Astroinformatika

Cesta k pochopení Vesmíru z astronomicky velkých dat

Petr Škoda

Astronomický ústav AVČR Ondřejov

S podporou grantu MŠMT COST LD-15113
akce COST TD-1403

Informatický večer FIT ČVUT Praha
7.11.2016

Credits

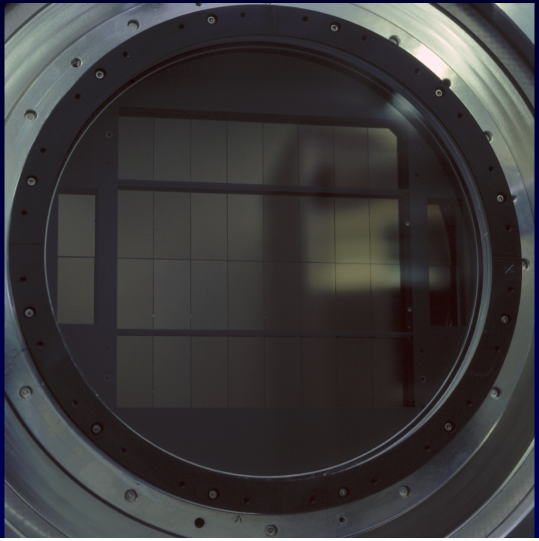
- The presentation is based on many different sources – mainly the on-line published slides from IVOA meetings, slides from Astroinformatics workshops or pictures found on Internet.
- We acknowledge namely materials of E. Solano, E. Hatsiminaoglu, B.Hanish, G. Djorgovski, G. Longo, O. Laurino, T. Hey, L. Fortson and presentations from AI2016 in Sorrento

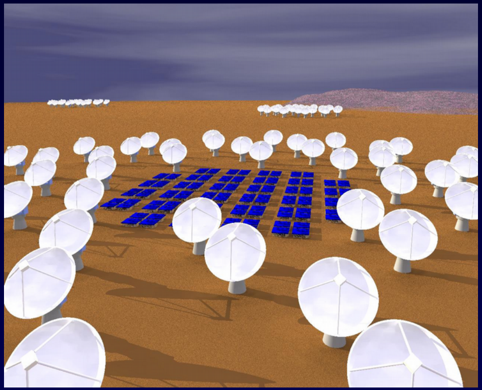
Outline of the Talk

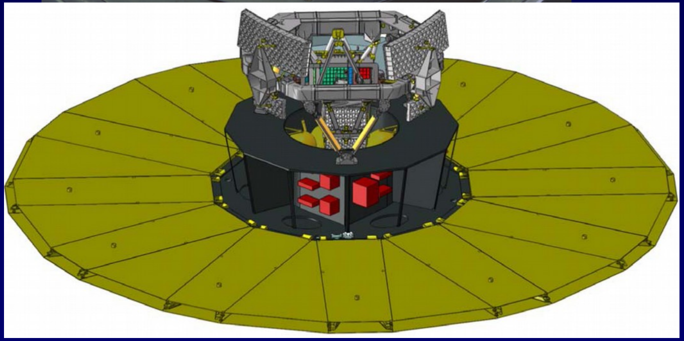
- Data Avalanche in astronomy
- Virtual Observatory
- Astroinformatics
- Visualizations
- Transfer of technology
- Citizen Science

- Astroinformatics in CR

Data Avalanche



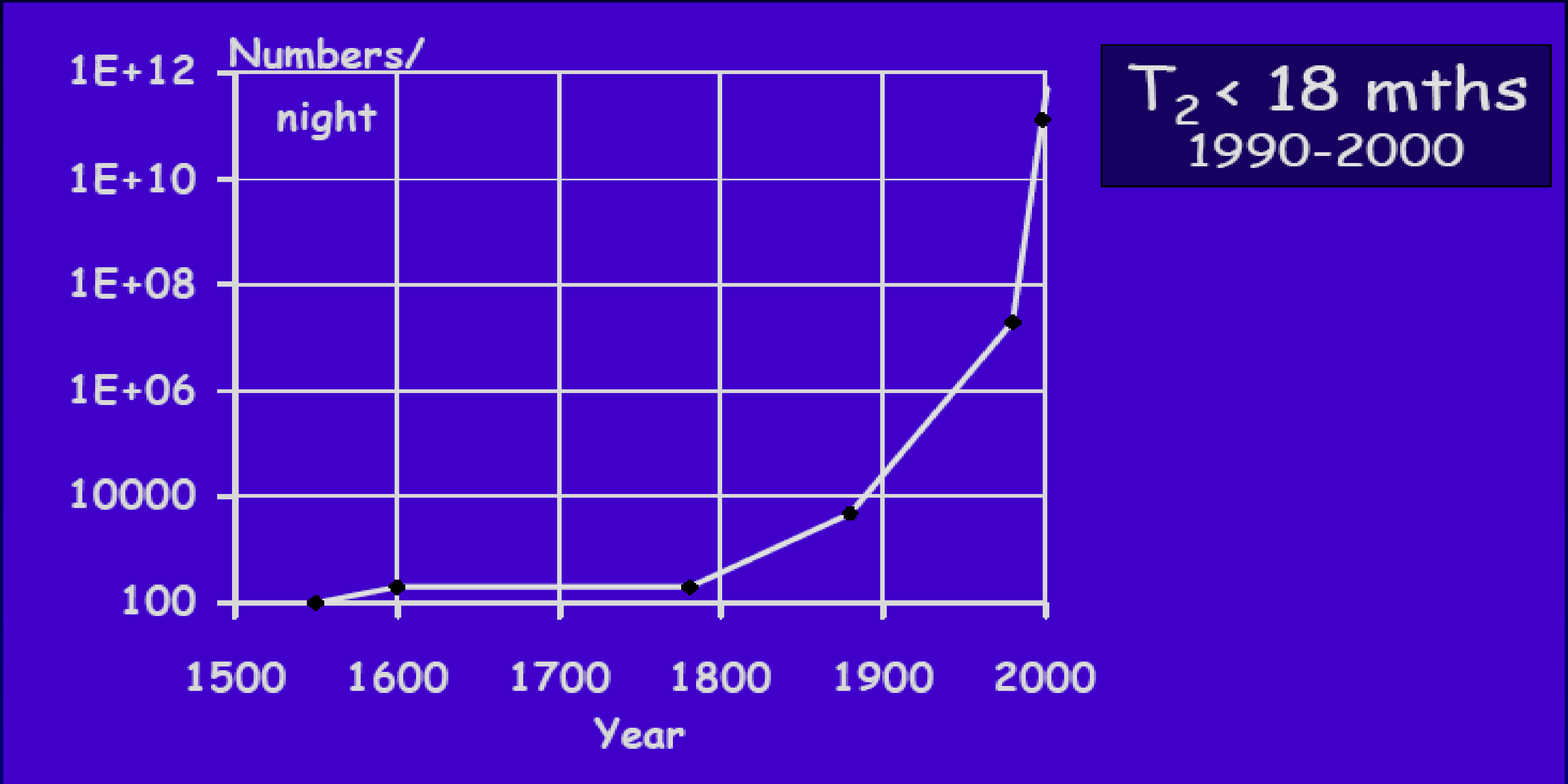




Data Avalanche

Moore law for chips –doubling 1.5 year

Data in astronomy – doubling < 1 yr ! (1000/10 yr)

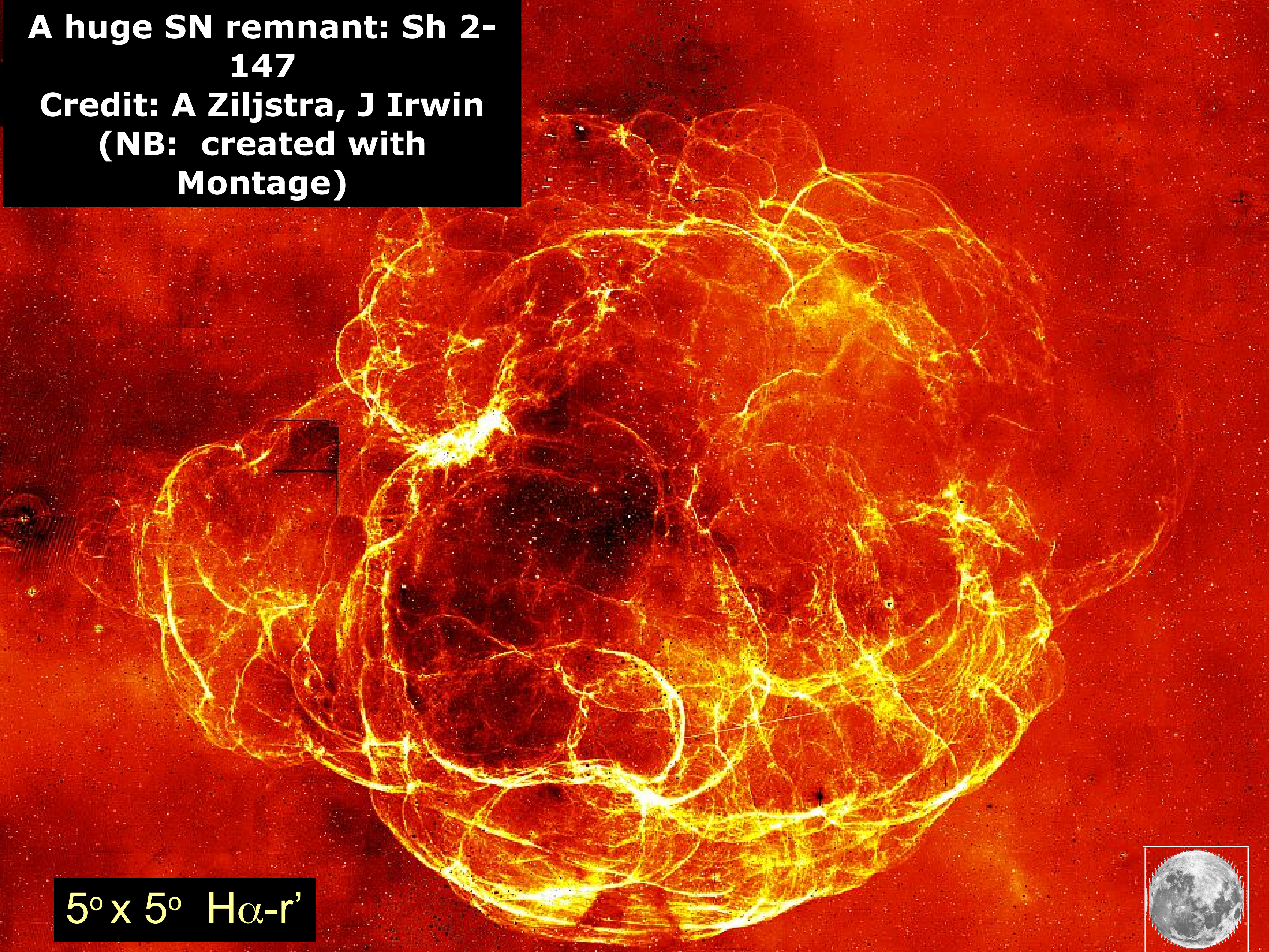


CD Sea

600 000 CD = 372 TB (CD 650MB)
600 000 DVD = 2.5 PB (DVD=4.5GB)

Bruce Monro
Kilmington UK

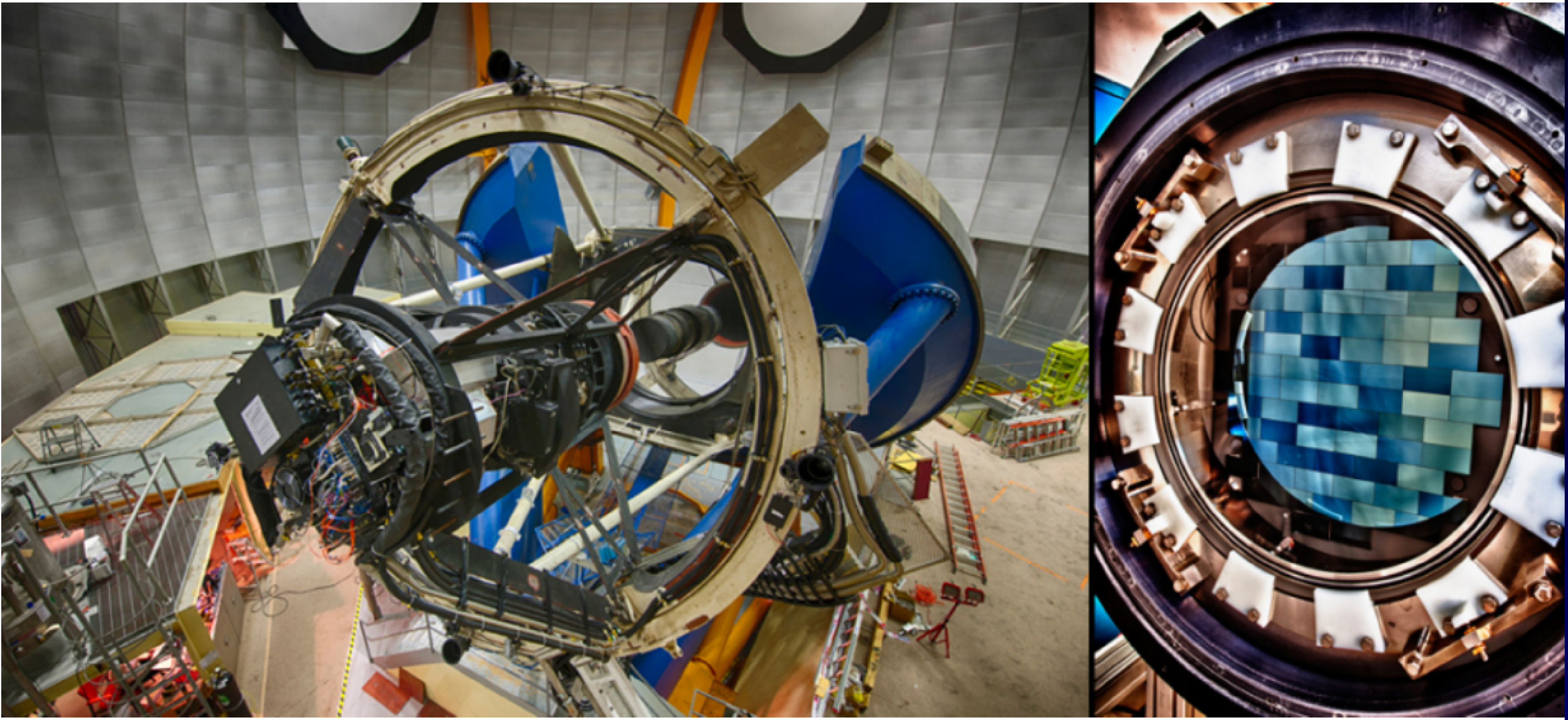
A huge SN remnant: Sh 2-147
Credit: A Ziljstra, J Irwin
(NB: created with Montage)



5° x 5° Hα-r'

Dark Energy Survey Camera

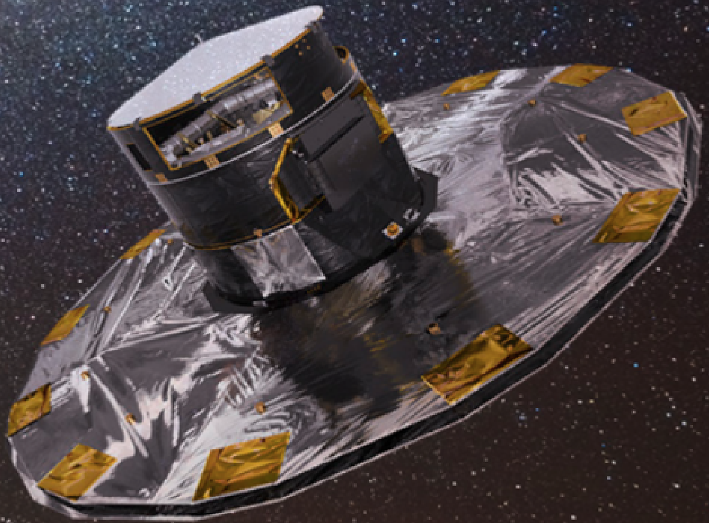
Dark Energy Camera (DECam)



~0.4 PB/yr

Gaia

- Gaia satellite
  - launched by ESA in december 2013
  - determines positions, velocities and astrophysical parameters of >10^9 stars of the Milky Way
  - First catalogue DR1 just out
    - ra, dec, G magnitude
  - DR2 ~1 year
  - Final catalogue ~2020



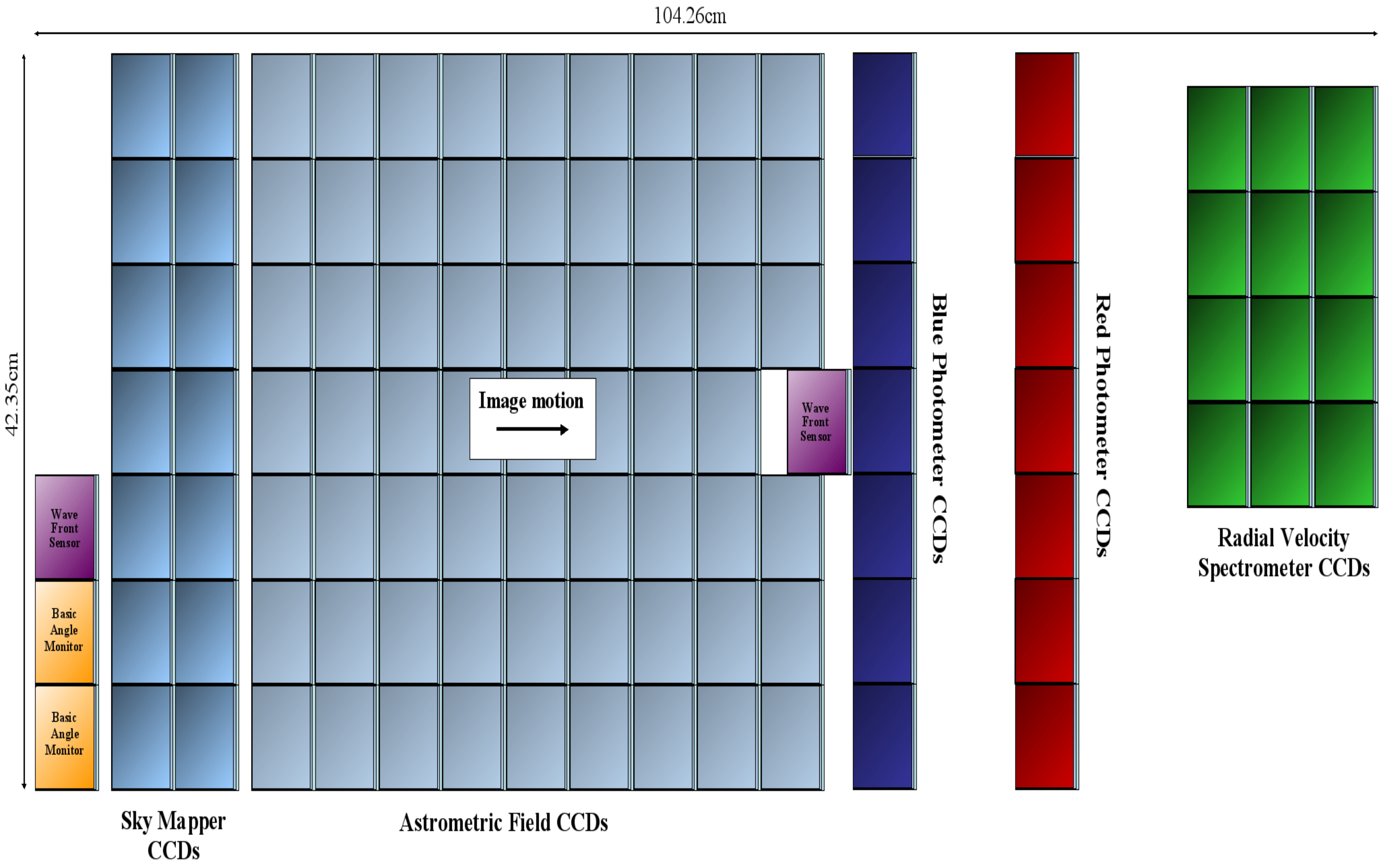
Copyright ESA/ATG medialab; background: ESO/S. Brunier

GAIA CCDs

106 CCDs

938 Mpix

2800cm^2



Large Synoptic Survey Telescope

Cerro Pachón – Future site of the LSST
LSST Rendering on El Peñón
SOAR
Gemini
Cerro Pachón ridge – view from northwest

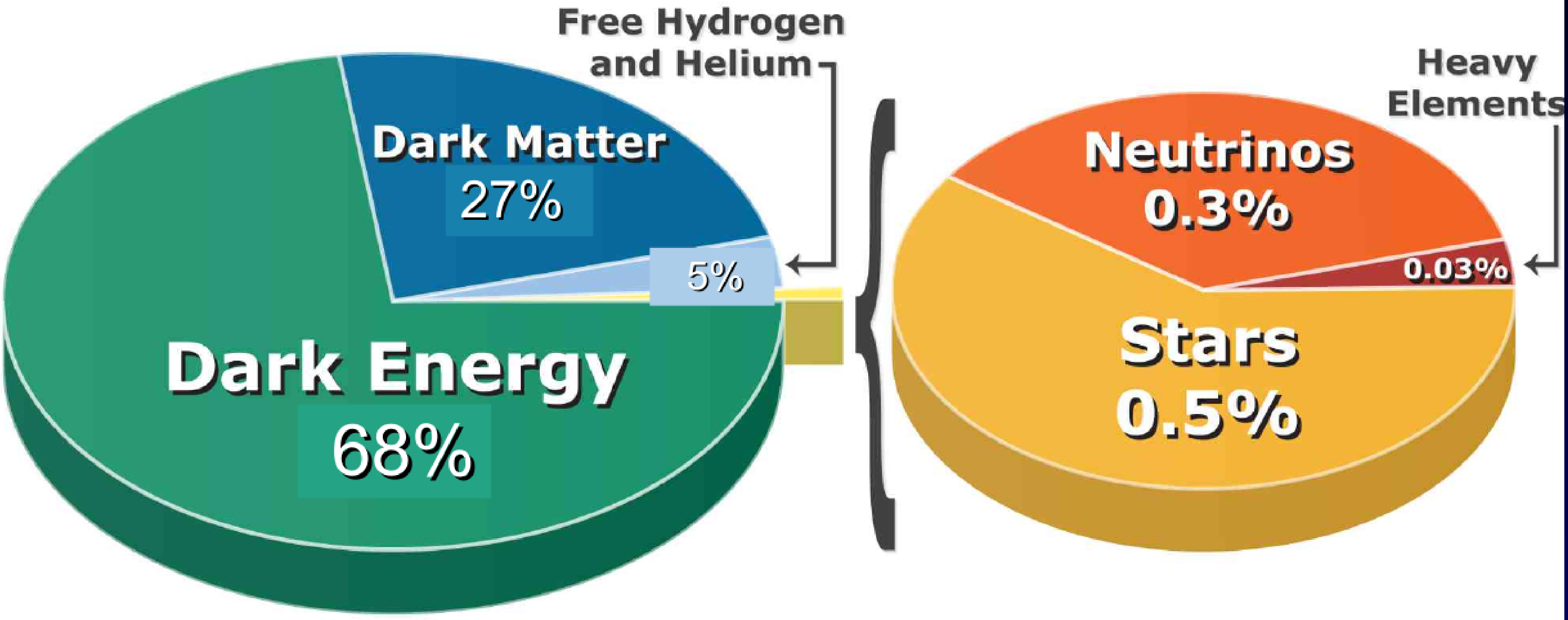
201 CCD 4kx4k,
3.2 Gpix every 20 sec
3.5 deg FOV (64cm)
20 TB/day=6 PB/yr RAW
1.5 PB catalogue !!!
detection of changes 60s!

38 billion objects x 1000
32 tril. meas. -5 PB table

Project EUCLID

The Euclid mission main goal

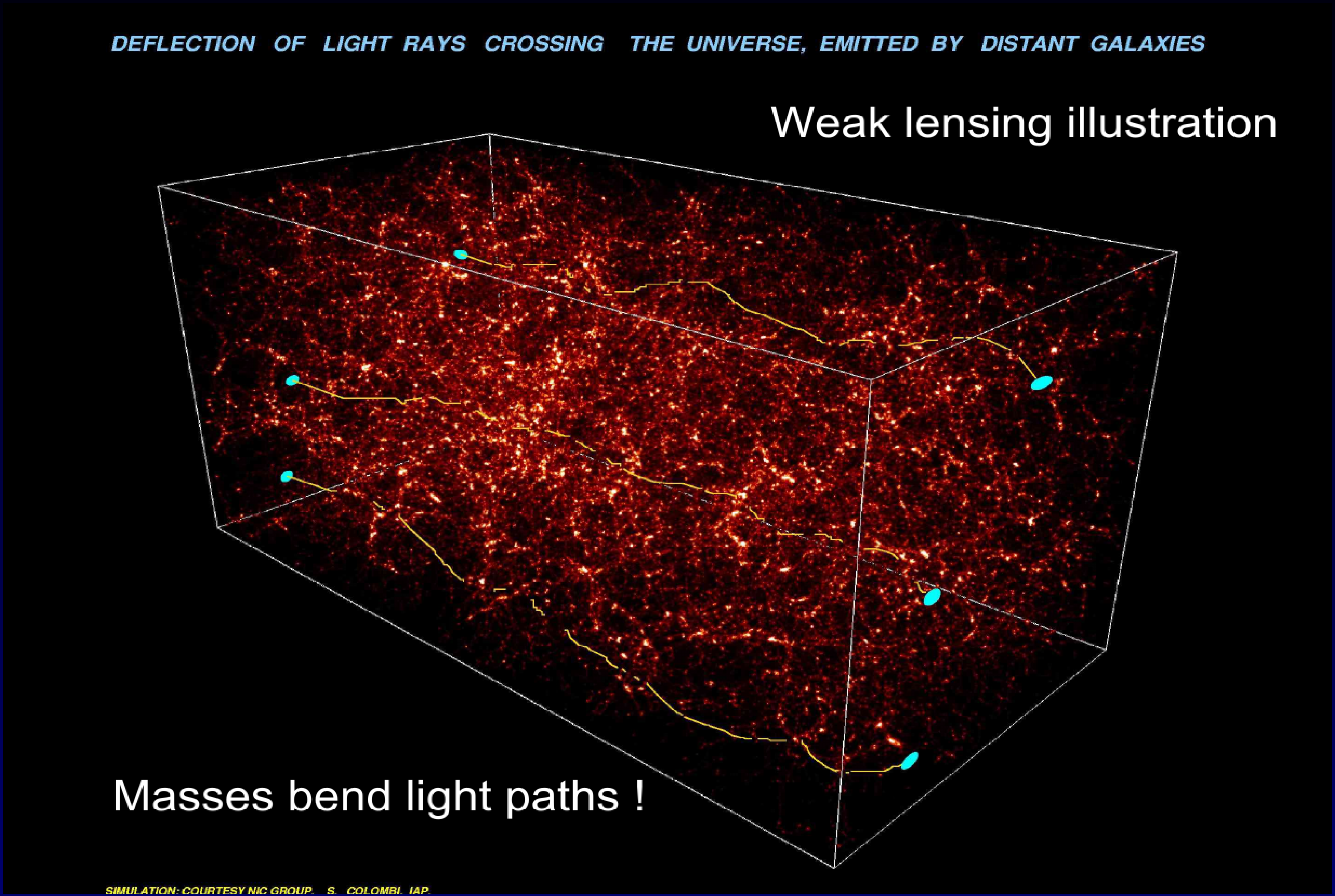
EUCLID CONSORTIUM



- What is the Nature of the Dark Matter and Energy?

Dubath 2016

EUCLID principles


DEFLECTION OF LIGHT RAYS CROSSING THE UNIVERSE, EMITTED BY DISTANT GALAXIES

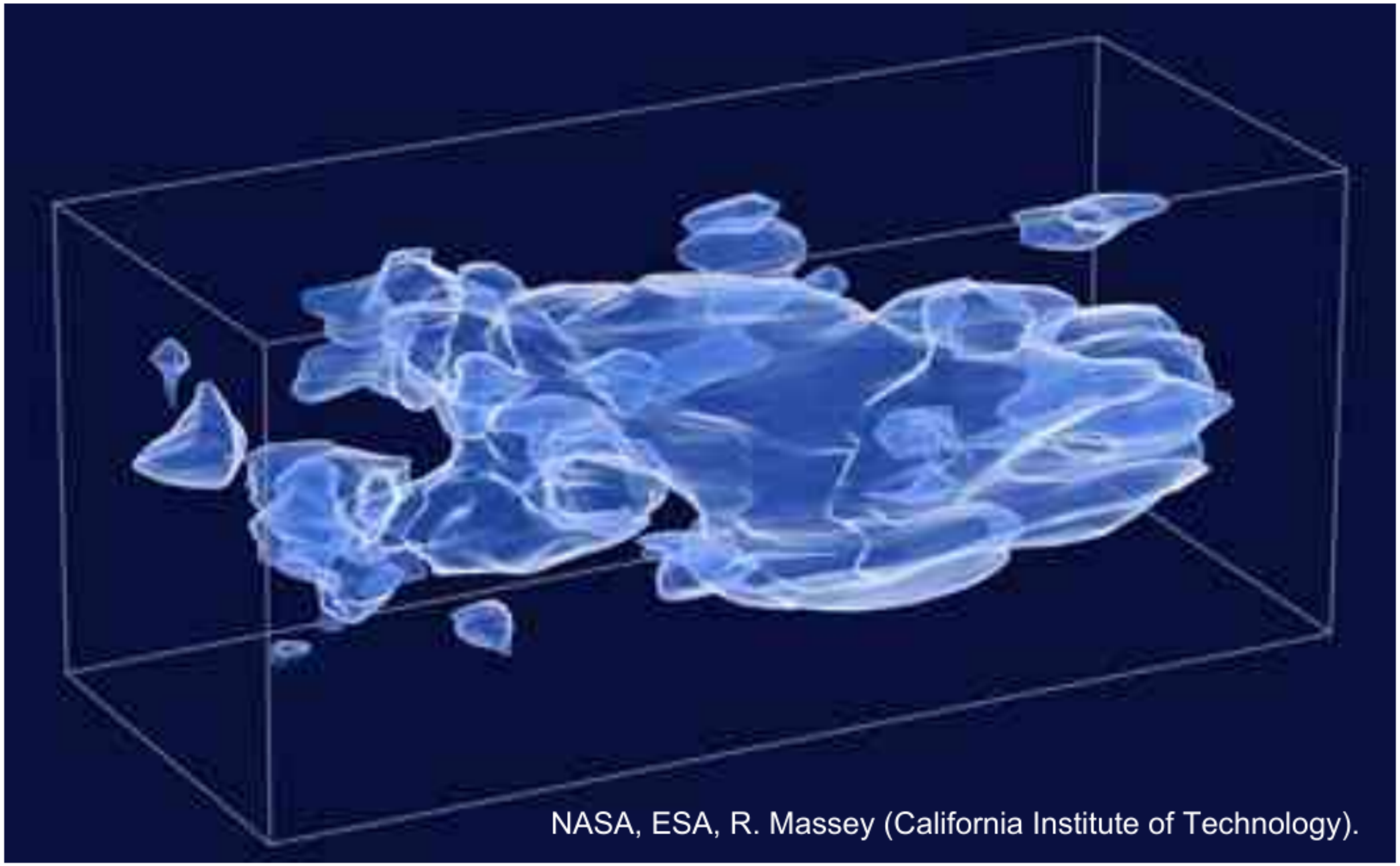
Weak lensing illustration

Masses bend light paths !

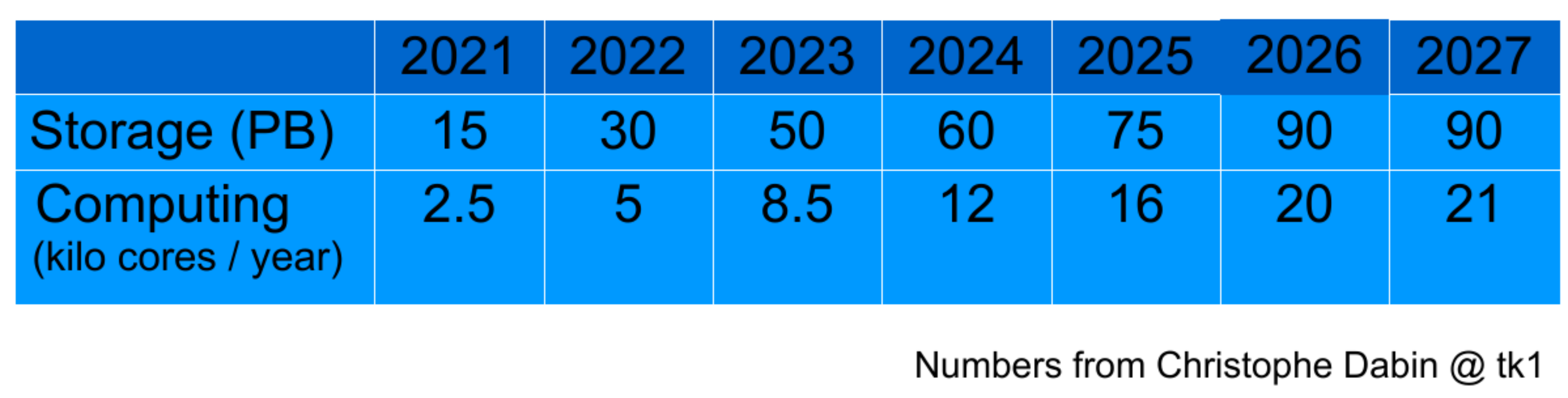
SIMULATION: COURTESY NIC GROUP. S. COLOMBI. IAP.

Dubath 2016

Euclid Data Archive



NASA, ESA, R. Massey (California Institute of Technology).



	2021	2022	2023	2024	2025	2026	2027
Storage (PB)	15	30	50	60	75	90	90
Computing (kilo cores / year)	2.5	5	8.5	12	16	20	21

Numbers from Christophe Dabin @ tk1

Atacama Large Milimeter Array ALMA

64 antennas 12m
Chajnator 5000m
Chile
2008-2013

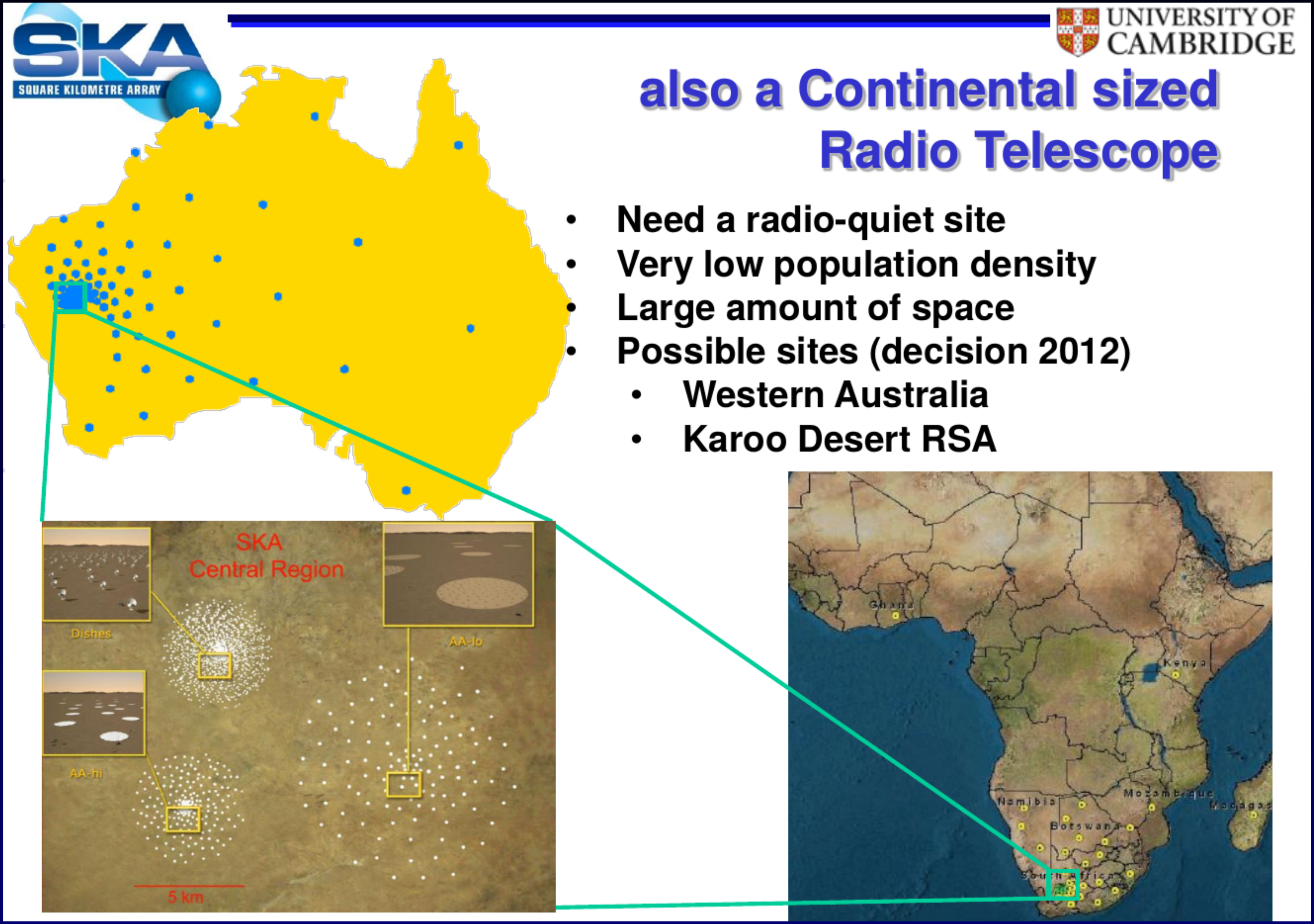
it is spectrograph
as well as ...

0.5-2 PB/yr RAW

LOFAR network

	LOFAR	SKA
Raw Telescope	112 PB/yr	60 EB/yr
Archive Rate	6 PB/yr	100 PB/yr

SKA



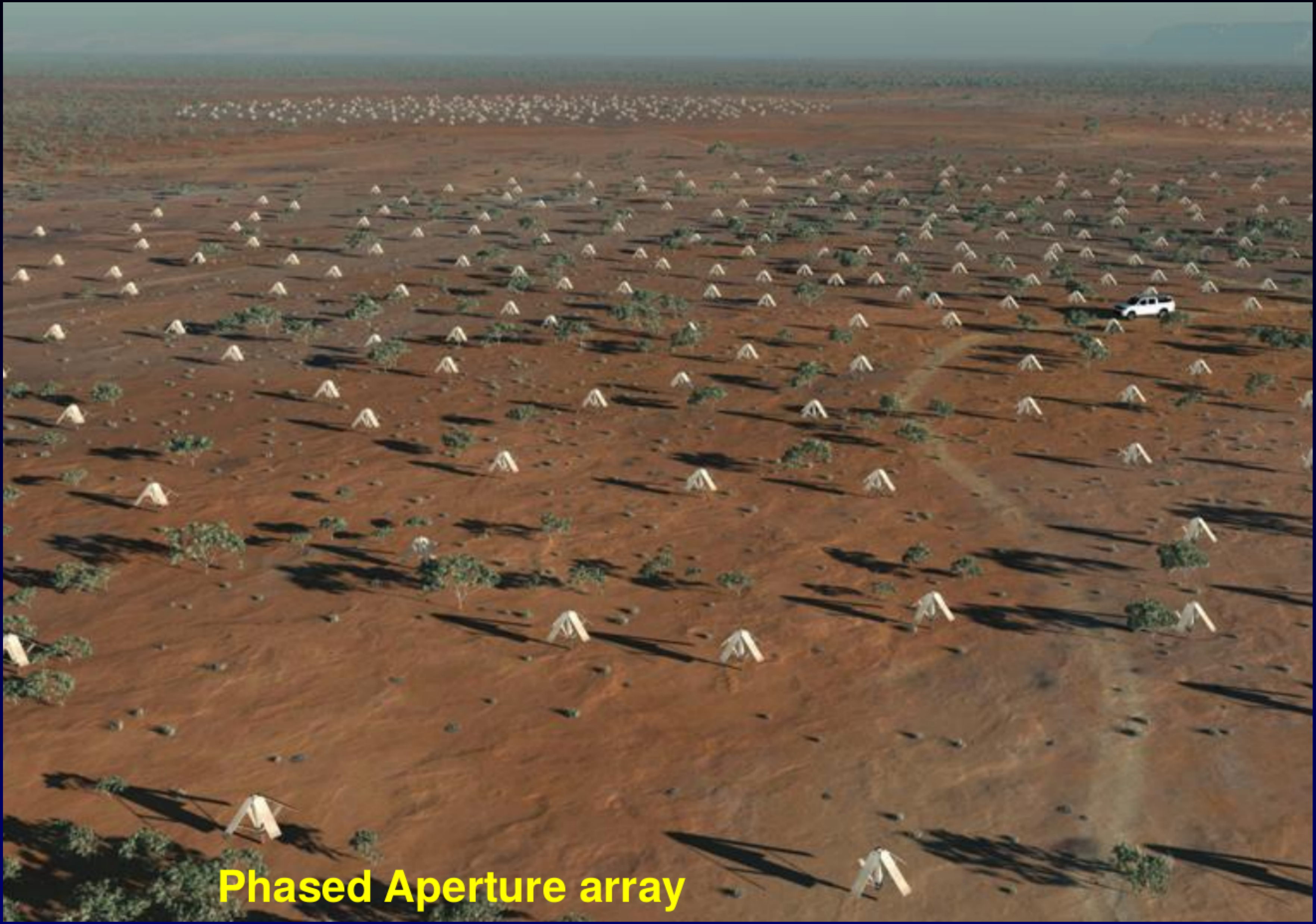
also a Continental sized Radio Telescope

- Need a radio-quiet site
- Very low population density
- Large amount of space
- Possible sites (decision 2012)
  - Western Australia
  - Karoo Desert RSA

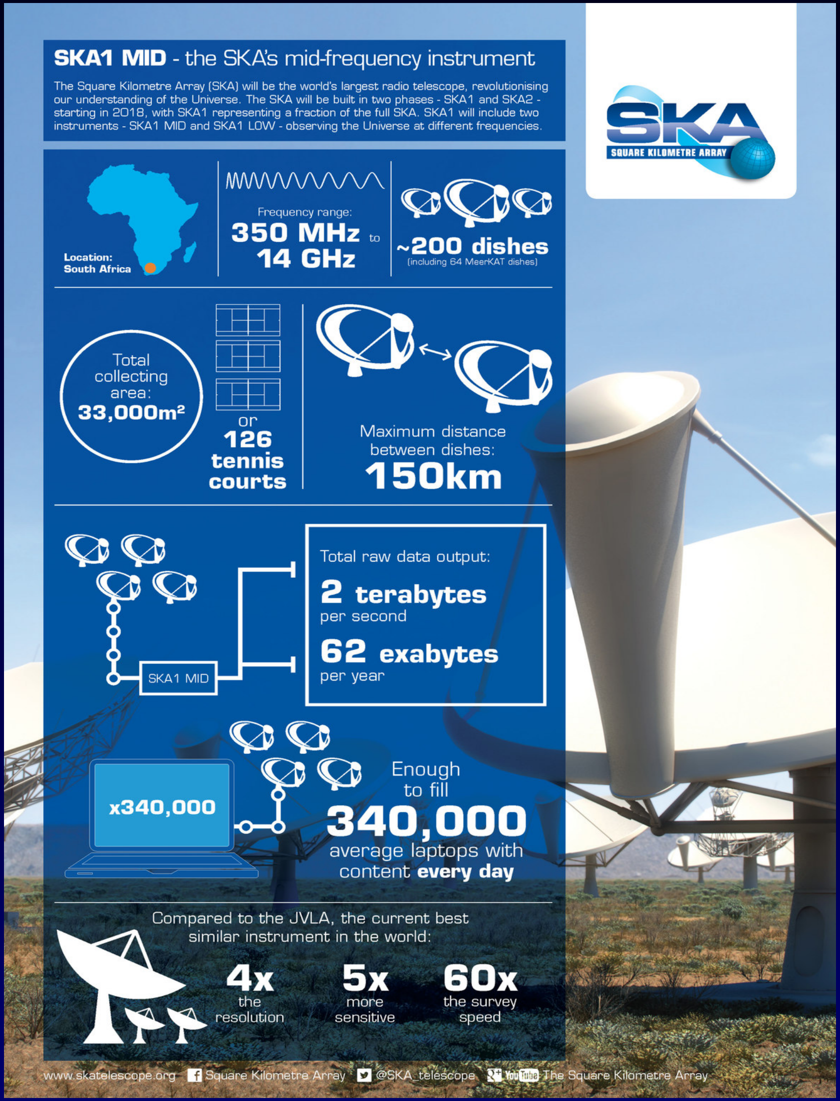
SKA

SPDO/Swinbur

SKA



Square Kilometer Array
SKA



SKA1 MID - the SKA's mid-frequency instrument

The Square Kilometre Array (SKA) will be the world's largest radio telescope, revolutionising our understanding of the Universe. The SKA will be built in two phases - SKA1 and SKA2 - starting in 2018, with SKA1 representing a fraction of the full SKA. SKA1 will include two instruments - SKA1 MID and SKA1 LOW - observing the Universe at different frequencies.

Location: South Africa

Frequency range: **350 MHz** to **14 GHz**

~200 dishes (including 64 MeerKAT dishes)

Total collecting area: **33,000m²** or **126 tennis courts**

Maximum distance between dishes: **150km**

Total raw data output:

2 terabytes per second

62 exabytes per year

Enough to fill **340,000** average laptops with content **every day**

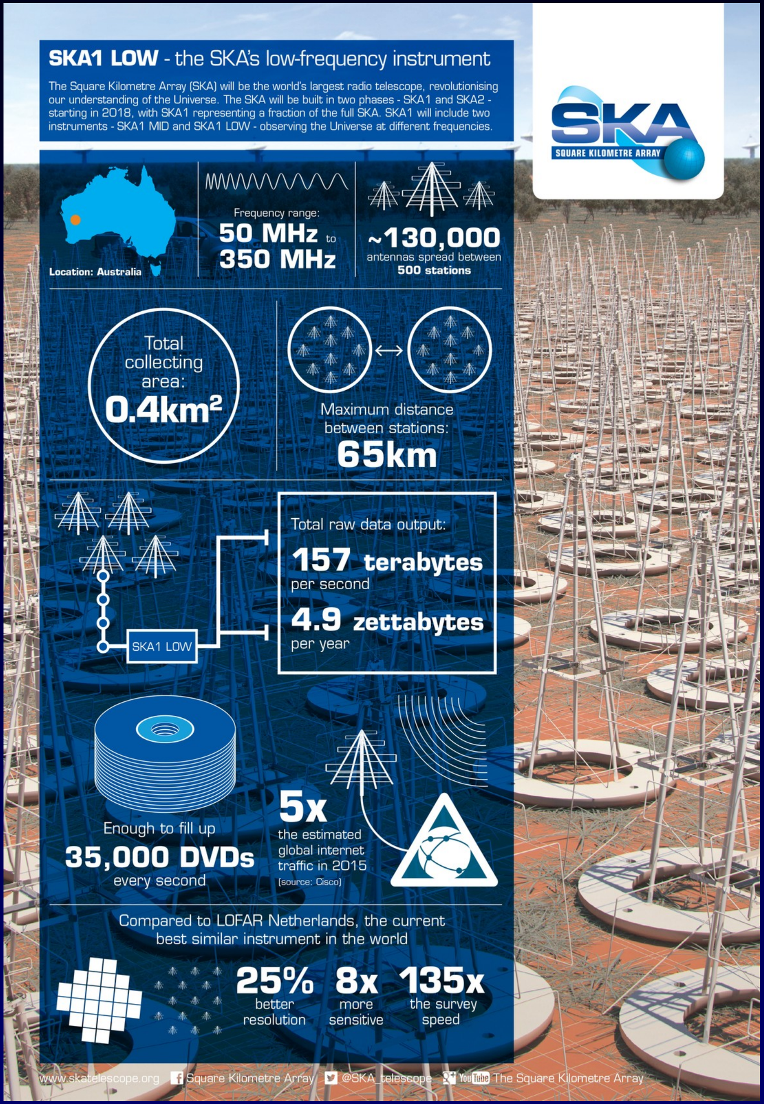
Compared to the JVLA, the current best similar instrument in the world:

4x the resolution

5x more sensitive

60x the survey speed

www.skatelescope.org Square Kilometre Array @SKA_telescope The Square Kilometre Array



SKA1 LOW - the SKA's low-frequency instrument

The Square Kilometre Array (SKA) will be the world's largest radio telescope, revolutionising our understanding of the Universe. The SKA will be built in two phases - SKA1 and SKA2 - starting in 2018, with SKA1 representing a fraction of the full SKA. SKA1 will include two instruments - SKA1 MID and SKA1 LOW - observing the Universe at different frequencies.

