Gaia Variability Studies: case for Postgres-XC.

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Gaia Data Processing Centre in Geneva,

Gaia Coordination Unit 7

PgCon

Ottawa 23rd May 2014

UNIVERSITÉ DE GENÈVE

Gaia DPAC

Includes slides courtesy of Berry Holl and Laurent Eyer

Structure

- My story
- Gaia mission
- Gaia science at CU7, Geneva
- Data model and processing model
- Hardware
- XC role
- Collaboration

Bio

- Corporate software lab; Poland, USA, UK,…
  - Primark Corp-> Thomson Financial -> IHS (4.5 years)
    - The biggest economical timeseries database
    - Global systems' integration
- CERN DB group (6.5 years); Geneva, Switzerland
    - Largest data migration at the time (2002):
      - 400TB moved from Objectivity to hybrid Oracle+in-house platform
      - Largest relational scientific database running at CERN *(Compass, Harp)*
    - Biomed secure middleware, Grid
- Gaia Geneva group (5 years); UNIGE/ISDC, Geneva
  - Coordination Unit 7 (CU7) Data Architect
  - Data Processing Centre for Geneva (DPCG) deputy
  - XLDB, timeseries, distributed systems, science, Literature, art, history, politics, basketball, paragliding, architecture, volleyball, sailing, biking,…

Structure

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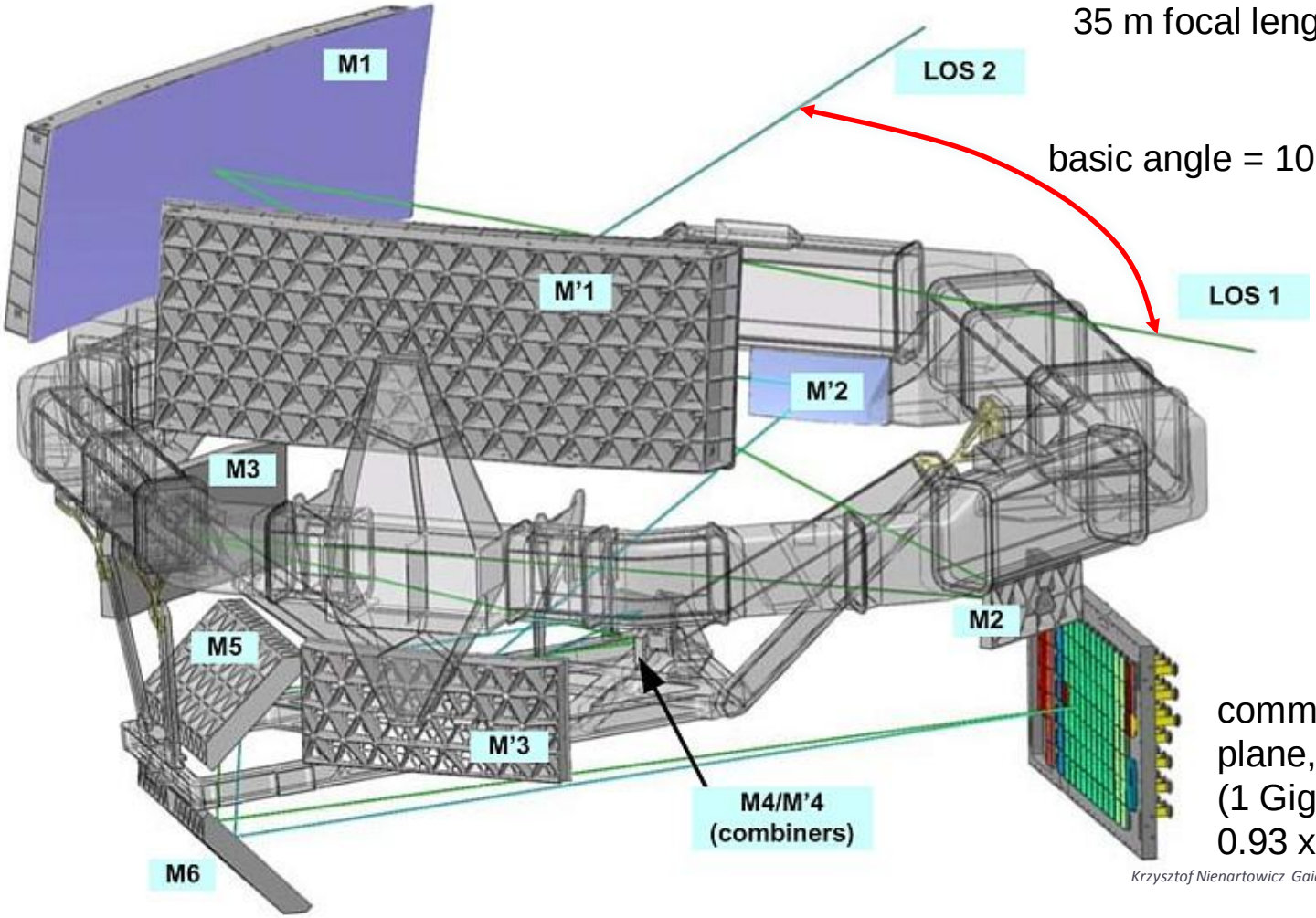
What is special about Gaia?

- European Space Agency cornerstone mission
  - No equivalent mission for 20-30+ years…
- Census of our Galaxy:
  - **All objects between 6 and 20th magnitude (~1.000.000.000 stars, asteroids, quasars, extragalactic supernovae, etc)**
  - **On average 80 times during its 5 year mission**
    - positions and parallax with a precision of 20 µasec (at V= 15 mag)
    - Proper motions with a precision of 20 µasec/year (at V= 15 mag)
    - Radial velocities with a precision of 2-10 km/s (for star V<17)
  - **Low resolution spectrum of each star:**
    - allows to determine many stellar properties
      - e.g. temperature, surface gravity, metalicity, age, ...
  - Can potentially discover as many as 10.000 exo-planets
  - **Estimated 10-20% of all population are variables**

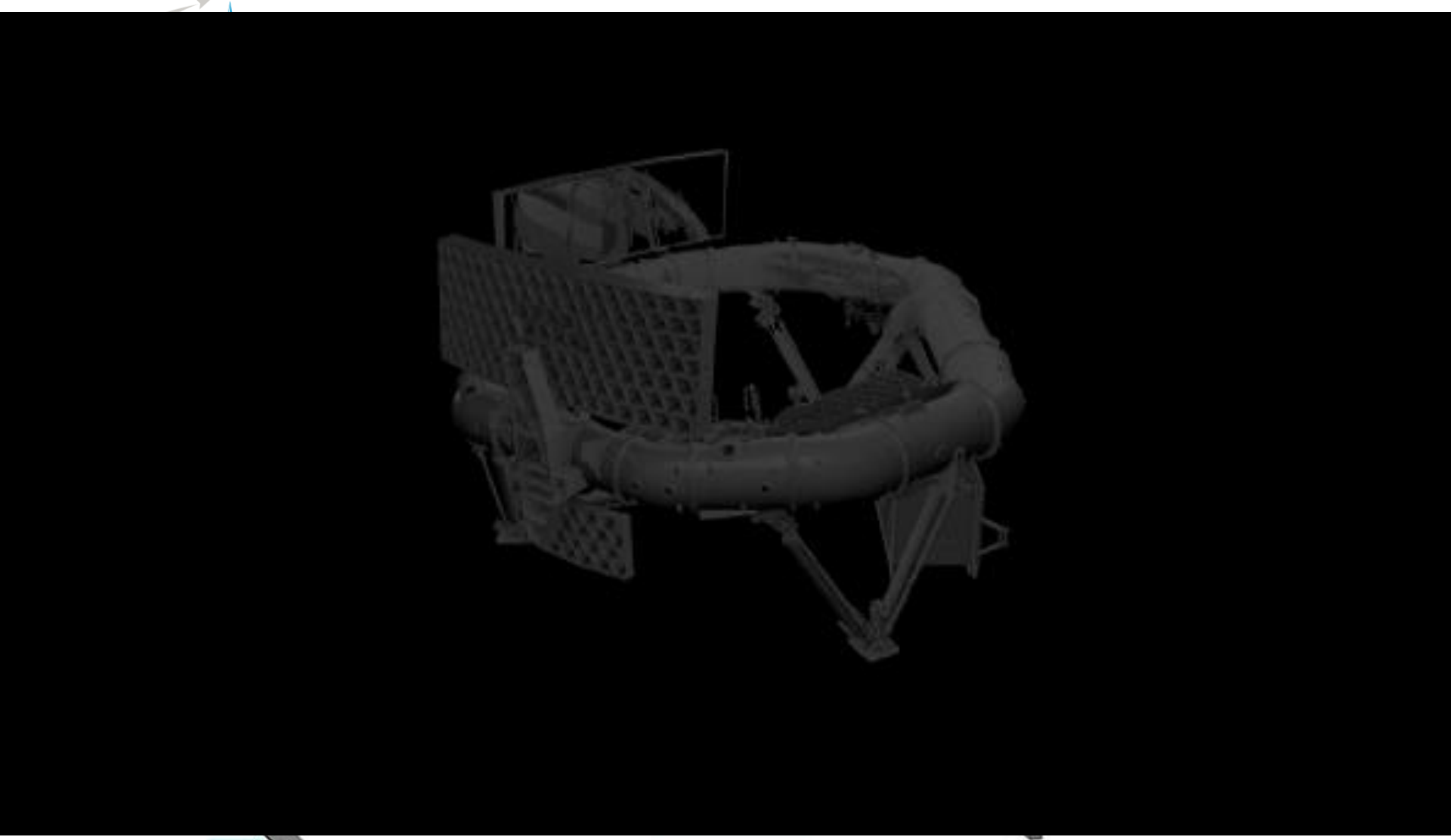
The Gaia instruments



2 off-axis telescopes
1.45 x 0.5 m^2 aperture
35 m focal length

common focal plane, 106 CCDs (1 Gigapixel)
0.93 x 0.42 m^2

The Gaia instruments



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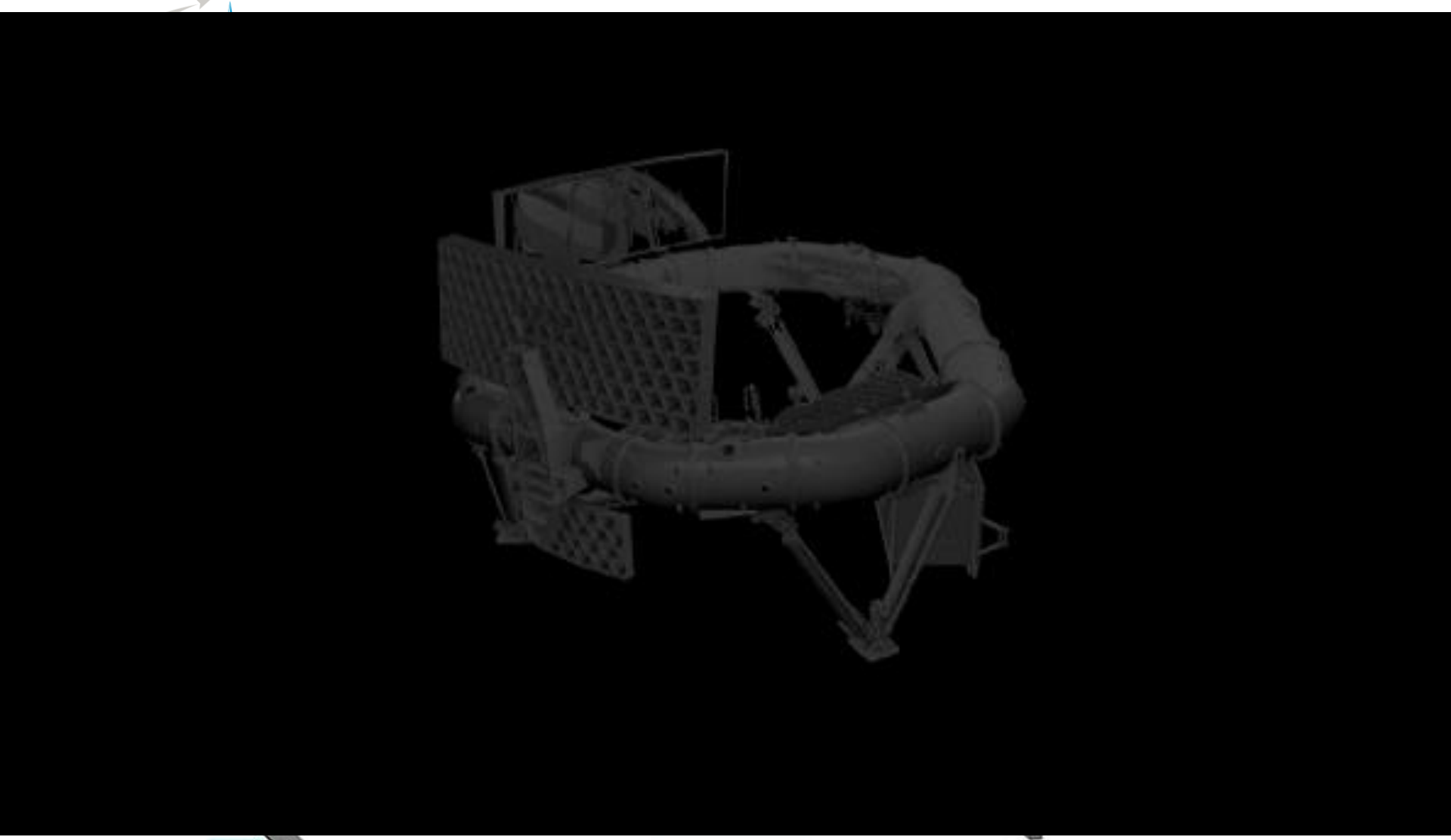
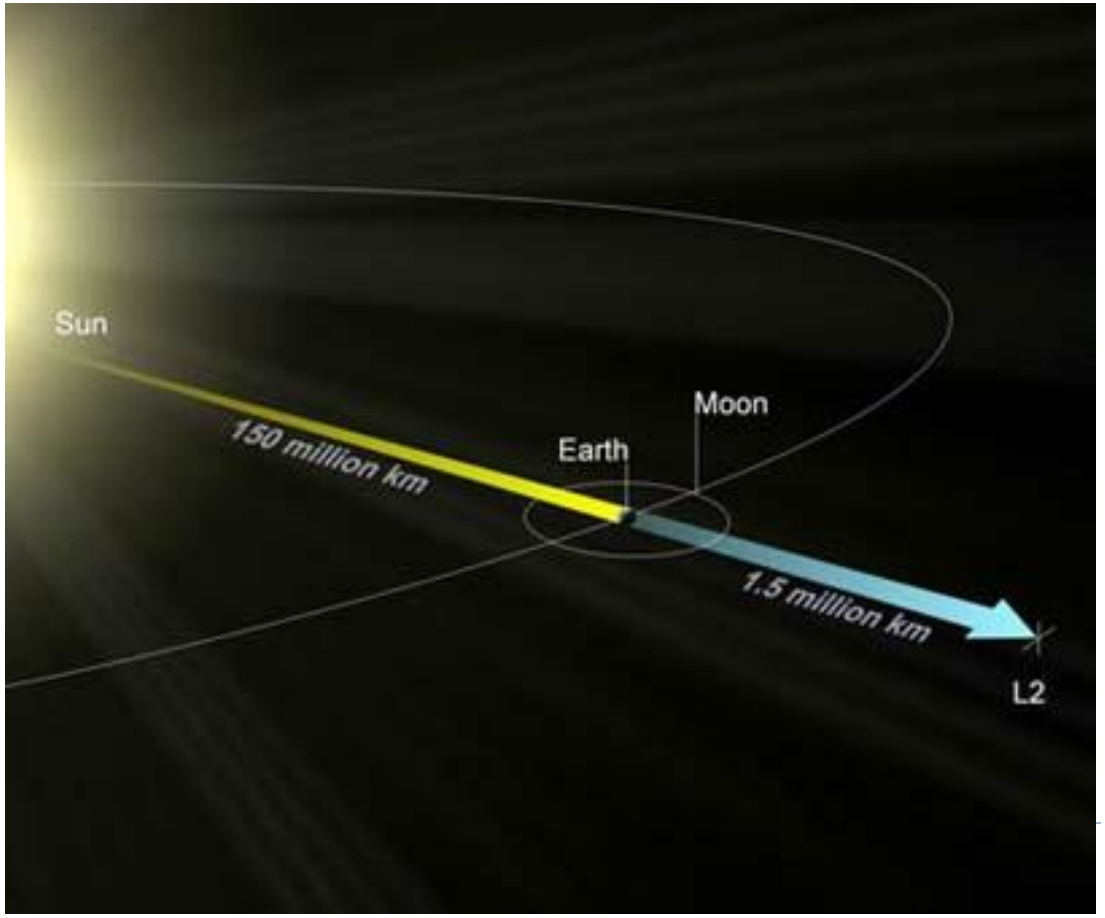


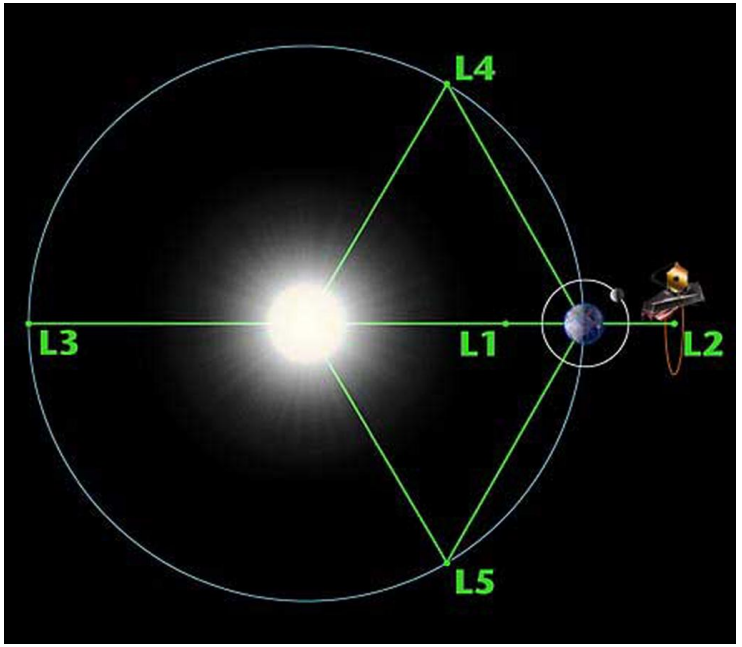
One of the two primary mirrors

esa EADS astrium SAFRAN Sagem

The Gaia satellite

- Location: Lagrange point 2
- Commissioning phase, first calibrated data: Q2/2015





Gaia scanning: Motion of viewing directions over **4 days**

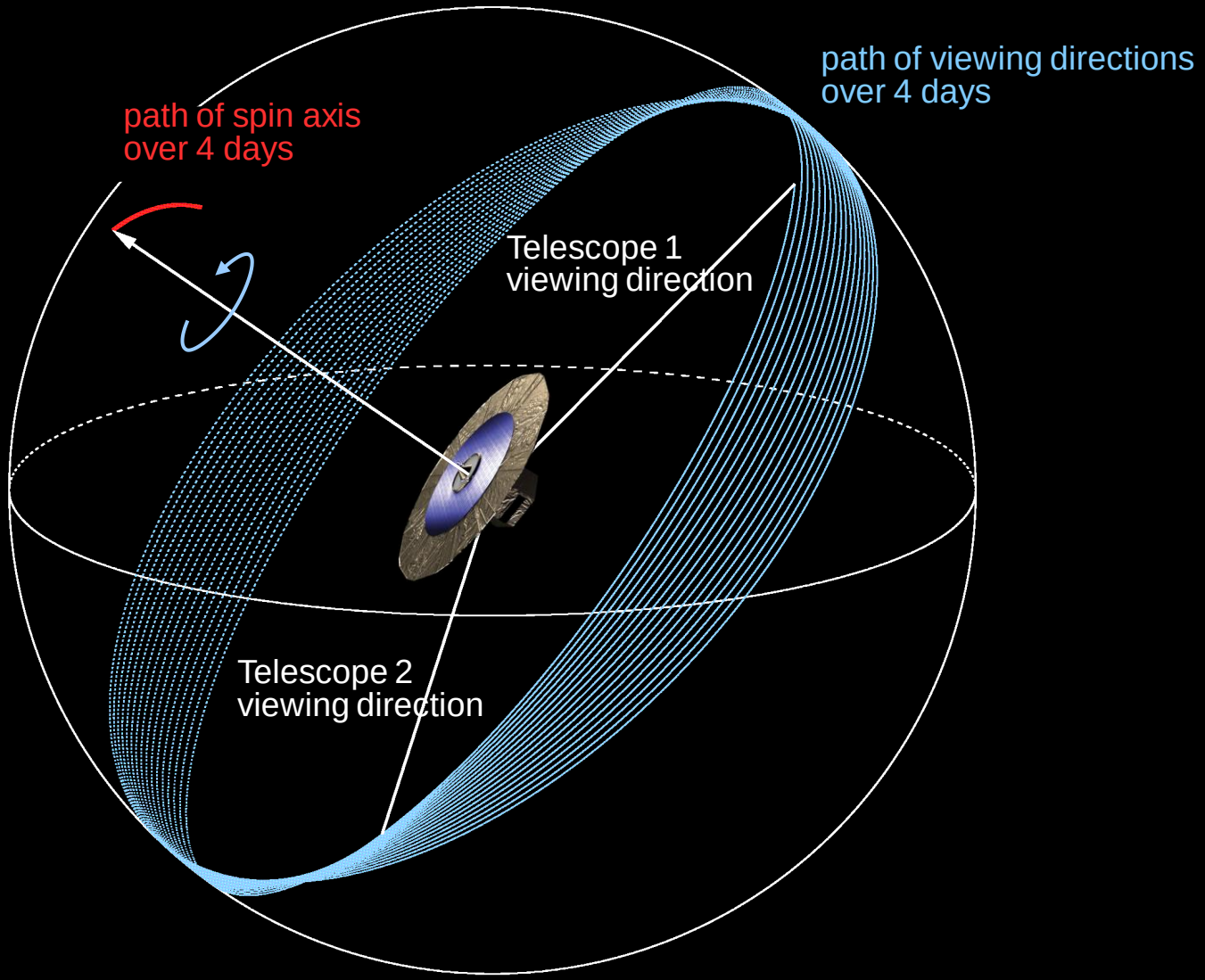
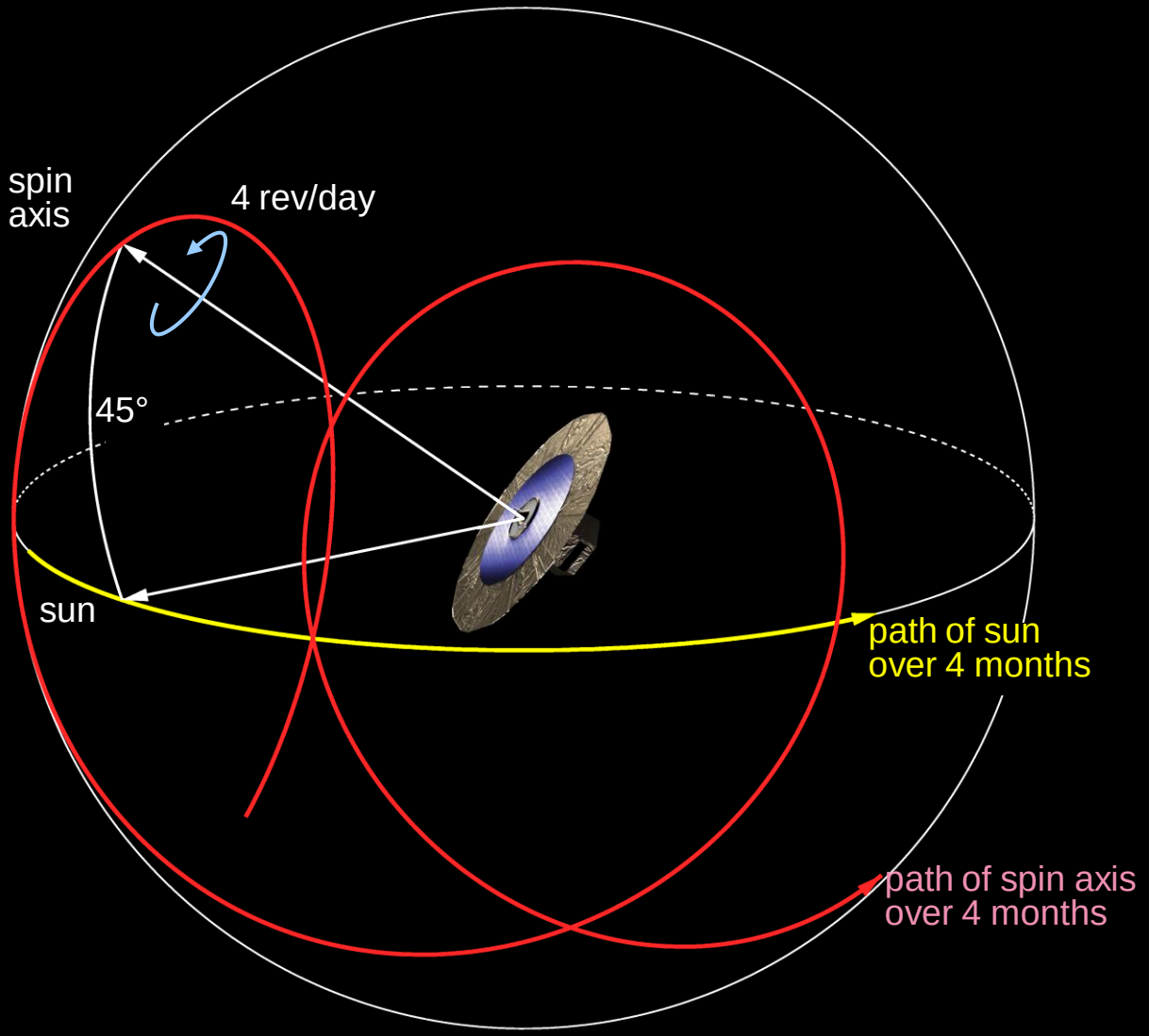


image credit: Lennart Lindegren

Gaia scanning: Motion of the spin axis over **4 months**



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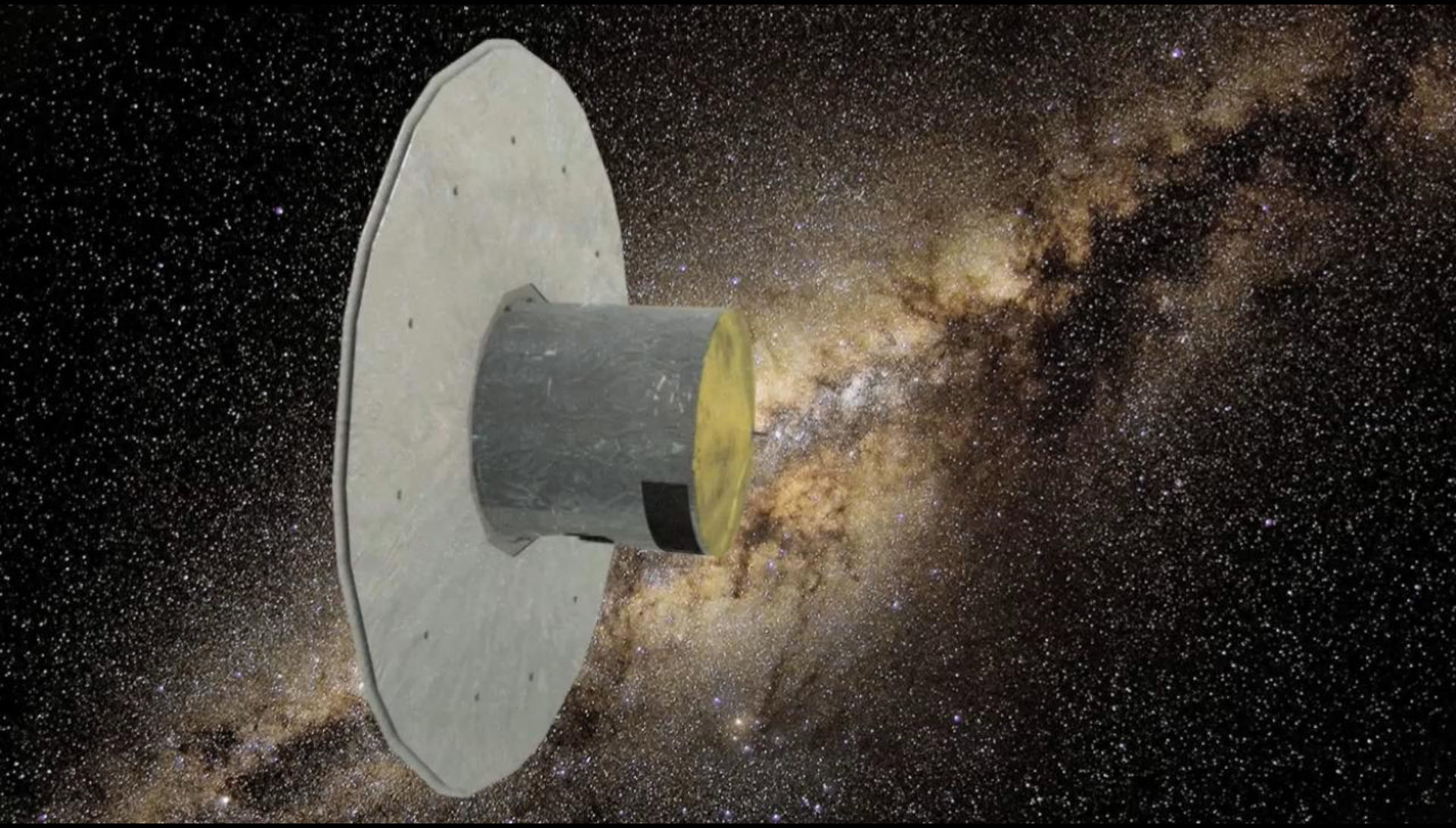

credit: ESA

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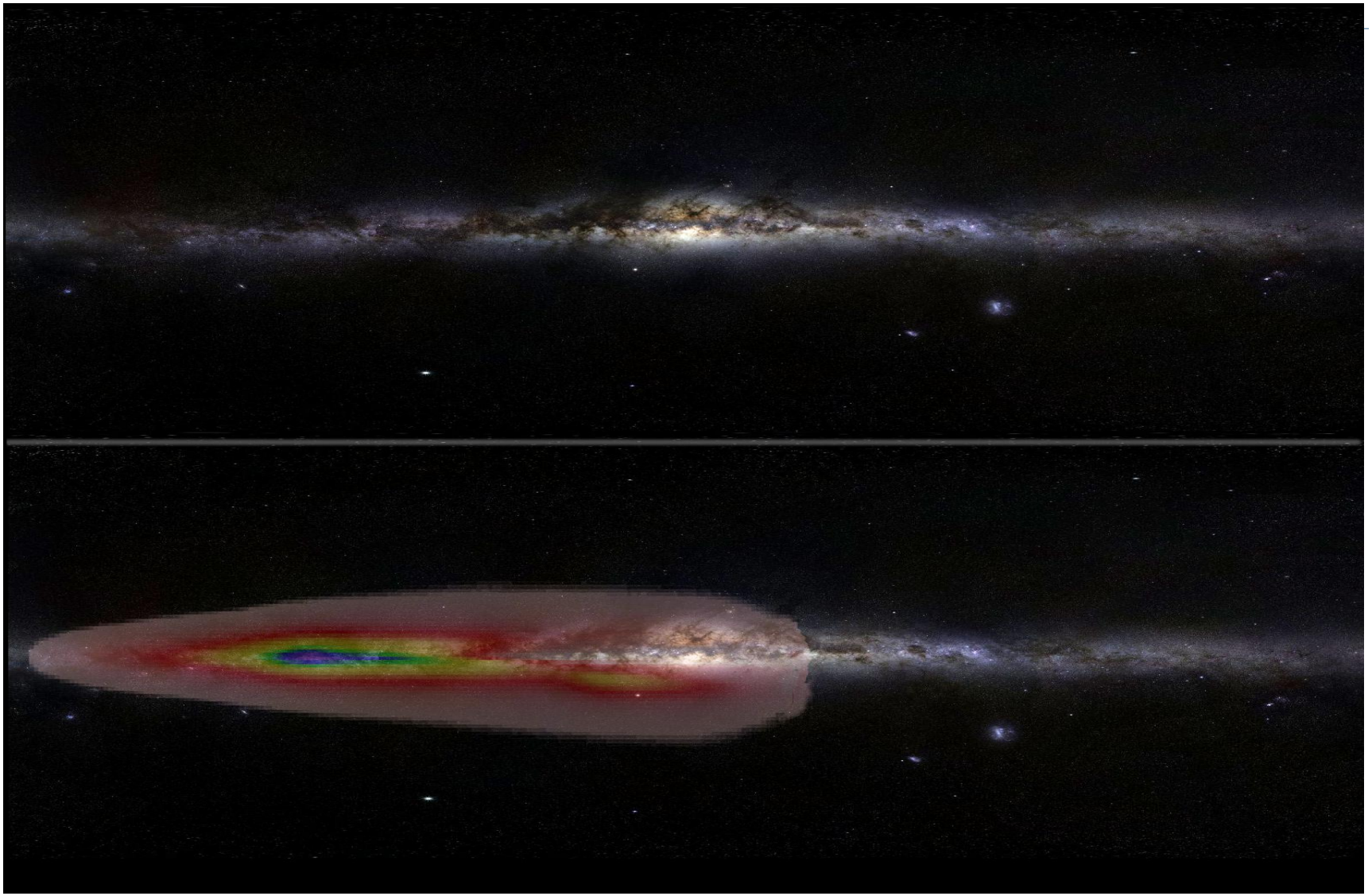
Gaia Science

Simulated coverage



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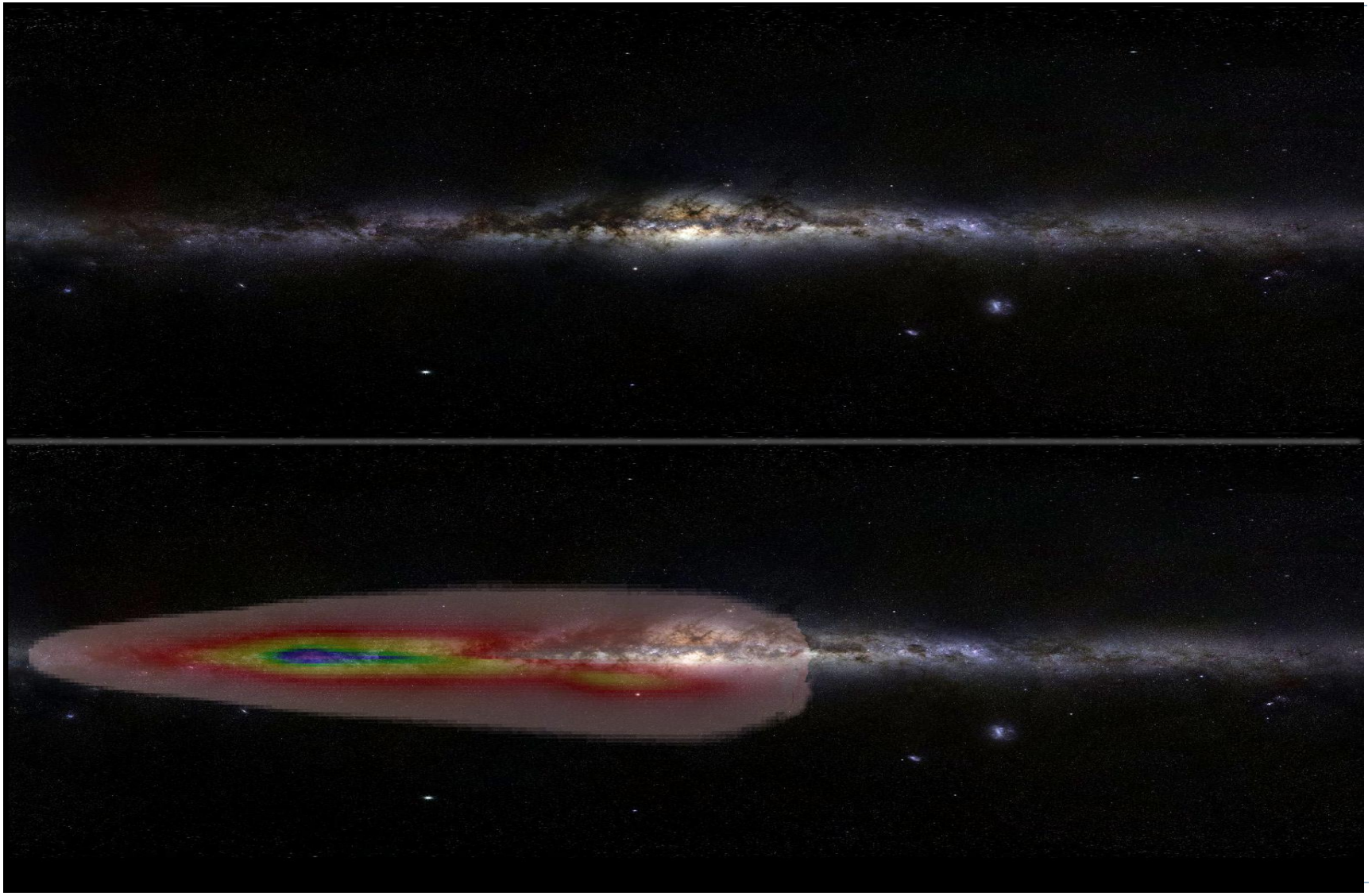

