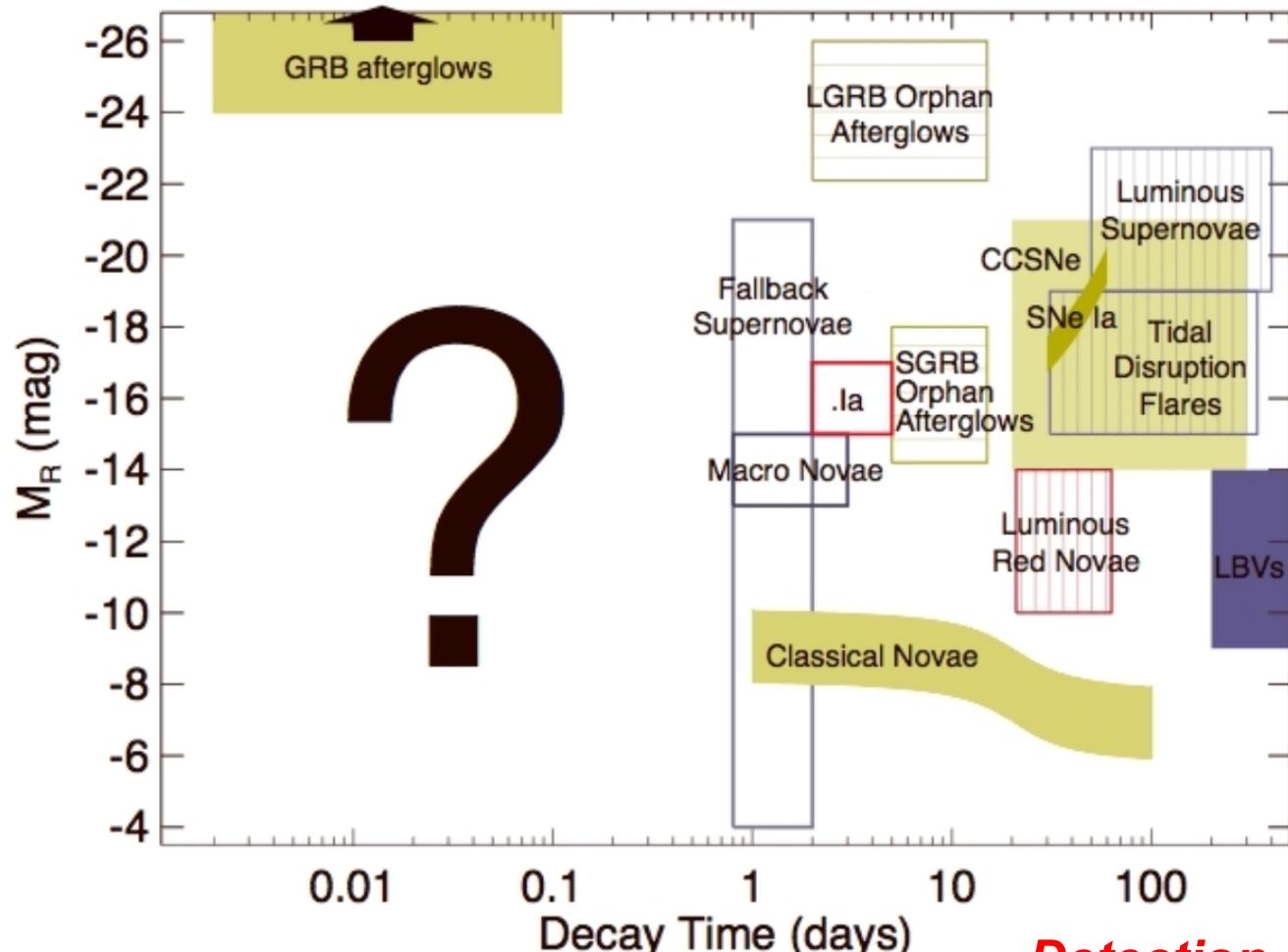
M. Moniez, LSST-France, Marseille, 18/01/2018

# The transient sky



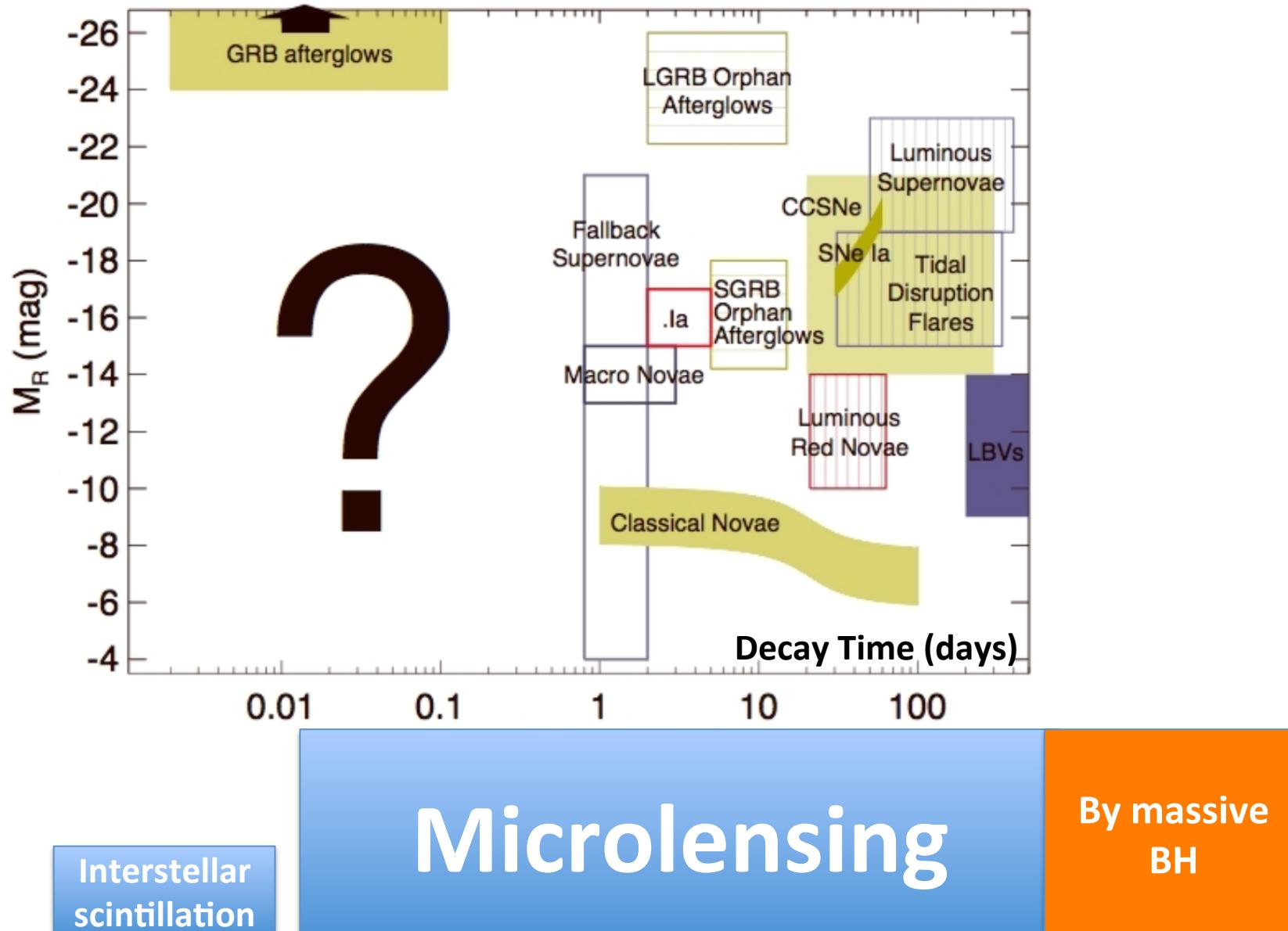
Updated from Kasliwal 2011 (PhDT) E. Bellm

