Ingestion de l'univers visible dans une base de données distribuée Cloud-Native

Speaker(s) :
Fabrice Jammes
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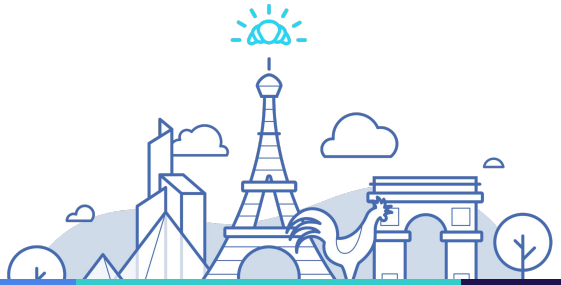


1. The Vera C. Rubin Observatory
2. The Rubin Science Platform
3. Qserv: the petascale Database
4. Cloud-Native: Kubernetes Operators
5. Cloud-Native: Workflows
6. What we have learnt

The Rubin Observatory

Telescope, catalogs and the IN2P3 role

The Vera C. Rubin Observatory

A revolutionary telescope

The **largest digital camera** in the world

Cerro Pachón at Chili (2647m slm)
8.4m primary mirror
3.2 Gpixel camera

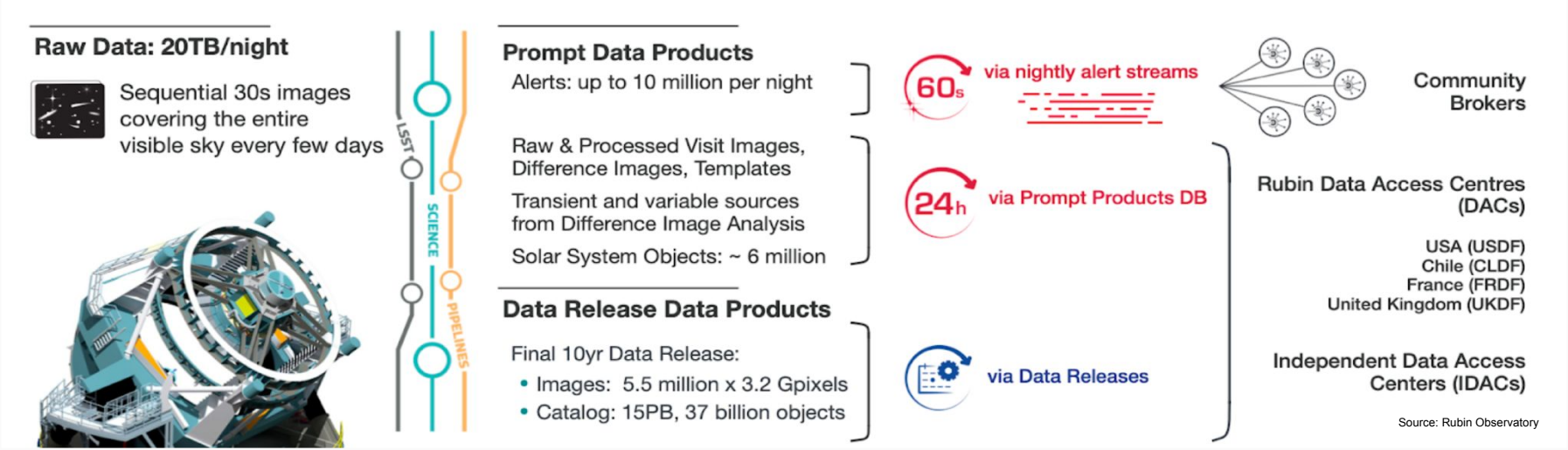
Three main Data Facilities: USDF, UKDF and FrDF (@ CC-IN2P3)

Funding

~$1 billion, 20% dedicated to data management

Main Objective:
Define the nature of dark energy and dark matter

The largest astronomical catalog

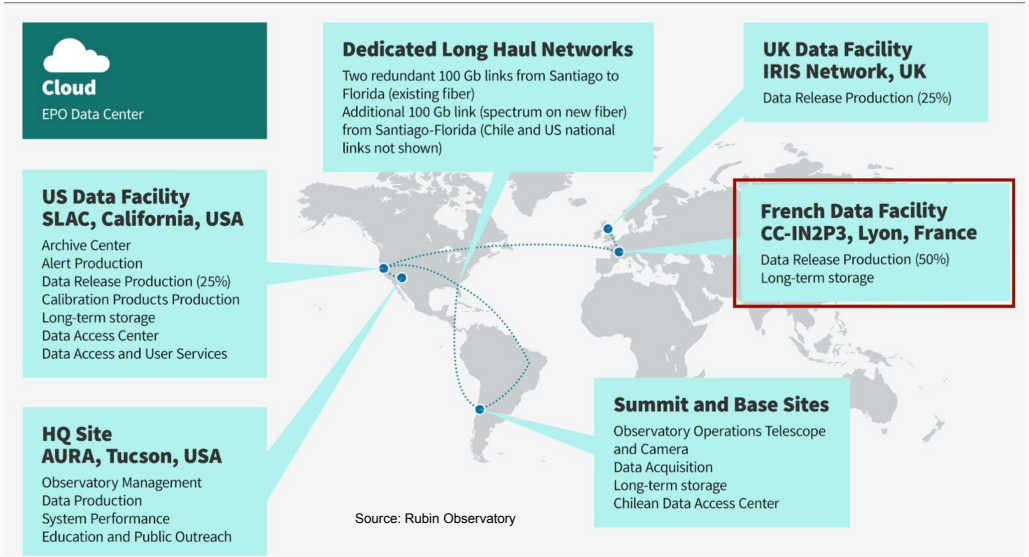


LSST will produce a catalog of **37 billion galaxies and stars** and their associated physical properties, i.e. **2 EB** of data

The IN2P3 Role

Development of Qserv and integration with Kubernetes
F. Jammes

CC-IN2P3 is the FrDF
50% of data produced by the telescope will be processed



900 Pb of data

30 Pb for the astronomical catalog

The CC-IN2P3 dedicated infrastructure

K8S physical cluster dedicated to Rubin:

- Shared by 2 applications: **Qserv** and **Rubin Science Platform**
- 25 workernodes
- 5 DELL PowerEdge R440
- 20 DELL PowerEdge R540
- 3 K8S Masters (R440)
- 2 Qserv Masters (R440)
- 15 Qserv Workers (R540)
- 5 Rubin Science Platform Workers (R540)
- QSERV nodes selected via taint

R540:

- 40 Intel Xeon Silver 4210 CPU @ 2.20GHz
- 256 GB of RAM
- 50 TB of local storage

R440:

- 40 Intel Xeon Silver 4114 CPU @ 2.20GHz
- 256 GB of RAM
- 18 TB of local storage

K8S OpenStack (small) cluster for test purpose:

- Shared by 2 applications: Qserv and Rubin Science Platform
- 8 VM
- 3 K8S masters
- 1 Qserv Master
- 3 Qserv Workers (1T of local storage per worker)
- 1 RSP Worker

Clusters managed via Puppet and Ansible

- Puppet used to configure the machines
- Ansible used to manage K8S: install, configuration etc.

