Astronomie des transitoires: coordination

Nicolas Leroy, Benoit Mours,
Julien Peloton, Frédéric Piron
With many co-authors and endorsers

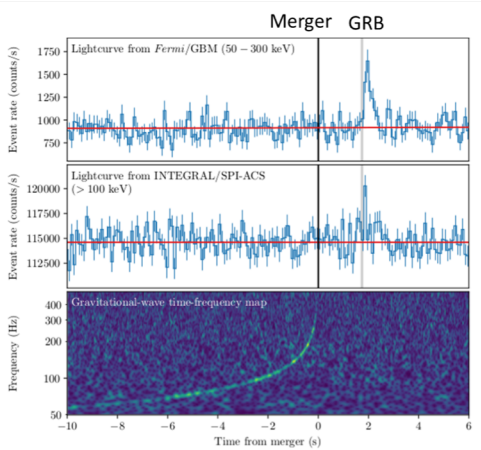
Mutli-messengers observations

GW170817 with AT2017gfo was very rich in physics

- First common detection
- Speed of gravity
- Equivalence principle tests
- Cosmology with H0

Many more candidates of GW events are observe in O3

- 36 unretracted candidates up to now : mainly BBH, few BNS
- Possible first NSBH observed
- Not yet confirmed counterpart observed



S191109d	BBH (>99%)	Nov. 9, 2019 01:07:17 UTC	GCN Circulars Notices | VOE		1 per 2.062e+05 years	
S191105e	BBH (95%), Terrestrial (5%)	Nov. 5, 2019 14:35:21 UTC	GCN Circulars Notices | VOE		1 per 1.3881 years	
S190930t	NSBH (74%), Terrestrial (26%)	Sept. 30, 2019 14:34:07 UTC	GCN Circulars Notices | VOE		1 per 2.0536 years	
S190930s	MassGap (95%), Terrestrial (5%)	Sept. 30, 2019 13:35:41 UTC	GCN Circulars Notices | VOE		1 per 10.534 years	
S190928c		Sept. 28, 2019 02:11:45 UTC	GCN Circulars Notices | VOE	No public skymap image found.	1 per 4.7092 years	RETRACTED
S190924h	MassGap (>99%)	Sept. 24, 2019 02:18:46 UTC	GCN Circulars Notices | VOE		1 per 3.5493e+10 years	

Need fast reactions and coordination

Need to have optimal follow-up

- Alerts as soon as possible
- Good coverage in electromagnetic spectrum
- From large field of view to spectroscopic capacities

Next generation of instruments will bring lot of alerts

- How to filter ?
- What to follow ?

Need also some coordinations of our community and increase our visibility

Low latency GW alert system

Auteurs: B. Mours (IPHC)
Coauteurs : les groupes Virgo de l'APC, d'ARTEMIS, de l'ILM, de l'IPHC, de l'IP2I, du LAL, du LAPP et du LKB

Real Time GW astronomy

Motivation: strong GW are produced during the most violent transient phenomena

- Like the merger of two compact objects,
- Release of a large amount of energy in a short time → transient events
- Can be associated with a variety of signatures
  - Electromagnetic signals or high energy particles – with timescales from seconds to weeks

Real time (RT) GW astronomy

- Find GW events and publish alerts ASAP to enable multi-messenger astronomy ?
- What to follow ?

RT GW astronomy: a discovery process to get answers to scientific questions

- Example: Hubble constant with GW is best done with EM counterpart.

Open-minded process with loose assumptions on the searched events

- Excess of energy searches and large parameters space for template based searches
- Rewarded by the discovery of heavy stellar BH population during the O1 and O2 runs

RT GW astronomy: some questions

What should be the parameter space used for the searches?

- Examples
  - Should we search for objects lighter than the usual 1 solar mass cut?
  - Should we consider higher spins for low mass system?

Should we put the same weight on all sources?

- What are the parts of the parameter space that are more likely to capture the not (yet) so well-known astrophysical source population that deserve counterparts search?

The low frequency sensitivity of the detectors is expected to improve

- It will increase the size of the template bank (already ~ 1 million of templates)
- How do deal with more and longer templates?

Detectors are not perfect

- How do we make the best use of data quality information that must be produced in real time with multiple detectors of different sensitivities and not perfect duty cycle?

RT GW astronomy: latency

RT GW astronomy needs low latency calibrated data

- Reducing the current h(t) latency (10-20 seconds) requires improving the whole chain
  - DAQ system, h(t) reconstruction, data distribution.
  - Keeping the reliability of the h(t) stream and of the data quality information.