Location: Australia

Frequency range: **50 MHz** to **350 MHz**

~130,000 antennas spread between **500 stations**

Total collecting area: **0.4km²**

Maximum distance between stations: **65km**

Total raw data output:

157 terabytes per second

4.9 zettabytes per year

Enough to fill up **35,000 DVDs** every second

5x the estimated global internet traffic in 2015 (source: Cisco)

Compared to LOFAR Netherlands, the current best similar instrument in the world

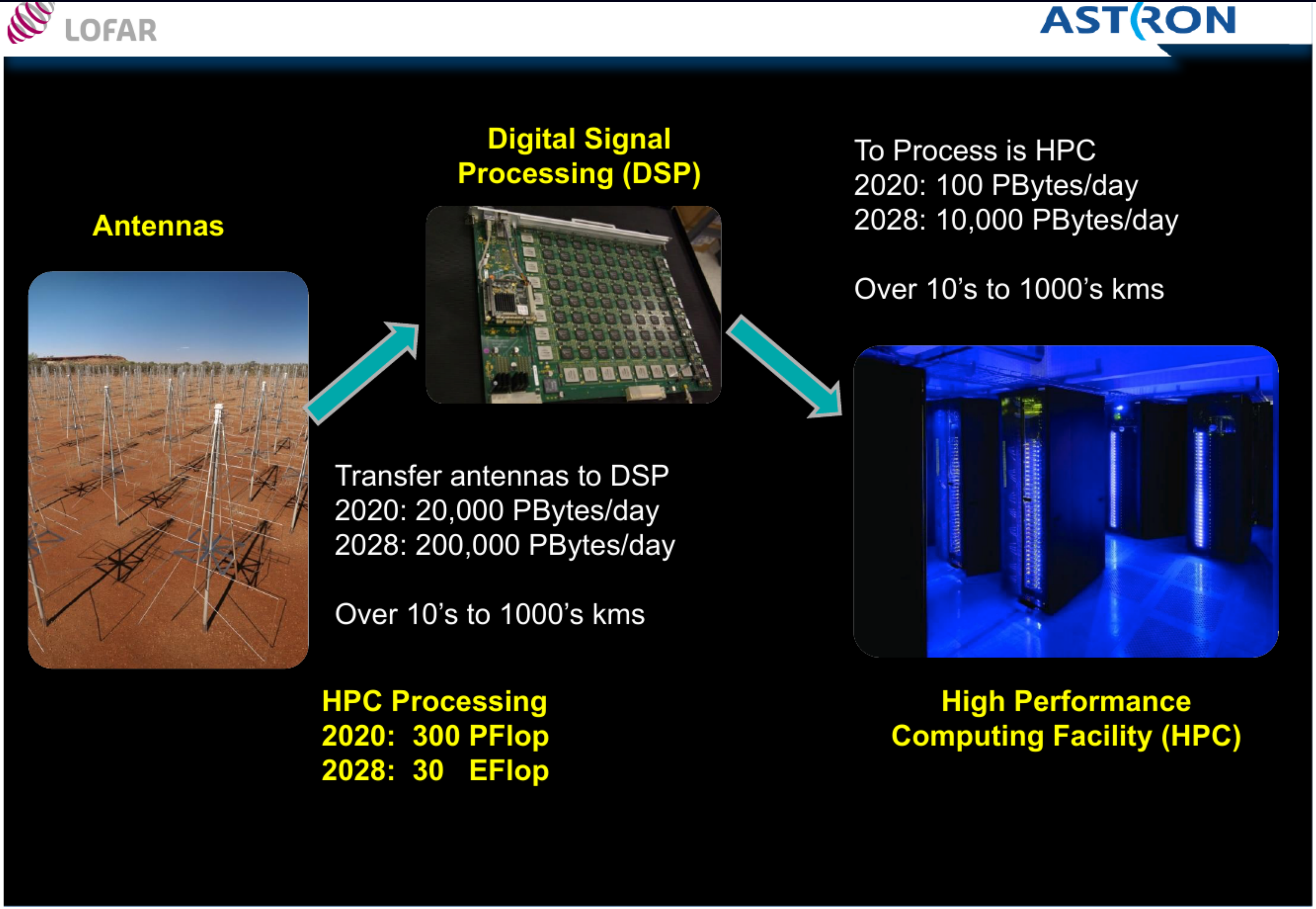
25% better resolution

8x more sensitive

135x the survey speed

www.skatelescope.org Square Kilometre Array @SKA_telescope The Square Kilometre Array

SKA Data Challenge



Antennas

Digital Signal Processing (DSP)

To Process is HPC
2020: 100 PBytes/day
2028: 10,000 PBytes/day

Over 10's to 1000's kms

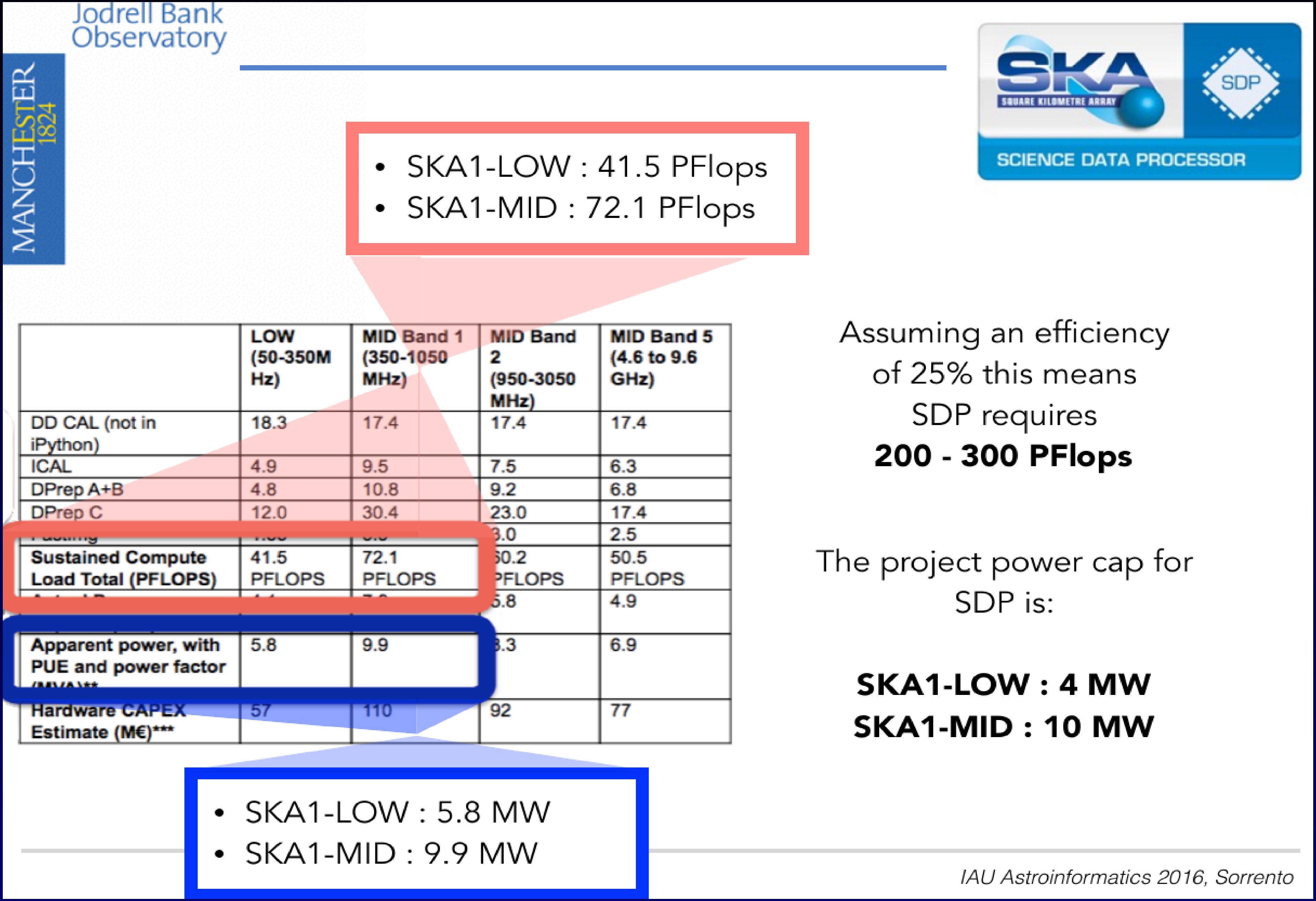
Transfer antennas to DSP
2020: 20,000 PBytes/day
2028: 200,000 PBytes/day

Over 10's to 1000's kms

HPC Processing
2020: 300 PFlop
2028: 30 EFlop

High Performance Computing Facility (HPC)

SKA Processing Challenge



- SKA1-LOW : 41.5 PFlops
- SKA1-MID : 72.1 PFlops

	LOW (50-350M Hz)	MID Band 1 (350-1050 MHz)	MID Band 2 (950-3050 MHz)	MID Band 5 (4.6 to 9.6 GHz)
DD CAL (not in iPython)	18.3	17.4	17.4	17.4
ICAL	4.9	9.5	7.5	6.3
DPrep A+B	4.8	10.8	9.2	6.8
DPrep C	12.0	30.4	23.0	17.4
[illegible]	[illegible]	[illegible]	3.0	2.5
Sustained Compute Load Total (PFLOPS)	41.5 PFLOPS	72.1 PFLOPS	50.2 PFLOPS	50.5 PFLOPS
[illegible]	[illegible]	[illegible]	5.8	4.9
Apparent power, with PUE and power factor (MVA)**	5.8	9.9	8.3	6.9
Hardware CAPEX Estimate (M€)***	57	110	92	77

- SKA1-LOW : 5.8 MW
- SKA1-MID : 9.9 MW

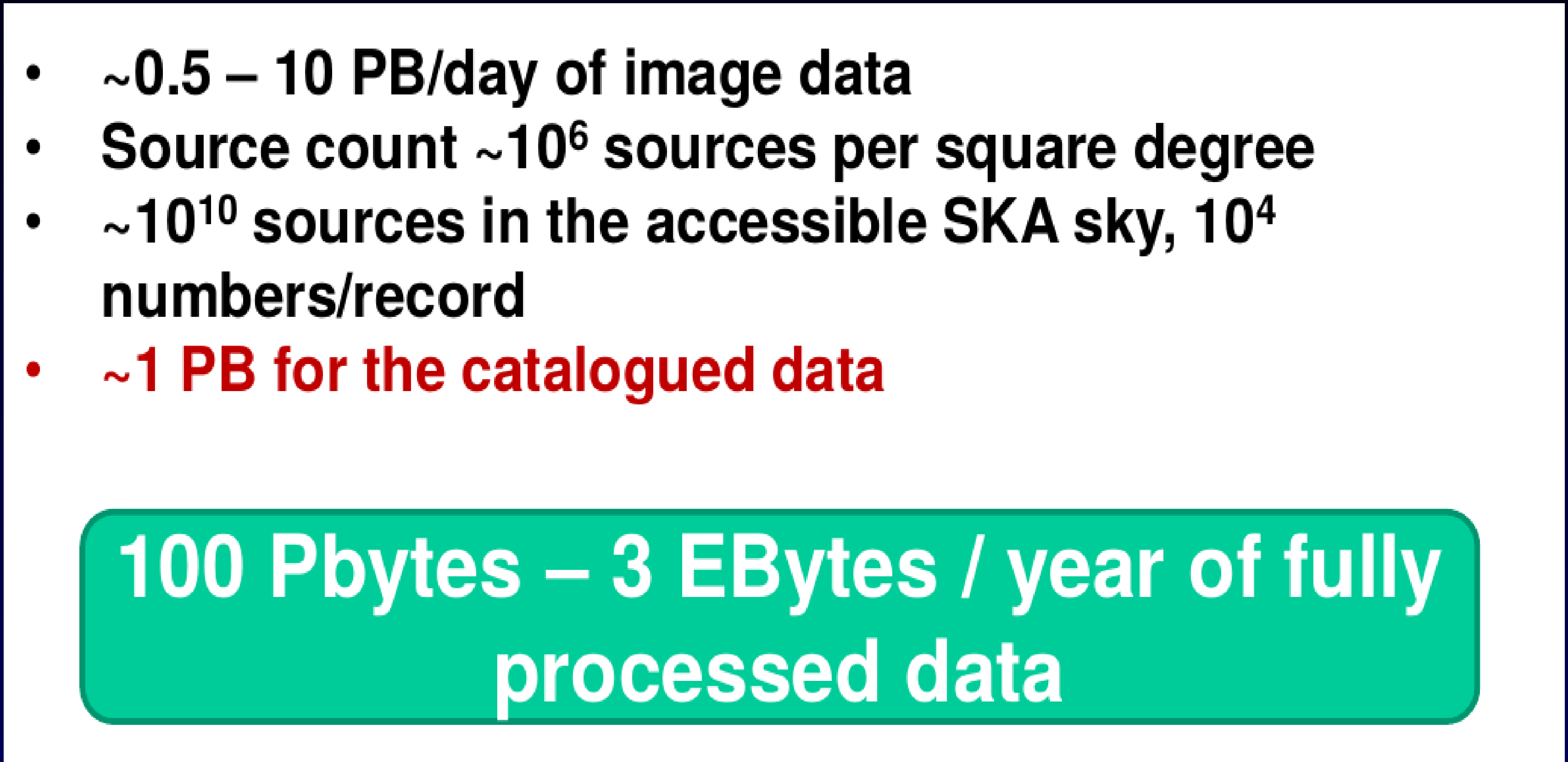
Assuming an efficiency of 25% this means SDP requires **200 - 300 PFlops**

The project power cap for SDP is:

SKA1-LOW : 4 MW
SKA1-MID : 10 MW

IAU Astroinformatics 2016, Sorrento

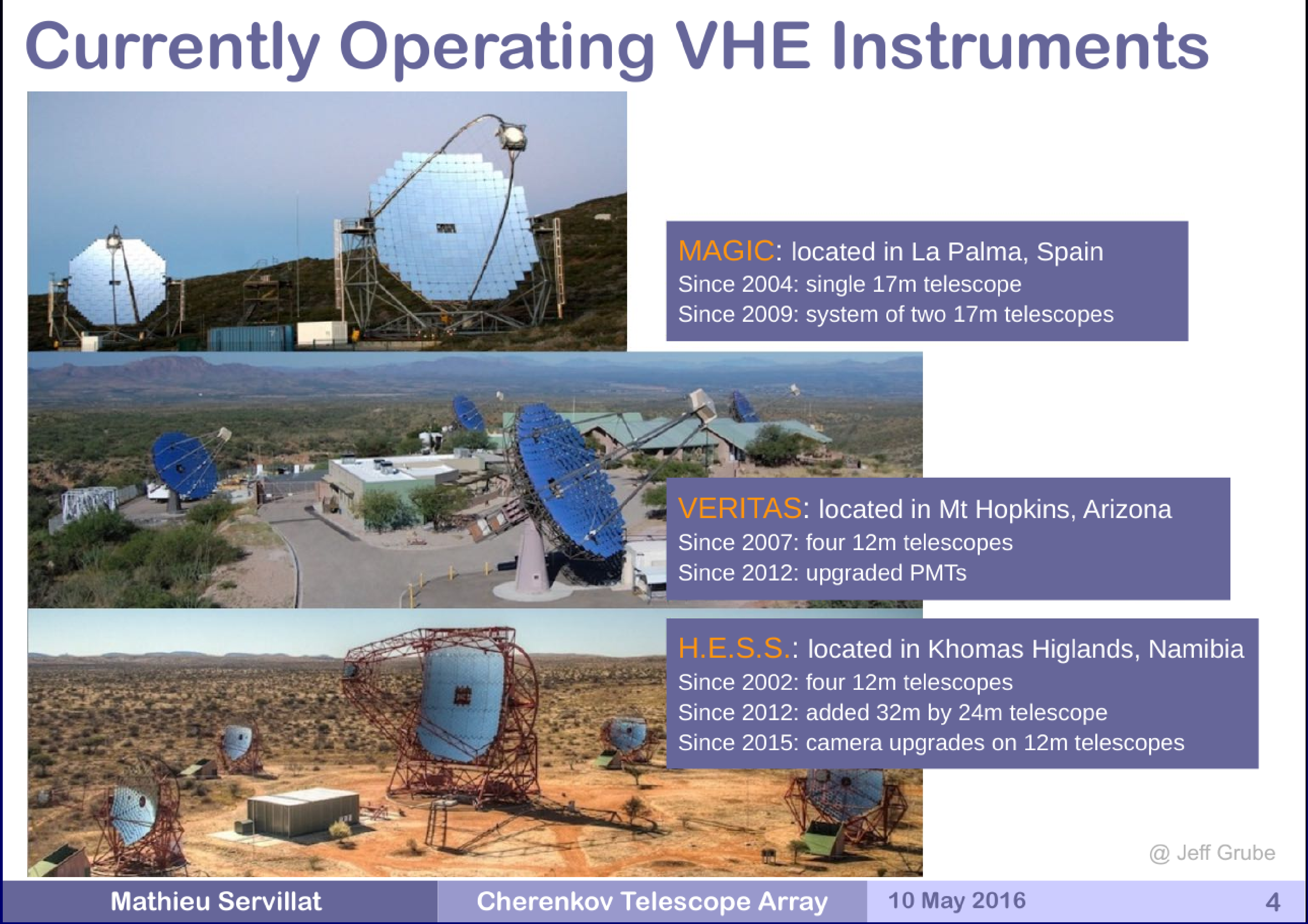
SKA Archive Volumes



- ~0.5 – 10 PB/day of image data
- Source count ~10^6 sources per square degree
- ~10^{10} sources in the accessible SKA sky, 10^4 numbers/record
- ~1 PB for the catalogued data

100 Pbytes – 3 EBytes / year of fully processed data

Cherenkov Telescopes - Current



Currently Operating VHE Instruments

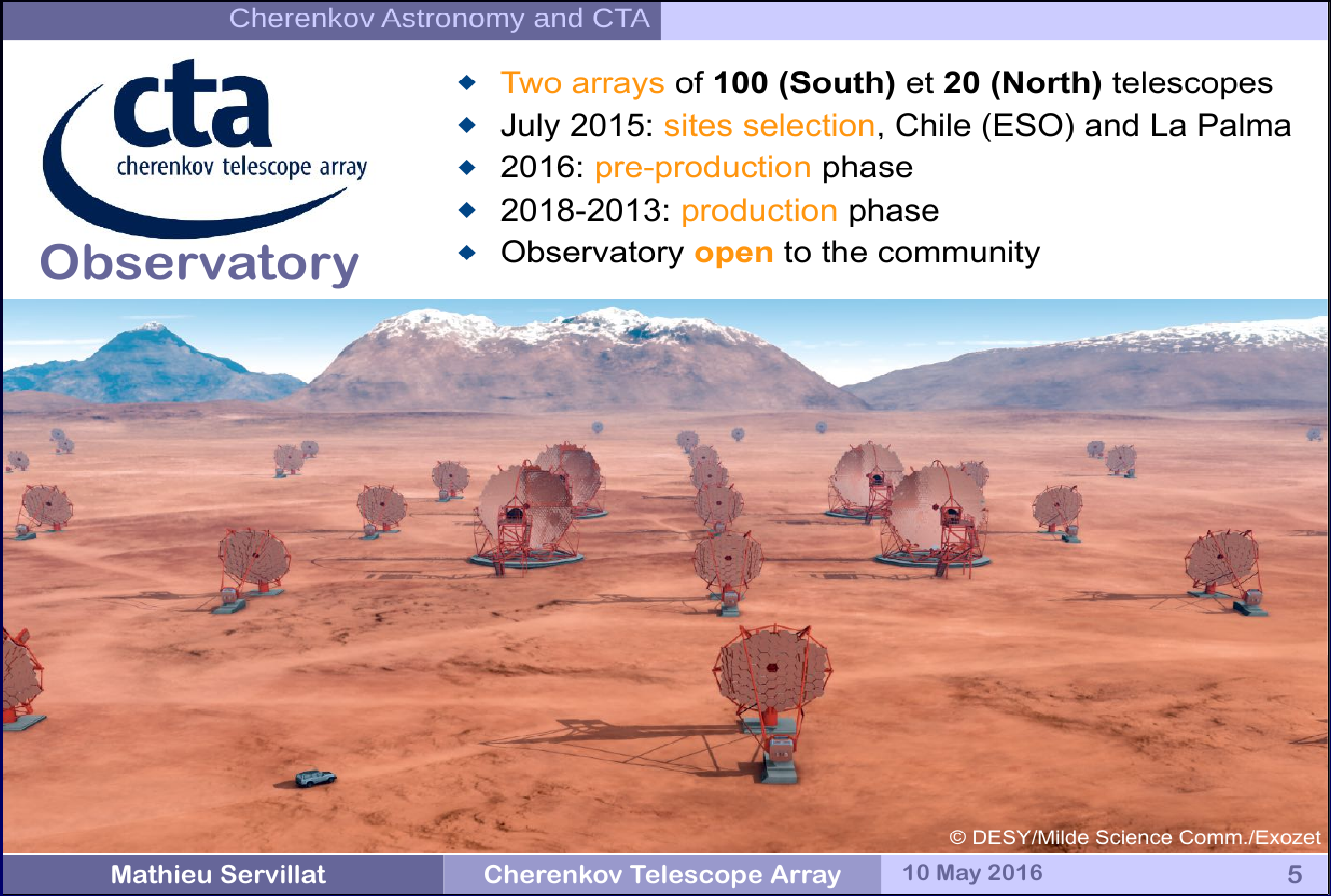
MAGIC: located in La Palma, Spain
Since 2004: single 17m telescope
Since 2009: system of two 17m telescopes

VERITAS: located in Mt Hopkins, Arizona
Since 2007: four 12m telescopes
Since 2012: upgraded PMTs

H.E.S.S.: located in Khomas Higlands, Namibia
Since 2002: four 12m telescopes
Since 2012: added 32m by 24m telescope
Since 2015: camera upgrades on 12m telescopes

@ Jeff Grube

Cherenkov Telescope Array



Cherenkov Astronomy and CTA

cta cherenkov telescope array

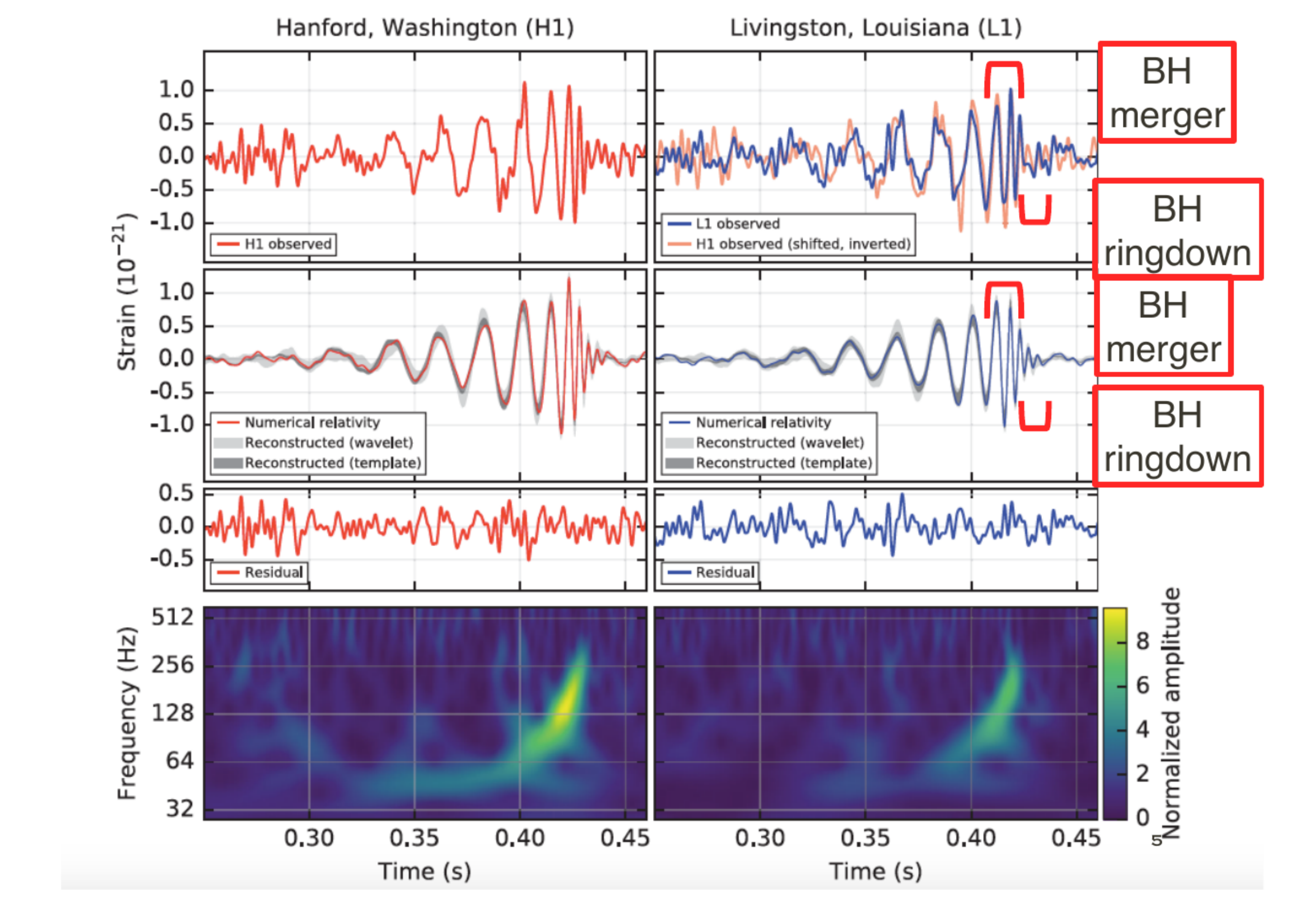
Observatory

- Two arrays of **100 (South)** et **20 (North)** telescopes
- July 2015: sites selection, Chile (ESO) and La Palma
- 2016: pre-production phase
- 2018-2013: production phase
- Observatory **open** to the community

© DESY/Milde Science Comm./Exozet

Mathieu Servillat | Cherenkov Telescope Array | 10 May 2016 | 5

Gravity Wave First Detection



BH merger

BH ringdown

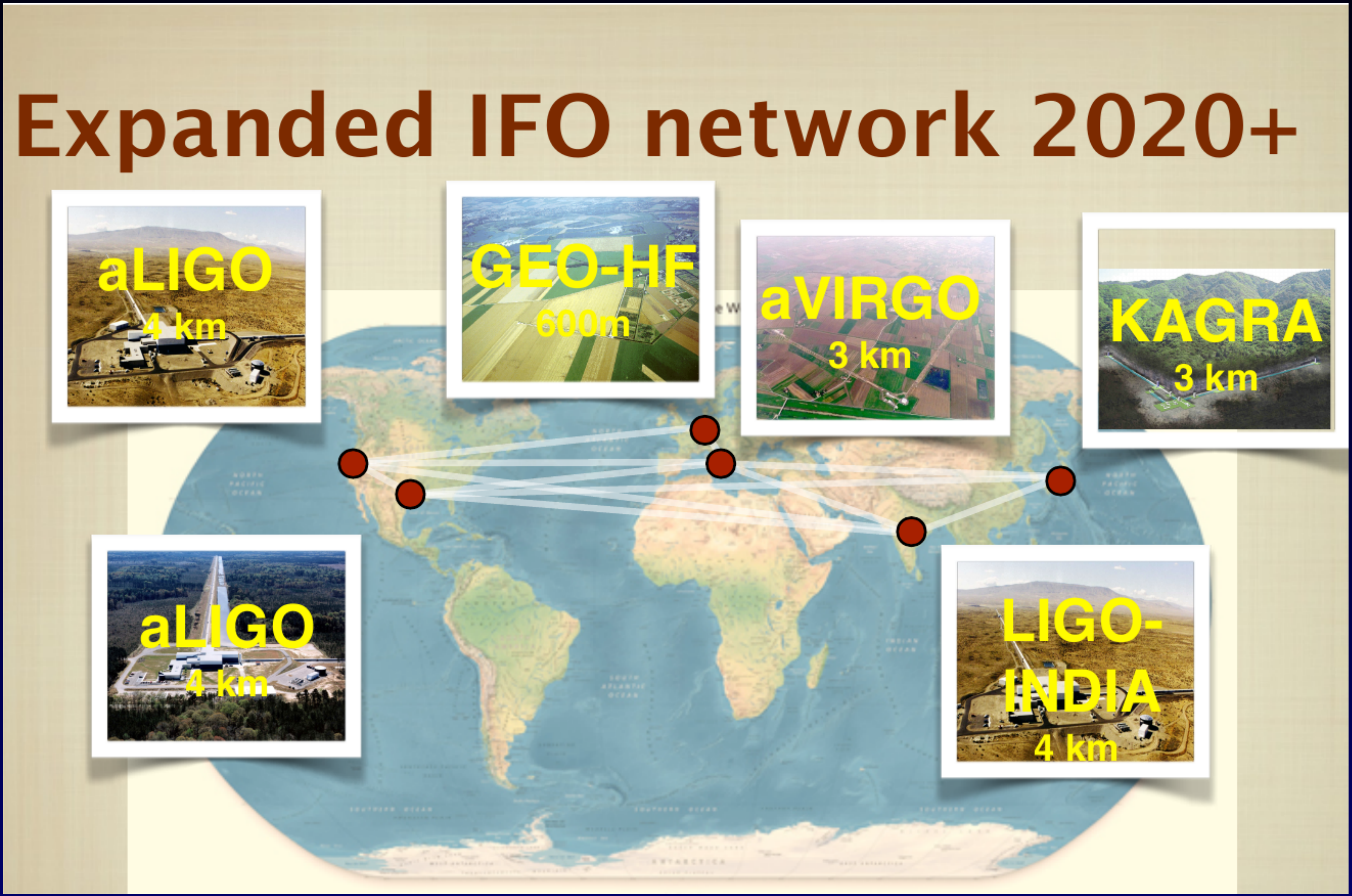
BH merger

BH ringdown

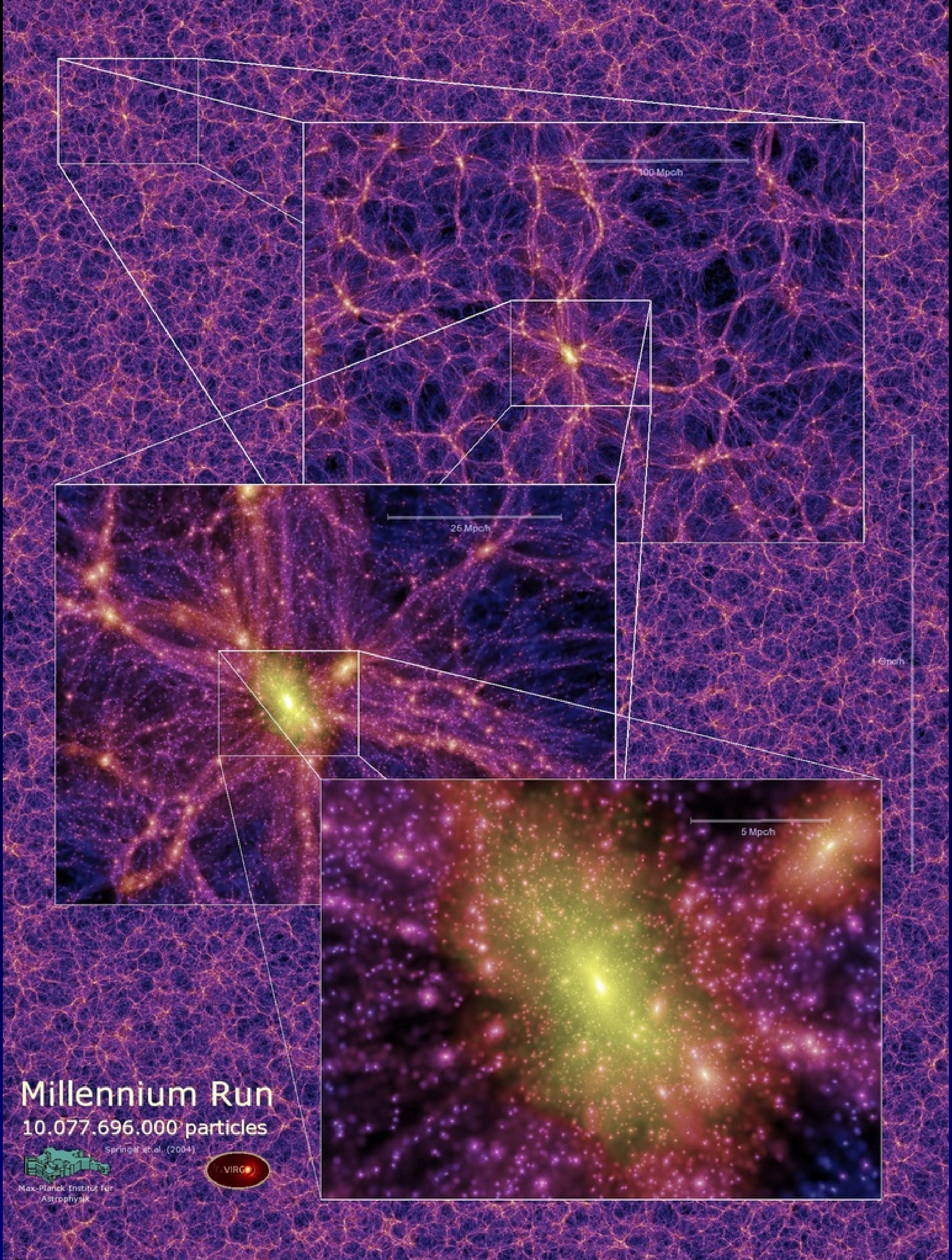
GW150914 BH Merger

BH 30+35 Msun = rotating BH 62 Msun, 3 Msun released in GW , 200ms chirp

Gravitation Wave Detection Network



Expanded IFO network 2020+



Millenium Run

10^10 particles

Several Gpc to

10 kpc

Cube 2 billion ly

One month MPSSC

25 TB

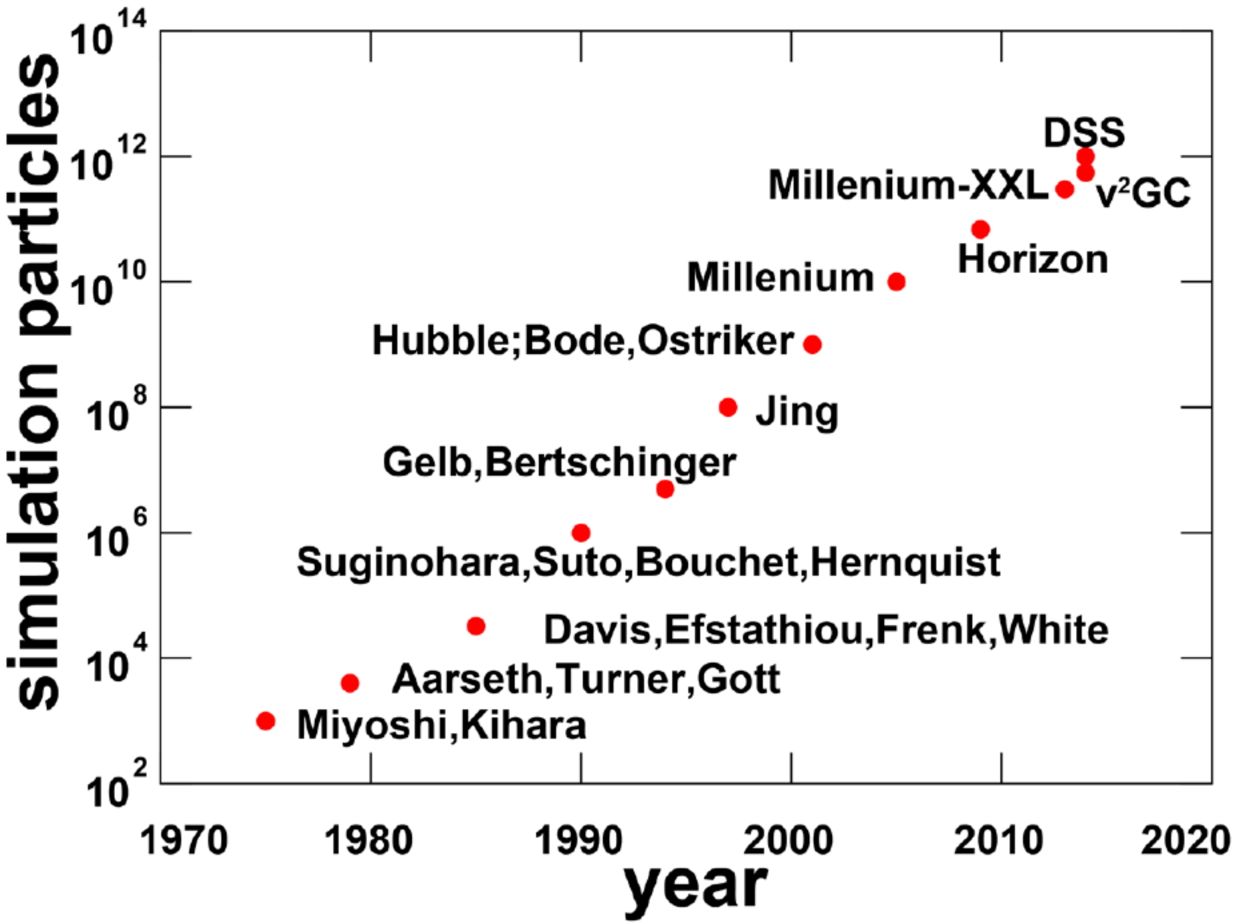
Evolution of 20 mil
galaxies

Evolution merger tree

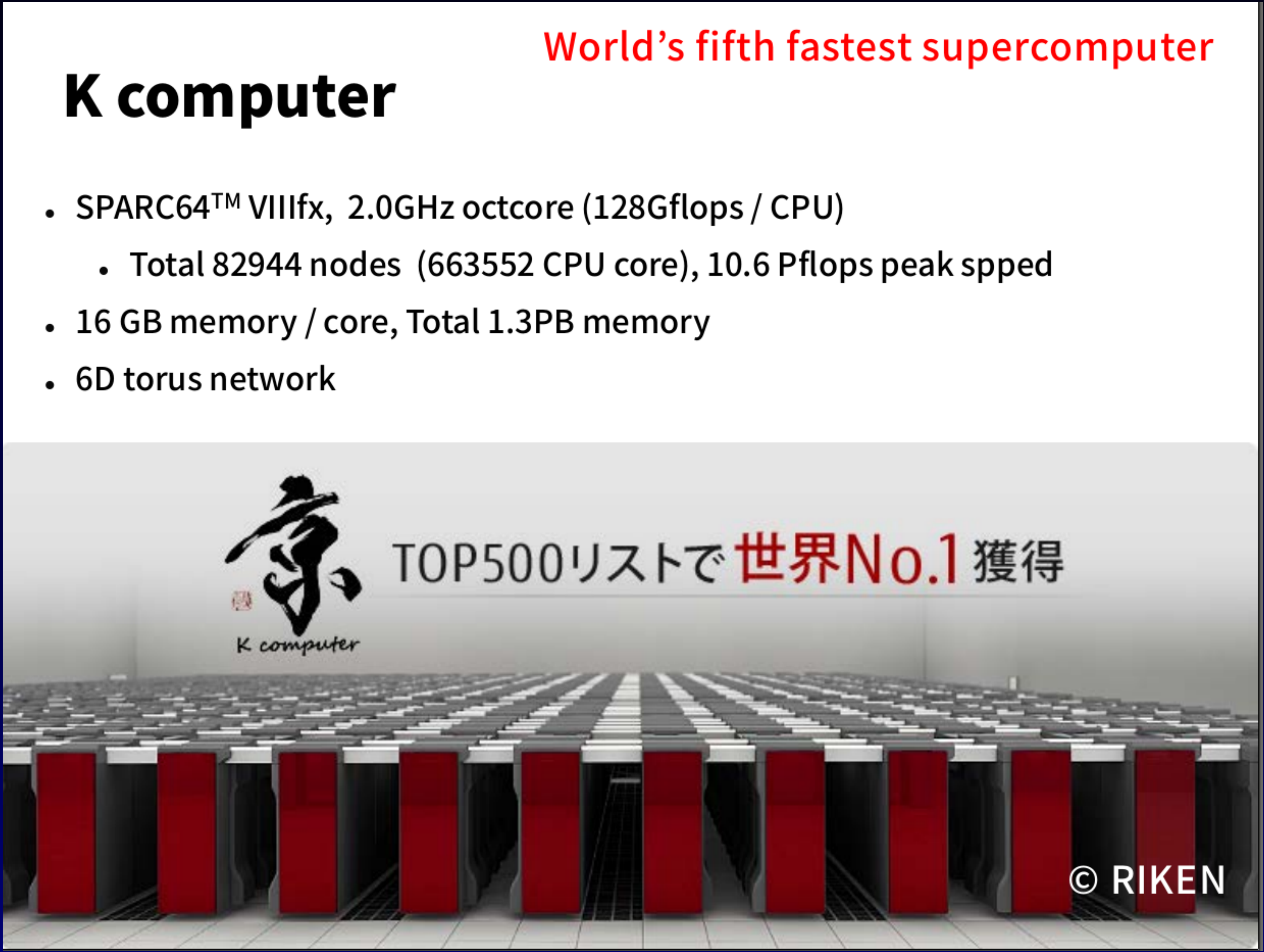
Simulations of the Universe

History of large cosmological *N*-body simulations (dm only)

Benchmark simulations are excluded



Simulation of the Universe

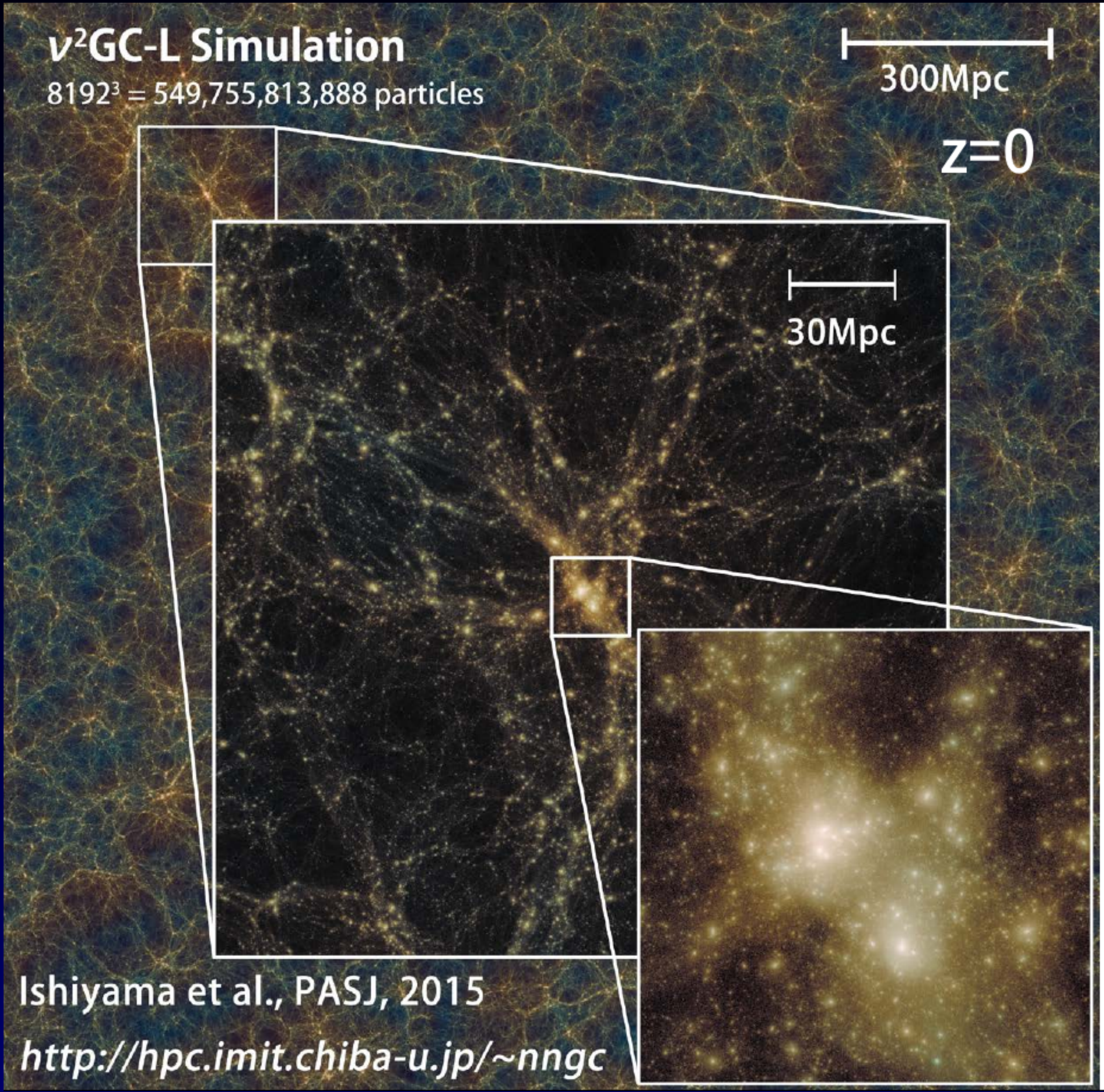


World's fifth fastest supercomputer

K computer

- SPARC64^{TM} VIIIfx, 2.0GHz octcore (128Gflops / CPU)
  - Total 82944 nodes (663552 CPU core), 10.6 Pflops peak spped
- 16 GB memory / core, Total 1.3PB memory
- 6D torus network

Simulation of Universe


ν²GC-L Simulation
8192³ = 549,755,813,888 particles
300Mpc
z=0
30Mpc
Ishiyama et al., PASJ, 2015
http://hpc.imit.chiba-u.jp/~nngc