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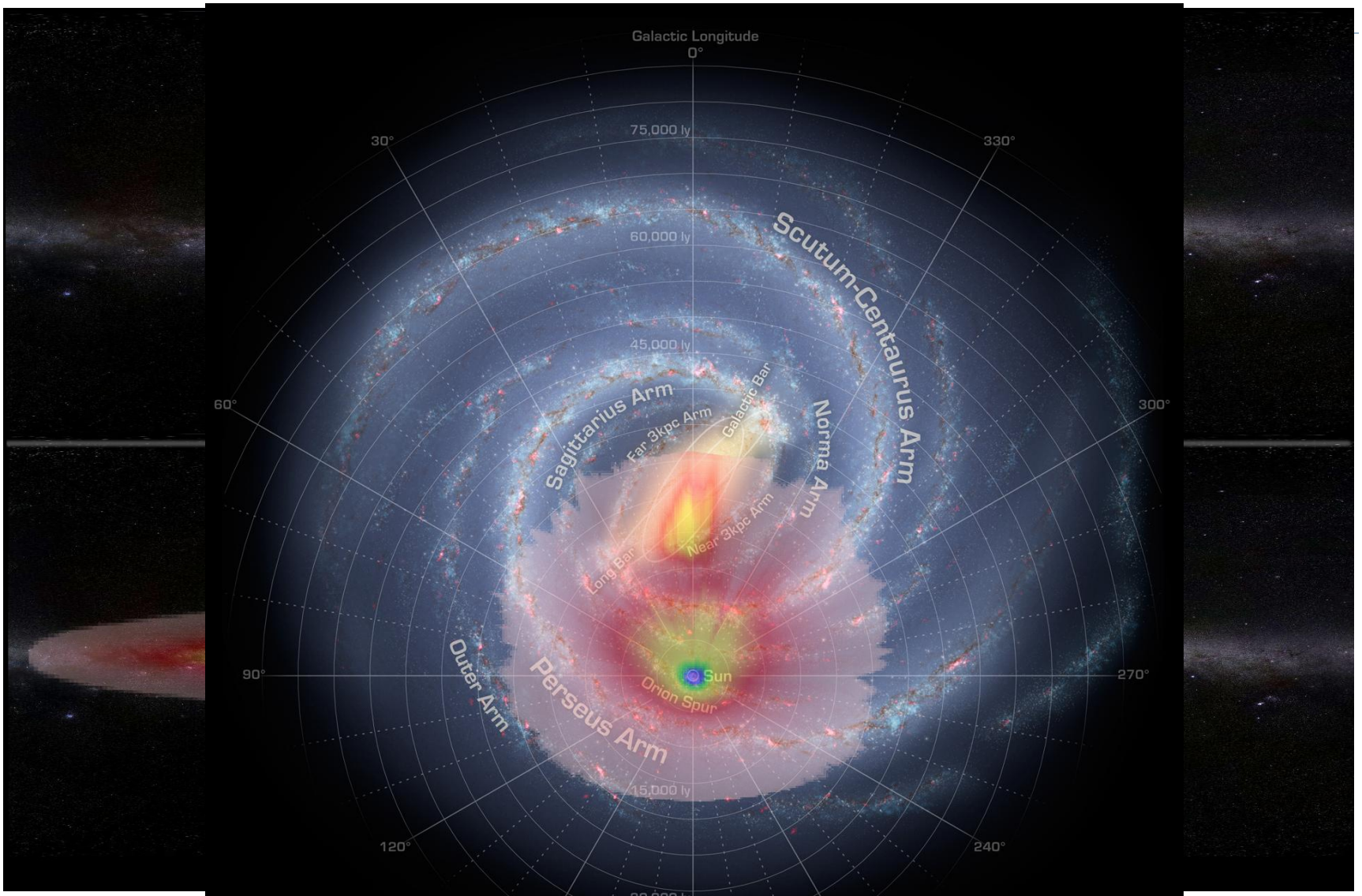


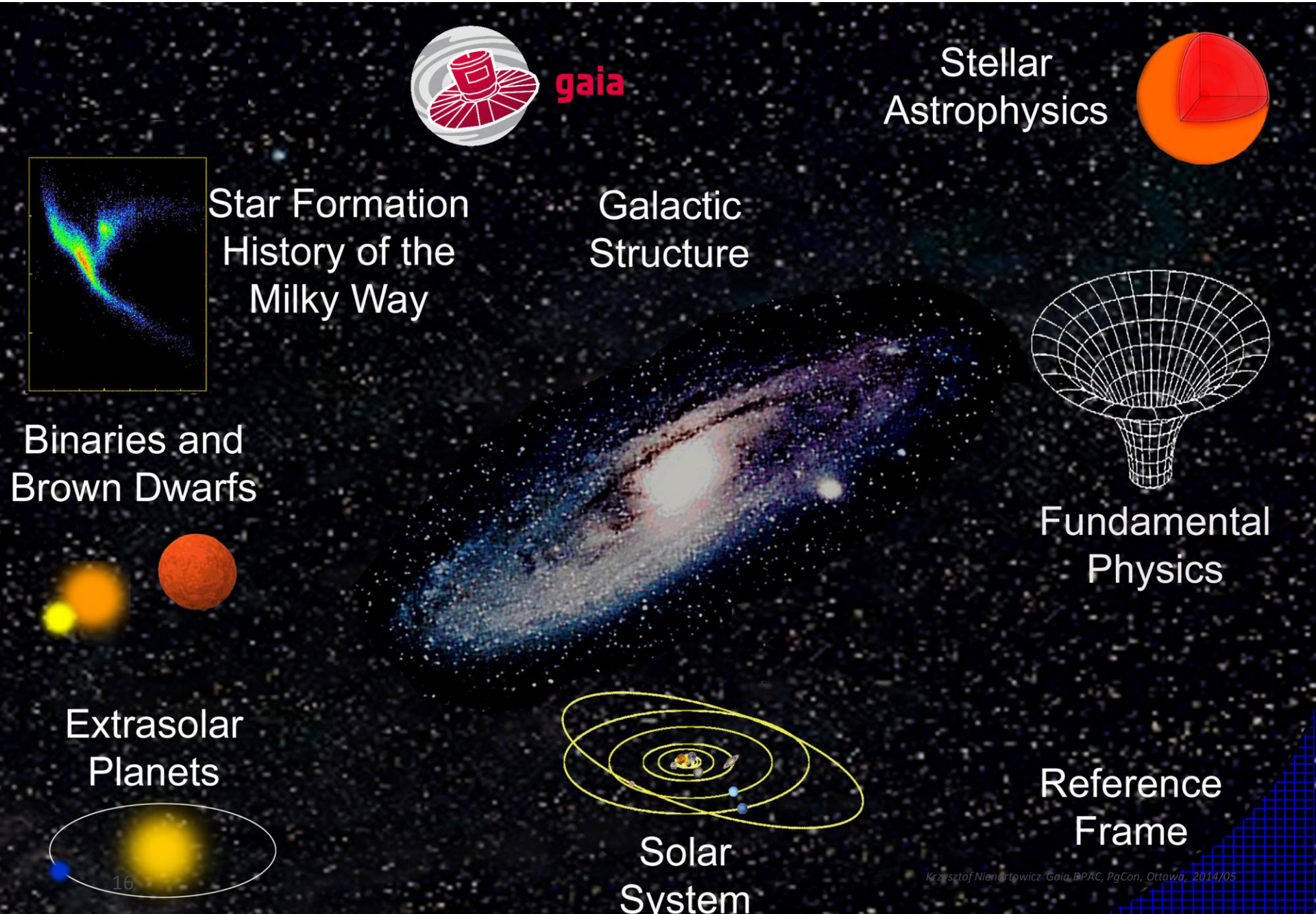
Gaia Science

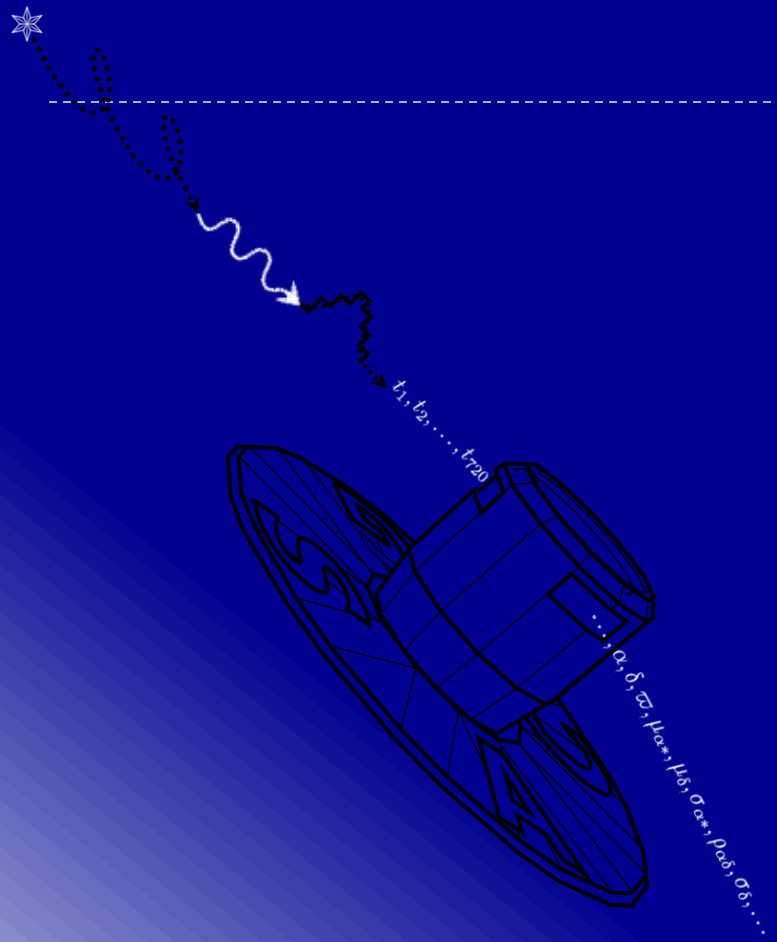
Parallax

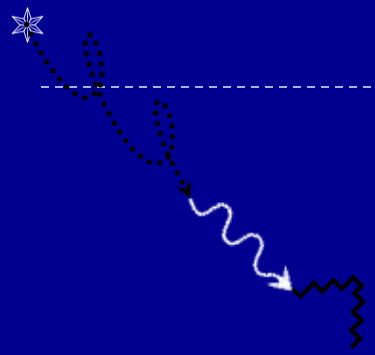
Gaia Science

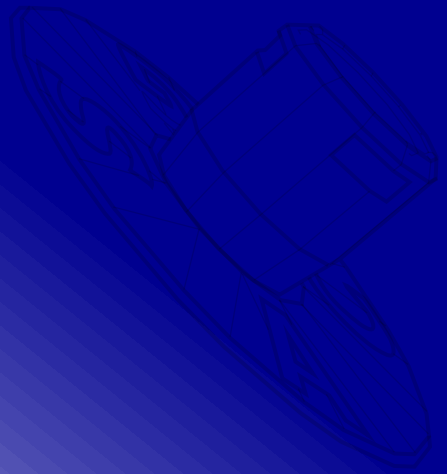
3D Galaxy structure, Galaxy dynamics thanks to parallax, Radial Velocity

Gaia Science




$t_1, t_2, \ldots, t_{720}$
$\ldots, \alpha, \delta, \varpi, \mu_{\alpha*}, \mu_\delta, \sigma_{\alpha*}, \rho_{\alpha\delta}, \sigma_\delta, \ldots$





Observing process:

- Apparent source motion on the sky,
- propagation of light to Gaia,
- Astrometric CCDs readout,
typically 6x1 binned counting profile

x 720 x 10^9 = **10^{12}**

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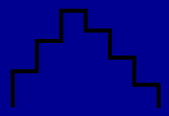


x 720 x 10^9 = $\mathbf{10^{12}}$

Forward modelling:

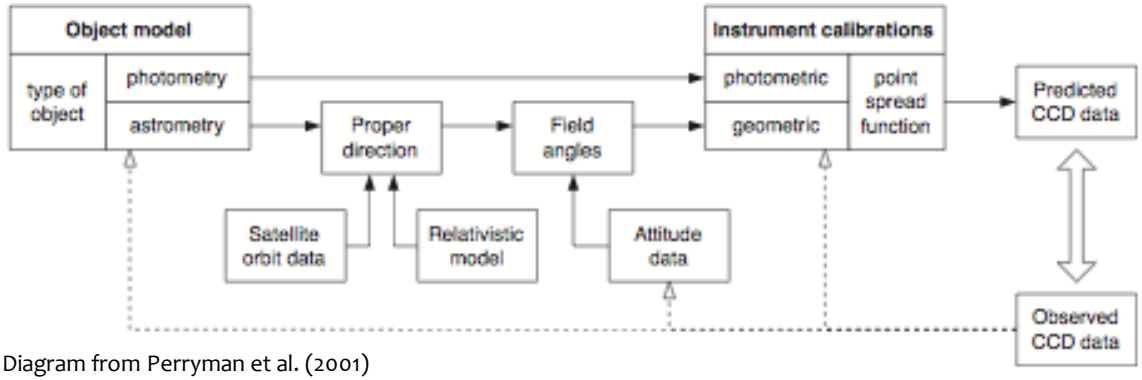
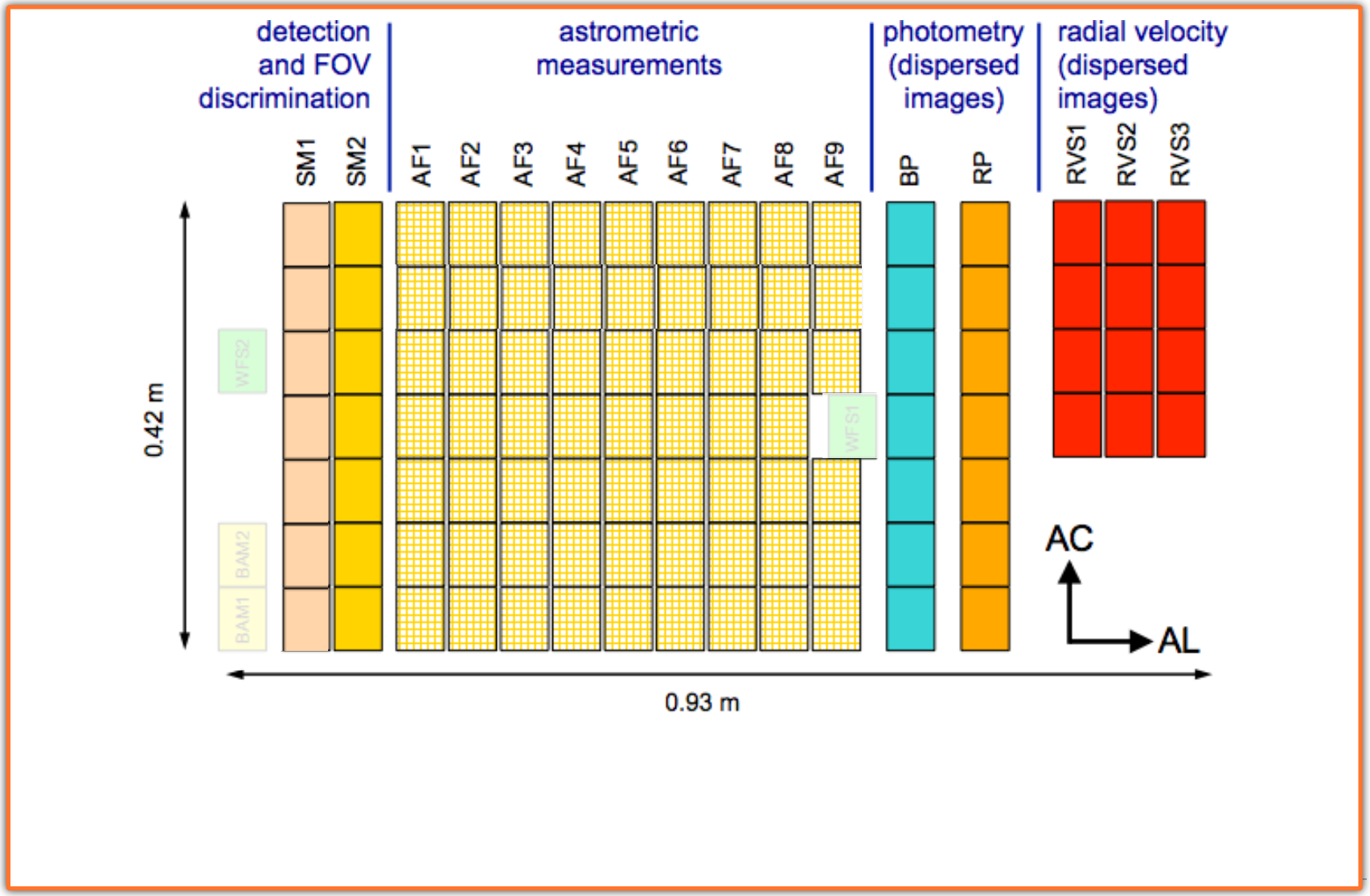


Diagram from Perryman et al. (2001)

Gaia focal plane: CDD, BP RP, RVS observations

938 million pixel camera



Courtesy Of Berry Holl

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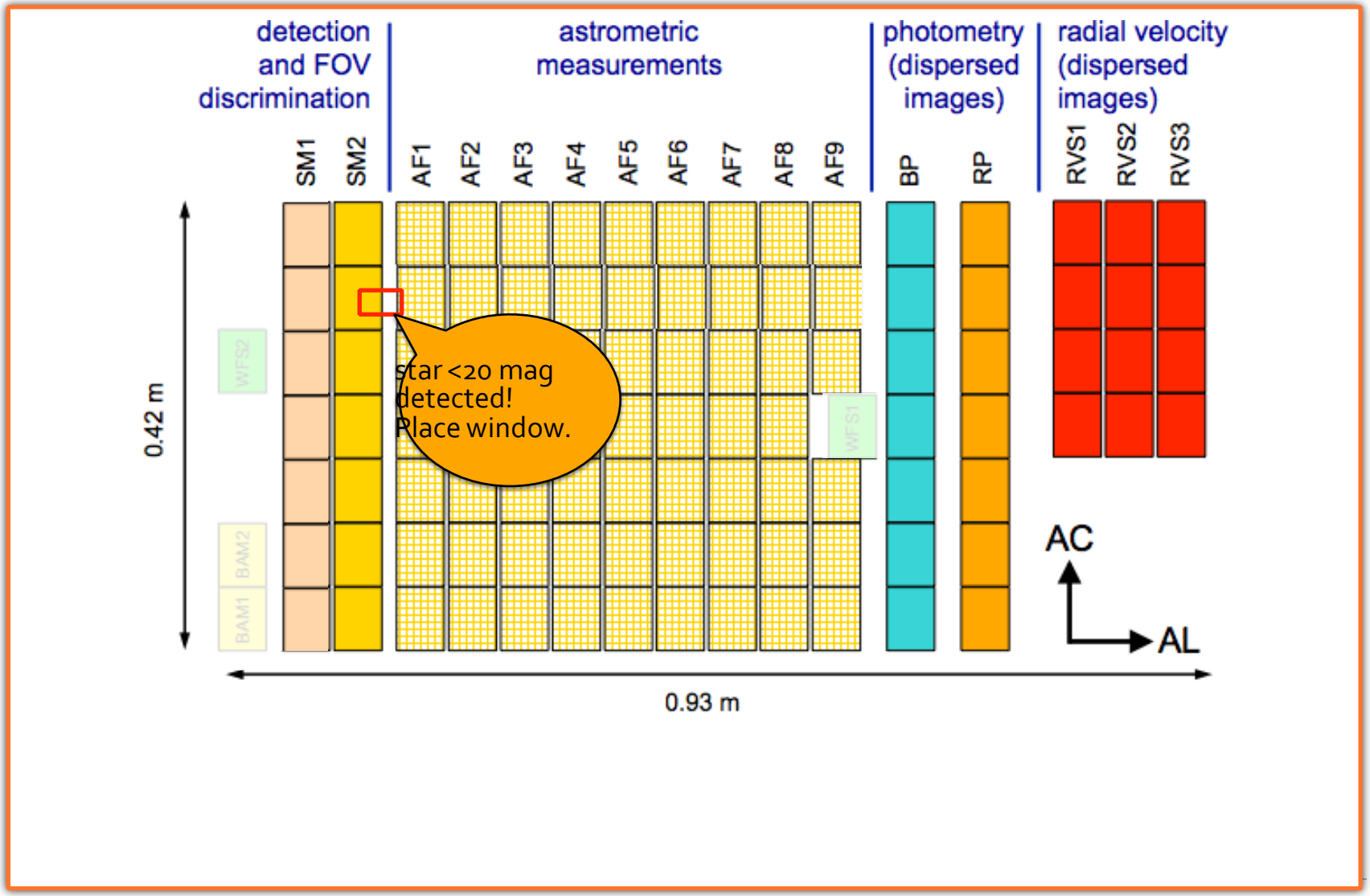

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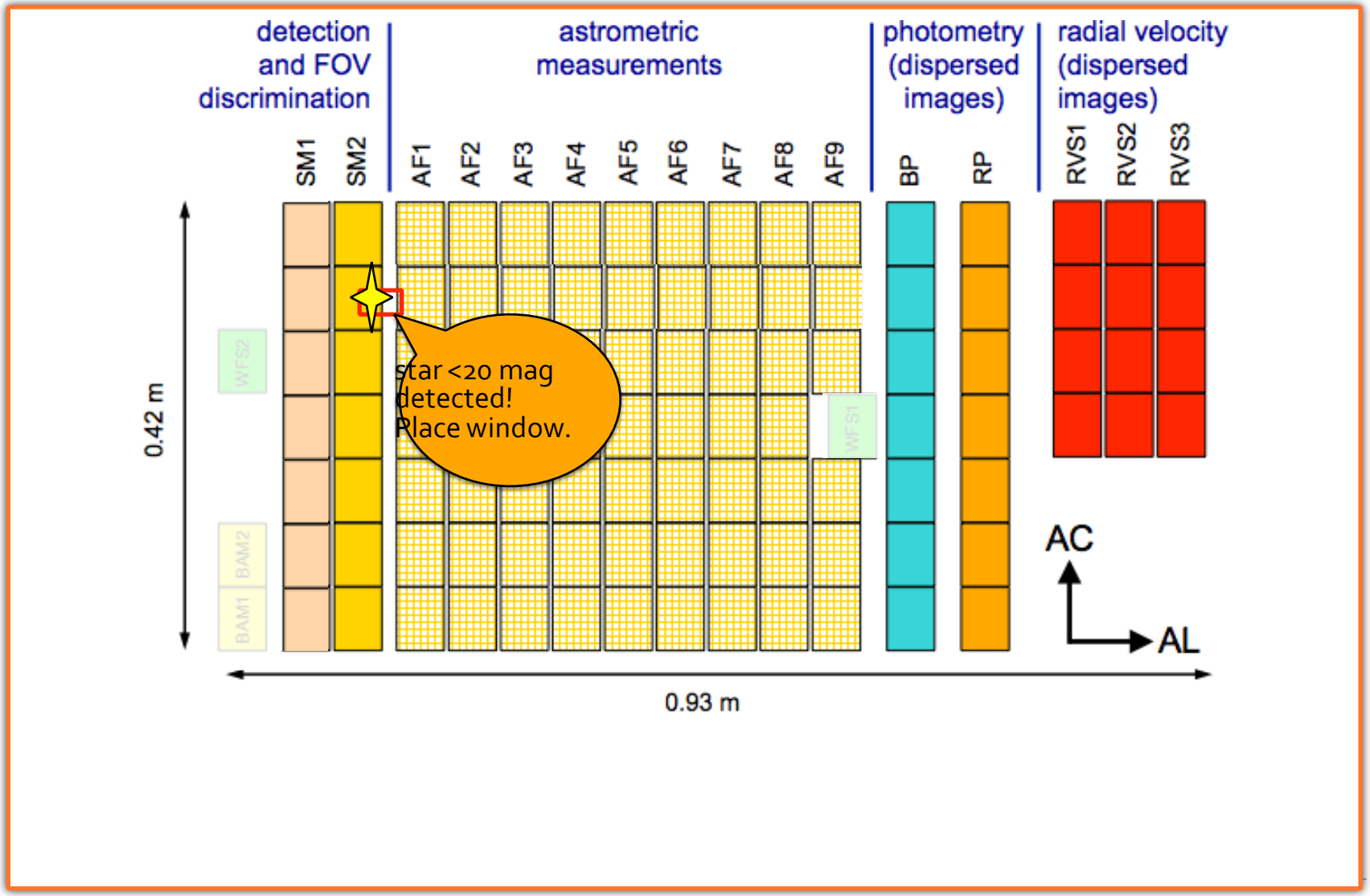

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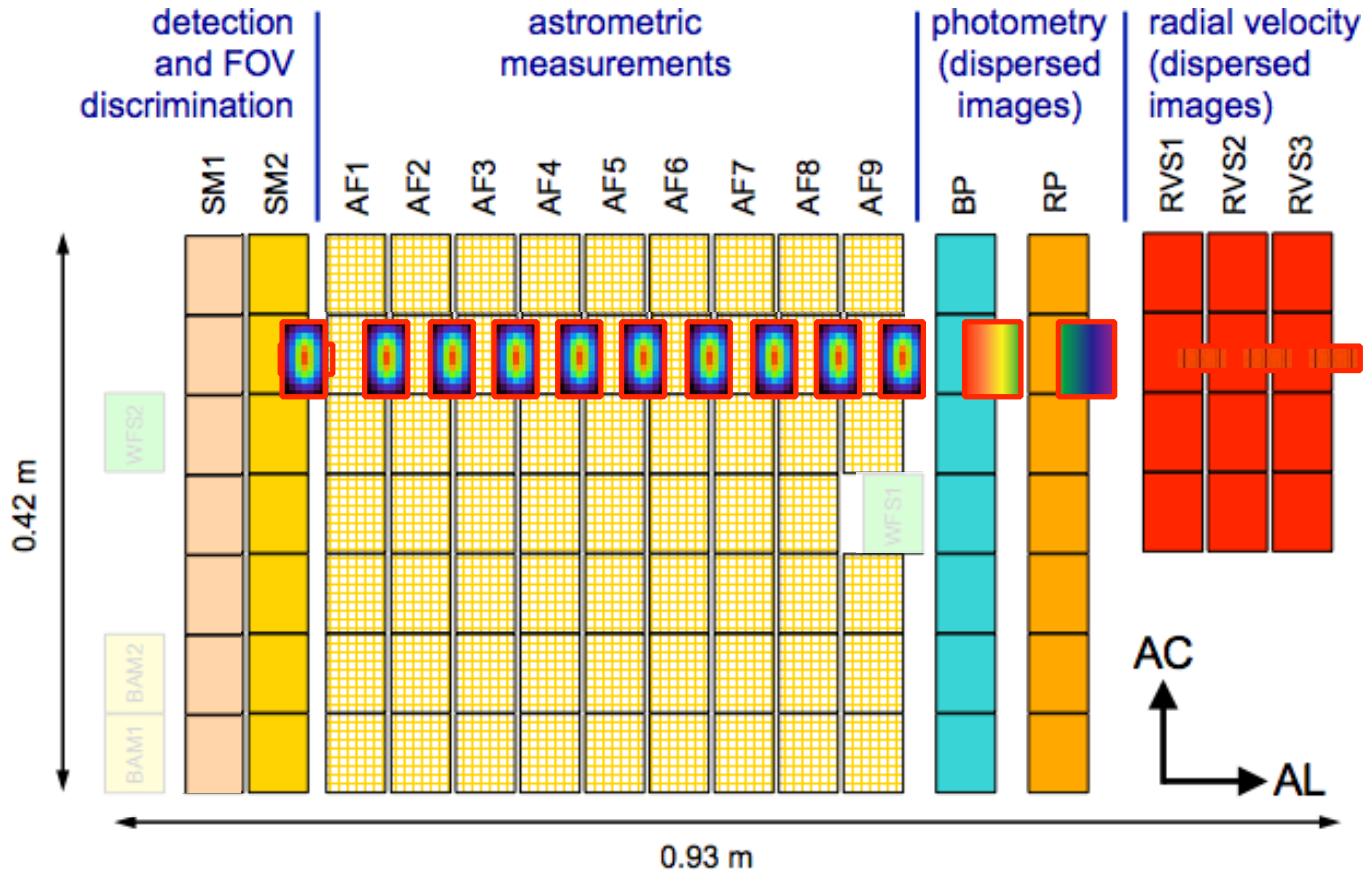

windows observed:

Courtesy Of Berry Holl

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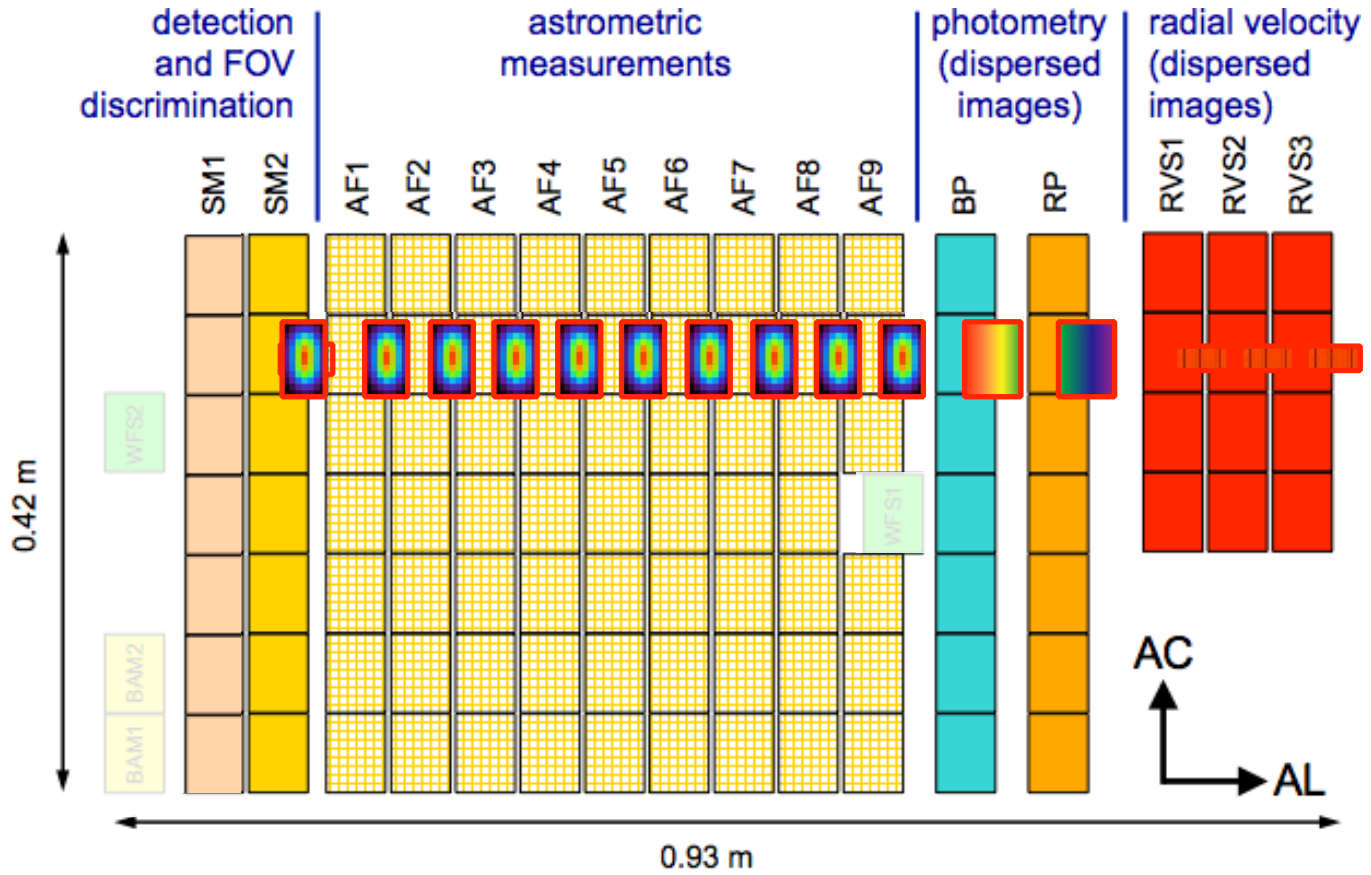

windows observed:

→ ~4.4 sec

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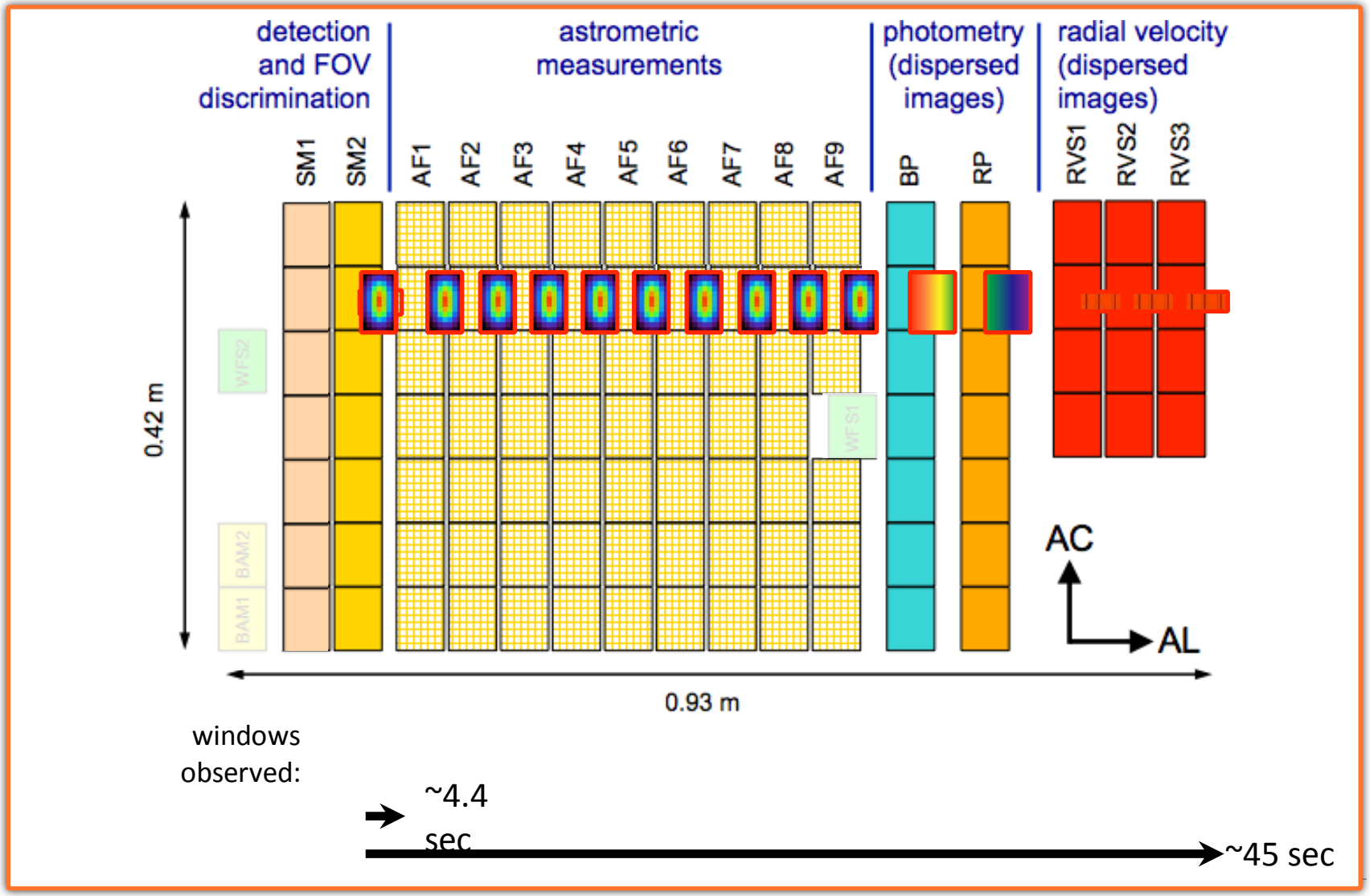
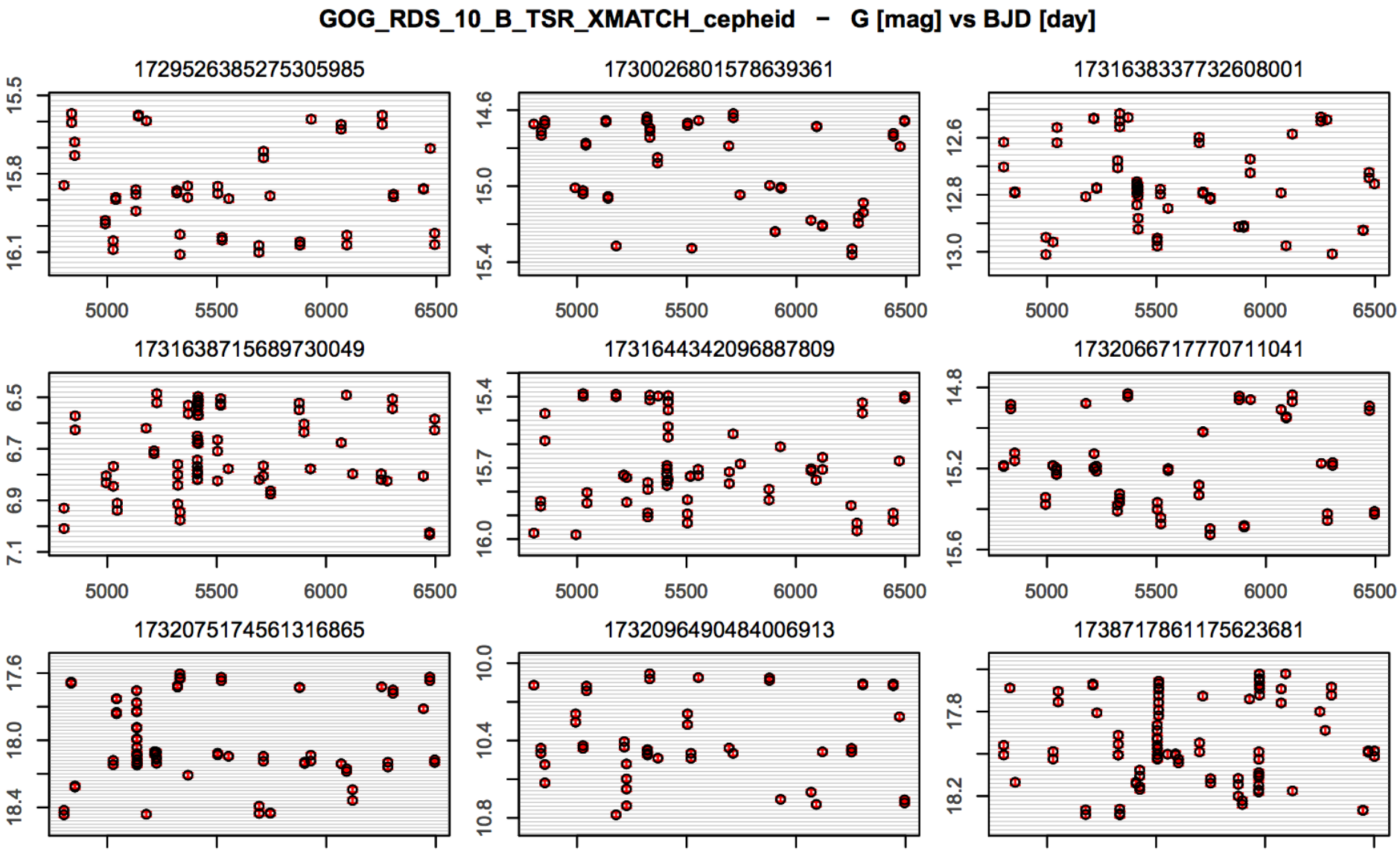
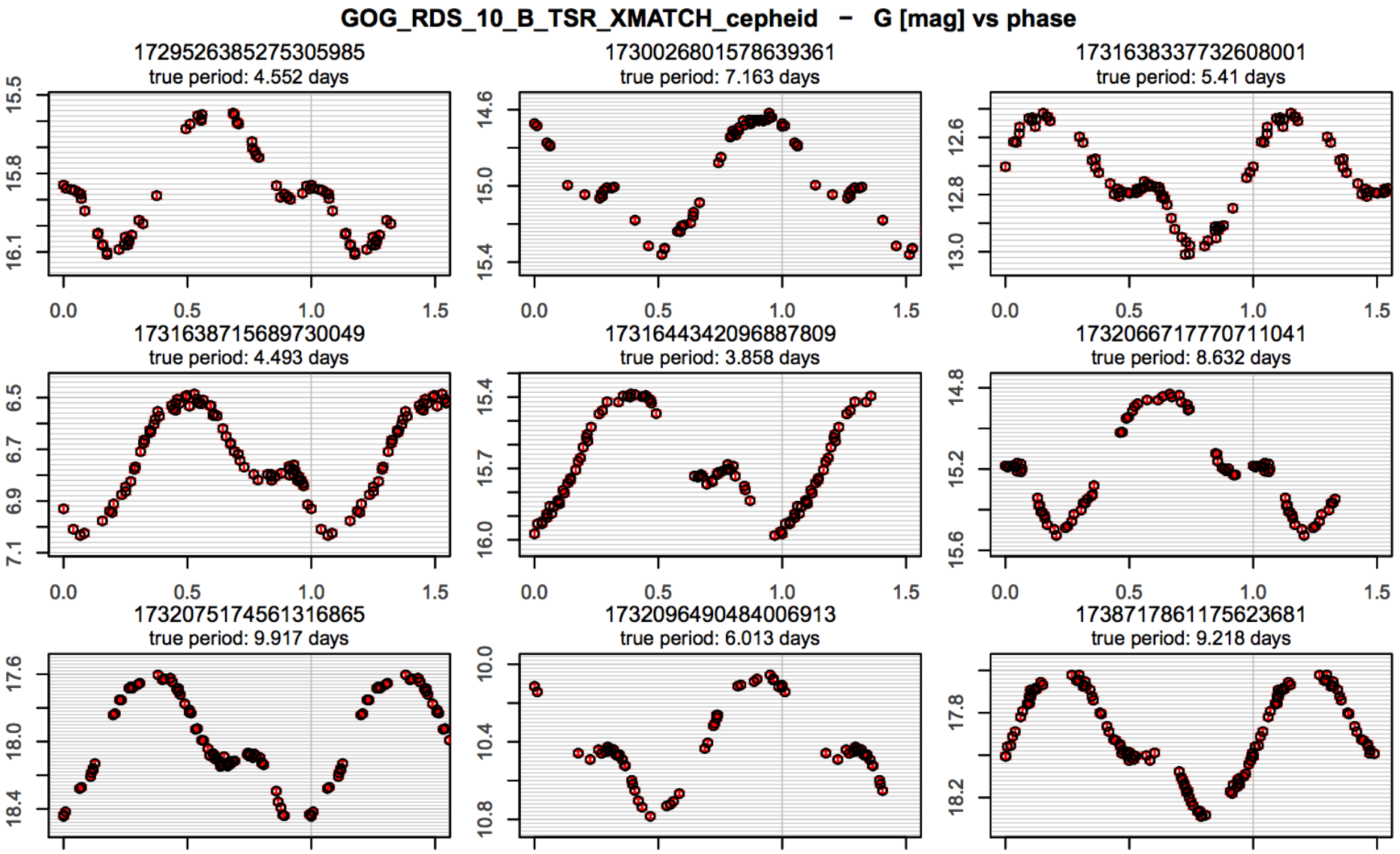


Courtesy Of Berry Holl

Lightcurves == Timeseries



Folded Lightcurves == Timeseries in phase



Hipparcos vs Gaia catalogue
Ultimate goal

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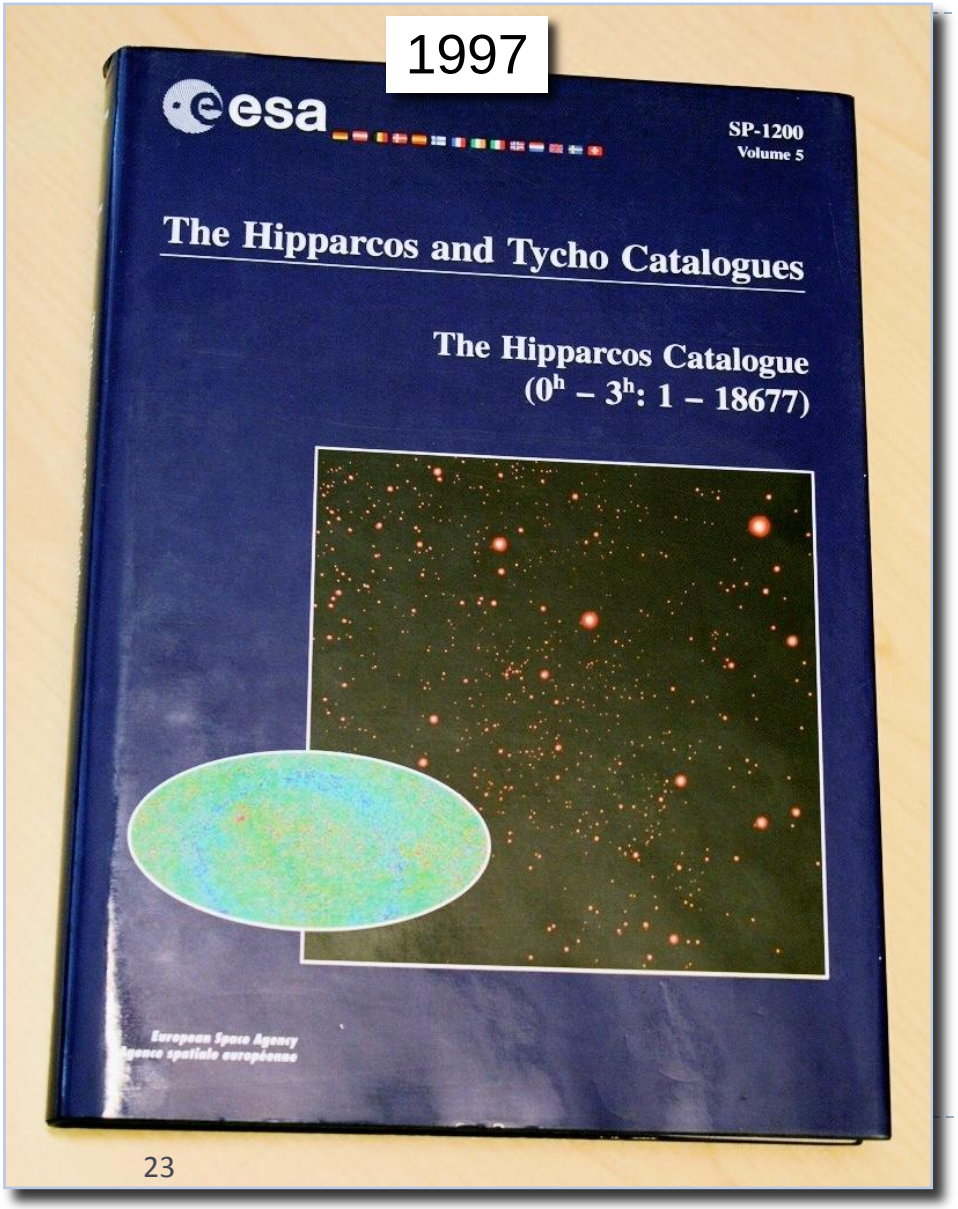

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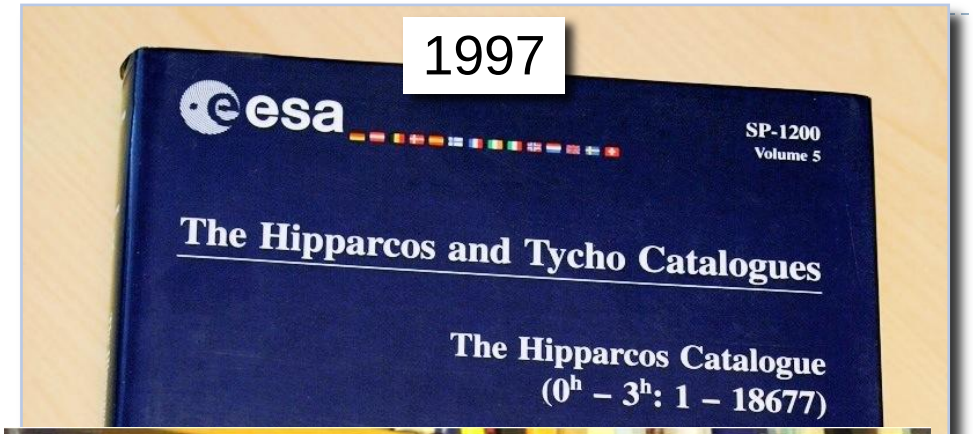

Hipparcos vs Gaia catalogue
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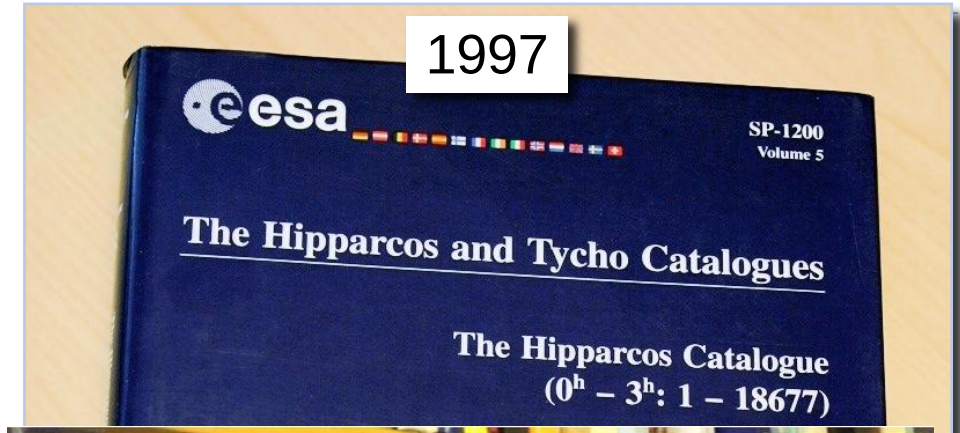
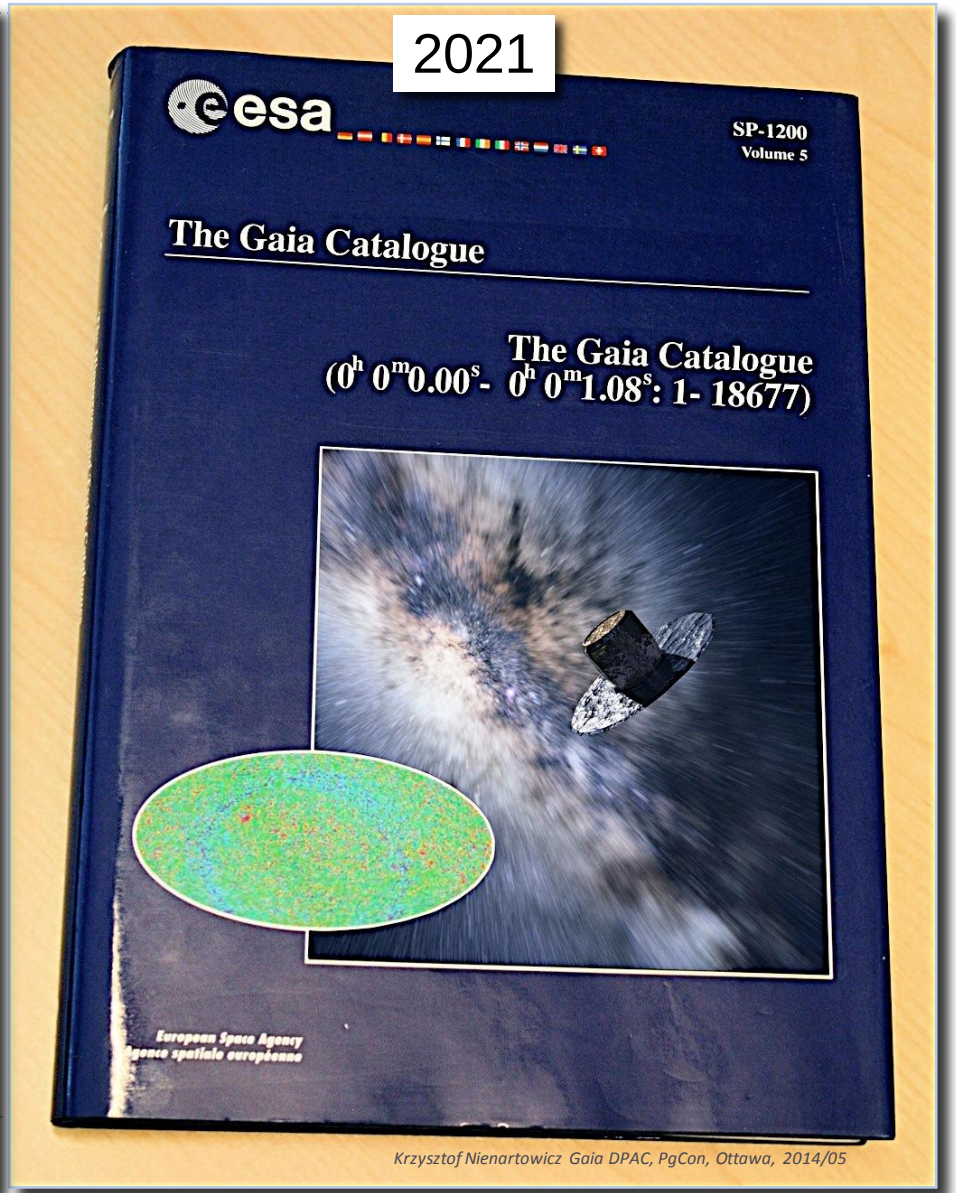
1997



2021



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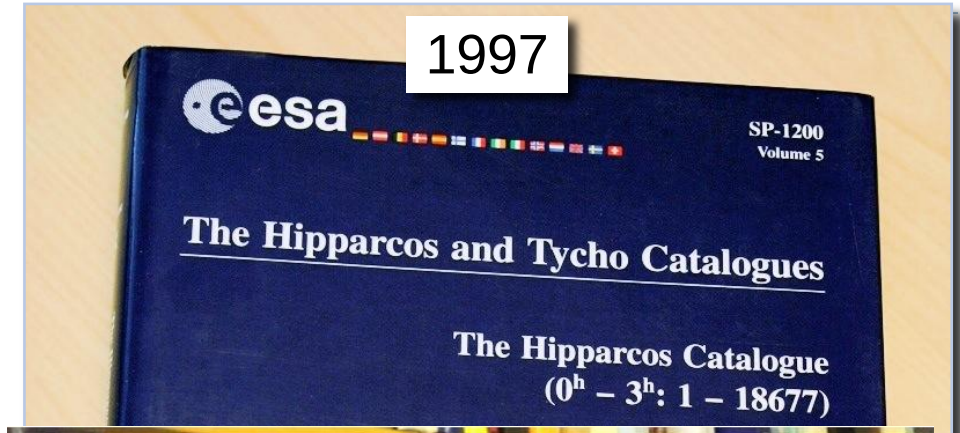

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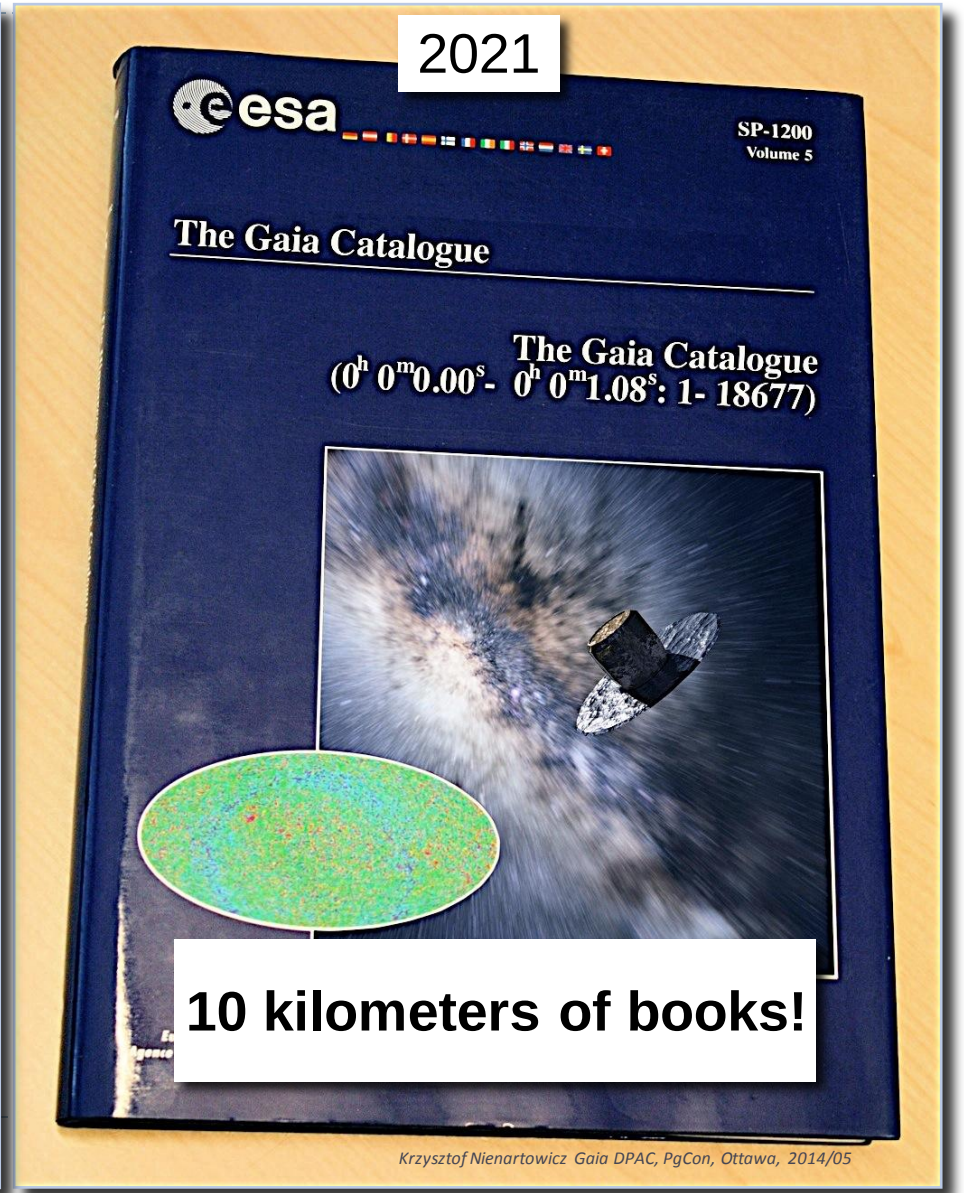
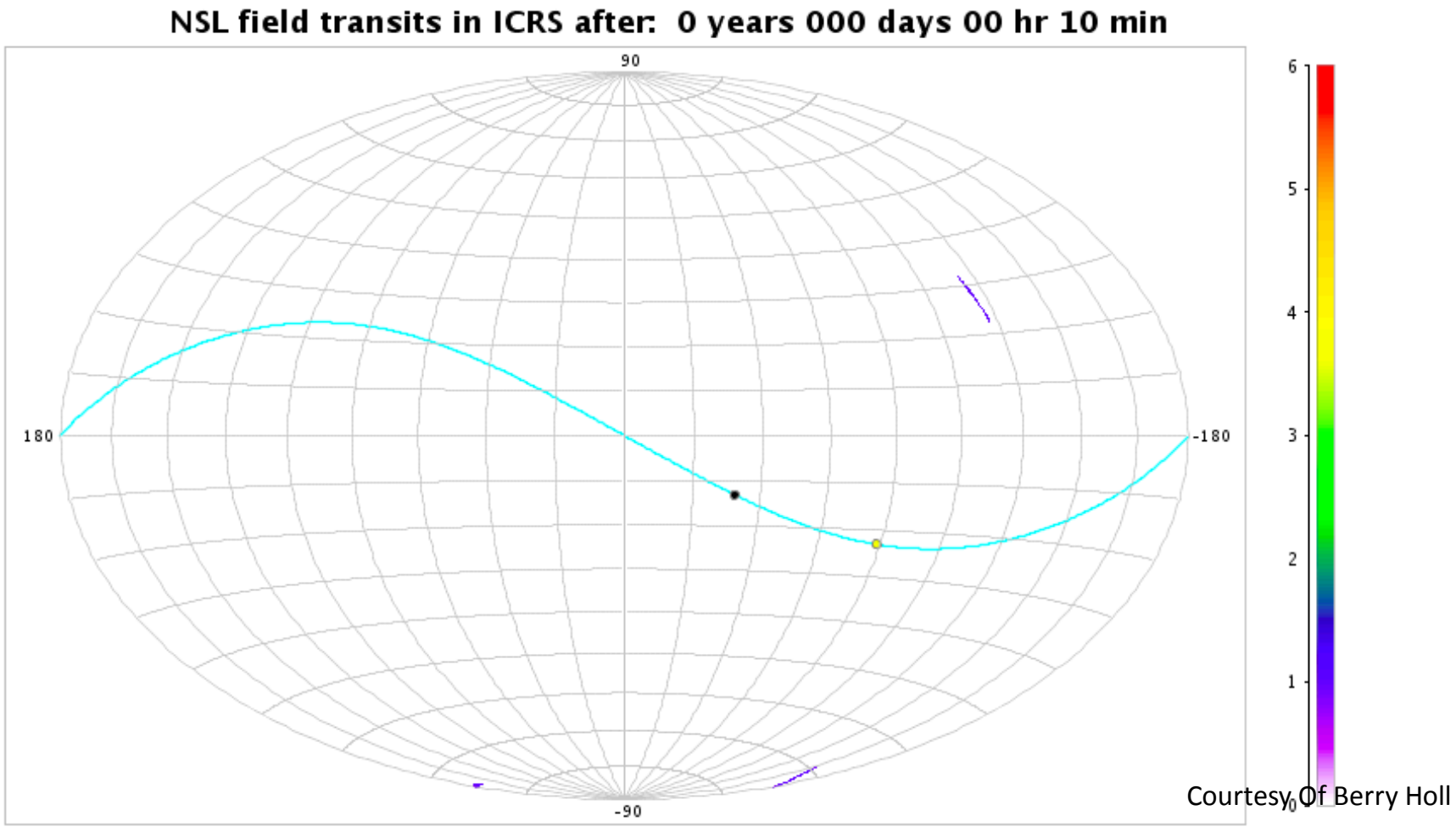


The Gaia scanning law

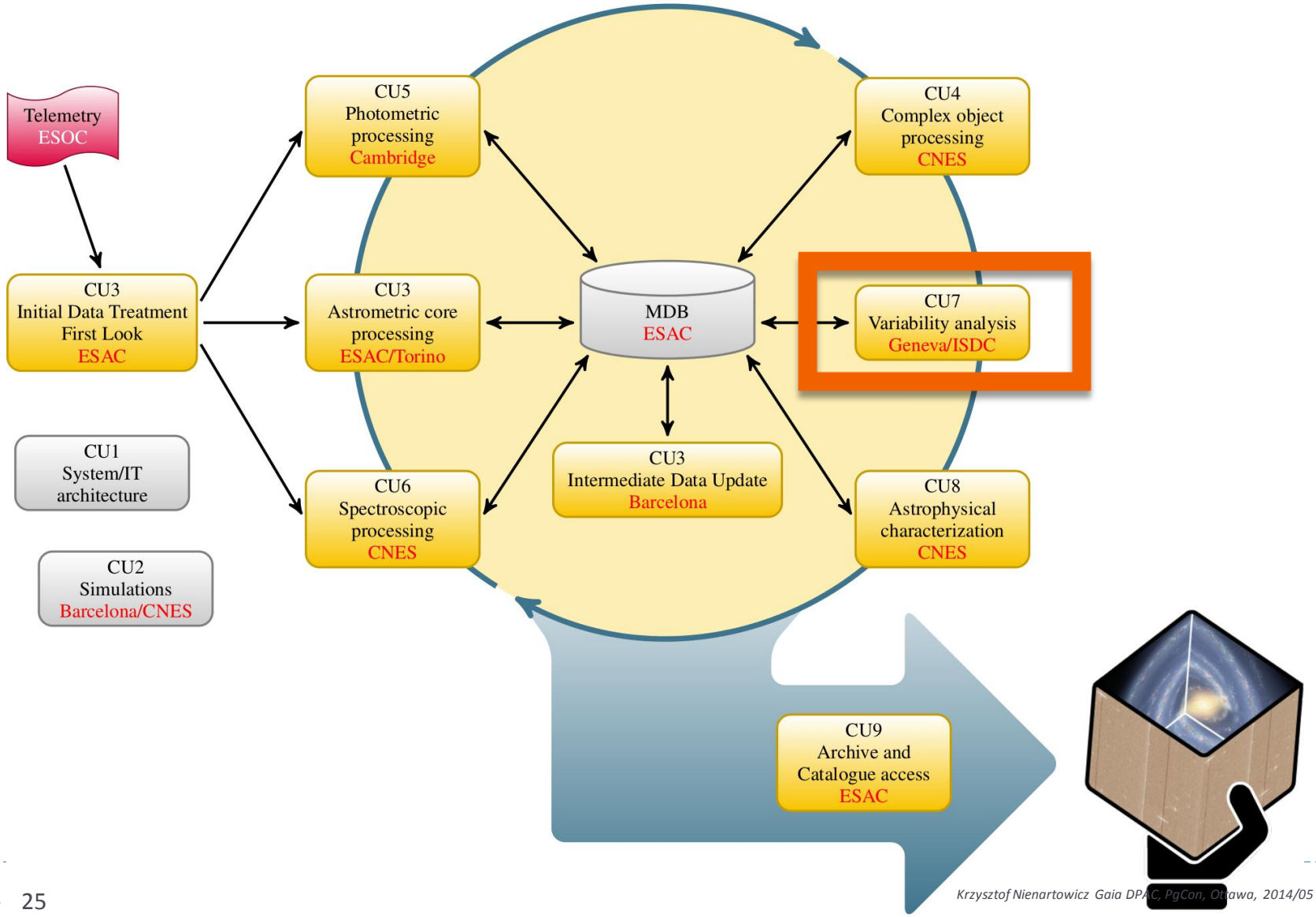


Courtesy Of Berry Holl

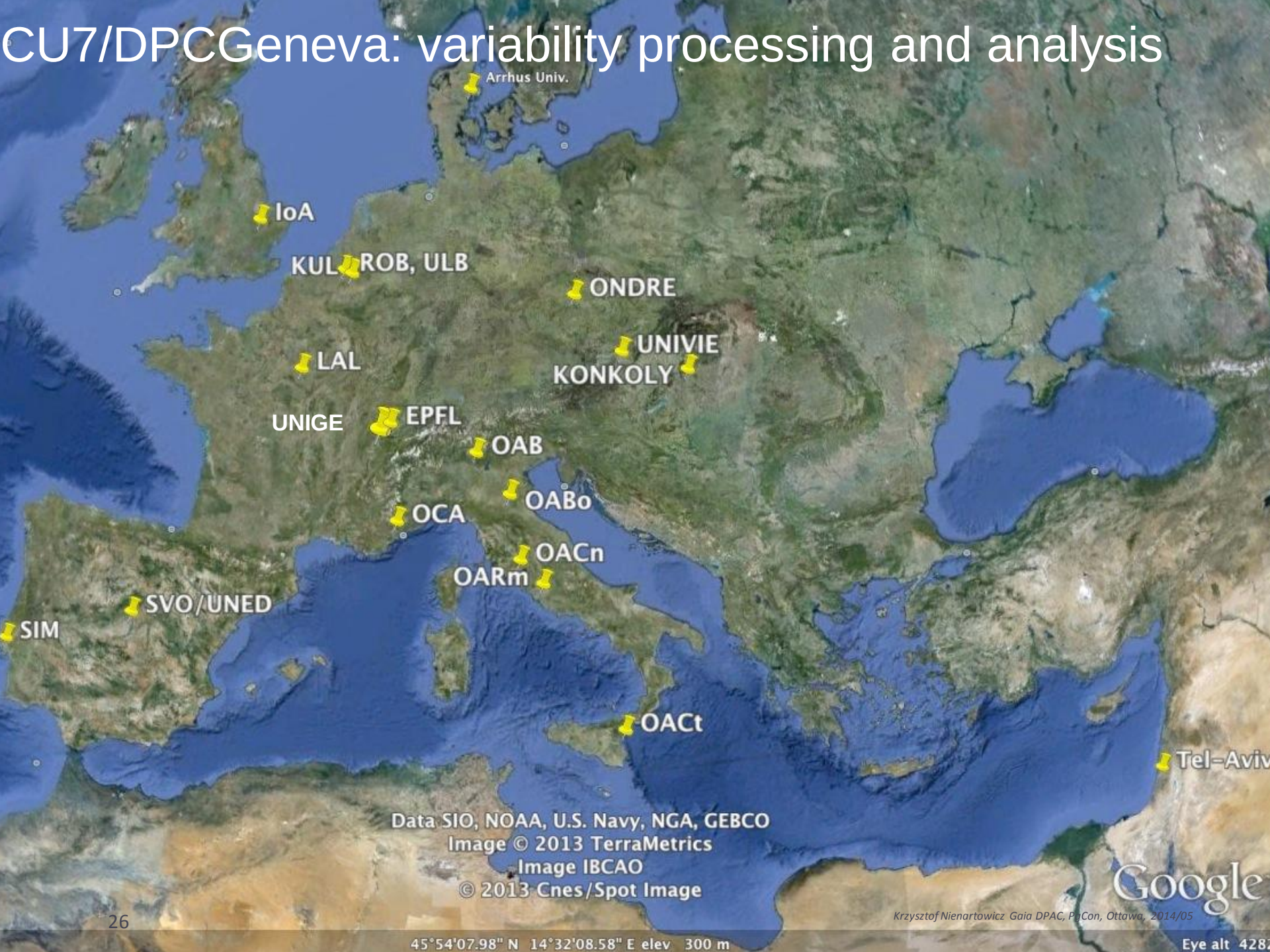
Mean of 70 G-band per-transit observations (40 - 250)