RT GW astronomy usually has two steps.

- Detection of candidates with initial parameters estimation, currently done in less than a minute.
  - Detection pipeline improvements are needed.
- More refined estimation of the parameters, could take many hours.
  - Need to develop parameter estimation tools providing the best results as soon as possible.

Multiples pipelines are running parallel searches to produces alerts

- How do we handle the aggregation of results from pipelines to get reliable alerts?
- How do we reduce the latency of the alert system?

What should be the target for the latency?

- What will be the latency of the non GW observatories in the long run?

RT GW astronomy: Pre-alerts?

CBC sources are observed before the final merger.

Dream: send pre-alerts to point telescopes and observe the EM counterpart.

- Requires updated algorithms and data analysis pipelines, (and improved LF sensitivity)
  - Able to deal with evolving information as the signal accumulate

An even more challenging dream: tune in real time the sensitivity of the detectors as the signal sweeps up the frequency band,

- Goal: collect more information on the high frequency part.
  - Better sky localization and science of the high frequency (EOS)
- Is this feasible? What is the cost/benefit ?

RT GW astronomy: other remarks

Online GW searches are connected to the offline searches

- Improvement in one type of searches benefit to the other one.

3G detectors should offer more than 3 orders of magnitude in the event rate

- How do we handle this rate, the pileup of events, and highlight the most interesting events?

Should we have different policies for subthreshold events?

- They will be produced with an even higher rate…

How is the science done in an open model?

- What is the return for people developing detectors and analysis pipelines?

A community broker by LSST-France

Principal (corresponding) author:
Name: Julien Peloton
Institution: LAL
Email: peloton@lal.in2p3.fr
Phone: +33 1 64 46 84 90

Co-authors and endorsers:
Alexandre Boucaud, Alexis Coleiro, Cyril Lachaud (APC)
Ada Nebot Gomez-Moran (CDS, ObAS)
Damien Dornic (CPPM)
Chris Arnault, Jérémy Neveu, Julius Hrivnac, Marc Moniez, Nicolas Leroy, Stéphane Plaszczynski (LAL)
Didier Verkindt, Dominique Boutigny, Marina Ricci (LAPP)
Anais Möller, Emille E. O. Ishida , Emmanuel Gangler (LPC - Clermont)
Johan Bregeon (LPSC)
Frédéric Piron, Johann Cohen-Tanugi (LUPM)

LSST & Transients

Now

Raw Data
Sequential 30s image, 20TB/night

Restricted data

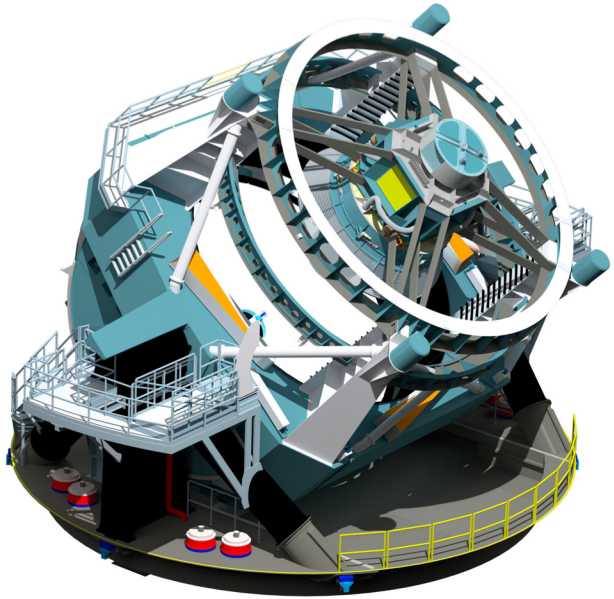
60s

Prompt Data Product
Difference Image Analysis
Alerts: up to 10 million per night

Public data!

?

Brokers & astronomy community
Follow-up, enrichment, classification, ….



Some Challenges...

Covering many science cases...