# The transient sky

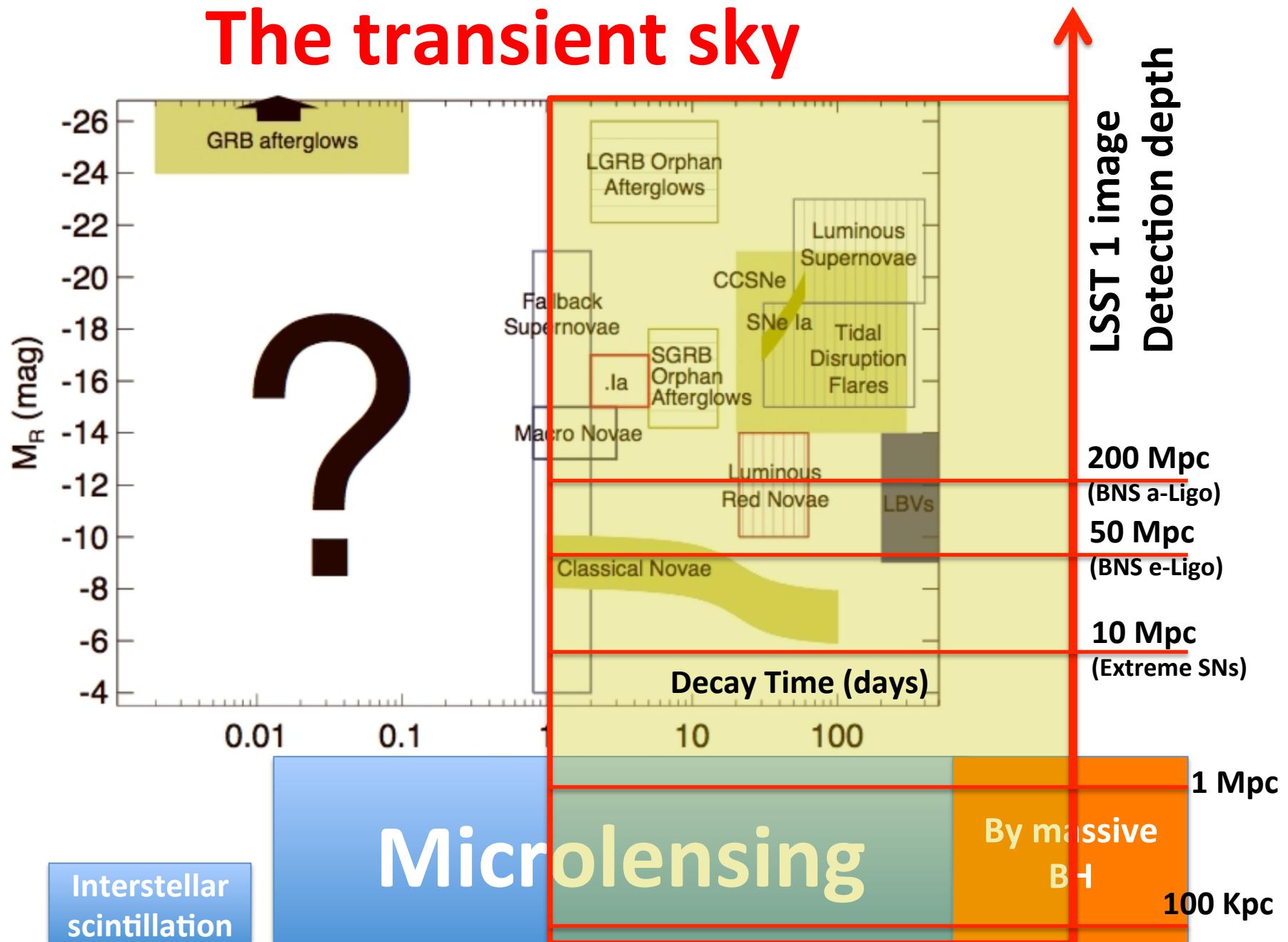


*Detection of transients  
announced within 60s.  
Expect ~ 1-10 million per night*