Gaia scientific responsibilities

Global dataflow



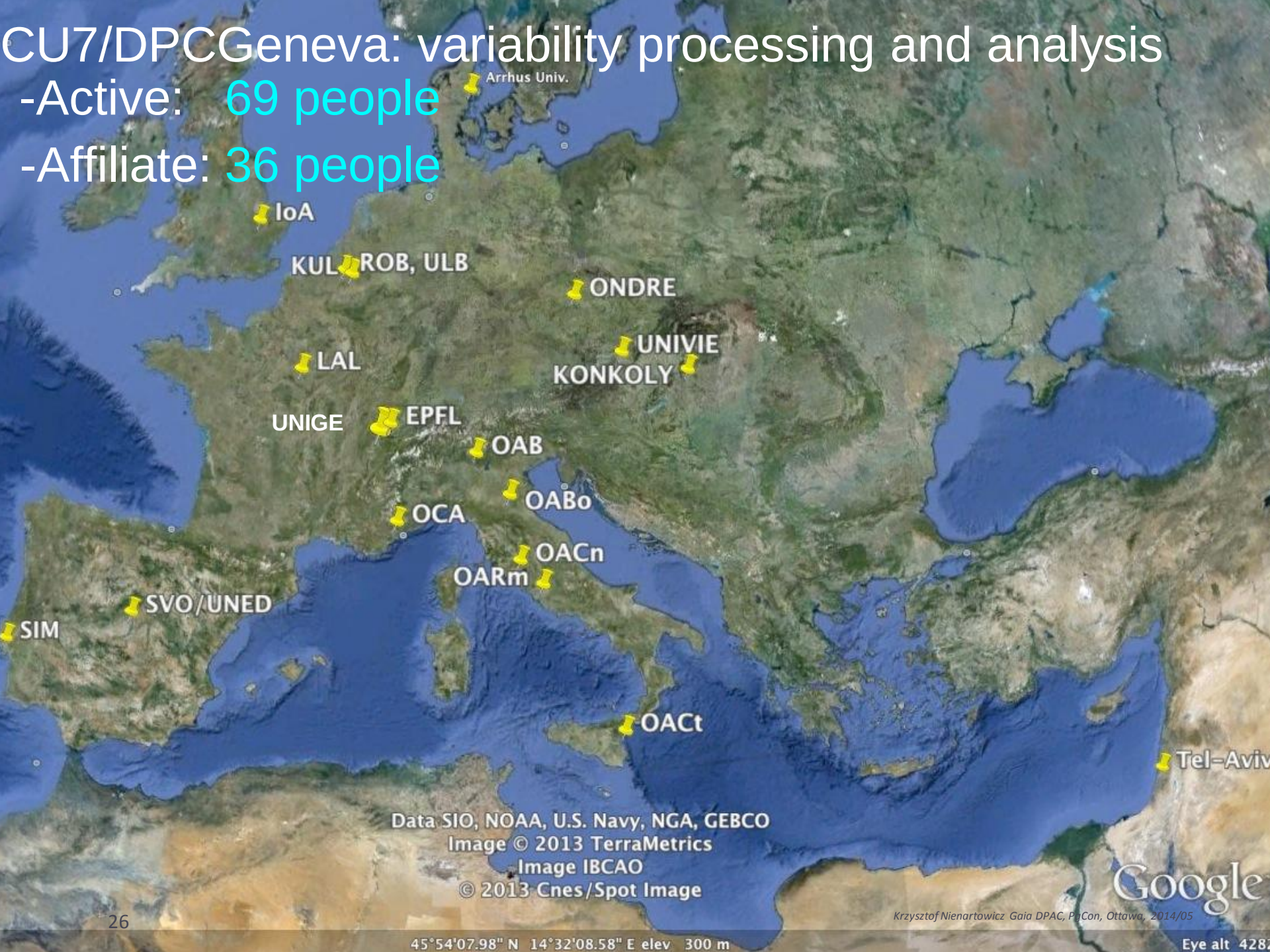
CU7/DPCGeneva: variability processing and analysis



CU7/DPCGeneva: variability processing and analysis

-Active: 69 people

-Affiliate: 36 people



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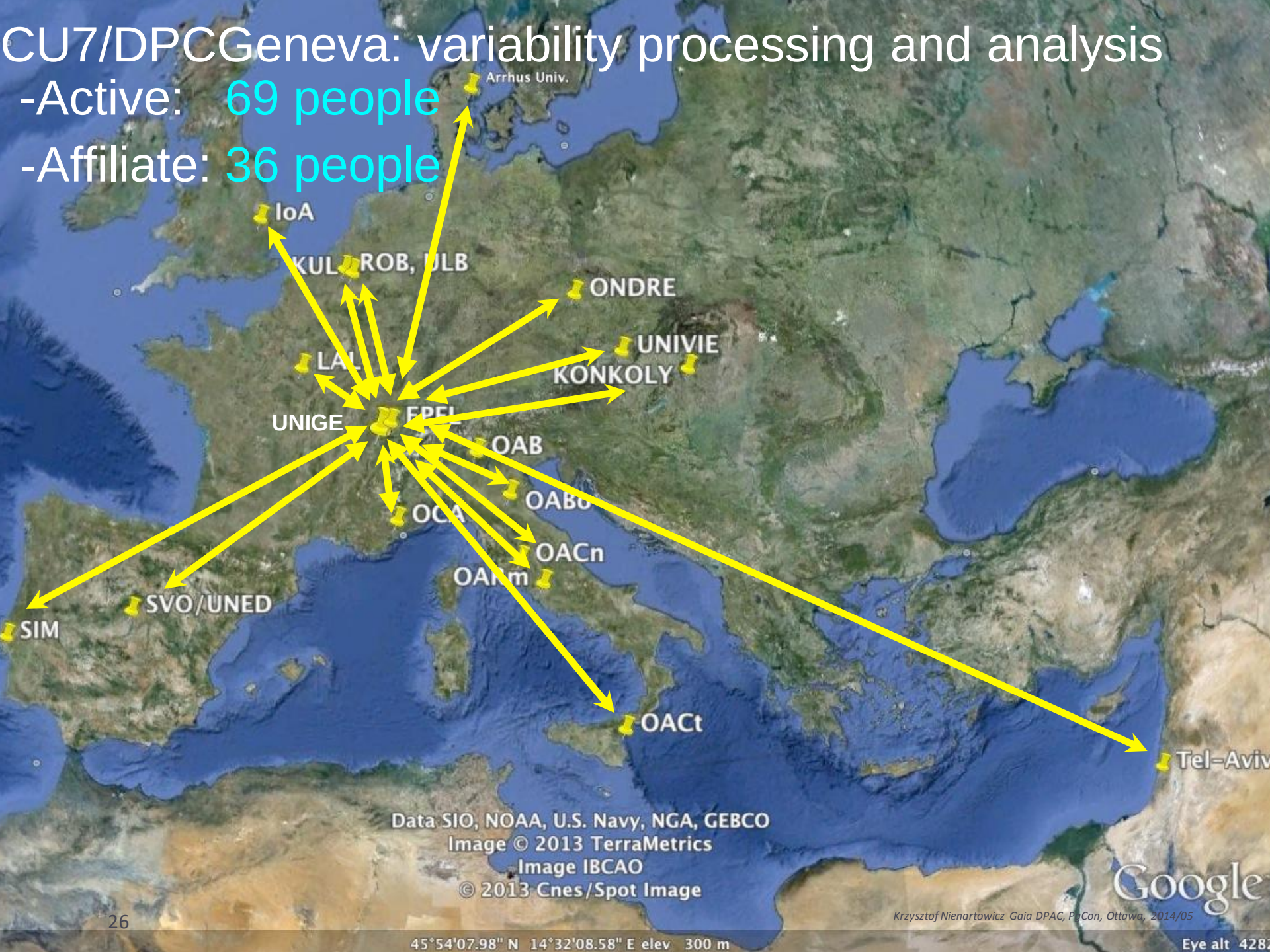
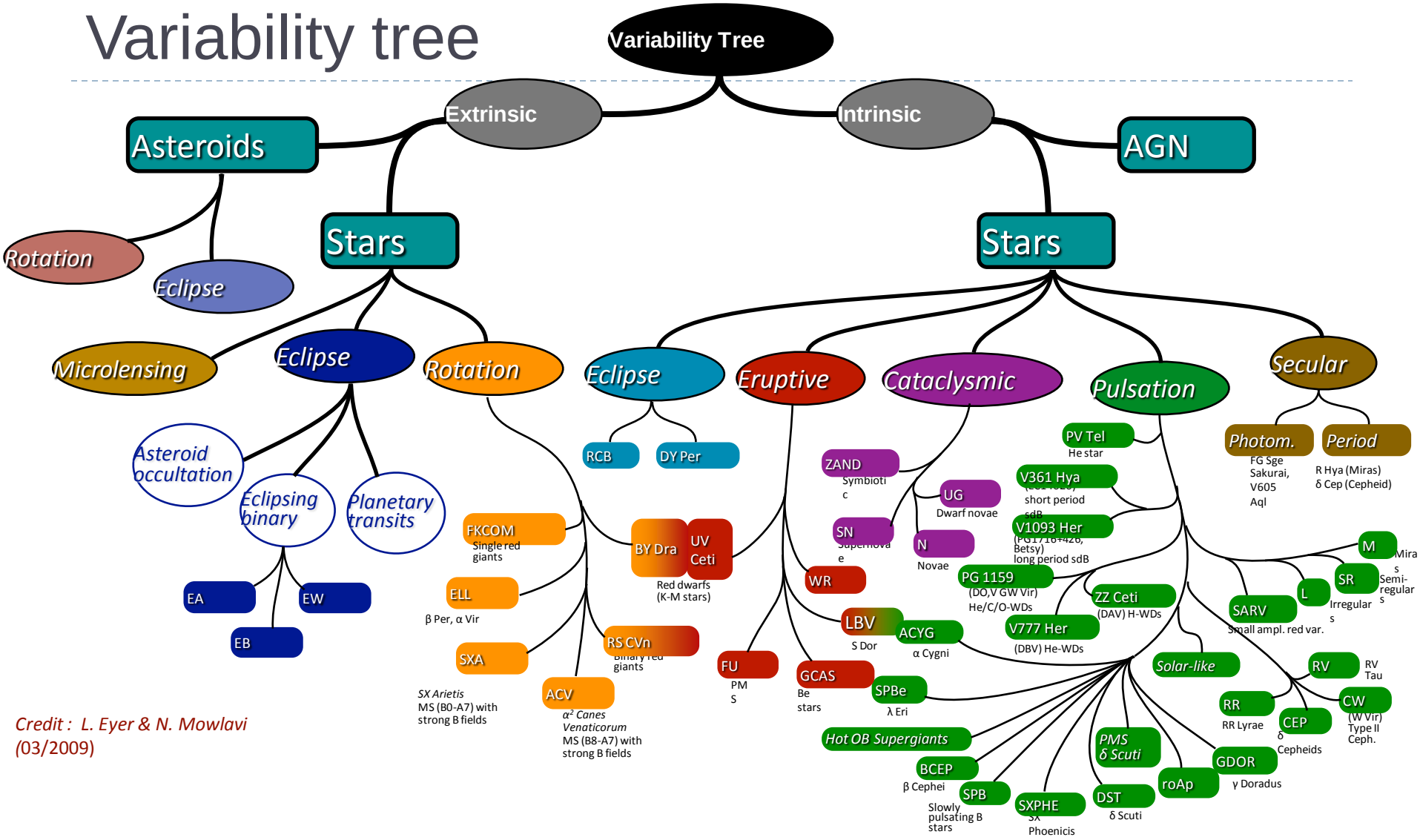
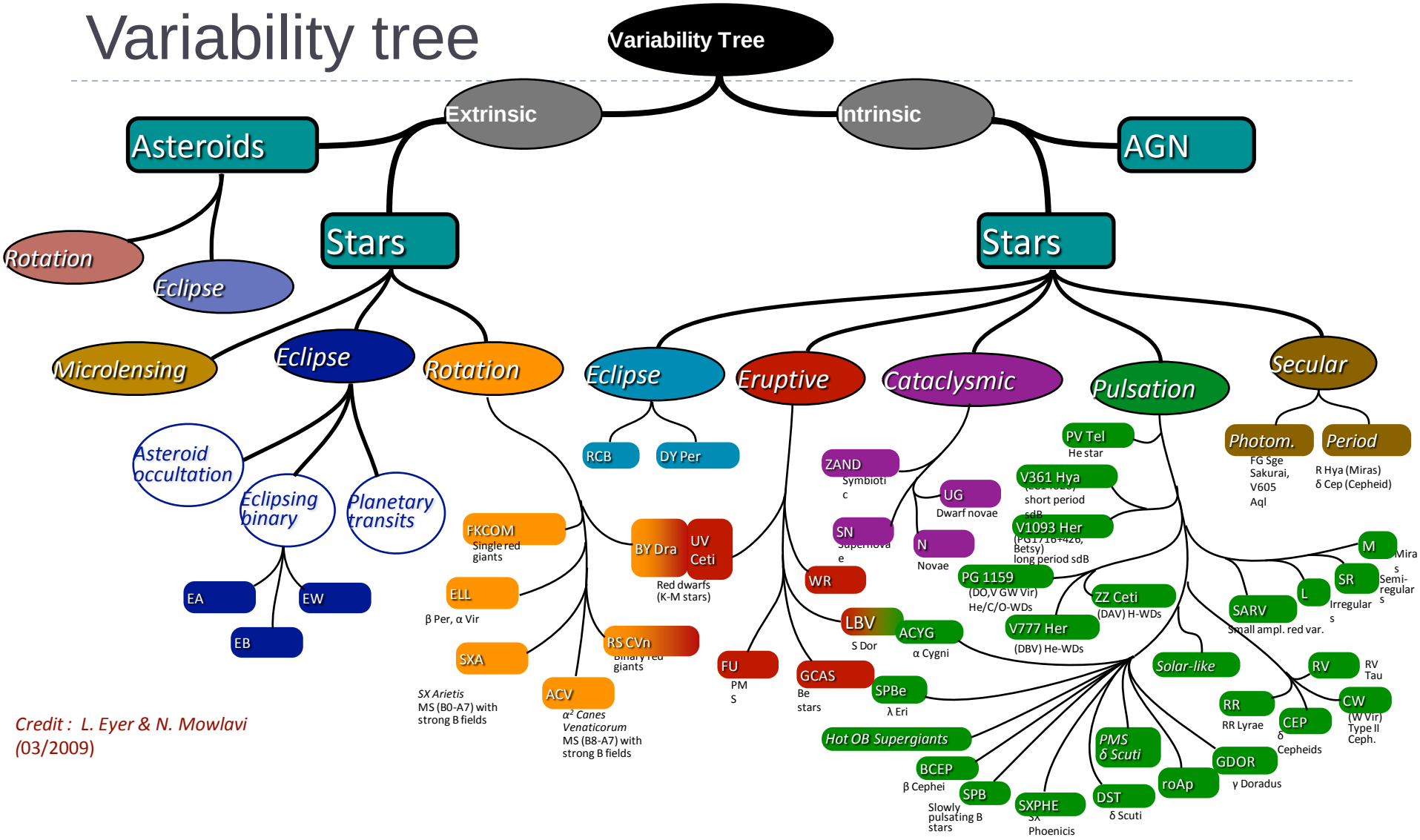


Variability tree



Credit : L. Eyer & N. Mowlavi (03/2009)

Variability tree



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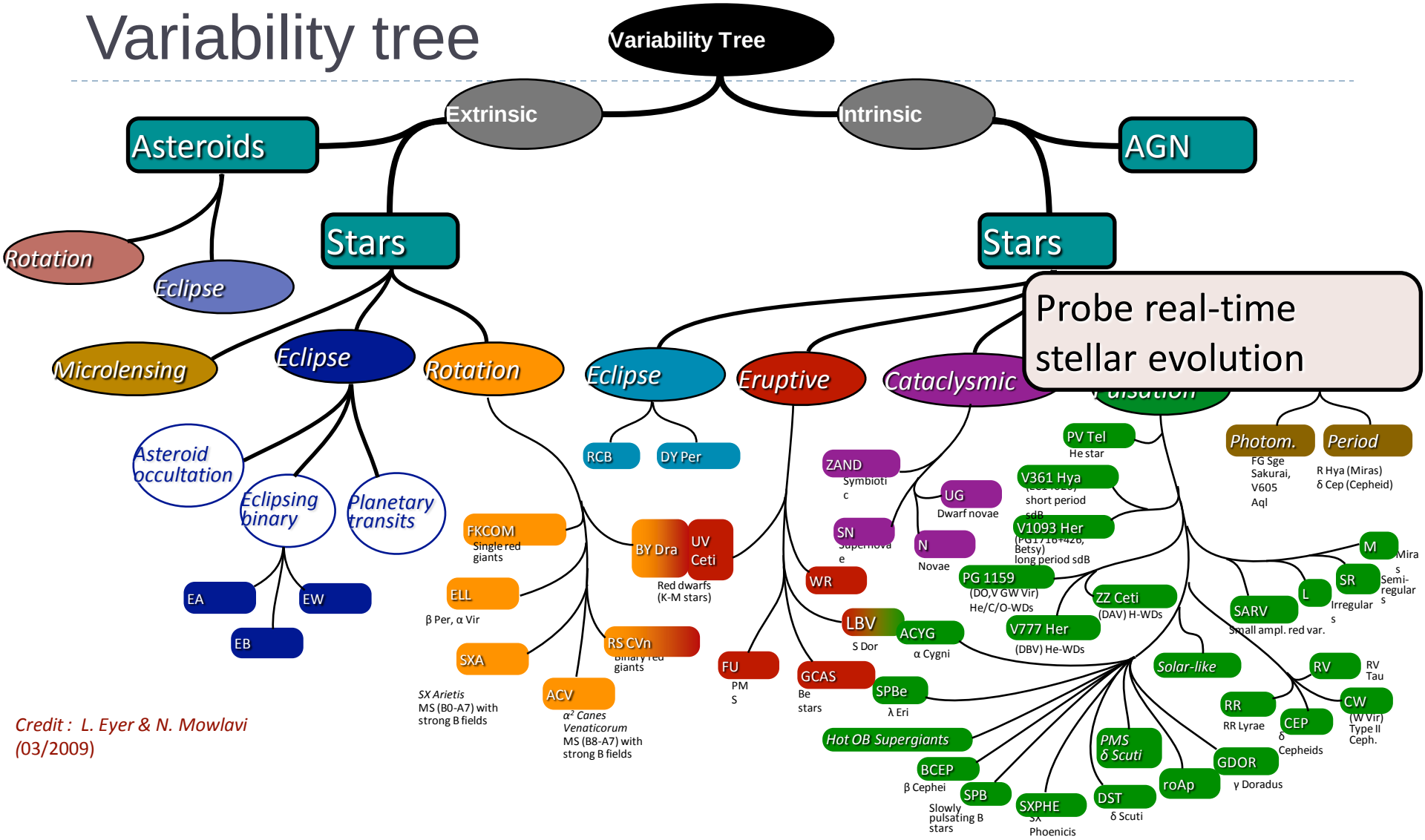
Gaia will detect most variable types on this tree

Variability tree



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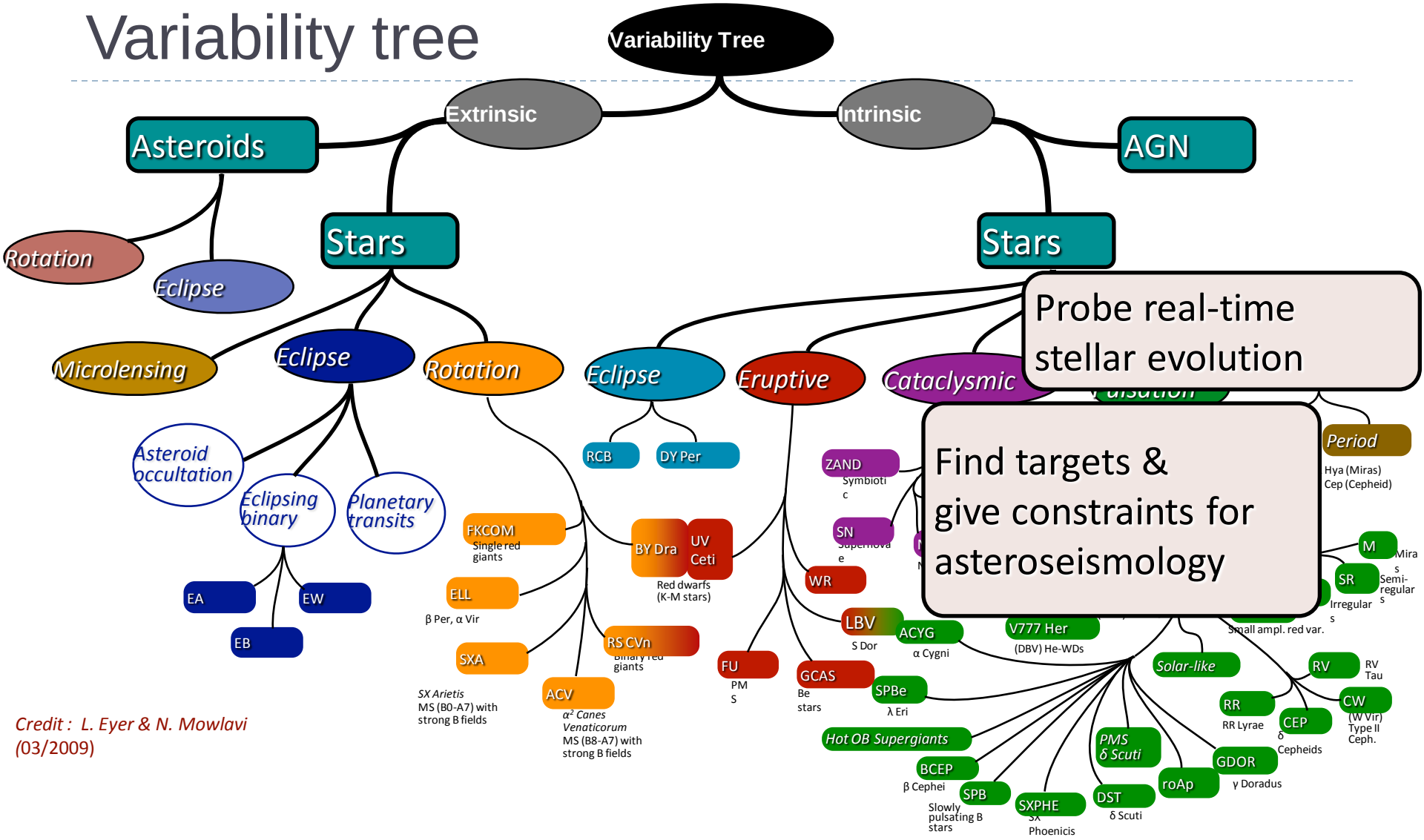

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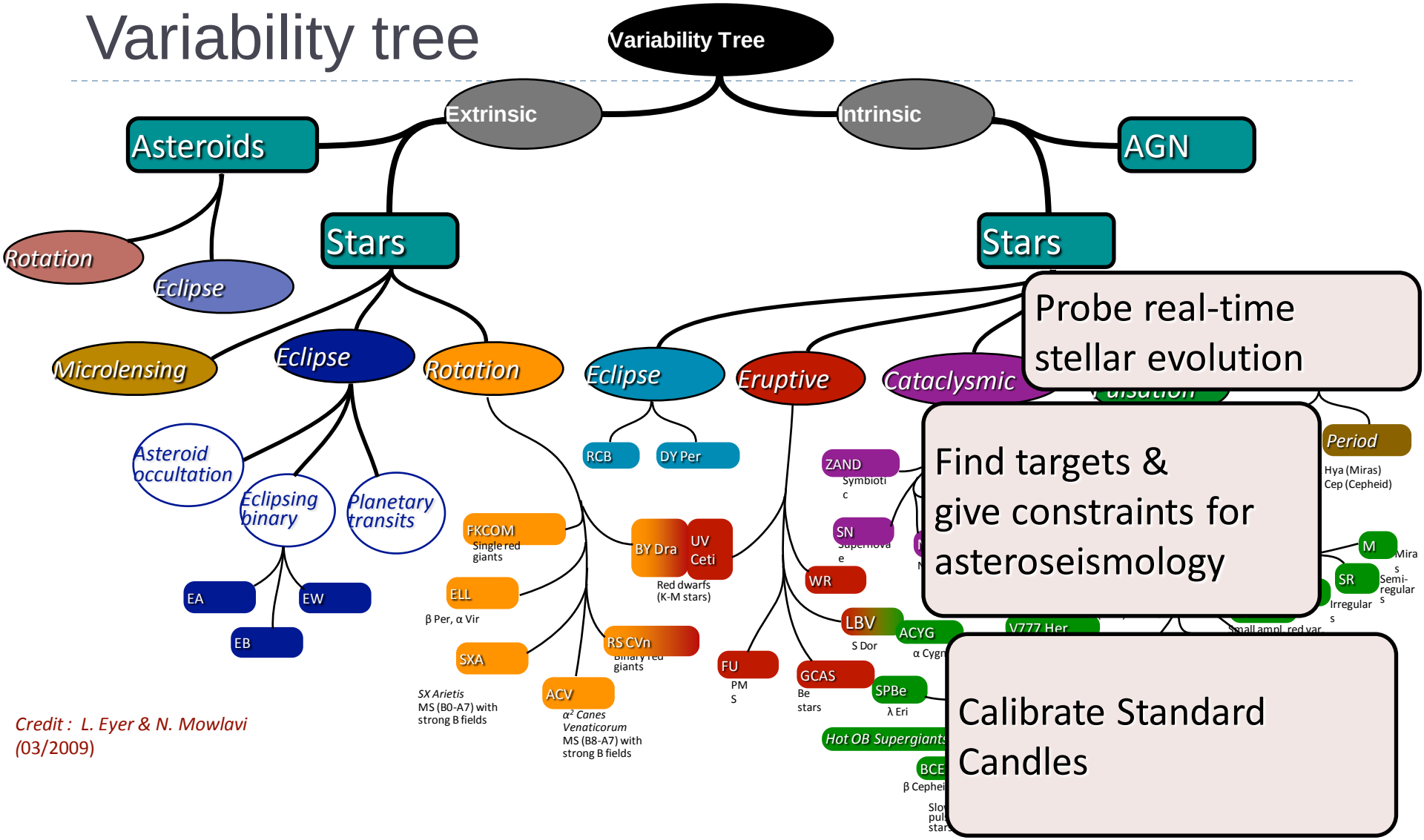

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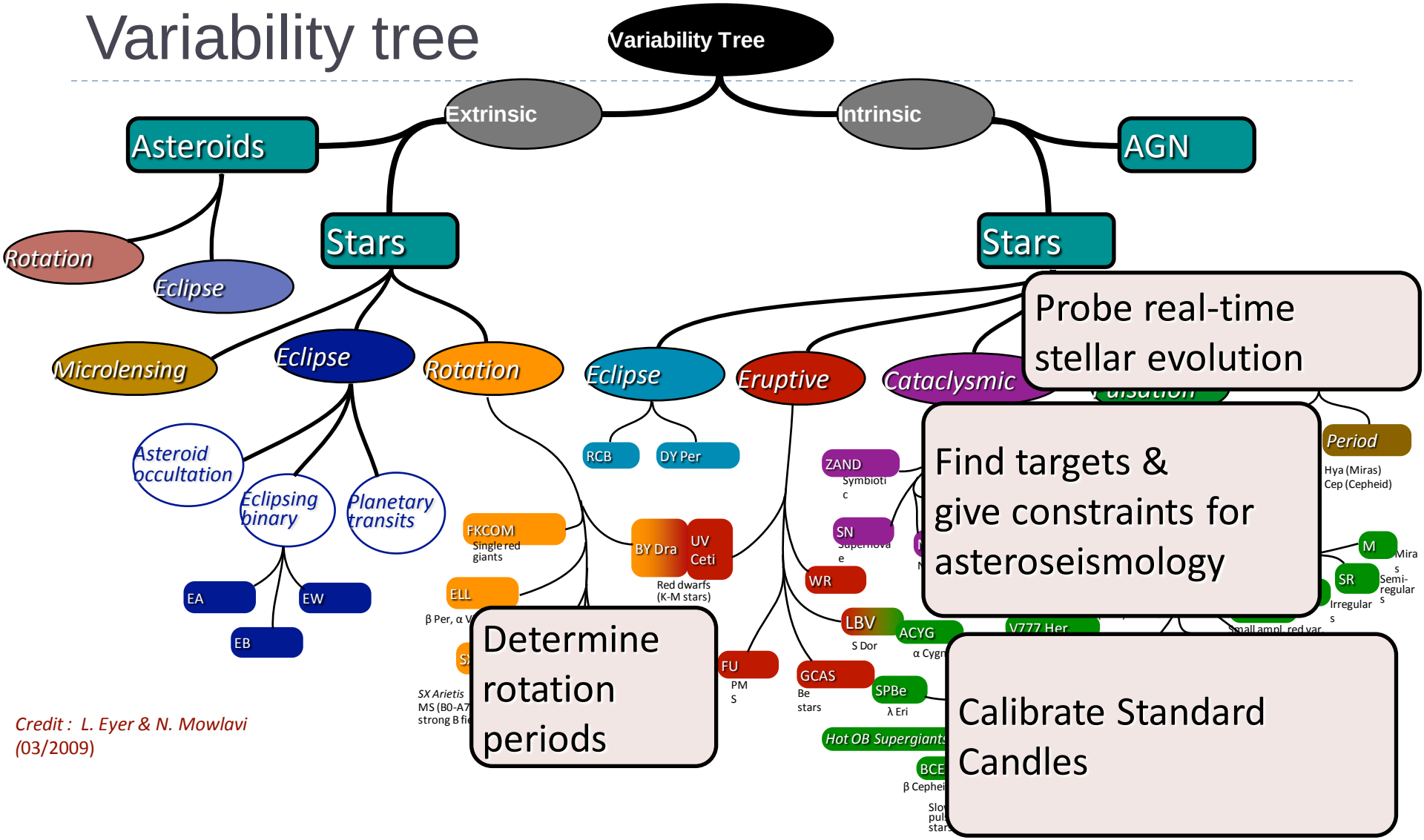

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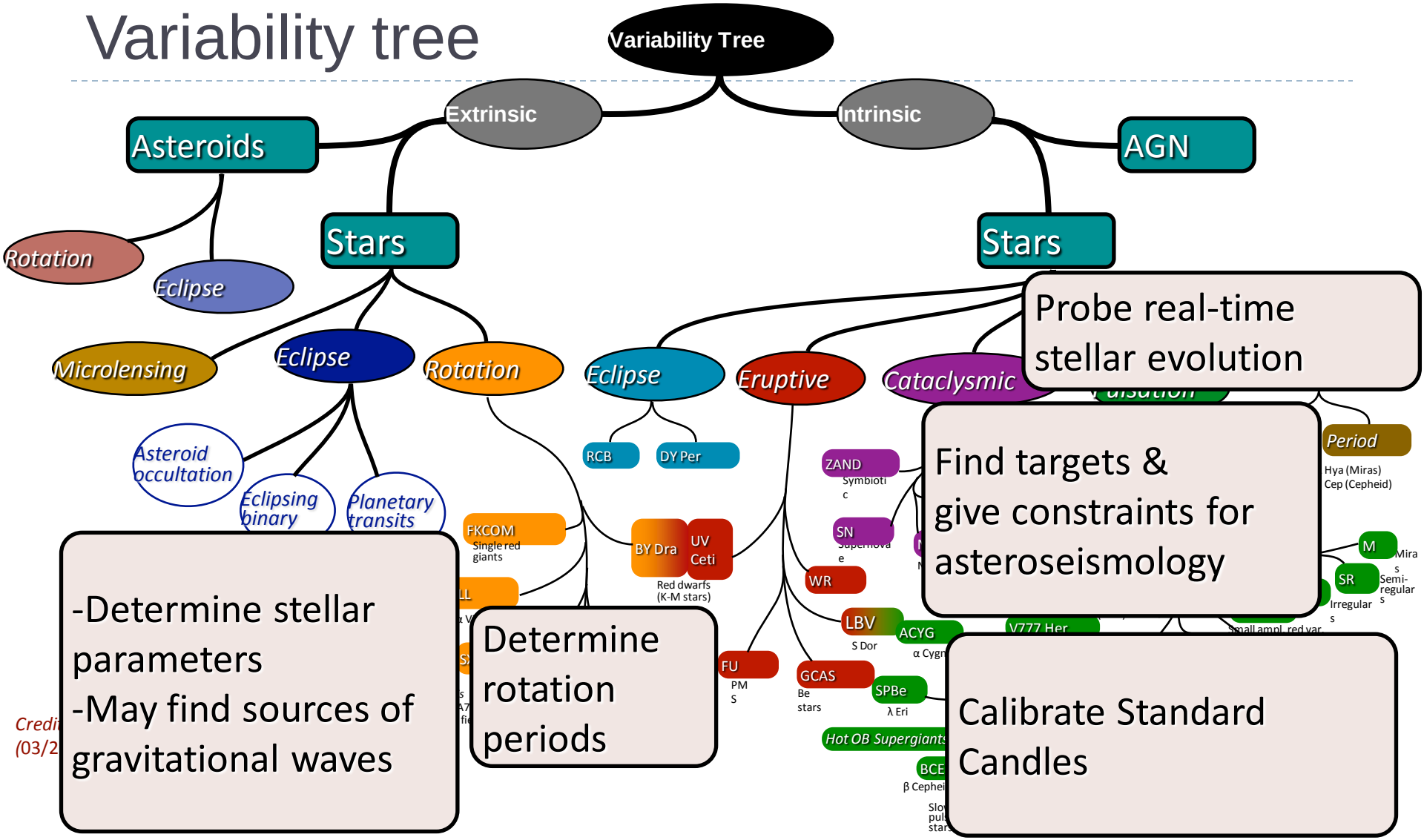

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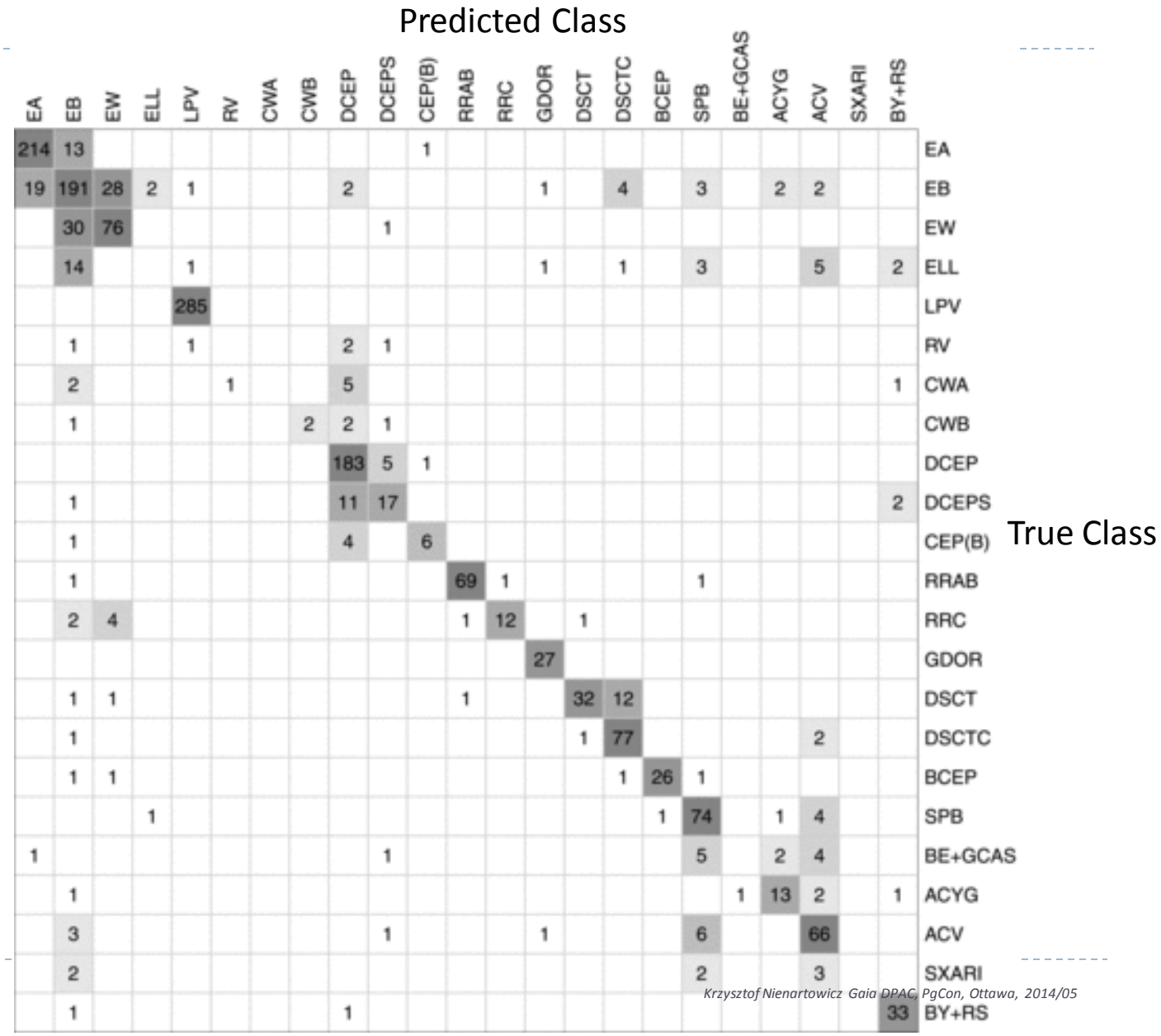
Classification of variable objects