Caddy web server to expose data to Qserv

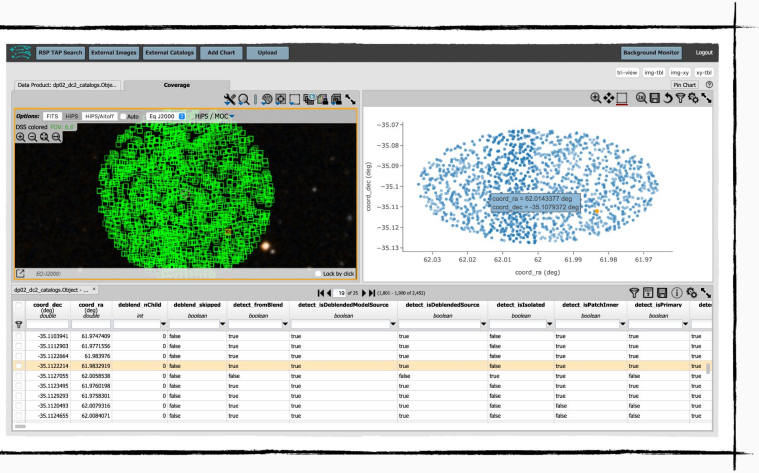
- 4 worker nodes

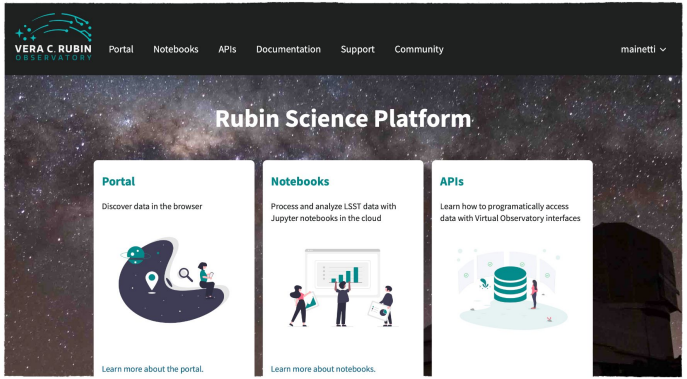
The Rubin Science Platform

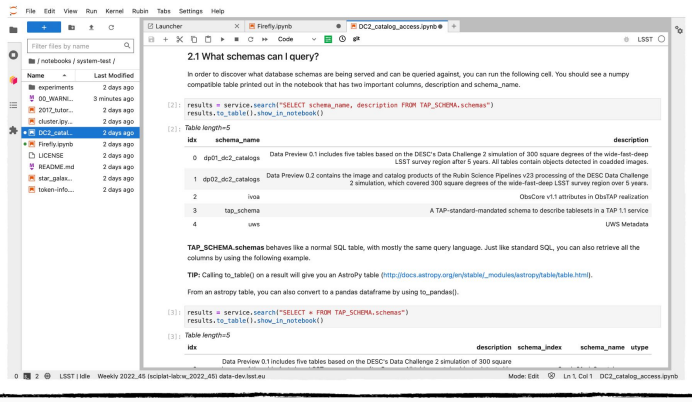
The Rubin Science Platform (RSP)

Web environment for interactive data analysis

- Qserv catalogs access via VO Table Access Protocol (UI or script)
- Table visualization and exploitation, graph, images visualization
- Access to external astronomical catalogs (Gaia, Planck, …) and images (SDSS, 2MASS, …)
- Integrated Jupyter platform (Python API)
- Qserv access portal for all the Virtual Observatory components (Topcat, DS9, Aladdin,...)







RSP Configuration and Deployment

- Configuration via Helm Chart
- A config for each environment (e.g. CC-IN2P3, SLAC, UKDF, …) and a config for each application

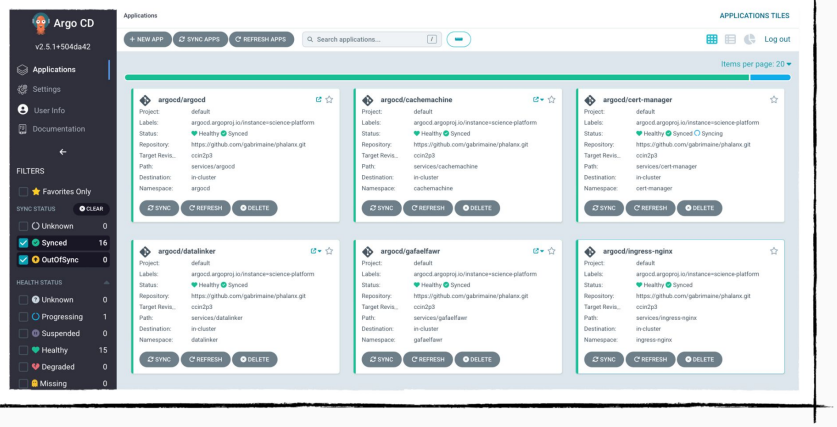
```
config:
  gcsBucket: "async-results.lsst.codes"
  gcsBucketUrl: "https://cccephs3.in2p3.fr:8080"
  gcsBucketType: "S3"
  jvmMaxHeapSize: "31G"

qserv:
  host: "ccqserv201.in2p3.fr:30040"
  mock:
    enabled: false
```