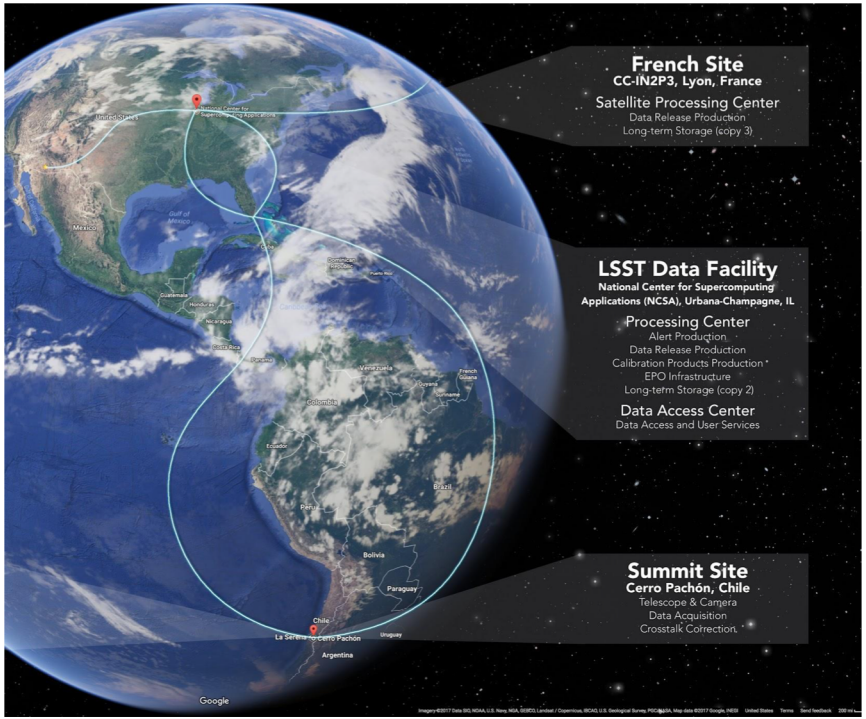
- Dark Energy & Dark Matter
- Solar System & Milky Way
- Multi-messenger astronomy

… with a deluge of data…

- ~10 million alerts per night
- ~82KB/alert, 800GB/night, 3PB total

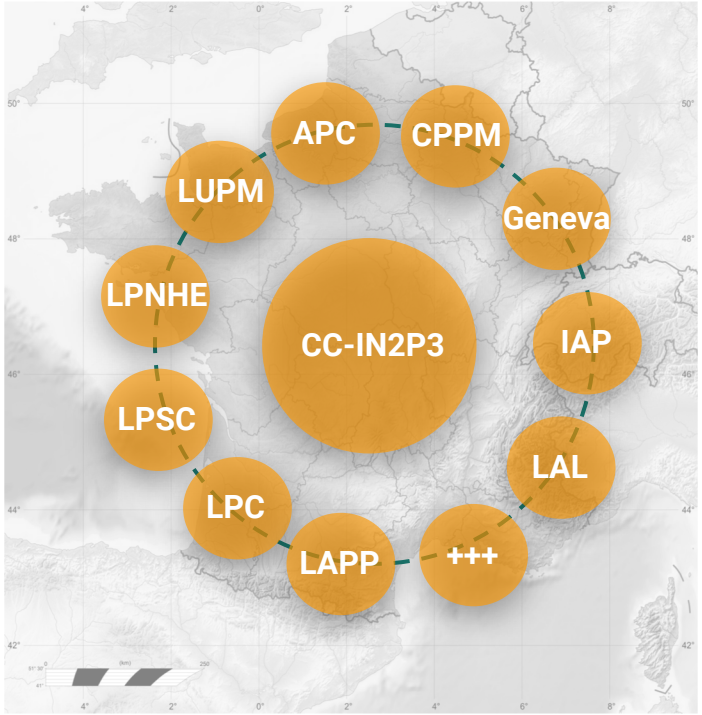
… In a minimum amount of time!

- 98% of alerts @ t+60s and processed before the next night!
- Often need quick follow-up



Fink Collaboration

- IN2P3 initiative to propose a broker to serve the need of LSST-France as well as the different french multi-messenger astronomy actors.
- Growing support from the French community
    - ~40 endorsers from a dozen of laboratories.
- Phase of selection by LSST: 2019-2020.



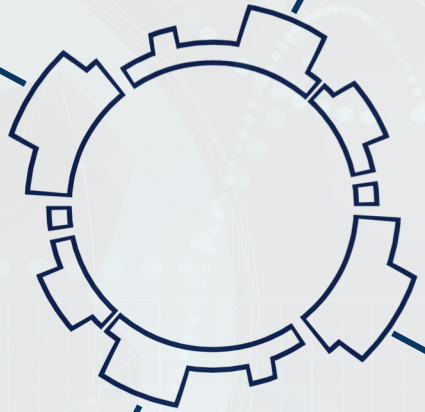
Fink Focus

Science

Supernovae / Microlensing
Anomaly detection / Multimessenger

Methods

Adaptive Learning
Bayesian NN



Interface

Streams ingestion & redistribution

Technology

Cloud computing
Big data processing

Fink for all

Done

Individuals

Subscribe to filtered streams and play with alerts.