Random Forest

Dubath et al. 2011

Similar study by Richards et al. 2011



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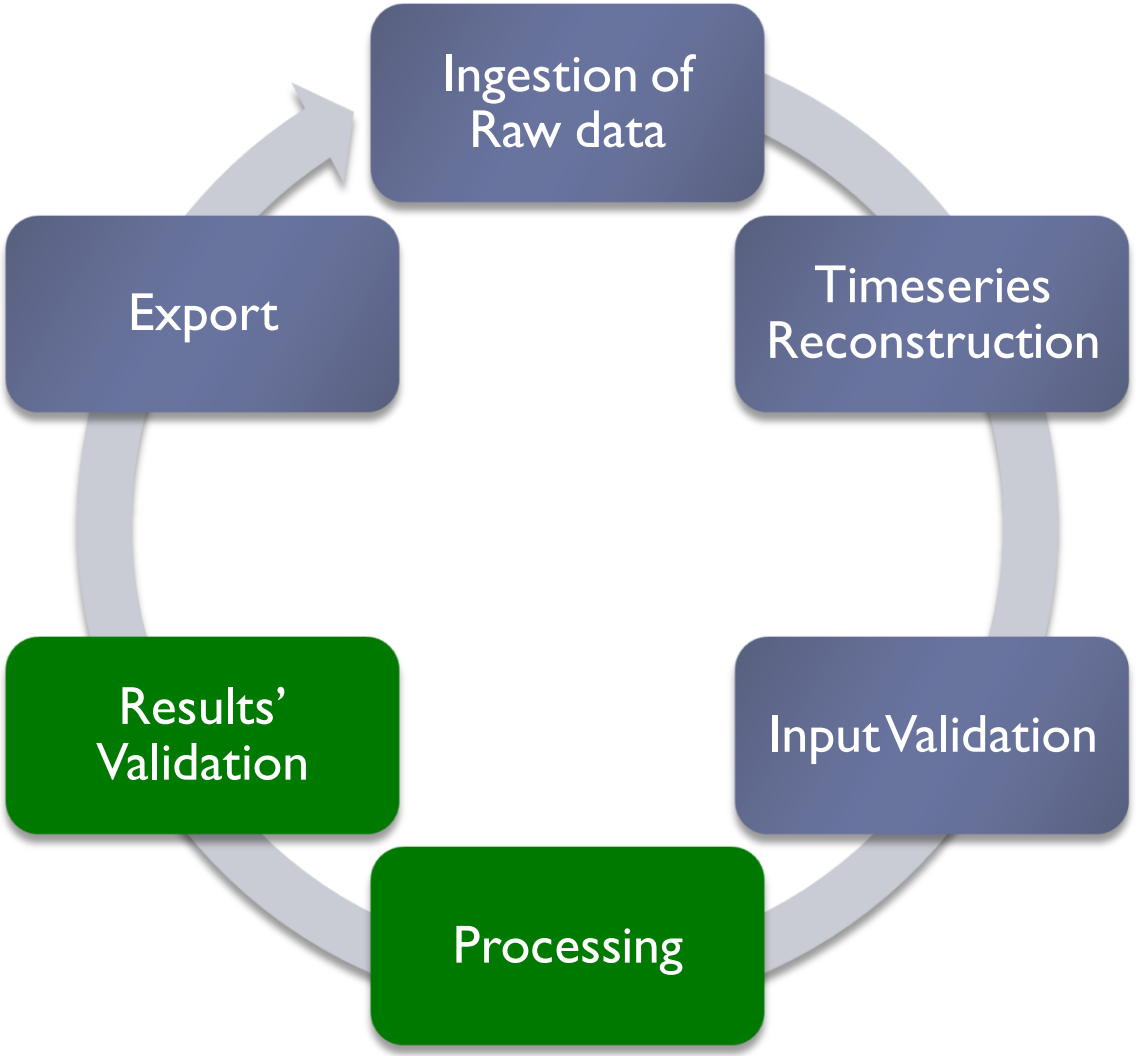
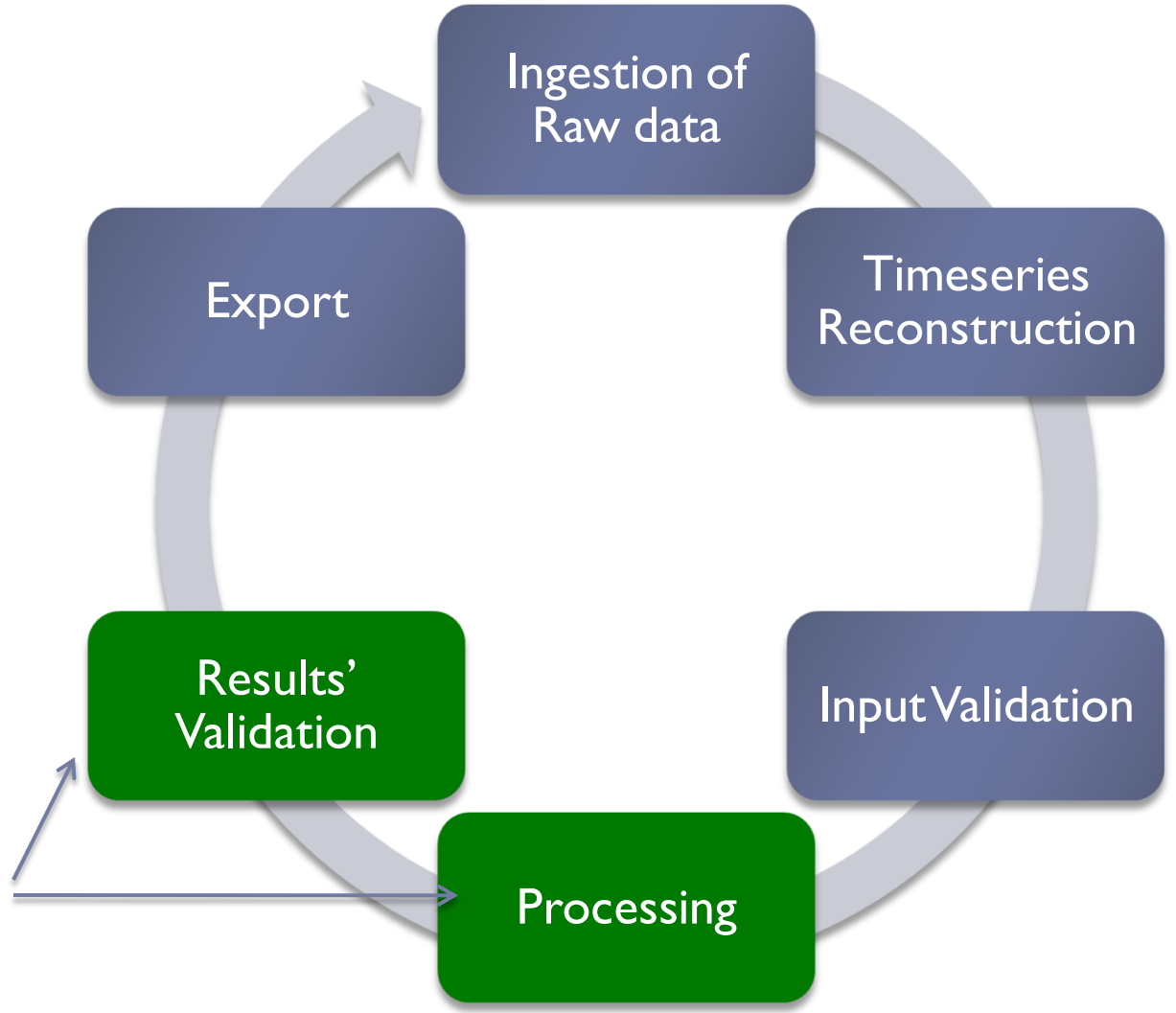
- **Processing model and Data model**
- XC role
- Hardware
- Collaboration

Cyclic Processing model
six months windows



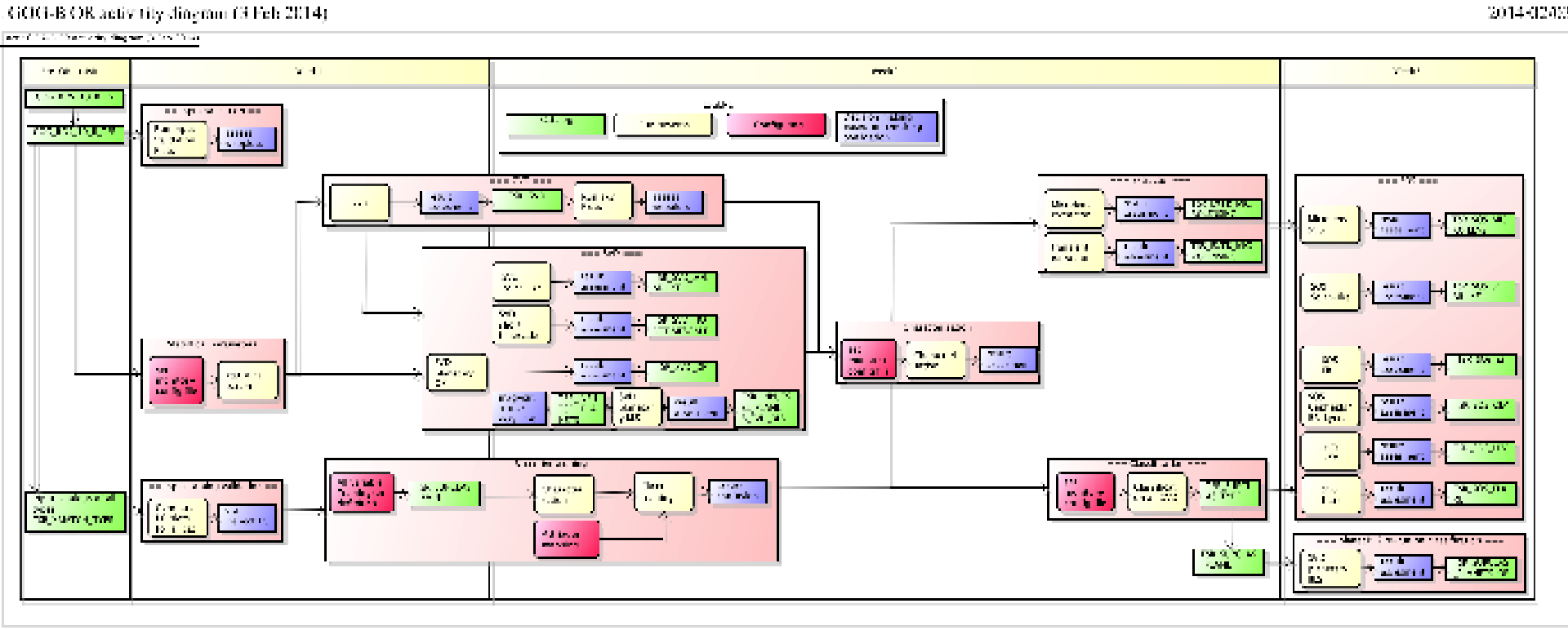
Cyclic Processing model
six months windows



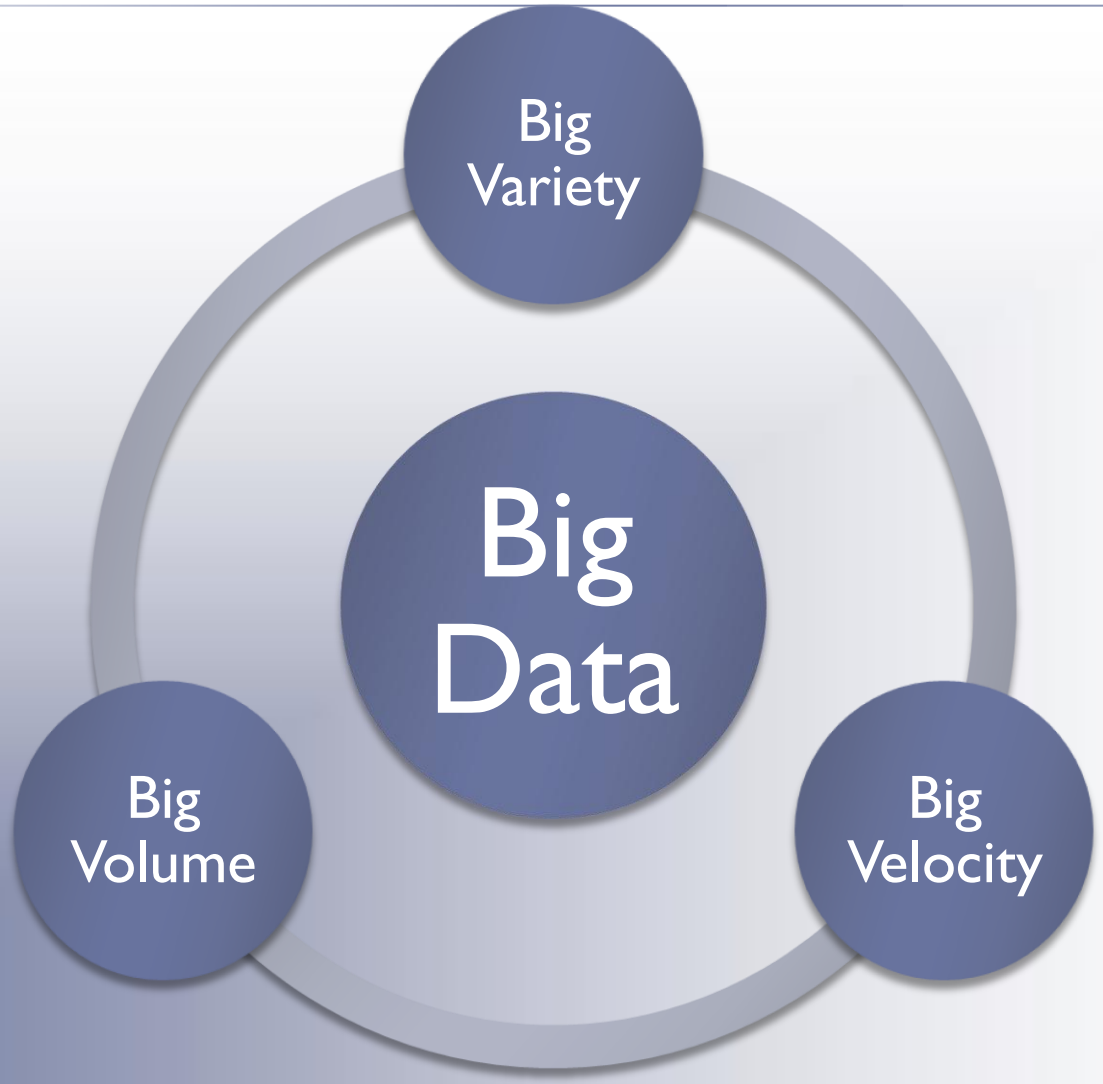
k-times during cycle on full dataset and samples < 30 days

Cyclic Processing model

one month processing sub-cycle

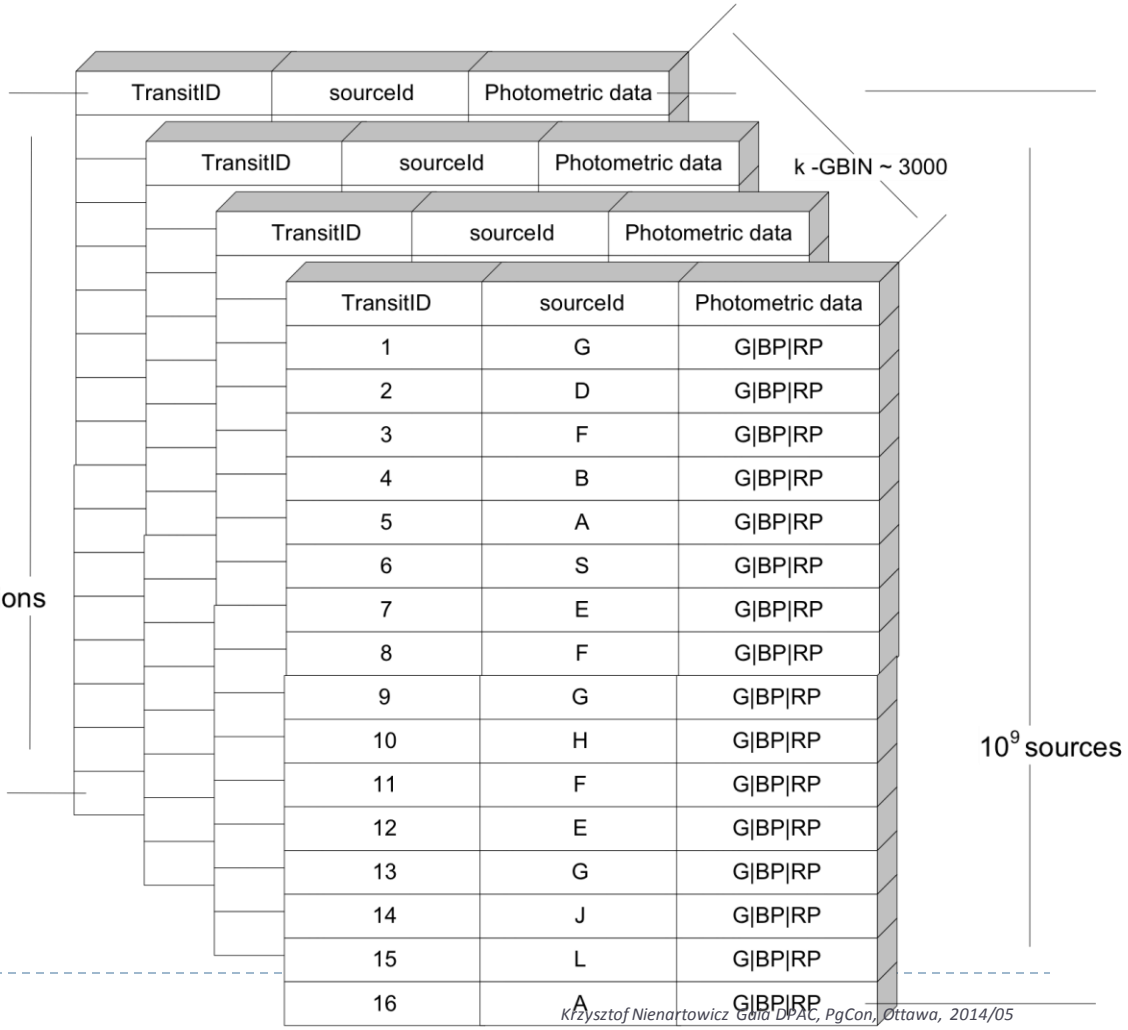


Big Data triangle
by M. Stonebreaker



Big Velocity
i.e. Ingestion

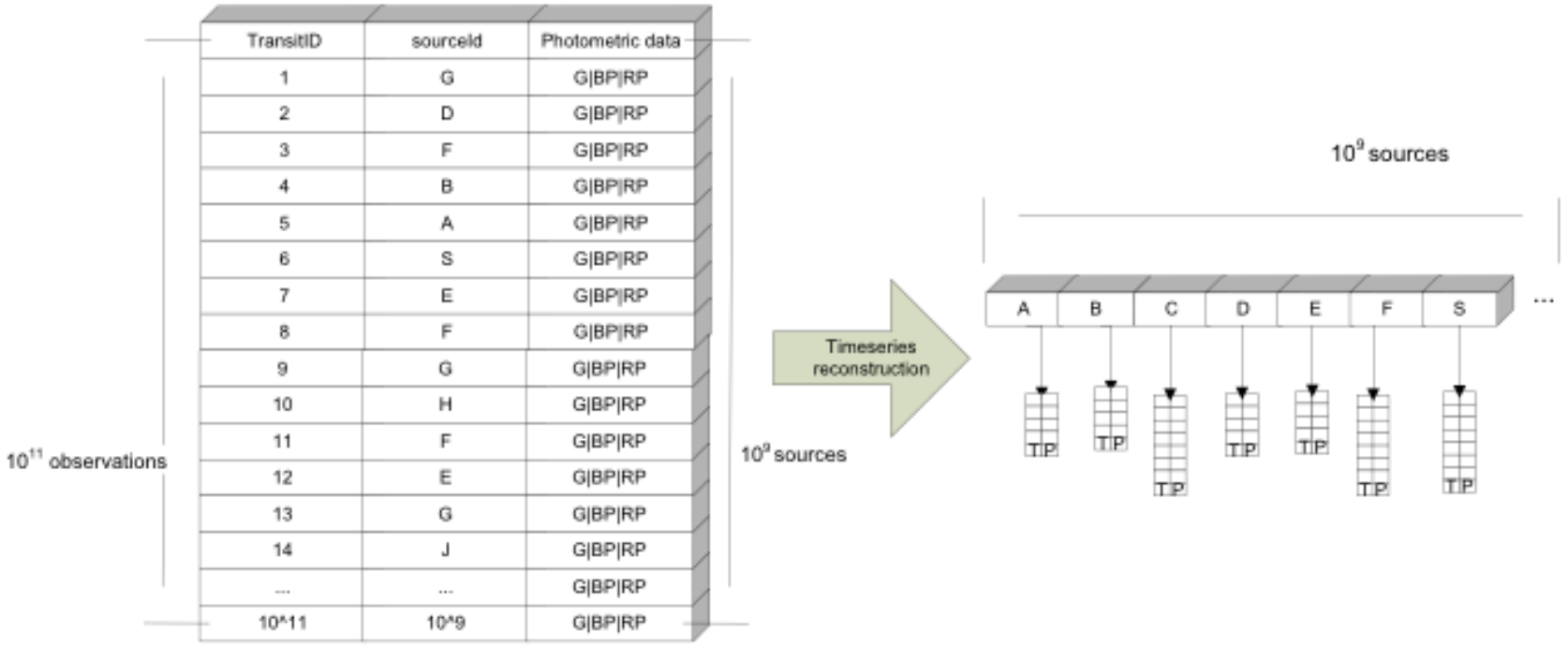
- All AstroElementaries distributed over multiple files.
  - We do not know how exactly
- GBINs are slow. CPU bound, not IO bound. <1MB/s
- 900 sec/1GB
- ~ 500h just to read 10^9*80 entries (single threaded)
- ~ 3-7TB of FovTransits (depends on the compression, we have 1/3 of fields now => G band only => 2.4TB of AE)
- ~3000 – 1GB compressed files to process for 10^9*80 tuples
- **Solution: Load into intermediate partitioned (distributed) table and run aggregating SQL reconstructing the timeseries**



Timeseries reconstruction

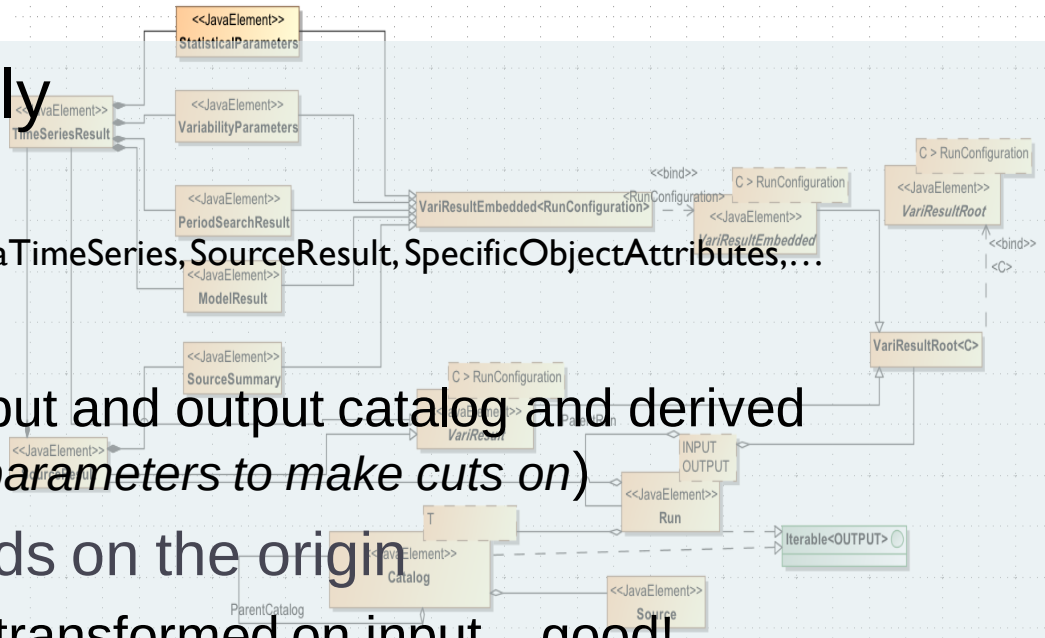
```
insert into gog_rds_10_c.ts(catalogid,sourceid,fvaluetype,obstimes,ftimeseriestype,vals,valserr,flags)
        -- convert and pivot data
        select
    gog_rds_10_c.getcatalogId('GOG_RDS_10_C') catalogid,
    sourceid,
    0 fvaluetype, -- flux type
    obs,
    (unnest(v)).*,
    StatusFlag from (
         select
         sourceid, converttobytea(array_agg(convertedTransitid)) obs,
         array[
         (getTsTypeId('GOG_RDS_10_C','GAIA_PHOT_G'),  converttobytea(array_agg(gflux)), converttobytea(array_agg(GFLuxError)) )::ts_buckets_bin
         (getTsTypeId('GAIA','BP'), converttobytea(array_agg(BPFlux)),converttobytea(array_agg(BPFluxError)) )::ts_buckets_bin ,
         (getTsTypeId('GAIA','RP'), converttobytea(array_agg(RpFlux)),converttobytea(array_agg(RpFluxError)) )::ts_buckets_bin
        ] v
         ,convertinttobytea(array_agg(StatusFlag)) StatusFlag
        from (select ( ((transitid >> 5) & CAST(x'003FFFFFFFFF000' AS bigint))::bigint * 50 / 10^9 / 60 / 60/ 24) convertedTransitid, calphot.*
            from gog_rds_10_C.calphotfovtransitimpl calphot join source s on (calphot.sourceid = s.sourceid) order by calphot.sourceid,1 ) a
        group by sourceid
    ) pivoted
    ;
```

Timeseries reconstruction



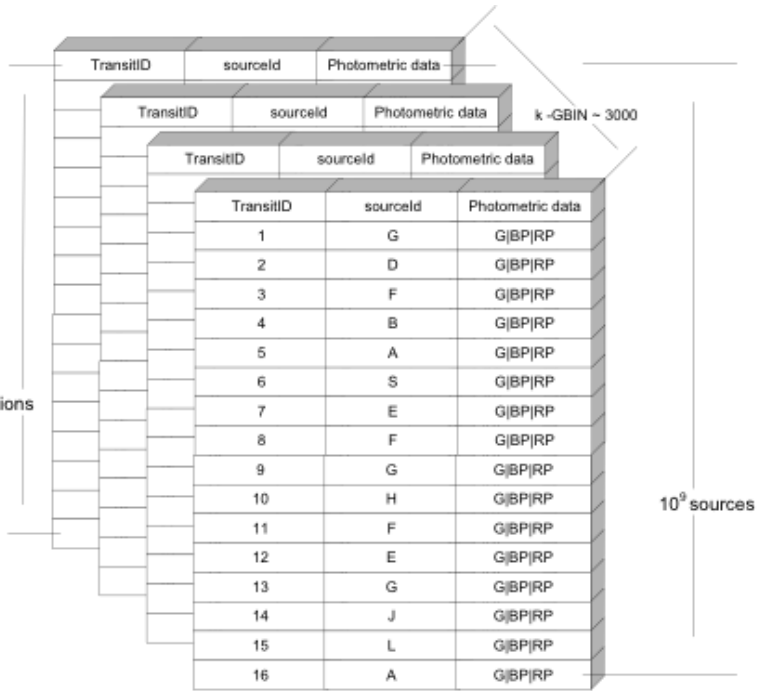
Big Variety

- CU7 OM has approximately
  - ~ 70 domain classes
    - Source, **Timeseries**, SpectraTimeSeries, SourceResult, SpecificObjectAttributes,…
  - Attributes
    - Possibly tens to hundreds input and output catalog and derived attributes used in analytics (*parameters to make cuts on*)
  - Input transformation depends on the origin
    - Gaia ~ 5-10 MDB tables are transformed on input – good!
    - Other surveys
      - From semi/quasi structured to structured formats -EAV
  - Production of the output is rather simple
    - **Analyzing it: Not!**

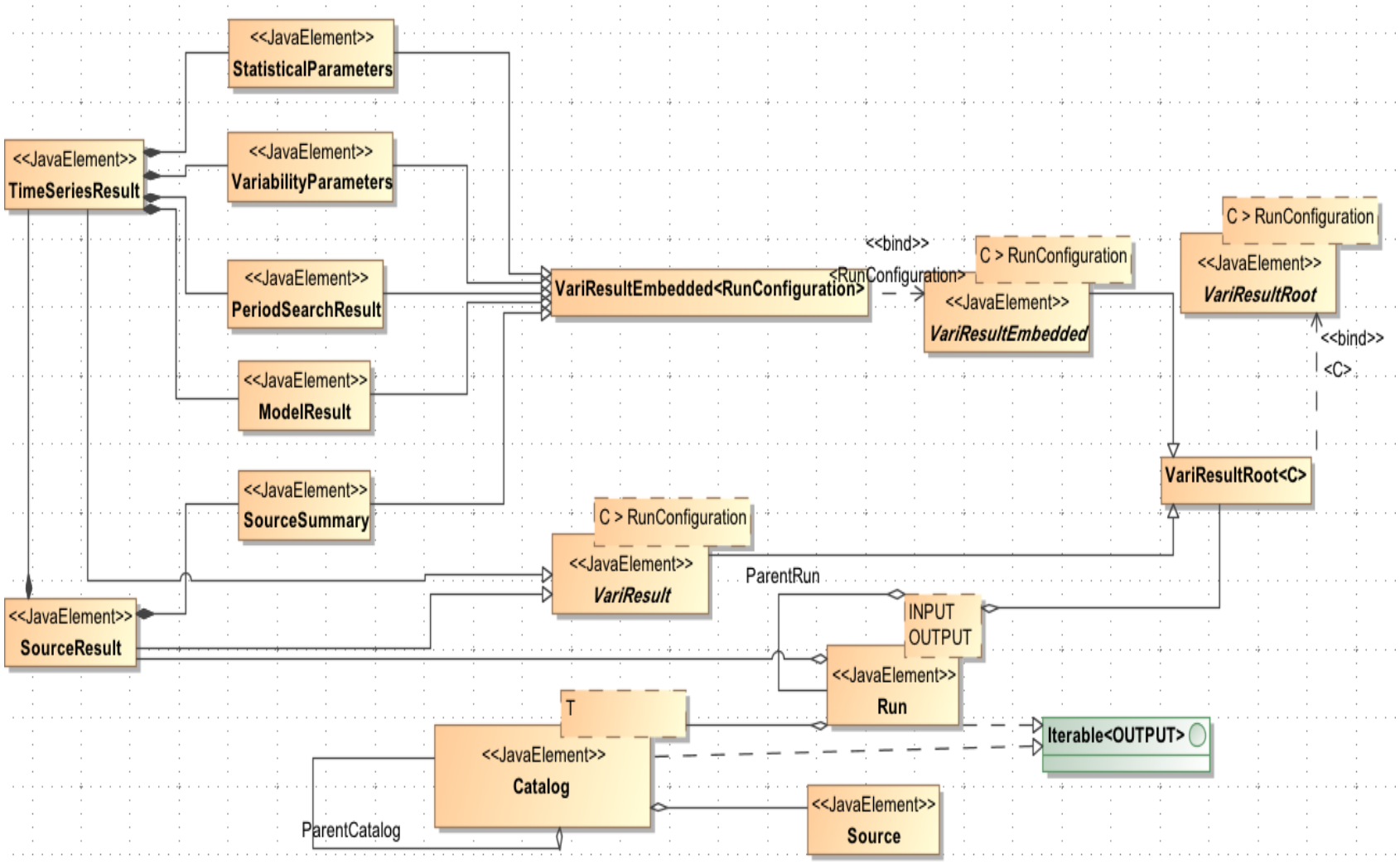


Big Volume

- ~50TB … 800TB
- Input
  - Hundreds catalogs,10^9 Sources, 5 x 10^9 Timeseries
  - Existing relatively large surveys
    - EROS, SuperWASP
  - Gaia input via GBINs
    - Deserialization
    - Reconstruction
  - Analysis of the input to find outliers,
    - Finding bugs in data in minutes – possible scanning 10^{11} entities in 10's of seconds
- Output
  - k-iterations on input: 10^9 source results, 5 x 10^9 TimeseriesResults
    - Results on all processed Sources/Timeseries
      - Re-run multiple times
    - Intermediate analytical results
    - Ad-hoc analytical results
  - Export of data into compressed GBINs



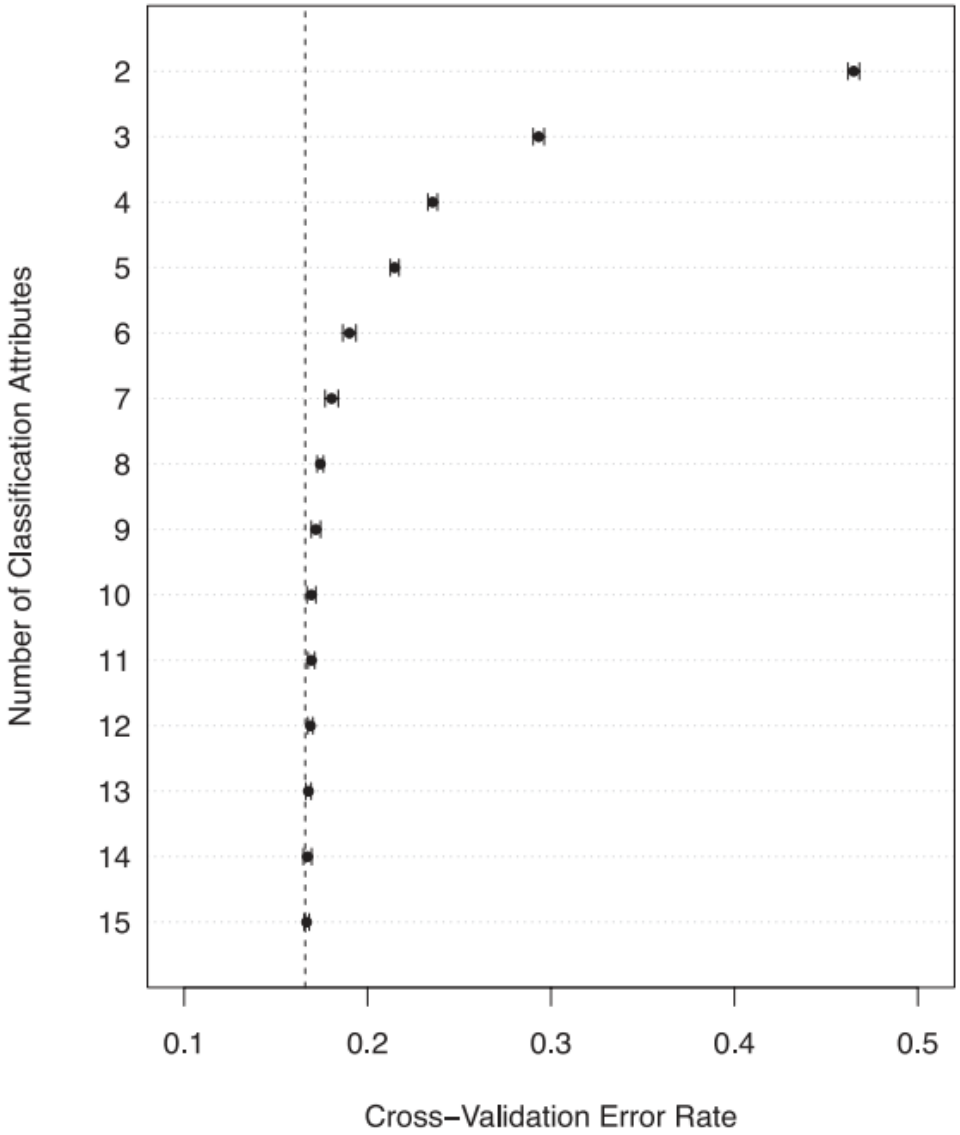
Data model
Java Persistence API, custom PG mappings