- Deployed via ArgoCD
- HashiCorp Vault used to manage secrets

https://github.com/lsst-sqre/phalanx

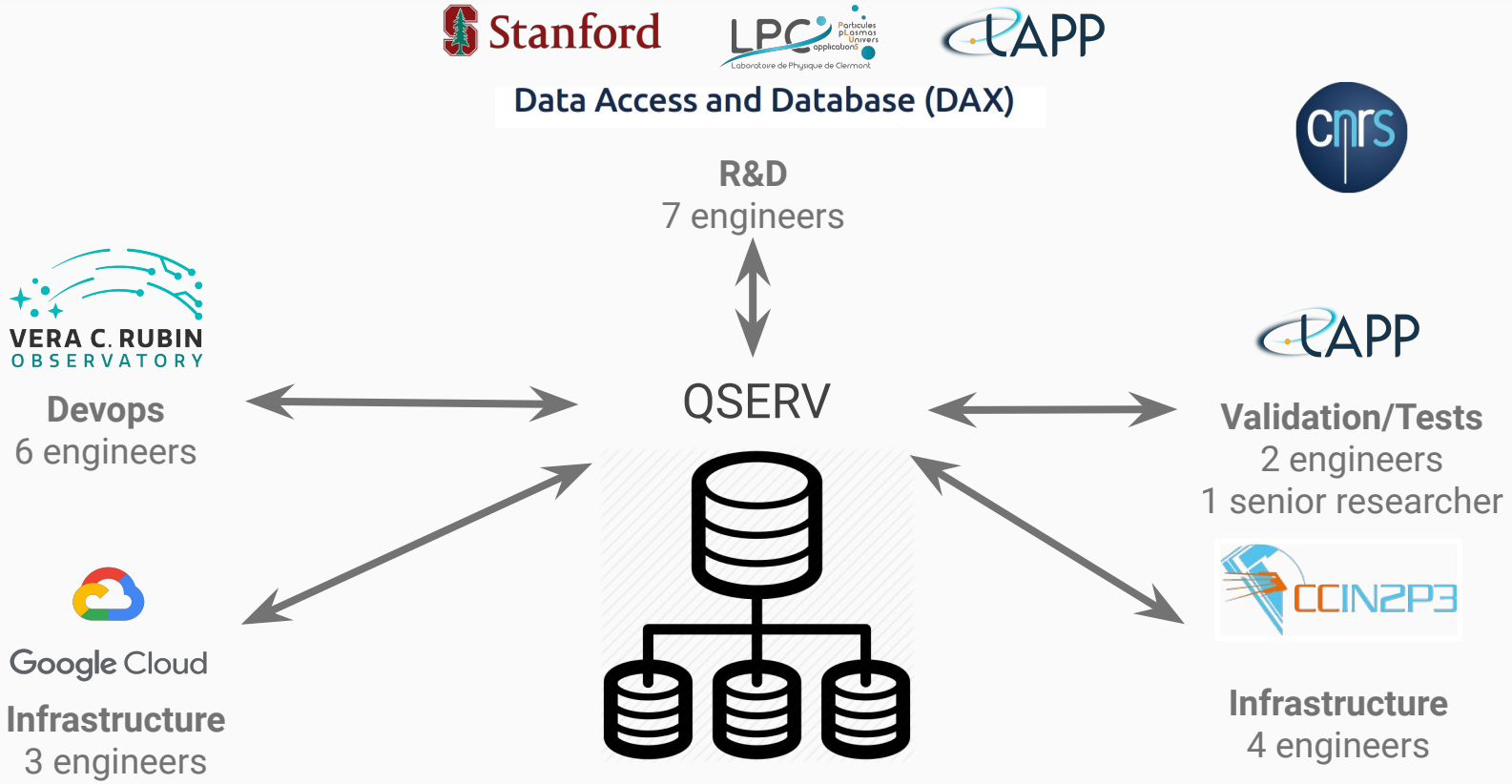
https://phalanx.lsst.io/

templates	Clean up the sqlproxy service
Chart.yaml	Fix typo in science-platform Chart.yaml
README.md	Updated missed values to reflect new naming
values-base.yaml	Delete obstap service
values-ccin2p3.yaml	activate datalinker
values-idfdev.yaml	adjusted naming to be more generic
values-idfint.yaml	Update values-idfint.yaml
values-idfprod.yaml	Delete obstap service