Ongoing

Telescopes

communicate filtered streams, collect other streams and cross-match.

Ongoing

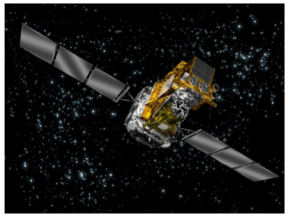
TOM, TNS, ...

Communicate filtered streams and publish new results.

CDS
CENTRE DE DONNÉES ASTRONOMIQUES DE STRASBOURG

TOM
TOM TOOLKIT Las Cumbres Observatory LCO

GRANDMA



SVOM

KM3NeT

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Keys for success

- Give to IN2P3, and the French community a strategic place in the transient sky for the next 10 years.
    - *Insure a stable, long lasting solution for coordination of alerts in MMA landscape. Increase competence in ML and big data.*
- The structuration of communities beyond individual experiments.
    - *All major IN2P3 experiments and beyond involved or targeted.*
- Connect different communities with efficient frameworks.
    - *Combining academic research with industry-level standards.*
- Sustain and benefit from activities already deployed or under development.
    - *IVOA, standard tools, communication protocols, networks of telescopes*

Organize the French community TS2020 - network

Auteur principal
Nom : **Frédéric Piron**
Institution : Laboratoire Univers et Particules de Montpellier (LUPM), CNRS/IN2P3
Courriel : piron@in2p3.fr
Téléphone : 04 67 14 93 04

Co-auteurs

- N. **Leroy**, LAL, CNRS/IN2P3

- C. **Lachaud**, A. **Coleiro,** S. **Antier**, V. **Van Elewyck,** S. **Pita**, A. **Kouchner**, É. **Chassande-Mottin**, APC, CNRS/IN2P3, Université de Paris
- D. **Dornic**, V. **Bertin**, P. **Coyle**, E. **Kajfasz**, CPPM, CNRS/IN2P3
- B. **Mours**, T. **Pradier**, IPHC, CNRS/IN2P3, Université de Strasbourg
- J. **Peloton,** F. **Robinet**, M. **Moniez**, LAL, CNRS/IN2P3
- F. **Marion,** L. **Rolland,** D. **Verkindt**, LAPP, CNRS/IN2P3
- J.-P. **Lenain**, O. **Martineau,** LPNHE, CNRS/IN2P3, Sorbonne Université
- J. **Bregeon**, LPSC, CNRS/IN2P3
- J. **Cohen-Tanugi**, A. **Marcowith**, M. **Renaud**, LUPM, CNRS/IN2P3, Université de Montpellier
- C. **Sauty**, LUPM/LUTH, CNRS/IN2P3/INSU
- M. A. **Bizouard**, M. **Boer**, N. **Christensen**, ARTEMIS, CNRS/IN2P3/INSU, OCA
- A. **Lamberts,** Laboratoires Lagrange/ARTEMIS, CNRS/INSU, OCA
- F. **Daigne**, K. **Kotera**, IAP, Sorbonne Université
- D. **Porquet**, LAM, CNRS/INSU, CNES, Université d'Aix-Marseille
- C. **Boisson**, H. **Sol**, S. **Vergani**, A. **Zech**, Observatoire de Paris, CNRS/INSU
- S. **Chaty**, A. **Claret**, D. **Götz**, F. **Schüssler**, IRFU, CEA Paris-Saclay

Transient sky @ IN2P3

- Numerous scientific themes within the IN2P3 "Astroparticles & Cosmology" perimeter
- Many among the most energetic sources are intrinsically transient : accretion/ejection around compact objects, collapse or coalescence
- Strong IN2P3 expertise and involvement in the construction and exploitation of major astroparticle experiments: ANTARES, Auger, H.E.S.S. (and predecessors), Fermi, Virgo
- New phenomena / new constraints: stellar mass BBH (more massive than expected), BNS with GW /SGRBs, TeV GRBs, cc-SNe and SN-Ia, Fundamental Physics (EOS, LIV, H0)
- Future is bright with the next generation of instruments: aVirgo, CTA, KM3Net, LSST, SVOM