$N = 8192^3 =$ 549,755,813,888

L = 1.12 Gpc/h
m = 2.2 x 10^8 Msun/h

Planck Cosmology

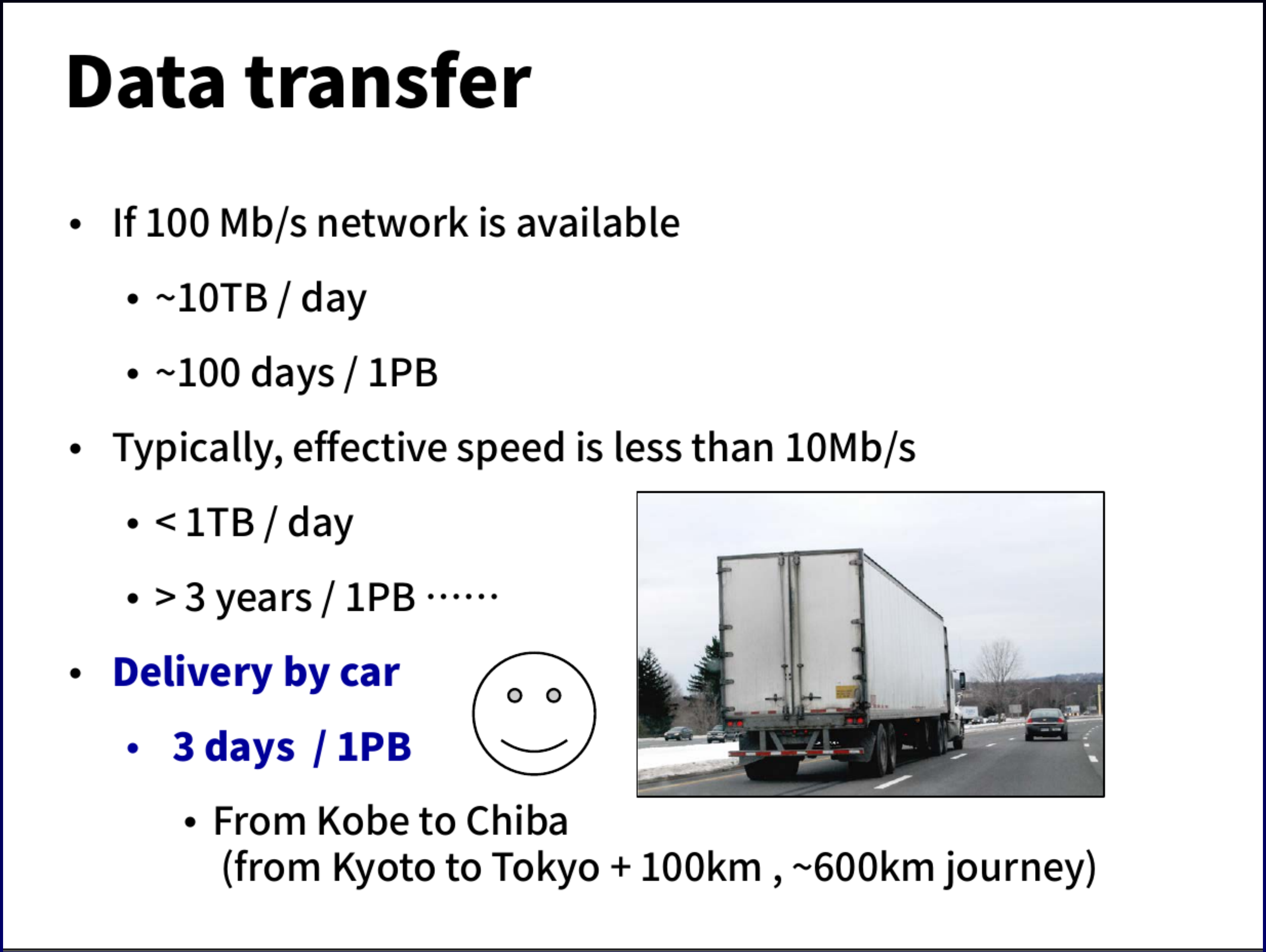
11x larger volume,
4x better mass res,
compared to
Millennium Run
(Springel+ 2005)

- $N = 2160^3$
- L = 0.5 Gpc/h
- m = 8.6 x 10^8 Msun/h
- WMAP1 (σ_8=0.9)

~ 100 hours on
131,072 CPU cores
of K computer

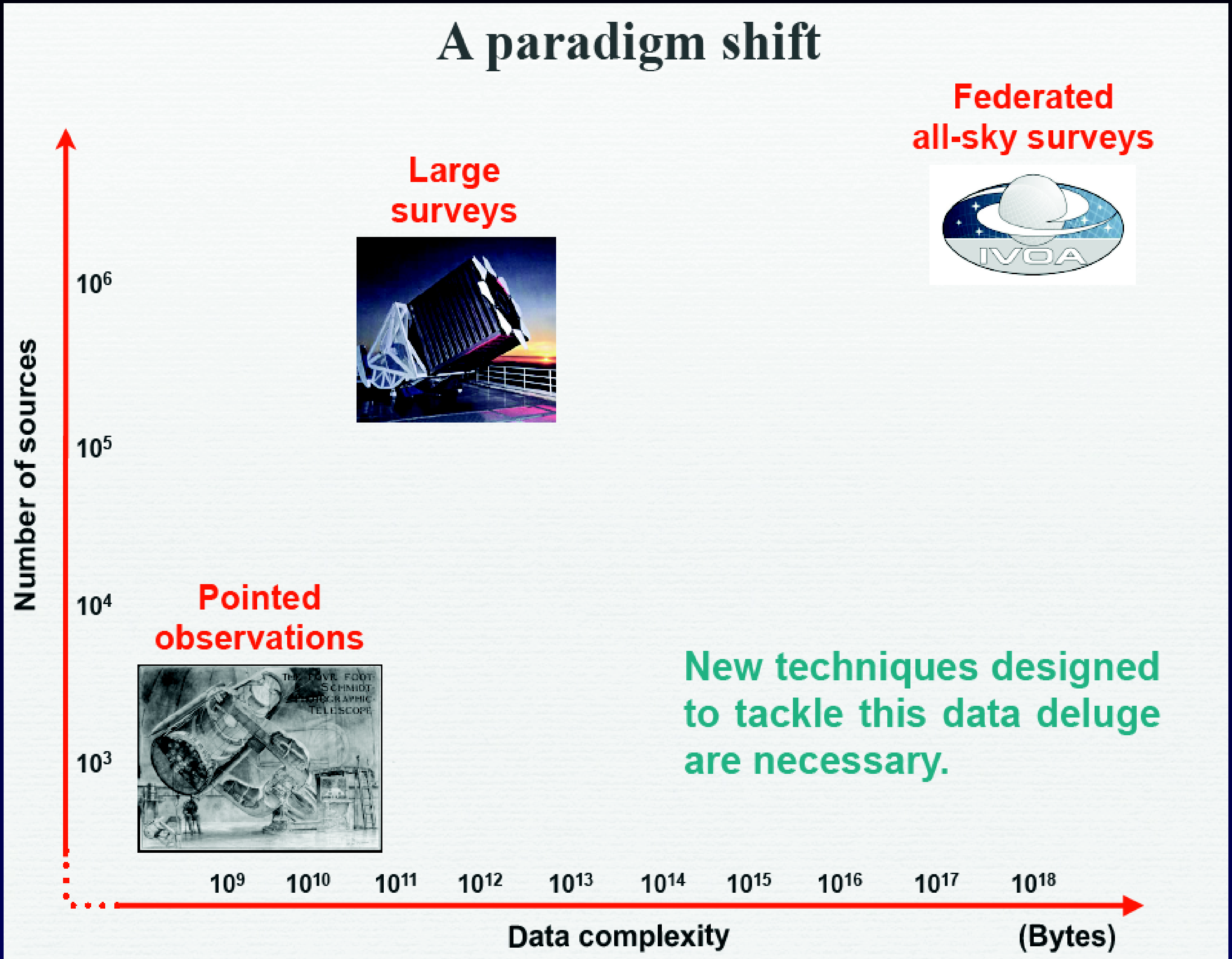
Data size : ~1PB

Problem of 1PB Data Transfer



Data transfer

- If 100 Mb/s network is available
  - ~10TB / day
  - ~100 days / 1PB
- Typically, effective speed is less than 10Mb/s
  - < 1TB / day
  - > 3 years / 1PB ……
- **Delivery by car**
  - **3 days / 1PB**
    - From Kobe to Chiba
      (from Kyoto to Tokyo + 100km , ~600km journey)



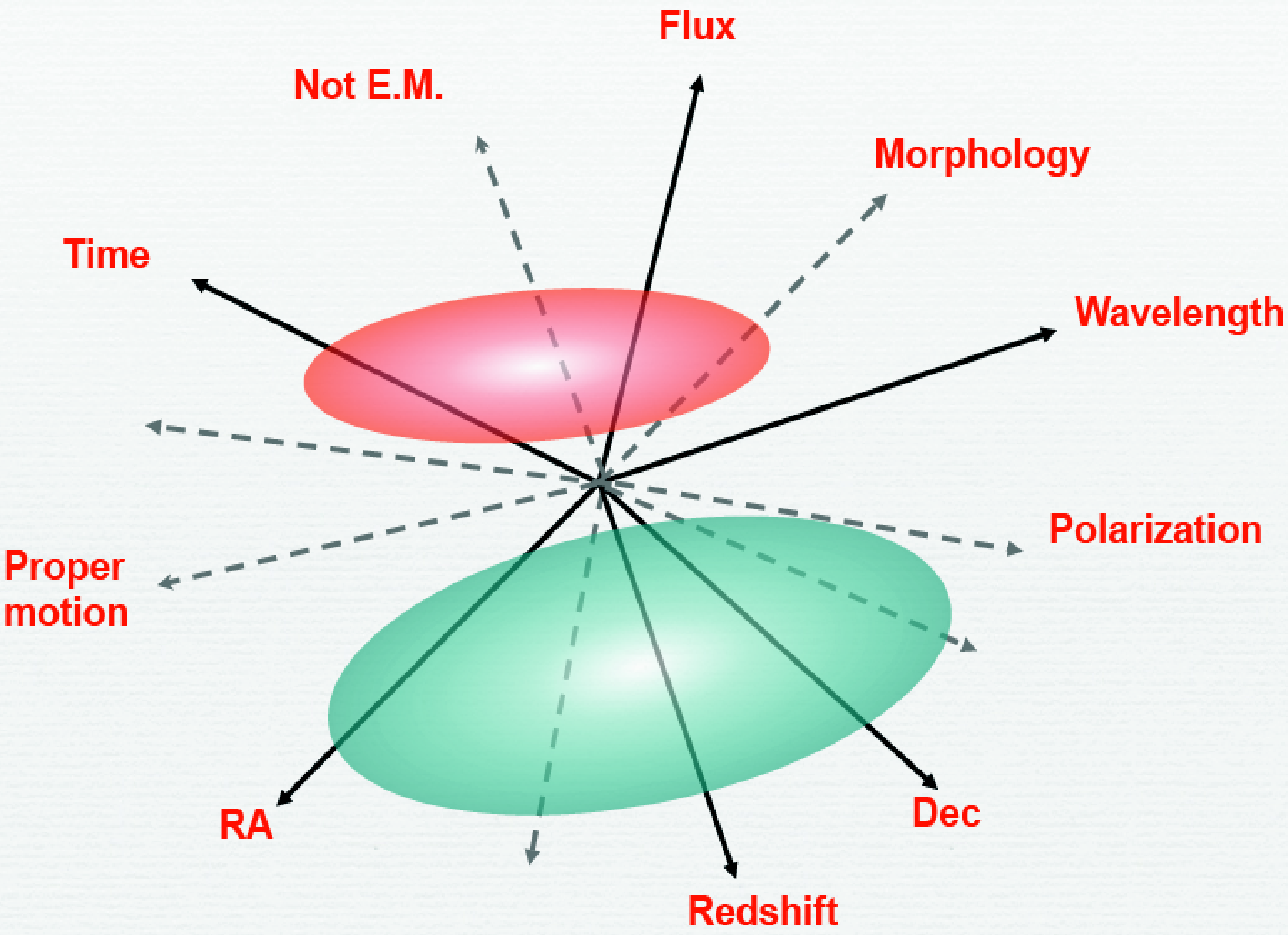
A paradigm shift

New techniques designed to tackle this data deluge are necessary.

Data analysis at storage place
Move processing = not data !

D'Abrusco 2010

A growing parameter space



Most discoveries were made in small regions of subspaces or along some of these axes

D'Abrusco 2010

Virtual Observatory : Key Definitions

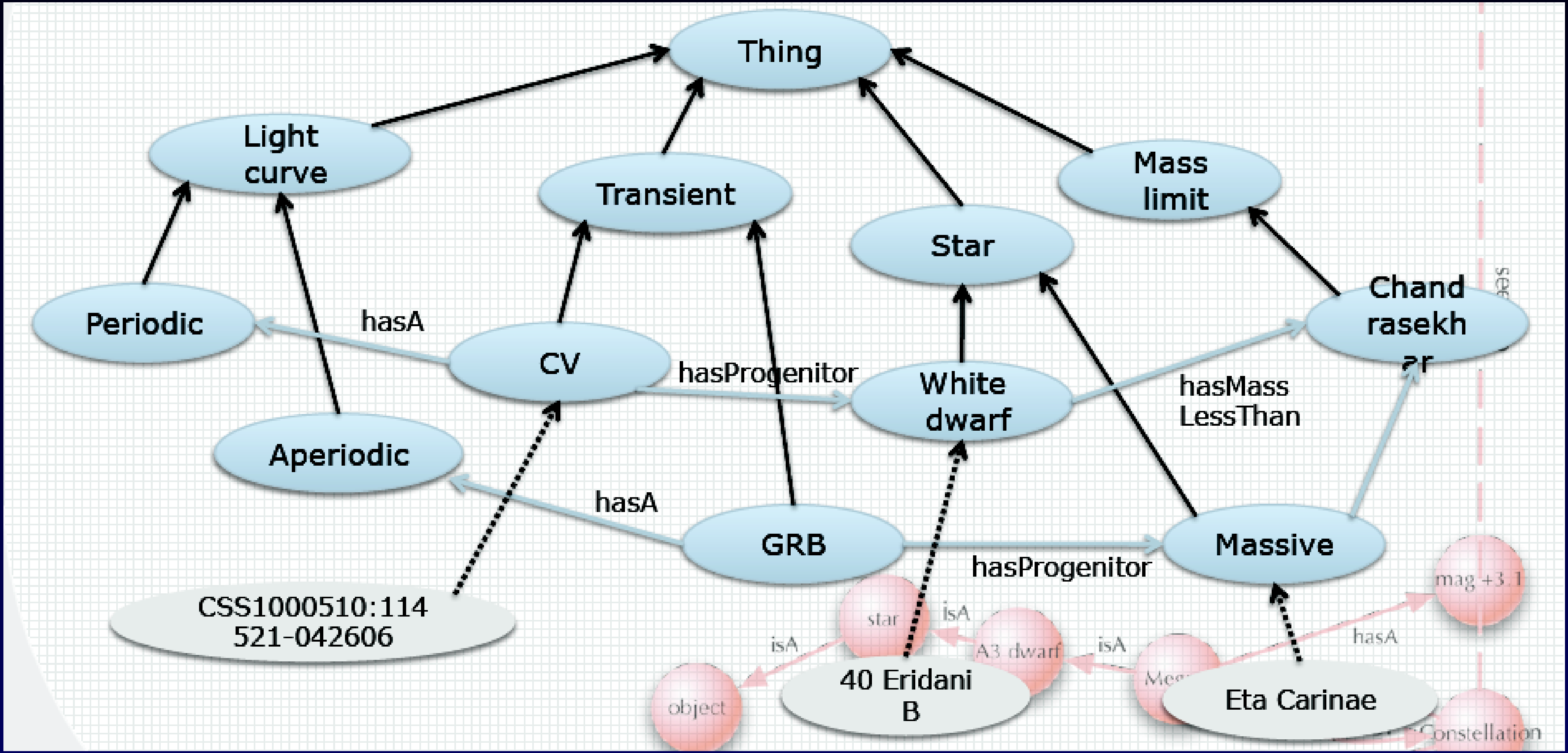
- *“The Virtual Observatory will be a system that allows astronomers to interrogate multiple data centers in a seamless and transparent way, which provides new powerful analysis and visualization tools within that system, and which gives data centers a standard framework for publishing and delivering services using their data”*.
- Standardization of data and metadata, and of data exchange methods.
- Registry, listing available services and what can be done with them.

R.J.Hanisch, P.J.Quinn, in “IVOA – Guidelines for participation”

IVOA

Astro Grid
ArVO
Armenian Virtual Observatory
Aus-VO
BRAVO
China-VO
CVO
esa
ESO
EURO VO
IVOA
VO France
GERMAN ASTROPHYSICAL
GAVO
VIRTUAL OBSERVATORY
HVO
Hungarian Virtual Observatory
JVO
NOVA
RVO
SVO
Spanish Virtual Observatory
vo-i
VAO
VIRTUAL ASTRONOMICAL OBSERVATORY
VObs.it

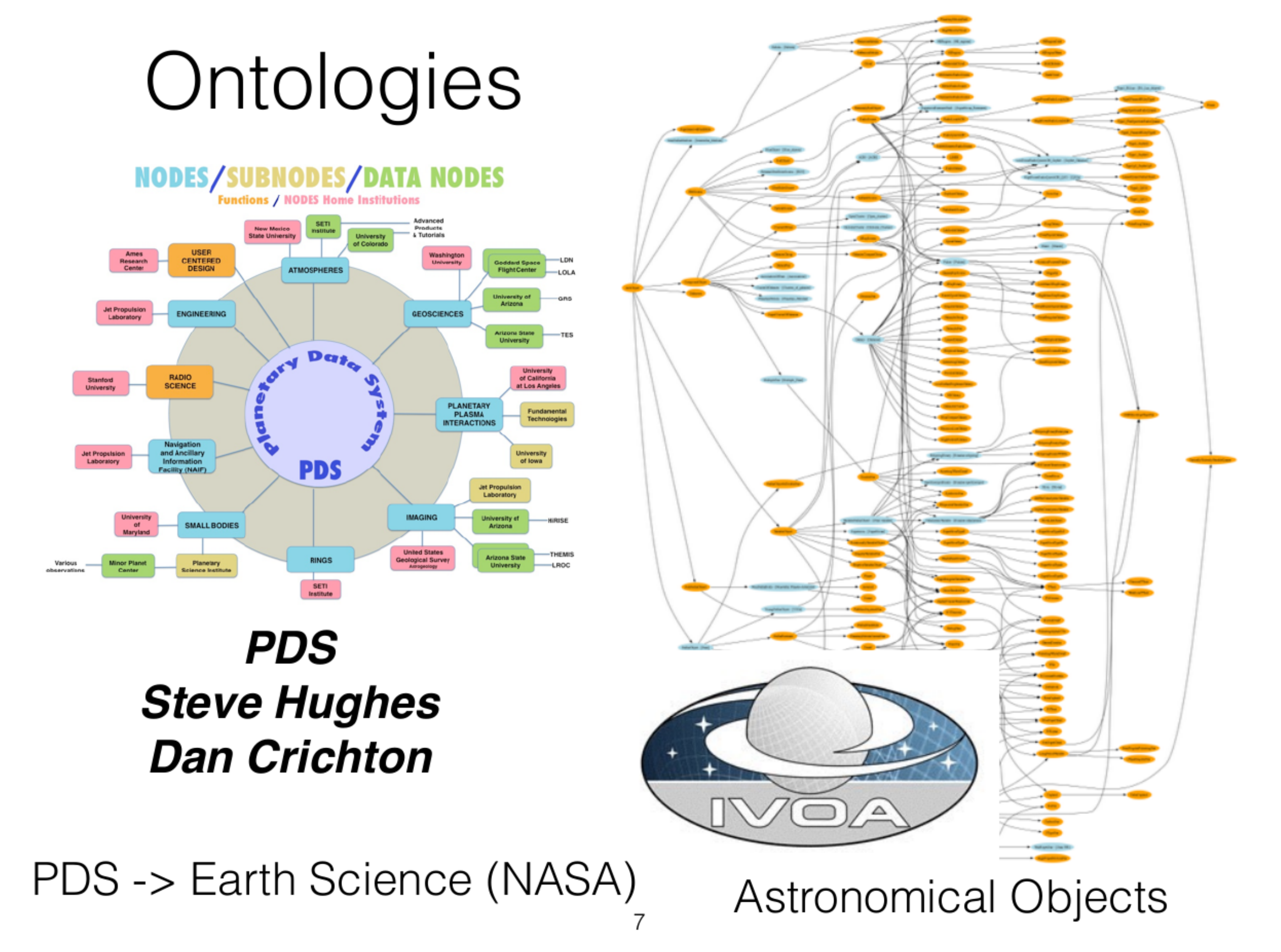
Ontologies in Astronomy



SKOS, RDF standards, search with understanding (not return QSO as binary star)

From Graham, M. AI2010

Ontologies



Ontologies

PDS
Steve Hughes
Dan Crichton

PDS -> Earth Science (NASA)

Astronomical Objects

Technology of VO

Unified data format– VOTable, UCD (Vizier)

Transparent transport (unit conversion)

Web services (WS) e-commerce, B2B, J2EE, .Net

VOregistry (DNS like) Google for data+WS

protocols

- ConeSearch (searching in circle on sky)
- SIAP (Simple Image Access Protocol)
- SSAP(Simple Spectral Access Protocol)
- SLAP(Simple Line Access Protocol)
- TAP (Table Access Protocol)
- VOEVENT (transients, robotic telescopes,Sun)
- more – datacubes, on-the-fly data generation....

Technology of VO

ADQL (Astronomical Data Query Language)

XMATCH, REGION (2 catalogues - shifted)

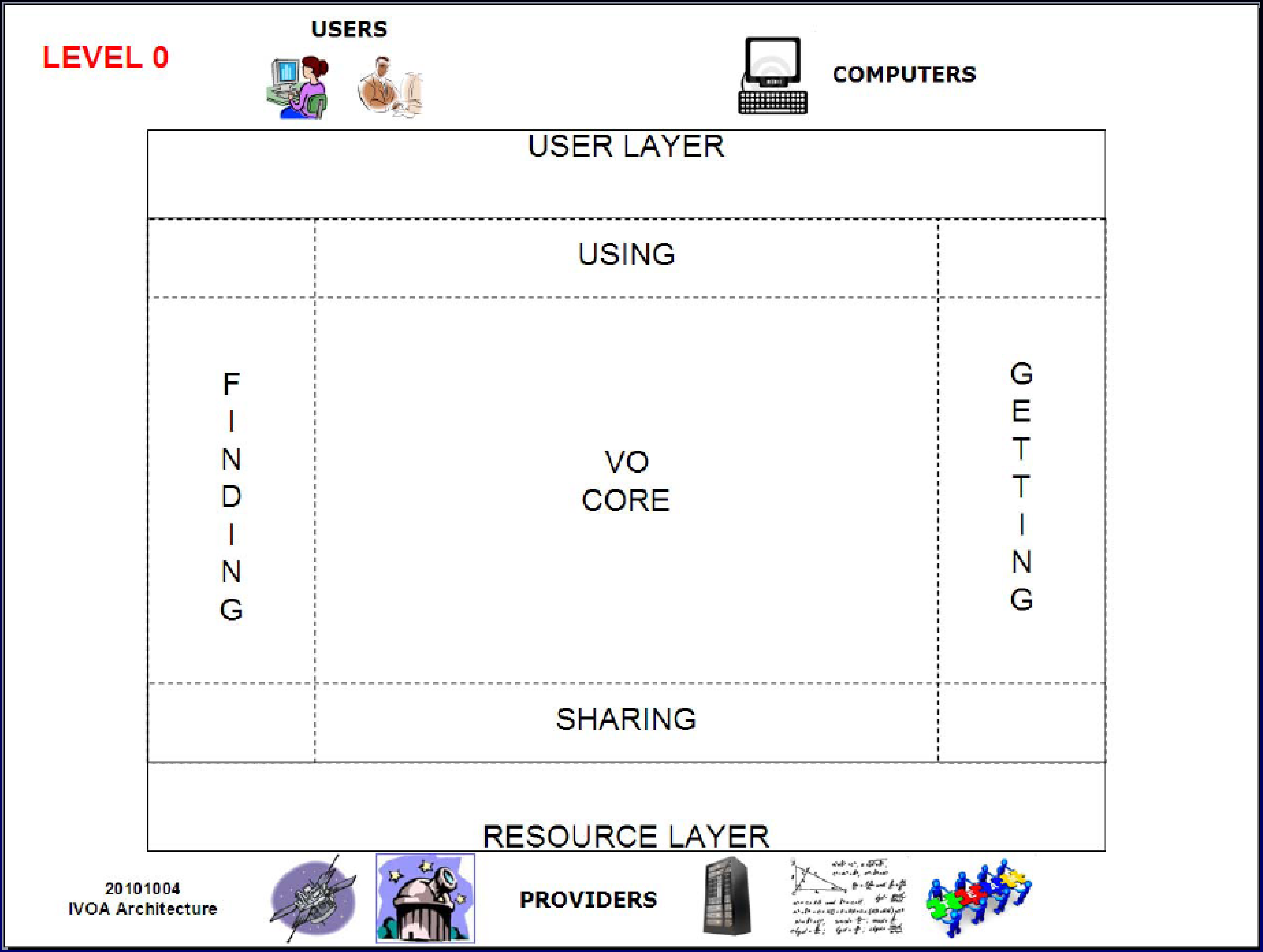
Application interoperabilty – (PLASTIC), SAMP

Allows develop applications as bricks

sending VOTABLES (catalogue-spectra-images)

Commercial interest (GoogleSky, MS WWT)

Ecosystem of VO – level 0



LEVEL 0

USERS

COMPUTERS

USER LAYER

USING

FINDING

VO CORE

GETTING

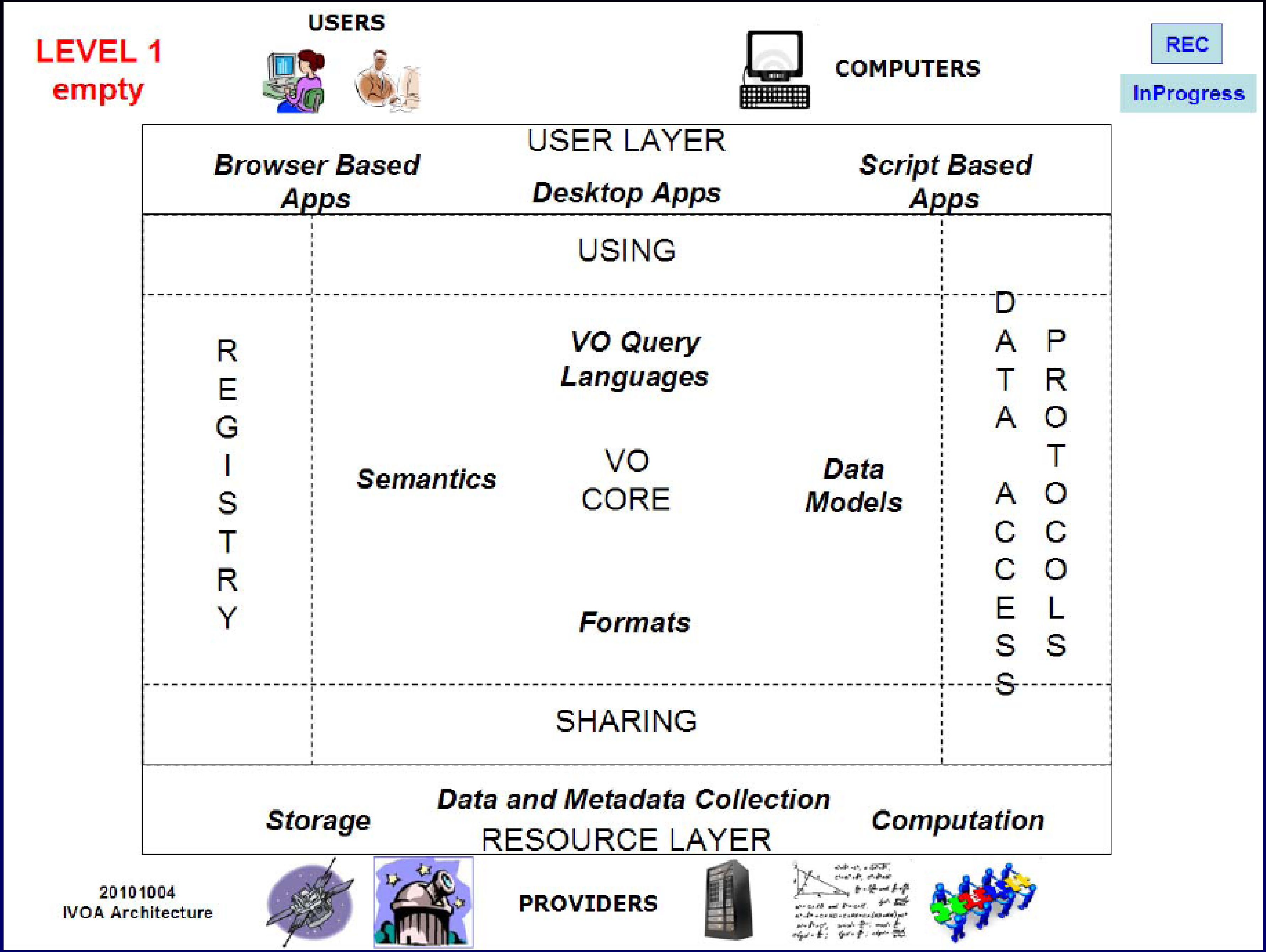
SHARING

RESOURCE LAYER

20101004
IVOA Architecture

PROVIDERS

Ecosystem of VO – level 1



LEVEL 1
empty

USERS

COMPUTERS

REC

InProgress

USER LAYER

Browser Based Apps

Desktop Apps

Script Based Apps

USING

REGISTRY

VO Query Languages

Semantics

VO CORE

Data Models

Formats

DATA ACCESS

PROTOCOLS

SHARING

Storage

Data and Metadata Collection

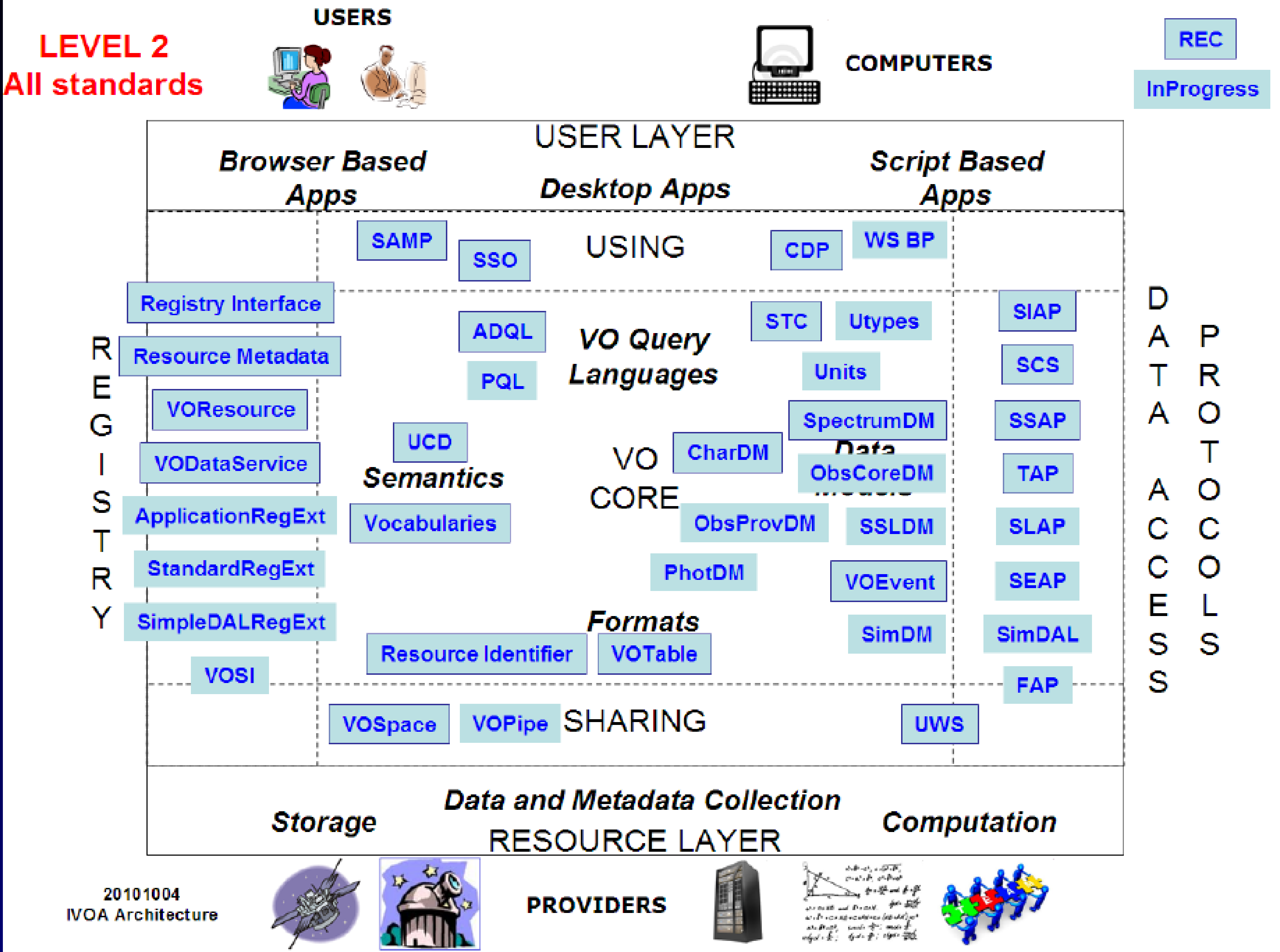
Computation

RESOURCE LAYER

20101004
IVOA Architecture

PROVIDERS

Ecosystem of VO – level 2



LEVEL 2
All standards

USERS

COMPUTERS

REC

InProgress

USER LAYER

Browser Based Apps

Desktop Apps

Script Based Apps

USING

SAMP

SSO

CDP

WS BP

REGISTRY

Registry Interface

Resource Metadata

VOResource

VODataService

ApplicationRegExt

StandardRegExt

SimpleDALRegExt

VOSI

VO Query Languages

ADQL

PQL

STC

Utypes

Units

SpectrumDM

Data

CharDM

ObsCoreDM

ObsProvDM

SSLDM

PhotDM

VOEvent

SimDM

VO CORE

UCD

Semantics

Vocabularies

Formats

Resource Identifier

VOTable

DATA ACCESS PROTOCOLS

SIAP

SCS

SSAP

TAP

SLAP

SEAP

SimDAL

FAP

SHARING

VOSpace

VOPipe

UWS

Data and Metadata Collection

Storage

Computation

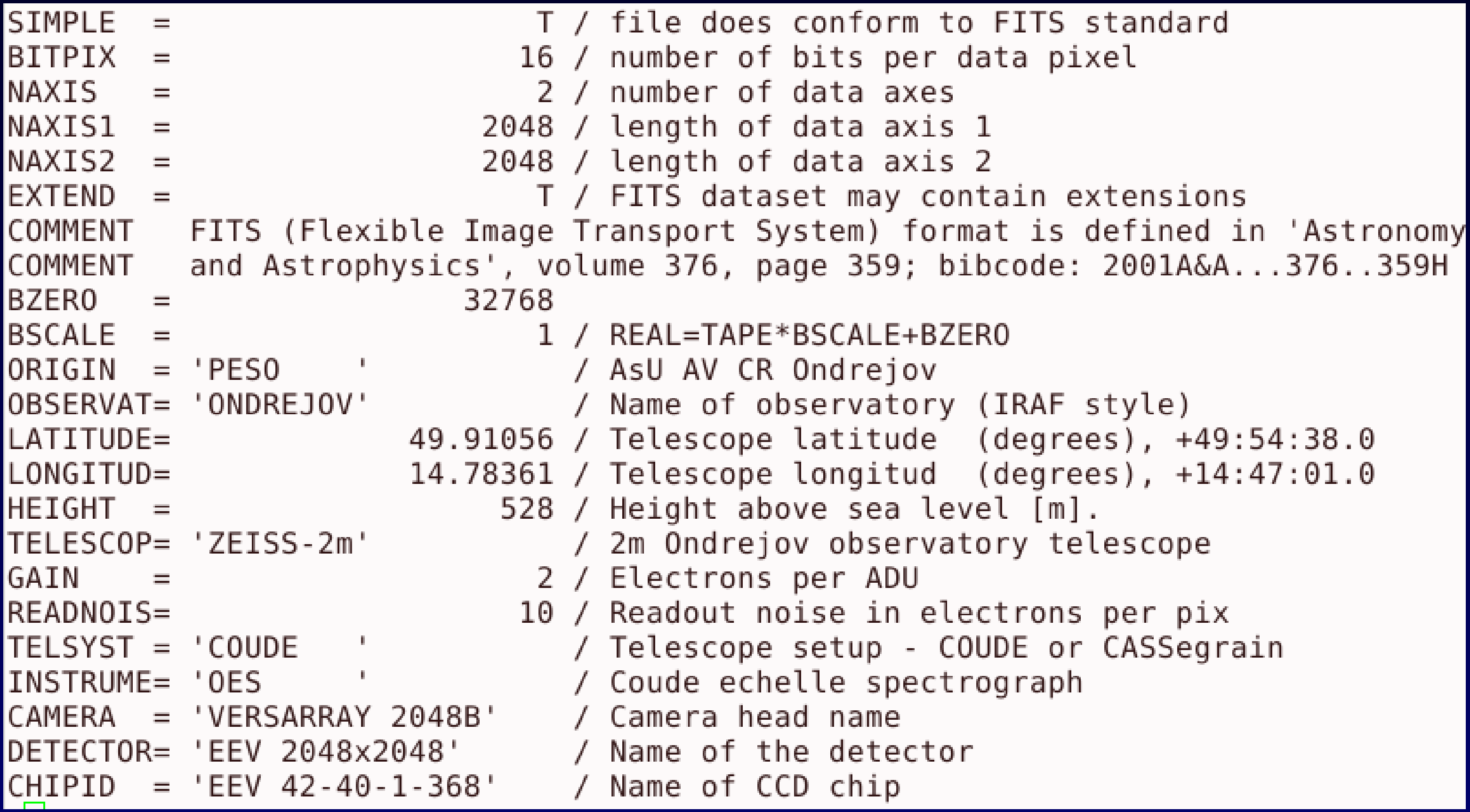
RESOURCE LAYER

PROVIDERS

20101004
IVOA Architecture

FITS standard

>30 years, separation of metadata (human readable and data)



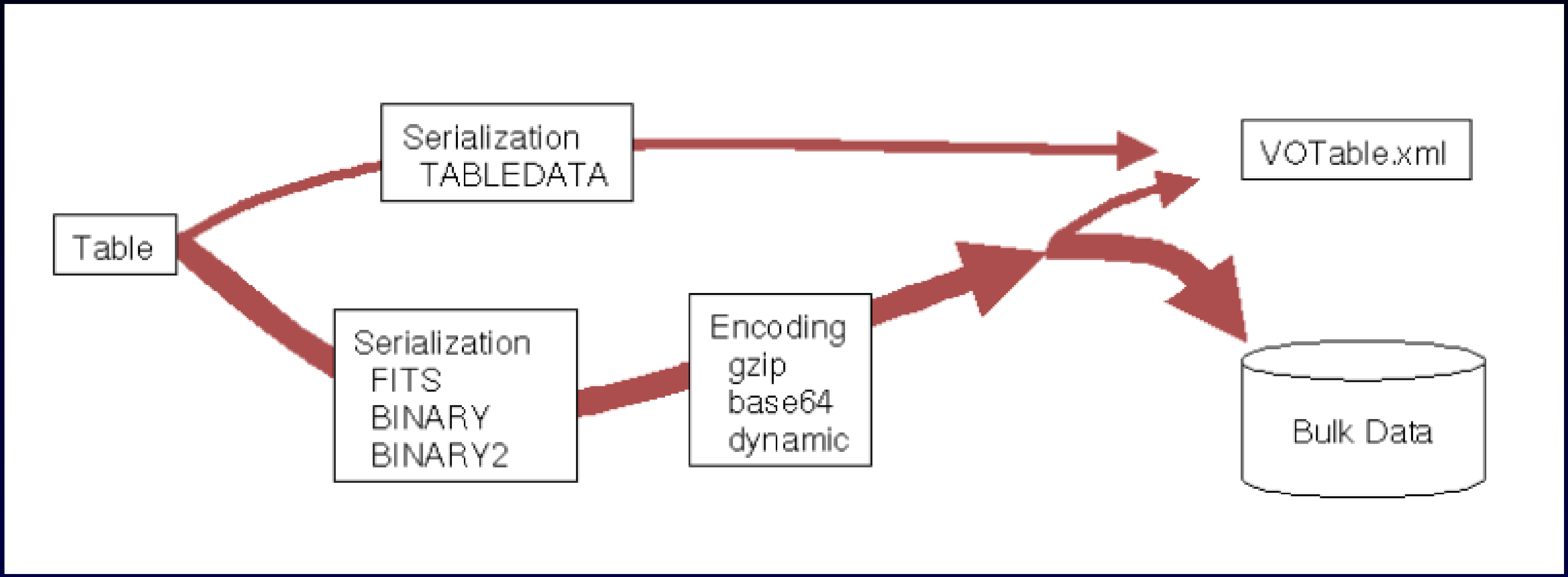
```
SIMPLE  =                    T / file does conform to FITS standard
BITPIX  =                   16 / number of bits per data pixel
NAXIS   =                    2 / number of data axes
NAXIS1  =                 2048 / length of data axis 1
NAXIS2  =                 2048 / length of data axis 2
EXTEND  =                    T / FITS dataset may contain extensions
COMMENT   FITS (Flexible Image Transport System) format is defined in 'Astronomy
COMMENT   and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
BZERO   =                32768
BSCALE  =                    1 / REAL=TAPE*BSCALE+BZERO
ORIGIN  = 'PESO    '           / AsU AV CR Ondrejov
OBSERVAT= 'ONDREJOV'           / Name of observatory (IRAF style)
LATITUDE=             49.91056 / Telescope latitude  (degrees), +49:54:38.0
LONGITUD=             14.78361 / Telescope longitud  (degrees), +14:47:01.0
HEIGHT  =                  528 / Height above sea level [m].
TELESCOP= 'ZEISS-2m'           / 2m Ondrejov observatory telescope
GAIN    =                    2 / Electrons per ADU
READNOIS=                   10 / Readout noise in electrons per pix
TELSYST = 'COUDE   '           / Telescope setup - COUDE or CASSegrain
INSTRUME= 'OES     '           / Coude echelle spectrograph
CAMERA  = 'VERSARRAY 2048B'    / Camera head name
DETECTOR= 'EEV 2048x2048'      / Name of the detector
CHIPID  = 'EEV 42-40-1-368'    / Name of CCD chip
```

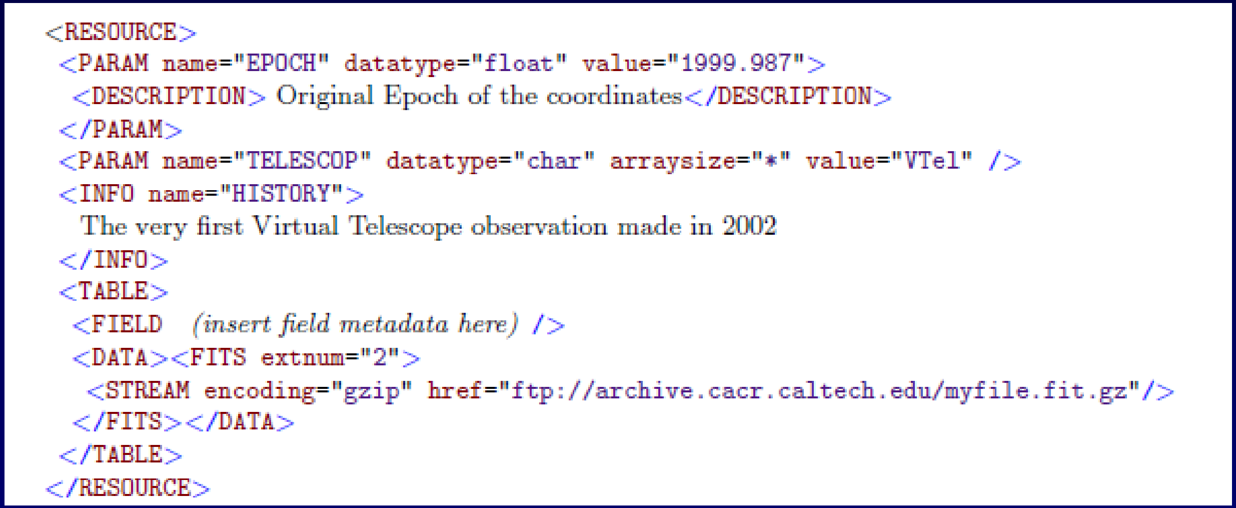
VOTable

```
<TABLE name="SpectroLog">
<FIELD name="Target" ucd="meta.id" datatype="char" arraysize="30*"/>
<FIELD name="Instr" ucd="instr.setup" datatype="char" arraysize="5*"/>
<FIELD name="Dur" ucd="time.expo" datatype="int" width="5" unit="s"/>
<FIELD name="Spectrum" ucd="meta.ref.url" datatype="float" arraysize="*"
        unit="mW/m2/nm" type="location">
<DESCRIPTION>Spectrum absolutely calibrated</DESCRIPTION>
<LINK type="location"
        href="http://ivoa.spectr/server?obsno="/>
</FIELD>
<DATA><TABLEDATA>
<TR><TD>NGC6543</TD><TD>SWS06</TD><TD>2028</TD><TD>01301903</
TD></TR>
<TR><TD>NGC6543</TD><TD>SWS07</TD><TD>2544</TD><TD>01302004</
TD></TR>
</TABLEDATA></DATA>
</TABLE>
```

Serialization (metadata first, end of data unknown, tree structure)

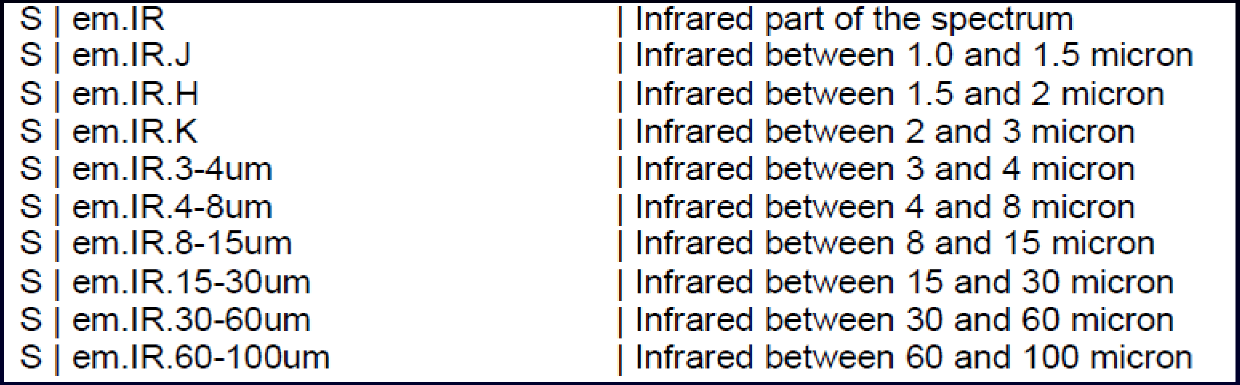
VOTable Serialization



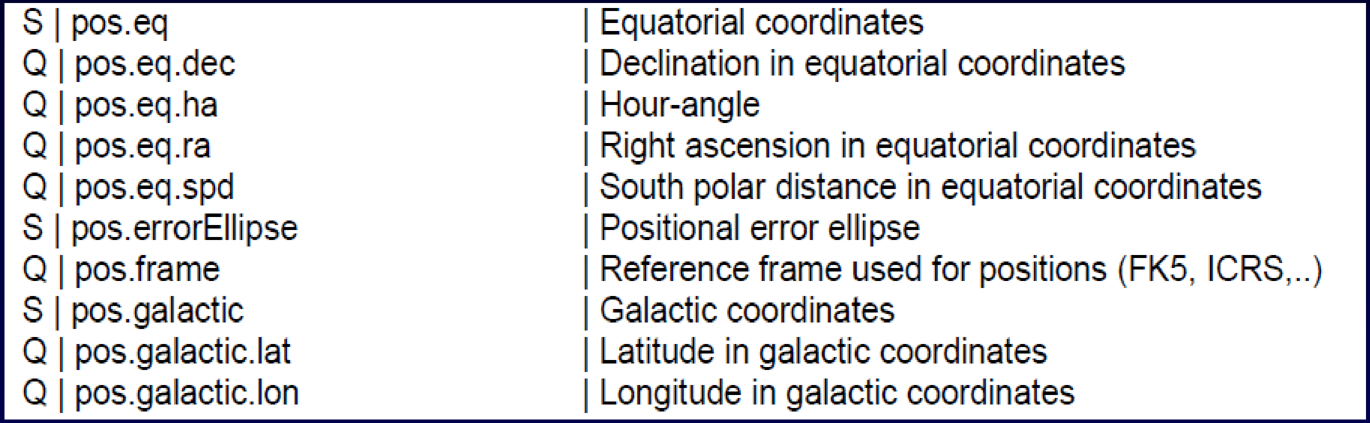


```
<RESOURCE>
 <PARAM name="EPOCH" datatype="float" value="1999.987">
  <DESCRIPTION> Original Epoch of the coordinates</DESCRIPTION>
 </PARAM>
 <PARAM name="TELESCOP" datatype="char" arraysize="*" value="VTel" />
 <INFO name="HISTORY">
   The very first Virtual Telescope observation made in 2002
 </INFO>
 <TABLE>
  <FIELD  (insert field metadata here) />
  <DATA><FITS extnum="2">
   <STREAM encoding="gzip" href="ftp://archive.cacr.caltech.edu/myfile.fit.gz"/>
  </FITS></DATA>
 </TABLE>
</RESOURCE>
```