Qserv
The Petascale database

International context

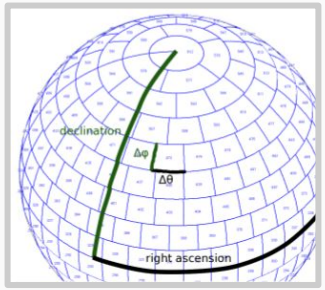


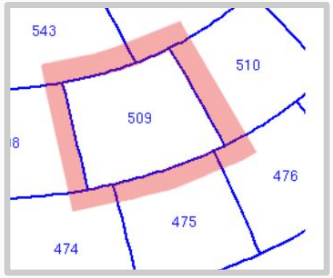
Qserv design

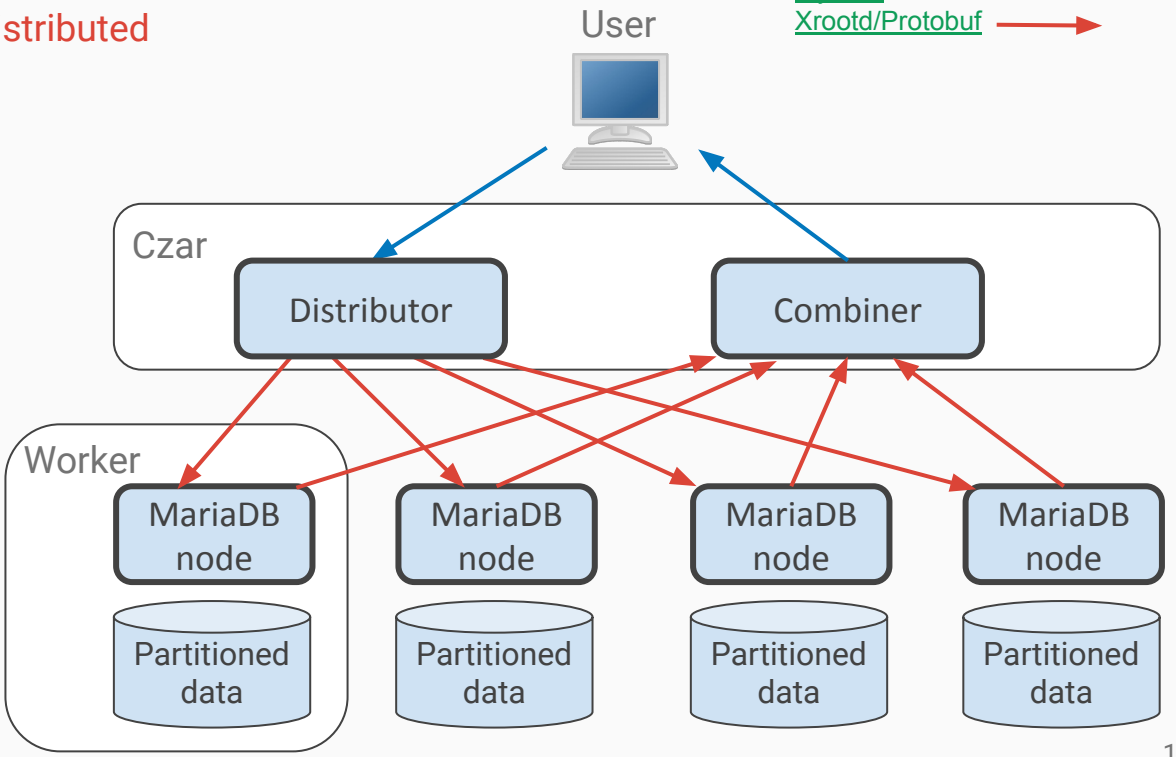
Relational database, 100% open source

Spatially-sharded with overlaps

Map/reduce-like processing, highly distributed







~1000 workers, 20 chunks/5TB per workers

Cloud-Native
Kubernetes operators

Operators embed ops knowledge from the experts

ops knowledge from the experts

operator implementation i.e. k8s controller

K8s standard API:
Deployments
StatefulSets
Autoscalers
Secrets
Config maps

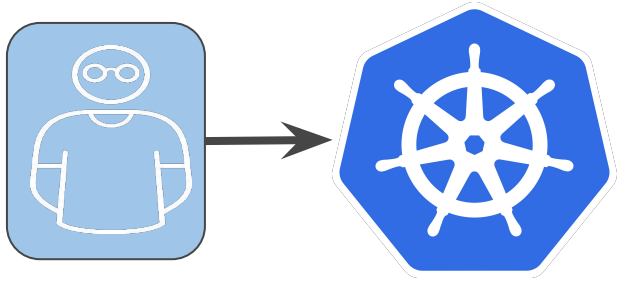
See

- https://kubernetes.io/docs/concepts/extend-kubernetes/operator/
- https://cloud.google.com/blog/products/containers-kubernetes/best-practices-for-building-kubernetes-operators-and-stateful-apps

Credits: Daniel Messer Product Manager, OpenShift - Guilherme Barros Product Manager, Cloud BU

Red Hat

How does an operator works?



Allow to deploy a complex application with only a few lines of yaml

Software Developer
Kubernetes user

K8s API

Kubernetes operator

Native Kubernetes
resources

Custom resource

```yaml
apiVersion: qserv.lsst.org/v1alpha1
kind: Qserv
metadata:
 name: qserv
 namespace: database
spec:
 czar:
   image: qserv/lite-qserv:2021.10.1-rc1
replicas: 1
   storage: 1Ti
 worker:
   image: qserv/lite-qserv:2021.10.1-rc1
replicas: 10
   ...
```

Custom Kubernetes controller

Watch Event

Reconcile

Custom resource definition

here Qserv

Deployments
StatefulSets
Autoscalers
Secrets
Config maps

What brings the Qserv operator?

Operators: both sysadmin + application experts

Easy Qserv install

On-prem, Cloud, CI, laptop

Easy configuration

Based on Qserv CRD

Admission Control Plugin:

manage default values and

update to configuration

Automated upgrade

Including database schemas

Install qserv-operator

```
kubectl apply -f manifests/operator.yaml
```

Install a qserv instance

```
kubectl apply -k manifests/base
```

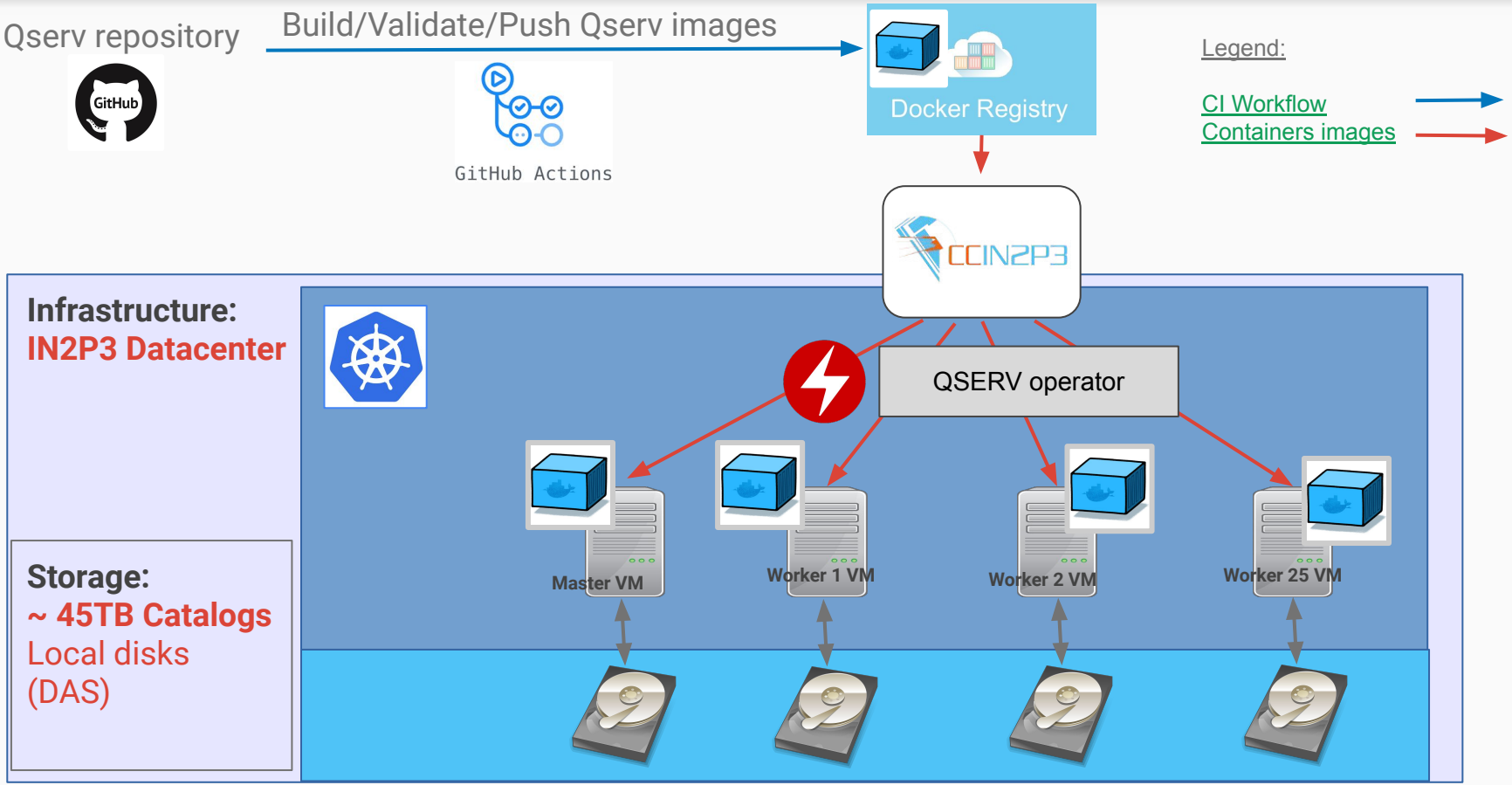
Monitor Qserv instance and related Pods

```
fjammes@clrinfopo18 ~/src/qserv-operator main kubectl get qservs.qserv.lsst.org
NAME    CZAR   INGEST-DB   REPL-CTL   REPL-DB   REPL-REGISTRY   WORKER   XROOTD   AGE
qserv   1/1    1/1         1/1        1/1       1/1             2/2      1/1      28m
```