Transient sky 2020 network

- Federate the French community interested in transient sky studies
- Discussions and meetings on instruments (and their complementarity) and modeling
- Having all components : GW, electromagnetic (radio to TeV), neutrinos, UHECR
- Prepare for the new generation of instruments
- Discuss recent developments (on models, tools, …) and how to share them
- 3 workshops already organized :
    - June 2017 : LAL, https://indico.in2p3.fr/event/14321/overview
    - June 2018 : LUPM, https://ts2020ll.sciencesconf.org
    - September 2019 : APC, https://indico.in2p3.fr/event/19471
- Funded by PNHE, University Paris-Sud, SKA-Lofar
- ~50 participants from IN2P3, INSU and Irfu

Main questions discussed (so far)

- Panorama of the next generation of instruments
- Scientific questions associated with transient sky
- Observation problems associated with these themes : type of telescopes, how to automatize alerts protocols, needs in spectroscopy, …

- Specific look on alerts
- Content and protocols used by the different communities
- Could we go towards a standardization
- How to use virtual observatories in that context

- Presentations on past and current efforts during the LVC O2 and O3a runs

Tools needed by our community

- Clear needs of common tools to avoid waste of efforts
- Can we organize the content of the alerts/report of observations
- Can we agree on format and protocols to be used
- Broker (e.g. FINK) needed to help classify LSST alerts (e.g., only one exceptional ToO / week with SVOM)
- Start discussion on tools especially for coordinated observations from different sites, for decisions
- Development of toolbox like ICARE done within GRANDMA and also used in SVOM
- Link with CDS and Target Observations Managers
- Links with International Virtual Observatory Alliance

Development of the community

- Link physicists/engineers from IN2P3, INSU and Irfu
- Many new instruments coming up, with many new challenges
- Importance of this scientific theme will grow in the next decade
- Clear need of better coordination : reinforce coordination between institutions
- Feeling that we are not in the core program of the different institutes and then quite complicate to appear as leader in the international competition
- Discussion on getting specific recruitments, a new CID is a possibility and has also been mentioned in INSU prospectives
- Suggestion to create inter-institute projects to foster the development of tools and share technical knowledge

What next ?

- New workshop planned in 2020
- Will be focused on tools with possible hand-on sessions
- Dedicated mailing list created (134 members as of today) TS2020-L@in2p3.fr
- Please contact us (piron@in2p3.fr, leroy@lal.in2p2.fr) if you want to join the network

Backup slides

Current prototype

Deployed broker instance for R&D in the VirtualData Cloud (UPSud)

- **Communication**: Apache Kafka cluster (5 machines, 20 cores)
- **Processing**: Apache Spark cluster (11 machines, ~200 cores)
- **Science DB**: Apache HBase (1 machine, 6 cores).