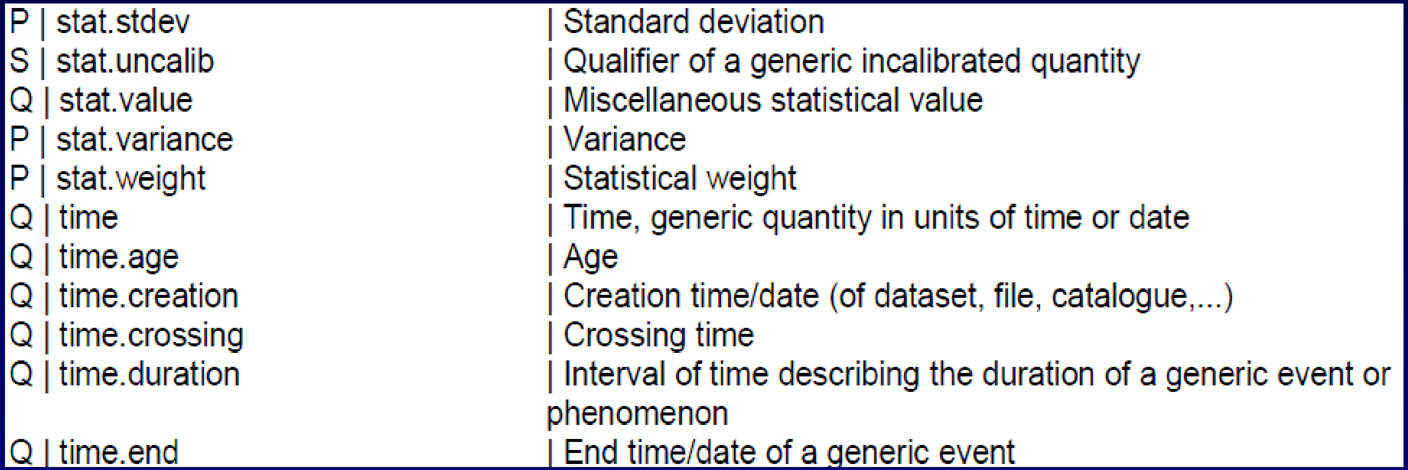
Universal Content Descriptors



S	em.IR	Infrared part of the spectrum
S	em.IR.J	Infrared between 1.0 and 1.5 micron
S	em.IR.H	Infrared between 1.5 and 2 micron
S	em.IR.K	Infrared between 2 and 3 micron
S	em.IR.3-4um	Infrared between 3 and 4 micron
S	em.IR.4-8um	Infrared between 4 and 8 micron
S	em.IR.8-15um	Infrared between 8 and 15 micron
S	em.IR.15-30um	Infrared between 15 and 30 micron
S	em.IR.30-60um	Infrared between 30 and 60 micron
S	em.IR.60-100um	Infrared between 60 and 100 micron



S	pos.eq	Equatorial coordinates
Q	pos.eq.dec	Declination in equatorial coordinates
Q	pos.eq.ha	Hour-angle
Q	pos.eq.ra	Right ascension in equatorial coordinates
Q	pos.eq.spd	South polar distance in equatorial coordinates
S	pos.errorEllipse	Positional error ellipse
Q	pos.frame	Reference frame used for positions (FK5, ICRS,..)
S	pos.galactic	Galactic coordinates
Q	pos.galactic.lat	Latitude in galactic coordinates
Q	pos.galactic.lon	Longitude in galactic coordinates



P	stat.stdev	Standard deviation
S	stat.uncalib	Qualifier of a generic incalibrated quantity
Q	stat.value	Miscellaneous statistical value
P	stat.variance	Variance
P	stat.weight	Statistical weight
Q	time	Time, generic quantity in units of time or date
Q	time.age	Age
Q	time.creation	Creation time/date (of dataset, file, catalogue,...)
Q	time.crossing	Crossing time
Q	time.duration	Interval of time describing the duration of a generic event or phenomenon
Q	time.end	End time/date of a generic event

Characterization

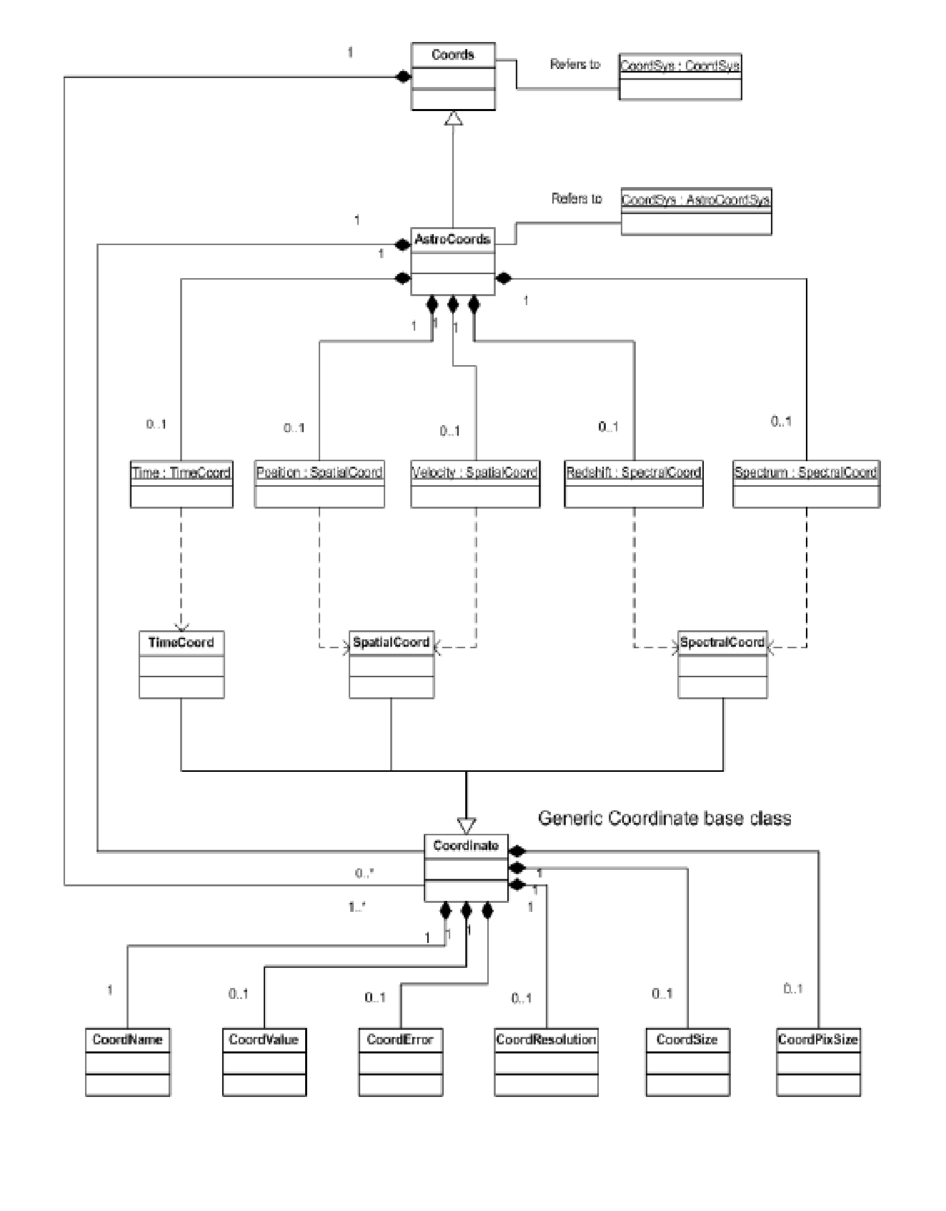
Curation – long time preservation issues (digital libraries)

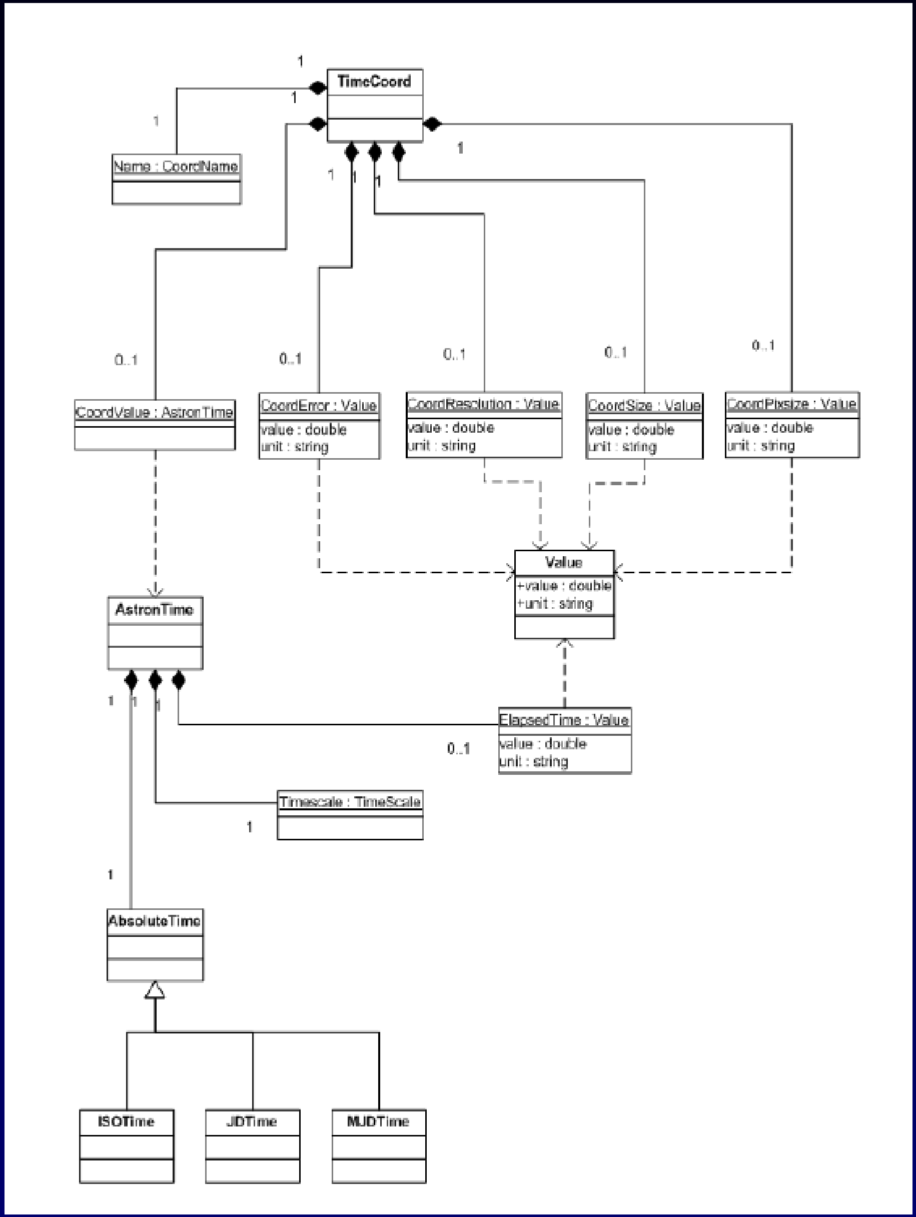
Provenance (how was processed, links to other products)

Characterization level 1 (spatial, spectral, temporal, polarization, location, coverage, porosity – SUB-CUBE)

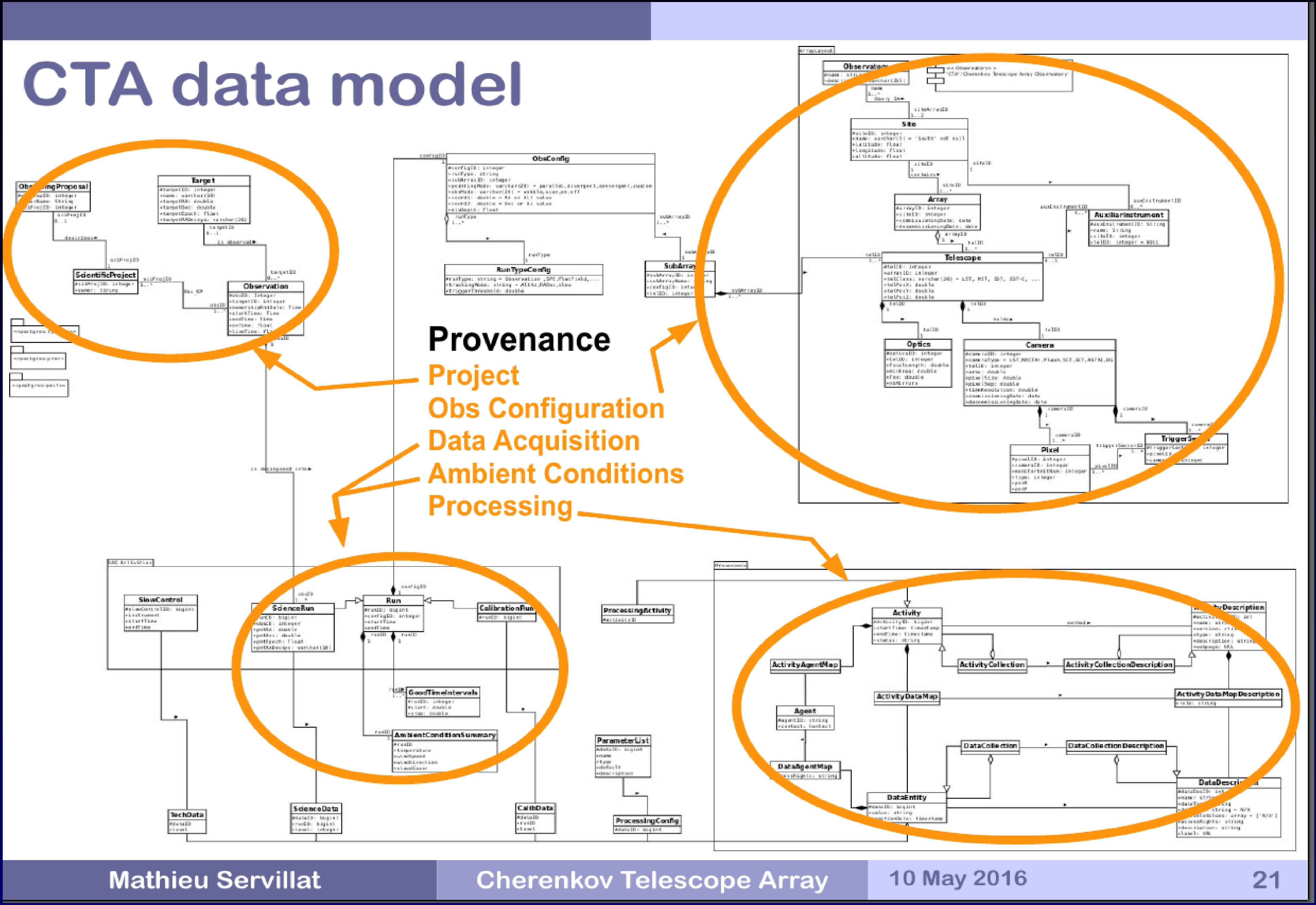
Characterization level 2 (distorsion in images, spectra with nonlinear resolution …..)

Space-Time-Coordinate Data Model





Cherenkov Telescope Array Data Model

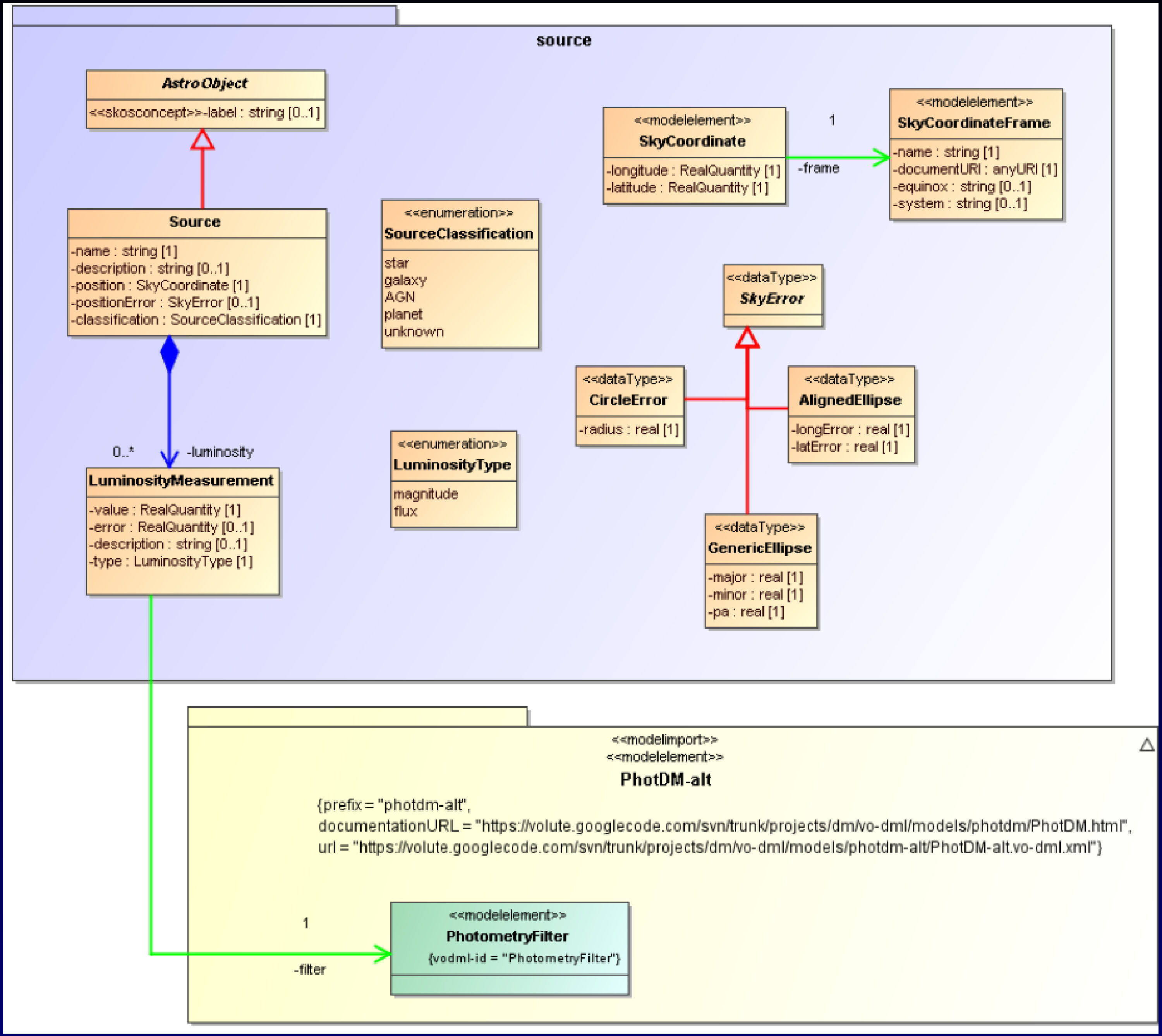


CTA data model

Provenance

Project
Obs Configuration
Data Acquisition
Ambient Conditions
Processing

VO-DML



source

AstroObject
<<skosconcept>>-label : string [0..1]

Source
-name : string [1]
-description : string [0..1]
-position : SkyCoordinate [1]
-positionError : SkyError [0..1]
-classification : SourceClassification [1]

0..* -luminosity

LuminosityMeasurement
-value : RealQuantity [1]
-error : RealQuantity [0..1]
-description : string [0..1]
-type : LuminosityType [1]

<<enumeration>>
SourceClassification
star
galaxy
AGN
planet
unknown

<<enumeration>>
LuminosityType
magnitude
flux

<<modelelement>>
SkyCoordinate
-longitude : RealQuantity [1]
-latitude : RealQuantity [1]

1 -frame

<<modelelement>>
SkyCoordinateFrame
-name : string [1]
-documentURI : anyURI [1]
-equinox : string [0..1]
-system : string [0..1]

<<dataType>>
SkyError

<<dataType>>
CircleError
-radius : real [1]

<<dataType>>
AlignedEllipse
-longError : real [1]
-latError : real [1]

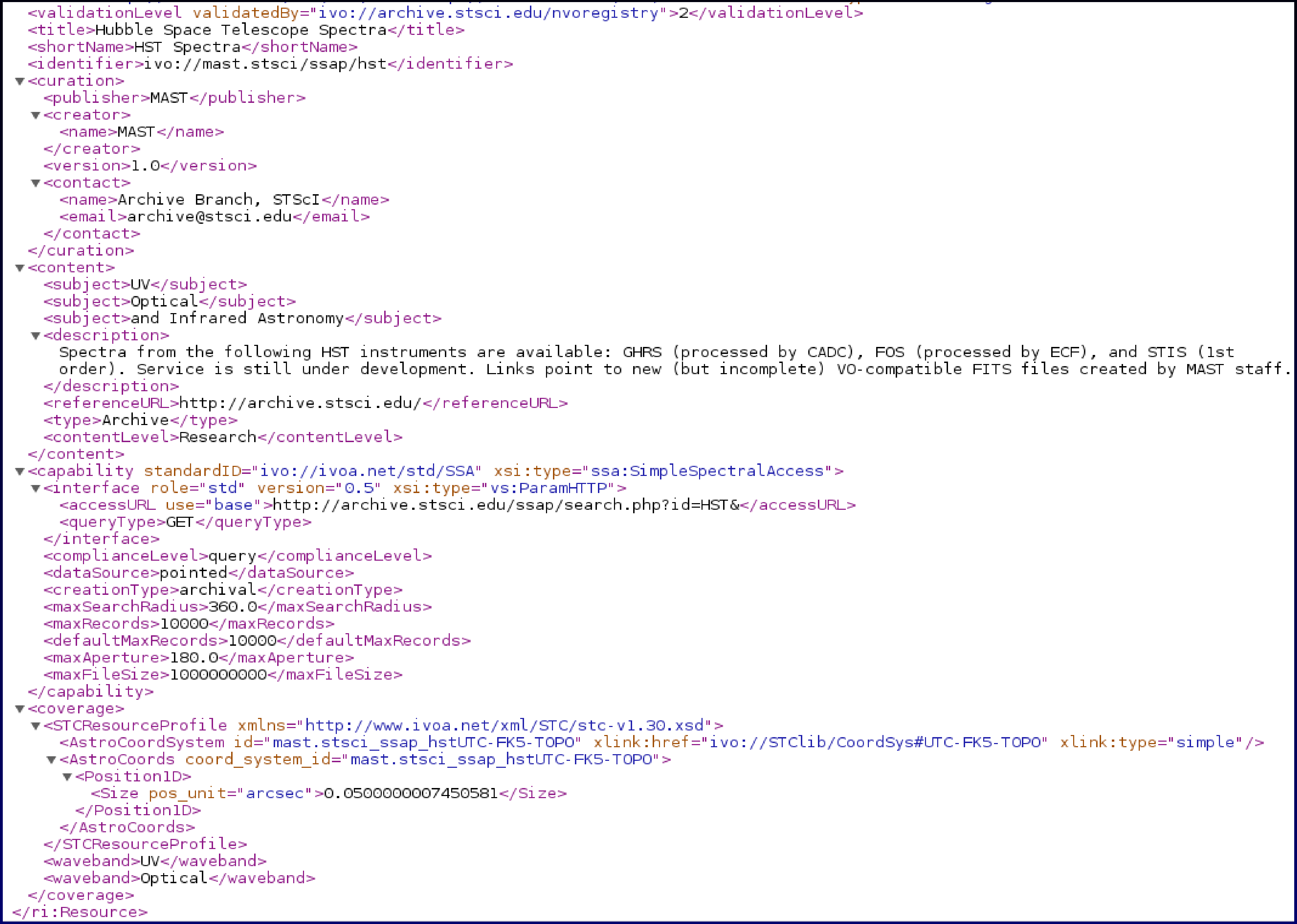
<<dataType>>
GenericEllipse
-major : real [1]
-minor : real [1]
-pa : real [1]

<<modelimport>>
<<modelelement>>
PhotDM-alt
{prefix = "photdm-alt",
documentationURL = "https://volute.googlecode.com/svn/trunk/projects/dm/vo-dml/models/photdm/PhotDM.html",
url = "https://volute.googlecode.com/svn/trunk/projects/dm/vo-dml/models/photdm-alt/PhotDM-alt.vo-dml.xml"}

1 -filter

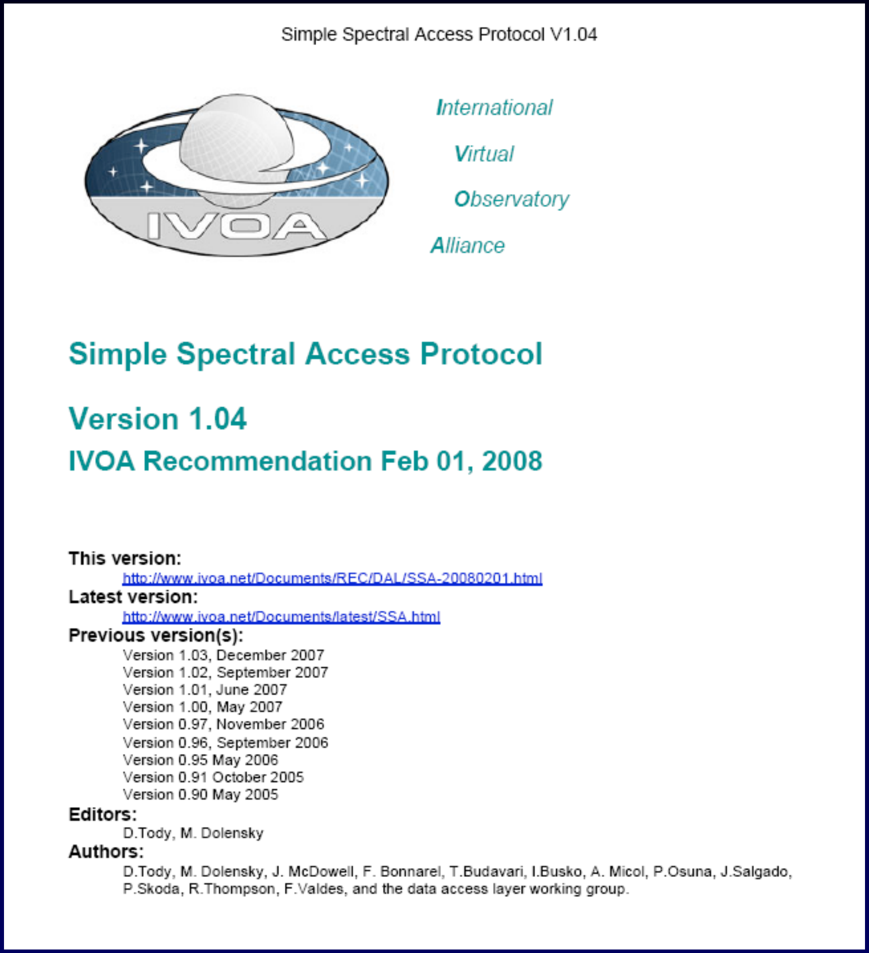
<<modelelement>>
PhotometryFilter
{vodml-id = "PhotometryFilter"}

VO Registry – XML



```
  <validationLevel validatedBy="ivo://archive.stsci.edu/nvoregistry">2</validationLevel>
  <title>Hubble Space Telescope Spectra</title>
  <shortName>HST Spectra</shortName>
  <identifier>ivo://mast.stsci/ssap/hst</identifier>
▼ <curation>
    <publisher>MAST</publisher>
  ▼ <creator>
      <name>MAST</name>
    </creator>
    <version>1.0</version>
  ▼ <contact>
      <name>Archive Branch, STScI</name>
      <email>archive@stsci.edu</email>
    </contact>
  </curation>
▼ <content>
    <subject>UV</subject>
    <subject>Optical</subject>
    <subject>and Infrared Astronomy</subject>
  ▼ <description>
      Spectra from the following HST instruments are available: GHRS (processed by CADC), FOS (processed by ECF), and STIS (1st
      order). Service is still under development. Links point to new (but incomplete) VO-compatible FITS files created by MAST staff.
    </description>
    <referenceURL>http://archive.stsci.edu/</referenceURL>
    <type>Archive</type>
    <contentLevel>Research</contentLevel>
  </content>
▼ <capability standardID="ivo://ivoa.net/std/SSA" xsi:type="ssa:SimpleSpectralAccess">
  ▼ <interface role="std" version="0.5" xsi:type="vs:ParamHTTP">
      <accessURL use="base">http://archive.stsci.edu/ssap/search.php?id=HST&</accessURL>
      <queryType>GET</queryType>
    </interface>
    <complianceLevel>query</complianceLevel>
    <dataSource>pointed</dataSource>
    <creationType>archival</creationType>
    <maxSearchRadius>360.0</maxSearchRadius>
    <maxRecords>10000</maxRecords>
    <defaultMaxRecords>10000</defaultMaxRecords>
    <maxAperture>180.0</maxAperture>
    <maxFileSize>1000000000</maxFileSize>
  </capability>
▼ <coverage>
  ▼ <STCResourceProfile xmlns="http://www.ivoa.net/xml/STC/stc-v1.30.xsd">
      <AstroCoordSystem id="mast.stsci_ssap_hstUTC-FK5-TOPO" xlink:href="ivo://STClib/CoordSys#UTC-FK5-TOPO" xlink:type="simple"/>
    ▼ <AstroCoords coord_system_id="mast.stsci_ssap_hstUTC-FK5-TOPO">
      ▼ <Position1D>
          <Size pos_unit="arcsec">0.0500000007450581</Size>
        </Position1D>
      </AstroCoords>
    </STCResourceProfile>
    <waveband>UV</waveband>
    <waveband>Optical</waveband>
  </coverage>
</ri:Resource>
```

Simple Spectra Access Protocol
Spectral Data Model



Simple Spectral Access Protocol V1.04

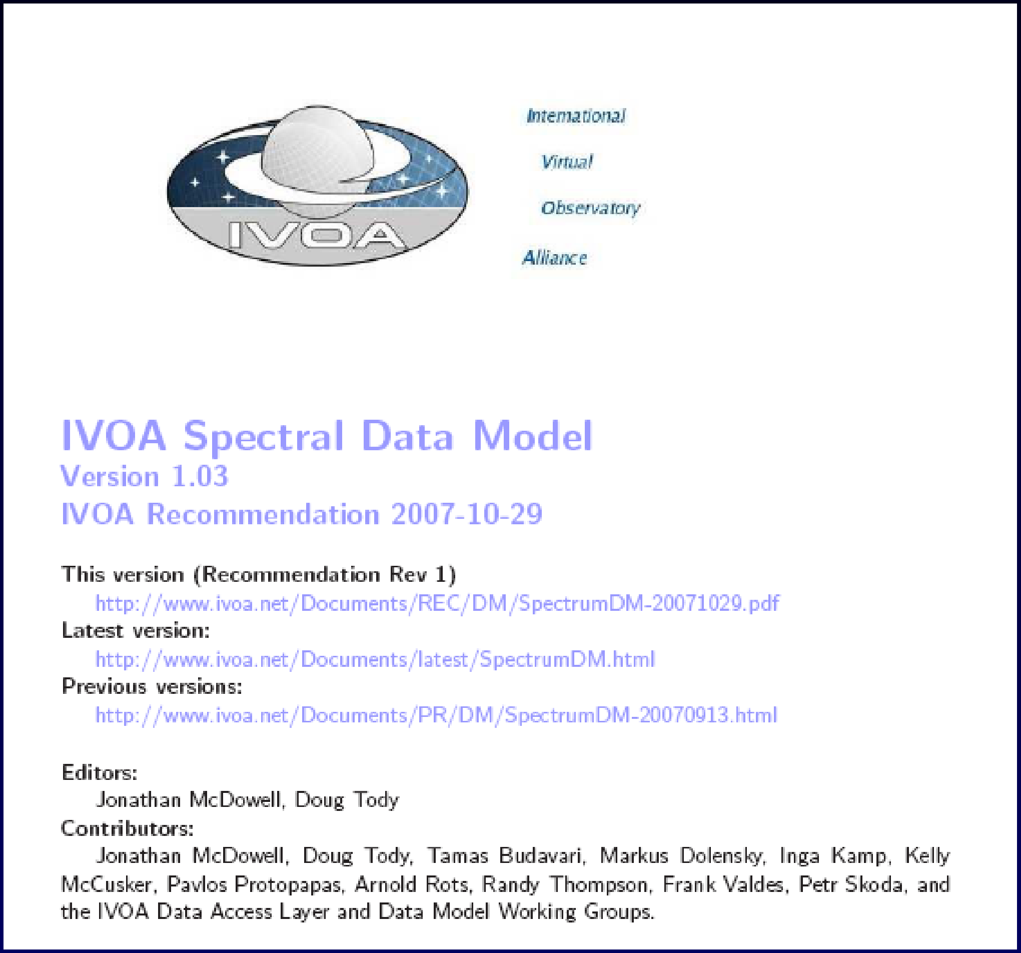
International
Virtual
Observatory
Alliance

Simple Spectral Access Protocol

Version 1.04

IVOA Recommendation Feb 01, 2008

This version:
http://www.ivoa.net/Documents/REC/DAL/SSA-20080201.html
Latest version:
http://www.ivoa.net/Documents/latest/SSA.html
Previous version(s):
Version 1.03, December 2007
Version 1.02, September 2007
Version 1.01, June 2007
Version 1.00, May 2007
Version 0.97, November 2006
Version 0.96, September 2006
Version 0.95 May 2006
Version 0.91 October 2005
Version 0.90 May 2005
Editors:
D.Tody, M. Dolensky
Authors:
D.Tody, M. Dolensky, J. McDowell, F. Bonnarel, T.Budavari, I.Busko, A. Micol, P.Osuna, J.Salgado, P.Skoda, R.Thompson, F.Valdes, and the data access layer working group.



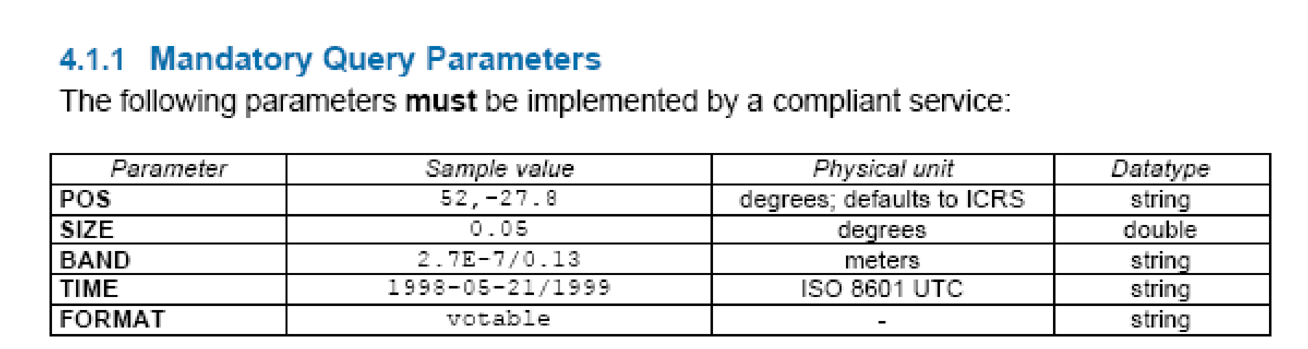
International
Virtual
Observatory
Alliance

IVOA Spectral Data Model
Version 1.03
IVOA Recommendation 2007-10-29

This version (Recommendation Rev 1)
http://www.ivoa.net/Documents/REC/DM/SpectrumDM-20071029.pdf
Latest version:
http://www.ivoa.net/Documents/latest/SpectrumDM.html
Previous versions:
http://www.ivoa.net/Documents/PR/DM/SpectrumDM-20070913.html

Editors:
Jonathan McDowell, Doug Tody
Contributors:
Jonathan McDowell, Doug Tody, Tamas Budavari, Markus Dolensky, Inga Kamp, Kelly McCusker, Pavlos Protopapas, Arnold Rots, Randy Thompson, Frank Valdes, Petr Skoda, and the IVOA Data Access Layer and Data Model Working Groups.

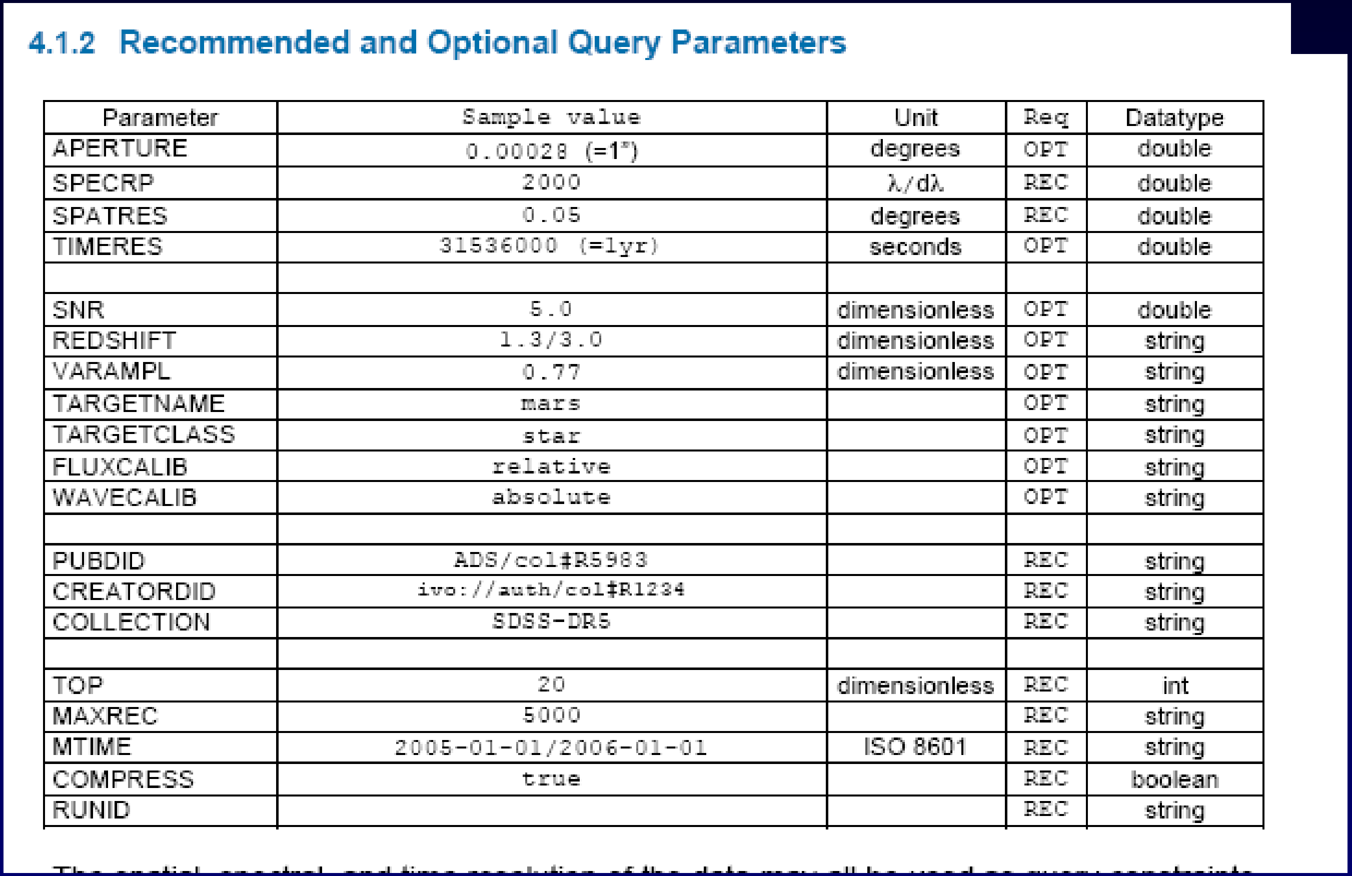
SSAP Parameters



4.1.1 Mandatory Query Parameters

The following parameters **must** be implemented by a compliant service:

Parameter	*Sample value*	*Physical unit*	*Datatype*
POS	`52,-27.8`	degrees; defaults to ICRS	string
SIZE	`0.05`	degrees	double
BAND	`2.7E-7/0.13`	meters	string
TIME	`1998-05-21/1999`	ISO 8601 UTC	string
FORMAT	`votable`	-	string



4.1.2 Recommended and Optional Query Parameters

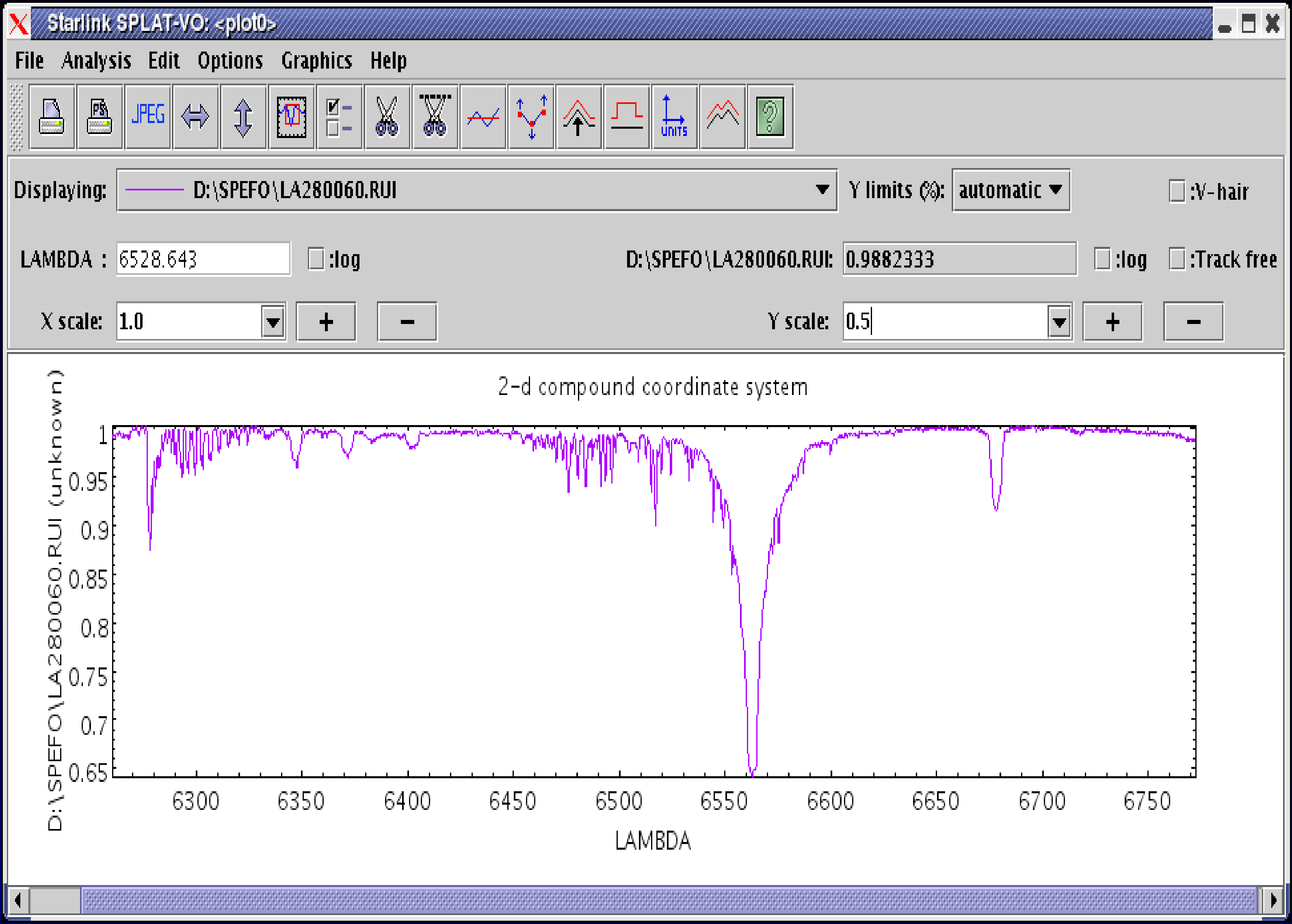
Parameter	Sample value	Unit	Req	Datatype
APERTURE	`0.00028` (=1")	degrees	OPT	double
SPECRP	`2000`	λ/dλ	REC	double
SPATRES	`0.05`	degrees	REC	double
TIMERES	`31536000 (=1yr)`	seconds	OPT	double
SNR	`5.0`	dimensionless	OPT	double
REDSHIFT	`1.3/3.0`	dimensionless	OPT	string
VARAMPL	`0.77`	dimensionless	OPT	string
TARGETNAME	`mars`		OPT	string
TARGETCLASS	`star`		OPT	string
FLUXCALIB	`relative`		OPT	string
WAVECALIB	`absolute`		OPT	string
PUBDID	`ADS/col#R5983`		REC	string
CREATORDID	`ivo://auth/col#R1234`		REC	string
COLLECTION	`SDSS-DR5`		REC	string
TOP	`20`	dimensionless	REC	int
MAXREC	`5000`		REC	string
MTIME	`2005-01-01/2006-01-01`	ISO 8601	REC	string
COMPRESS	`true`		REC	boolean
RUNID			REC	string

The spatial, spectral, and time resolution of the data may all be used as query constraints

Big Data handling

VO Space	Moving big tables across (load only results)
SSO	Authentication, authorization, groups and consortia
UWS	Universal worker service (job synch, asynch)
PDL	Parameter Description Language
SIM-DB	Simulations, theory data

SPLAT-VO (Starlink, JAC)



Starlink SPLAT-VO: <plot0>
File Analysis Edit Options Graphics Help
JPEG
UNITS
+
−
+
−
2-d compound coordinate system
D:\SPEFO\LA280060.RUI (unknown)
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
6300
6350
6400
6450
6500
6550
6600
6650
6700
6750
LAMBDA