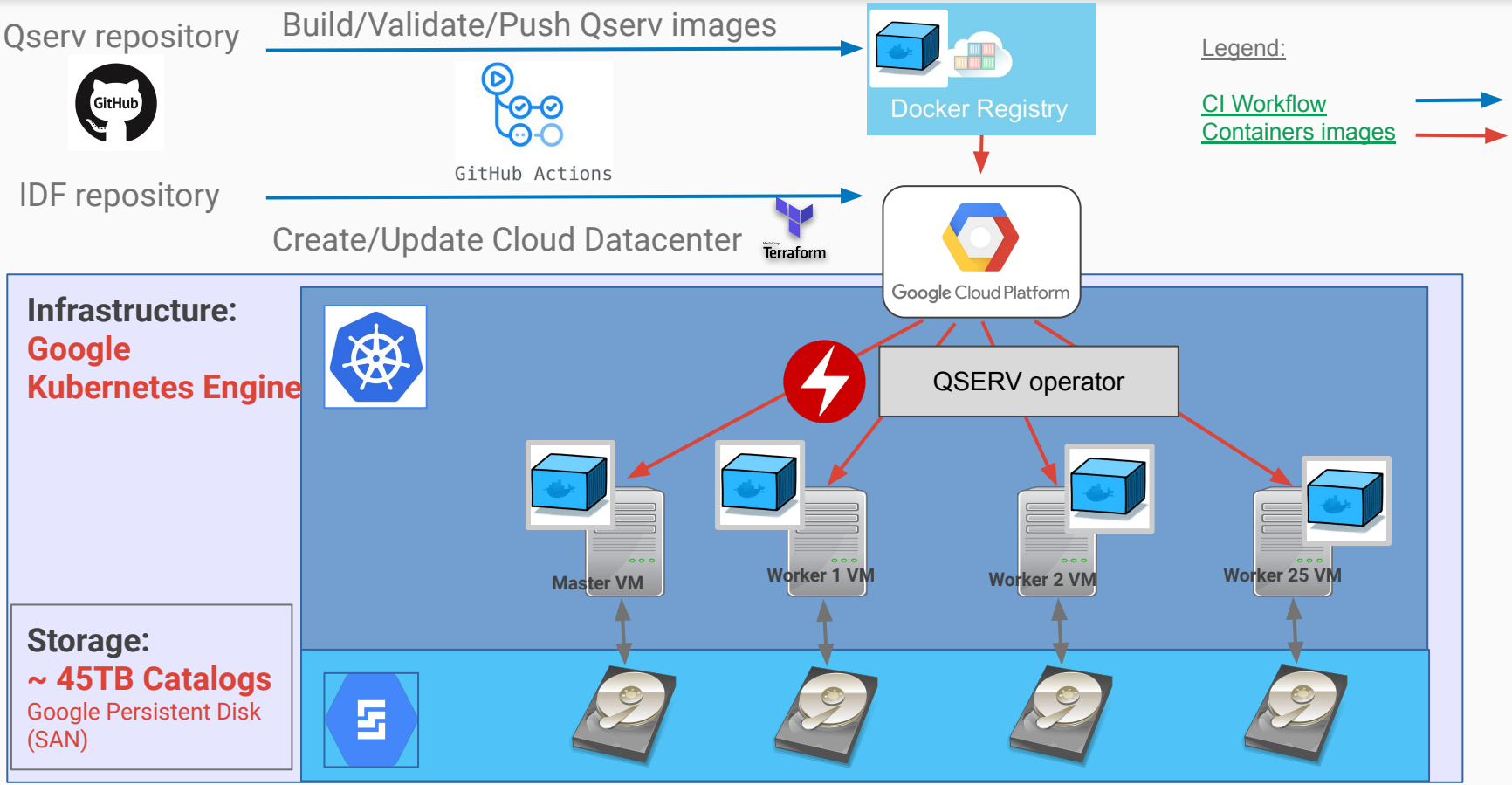
```
fjammes@clrinfopo18 ~/src/qserv-operator main kubectl get pod
NAME                                  READY   STATUS    RESTARTS   AGE
qserv-czar-0                          2/2     Running   0          28m
qserv-ingest-db-0                     1/1     Running   0          28m
qserv-repl-ctl-0                      1/1     Running   0          28m
qserv-repl-db-0                       1/1     Running   0          28m
qserv-repl-registry-78cc7b9cc-2jh2h   1/1     Running   0          28m
qserv-worker-0                        4/4     Running   0          28m
qserv-worker-1                        4/4     Running   0          28m
qserv-xrootd-redirector-0             2/2     Running   0          28m
```