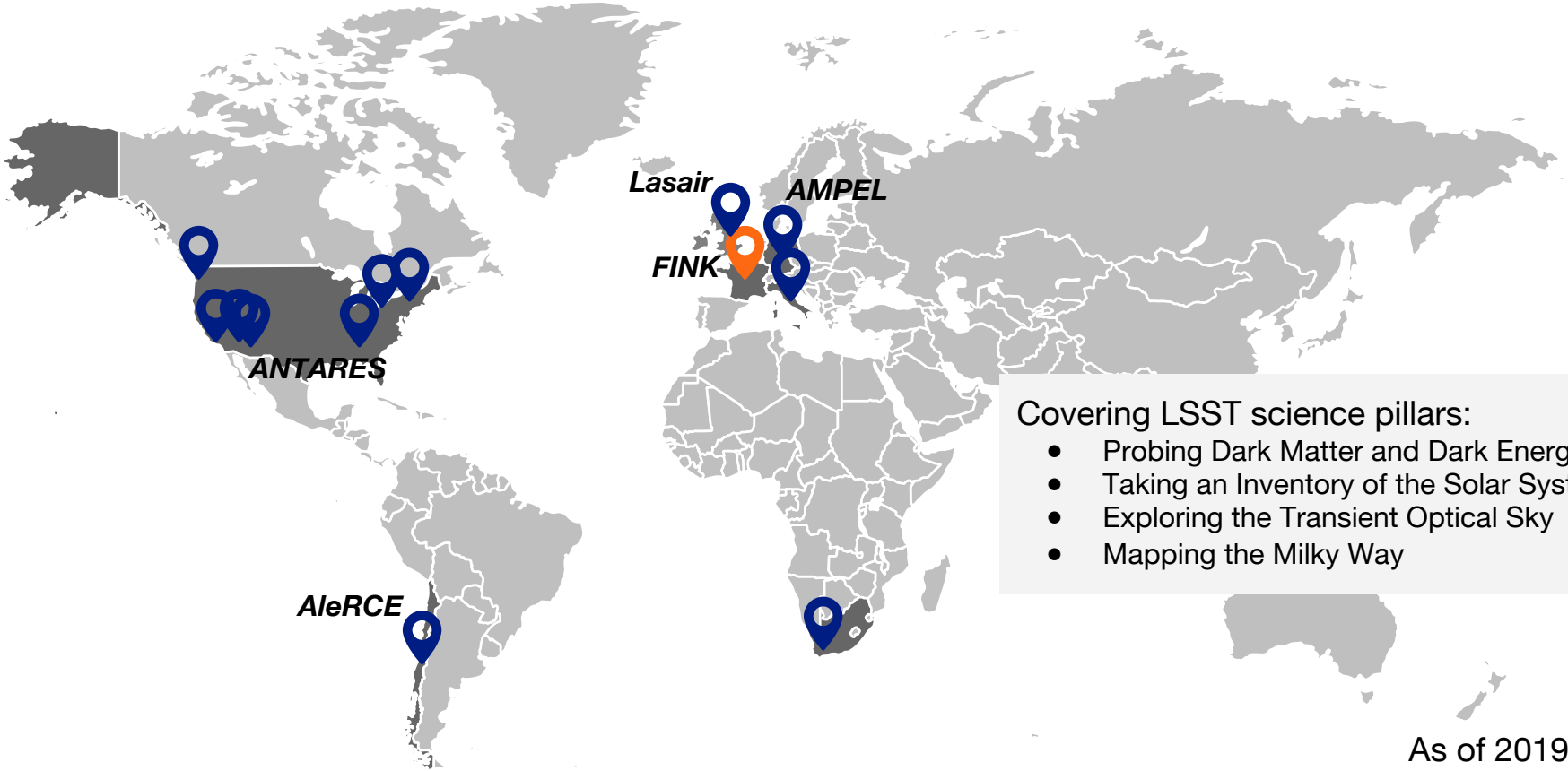
Science storage: 35TB distributed storage (HDFS, Ceph + s3)

Tests in near-real condition with good scalability:

- **LSST rate:** 10,000 alerts/30 seconds (tested up to 10x this with margins).
- **LSST science content:** Alerts coming from ZTF (LSST pathfinder).
- **Science filters:** Only simple filters active so far.

Client for physicists under tests.

LSST Broker landscape

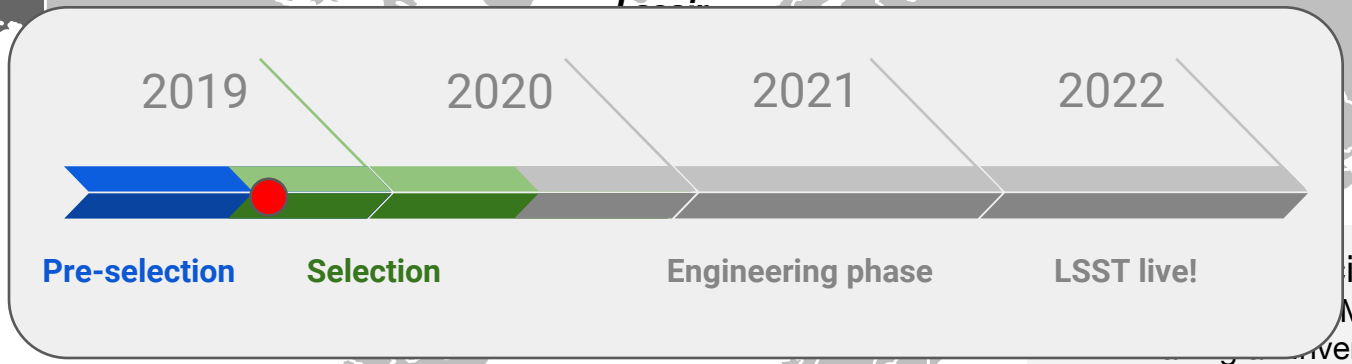


Covering LSST science pillars:

- Probing Dark Matter and Dark Energy
- Taking an Inventory of the Solar System
- Exploring the Transient Optical Sky
- Mapping the Milky Way

As of 2019

LSST Broker landscape



ience pillars:

Matter and Dark Energy

ventory of the Solar System

- Exploring the Transient Optical Sky
- Mapping the Milky Way

As of 2019

Fink in few dates

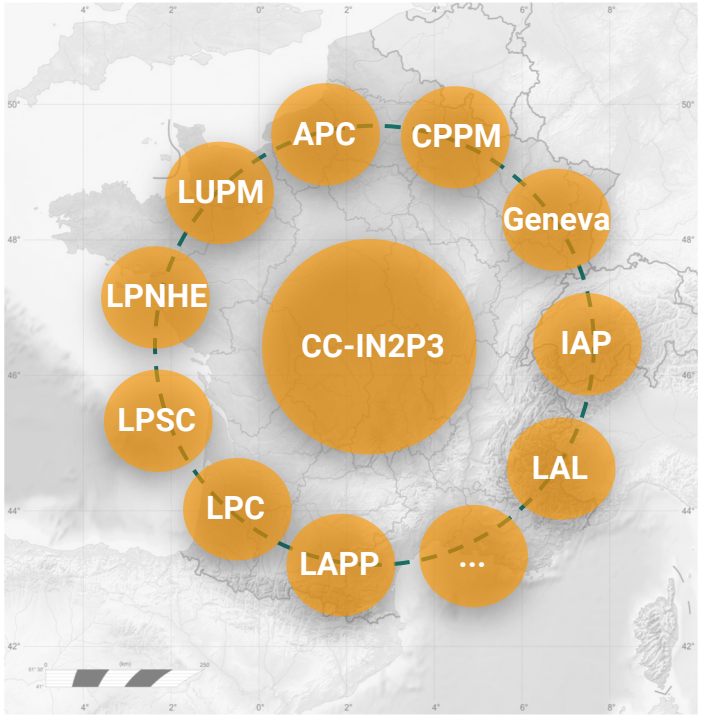
02/19: Start
- LAL & LPC

05/19: Letter of Intent.
- ~30 endorsers (IN2P3, INSU). ⅓ non-LSST.

06/19: LSST broker workshop
- Official presentation

08/19: Pre-selection by LSST
- Full proposal by Q2 2020

09/19: GT04 IN2P3 prospectives
- IN2P3 + INSU, CEA. ⅓ non-LSST.



Scientific goals

Optimize the scientific impact of LSST alerts for a set of science cases

Supernovae

Time Frame: days to months

- ≈30.000 well sampled type Ia SNe light curves per year
- ≈1000 are expected spectroscopically confirmed per year

Microlensing

Time Frame: hours to months

- Large impact on extra-solar planet search
- Explore the mass distributions and the Milky Way dynamics.
- LSST will reach fainter

Multi-msg Astronomy

Time frame: minutes to days

- Optical counterparts for many experiments: CTA, LIGO, Virgo, KAGRA, SVOM, KM3NET, …

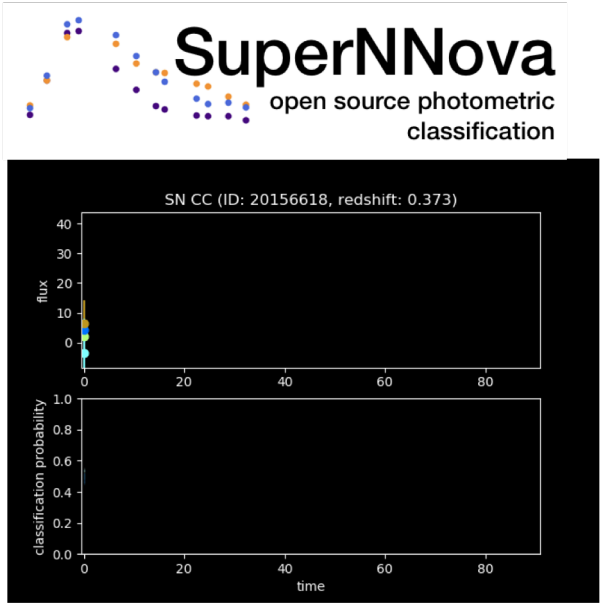
Anomaly detection

Time Frame: minutes to months

- Unforeseen astronomical sources is one of the most exciting outcomes.
- Should be more pronounced after a