# The transient sky

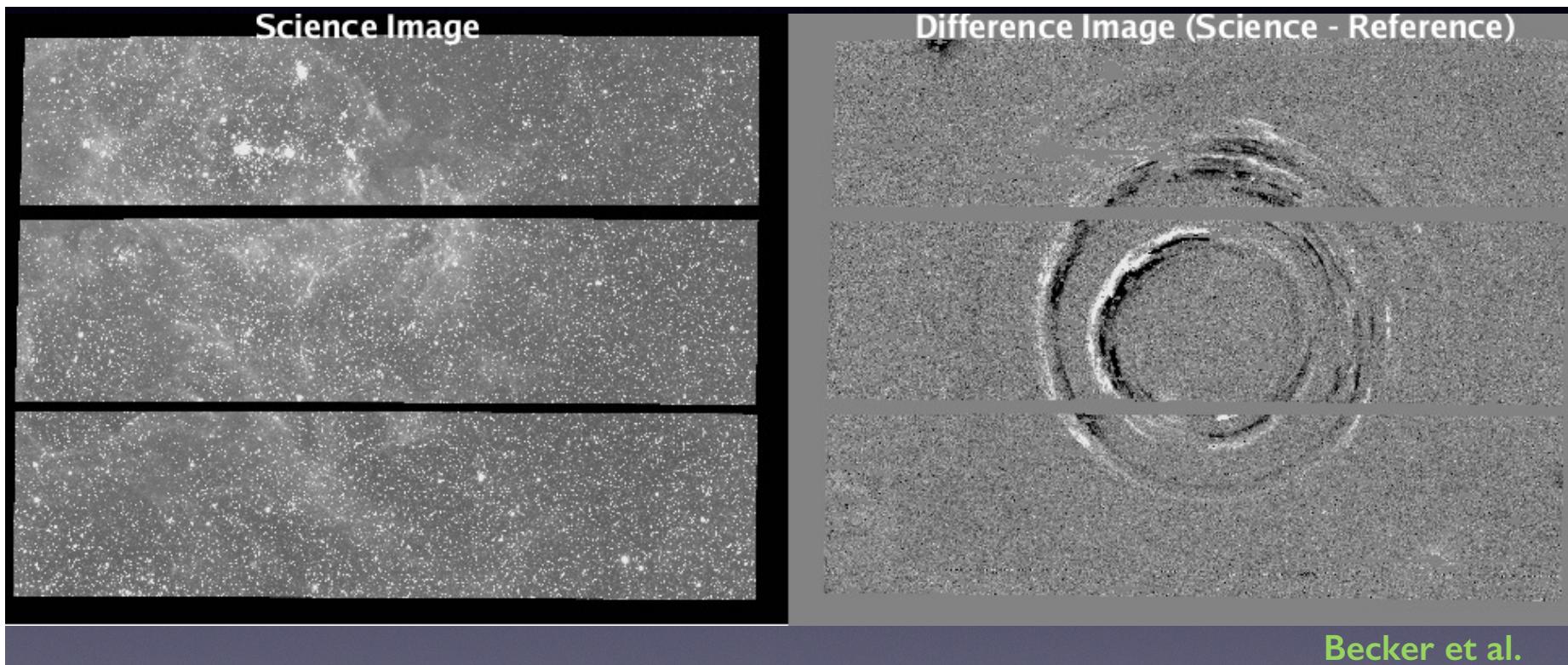


# The transient sky



# Not only point-sources

- LSST will extend time-volume space a thousand times over current surveys (new classes of object?)!
- Not only point sources - echo of a supernova explosion



# LSST visits

- the total number of visits is 2.45 million, with
- **85.1% spent on the Universal proposal (the main deep-wide-fast survey)**
  - **6.5% on the North Ecliptic proposal**
  - **1.7% on the Galactic plane proposal**
  - **2.2% on the South Celestial pole proposal**
  - **4.5% on the Deep Drilling proposal (5 fields)**

# LSST Observing Cadence

<https://www.youtube.com/watch?v=PKNal3fAST4>

- Pairs of 15s exposures (to 24.5 mag) per visit to a given position in the sky
- Visit this position again within the night with another pair of exposures
- Number of 9.6 sq.deg FOV visits per night: **900**
- Fields in the **main survey** revisited every ~3 days in every filter, and every ~15 days in *r* band
- **Deep-Drilling:** 1 hour/night. 50 consecutive 15s exposures x 4 filters
- Median slew time between visits = 5s
- Average slew time between visits = 12s

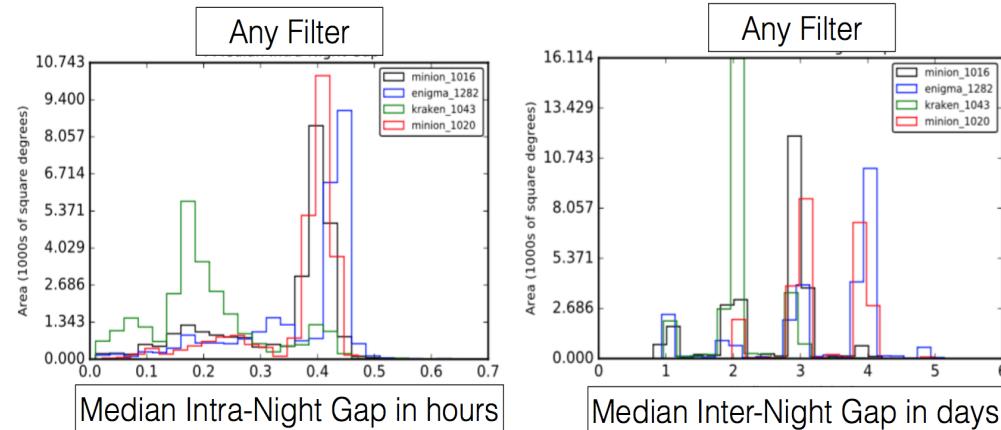


Figure 6.2: Histograms of median intra- (left) and inter- (right) night visit gaps for any band for several OpSim runs.

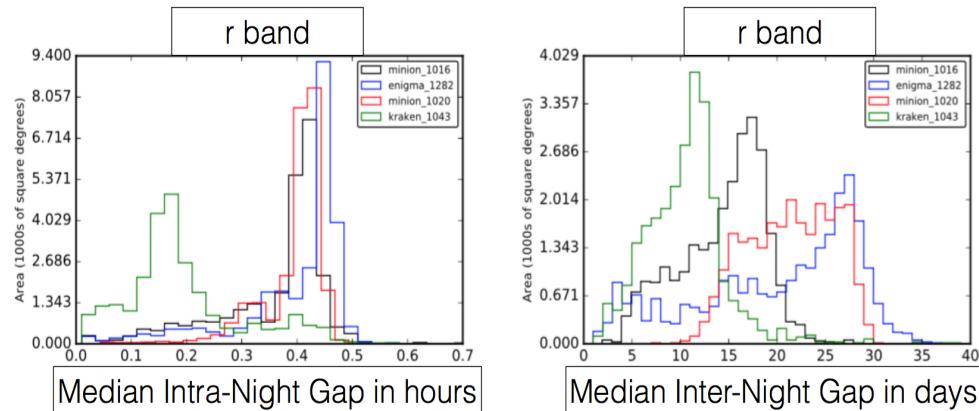


Figure 6.3: Histograms of median *r*-band intra- (left) and inter- (right) night visit gaps for several OpSim runs.