Full demo https://asciinema.org/a/uWCPVytEy2ravJs27agj2uqpB

Automated deployment: On Prem



Automated deployment: Cloud Native



CI Setup with KIND

For each commit
- Build Qserv image
- Start kind
- Start Qserv
- Launch integration tests
- Push image to registry

KIND

kind-control-plane (master)

Container Runtime

kind-worker

Qserv Czar

Qserv Worker 1

Container Runtime

kind-worker2

Qserv Worker 2

Qserv Worker 2

Container Runtime

QSERV operator

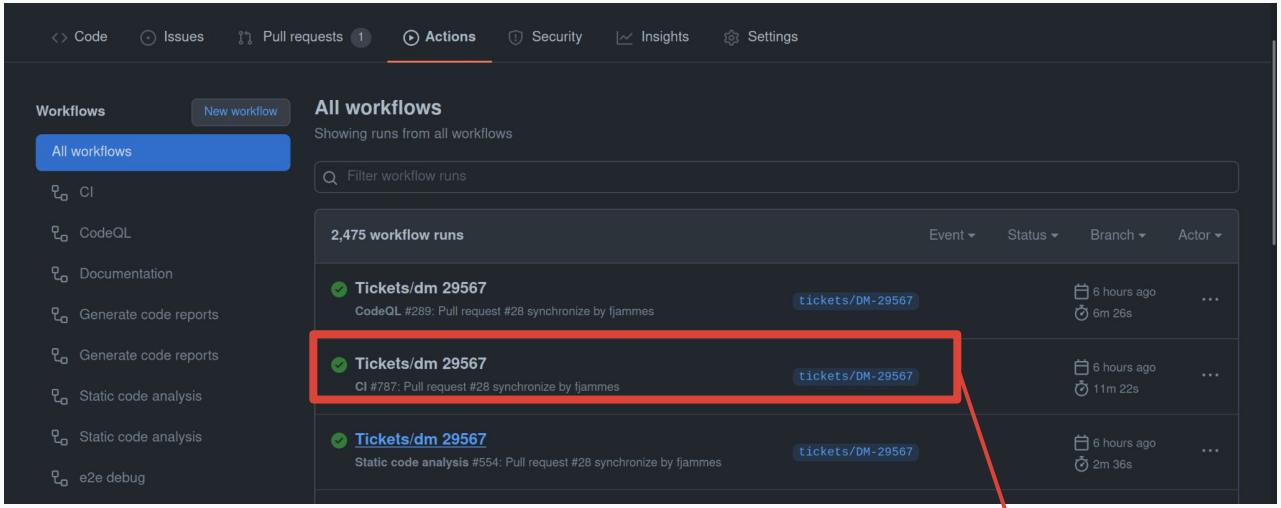
Docker runtime

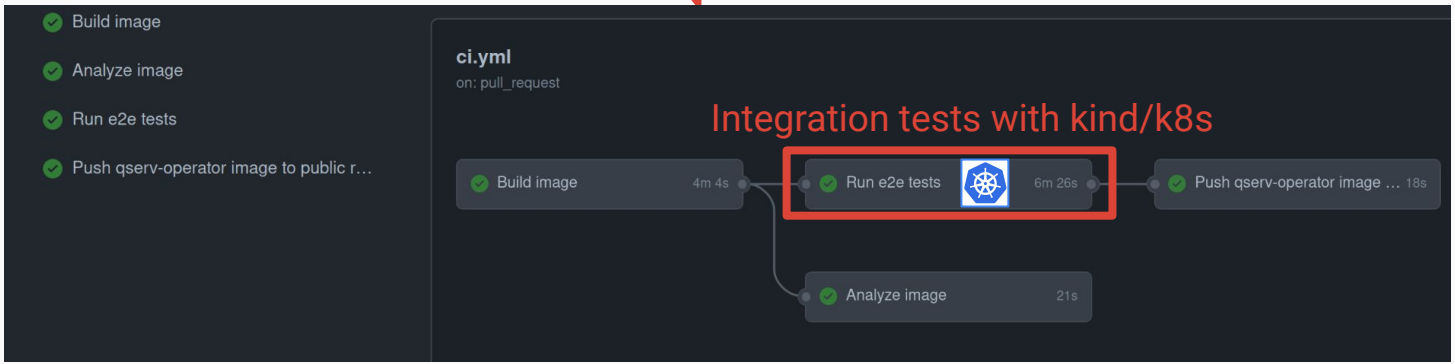
Github Action VM

https://kind.sigs.k8s.io/

Wrapper for CI: https://github.com/k8s-school/kind-helper

CI in practice: Qserv integration tests





Cloud-Native Workflows

A powerful data ingest workflow

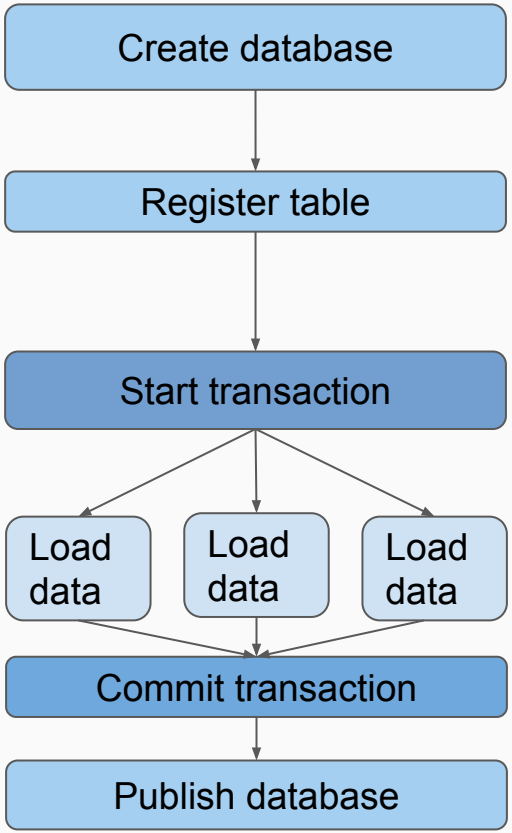
Qserv has a powerful distributed ingest algorithm

Flexible but require orchestrating tasks (DAG)