machine learning for photometric classification

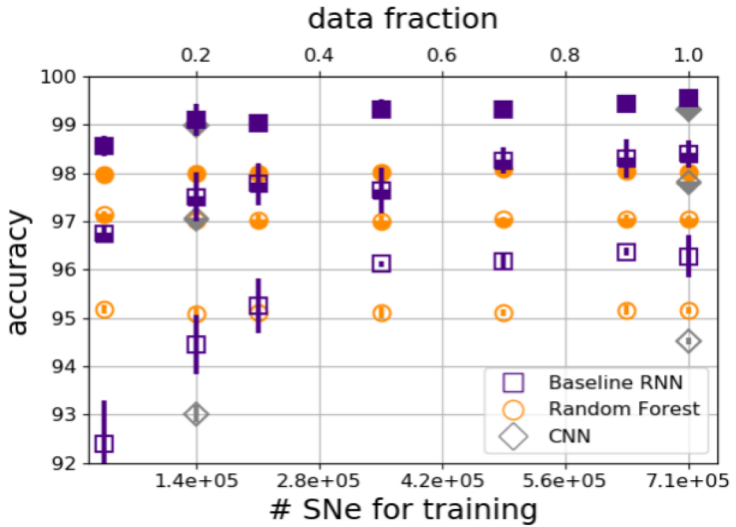
* Impacting:
  - time-domain astronomy
  - supernova cosmology



Möller + 2019

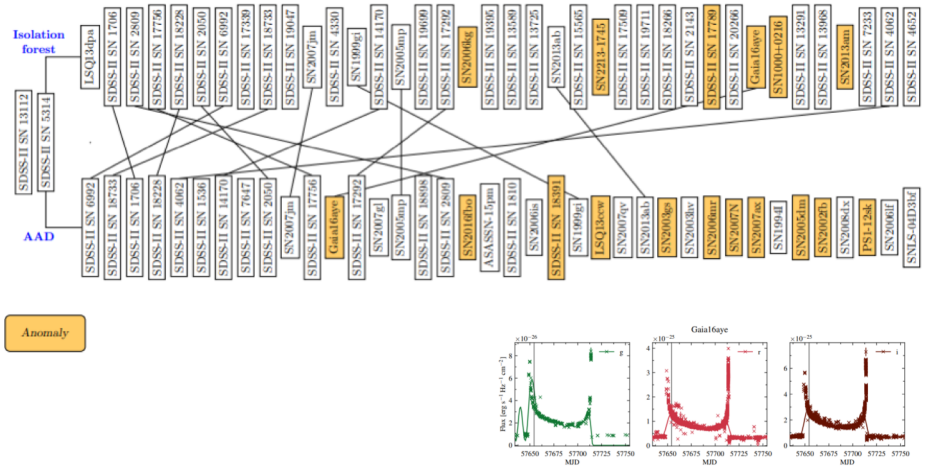
* New deep learning networks:
Bayesian, Convolutional, Recurrent

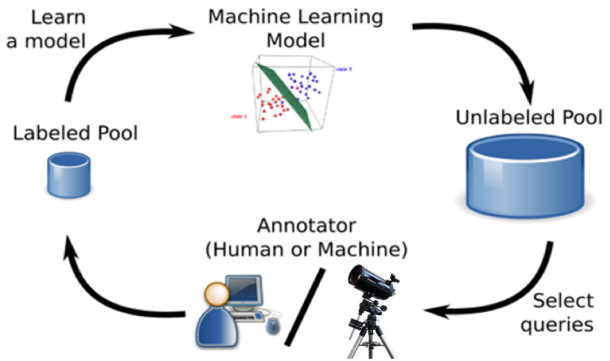
* Suitable for the big data era

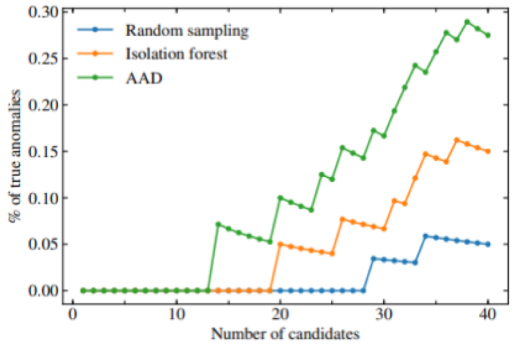


Adaptive Machine Learning

We can deliver a broker with evolving added values which can optimize not only classification, but also discovery!







Ishida et al., 2019 - https://arxiv.org/abs/1909.13260