Data model
Java Persistence API, custom PG mappings

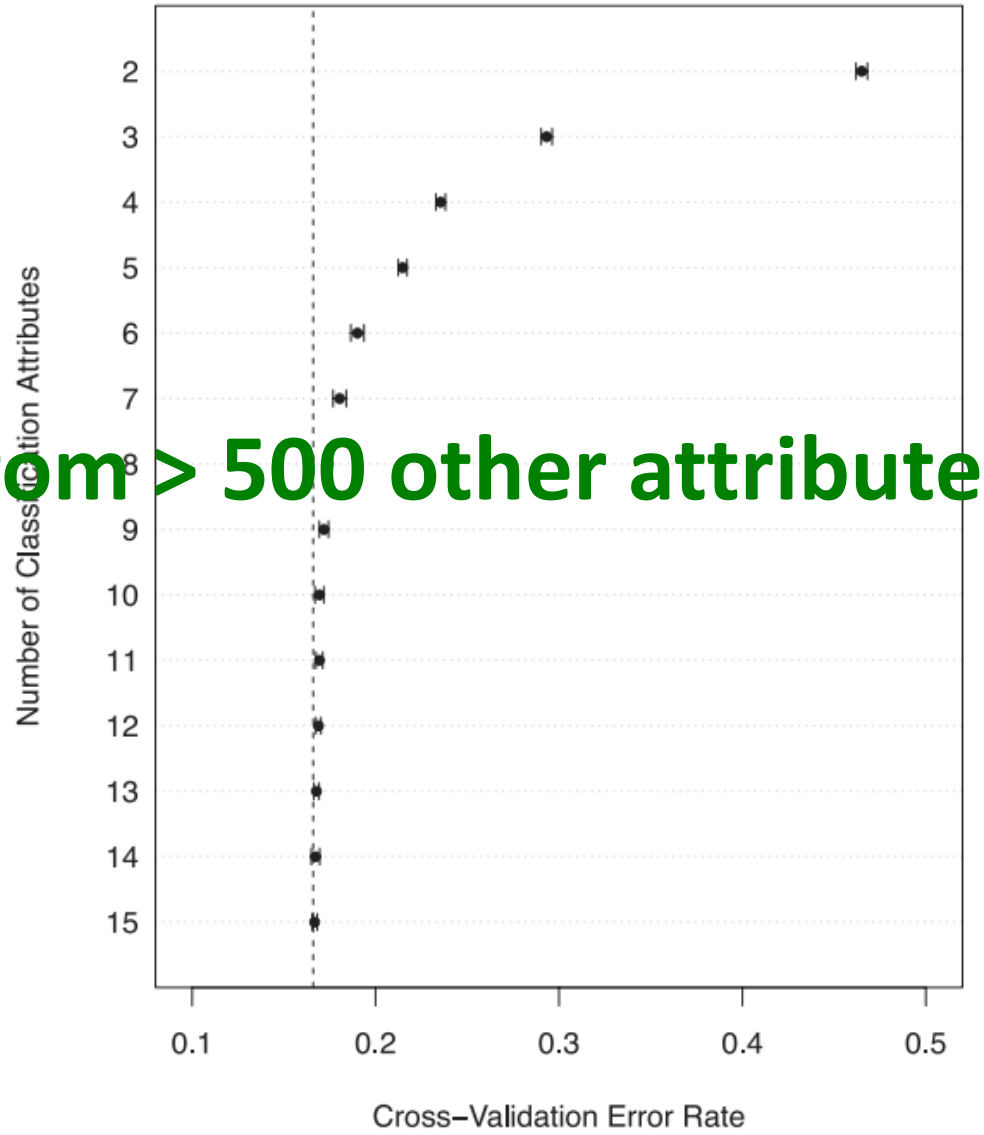
- Native ORM mappings:
  - 1-> *
  - 1-1:
    - Embedded
- Custom OO mappings:
  - hstore + metadata: EAV
  - PG objects <compositeType>
  - Arrays of PgObjects
  - Arrays of Arrays of Arrays of … PG Objects

Attributes



L. Rimoldini et al 2012

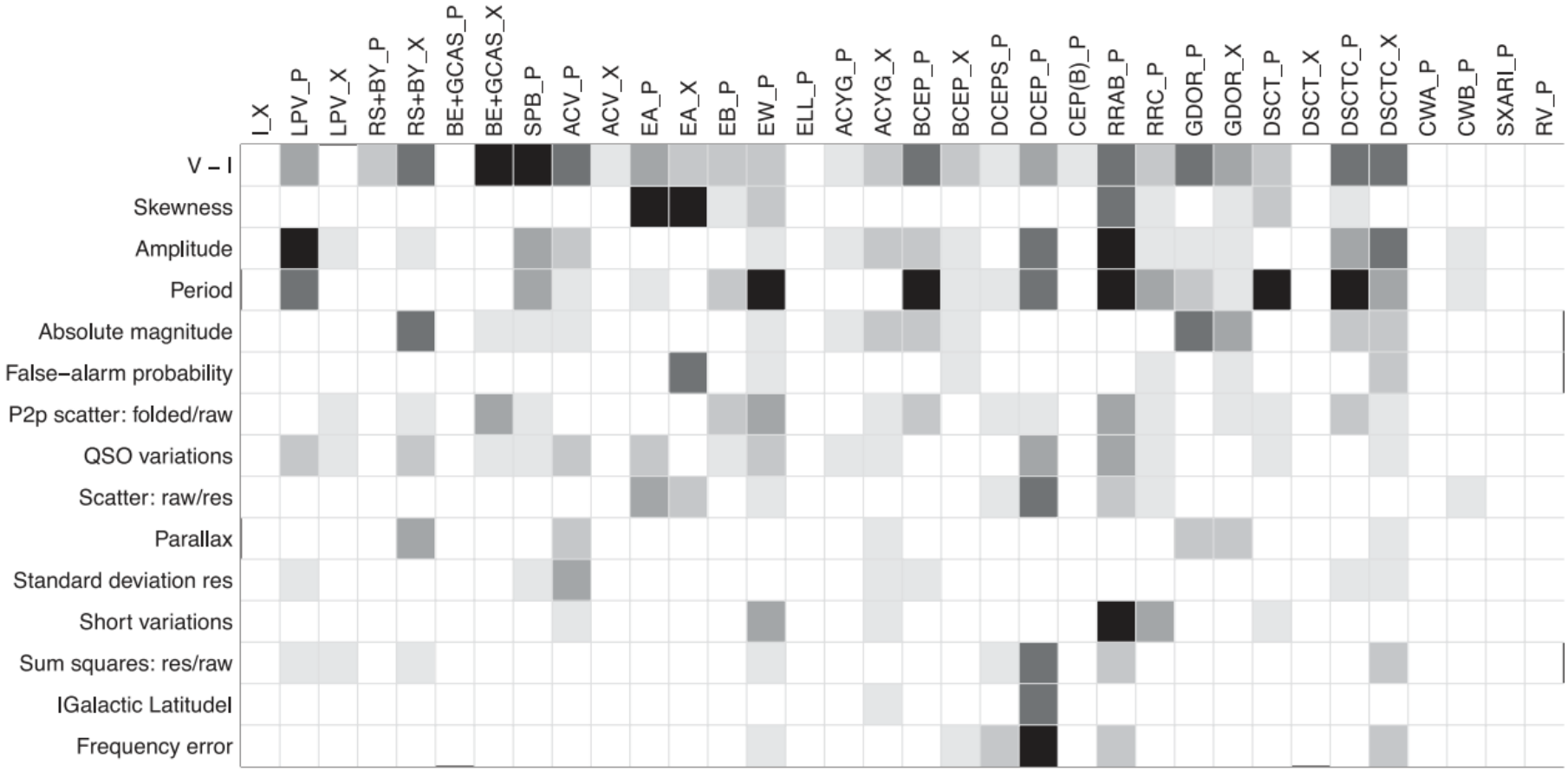
Attributes



From > 500 other attributes….

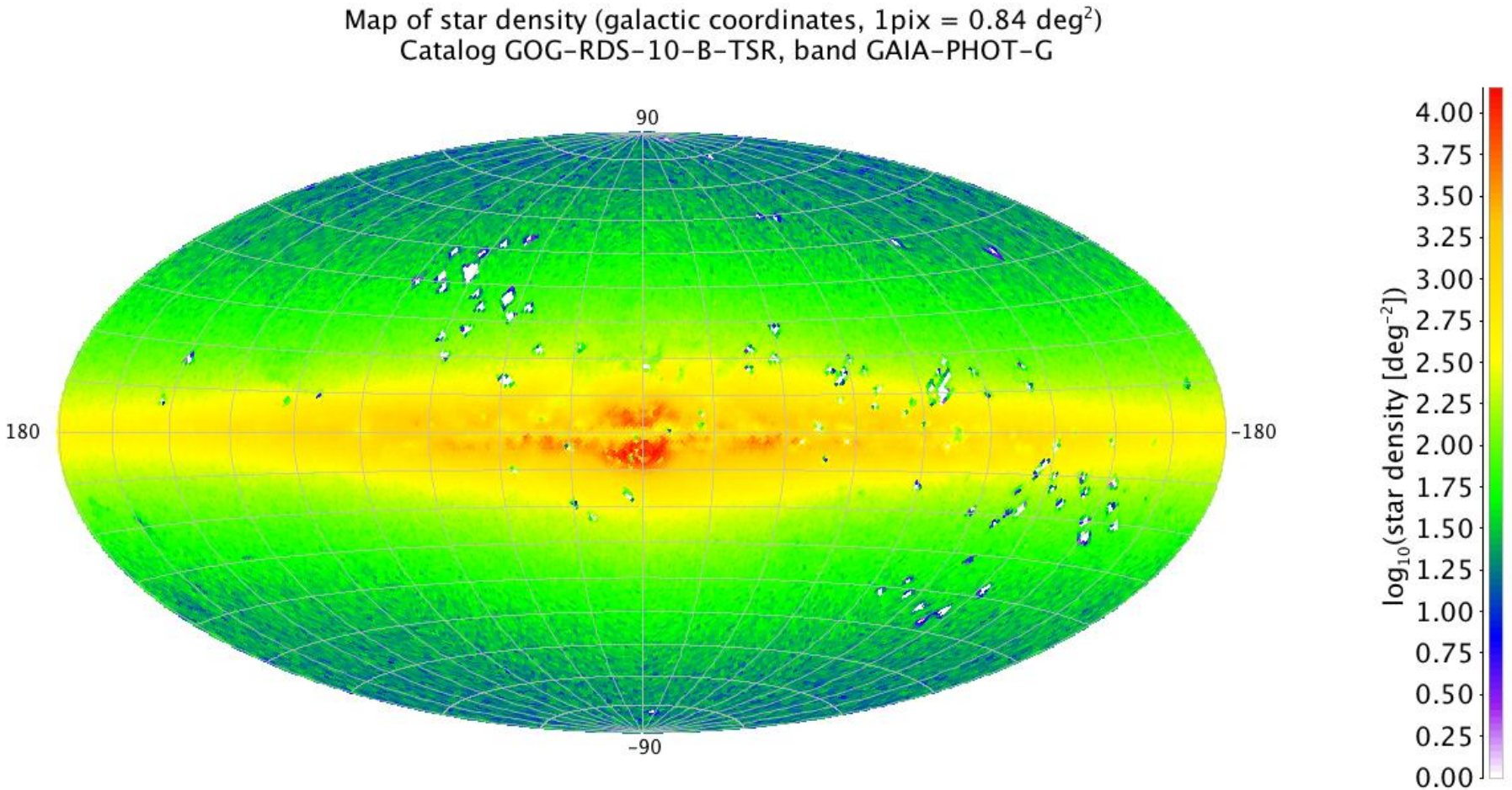
L. Rimoldini et al 2012

Attributes
(columnX, array[i], (pgType[j]).type2[i]…)



L. Rimoldini et al 2012

Analytics via SQL



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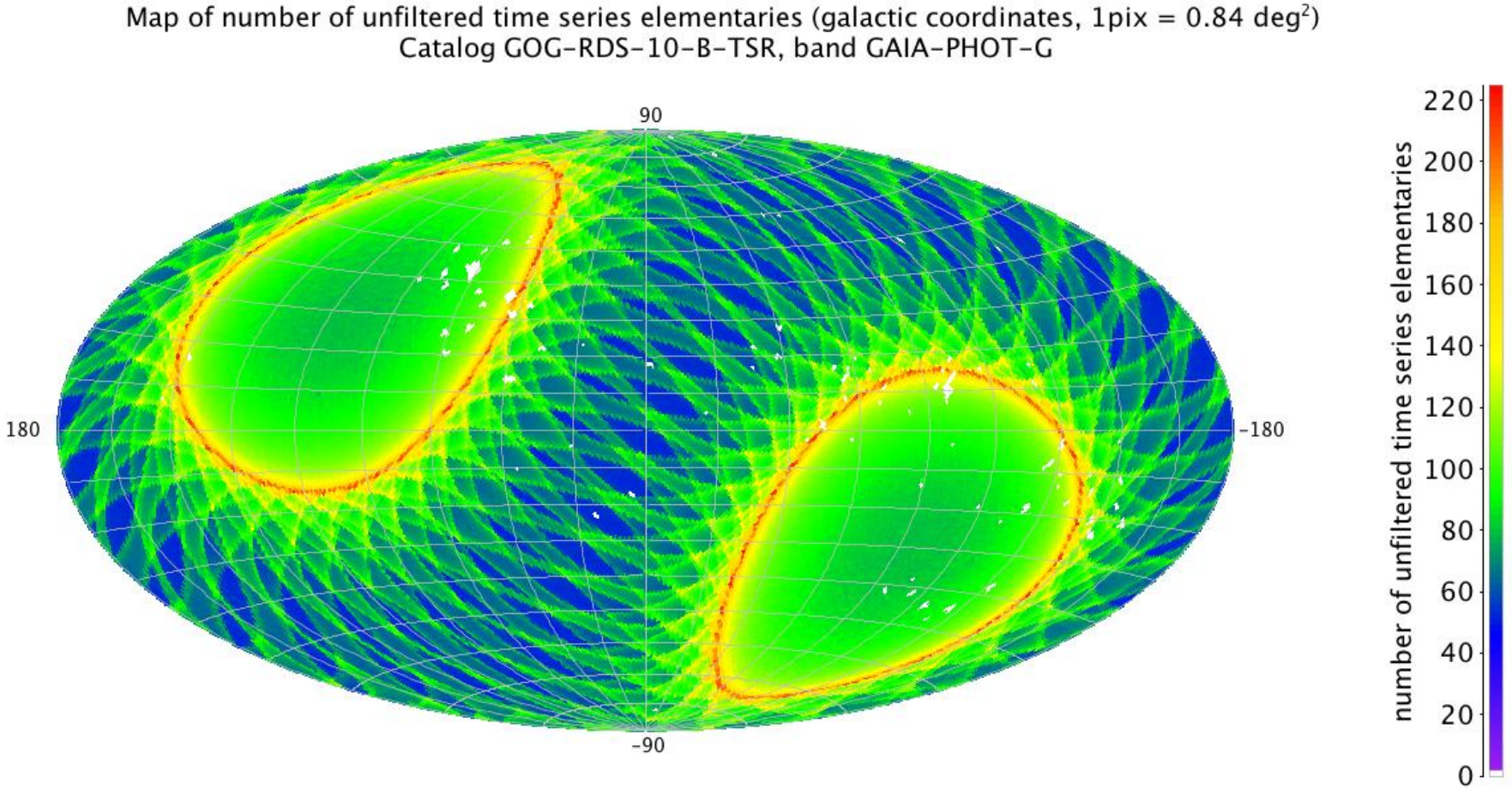

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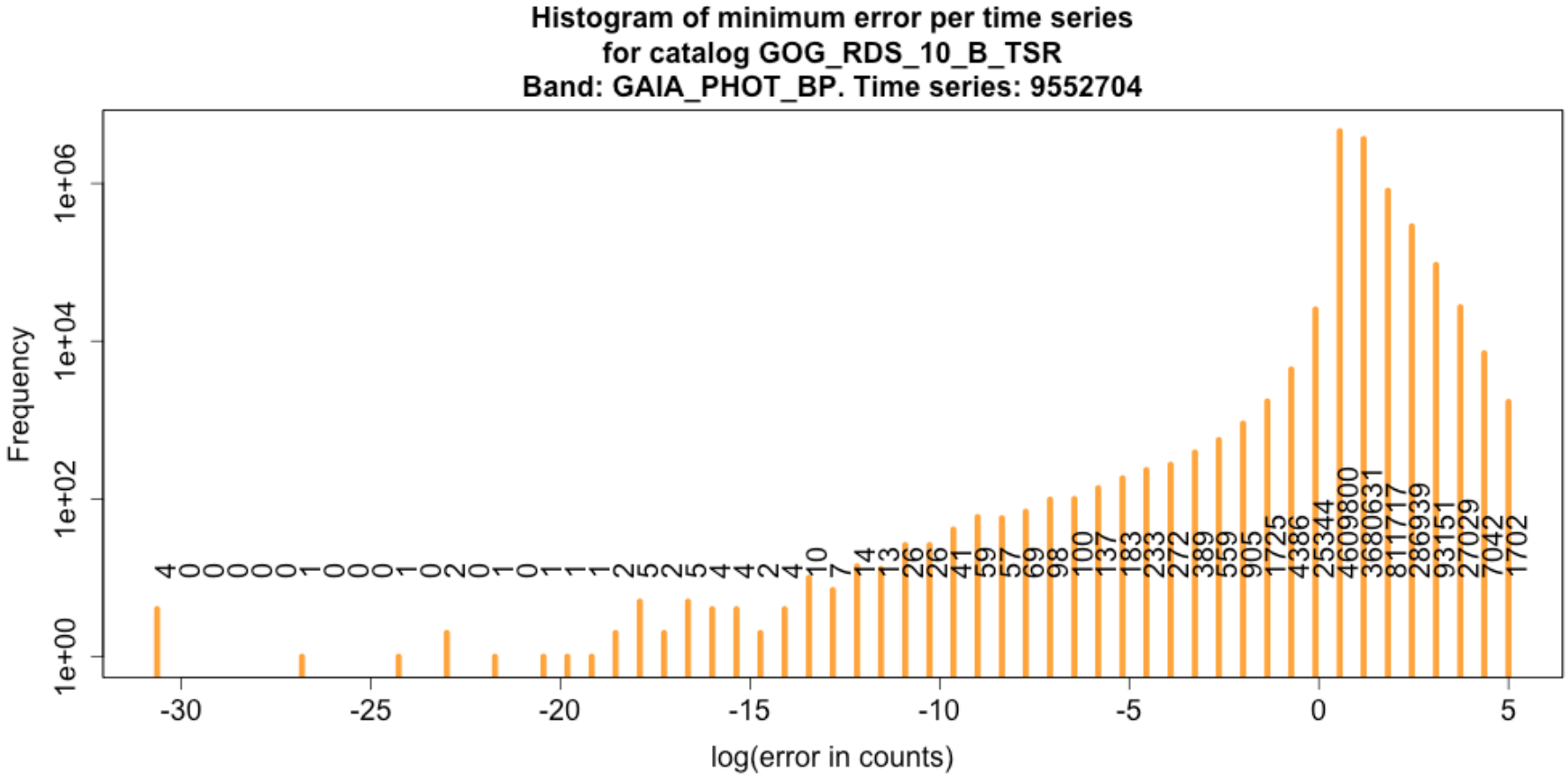

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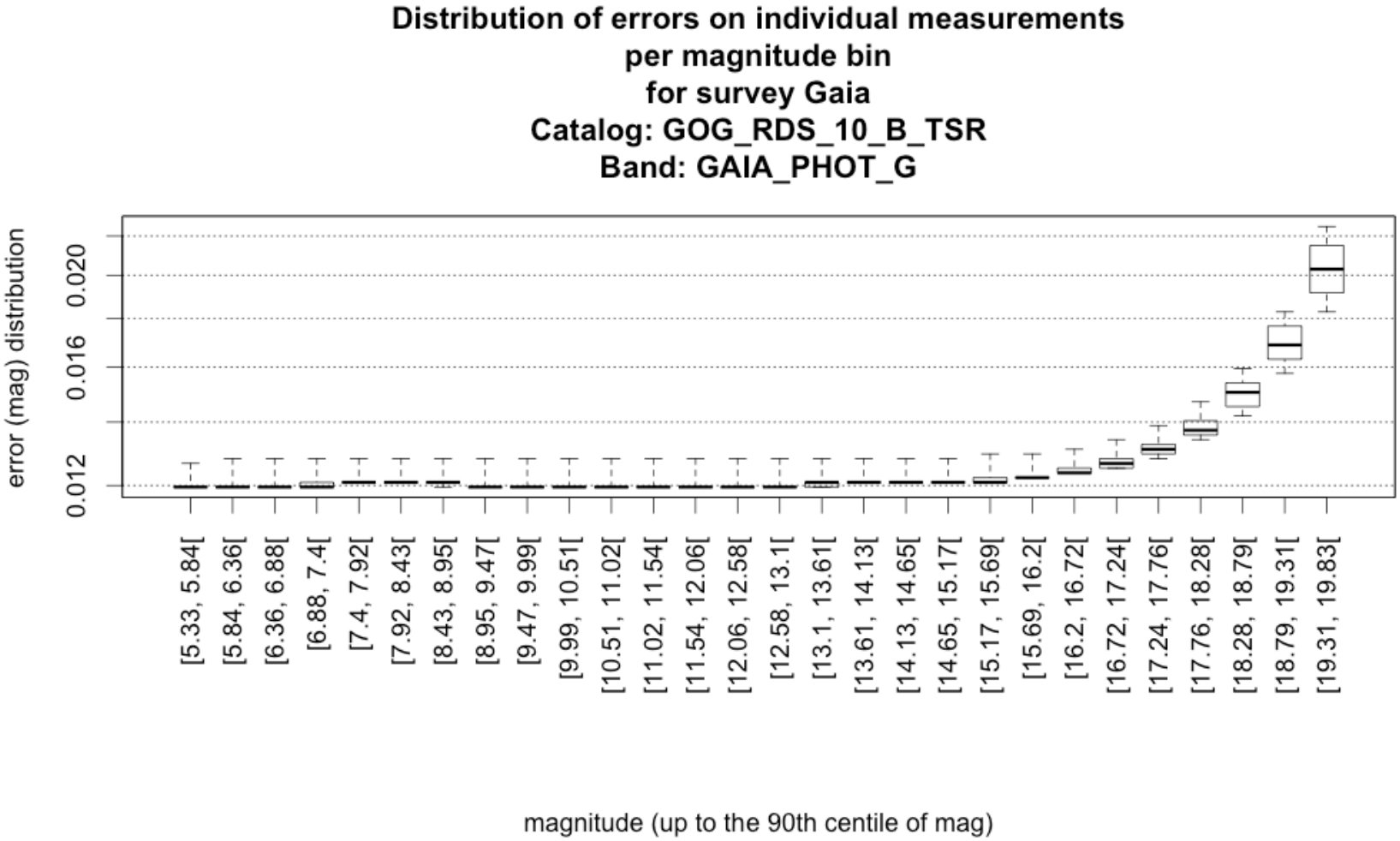

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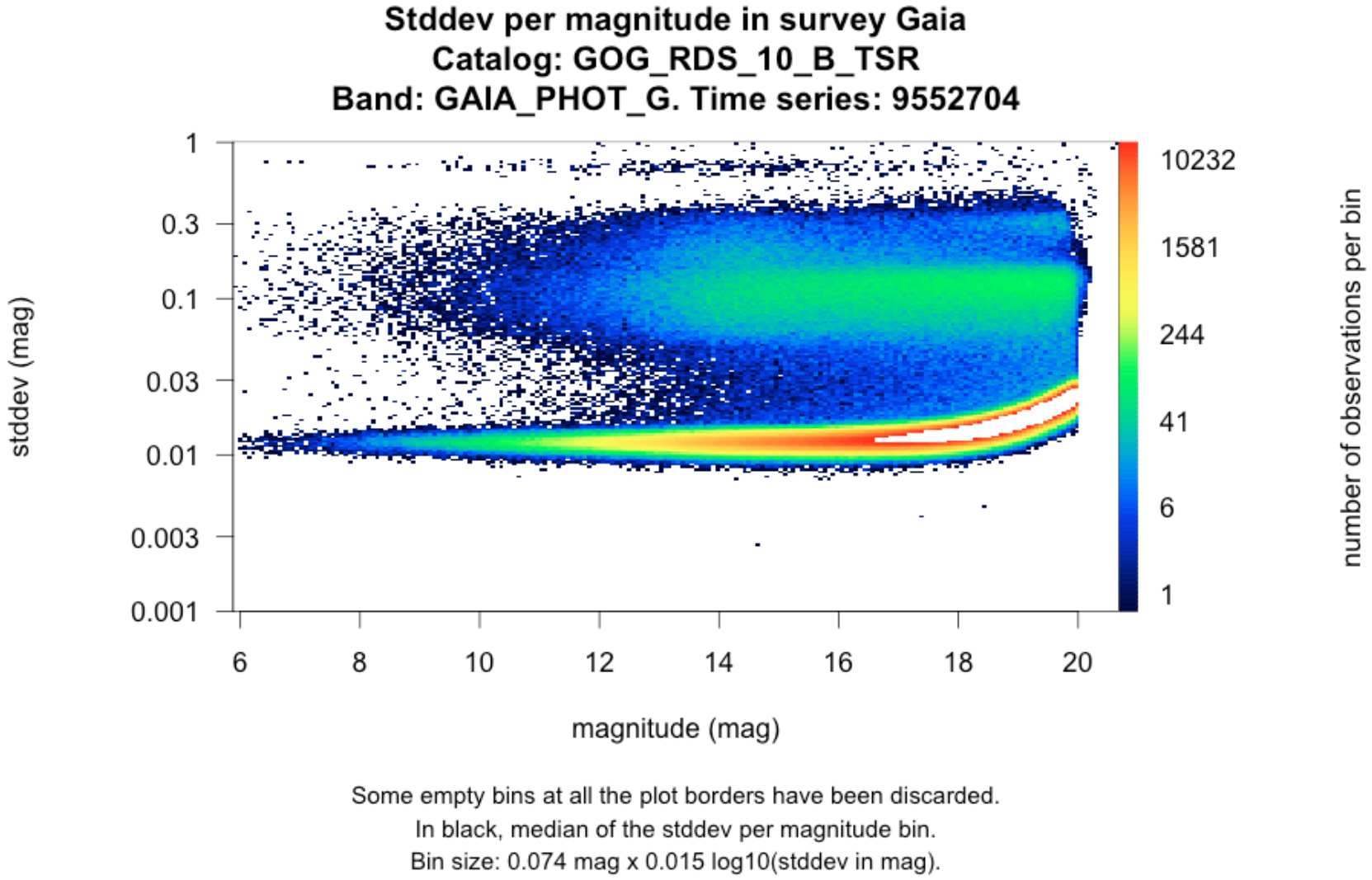

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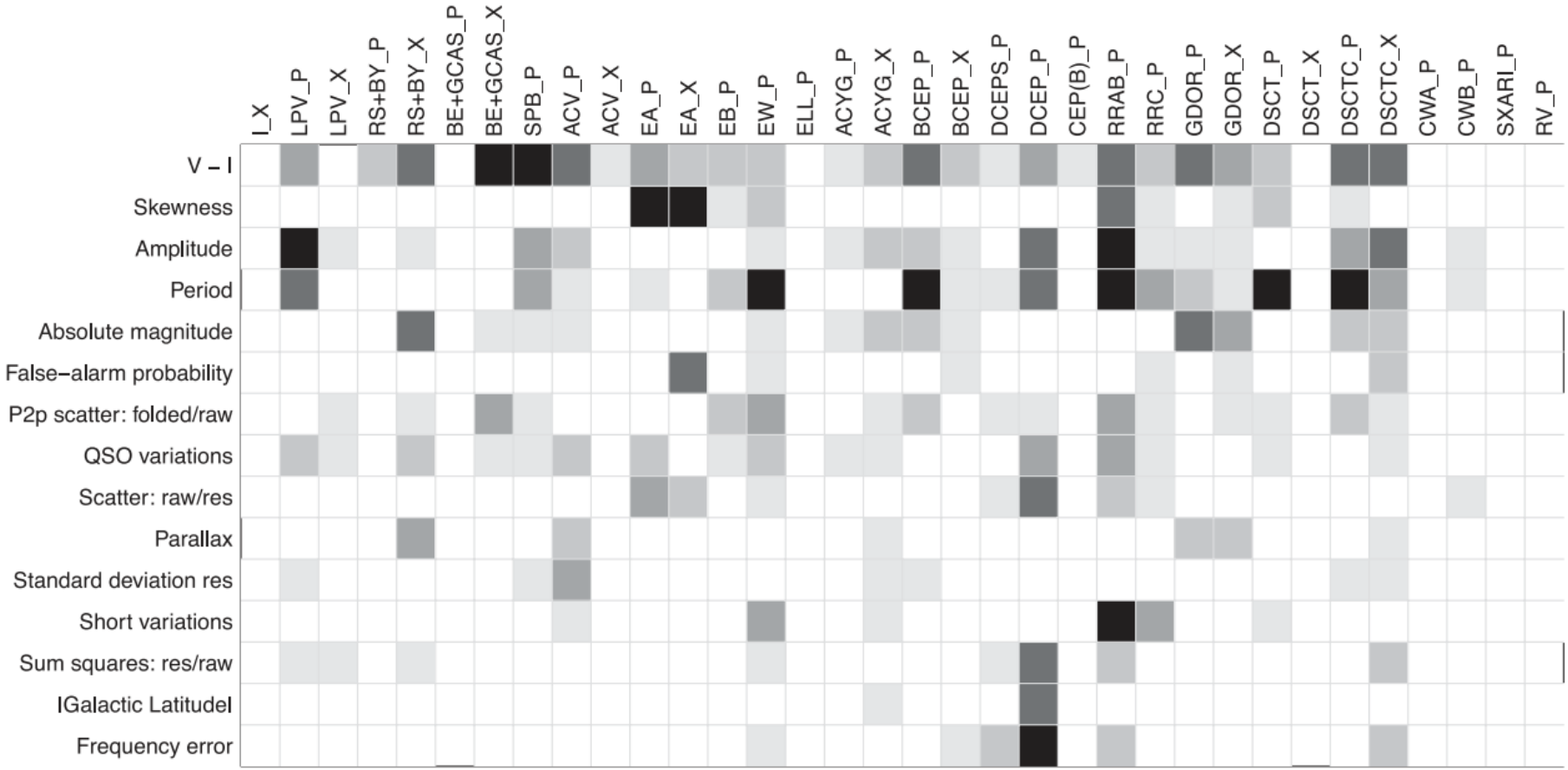
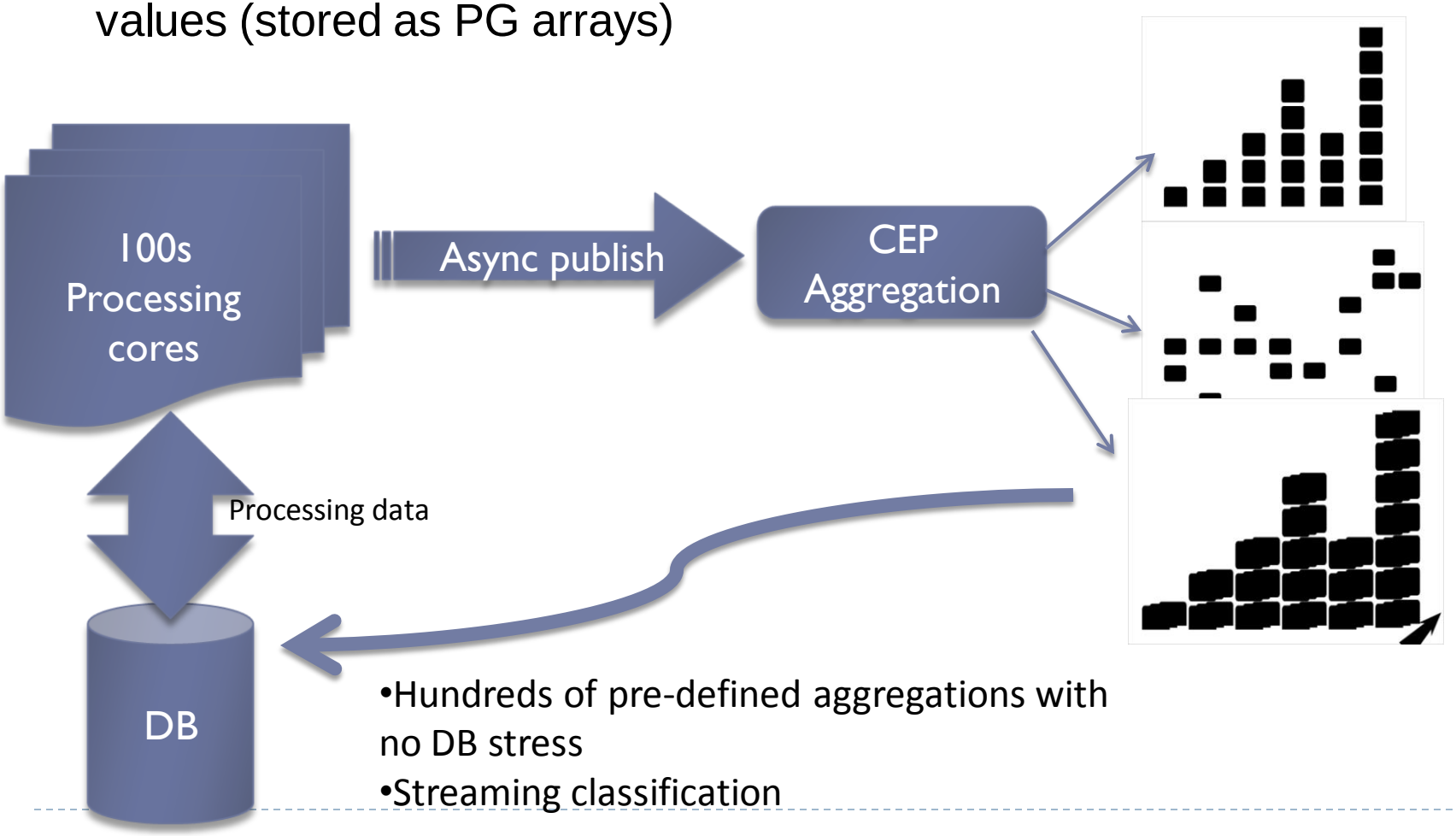


Complex Event Processing

- Stream of results is continuously aggregated externally via subpackage based on Camel/Esper and stored as scalar, 1D, 2D values (stored as PG arrays)



- Hundreds of pre-defined aggregations with no DB stress
- Streaming classification

Complex Event Processing
EQL with Apache Camel

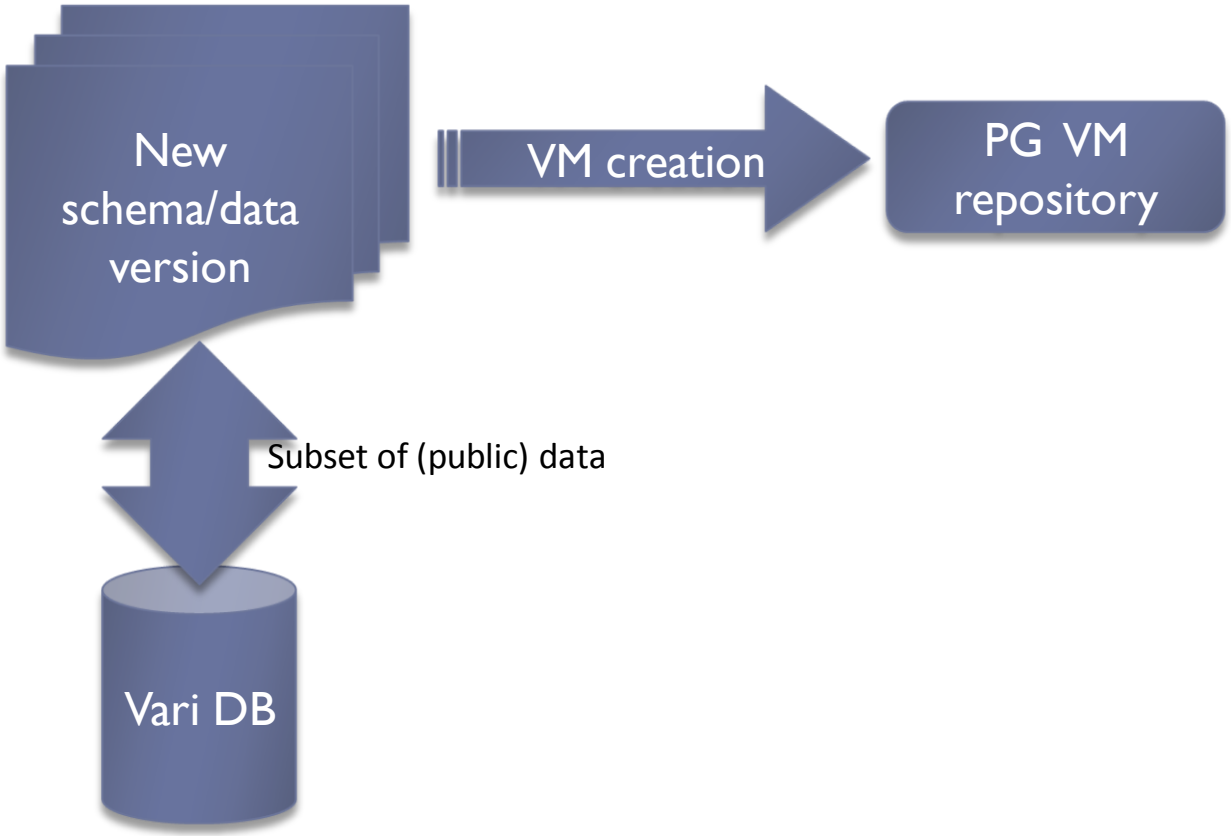
```
from("esper://sourceresult?eql=insert into PeriodSearchResultList select run.runId as runid,  " +
        "hist('skewness', -5.0, 5.0, 0.5, "
        + "((timeSeriesResult('HIPPARCOS')).getStatisticalParameters()).getSkewness()) as histogram " +
        "from SourceResult.win:time_batch(10 sec) " +
        "where ((timeSeriesResult('HIPPARCOS')).getStatisticalParameters()).getSkewness() > 0 "+
        "group by run.runId")
        .process(new Processor() {
            @SuppressWarnings("unchecked")
            public void process(Exchange exchange) throws Exception {
                com.espertech.esper.event.map.MapEventBean ev = (com.espertech.esper.event.map.MapEventBean) exchange
                        .getIn().getBody();
                Map map = (Map) ev.getUnderlying();
                exchange.getOut().setHeaders(exchange.getIn().getHeaders());
                exchange.getOut().setHeader("runid", map.get("runid"));
                exchange.getOut().setBody(map.get("histogram"));
            }
        }).log("${body}").to("activemq:varisystem.monitoring.histogram");
```