Argo Workflow project help us a lot

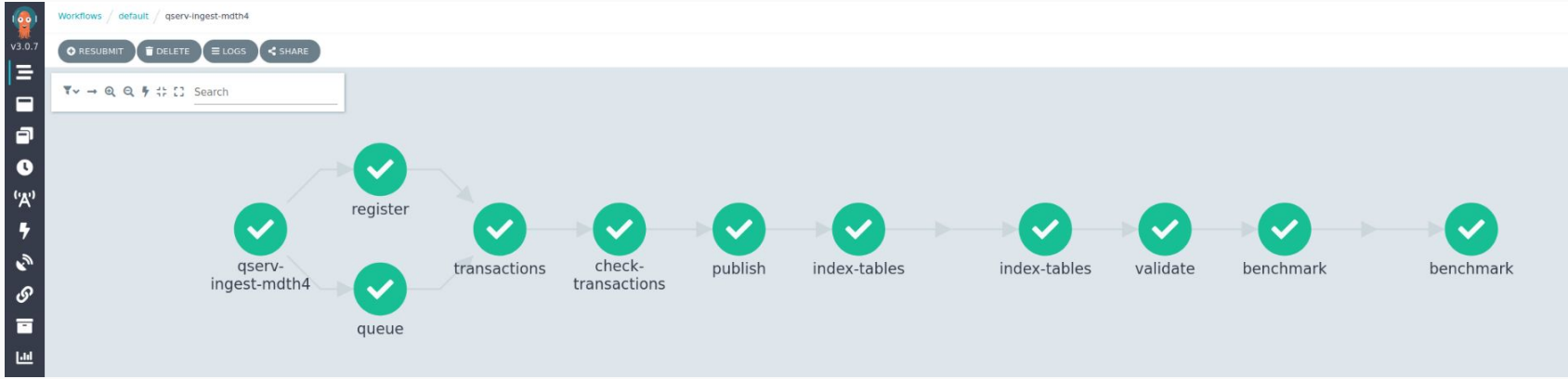
Case study 2022: **Implementation of a large-scale data loading algorithm**

Ingestion of 2M files and ~40TB in 5h

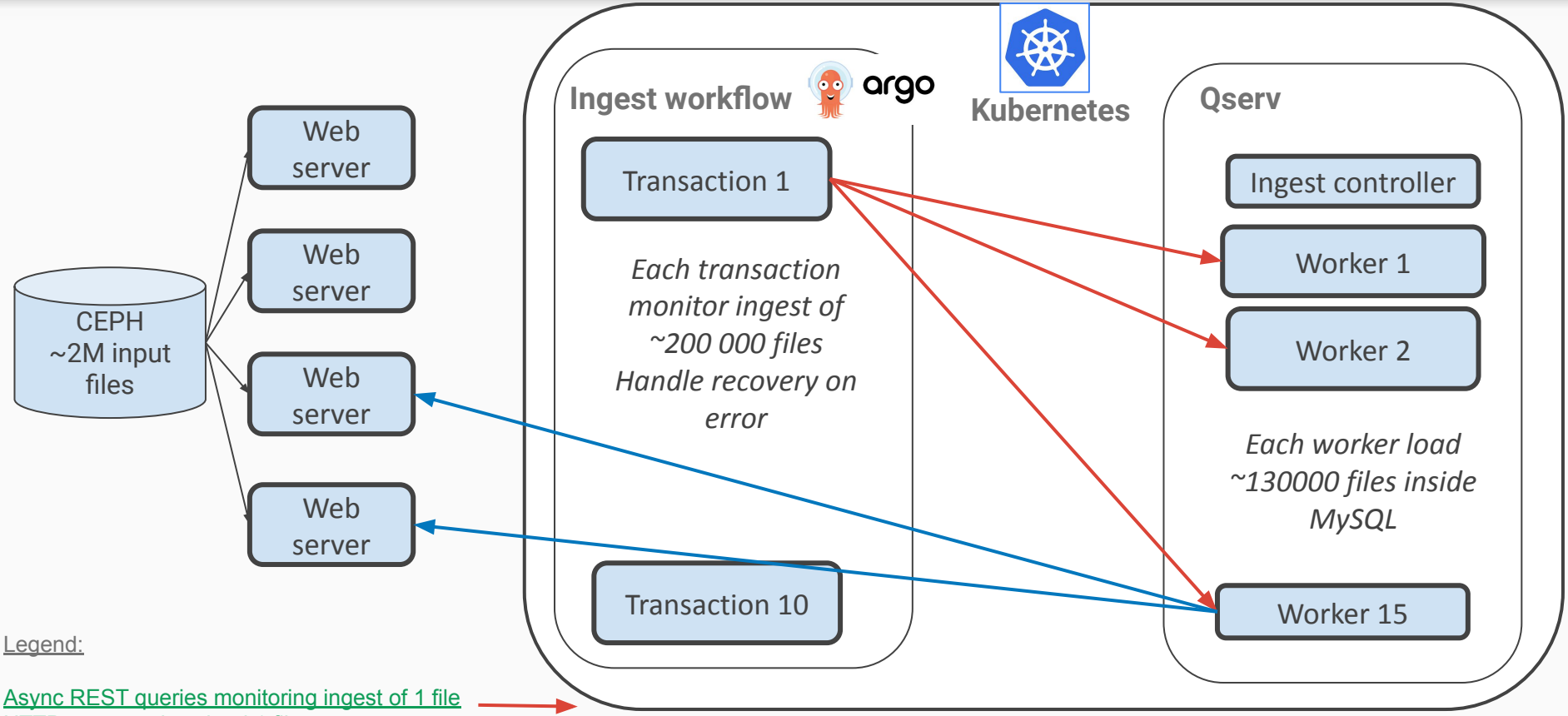


Argo: screenshots

```
fjammes@clrinfoport18 ~ argo get @latest | tail -n 15
STEP                        TEMPLATE      PODNAME                          DURATION
 ✔ qserv-ingest-mdth4       main
 ├─✔ queue                  ingest-step   qserv-ingest-mdth4-2075476264    3s
 ├─✔ register               ingest-step   qserv-ingest-mdth4-964548720     4s
 ├─✔ transactions           transactions  qserv-ingest-mdth4-1041421248    14s
 ├─✔ check-transactions     ingest-step   qserv-ingest-mdth4-3195504171    2s
 ├─✔ publish                ingest-step   qserv-ingest-mdth4-4256901816    12s
 ├─✔ index-tables           index-tables
 │ └─✔ index-tables         ingest-step   qserv-ingest-mdth4-1866502525    2s
 ├─✔ validate               ingest-step   qserv-ingest-mdth4-493206715     2s
 └─✔ benchmark              benchmark
   └─✔ benchmark            ingest-step   qserv-ingest-mdth4-1797710727    5s
```