Displaying: D:\SPEFO\LA280060.RUI

Y limits (%): automatic

□ :V-hair

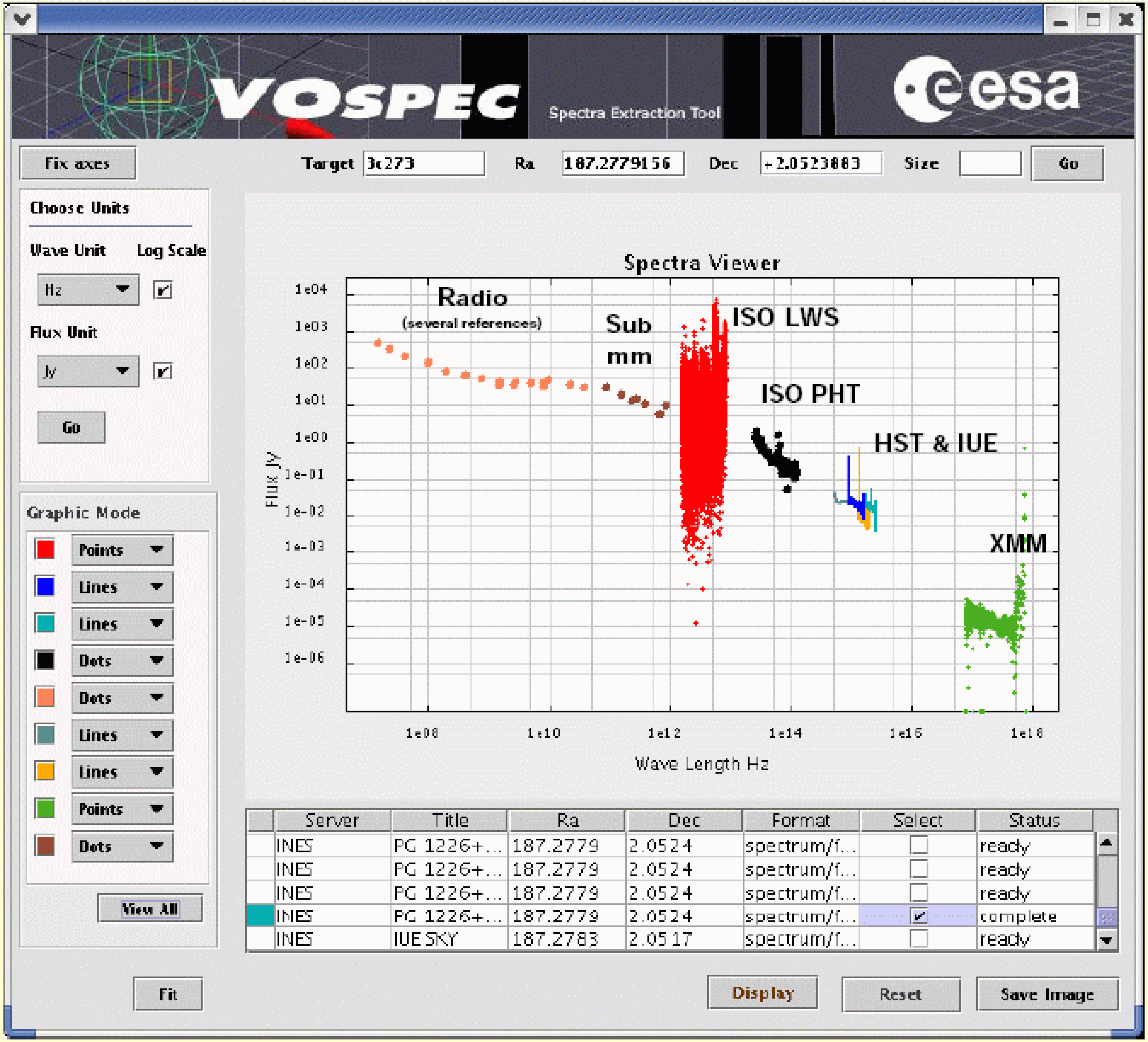
LAMBDA : 6528.643 □ :log

D:\SPEFO\LA280060.RUI: 0.9882333 □ :log □ :Track free

X scale: 1.0

Y scale: 0.5

VOspec (ESAC)



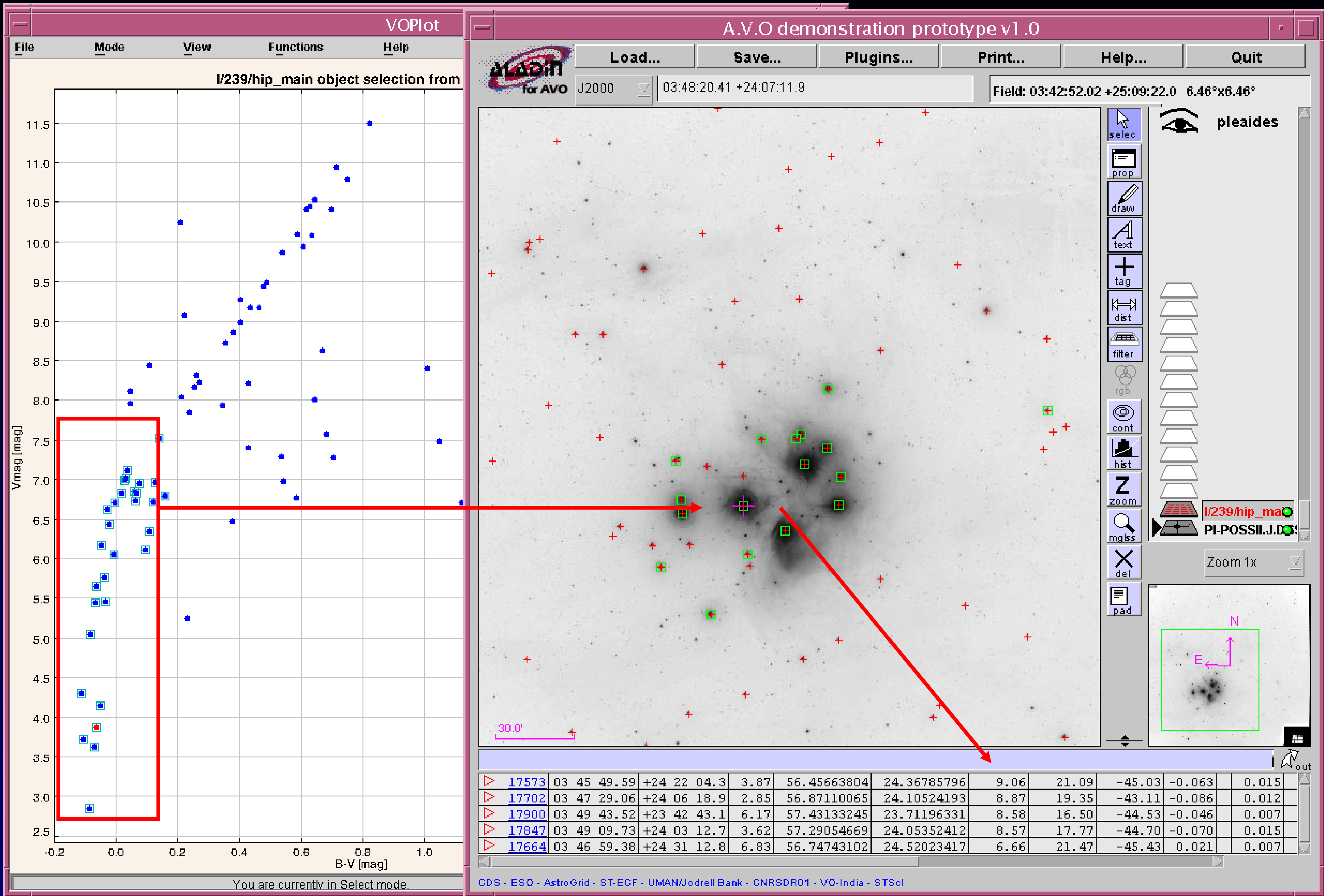
Target 3c273 Ra 187.2779156 Dec +2.0523083 Size

Wave Unit: Hz ☑ Log Scale

Flux Unit: Jy ☑

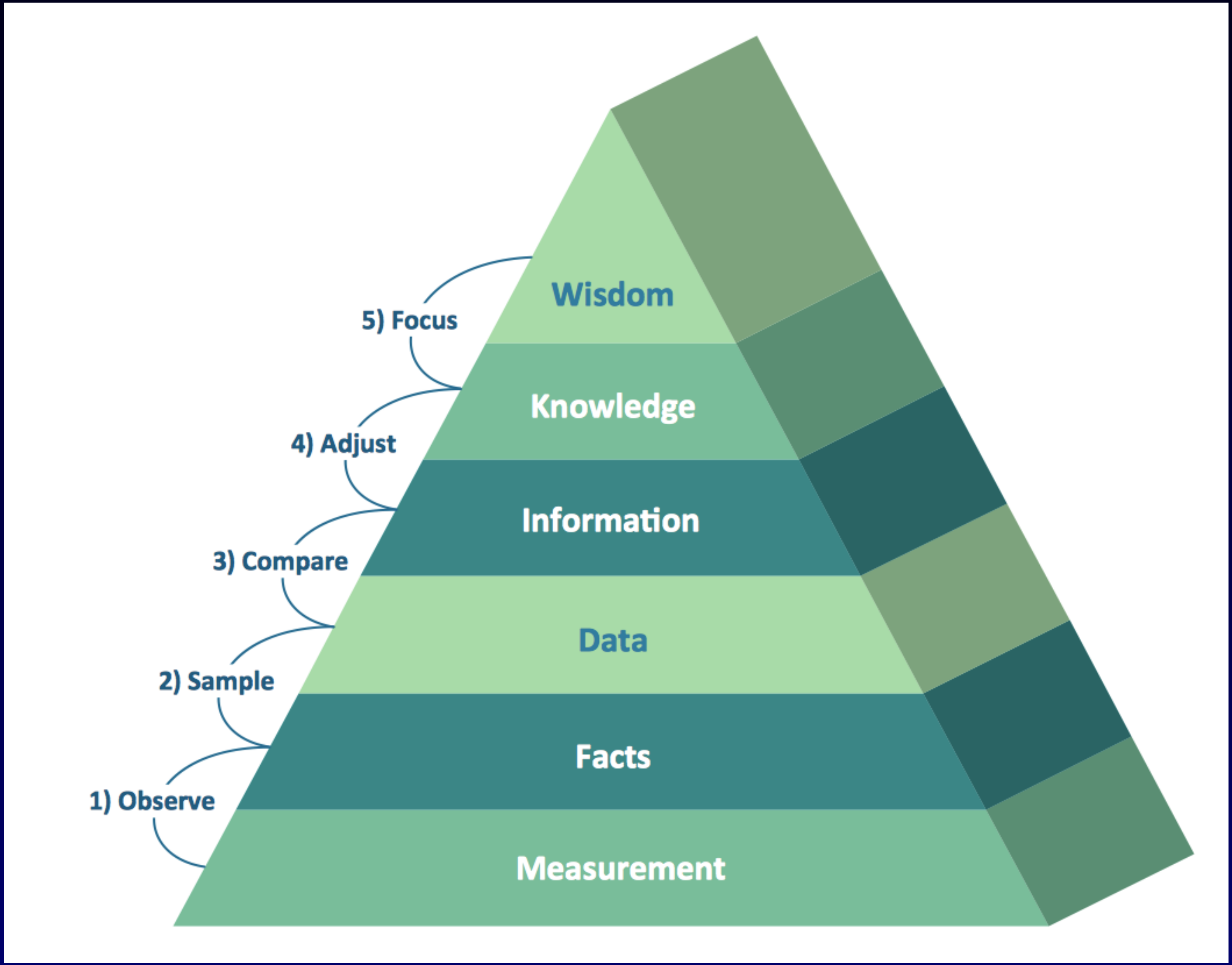
Server	Title	Ra	Dec	Format	Select	Status
INES	PG 1226+...	187.2779	2.0524	spectrum/f...	□	ready
INES	PG 1226+...	187.2779	2.0524	spectrum/f...	□	ready
INES	PG 1226+...	187.2779	2.0524	spectrum/f...	□	ready
INES	PG 1226+...	187.2779	2.0524	spectrum/f...	☑	complete
INES	IUE SKY	187.2783	2.0517	spectrum/f...	□	ready

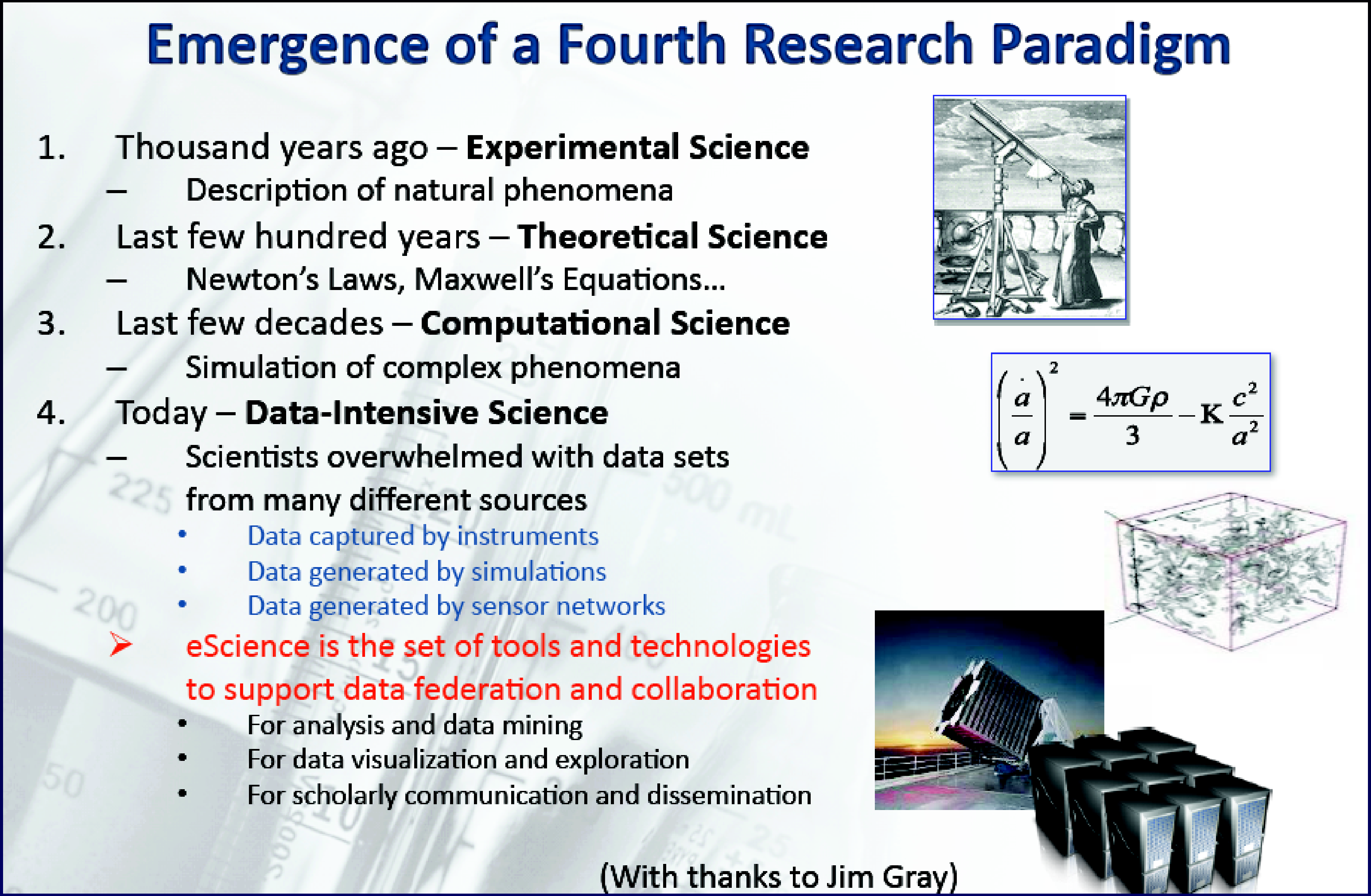
Colour-magnitude diagram



▷	17573	03 45 49.59	+24 22 04.3	3.87	56.45663804	24.36785796	9.06	21.09	-45.03	-0.063	0.015
▷	17702	03 47 29.06	+24 06 18.9	2.85	56.87110065	24.10524193	8.87	19.35	-43.11	-0.086	0.012
▷	17900	03 49 43.52	+23 42 43.1	6.17	57.43133245	23.71196331	8.58	16.50	-44.53	-0.046	0.007
▷	17847	03 49 09.73	+24 03 12.7	3.62	57.29054669	24.05352412	8.57	17.77	-44.70	-0.070	0.015
▷	17664	03 46 59.38	+24 31 12.8	6.83	56.74743102	24.52023417	6.66	21.47	-45.43	0.021	0.007

Data-Knowledge-Wisdom Pyramid





Emergence of a Fourth Research Paradigm

1. Thousand years ago – **Experimental Science**
   – Description of natural phenomena
2. Last few hundred years – **Theoretical Science**
   – Newton's Laws, Maxwell's Equations…
3. Last few decades – **Computational Science**
   – Simulation of complex phenomena
4. Today – **Data-Intensive Science**
   – Scientists overwhelmed with data sets from many different sources
   - Data captured by instruments
   - Data generated by simulations
   - Data generated by sensor networks

➢ eScience is the set of tools and technologies to support data federation and collaboration

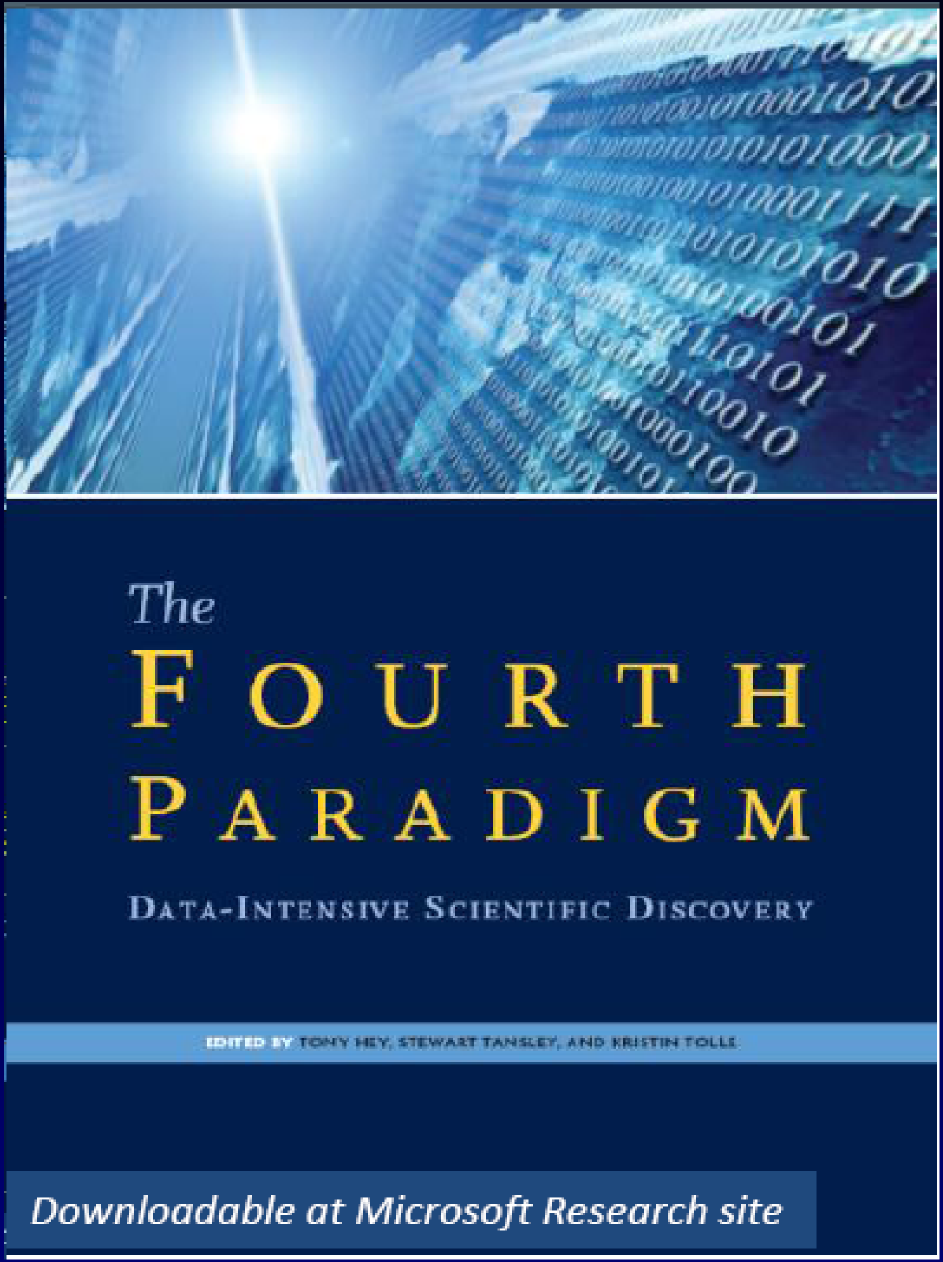
- For analysis and data mining
- For data visualization and exploration
- For scholarly communication and dissemination

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{4\pi G\rho}{3} - K\frac{c^2}{a^2}$$

(With thanks to Jim Gray)

From T. Hey, AI2010

X-informatics



The FOURTH PARADIGM

DATA-INTENSIVE SCIENTIFIC DISCOVERY

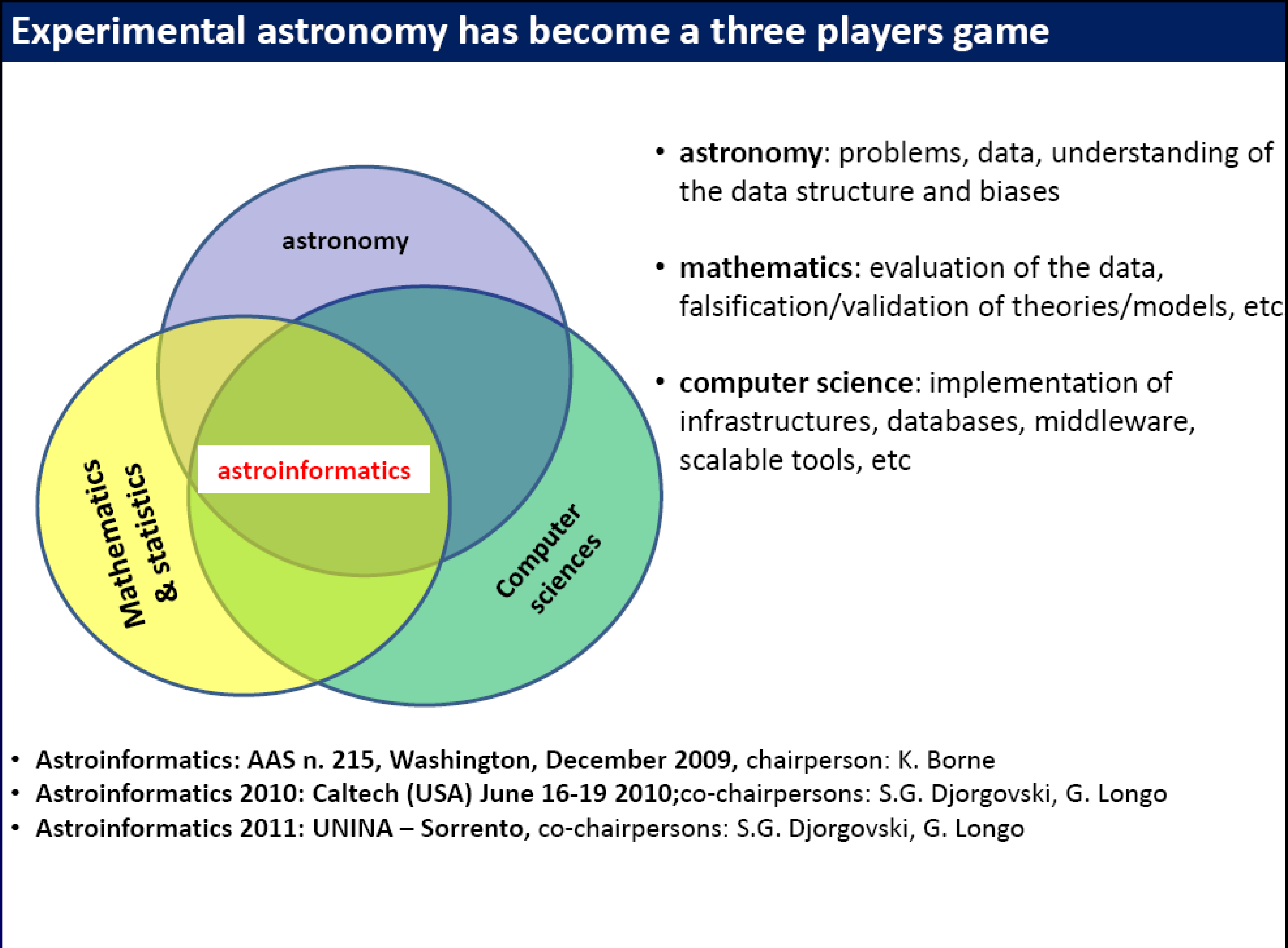
EDITED BY TONY HEY, STEWART TANSLEY, AND KRISTIN TOLLE

Downloadable at Microsoft Research site

Changing methodology of the Science

Synergy between different worlds

Sociological aspects (net-based research communities)



Experimental astronomy has become a three players game

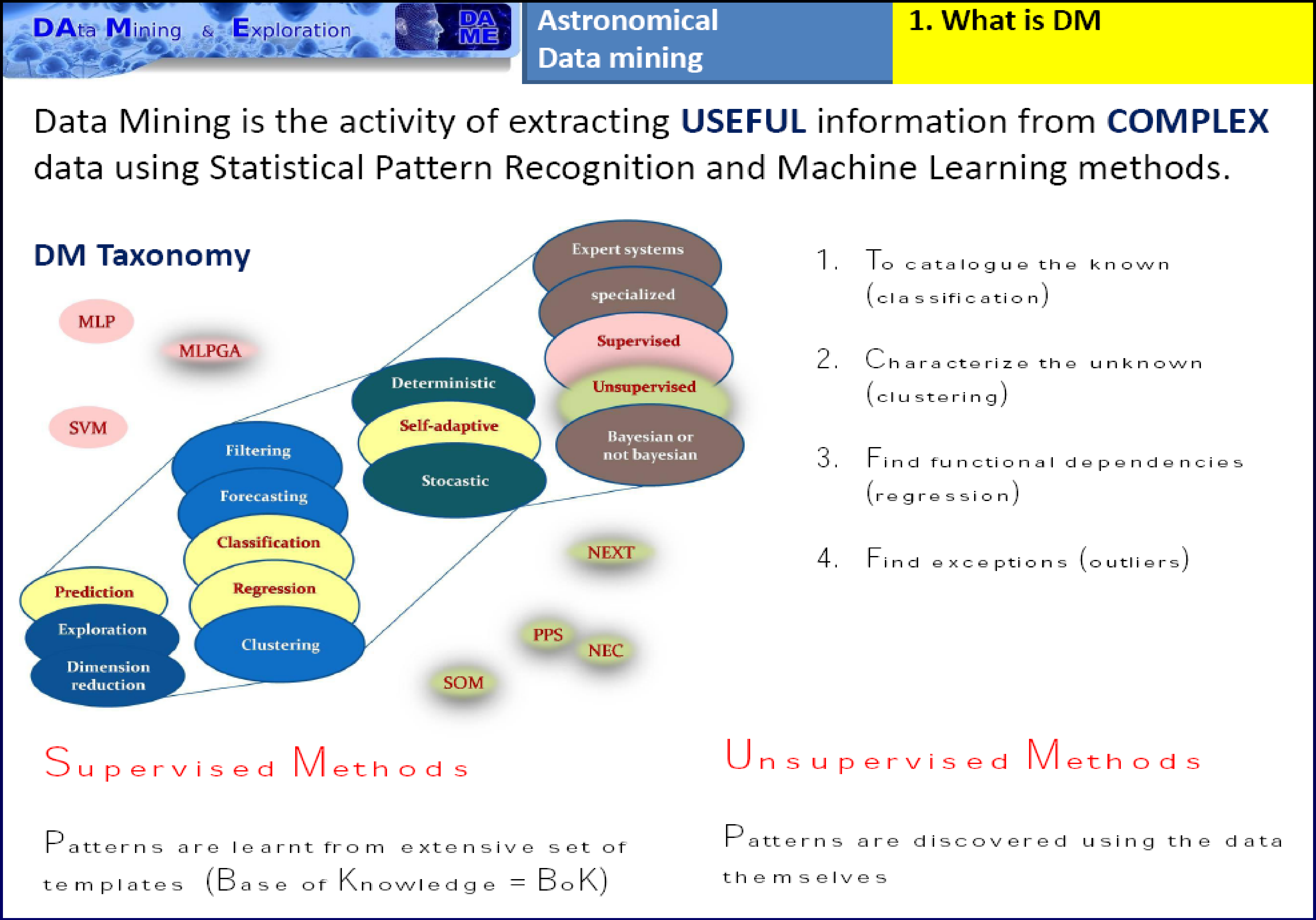
- **astronomy**: problems, data, understanding of the data structure and biases
- **mathematics**: evaluation of the data, falsification/validation of theories/models, etc
- **computer science**: implementation of infrastructures, databases, middleware, scalable tools, etc

- **Astroinformatics: AAS n. 215, Washington, December 2009,** chairperson: K. Borne
- **Astroinformatics 2010: Caltech (USA) June 16-19 2010;**co-chairpersons: S.G. Djorgovski, G. Longo
- **Astroinformatics 2011: UNINA – Sorrento,** co-chairpersons: S.G. Djorgovski, G. Longo

Longo 2010

Astroinformatics

- Analogy – Bioinformatics (Genome analysis with GRIDS, ATB)
- e-Science in Astronomy
- Data mining, Knowledge discovery - VO-NEURAL, DAME
- Examples
  - Photometric RedShift
  - Searching for QSO (light curves, MOS)
  - Automatic Light curves classification (GAIA, LSST)
- New ways of scholar communication (VR, 2nd Life, U-Science)
- BIG data problems, GPUs, NoSQL DB, visualization,
- Very NEW – emerging discipline



DAta Mining & Exploration

Astronomical Data mining

1. What is DM

Data Mining is the activity of extracting **USEFUL** information from **COMPLEX** data using Statistical Pattern Recognition and Machine Learning methods.

DM Taxonomy

1. To catalogue the known (classification)
2. Characterize the unknown (clustering)
3. Find functional dependencies (regression)
4. Find exceptions (outliers)

Supervised Methods

Patterns are learnt from extensive set of templates (Base of Knowledge = BoK)

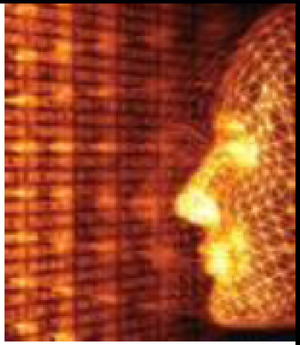
Unsupervised Methods

Patterns are discovered using the data themselves

Longo 2009

Need for a new science: Astroinformatics

Knowledge Discovery in Databases



Data Gathering (e.g., from sensor networks, telescopes…)

→ Data Farming:

- Storage/Archiving
- Indexing, Searchability
- Data Fusion, Interoperability, ontologies, etc.

→ Data Mining (or Knowledge Discovery in Databases):

- Pattern or correlation search
- Clustering analysis, automated classification
- Outlier / anomaly searches
- Hyperdimensional visualization

→ Data understanding

- Computer aided understanding
- KDD
- Etc.

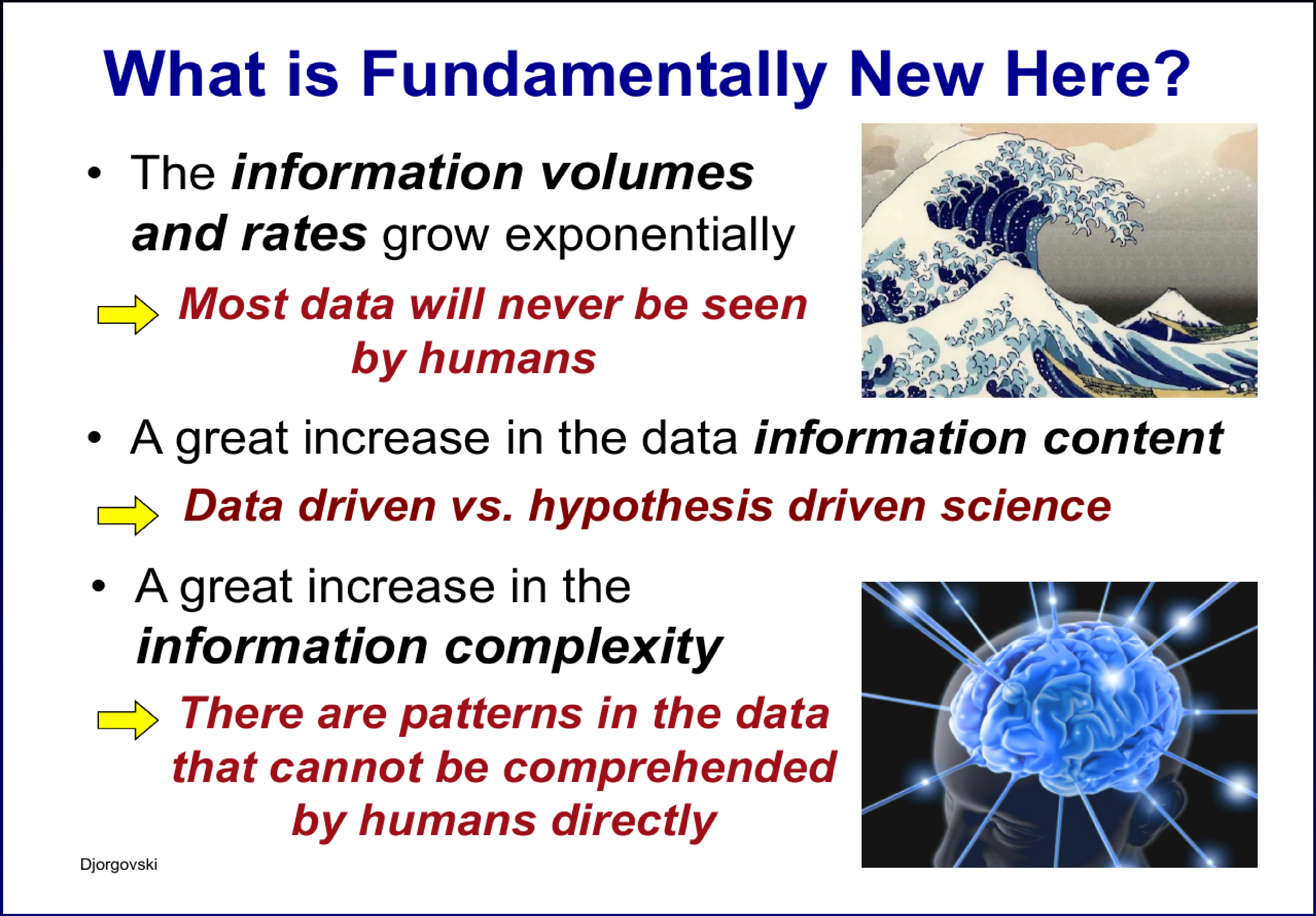
→ New Knowledge

Database technologies

Key mathematical issues

Ongoing research

Data Driven Science



What is Fundamentally New Here?

- The ***information volumes and rates*** grow exponentially

⇨ ***Most data will never be seen by humans***

- A great increase in the data ***information content***

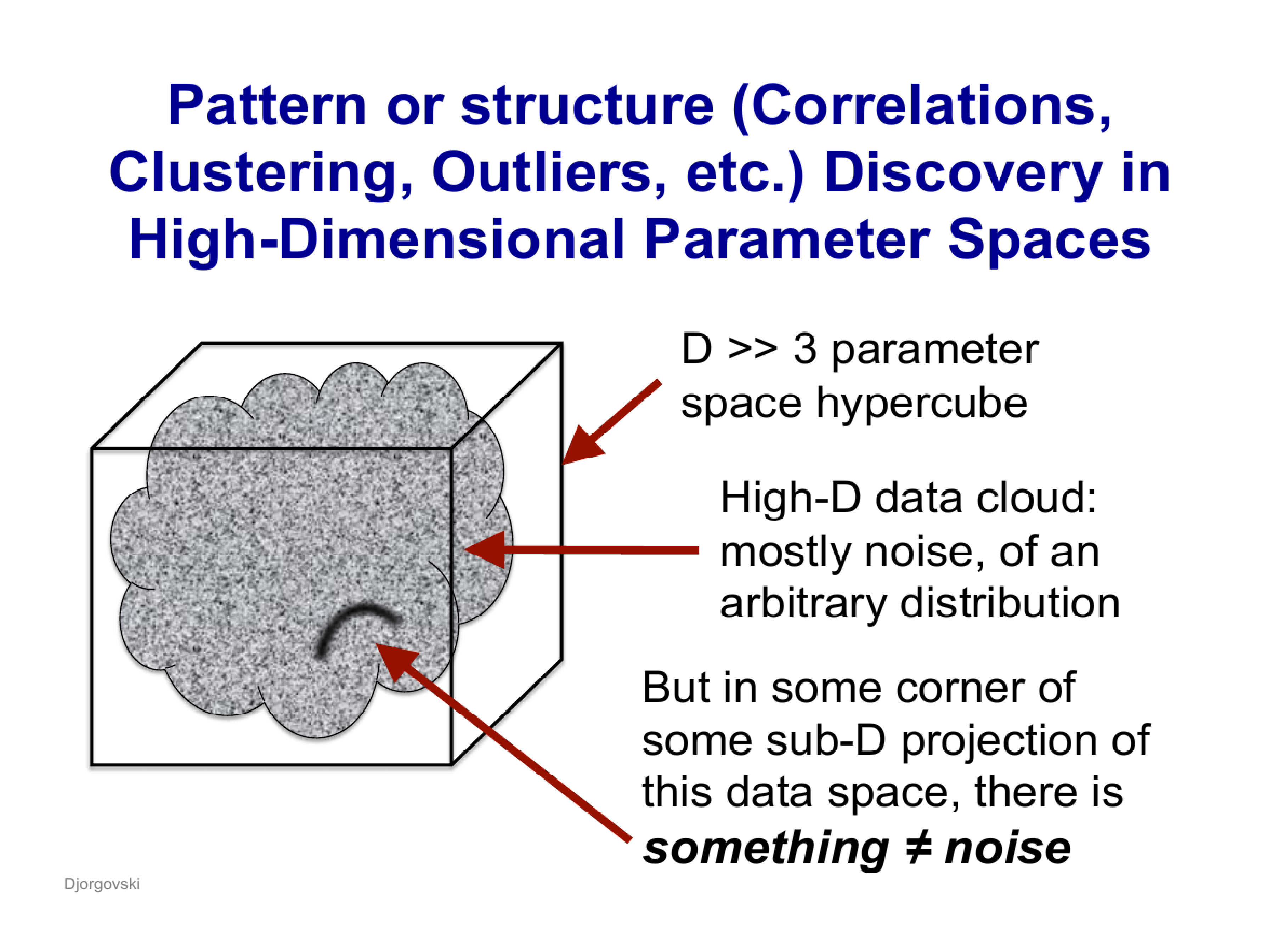
⇨ ***Data driven vs. hypothesis driven science***

- A great increase in the ***information complexity***

⇨ ***There are patterns in the data that cannot be comprehended by humans directly***

Djorgovski

Hidden Patterns in Data



Pattern or structure (Correlations, Clustering, Outliers, etc.) Discovery in High-Dimensional Parameter Spaces

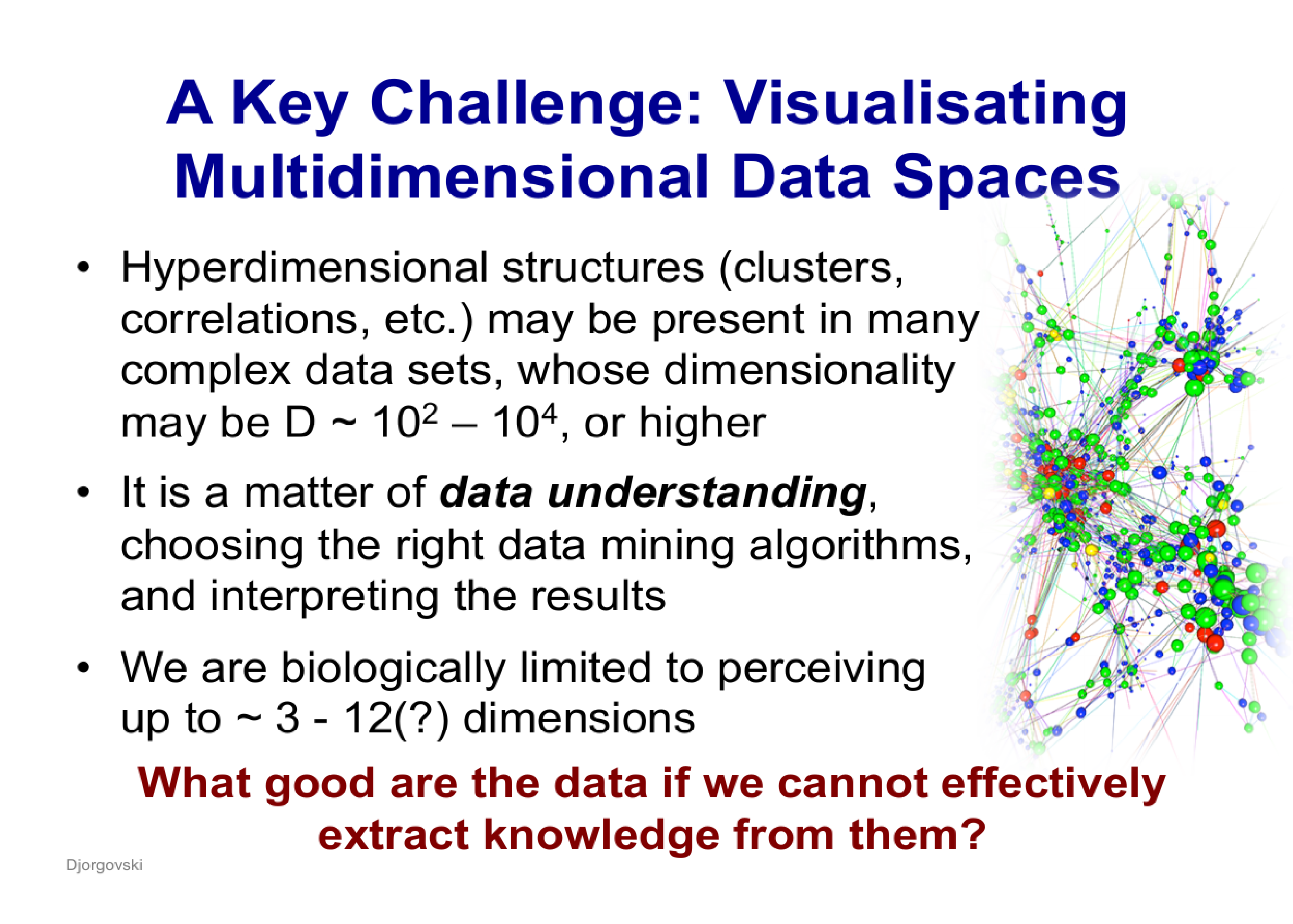
D >> 3 parameter space hypercube

High-D data cloud: mostly noise, of an arbitrary distribution

But in some corner of some sub-D projection of this data space, there is ***something ≠ noise***

Djorgovski

Visualization in Machine Learning



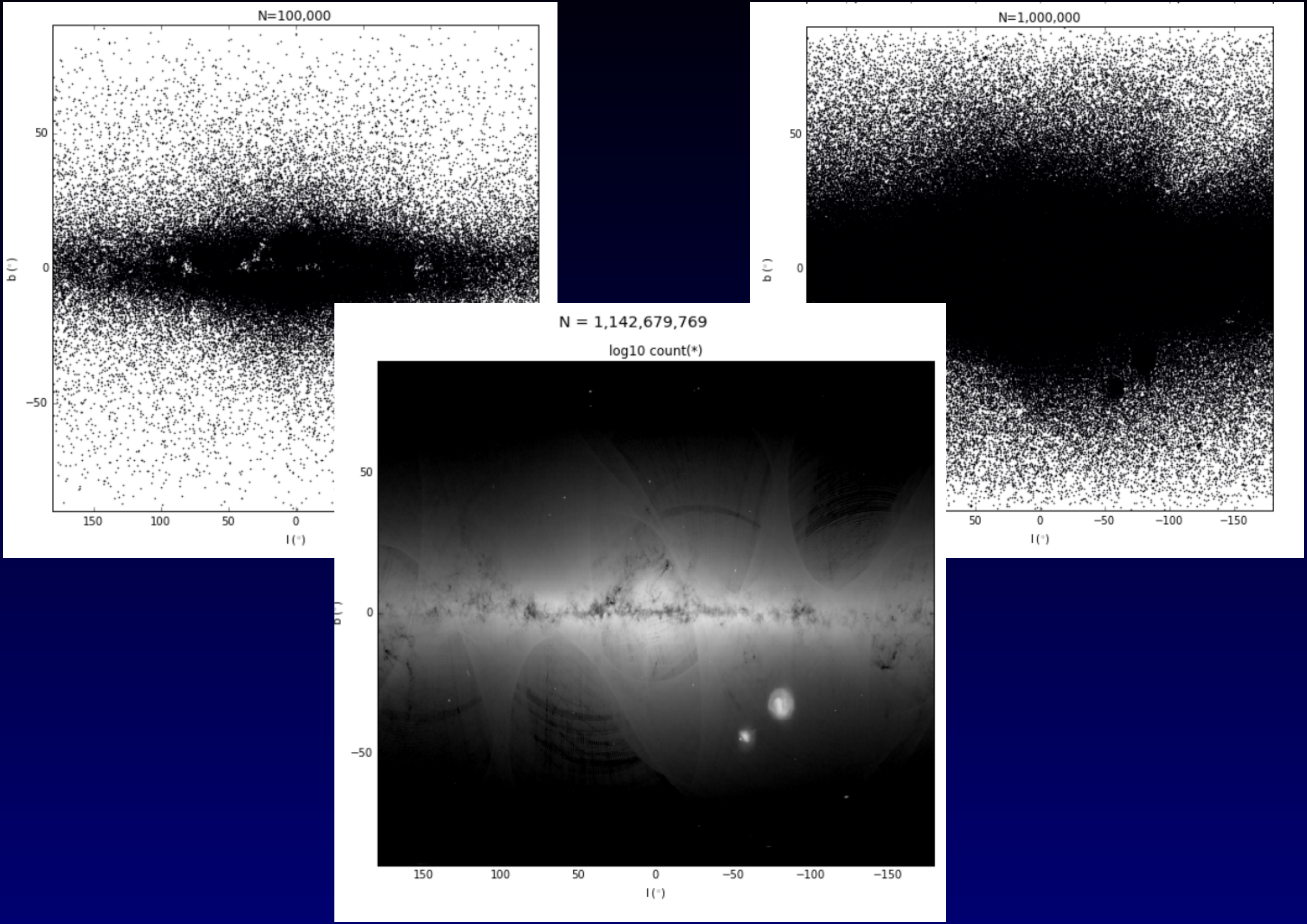
A Key Challenge: Visualisating Multidimensional Data Spaces

- Hyperdimensional structures (clusters, correlations, etc.) may be present in many complex data sets, whose dimensionality may be D ~ $10^2 – 10^4$, or higher
- It is a matter of ***data understanding***, choosing the right data mining algorithms, and interpreting the results
- We are biologically limited to perceiving up to ~ 3 - 12(?) dimensions

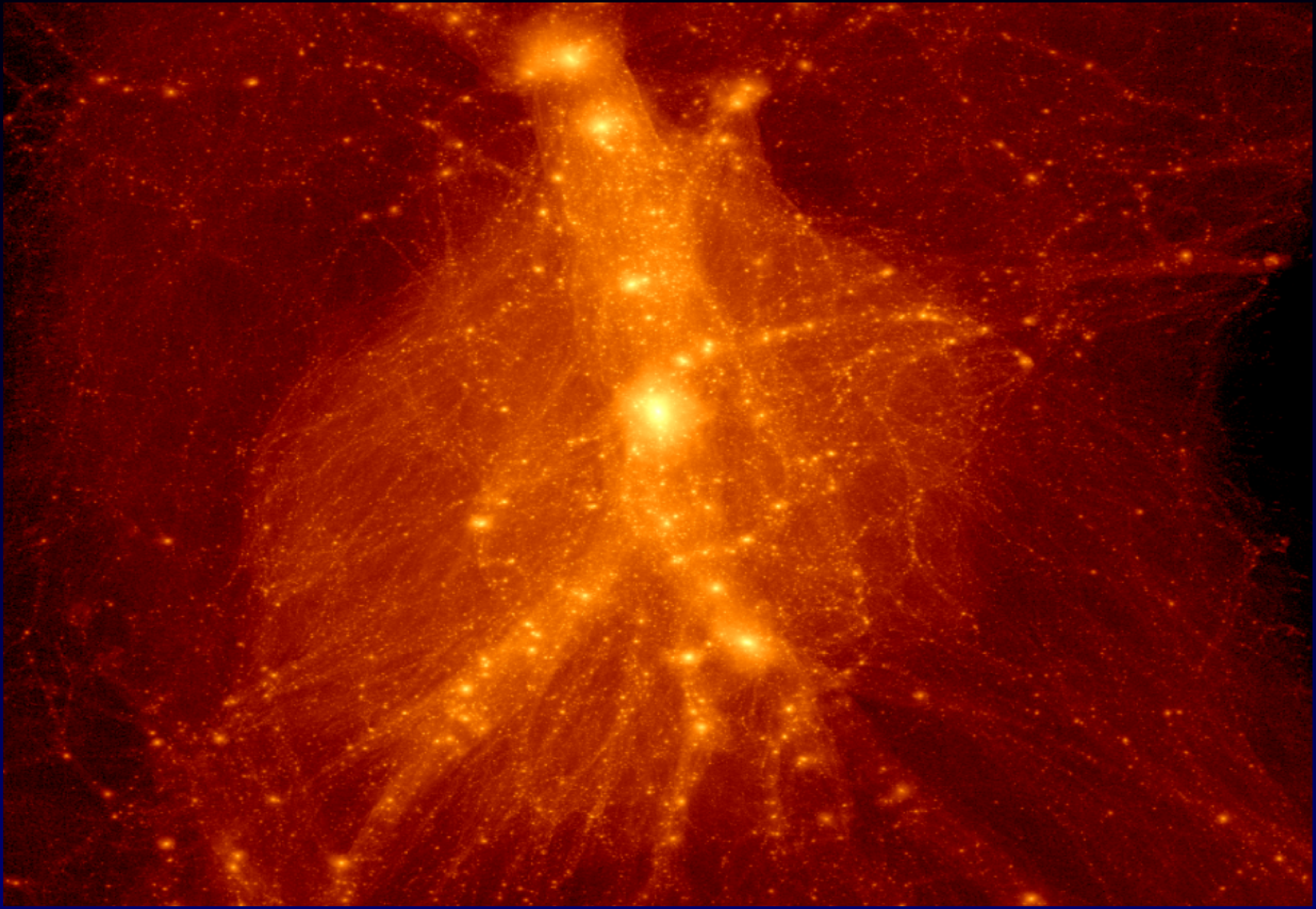
What good are the data if we cannot effectively extract knowledge from them?