Complex Event Processing

real time monitoring

Data distribution for development

- Development, public data is distributed via PG Appliances
  - 5-15GB
  - ~0.5-5M sources



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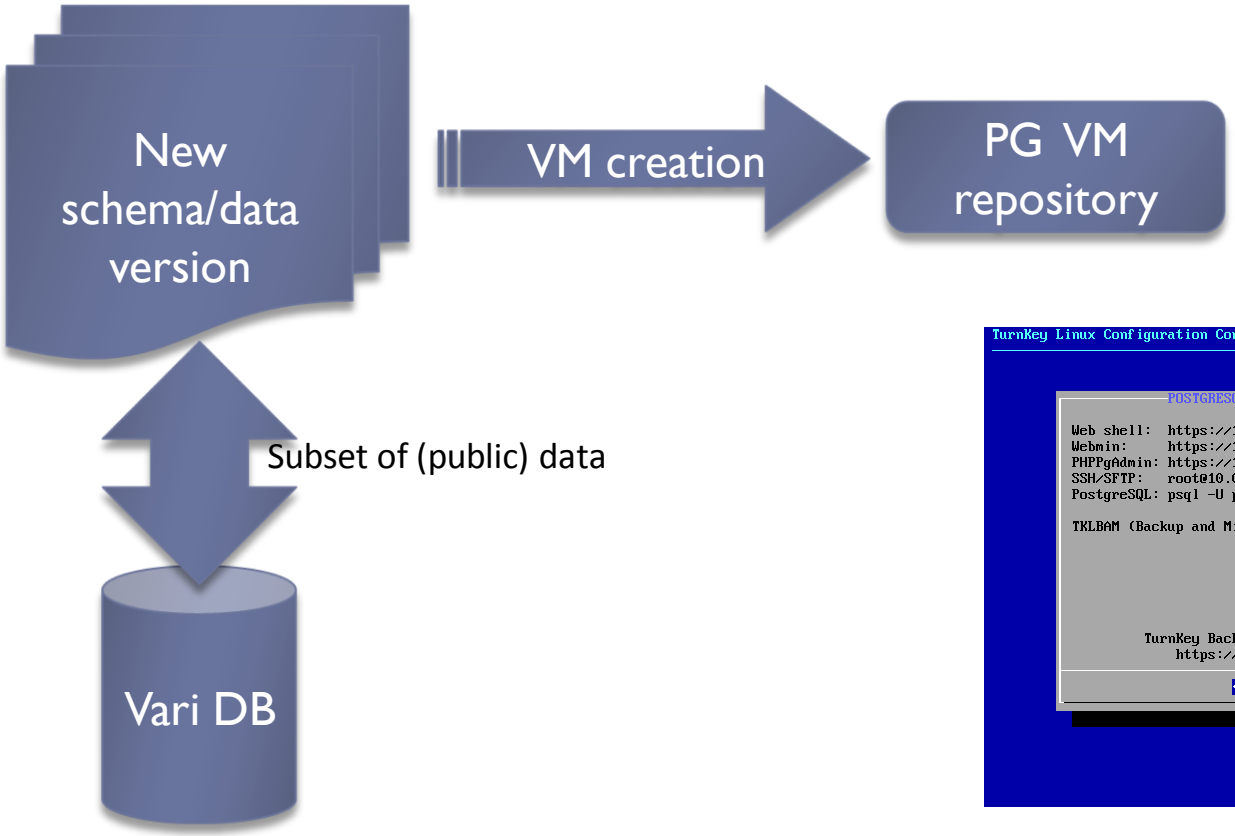

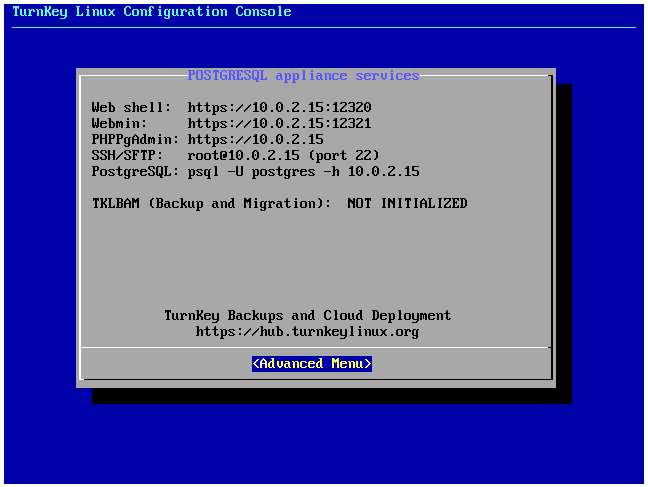

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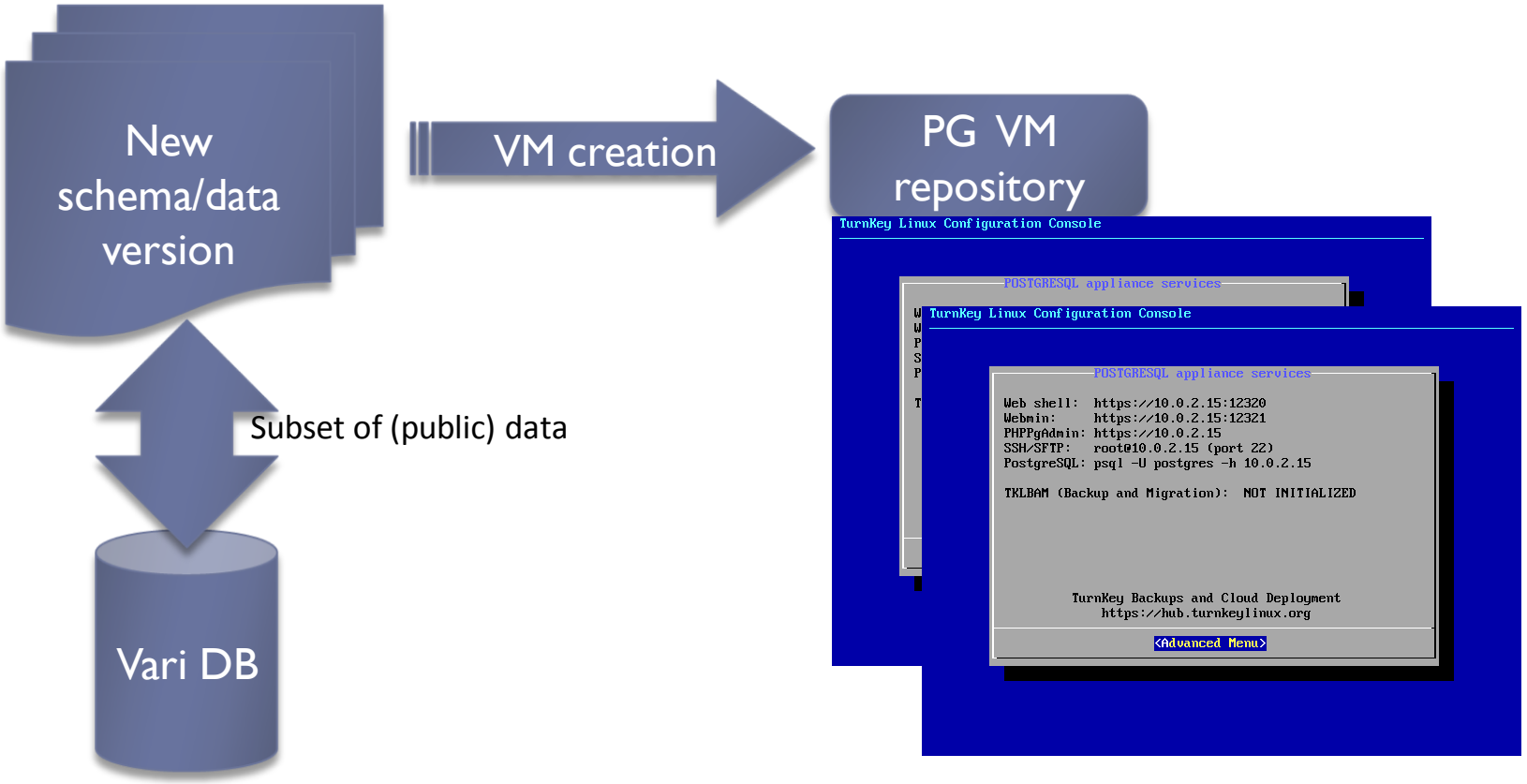

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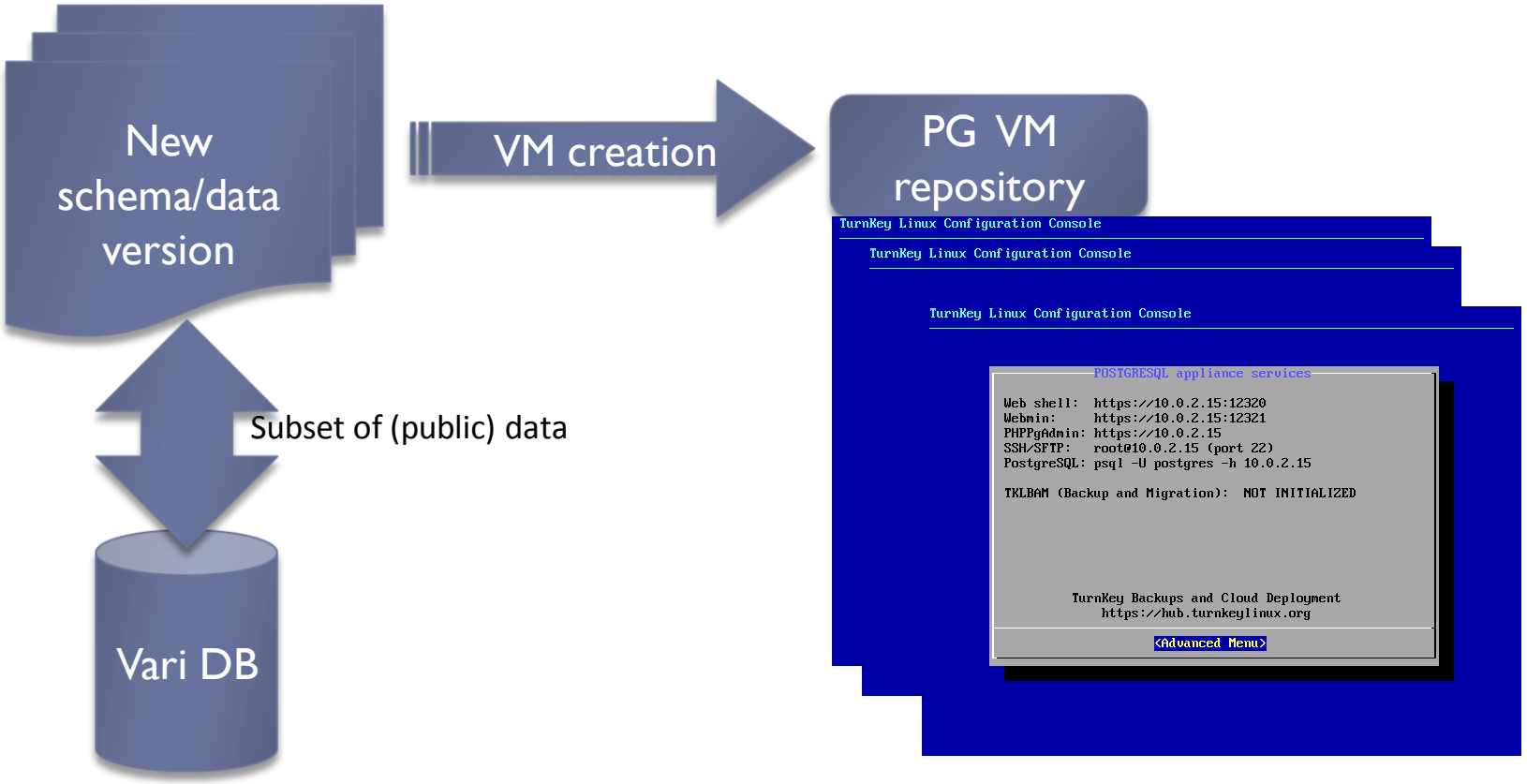

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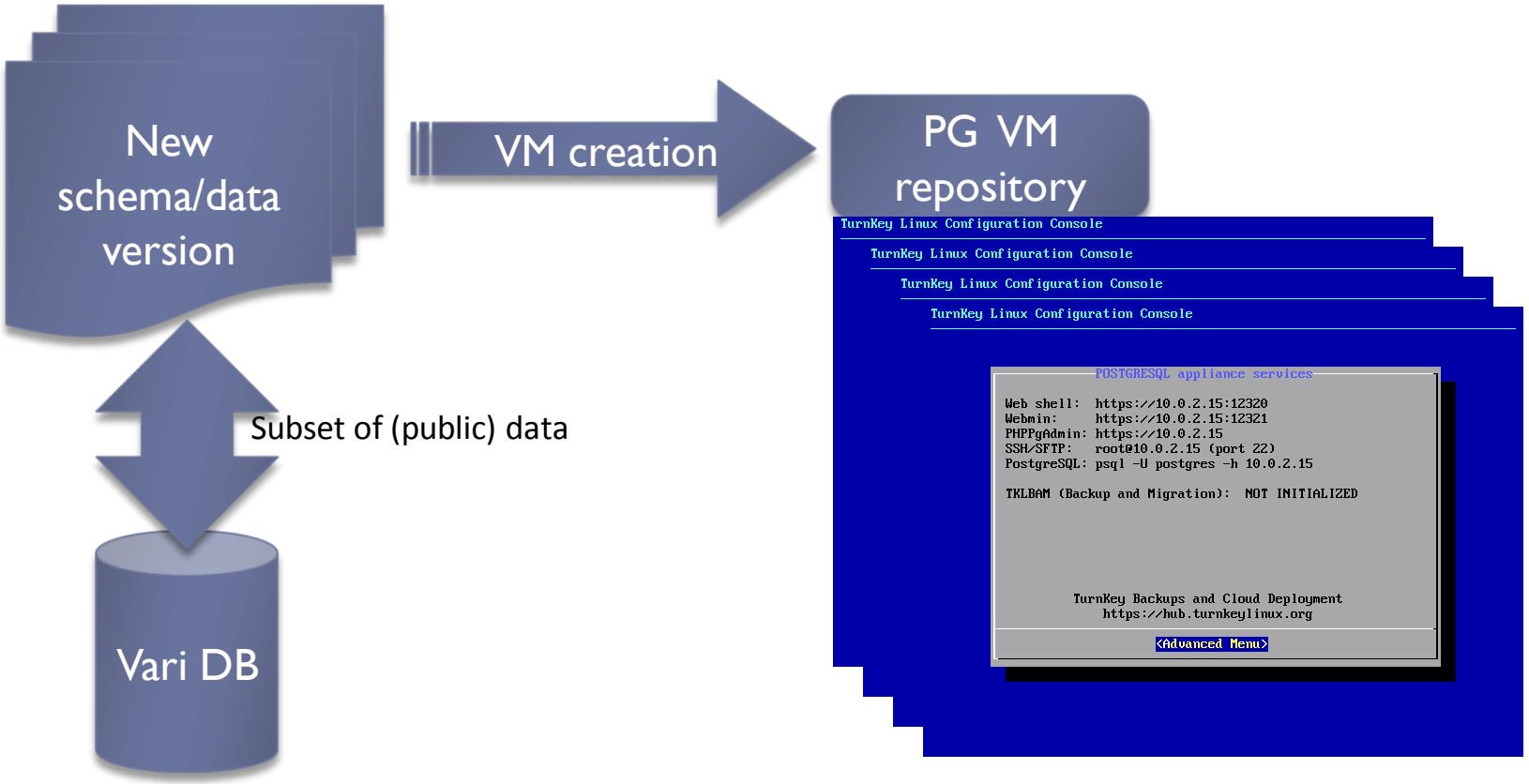
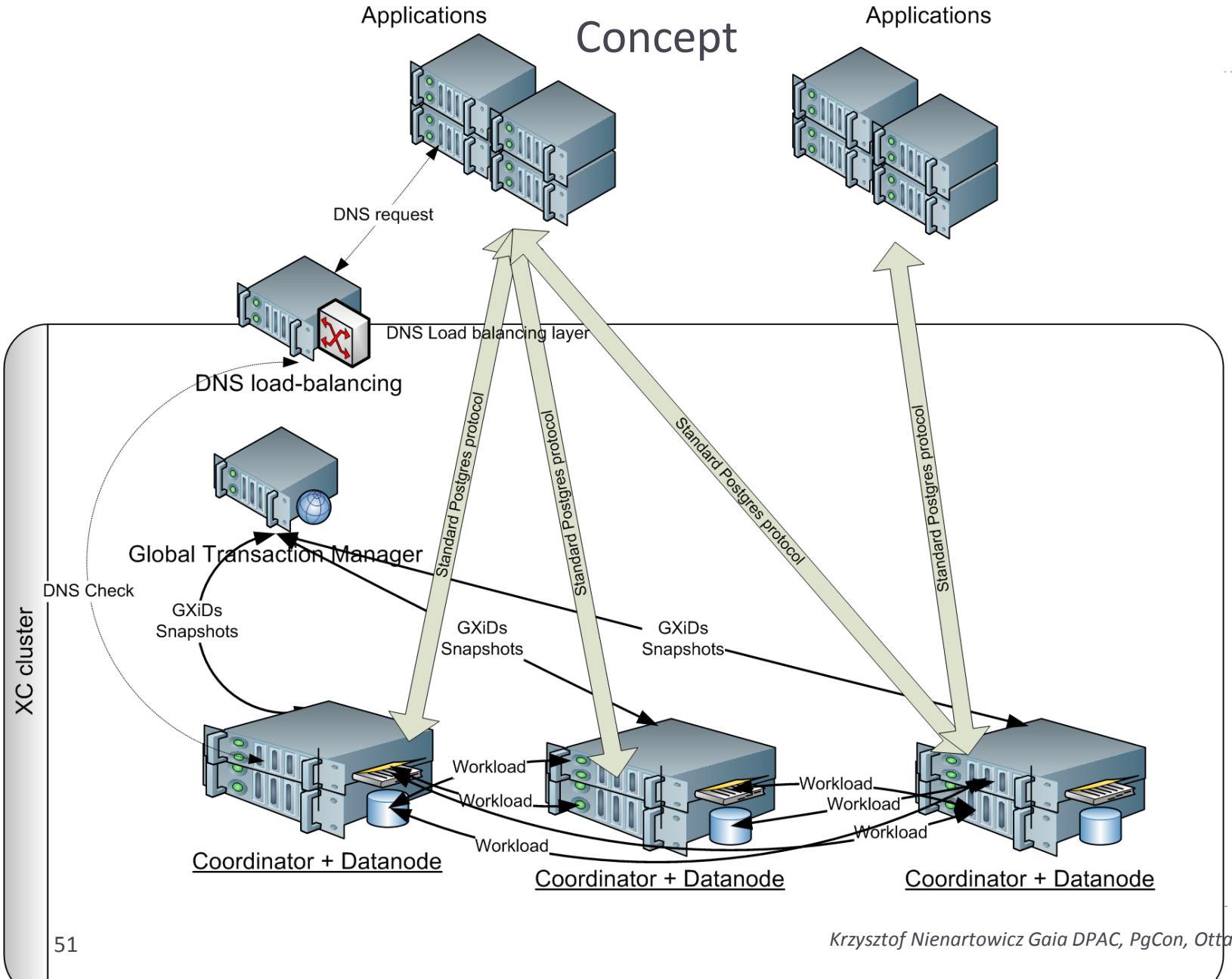


Structure

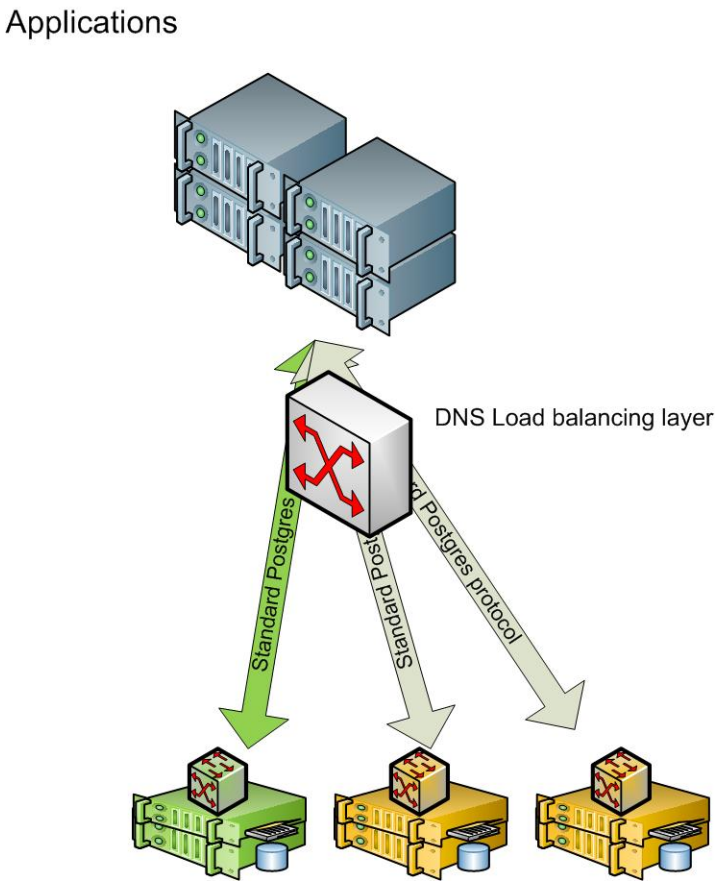
- My story
- Gaia mission
- Gaia science at CU7, Geneva
- Processing model
- Data model
- **XC role**
- Hardware
- Collaboration

Data platform: Postgres – XC/XL



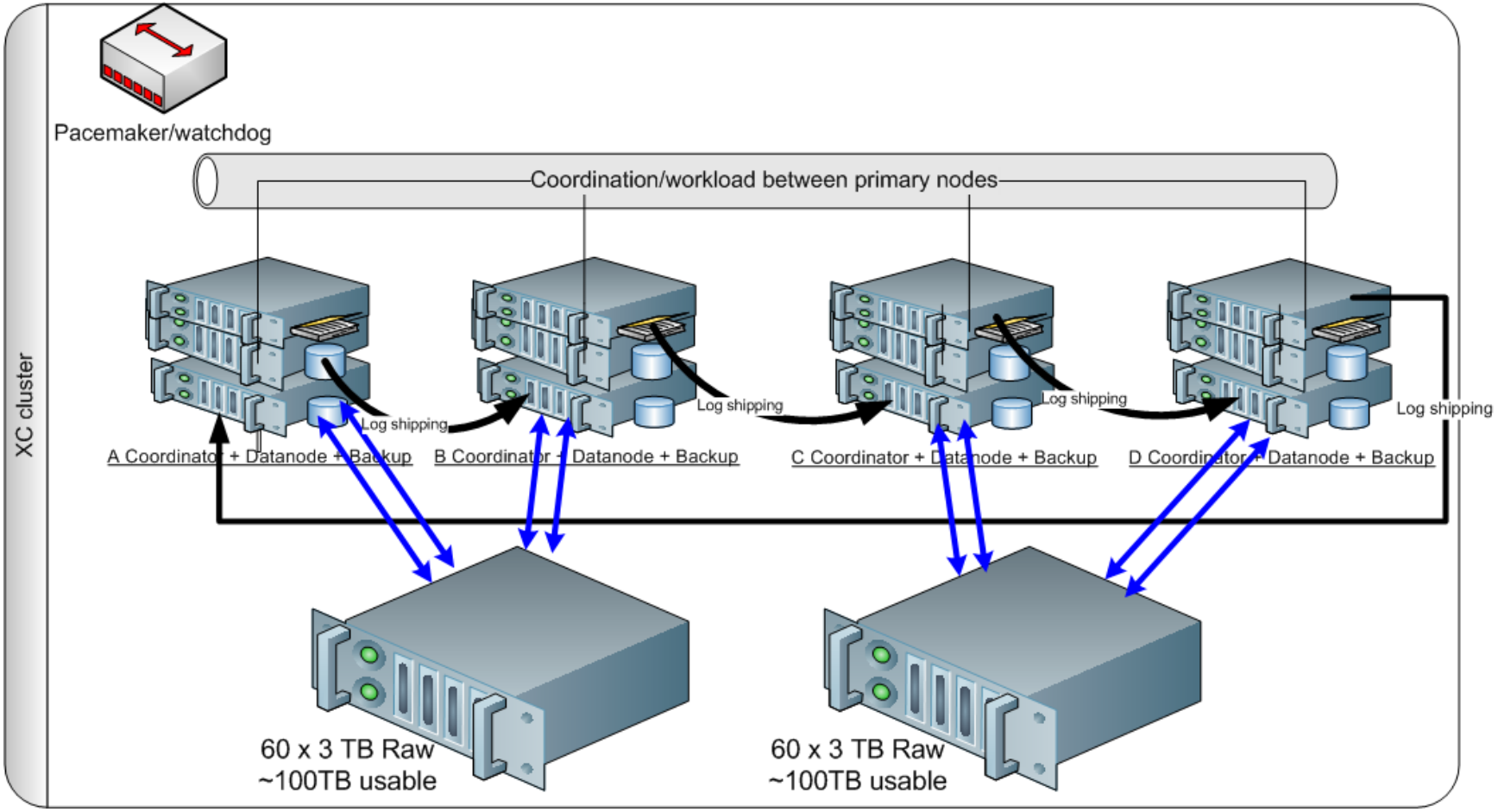
Postgres XC/XL

Load balancing – Jim Mlogdenski



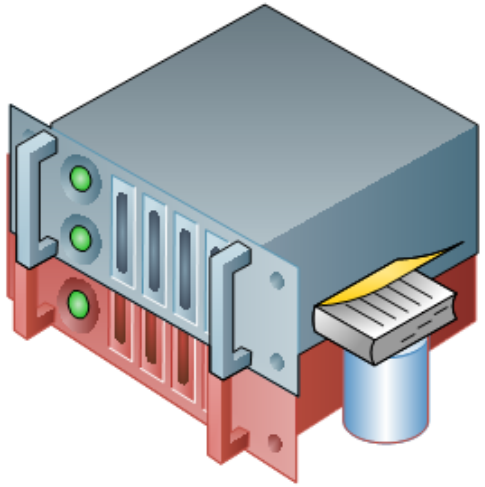
Postgres XC/XL (Koichi)

RAID1E



Postgres XC/XL

DB node



Coordinator + Datanode+Backup combined

DataNode storage

Storage for primary operations
Separate OS disk
WAL – Write Ahead Log: min 2x15K 300GB, RAID0(1 optional), quasi-sequential
Main Data Partition: 15-20TB usable per box, RAID10, mixed random + sequential
Data+seldomly used index
~1GB/s sequential
> 2000 real IOPS
Index and reconstruction space: SSD ~2TB, RAID10
>1GB/s sequential
>40000 real IOPS
Separate IO channel for Main data partition and index partition.
Needs Min 128GB RAM, lots of cores 32+
2x infiniband

Coordinator storage

Coordination:
In principle can sit on the same partitions as DataNode
or one dedicated RAID10 with relatively fast IOPS,
<500GB of storage.
Needs min ~16GB of RAM,
symmetric number of cores (shared with datanode),
mostly idling if done properly

Backup DataNode storage

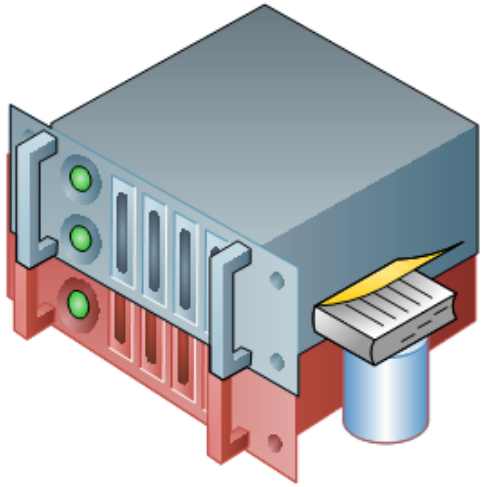
Storage for backup operations
WAL – Write Ahead Log: min 2x15K 300GB, RAID0(1 optional), quasi-sequential
Main Data Partition: 15-20TB usable per box, RAID6, quasi sequential + sequential
Data+seldomly used index
~1GB/s sequential
> 500 real IOPS
Separate IO channel for backup and primary.
Needs Min 16GB RAM,few cores

Backup Coordinator storage

Coordination:
In principle can sit on the same partitions as Backup DataNode
Needs min ~8GB of RAM,
symmetric number of cores (shared with backup datanode),
mostly idling if done properly

Postgres XC/XL

DB node



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Primary storage

Primary coordinator

Backup storage

Backup coordinator

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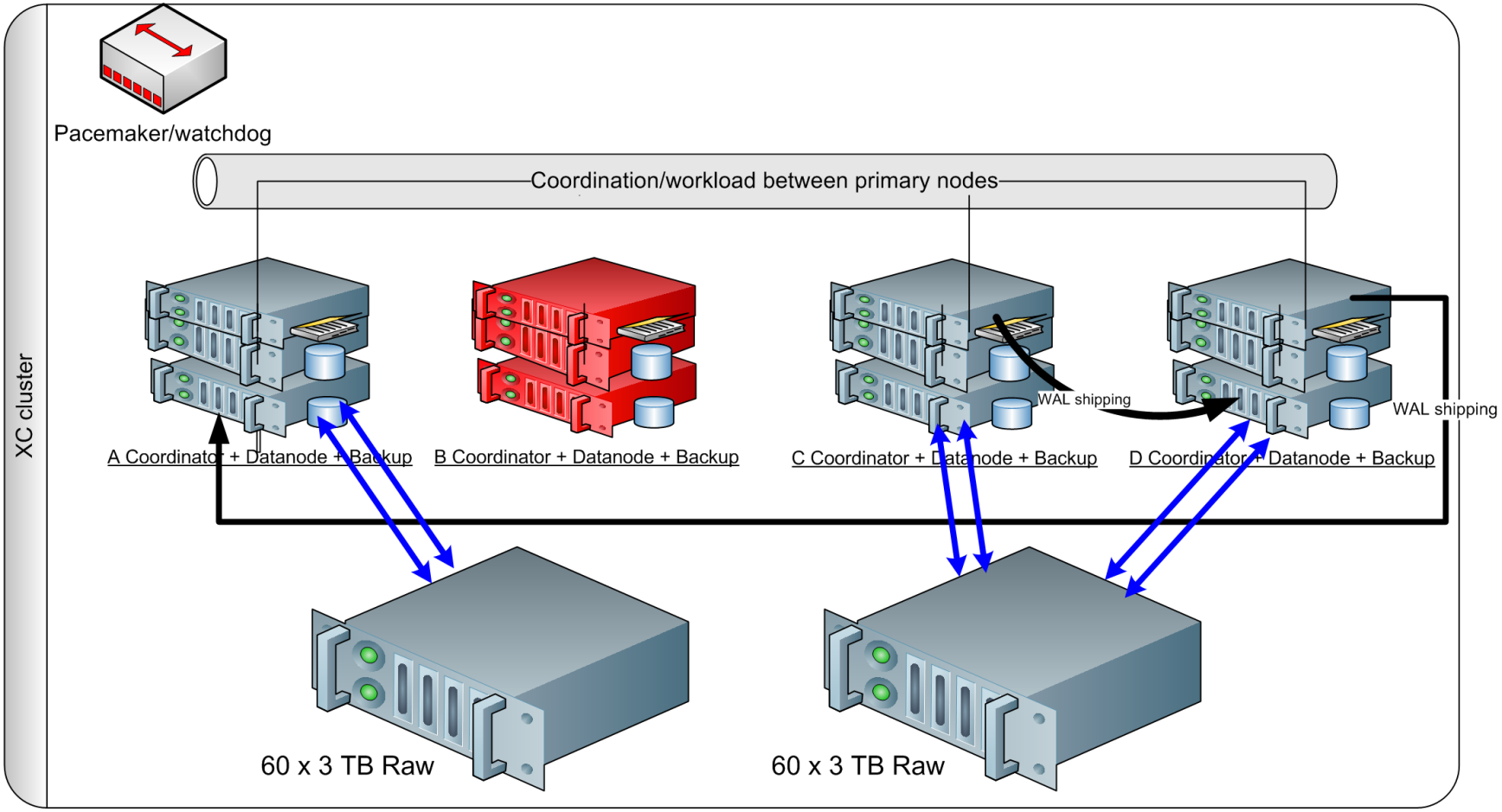
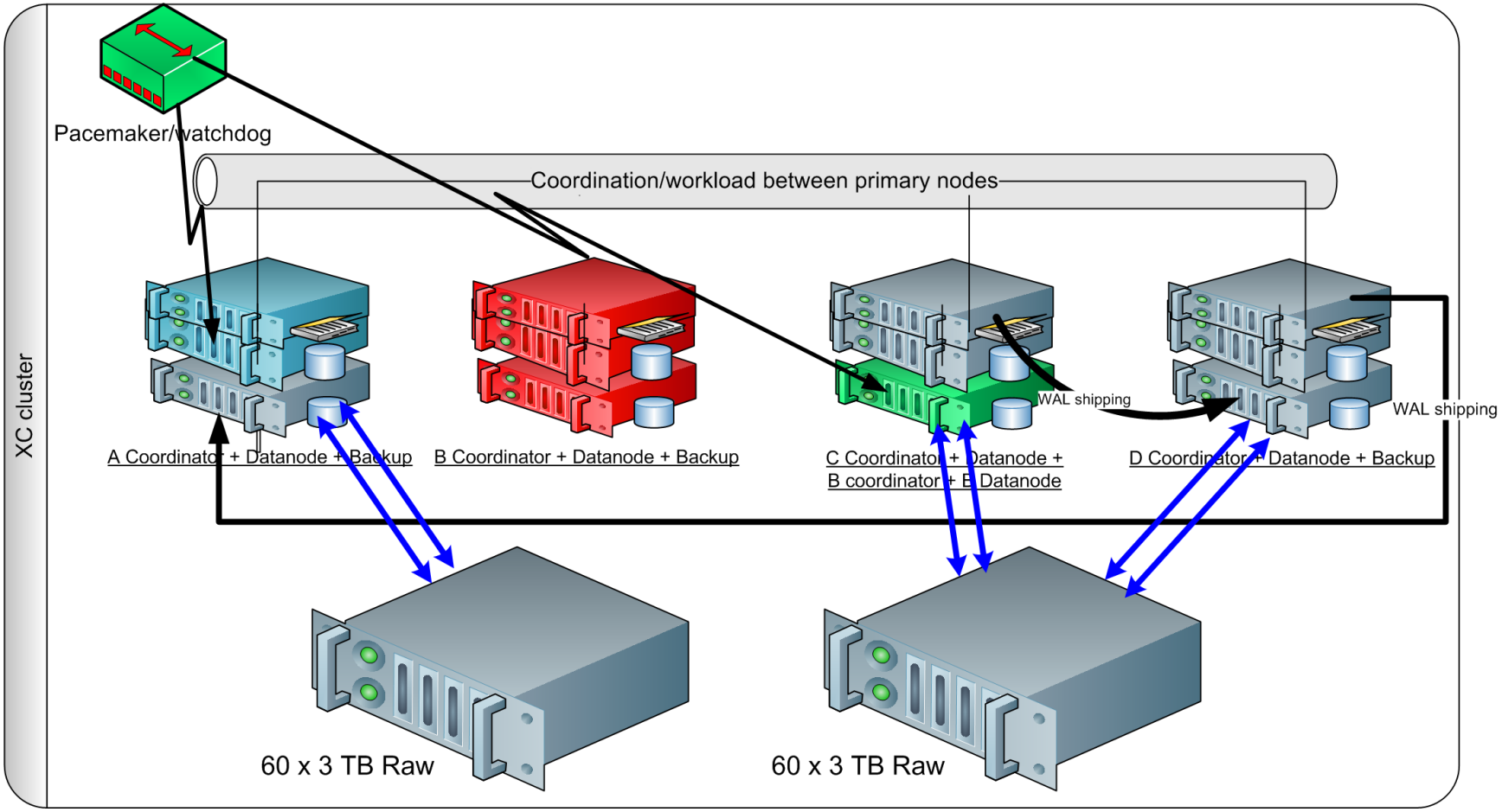
Postgres XC/XL