# Alert generation Pipeline

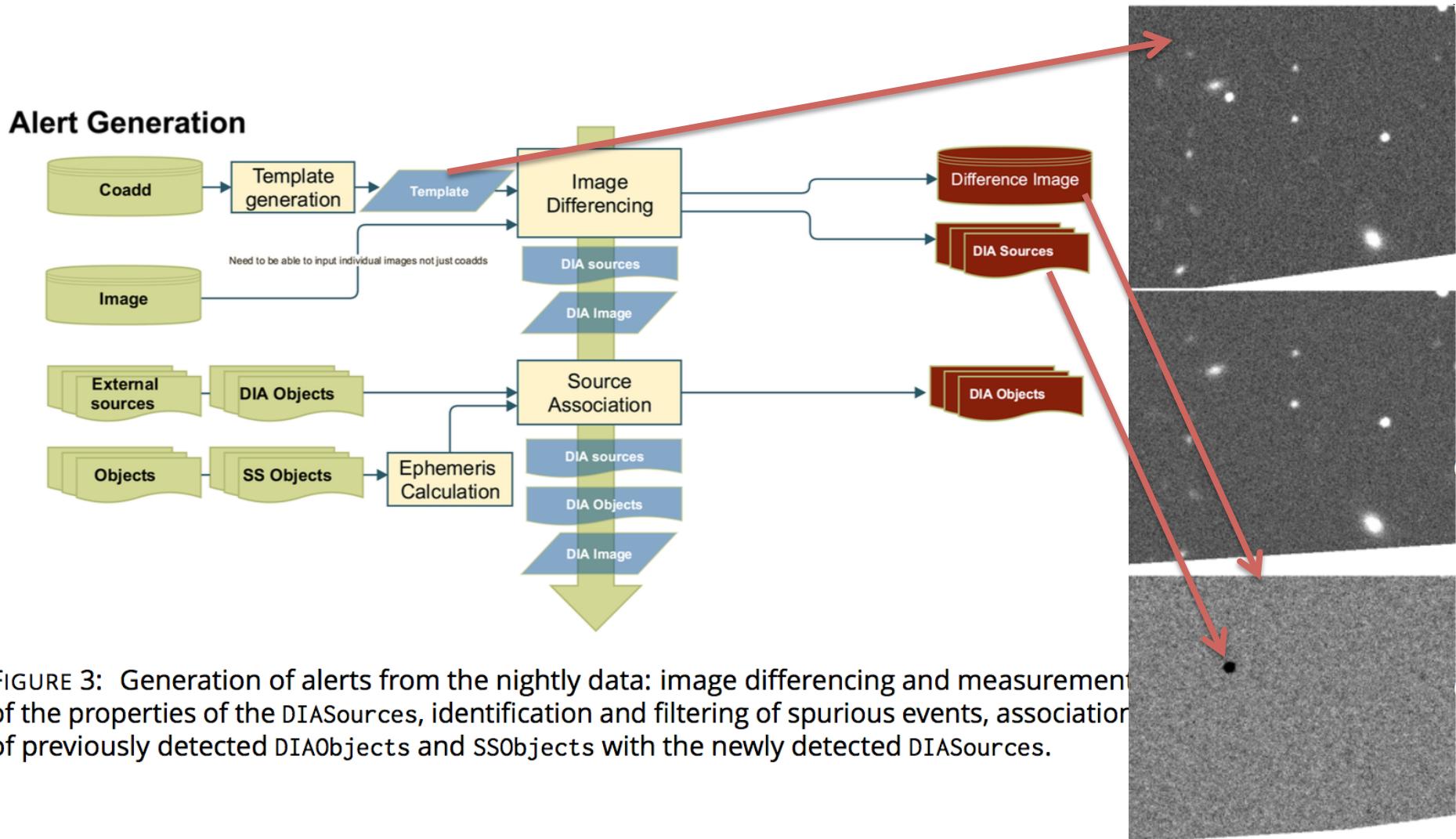
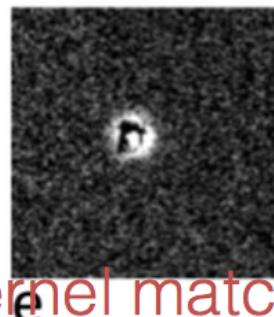


FIGURE 3: Generation of alerts from the nightly data: image differencing and measurement of the properties of the DIASources, identification and filtering of spurious events, association of previously detected DIAObjects and SSObjects with the newly detected DIASources.

# Déclenchement niveau 1

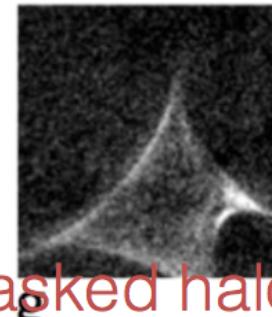
- **Alerte** = apparition/disparition de source sur images différentielles à  $5\sigma$  (correspond à une probabilité théorique de fausse alarme de  $5.7 \times 10^{-7}$ , mais...)
- Opérations différence / détection / caractérisation de source DIA en <24s
- Challenging: éliminer toutes les sources de fausse détection
- Les alertes seront livrées en 60s
- **Etoiles variables, SN et tout le reste**
- -> filtrage robuste de 1-10 millions de sources différentielles/nuit (10000/visite, 50/CCD) et follow-up rapide