Djorgovski

Visualization of 1 B points – Gaia DR1

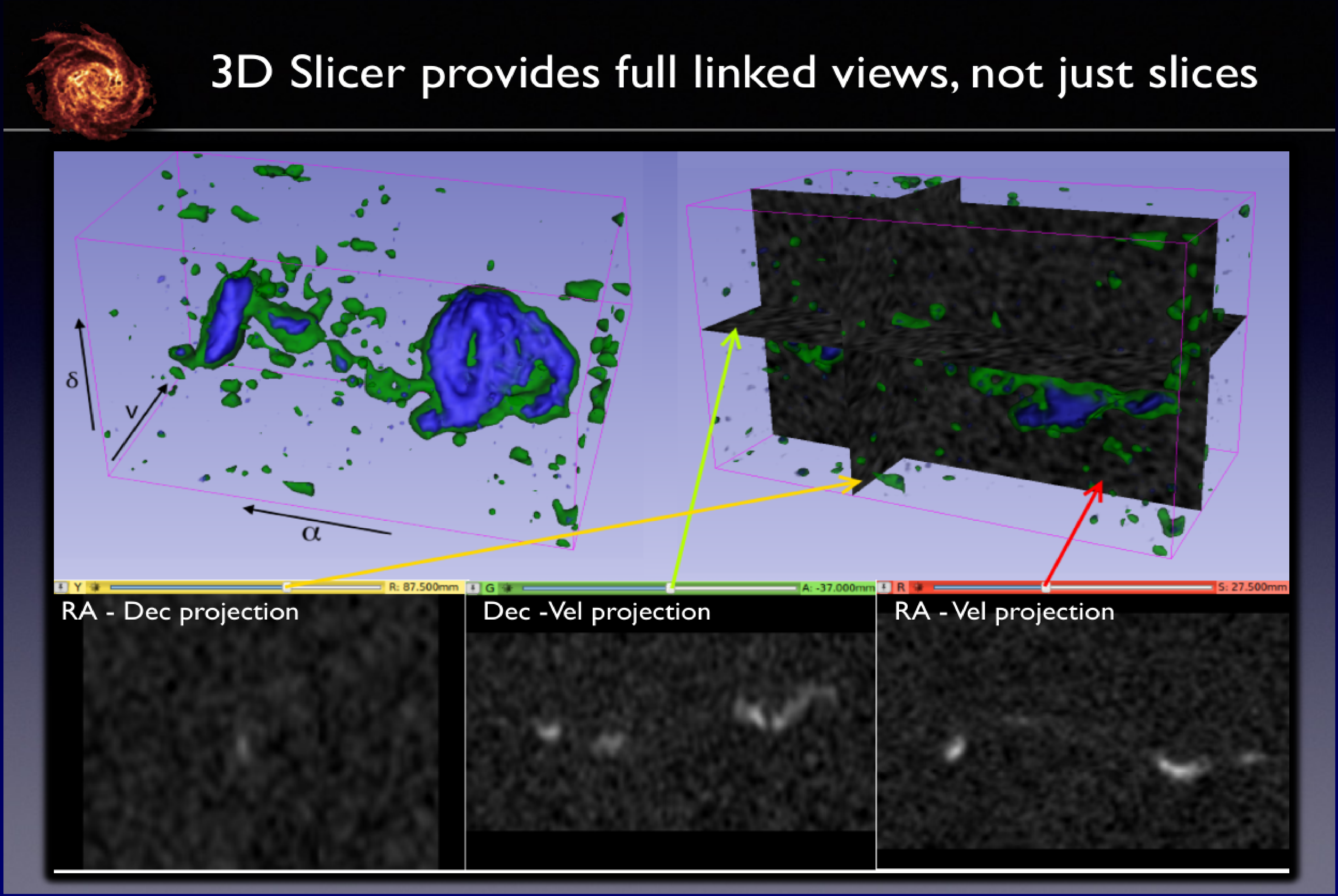


Visualization of Big Data



Visualization of Big Data

Visualization of Radio Data Cubes



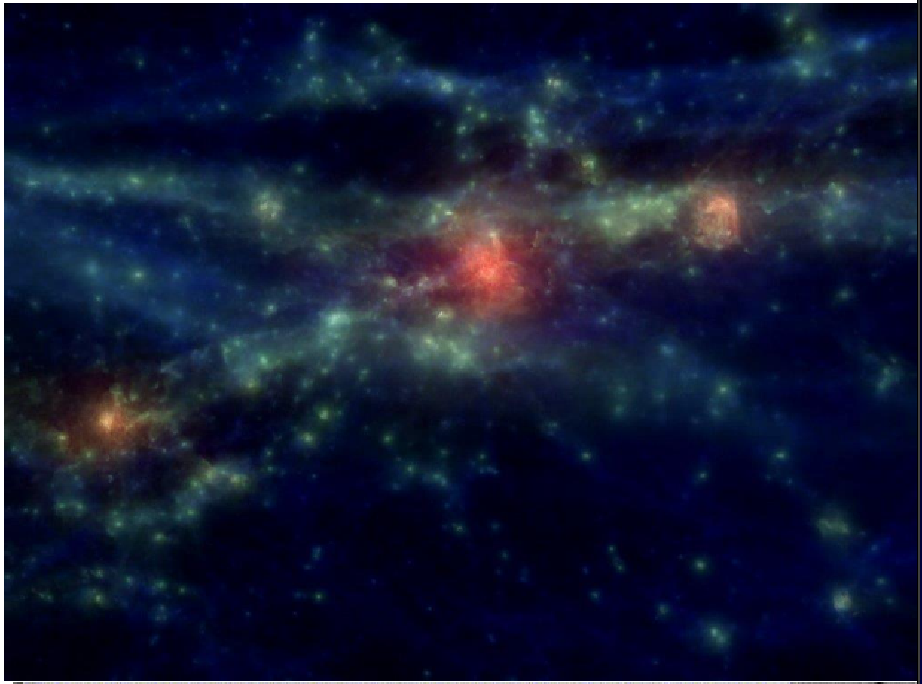
3D Slicer provides full linked views, not just slices

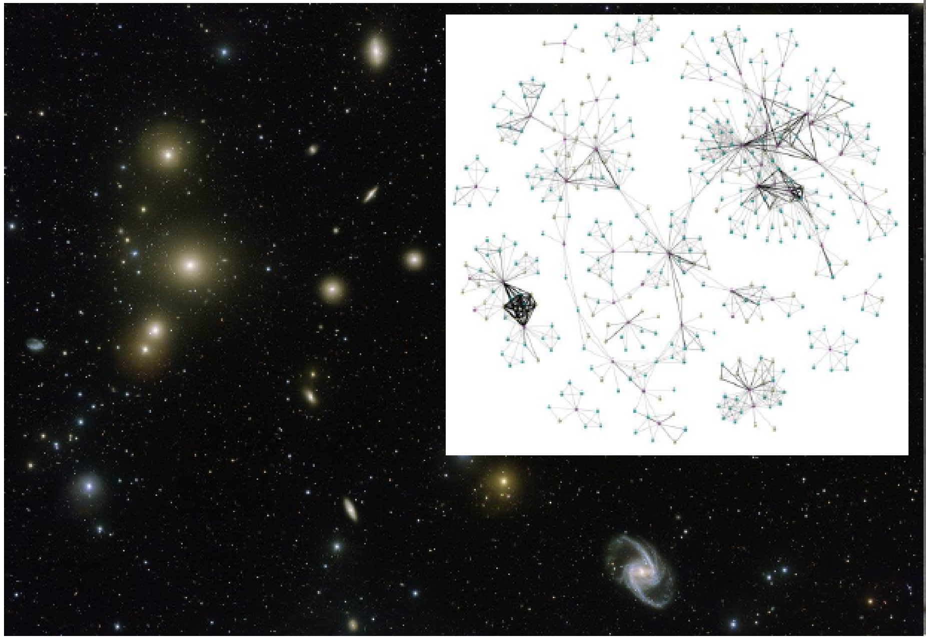
Advanced Visualization

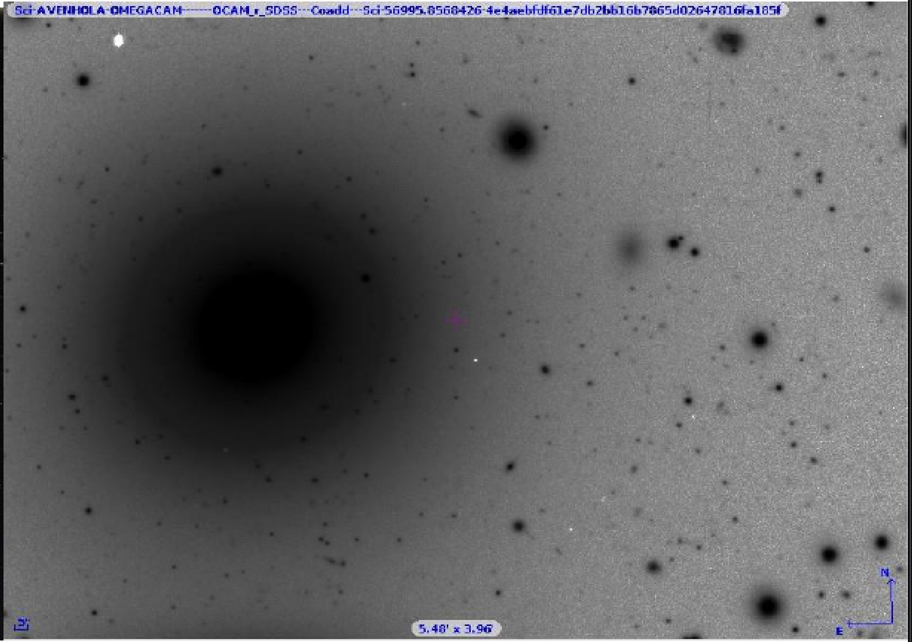
Visualization

- Develop visual data analytic tools to optimally visualize simulations and observations.

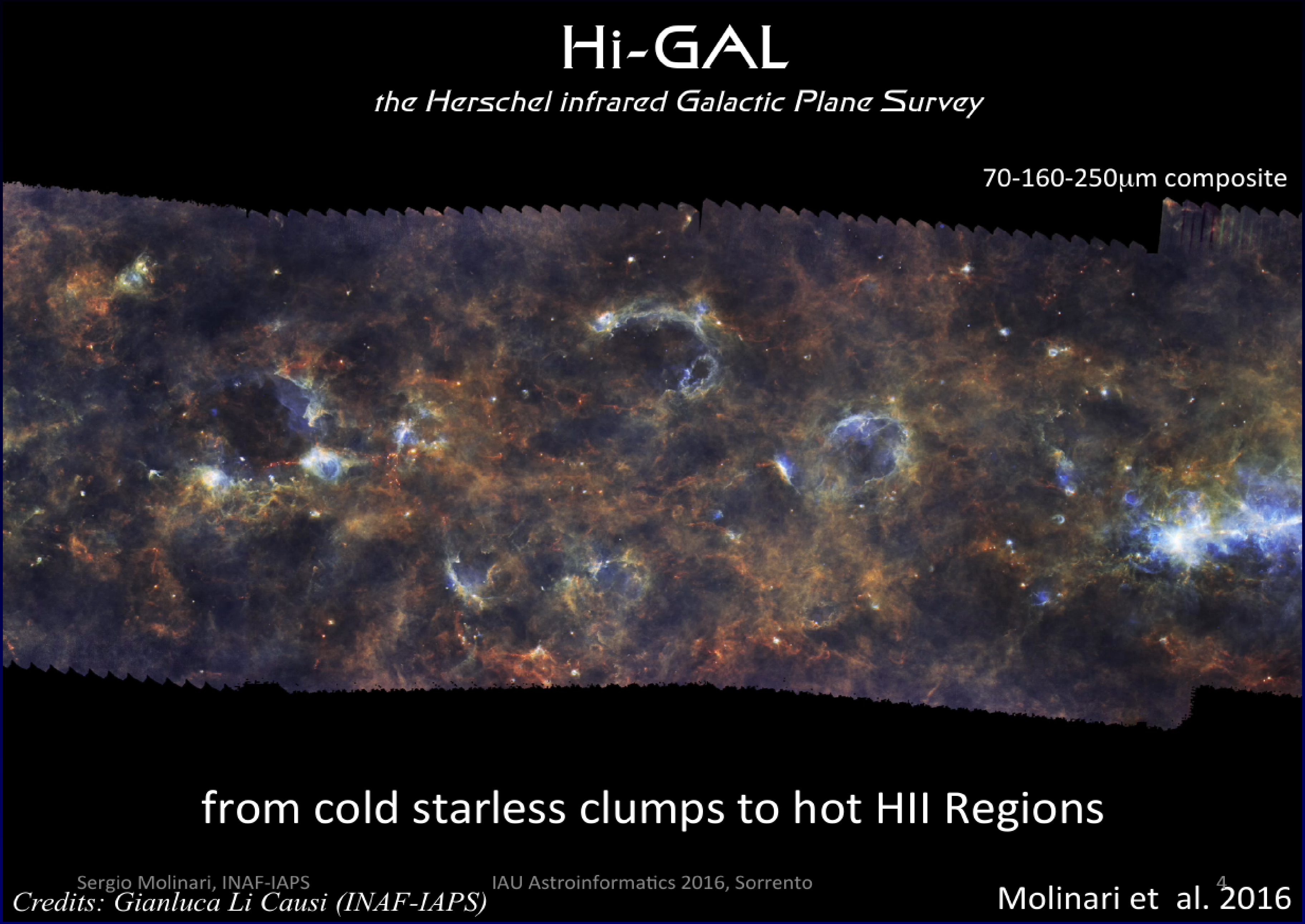
- Follow newest developments, in connection with companies.






Sci-AVENHOLA-OMEGACAM------OCAM_r_SDSS---Coadd---Sci-56995.8568426-4e4aebfdf61e7db2bb16b7865d02647816fa185f
5.48' x 3.96'
N
E

Star Forming Regions in Galaxy



Hi-GAL

the Herschel infrared Galactic Plane Survey

70-160-250μm composite

from cold starless clumps to hot HII Regions

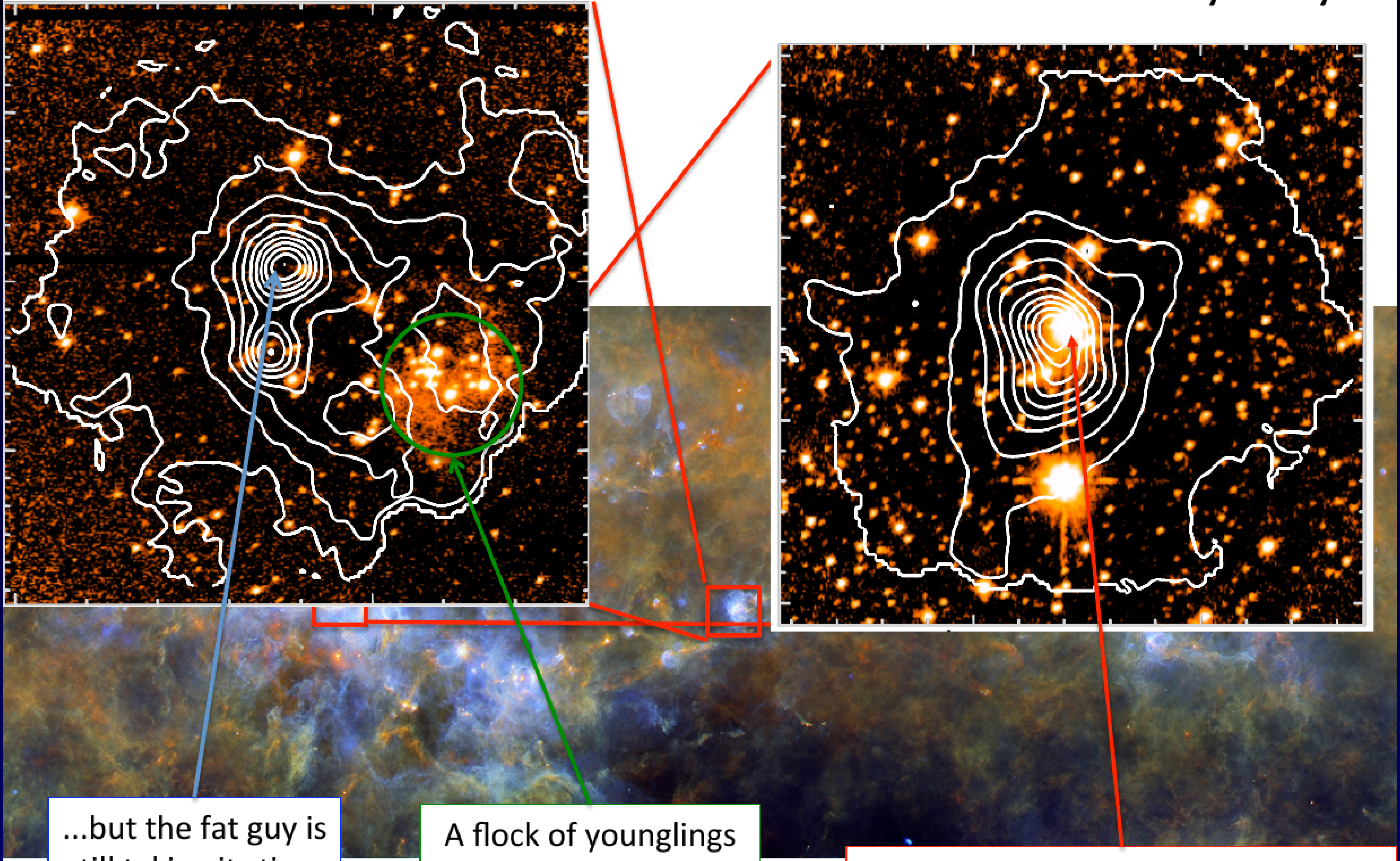
Sergio Molinari, INAF-IAPS IAU Astroinformatics 2016, Sorrento 4

Credits: Gianluca Li Causi (INAF-IAPS)

Molinari et al. 2016

Via Lactea – Star Forming

Star Formation Histories in Nurseries across the Milky Way

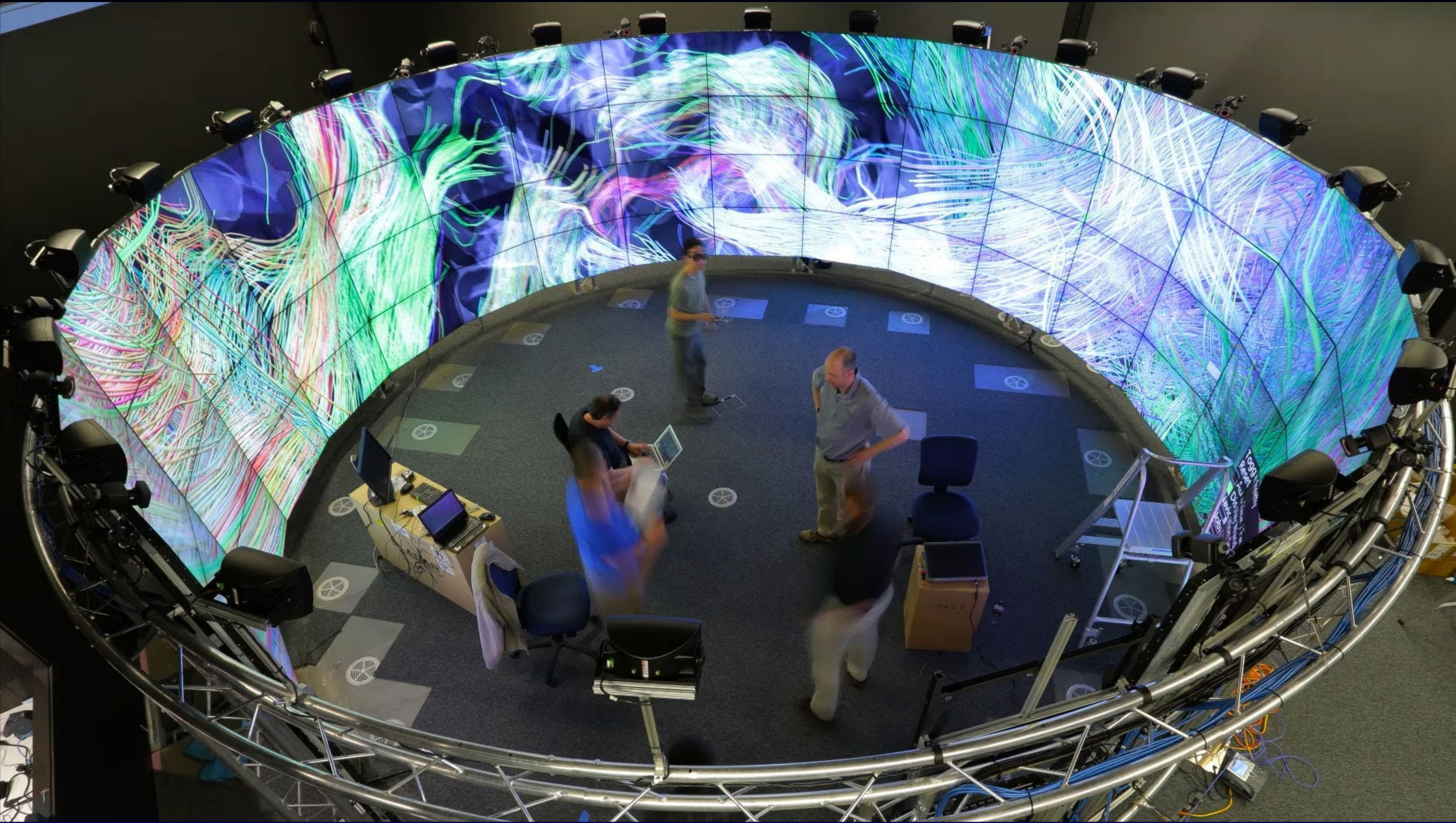


...but the fat guy is still taking its time

A flock of younglings is about to be born

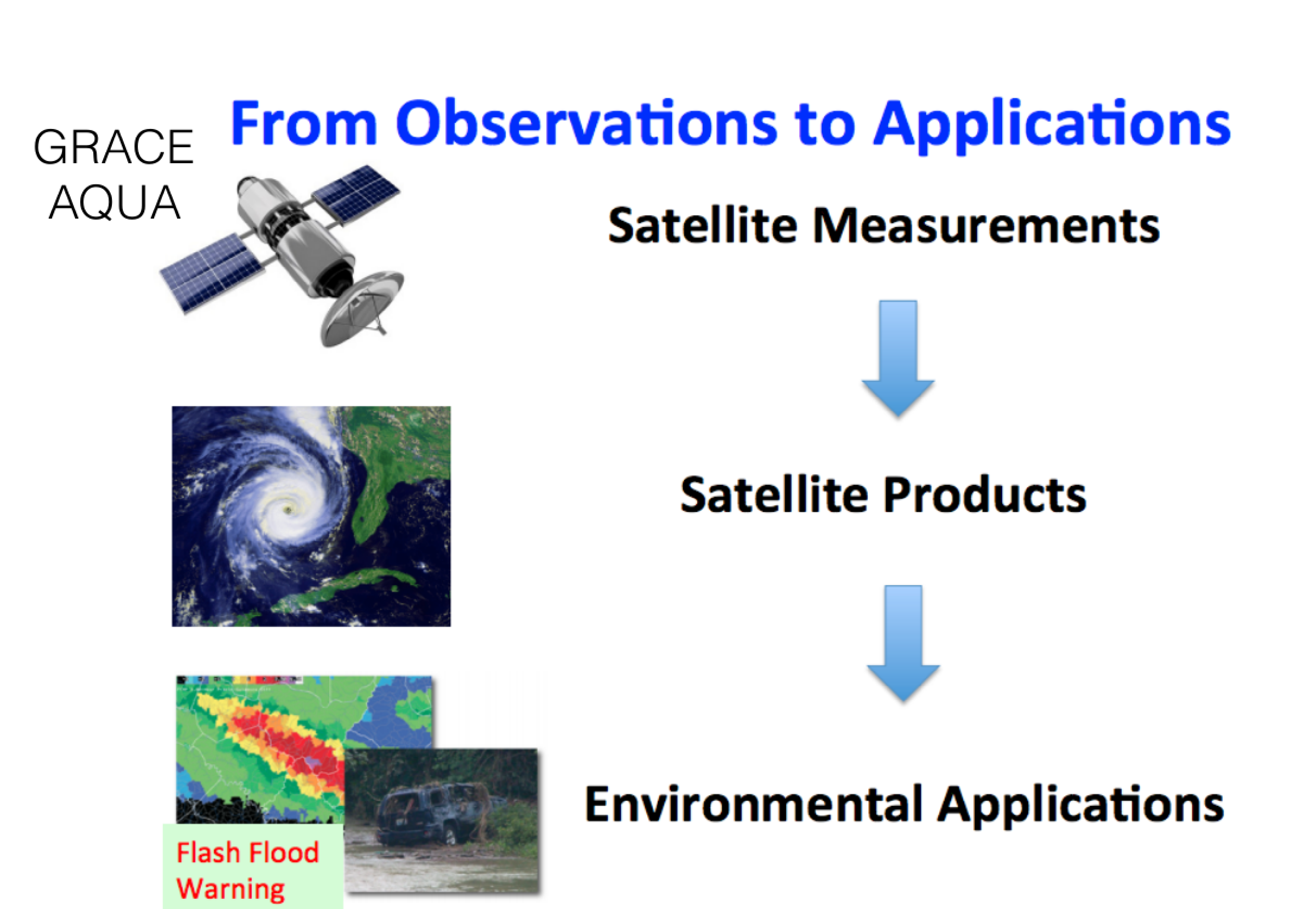
The fat guy is already almost formed

CAVE2 Monash University AU



8m diameter, 330 deg FOV , 80x LCD 46“ 1366x768 Stereo + head tracking …...

From Astronomy to Earth Sciences



From Observations to Applications

GRACE
AQUA

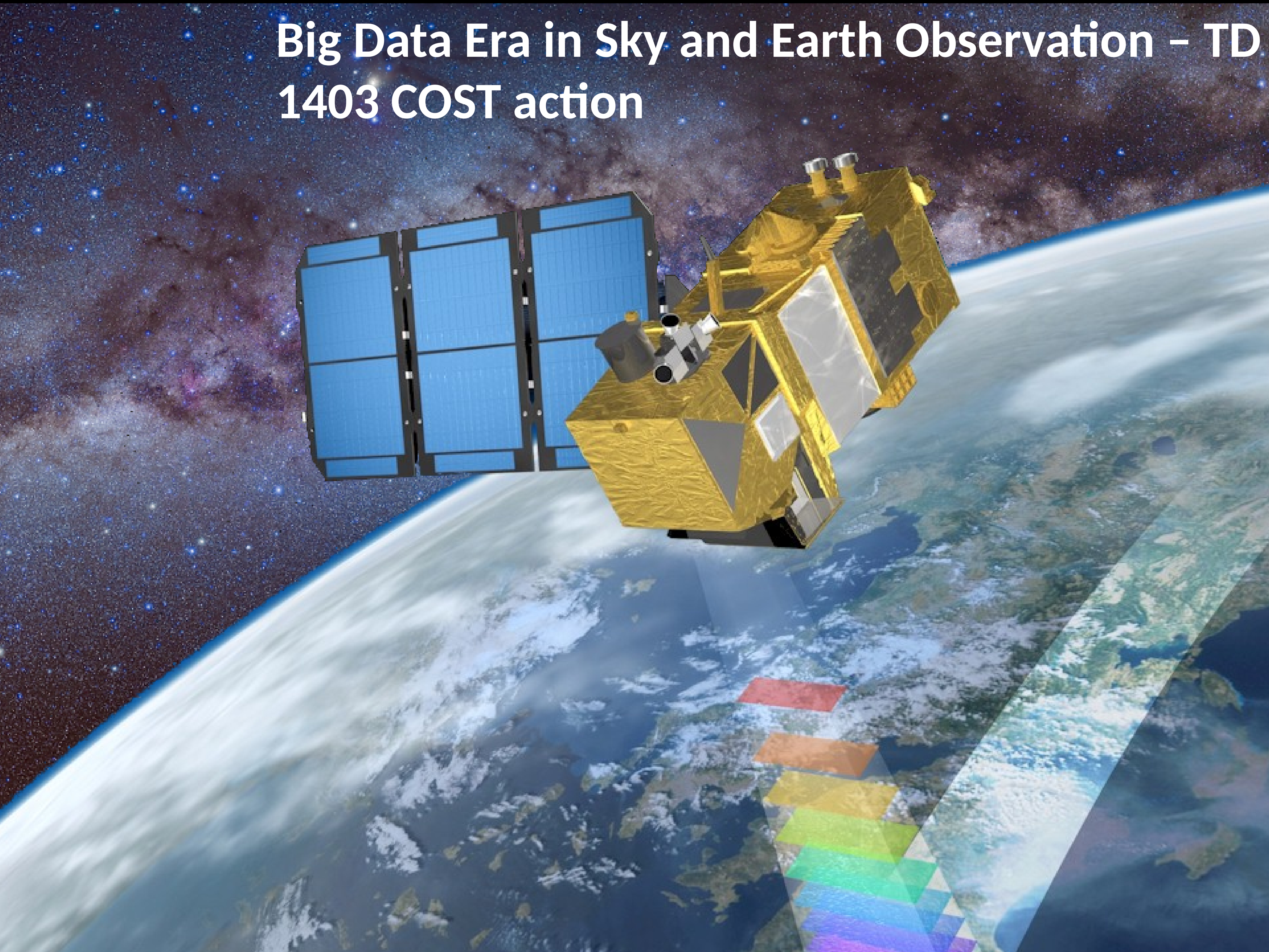
Satellite Measurements

Satellite Products

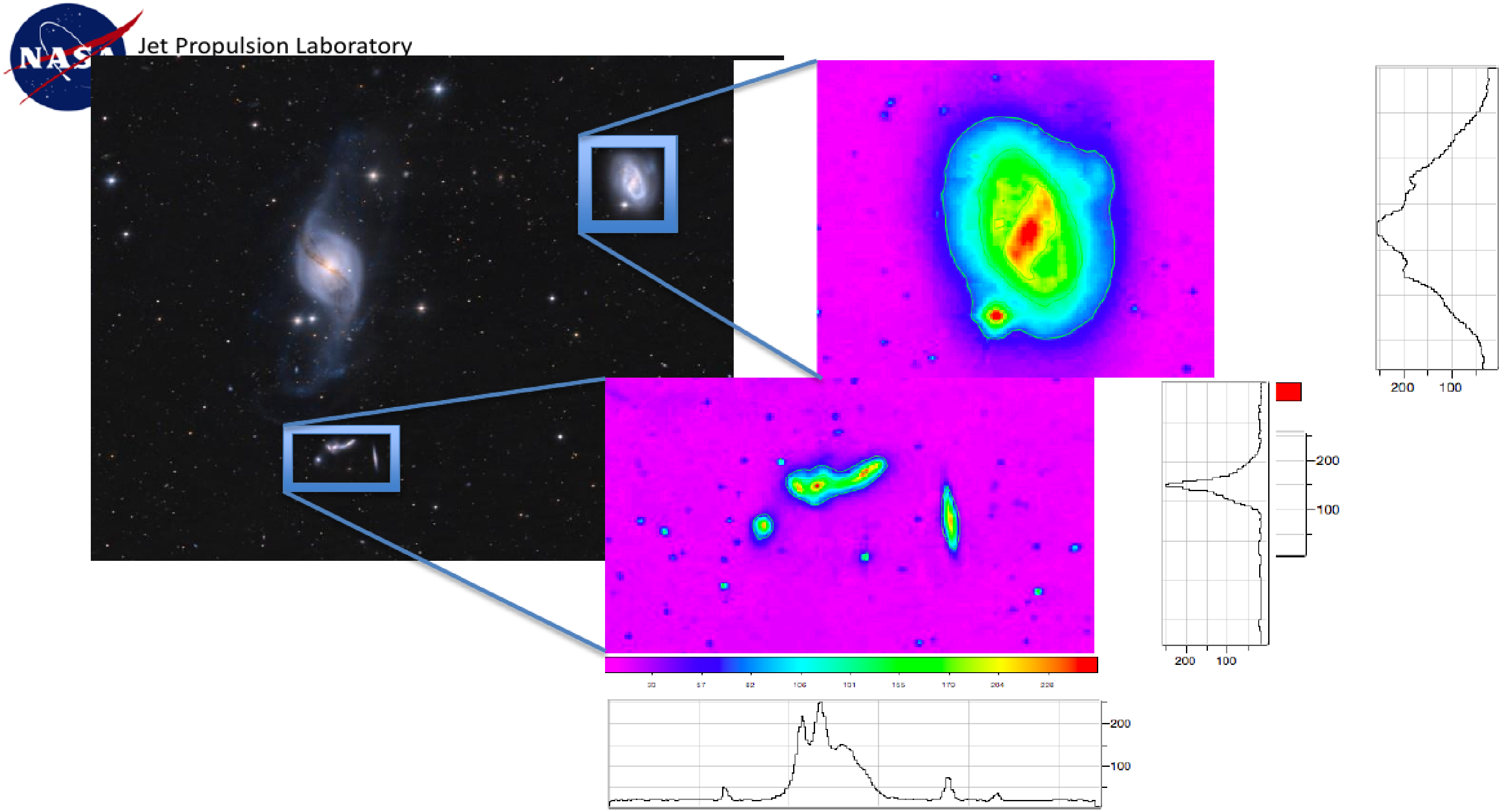
Environmental Applications

Flash Flood
Warning

Big Data Era in Sky and Earth Observation – TD 1403 COST action

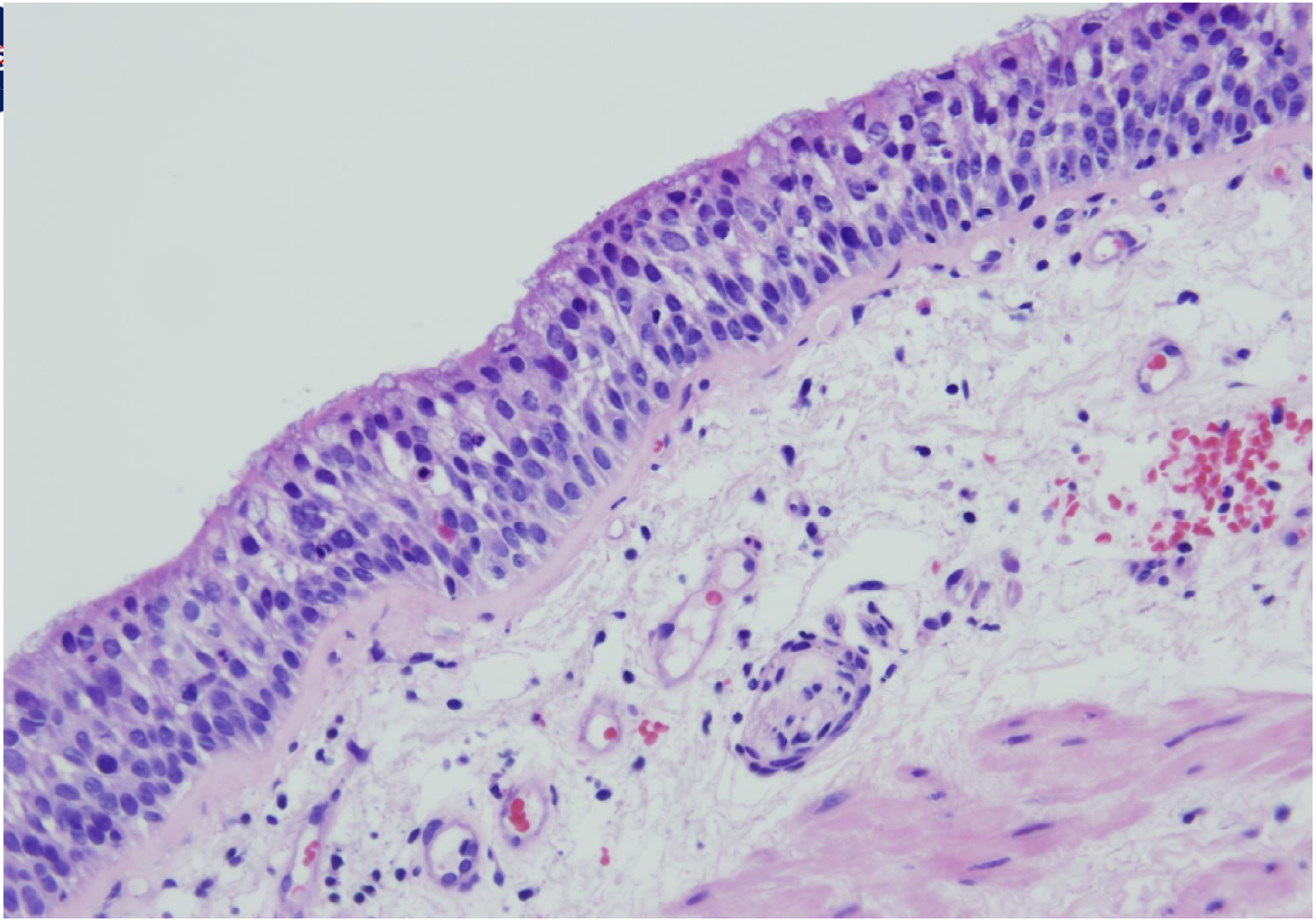


Finding Galaxies by Shape NASA



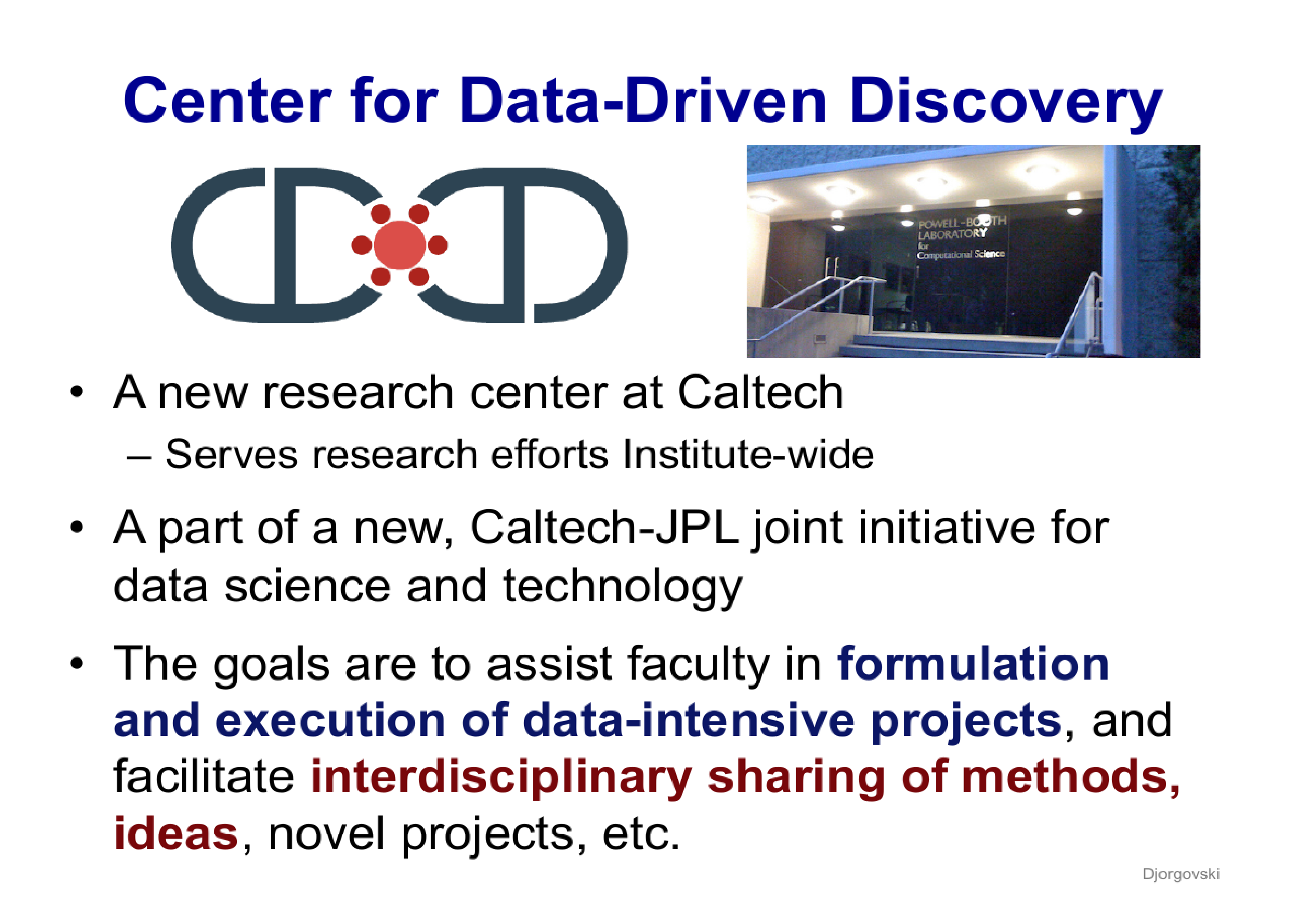
Description: Detecting objects from astronomical measurements by evaluating light measurements in pixels using intelligent software algorithms.
Image Credit: Catalina Sky Survey (CSS), of the Lunar and Planetary Laboratory, University of Arizona, and Catalina Realtime Transient Survey (CRTS), Center for Data-Driven Discovery, Caltech.

Finding Cancer Signatures NASA



Description: Detecting objects from oncology images using intelligent software algorithms transferred to and from space science.
Image Credit: EDRN Lung Specimen Pathology image example, University of Colorado

New e-Science Collaborations



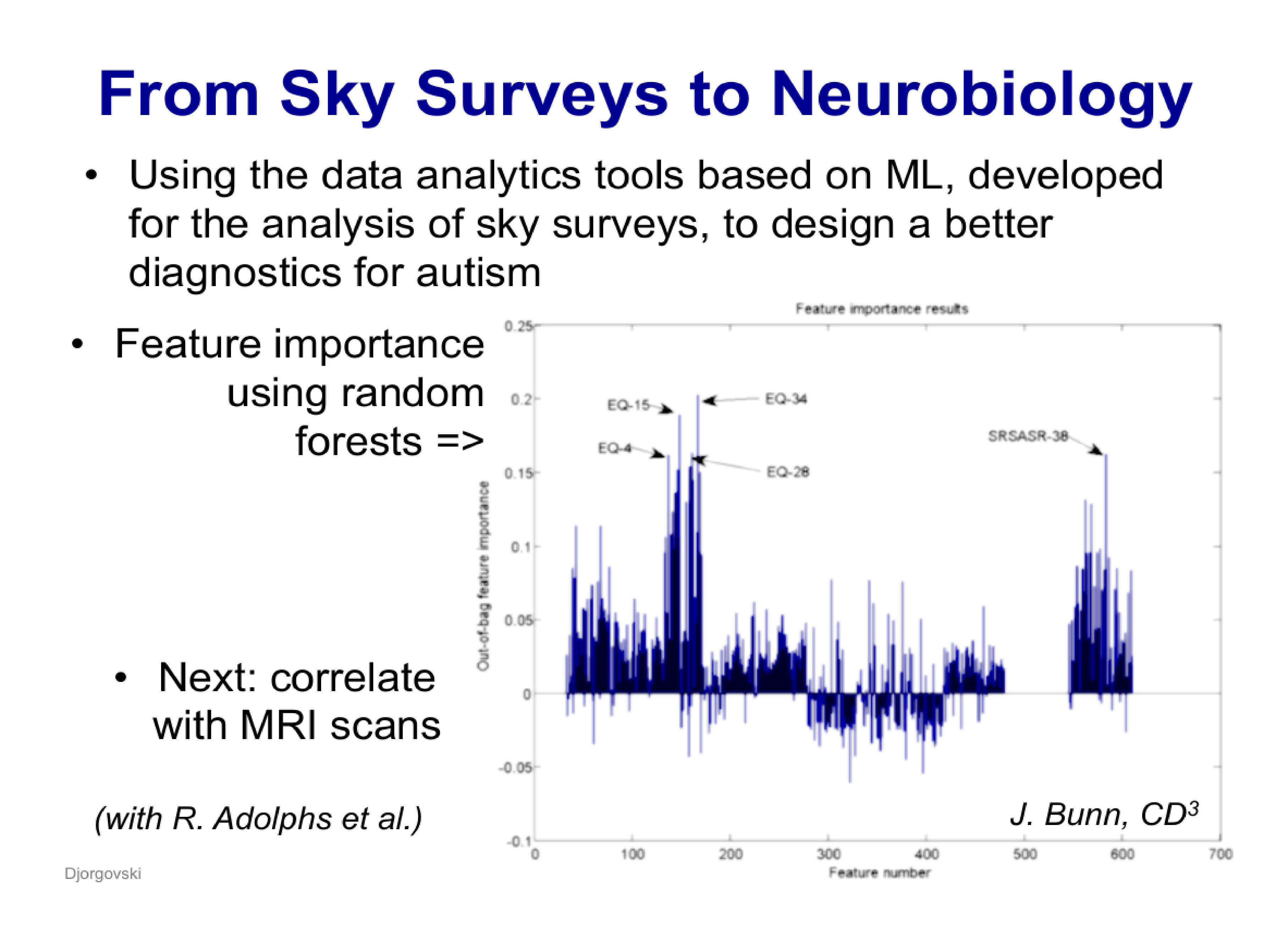
POWELL-BOOTH
LABORATORY
for
Computational Science

Center for Data-Driven Discovery

- A new research center at Caltech
  - Serves research efforts Institute-wide
- A part of a new, Caltech-JPL joint initiative for data science and technology
- The goals are to assist faculty in **formulation and execution of data-intensive projects**, and facilitate **interdisciplinary sharing of methods, ideas**, novel projects, etc.

Djorgovski

Astro-Neurology



From Sky Surveys to Neurobiology

- Using the data analytics tools based on ML, developed for the analysis of sky surveys, to design a better diagnostics for autism

- Feature importance using random forests =>

- Next: correlate with MRI scans

(with R. Adolphs et al.)