High availability - Failure



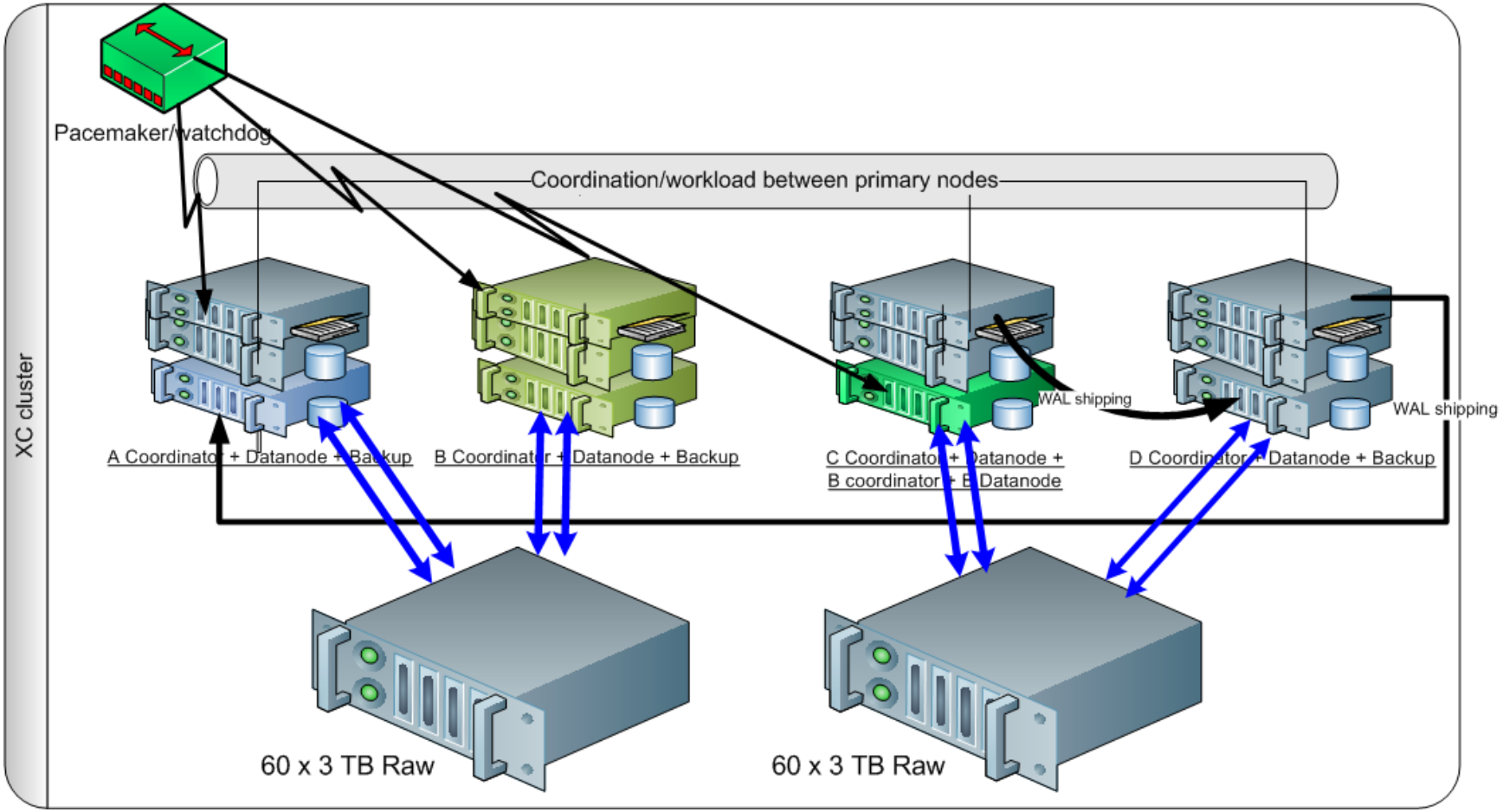
Postgres XC/XL

HA – Backup promotion



Postgres XC/XL

HA: recovery and backup demotion



Postgres XC/XL

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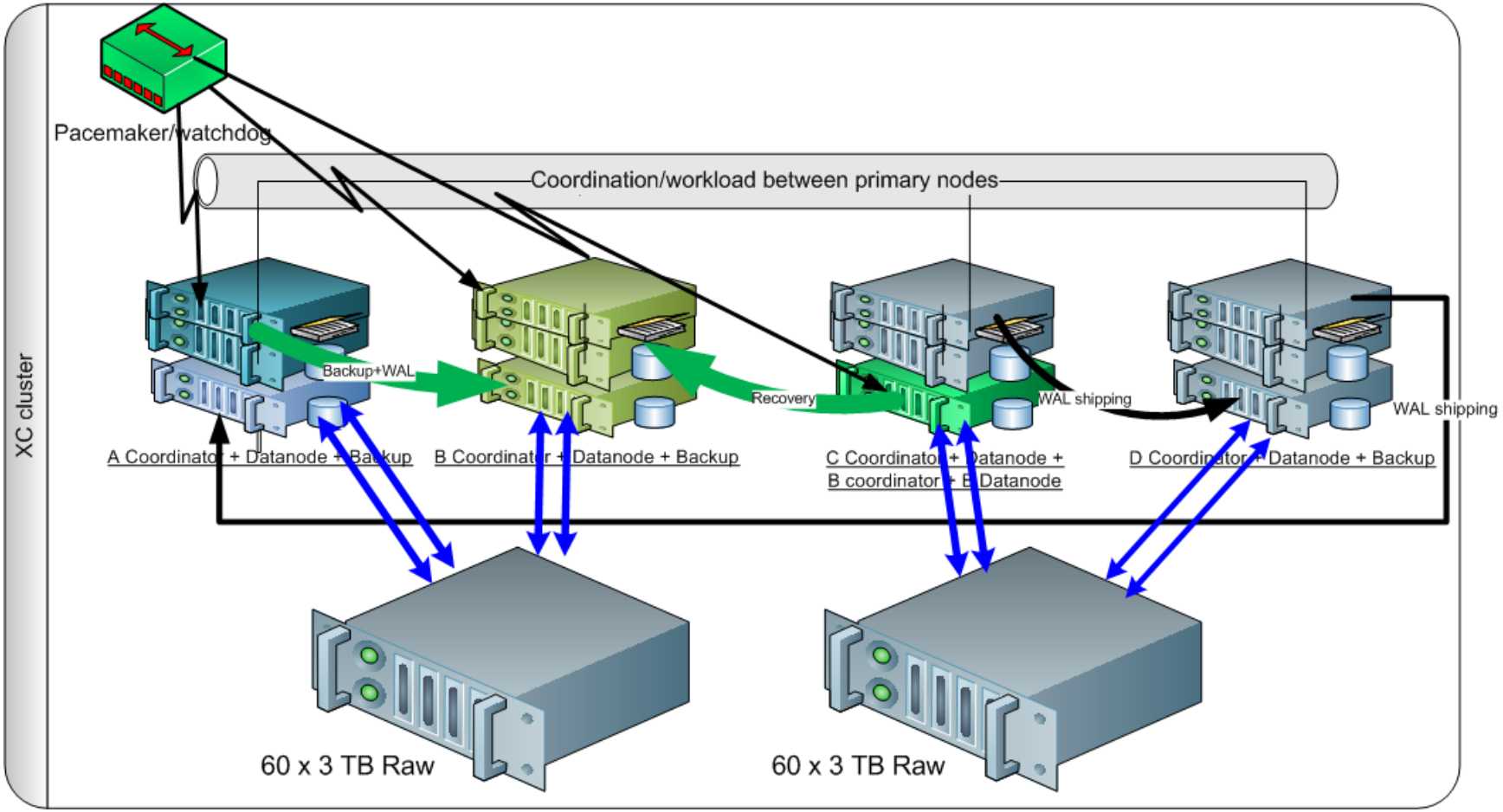

Postgres XC/XL

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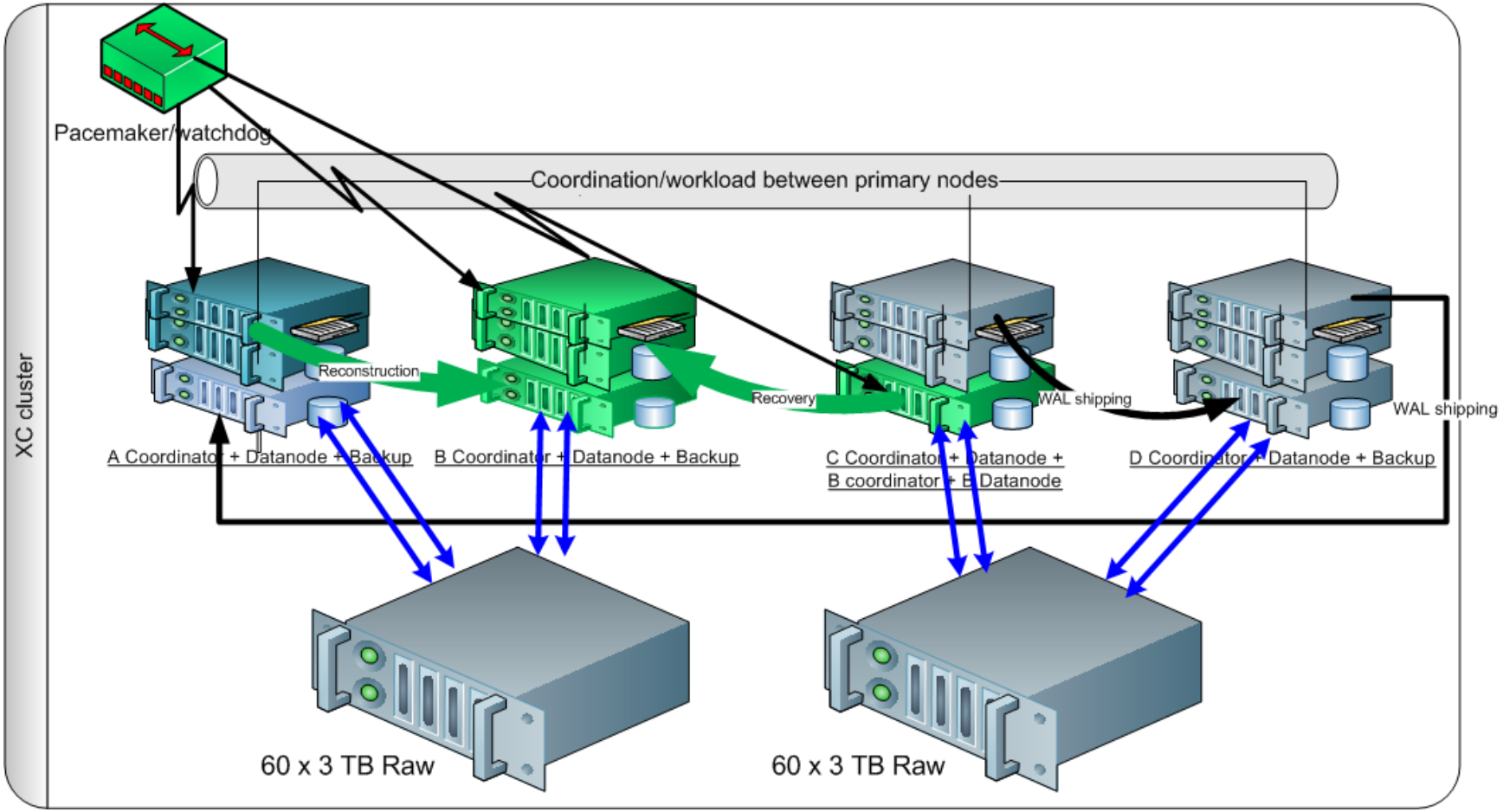

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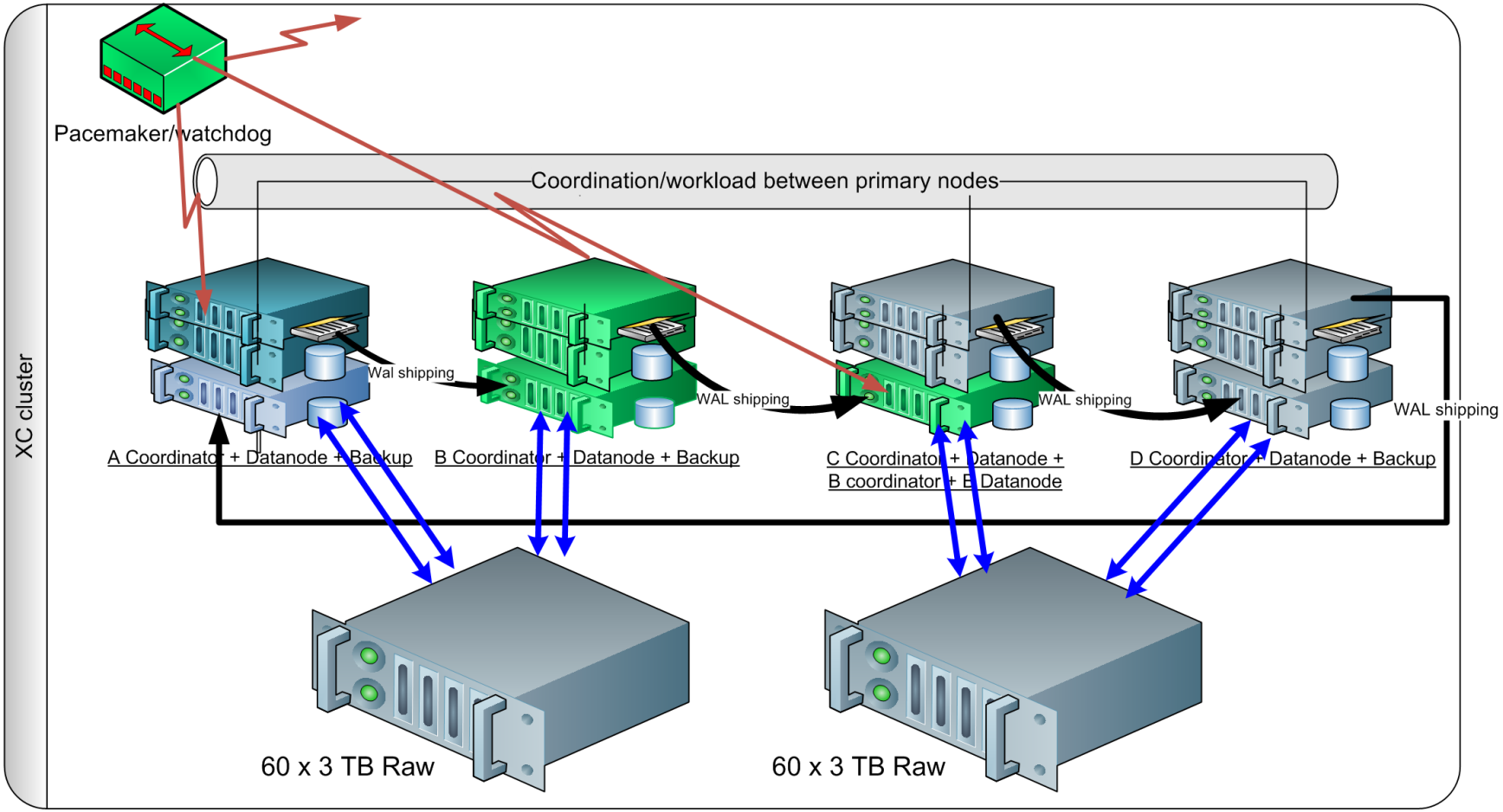
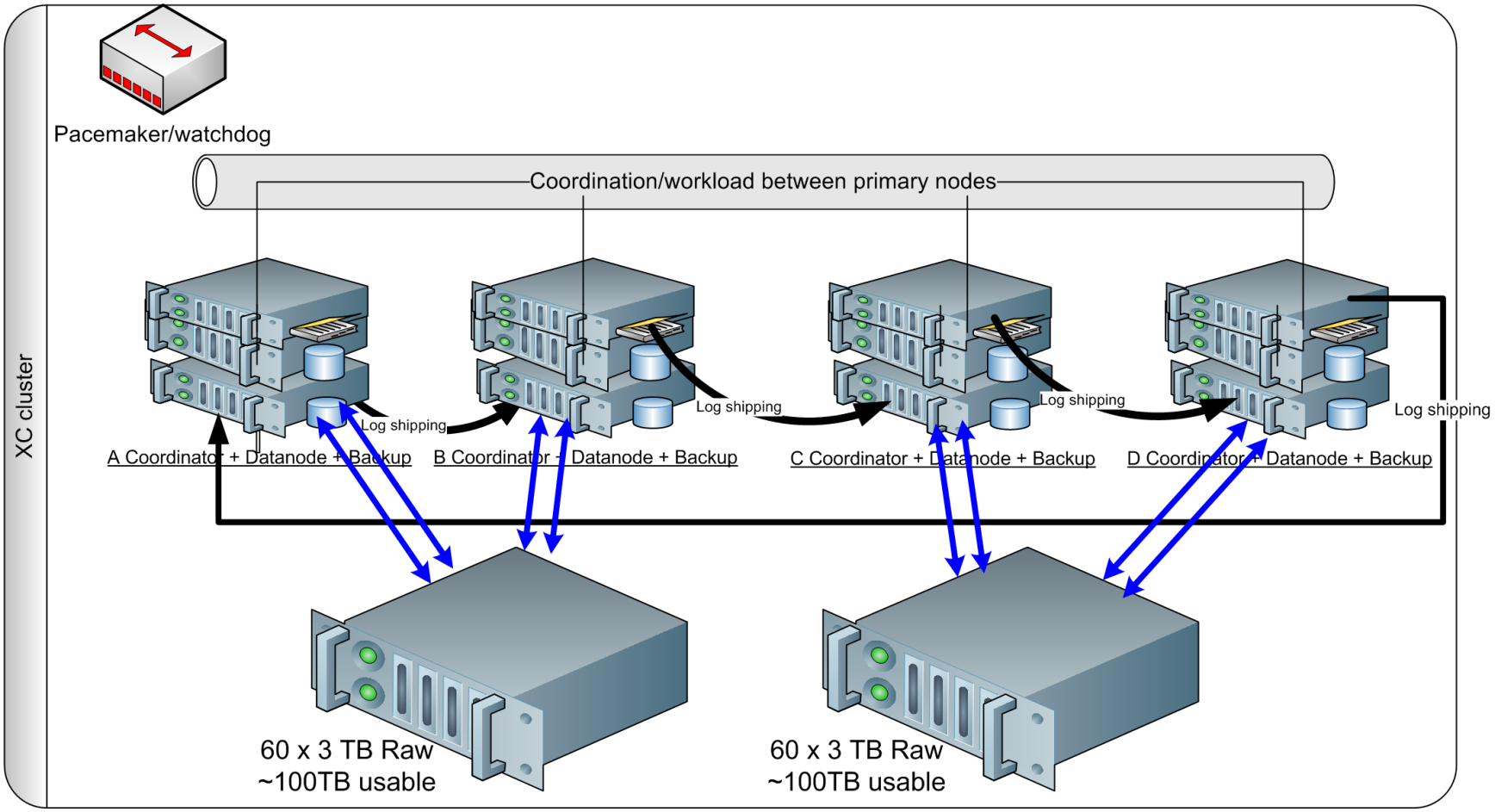


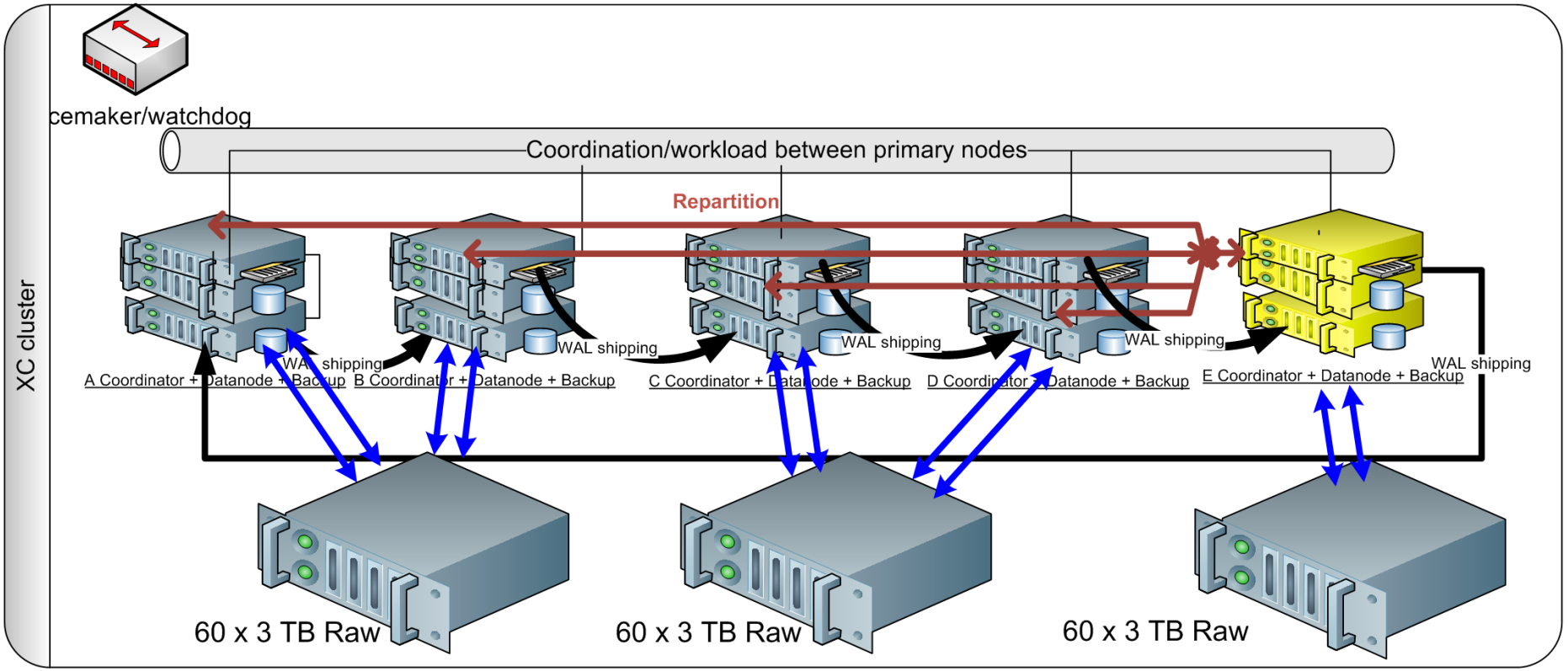
Postgres XC/XL

HA: recovery and backup demotion



Postgres XC/XL

Scalability: expansion, repartitioning



Postgres XC/XL role

- Postgres-XC integration seamlessness
  - Postgres compatible
    - PG SQL (psql, pgAdmin, JPA, hstore, object types, spatial indicies, n-dimensional knn-searches)
    - R: RPostgreSQL
  - CU7 Framework compatible
    - OpenJPA
    - Java (JDBC, PG copy protocol)
  - Scalability
    - Horizontal + veritcal - 50TB …. ~ 1PB, 10^{12} entities
    - Timeseries reconstruction
    - Batch processing, source oriented
    - Analytical processing, ad hoc
  - High Availability

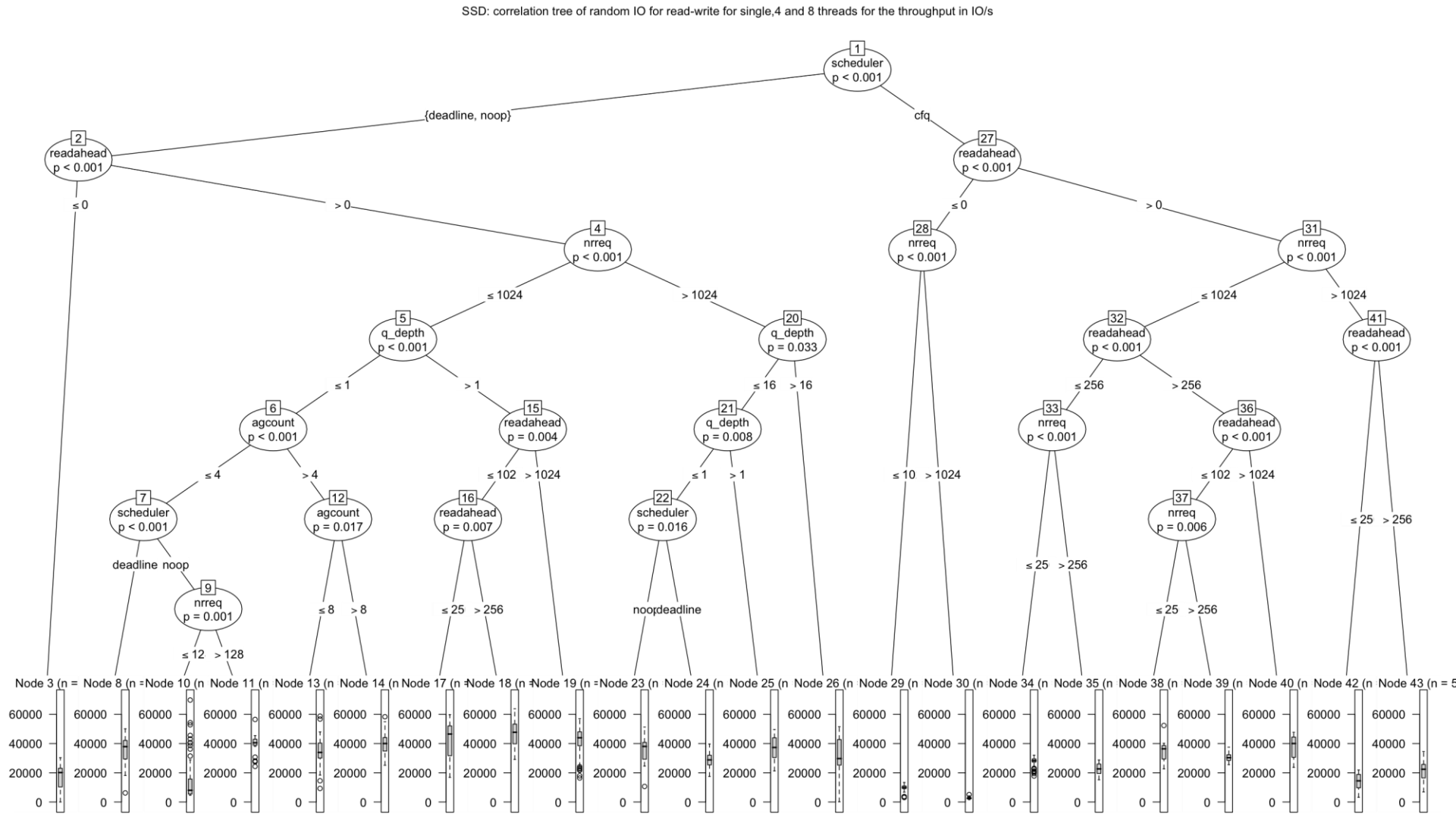
Postgres XC/XL role – what do we need

- Very High priority
  - Stability
  - Performance
  - Partitioning
  - PG type model (objects, arrays of objects)
  - JDBC working (pooling)
  - R working
  - Parallel loading into **partitions** of XC distributed tables
    - Support for COPY (via JDBC or other Java driver)
    - UDF for custom distribution logic (or as external API)
  - Custom aggregates
  - Load balancing
  - Support for existing index extensions
  - PLJava, plR working
- High priority
  - Query estimates available on the coordinator
  - OLAP features:
    - In-node query parallelization
    - Index organized tables
    - Working Bitmap, Bloom indicies
    - Column store
    - Estimators
    - Effective knn-searches
    - Compression
    - Read-only tables(paces)

Structure

- My story
- Gaia mission
- Gaia science at CU7, Geneva
- Processing model
- Data model
- XC role
- **Hardware**
- Collaboration

OS IO tuning


SSD: correlation tree of random IO for read-write for single,4 and 8 threads for the throughput in IO/s
1 scheduler p < 0.001
{deadline, noop}
cfq
2 readahead p < 0.001
27 readahead p < 0.001
≤ 0
> 0
4 nrreq p < 0.001
28 nrreq p < 0.001
31 nrreq p < 0.001
≤ 1024
> 1024
5 q_depth p < 0.001
20 q_depth p = 0.033
32 readahead p < 0.001
41 readahead p < 0.001
≤ 1
> 1
≤ 16
> 16
6 agcount p < 0.001
15 readahead p = 0.004
21 q_depth p = 0.008
33 nrreq p < 0.001
36 readahead p < 0.001
≤ 4
> 4
≤ 102
> 1024
≤ 1
> 1
≤ 10
> 1024
≤ 256
> 256
7 scheduler p < 0.001
12 agcount p = 0.017
16 readahead p = 0.007
22 scheduler p = 0.016
37 nrreq p = 0.006
deadline
noop
9 nrreq p = 0.001
≤ 8
> 8
≤ 25
> 256
noop
deadline
≤ 12
> 128
Node 3 (n = 60000 40000 20000 0
Node 8 (n = 60000 40000 20000 0
Node 10 (n = 60000 40000 20000 0
Node 11 (n = 60000 40000 20000 0
Node 13 (n = 60000 40000 20000 0
Node 14 (n = 60000 40000 20000 0
Node 17 (n = 60000 40000 20000 0
Node 18 (n = 60000 40000 20000 0
Node 19 (n = 60000 40000 20000 0
Node 23 (n = 60000 40000 20000 0
Node 24 (n = 60000 40000 20000 0
Node 25 (n = 60000 40000 20000 0
Node 26 (n = 60000 40000 20000 0
Node 29 (n = 60000 40000 20000 0
Node 30 (n = 60000 40000 20000 0
Node 34 (n = 60000 40000 20000 0
Node 35 (n = 60000 40000 20000 0
Node 38 (n = 60000 40000 20000 0
Node 39 (n = 60000 40000 20000 0
Node 40 (n = 60000 40000 20000 0
Node 42 (n = 60000 40000 20000 0
Node 43 (n = 5 60000 40000 20000 0

Big Volume vs Constraints

Big Volume vs Constraints

- Growing number of cores

Big Volume vs Constraints

- Growing number of cores
- Growing number of users

Big Volume vs Constraints

- Growing number of cores

Procurement Plan

	Today	2013	2014	2018
Cores	O(100)	O(100)	O(300)	O(1000+)
DB Nodes	1	3+2	4 +1	8+2
Storage	24TB	50TB	75-315 TB	200-950 TB
		Launch	IDR(*1)	FDR(*2)

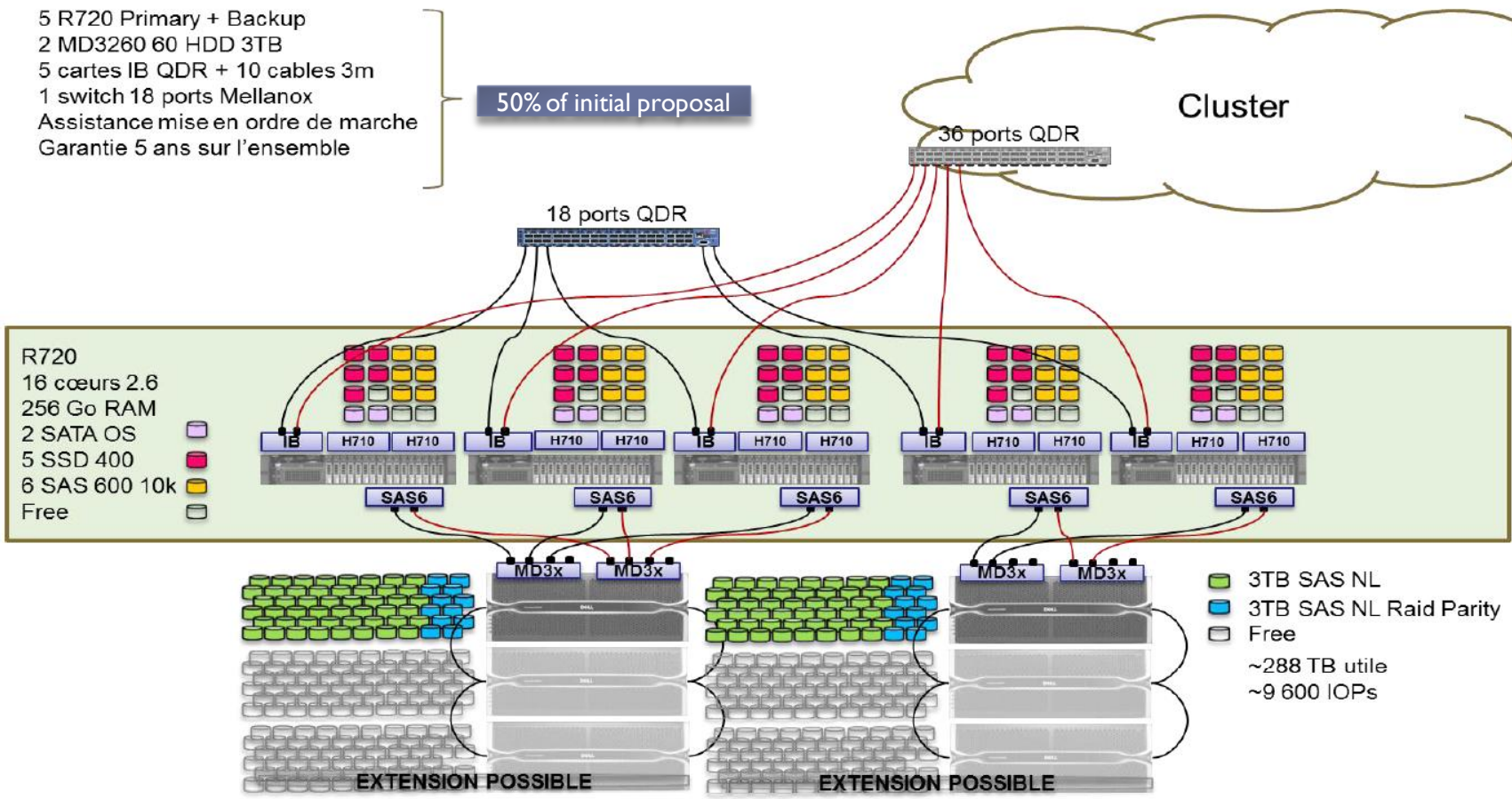
(*1) IDR: Intermediate **D**ata **R**eduction

(*2) FDR: Final **D**ata **R**eduction

- Growing number of users

Hardware
Dell, 180 disks, 540TB raw
WAL space, SSDs: 2TB per node…

Ref.	Description	Qté.	PU € HT	Disc	PU remisé € HT	Prix total € HT



Collaboration - Conclusion

- We are few of milestone astronomical experiments
  - Relying on Postgres already
    - Made few strategic choices because of XC existence
  - Willing to invest:
    - time in Postgres XC/XL
  - **Hoping XC/XL will merge their efforts into a holistic solution!!!**
  - Encouraging Tokyo meeting in 2014/03

  - Invested into:
    - testing and
    - into relevant hardware already
    - ported some extensions, i.e. plJava, tested many more..

  - Visible in the Gaia consortium
    - Linked to the final Gaia catalogue, possibly influencing their choice
  - Veeeery long term user
    - **production starts in mid 2015! – we will be deploying it next weeks!**

QA…