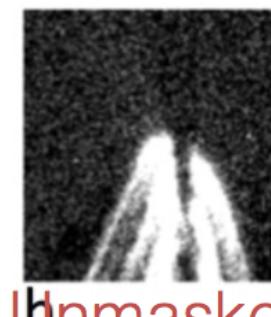
e Kernel matching failure



f streak



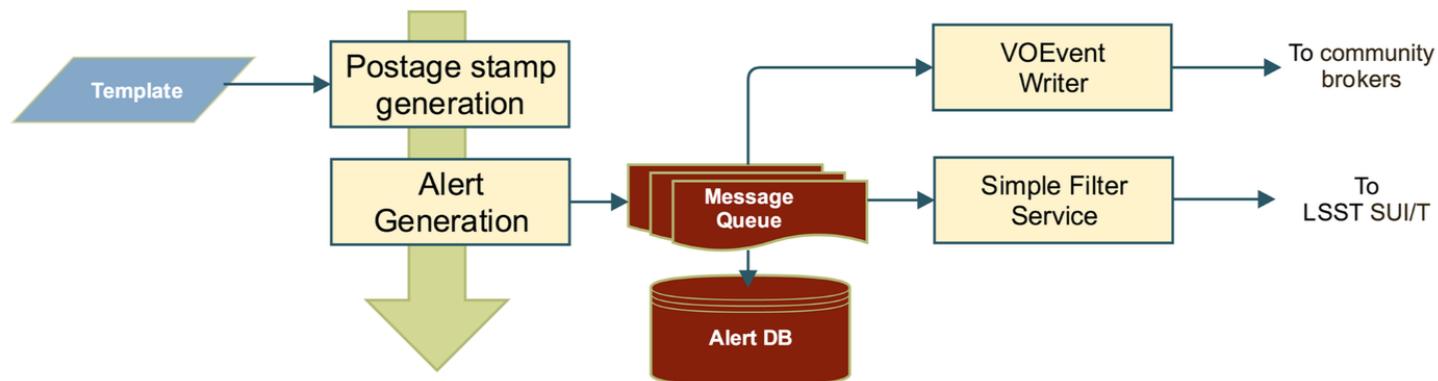
g Unmasked halo



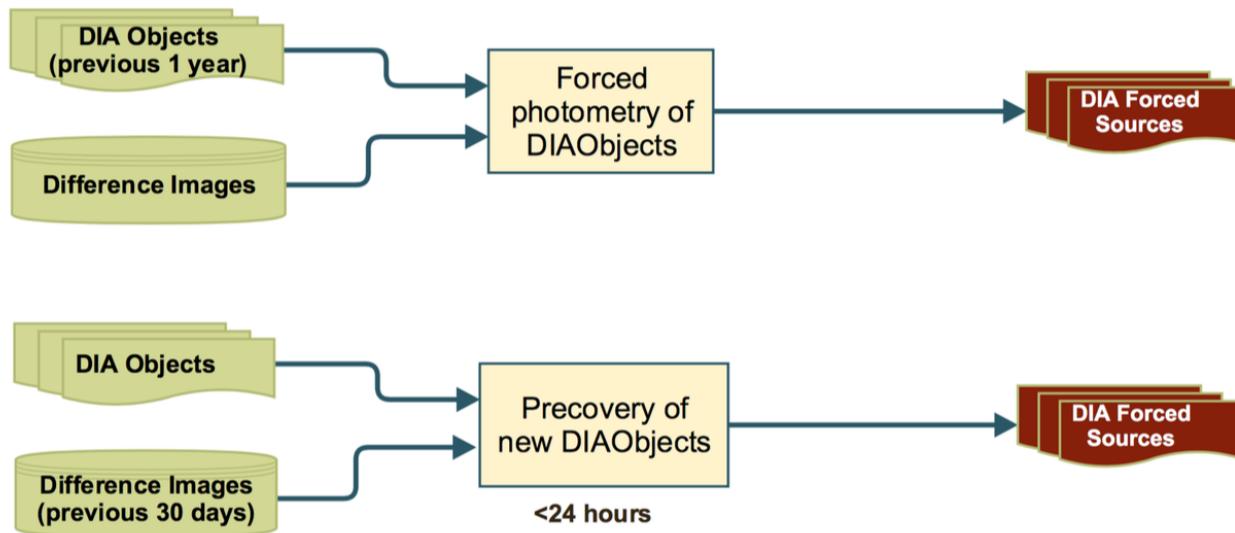
h Unmasked glint

# Alert distribution and post processing

## Alert Distribution



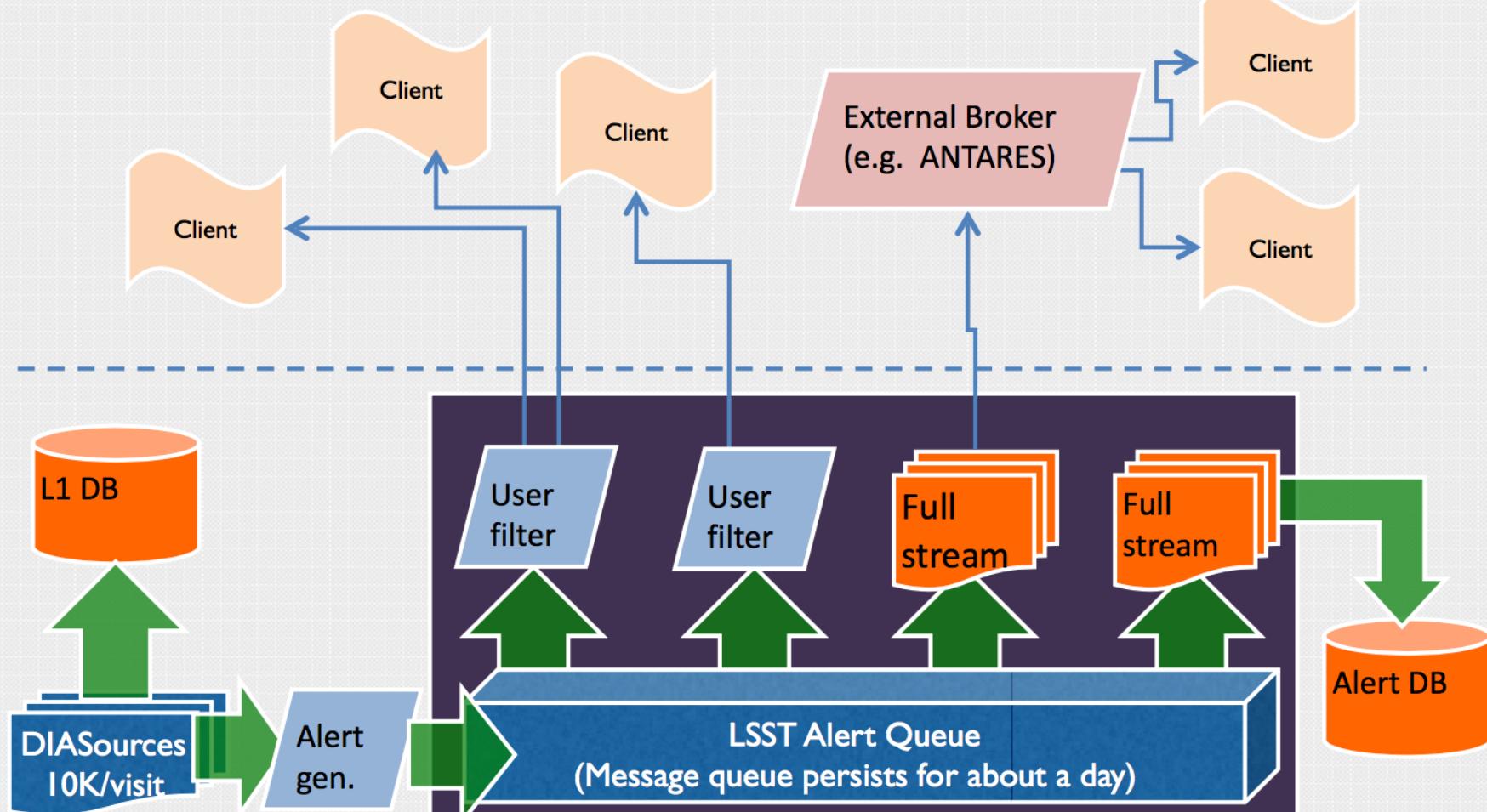
## Recovery and Forced Photometry



# Livraison (60s)

- Positions, formes (moments), PSF, flux et (co)variances
- Estimation fiabilité de l'alerte
- Découpe 30x30 pixels sur image différentielle, et image de référence (avec masque et variance)
- 6 mois d'historique: variations associées à l'objet trouvé en imagerie différentielle
  - Caractéristiques de variabilité (mais pas d'astro)
  - Environnement (objets voisins)
  - IDs, distances des objets voisins dans le processing annuel.
  - Détails dans lsst/LDM-151
- Les alertes alimenteront des « brokers » (1 en préparation en UK)

## LSST alert distribution requires a new community ecosystem.



At ~20 full sized events per visit per user (or summarizing the lightcurve for all events in ~40 numbers) we can serve ~500 simultaneous users for the cost of a single full data stream

# Alerts...

*Detection of transients  
announced within 60s.*