Technical details about ingest process



Qserv catalogs now

Catalog	Size (TB)	# of lines (Billions)
DP0.2	36.6	139
DP0.1	1.1	1.7
SkySim 5000	13.6	20.5
Cosmo DC2	3.7	5.5

			Data [GB]																			
			in unique chunks										in all replicas									
	#chunks		chunks			overlaps			regular				chunks			overlaps			regular			
Database	unique	replicas	data	index	Σ	data	index	Σ	data	index	Σ	Σ	data	index	Σ	data	index	Σ	data	index	Σ	Σ
cosmoDC2_v1_1_4_image	1730	1744	3569.4	69.4	3638.7	41.9	<0.1	41.9	0.0	0.0	0.0	3680.7	3569.4	69.4	3638.7	41.9	<0.1	41.9	0.0	0.0	0.0	3680.7
dp01_dc2_catalogs	1398	1412	915.3	58.9	974.2	114.3	<0.1	114.3	0.0	0.0	0.0	1088.5	915.3	58.9	974.2	114.3	<0.1	114.3	0.0	0.0	0.0	1088.5
dp02_dc2_catalogs	1478	1492	31746.3	2737.4	34483.7	2138.3	<0.1	2138.3	0.0	0.0	0.0	36622.0	31746.3	2737.4	34483.7	2138.3	<0.1	2138.3	0.0	0.0	0.0	36622.0
skysim5000_v1_1_1_parquet	18738	18752	13171.2	261.5	13432.7	157.9	<0.1	158.0	0.0	0.0	0.0	13590.7	13171.2	261.5	13432.7	157.9	<0.1	158.0	0.0	0.0	0.0	13590.7
Total [TB for data]	23344	23400	49.4	3.1	52.5	2.5	<0.1	2.5	0.0	0.0	0.0	55.0	49.4	3.1	52.5	2.5	<0.1	2.5	0.0	0.0	0.0	55.0

What we have learnt

1. **Keep operator simple**

   Handle complexity inside application

   And expose simple management API

   to operator

2. **Scale up with asynchronous queries**

   Easier to handle network failures which

   Always occur at scale

3. **Error recovery is a MUST HAVE**

   Transaction and Mariadb partitioning

Q&A

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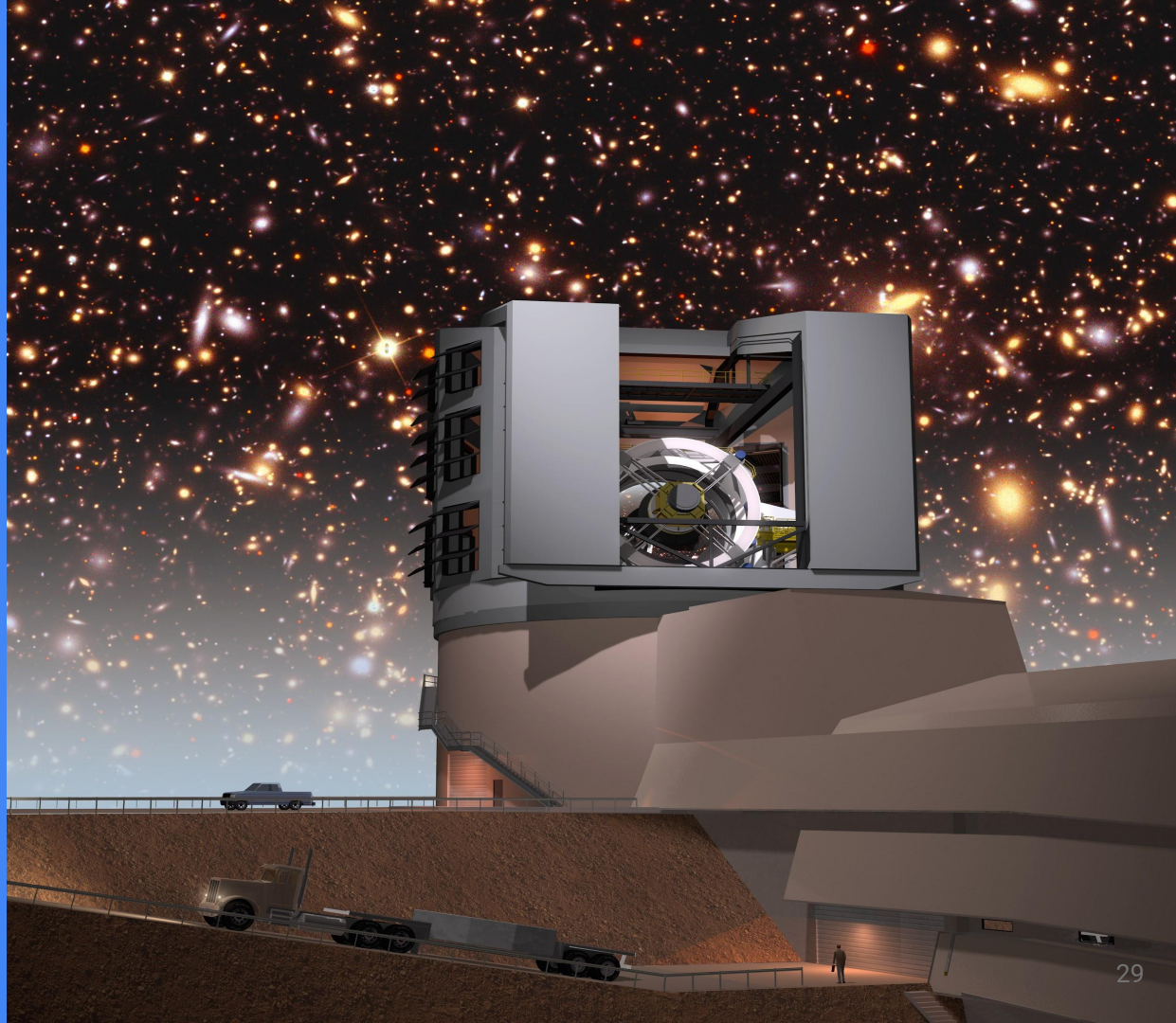
Laboratoire de Physique de Clermont



Contact us!

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