J. Bunn, CD^3

Djorgovski

U-Science, Carbon Computing

e-Science emerged ~10 yrs ago using the web protocols that were common at that time:
– web services, XML-based information exchange, registries, distributed data access, distributed computing (Grid) = machine-to-machine communication

U-Science is now emerging from today's web protocols:
– social networking, ubiquitous devices, user-centric experiences, user-led activities, user-generated content, wikis, blogs, mashups, tagging, annotation, ontologies (semantic web), folksonomies, knowledge-sharing, user recommendations = user-to-user communication

- The emergence of Citizen Science:

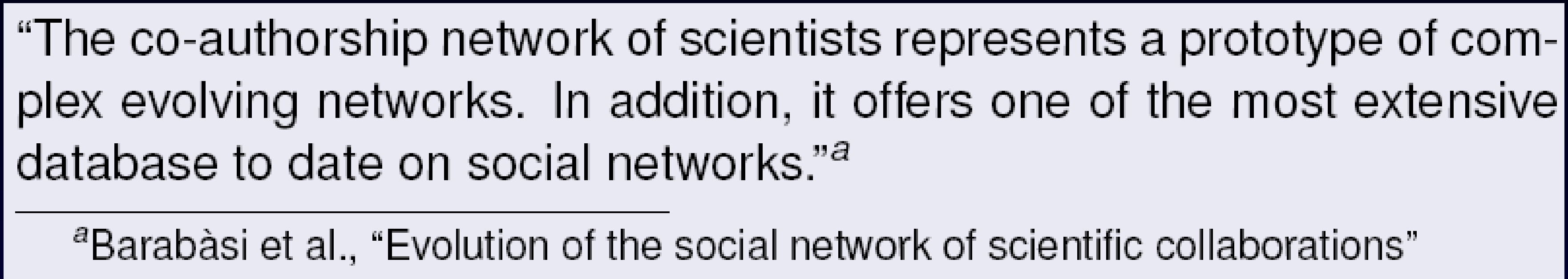
– Anybody can participate in the science discovery process

- Anyone can annotate, tag, and label scientific results:

– scientists, students, and citizen scientists

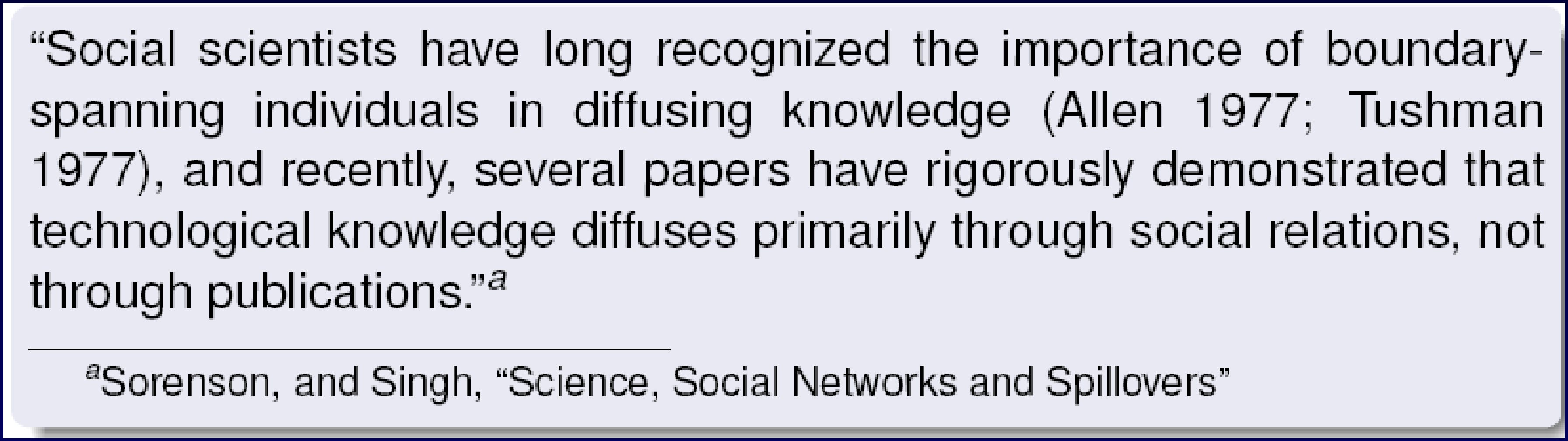
From K. Borne AI2010

Scientific Communities



"The co-authorship network of scientists represents a prototype of complex evolving networks. In addition, it offers one of the most extensive database to date on social networks."[a]

[a] Barabàsi et al., "Evolution of the social network of scientific collaborations"



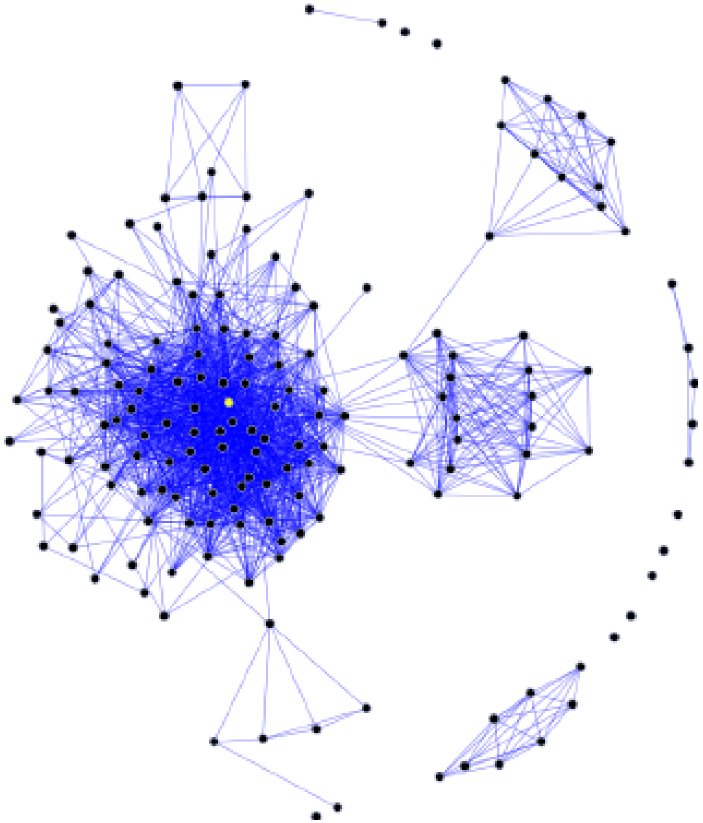
"Social scientists have long recognized the importance of boundary-spanning individuals in diffusing knowledge (Allen 1977; Tushman 1977), and recently, several papers have rigorously demonstrated that technological knowledge diffuses primarily through social relations, not through publications."[a]

[a] Sorenson, and Singh, "Science, Social Networks and Spillovers"

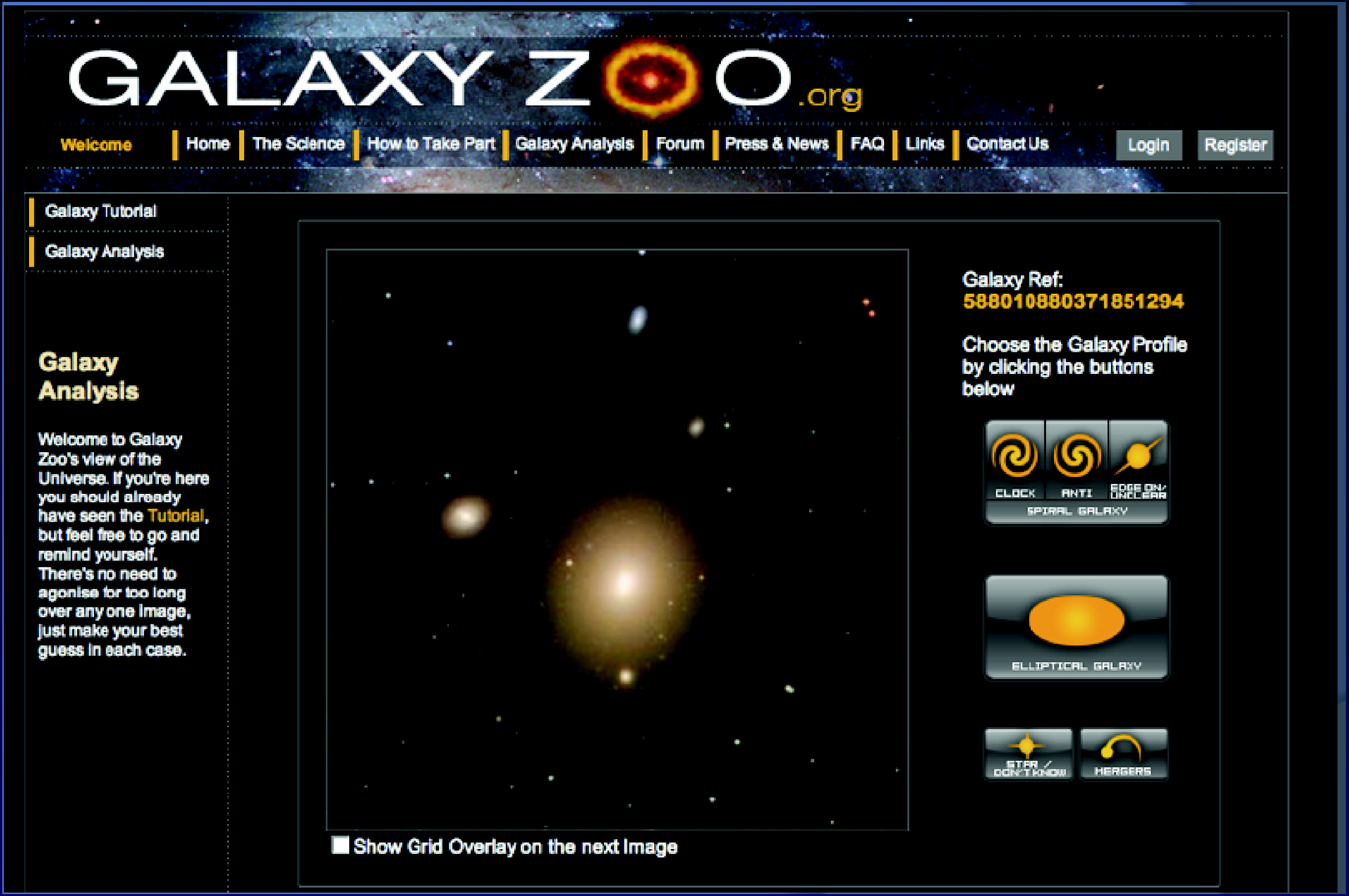
From O. Laurino - AI2010

Motivations of a social networking IT platform for science

- The importance of boundary-spanning individuals in social networks might be what X-informatics is all about;
- we break scientific *cliques* and create new, unexpected, effective links across the science community's network;
- an effective scientific social network platform may be an effective step towards *seamless astronomy*. Seamless not only in terms of data and applications access, but also in terms of social interactions between people in the scientific network.



Galaxy ZOO



Galaxy Analysis

Welcome to Galaxy Zoo's view of the Universe. If you're here you should already have seen the Tutorial, but feel free to go and remind yourself. There's no need to agonise for too long over any one image, just make your best guess in each case.

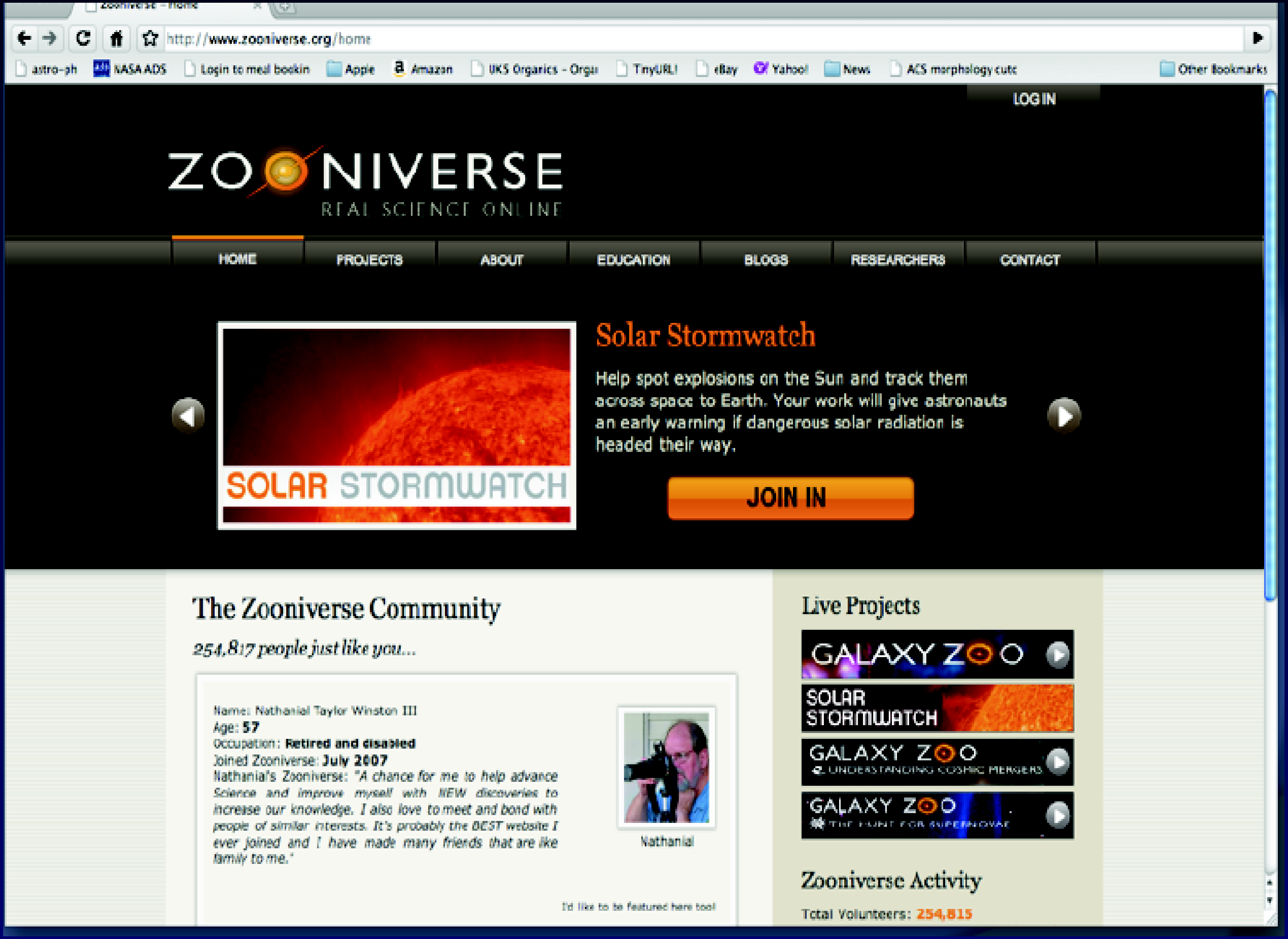
Galaxy Ref:
588010880371851294

Choose the Galaxy Profile by clicking the buttons below

□ Show Grid Overlay on the next Image

> 20 Science papers published so far

www.zooniverse.org



Solar Stormwatch

Help spot explosions on the Sun and track them across space to Earth. Your work will give astronauts an early warning if dangerous solar radiation is headed their way.

The Zooniverse Community

254,817 people just like you...

Name: Nathanial Taylor Winston III
Age: **57**
Occupation: **Retired and disabled**
Joined Zooniverse: **July 2007**
Nathanial's Zooniverse: *"A chance for me to help advance Science and improve myself with NEW discoveries to increase our knowledge. I also love to meet and bond with people of similar interests. It's probably the BEST website I ever joined and I have made many friends that are like family to me."*

Nathanial

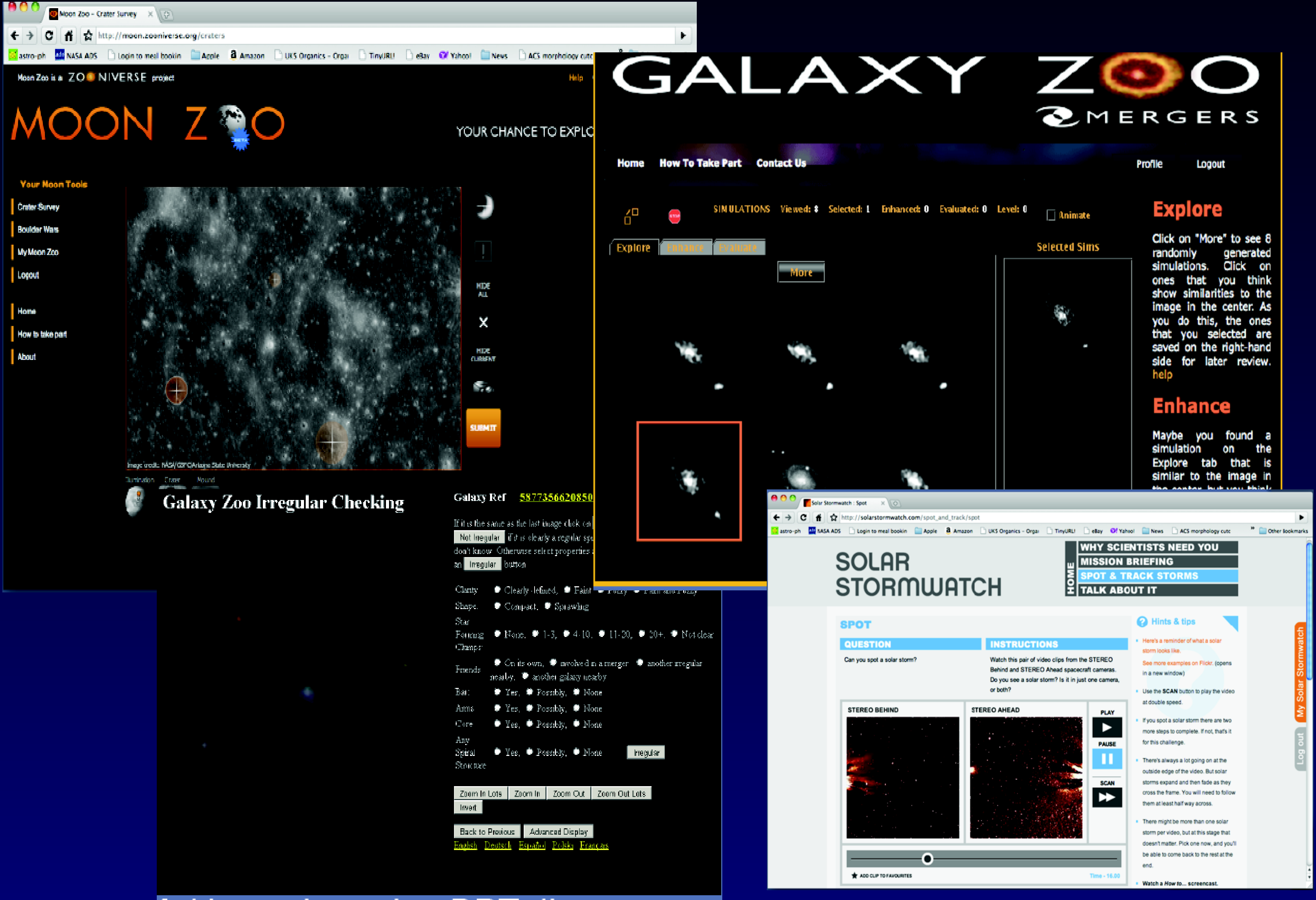
I'd like to be featured here too!

Live Projects

Zooniverse Activity

Total Volunteers: 254,815

Examples ZOOniverse



Explore

Click on "More" to see 8 randomly generated simulations. Click on ones that you think show similarities to the image in the center. As you do this, the ones that you selected are saved on the right-hand side for later review. help

Enhance

Maybe you found a simulation on the Explore tab that is similar to the image in the center, but you think

Galaxy Zoo Irregular Checking

Galaxy Ref 5877356620850

If it is the same as the last image click on
Not Irregular if it is clearly a regular sp
don't know. Otherwise select properties
an Irregular button

Clarity ● Clearly-defined, ● Faint ● Fuzzy ● Faint and Fuzzy
Shape. ● Compact, ● Sprawling
Star Forming Clumps ● None, ● 1-3, ● 4-10, ● 11-20, ● 20+, ● Not clear
Friends ● On its own, ● involved in a merger ● another irregular nearby, ● another galaxy nearby
Bar: ● Yes, ● Possibly, ● None
Arms ● Yes, ● Possibly, ● None
Core ● Yes, ● Possibly, ● None
Any Spiral Structure ● Yes, ● Possibly, ● None Irregular

QUESTION

Can you spot a solar storm?

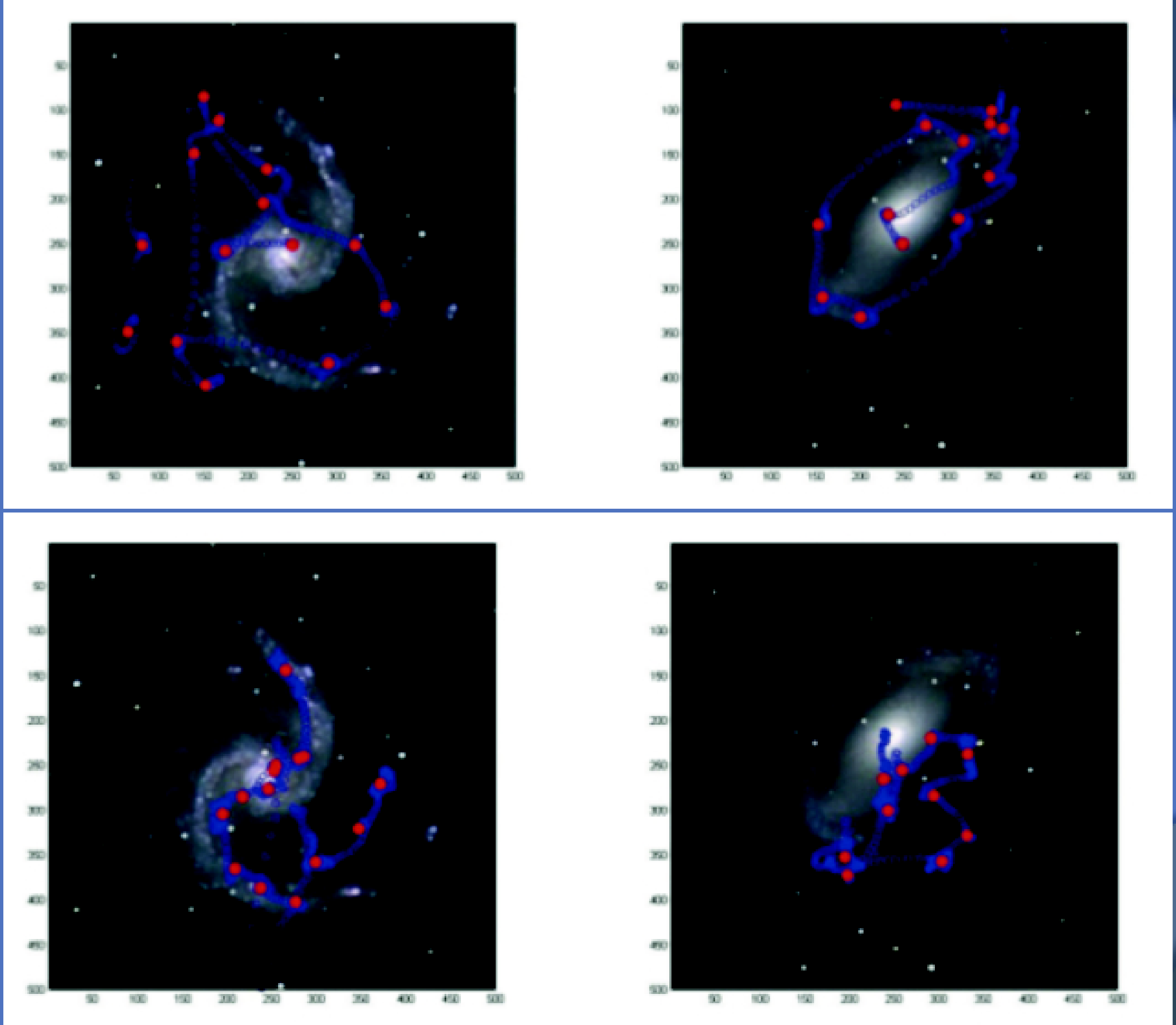
INSTRUCTIONS

Watch this pair of video clips from the STEREO Behind and STEREO Ahead spacecraft cameras. Do you see a solar storm? Is it in just one camera, or both?

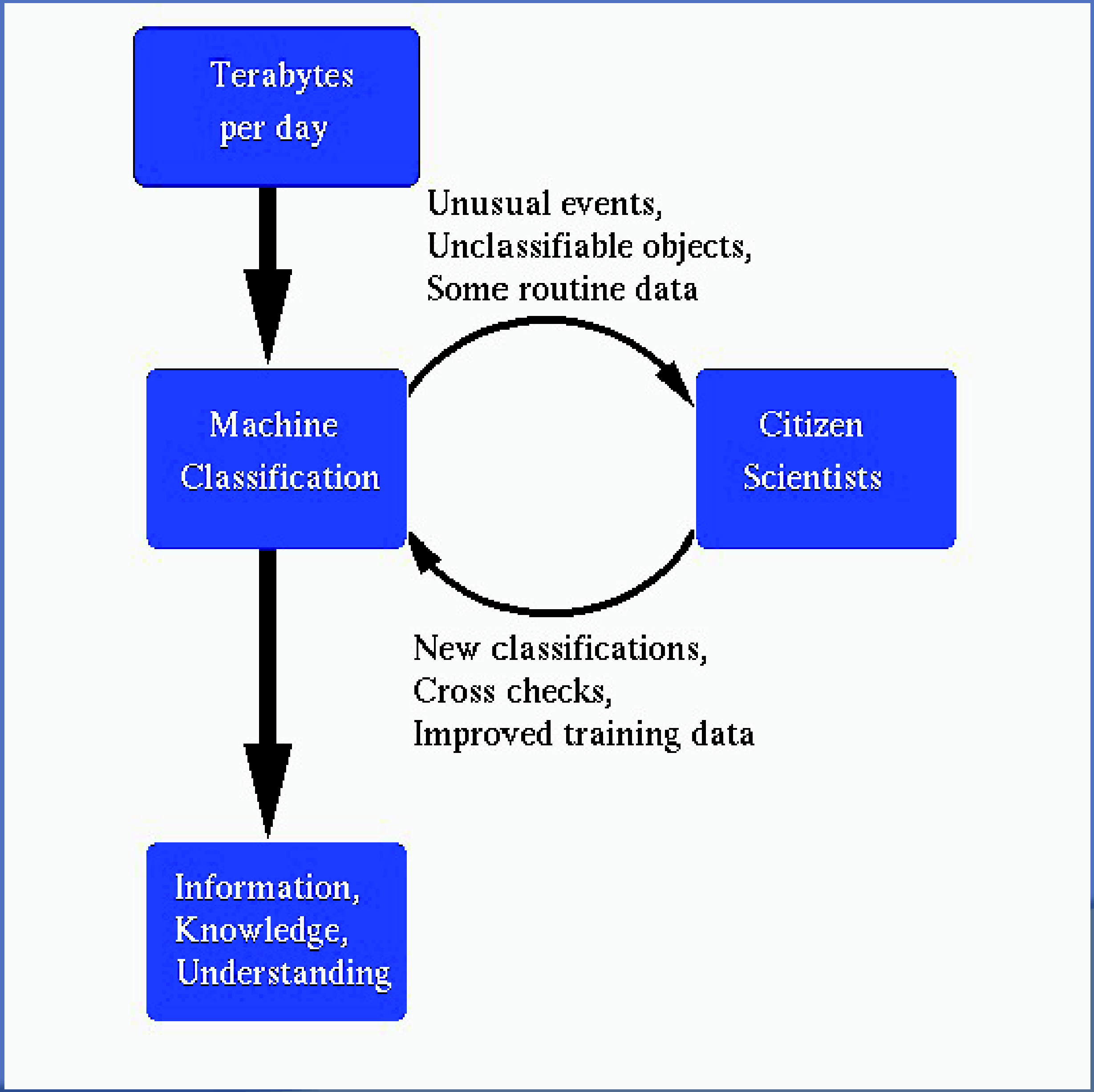
Hints & tips

- Here's a reminder of what a solar storm looks like. See more examples on Flickr. (opens in a new window)
- Use the **SCAN** button to play the video at double speed.
- If you spot a solar storm there are two more steps to complete. If not, that's it for this challenge.
- There's always a lot going on at the outside edge of the video. But solar storms expand and then fade as they cross the frame. You will need to follow them at least half way across.
- There might be more than one solar storm per video, but at this stage that doesn't matter. Pick one now, and you'll be able to come back to the rest at the end.
- Watch a *How to...* screencast.

Expert vs Non-expert Classifier



Machine-Human Learning Cycle



Terabytes per day

Unusual events,
Unclassifiable objects,
Some routine data

Machine Classification

Citizen Scientists

New classifications,
Cross checks,
Improved training data

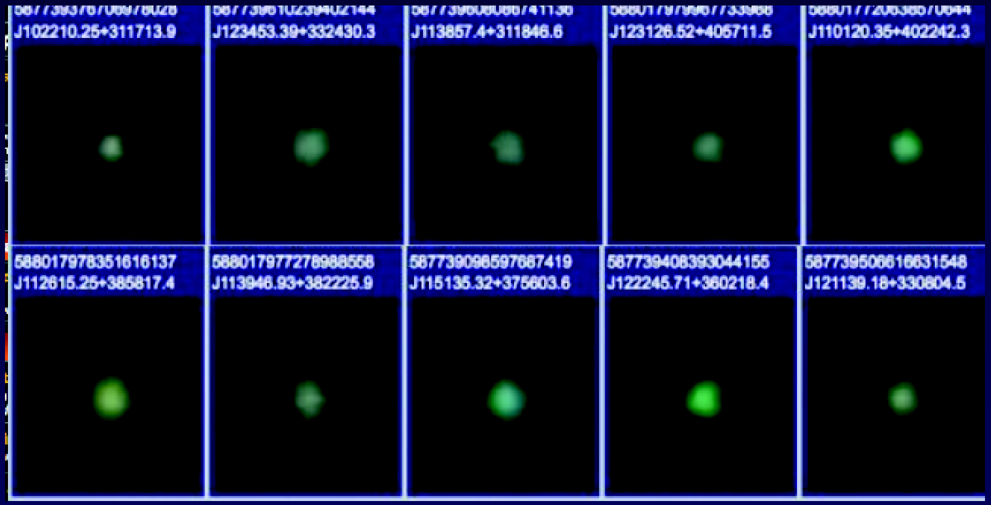
Information,
Knowledge,
Understanding

Citizen Science x Expert Science

Verified by human – training sets

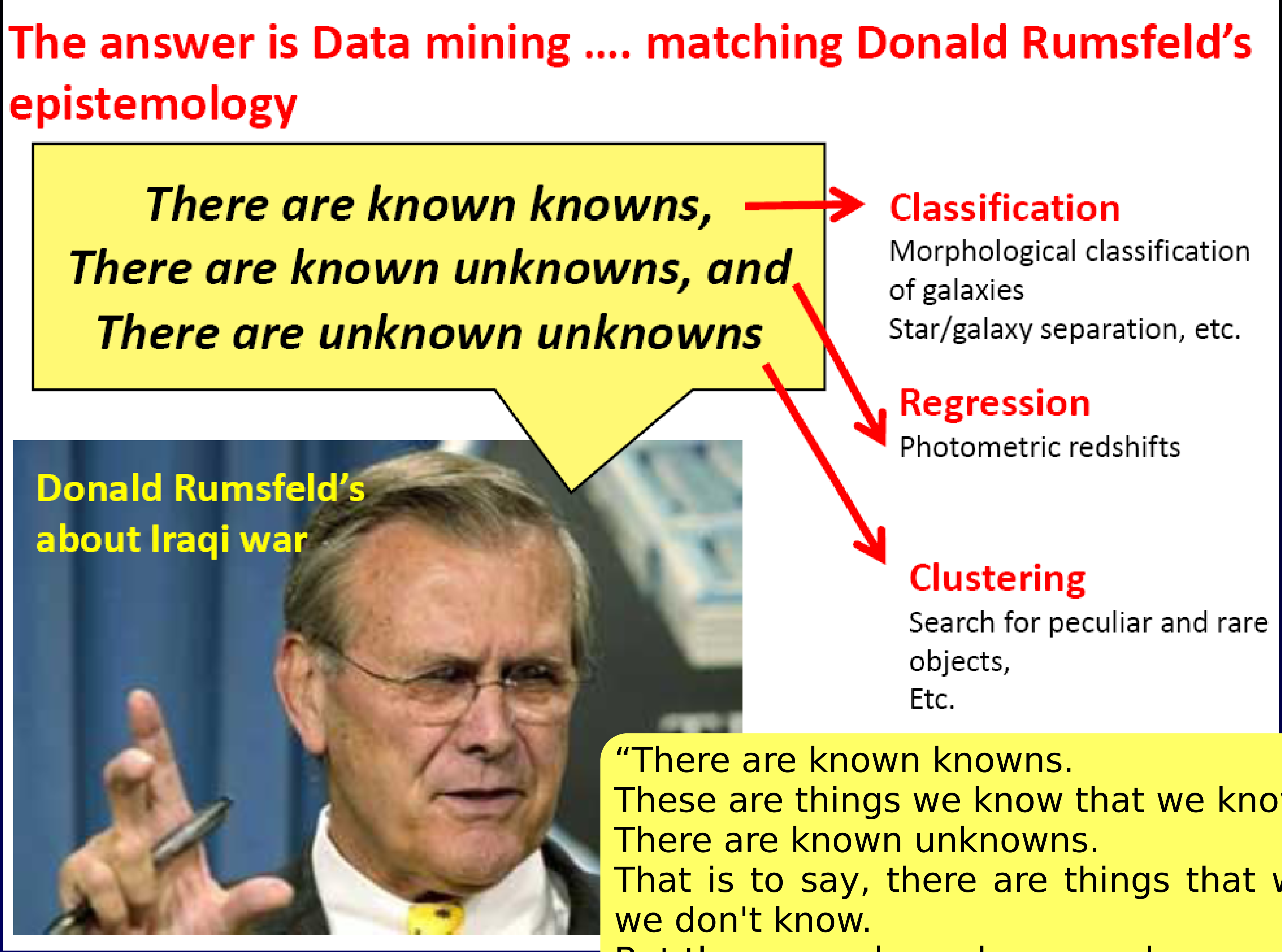
Independent answers=estimate of error

Serendipitious discovery



Galactic Peas

Scale - complexity



The answer is Data mining …. matching Donald Rumsfeld's epistemology

There are known knowns,
There are known unknowns, and
There are unknown unknowns

Classification
Morphological classification of galaxies
Star/galaxy separation, etc.

Regression
Photometric redshifts

Clustering
Search for peculiar and rare objects,
Etc.

Donald Rumsfeld's about Iraqi war

"There are known knowns.
These are things we know that we know.
There are known unknowns.
That is to say, there are things that we know we don't know.
But there are also unknown unknowns.
There are things we don't know we don't know."

Longo 2010

Knowledge Discovery in U-Science

Known knowns :
Primary task. Data reduction by science team.

Known unknowns :
Related to primary task. Results funneled to specific researchers.

Unknown unknowns :
Serendipity. Currently rely on forum moderators to filter.

Hanny van Arkel - Voorwerp

Light echo of quasar?

Challenges of (Astro)informatics

Big Data 3(5)xV

- Complex
- Missing values
- Censoring
- Upper limits
- Parallelization (Massive - GPU – new algorithms)
- Queries in PB table
- Visualization of many dimensions
- Stream processing
- Non- Gaussian Statistics, PDF

Příklady BP a DP na FIT z astroinformatiky a VO

•FIT VUT Brno

1 BP (Random Forests in Astronomy)
1 PhD – Wavelets Dimensionality Reduction (pending)

•VŠB-TU Ostrava

1 BP + 1 DP - SPLAT-VO

•MU PřF Brno

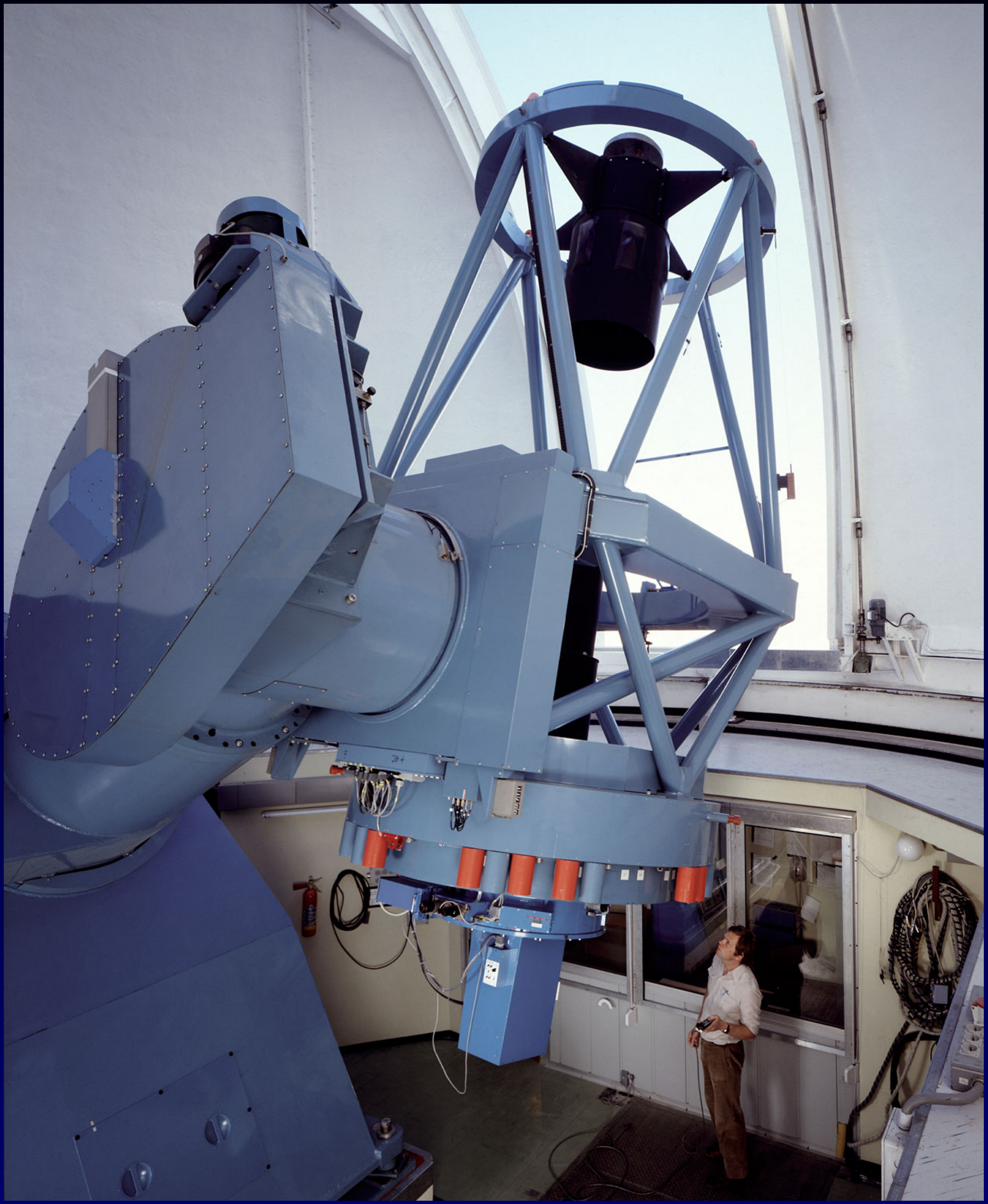
2 DP + 2 PhD. (ML of Spectra (pending) + precise RV for exoplanets – SW ?)

•FIT ČVUT

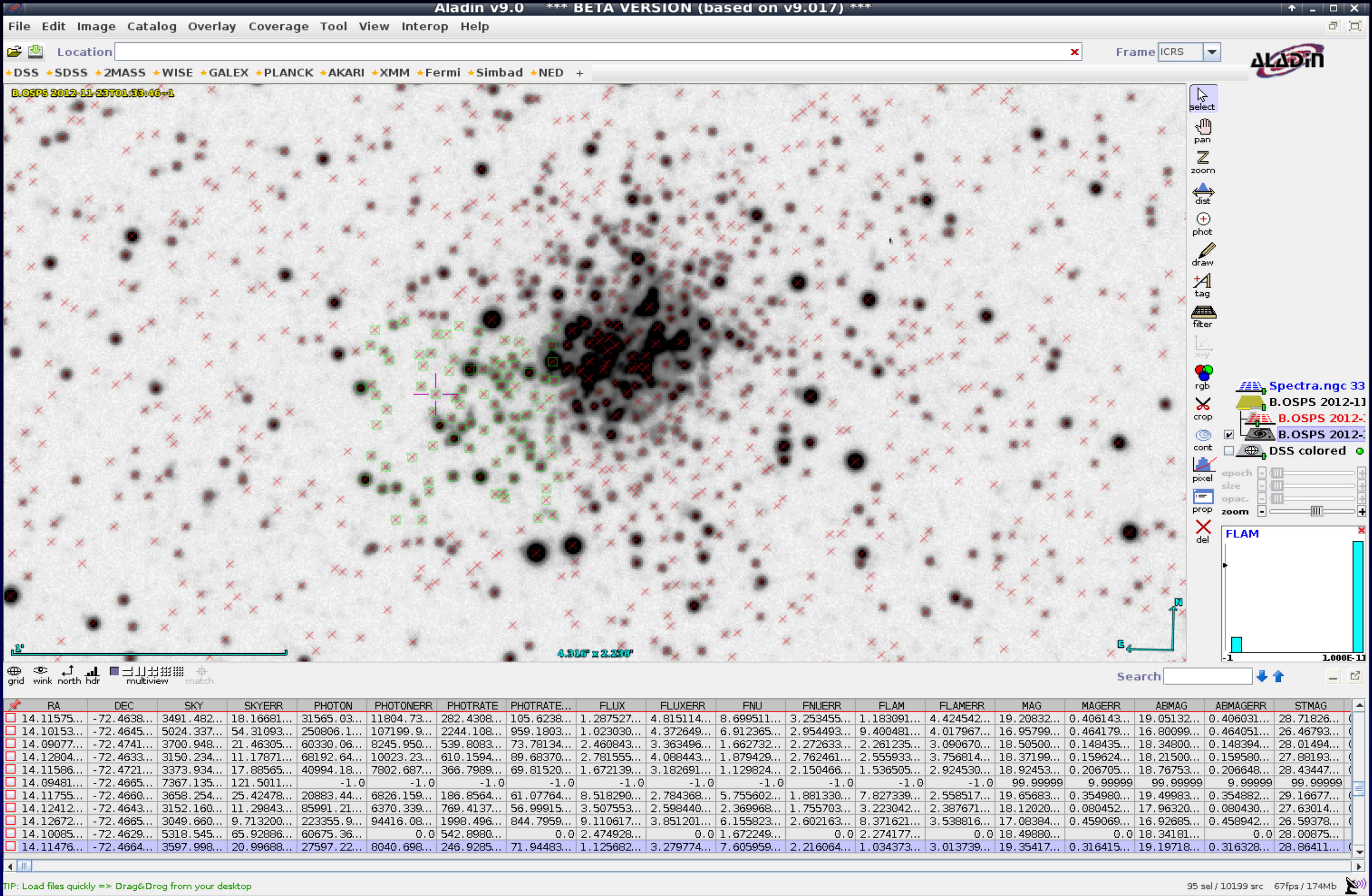
- 2012 2 BP (VO-Korel+SSA proxy)
- 2013 2 BP (OSPS Image + Catalogue Server)
- 2014 2 BP (Random Forests + SOM)
- 2015 1 BP (VO-Cloud)
  2 DP (Clustering OSPS + Deep Learning)
- 2016 2 DP (Semisupervised learning + Outlier finding)
- 2017 1 DP + 2 BP ????