*Expect ~ 10 million per night*

**Given a stream of ~ 10,000 DIASources every ~ 40s (per 10 sq.deg. field)**

- Asteroids will dominate on the Ecliptic, become insignificant >30° from it.
- Variable stars (~ 1 % of all stars) will dominate in the Galactic plane, always significant (~ **400/field** @ Galactic pole)
- Quasars will contribute up to **500/field** (but likely several times lower)
- SNe will contribute up to about **100/field**

**Discovery rates will drop fast (factor of ~ 100 after 2 years)**

new DIASources will become dominated by cataclysmic variable stars and quasars

# Trigger <-> LSST dans tous les sens

LSST alerts -> immediate trigger follow-up for specific events

- Microlensing (with caustic crossing) -> *Dark matter*
- SNe
- Asteroids
- ...

Search for optical counterparts AND trigger follow-up

- GW -> *Hubble constant* (with spectro-z)
- GRB afterglows
- Neutrino sources
- High Energy cosmic ray sources

Trigger LSST-searches?

- For exceptional opportunities only (LSST is a survey): GW found in a few LSST-pointings, follow-up by others
  - with negligible false positive

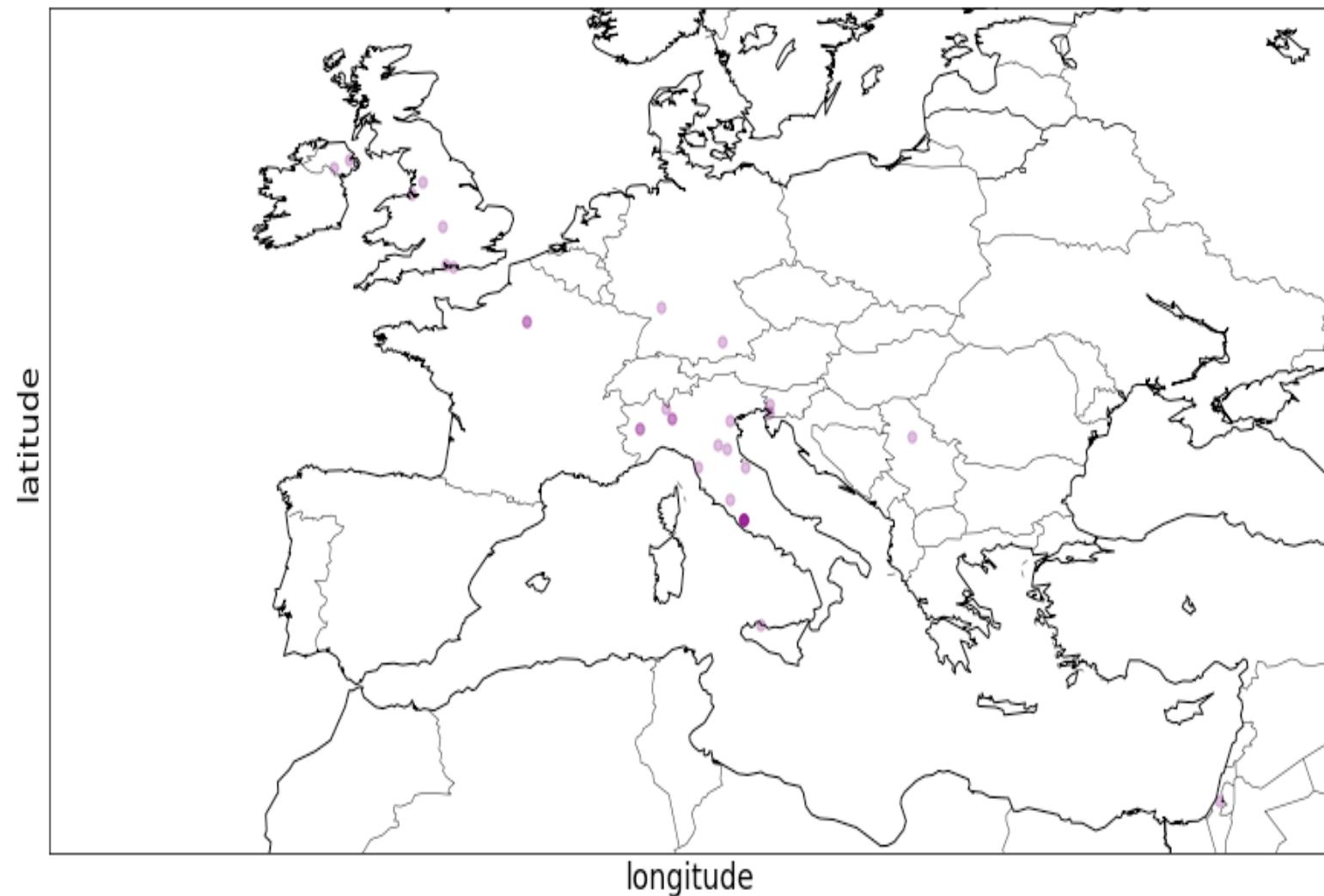
----- Time critical, and careful specific filtering -----

**BUT specific LSST alerts can be used**

- to retroactively search for localized events in the interferometer records
- > Potential factor 2 for GW searches

# Compléments

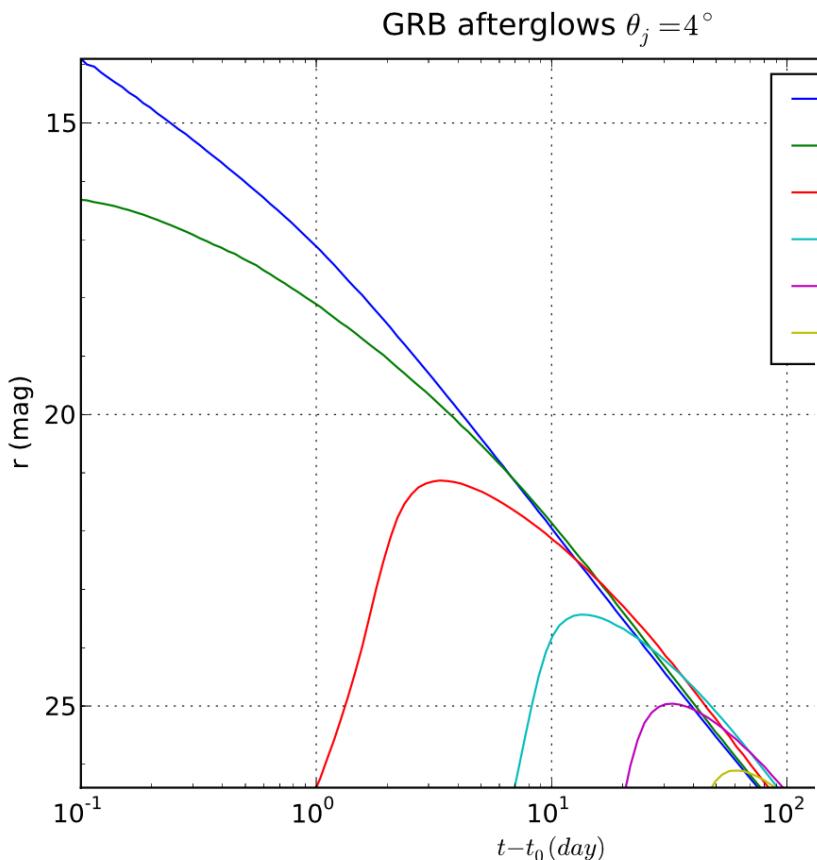
# Participants européens



# Alerts will be available through a hierarchy of services

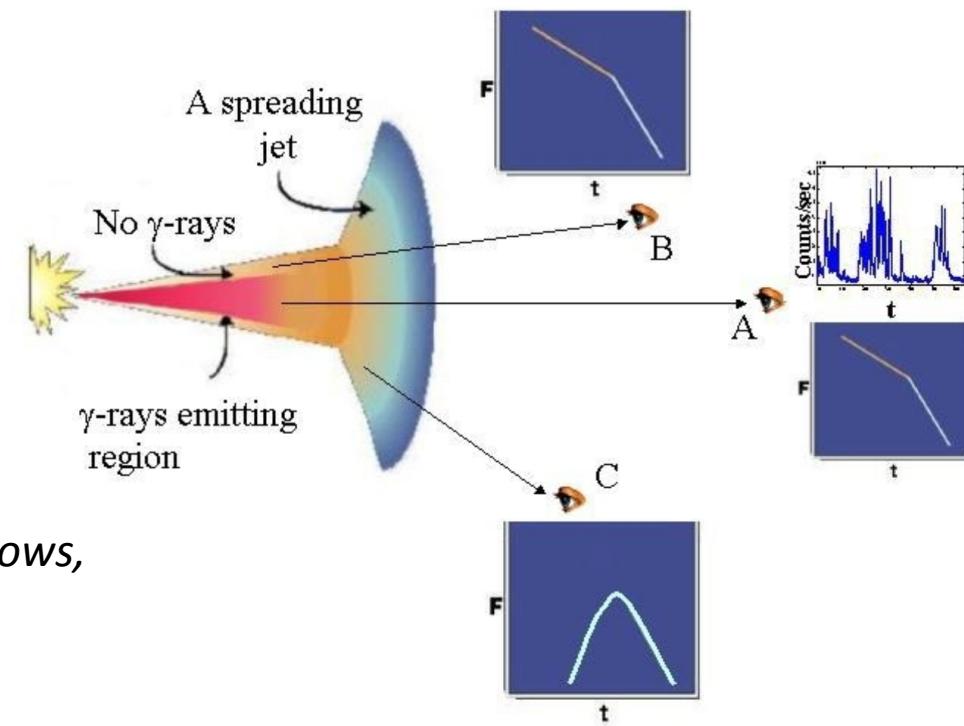
- **External value-adding systems (“brokers”: e.g., ANTARES)**
  - Validated and tested systems that ingest the full LSST data stream and provide additional information about events (e.g., astrophysical classifications, matches to external datasets)
  - Systems that rebroadcast the LSST data stream (a cascade effect increasing the number of access points without needing bandwidth)
- **A limited LSST filtering service (“mini-broker”)**
  - Configurable agents that return subsets of the attributes of events (e.g. summaries of the light curve, exclusion on cutout images)
  - Access to these agents will be through standard VOEvent clients and will require authentication
- **Access to historical alerts through the L1 and alert databases**
  - L1 DB: query for DIAObjects/DIASources/SSObjects by properties
  - Alert DB: enables training of brokers/classification algorithms by replaying previous alert stream

# Detection of $\gamma$ -ray burst afterglows

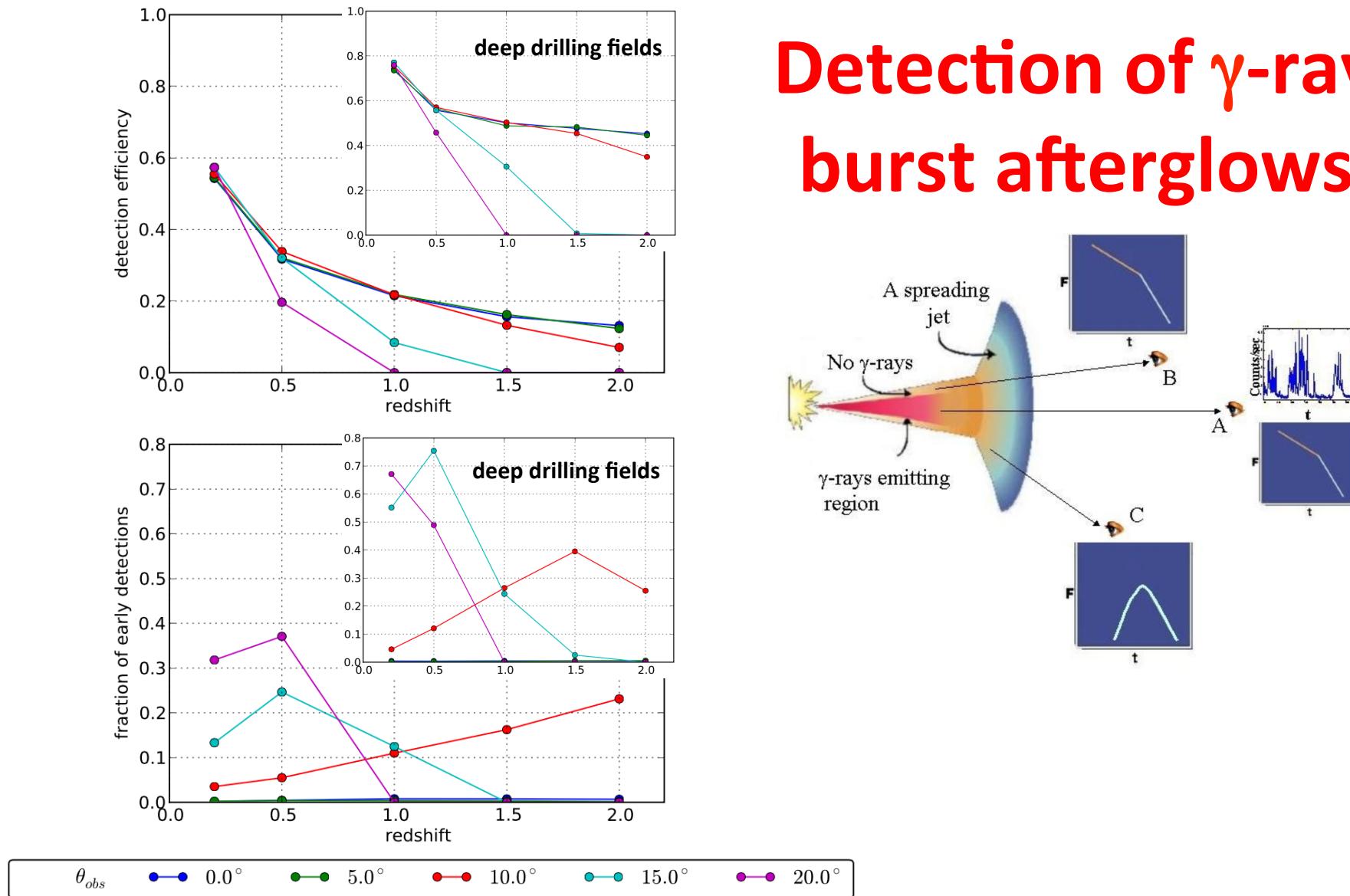


*Predicted light curves of GRB afterglows,  
assuming a source redshift  $z = 1$*

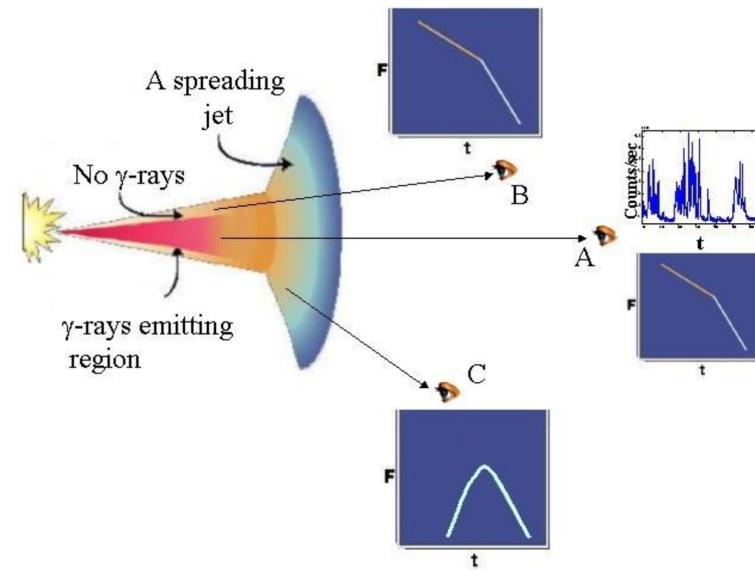
**Visibility delayed  
depending on angle**



# Detection of $\gamma$ -ray burst afterglows



At  $\theta_{obs} \approx 20^\circ$  only the closest events ( $z < 0.5$ ) are still accessible to LSST



# Horizon ?

- **GRB afterglows horizon**
- **GW within the local galactic group**  
(NBS coalescence)
  - Expect to detect counterparts with the sun luminosity or more
- **GW detectors' range**  
(neutron star coalescence)
  - > at the time of LSST: O(100)Mpc ->  
Detect counterparts with absolute magnitude < -10 (@horizon)
- **AUGER detector's horizon (GZK cut)**
  - 100Mpc for  $E\gamma > 10^{20}$  eV