Danish 1.54m at La Silla robotized in Summer 2012

Danish 1.54m Telescope



Reduced OSPS image + bintable photometry in 2nd extension


Aladin v9.0 *** BETA VERSION (based on v9.017) ***
File Edit Image Catalog Overlay Coverage Tool View Interop Help
Location
Frame ICRS
DSS SDSS 2MASS WISE GALEX PLANCK AKARI XMM Fermi Simbad NED
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select pan zoom dist phot draw tag filter x-y rgb crop cont pixel prop del
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B.OSPS 2012-11
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DSS colored
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Search

RA	DEC	SKY	SKYERR	PHOTON	PHOTONERR	PHOTRATE	PHOTRATE...	FLUX	FLUXERR	FNU	FNUERR	FLAM	FLAMERR	MAG	MAGERR	ABMAG	ABMAGERR	STMAG
14.11575...	-72.4638...	3491.482...	18.16681...	31565.03...	11804.73...	282.4308...	105.6238...	1.287527...	4.815114...	8.699511...	3.253455...	1.183091...	4.424542...	19.20832...	0.406143...	19.05132...	0.406031...	28.71826...
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14.11755...	-72.4660...	3658.254...	25.42478...	20883.44...	6826.159...	186.8564...	61.07764...	8.518290...	2.784368...	5.755602...	1.881330...	7.827339...	2.558517...	19.65683...	0.354980...	19.49983...	0.354882...	29.16677...
14.12412...	-72.4643...	3152.160...	11.29843...	85991.21...	6370.339...	769.4137...	56.99915...	3.507553...	2.598440...	2.369968...	1.755703...	3.223042...	2.387671...	18.12020...	0.080452...	17.96320...	0.080430...	27.63014...
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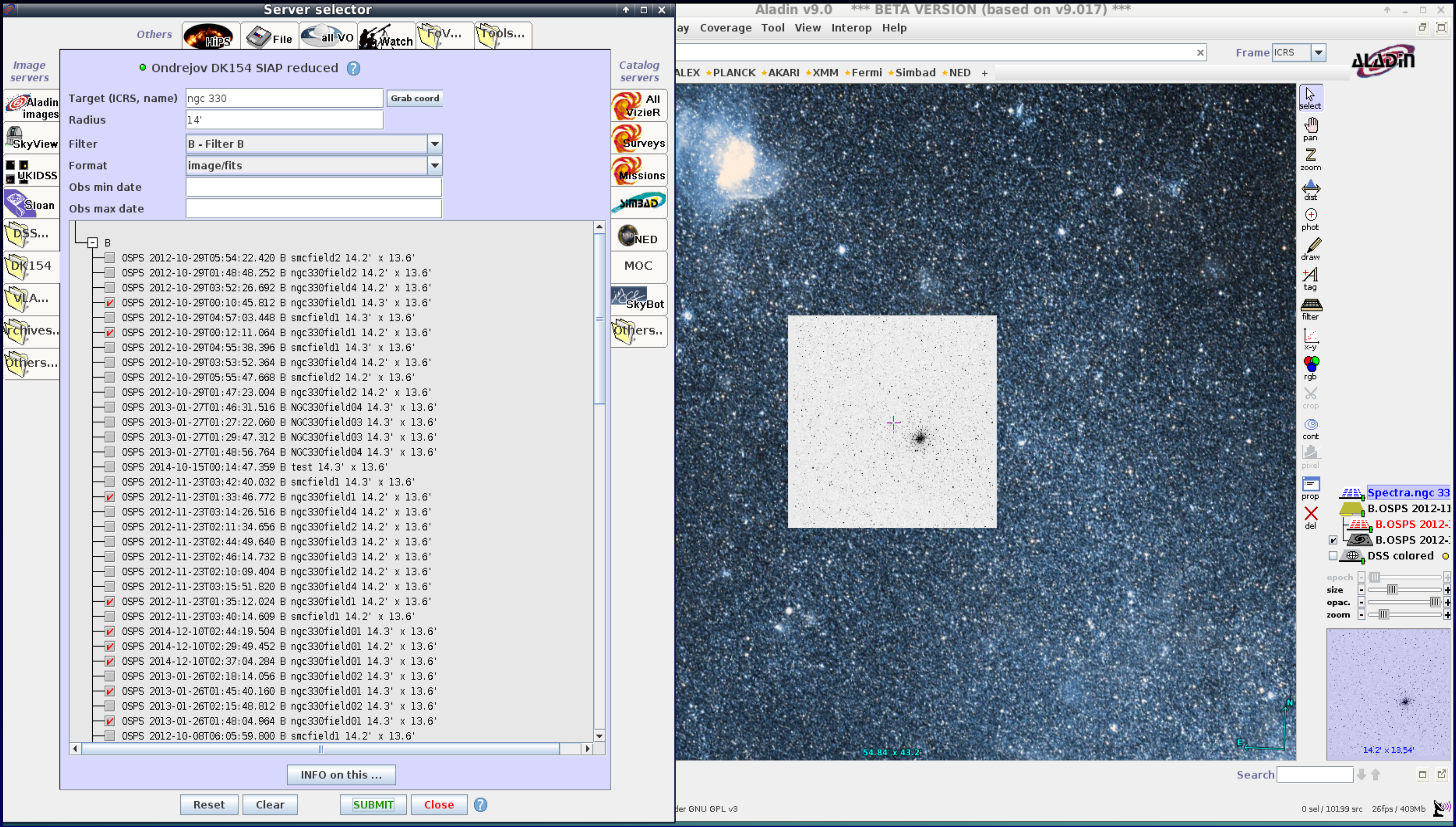
TIP: Load files quickly => Drag&Drog from your desktop

95 sel / 10199 src 67fps / 174Mb

OSPS SIAP in Aladin (DSS in back)



● Ondrejov DK154 SIAP reduced

Target (ICRS, name): ngc 330 (Grab coord)

Radius: 14'

Filter: B - Filter B

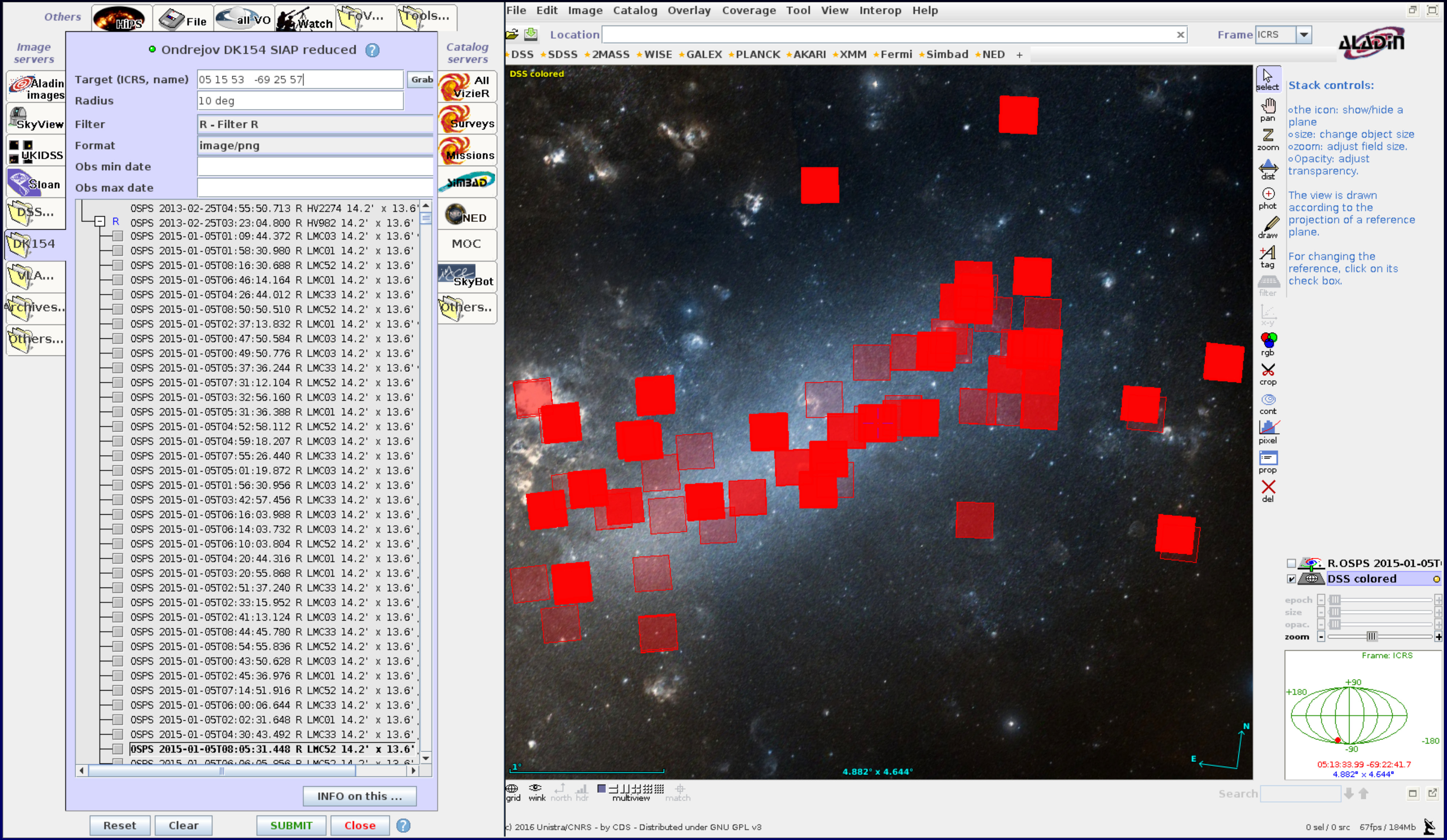
Format: image/fits

Obs min date:

Obs max date:

```
B
□ OSPS 2012-10-29T05:54:22.420 B smcfield2 14.2' x 13.6'
□ OSPS 2012-10-29T01:48:48.252 B ngc330field2 14.2' x 13.6'
□ OSPS 2012-10-29T03:52:26.692 B ngc330field4 14.2' x 13.6'
☑ OSPS 2012-10-29T00:10:45.812 B ngc330field1 14.3' x 13.6'
□ OSPS 2012-10-29T04:57:03.448 B smcfield1 14.3' x 13.6'
☑ OSPS 2012-10-29T00:12:11.064 B ngc330field1 14.2' x 13.6'
□ OSPS 2012-10-29T04:55:38.396 B smcfield1 14.3' x 13.6'
□ OSPS 2012-10-29T03:53:52.364 B ngc330field4 14.2' x 13.6'
□ OSPS 2012-10-29T05:55:47.668 B smcfield2 14.2' x 13.6'
□ OSPS 2012-10-29T01:47:23.004 B ngc330field2 14.2' x 13.6'
□ OSPS 2013-01-27T01:46:31.516 B NGC330field04 14.3' x 13.6'
□ OSPS 2013-01-27T01:27:22.060 B NGC330field03 14.3' x 13.6'
□ OSPS 2013-01-27T01:29:47.312 B NGC330field03 14.3' x 13.6'
□ OSPS 2013-01-27T01:48:56.764 B NGC330field04 14.3' x 13.6'
□ OSPS 2014-10-15T00:14:47.359 B test 14.3' x 13.6'
□ OSPS 2012-11-23T03:42:40.032 B smcfield1 14.3' x 13.6'
☑ OSPS 2012-11-23T01:33:46.772 B ngc330field1 14.2' x 13.6'
□ OSPS 2012-11-23T03:14:26.516 B ngc330field4 14.2' x 13.6'
□ OSPS 2012-11-23T02:11:34.656 B ngc330field2 14.2' x 13.6'
□ OSPS 2012-11-23T02:44:49.640 B ngc330field3 14.2' x 13.6'
□ OSPS 2012-11-23T02:46:14.732 B ngc330field3 14.2' x 13.6'
□ OSPS 2012-11-23T02:10:09.404 B ngc330field2 14.2' x 13.6'
□ OSPS 2012-11-23T03:15:51.820 B ngc330field4 14.2' x 13.6'
☑ OSPS 2012-11-23T01:35:12.024 B ngc330field1 14.2' x 13.6'
□ OSPS 2012-11-23T03:40:14.609 B smcfield1 14.2' x 13.6'
☑ OSPS 2014-12-10T02:44:19.504 B ngc330field01 14.3' x 13.6'
☑ OSPS 2014-12-10T02:29:49.452 B ngc330field01 14.2' x 13.6'
☑ OSPS 2014-12-10T02:37:04.284 B ngc330field01 14.3' x 13.6'
□ OSPS 2013-01-26T02:18:14.056 B ngc330field02 14.3' x 13.6'
☑ OSPS 2013-01-26T01:45:40.160 B ngc330field01 14.3' x 13.6'
□ OSPS 2013-01-26T02:15:48.812 B ngc330field02 14.3' x 13.6'
☑ OSPS 2013-01-26T01:48:04.964 B ngc330field01 14.3' x 13.6'
□ OSPS 2012-10-08T06:05:59.800 B smcfield1 14.2' x 13.6'
```

OSPS Image coverage (footprints)



Ondrejov DK154 SIAP reduced

Target (ICRS, name): 05 15 53 -69 25 57

Radius: 10 deg

Filter: R - Filter R

Format: image/png

Obs min date:

Obs max date:

```
OSPS 2013-02-25T04:55:50.713 R HV2274 14.2' x 13.6'
R OSPS 2013-02-25T03:23:04.800 R HV982 14.2' x 13.6'
OSPS 2015-01-05T01:09:44.372 R LMC03 14.2' x 13.6'
OSPS 2015-01-05T01:58:30.980 R LMC01 14.2' x 13.6'
OSPS 2015-01-05T08:16:30.688 R LMC52 14.2' x 13.6'
OSPS 2015-01-05T06:46:14.164 R LMC01 14.2' x 13.6'
OSPS 2015-01-05T04:26:44.012 R LMC33 14.2' x 13.6'
OSPS 2015-01-05T08:50:50.510 R LMC52 14.2' x 13.6'
OSPS 2015-01-05T02:37:13.832 R LMC01 14.2' x 13.6'
OSPS 2015-01-05T00:47:50.584 R LMC03 14.2' x 13.6'
OSPS 2015-01-05T00:49:50.776 R LMC03 14.2' x 13.6'
OSPS 2015-01-05T05:37:36.244 R LMC33 14.2' x 13.6'
OSPS 2015-01-05T07:31:12.104 R LMC52 14.2' x 13.6'
OSPS 2015-01-05T03:32:56.160 R LMC03 14.2' x 13.6'
OSPS 2015-01-05T05:31:36.388 R LMC01 14.2' x 13.6'
OSPS 2015-01-05T04:52:58.112 R LMC52 14.2' x 13.6'
OSPS 2015-01-05T04:59:18.207 R LMC03 14.2' x 13.6'
OSPS 2015-01-05T07:55:26.440 R LMC33 14.2' x 13.6'
OSPS 2015-01-05T05:01:19.872 R LMC03 14.2' x 13.6'
OSPS 2015-01-05T01:56:30.956 R LMC03 14.2' x 13.6'
OSPS 2015-01-05T03:42:57.456 R LMC33 14.2' x 13.6'
OSPS 2015-01-05T06:16:03.988 R LMC03 14.2' x 13.6'
OSPS 2015-01-05T06:14:03.732 R LMC03 14.2' x 13.6'
OSPS 2015-01-05T06:10:03.804 R LMC52 14.2' x 13.6'
OSPS 2015-01-05T04:20:44.316 R LMC01 14.2' x 13.6'
OSPS 2015-01-05T03:20:55.868 R LMC01 14.2' x 13.6'
OSPS 2015-01-05T02:51:37.240 R LMC33 14.2' x 13.6'
OSPS 2015-01-05T02:33:15.952 R LMC03 14.2' x 13.6'
OSPS 2015-01-05T02:41:13.124 R LMC03 14.2' x 13.6'
OSPS 2015-01-05T08:44:45.780 R LMC33 14.2' x 13.6'
OSPS 2015-01-05T08:54:55.836 R LMC52 14.2' x 13.6'
OSPS 2015-01-05T00:43:50.628 R LMC03 14.2' x 13.6'
OSPS 2015-01-05T02:45:36.976 R LMC01 14.2' x 13.6'
OSPS 2015-01-05T07:14:51.916 R LMC52 14.2' x 13.6'
OSPS 2015-01-05T06:00:06.644 R LMC33 14.2' x 13.6'
OSPS 2015-01-05T02:02:31.648 R LMC01 14.2' x 13.6'
OSPS 2015-01-05T04:30:43.492 R LMC33 14.2' x 13.6'
OSPS 2015-01-05T08:05:31.448 R LMC52 14.2' x 13.6'
OSPS 2015-01-05T06:06:05.956 R LMC52 14.2' x 13.6'
```

Stack controls:

- the icon: show/hide a plane
- size: change object size
- zoom: adjust field size.
- Opacity: adjust transparency.

The view is drawn according to the projection of a reference plane.

For changing the reference, click on its check box.

□ R.OSPS 2015-01-05T
☑ DSS colored

Frame: ICRS

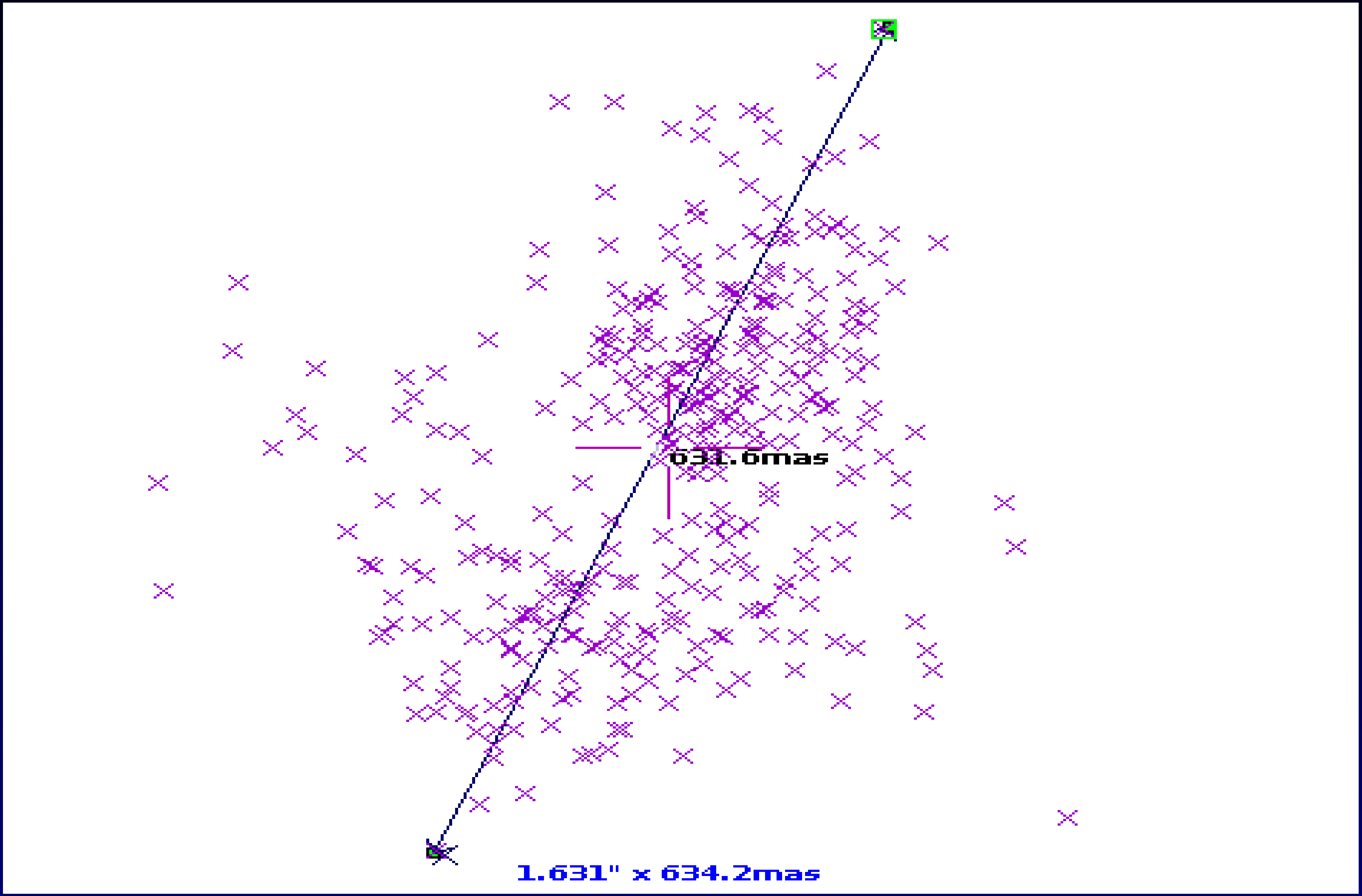
05:13:33.99 -69:22:41.7

4.882° x 4.644°

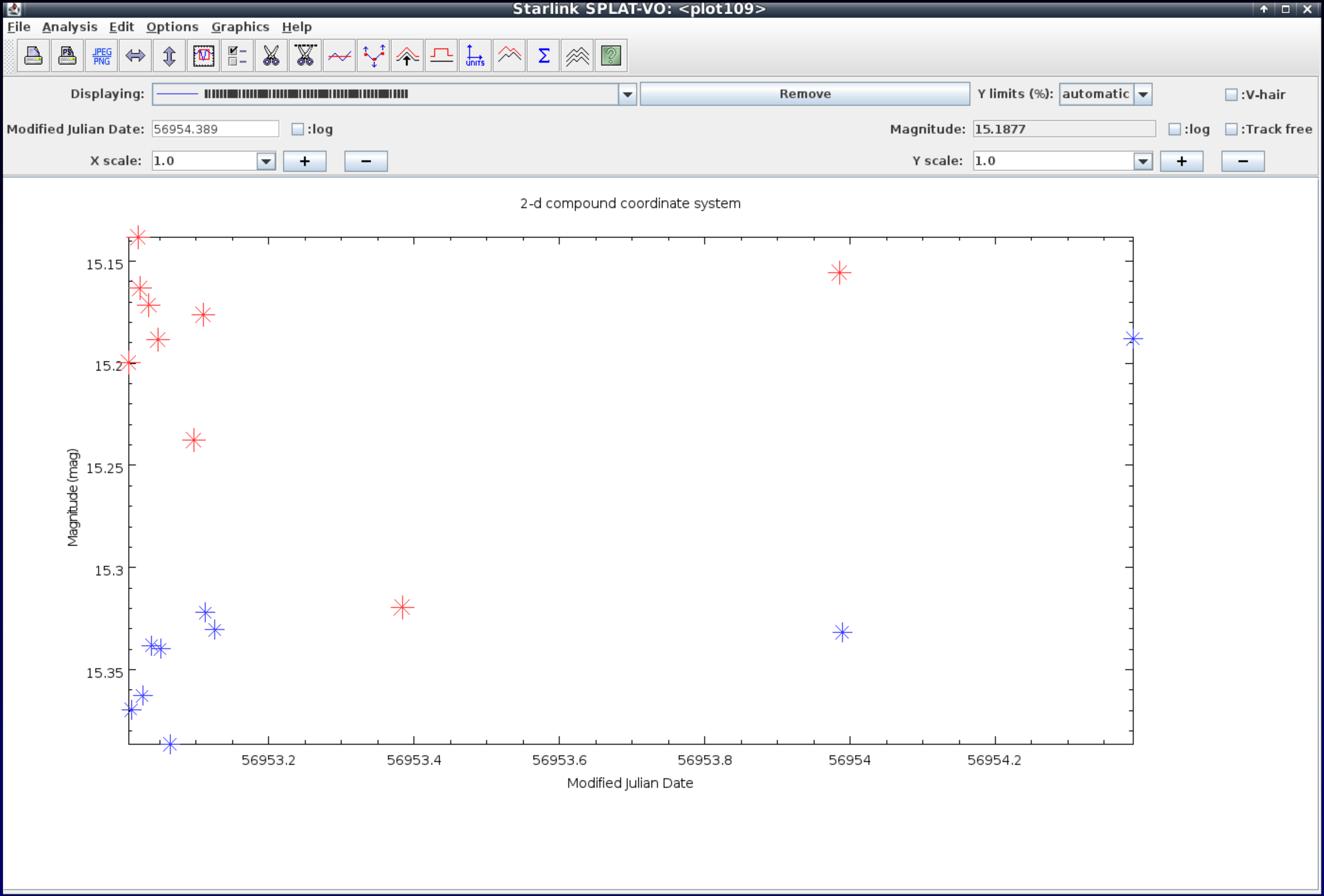
c) 2016 Unistra/CNRS - by CDS - Distributed under GNU GPL v3

0 sel / 0 src 67fps / 184Mb

Parallelized Clustering of Positions



OSPS Light Curve in SPLAT



Displaying:

Y limits (%): automatic

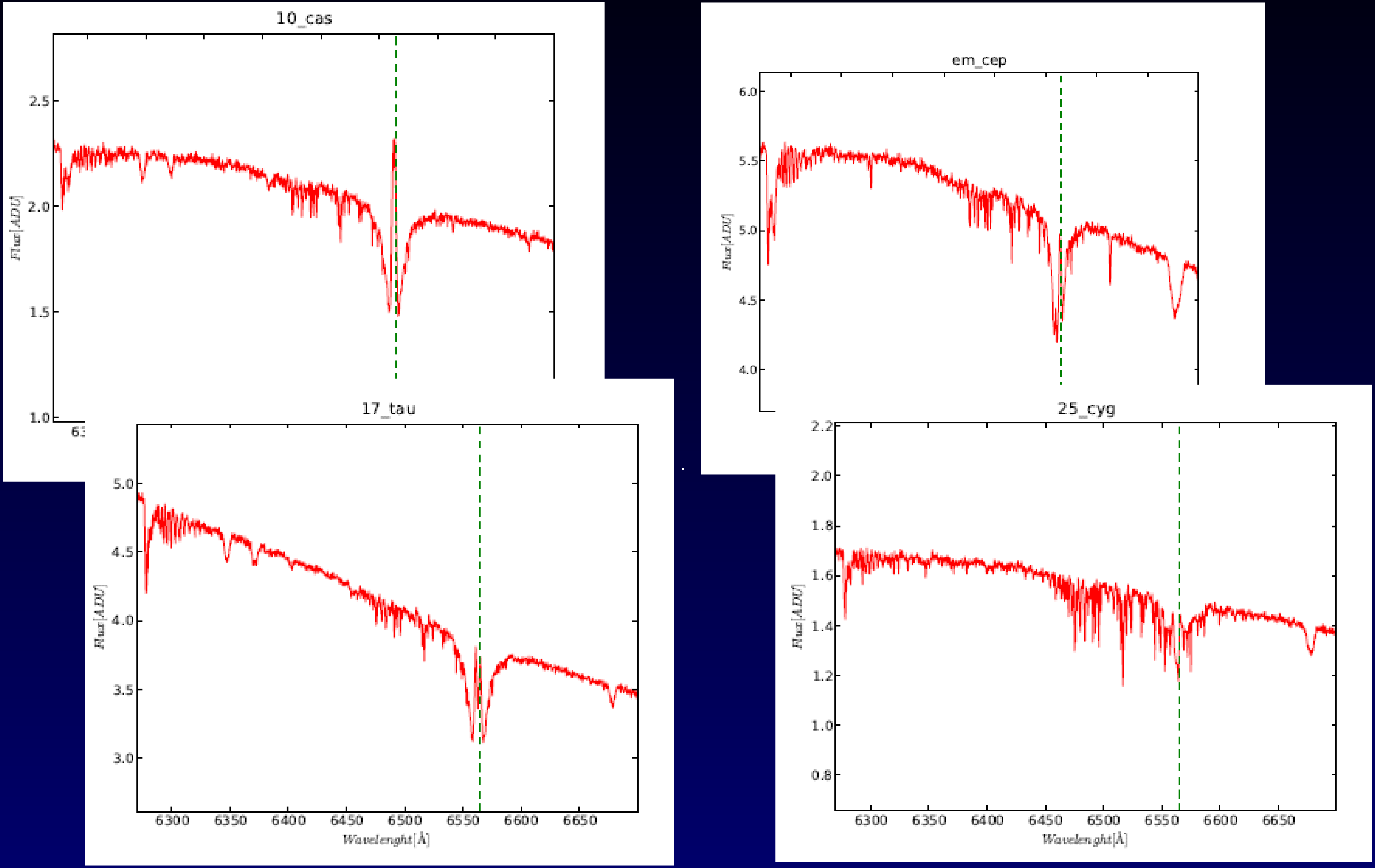
Modified Julian Date: 56954.389 □ :log

Magnitude: 15.1877 □ :log □ :Track free

X scale: 1.0

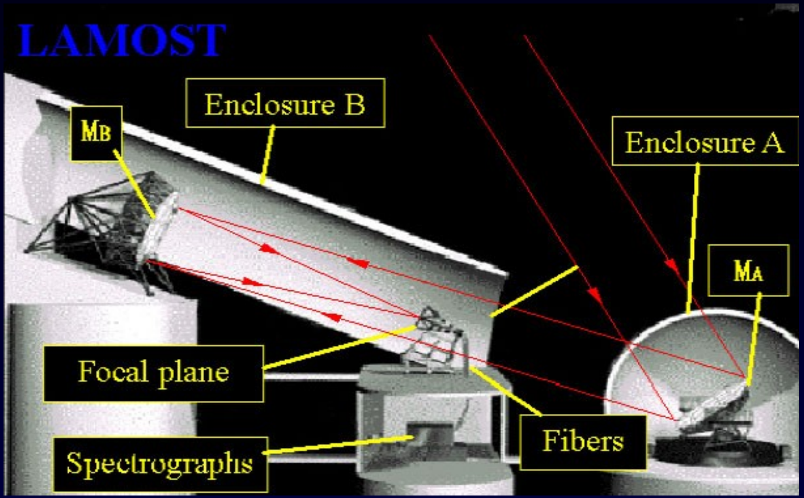
Y scale: 1.0

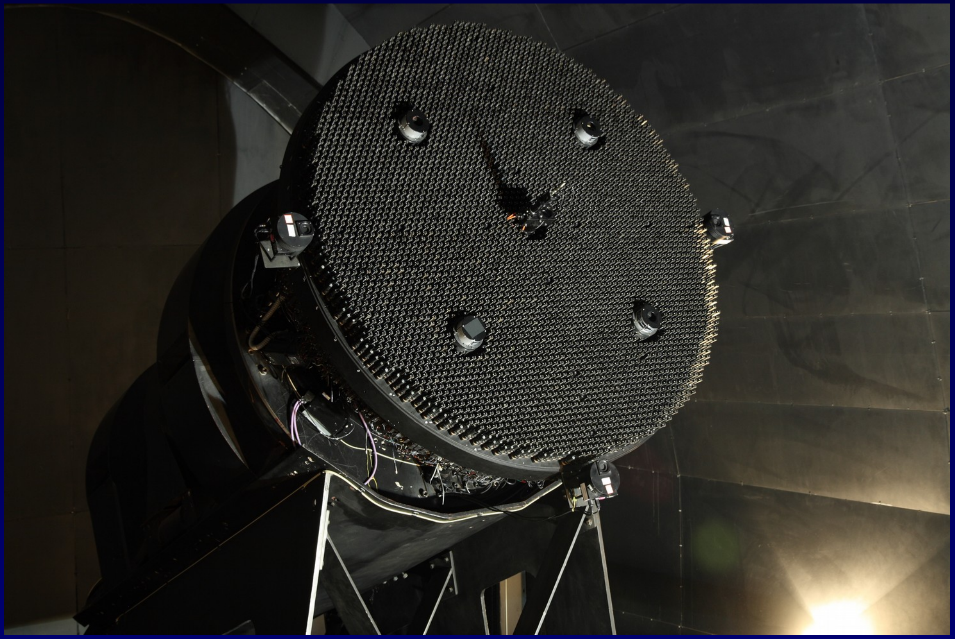
Be Stars : Emission in absorption



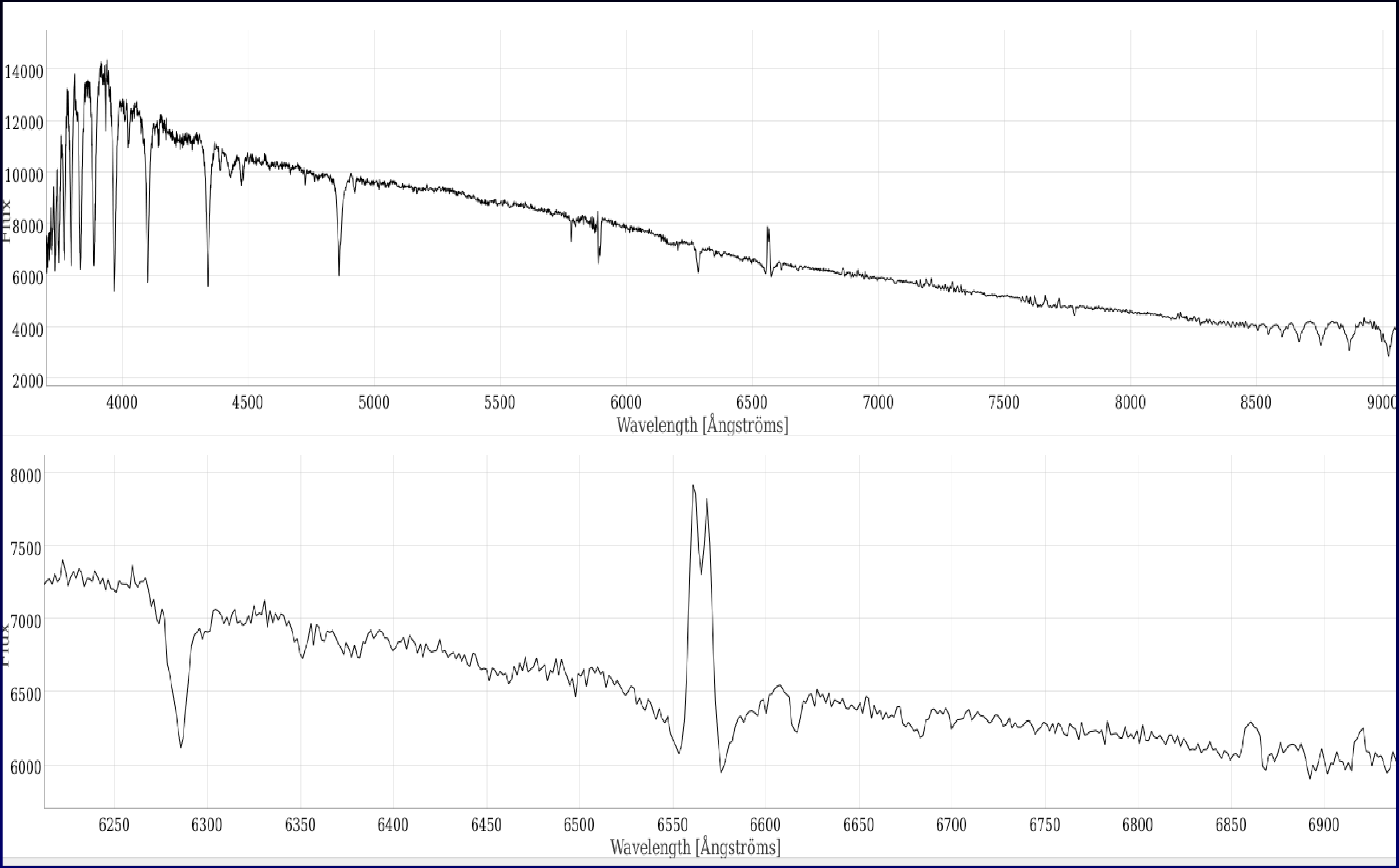
LAMOST (Guoshoujing)

Xinglong- China
4m mirror (30 deg meridian)
4000 fibers
10 mil spectra / 5 yr
Automatic RV-z

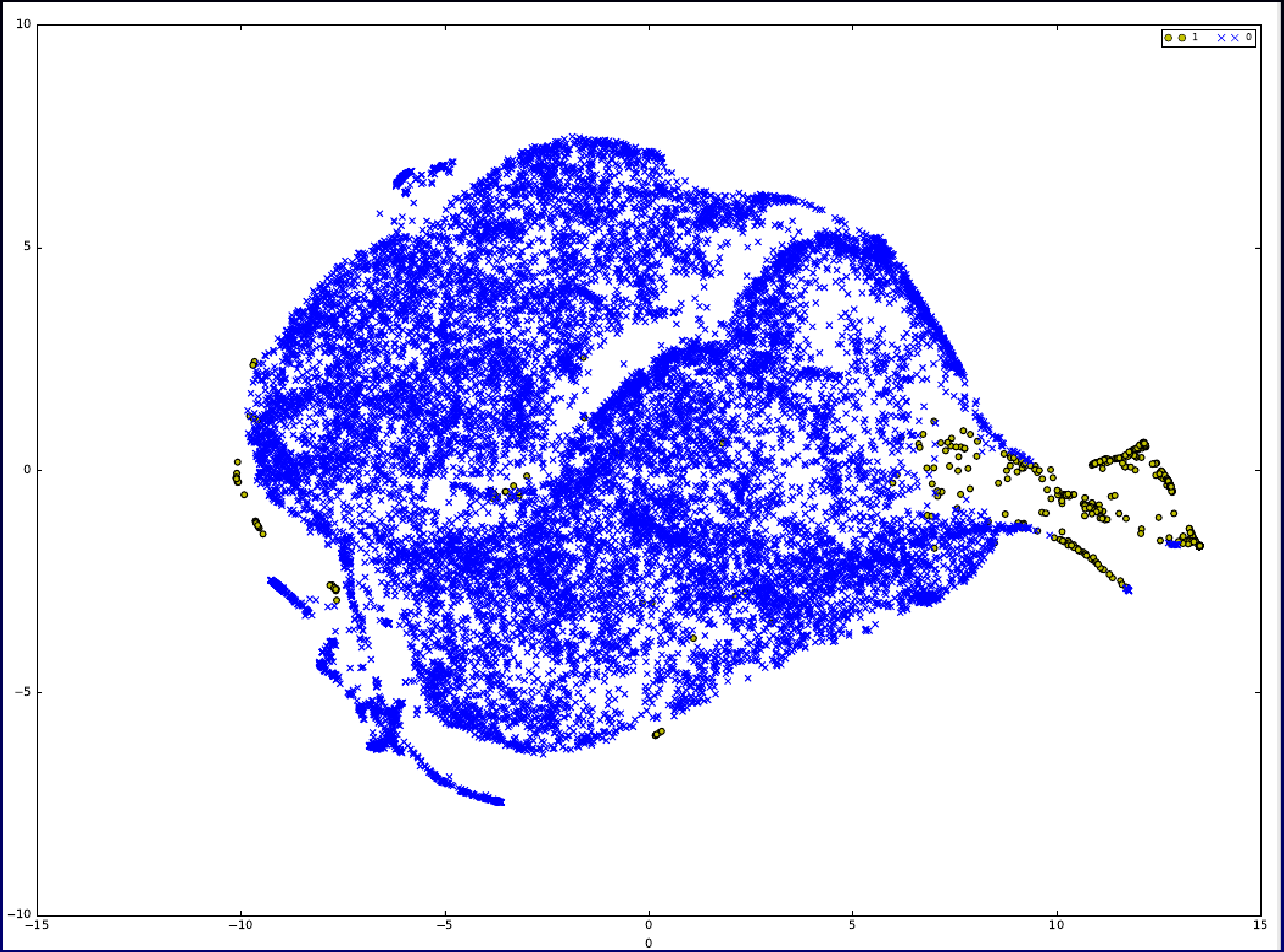




Be Candidates Found



LAMOST TSNE Structure



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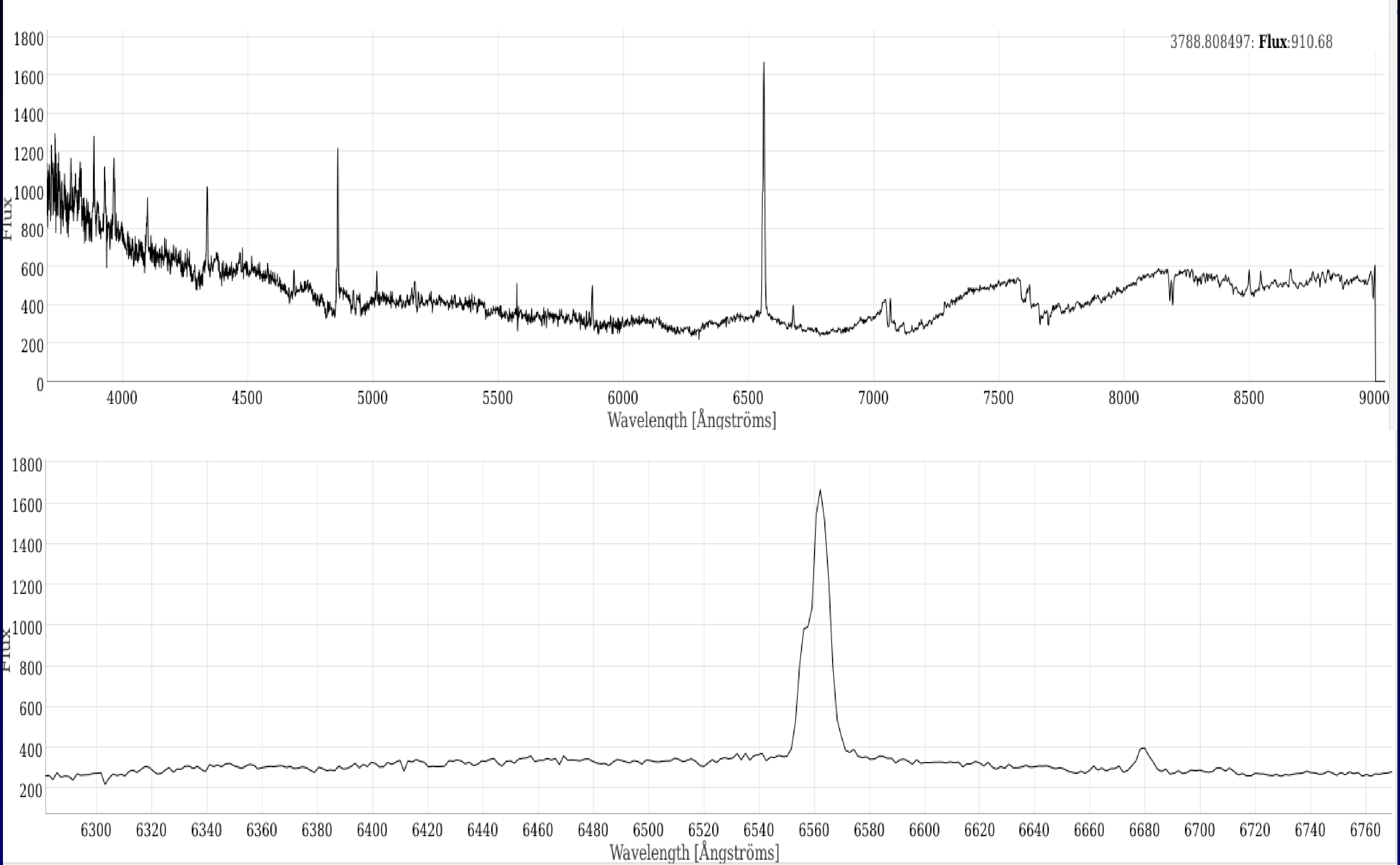

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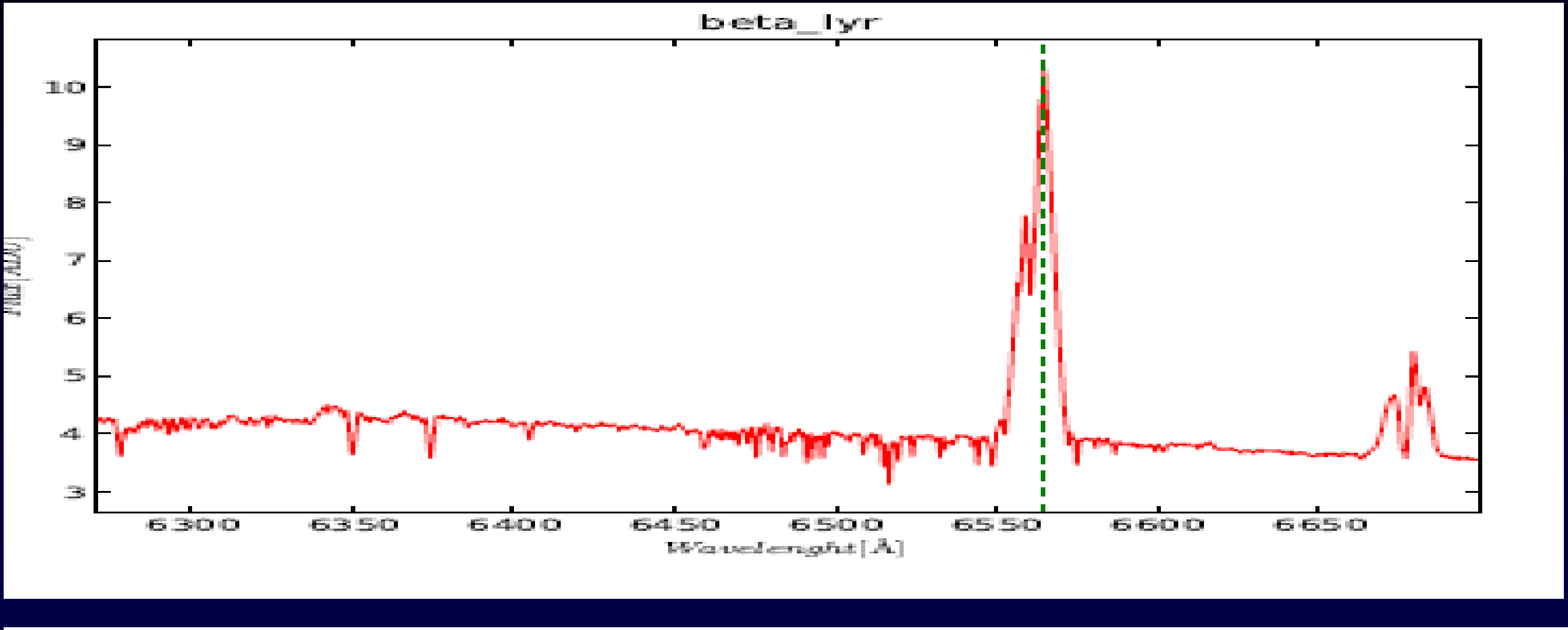
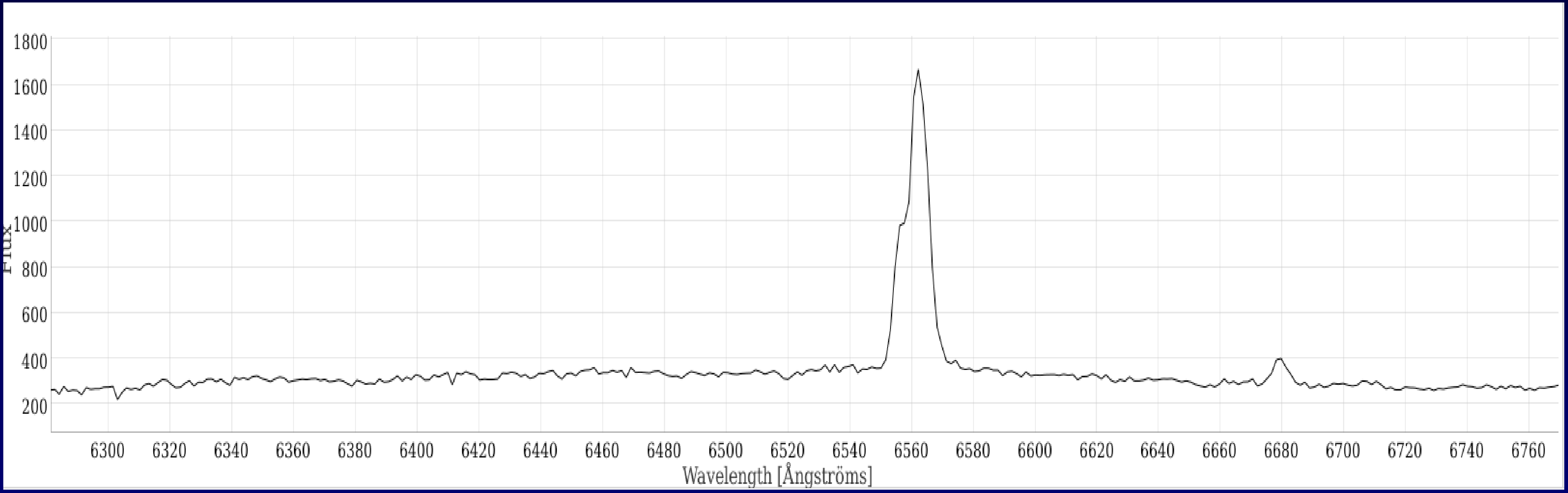
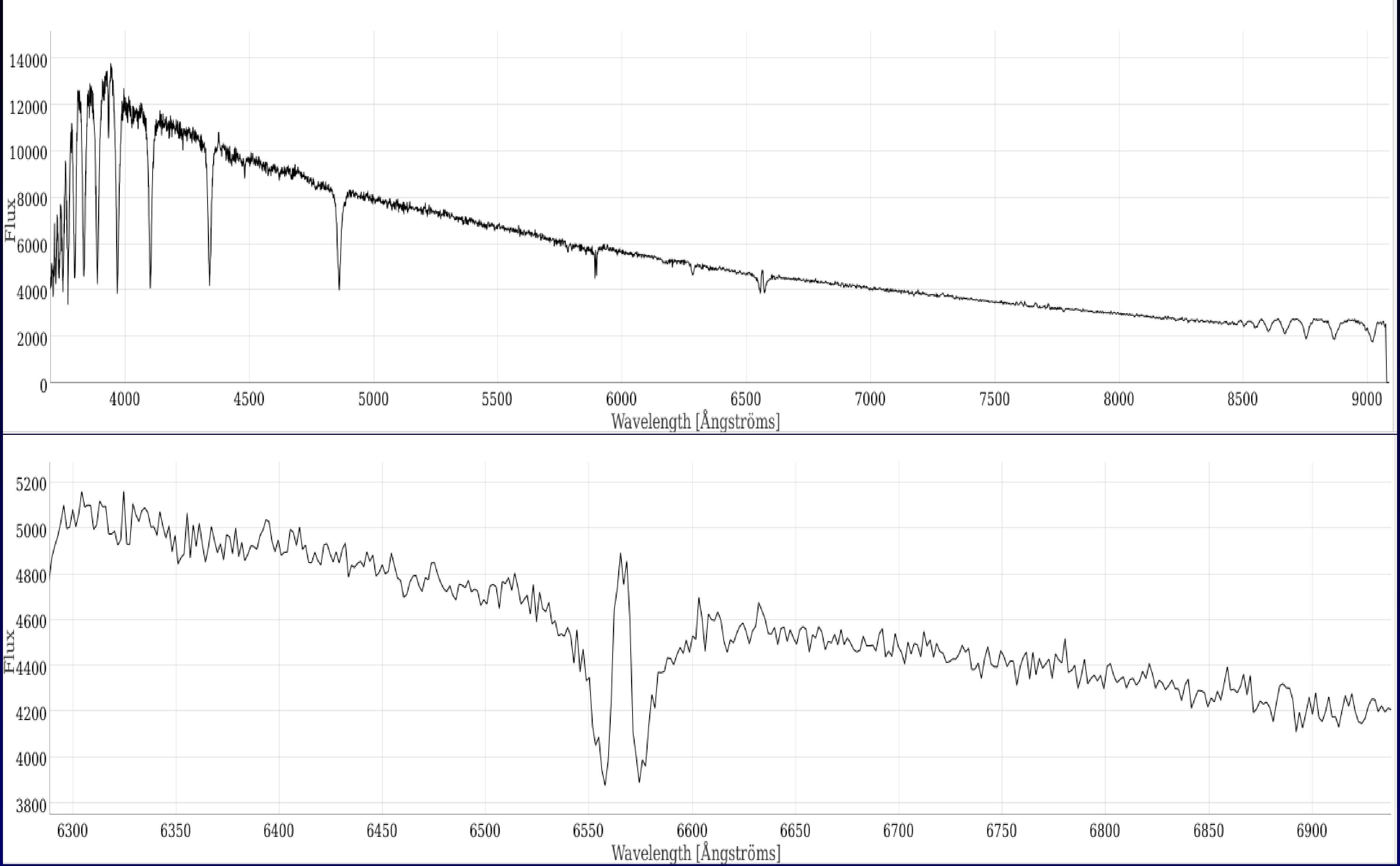
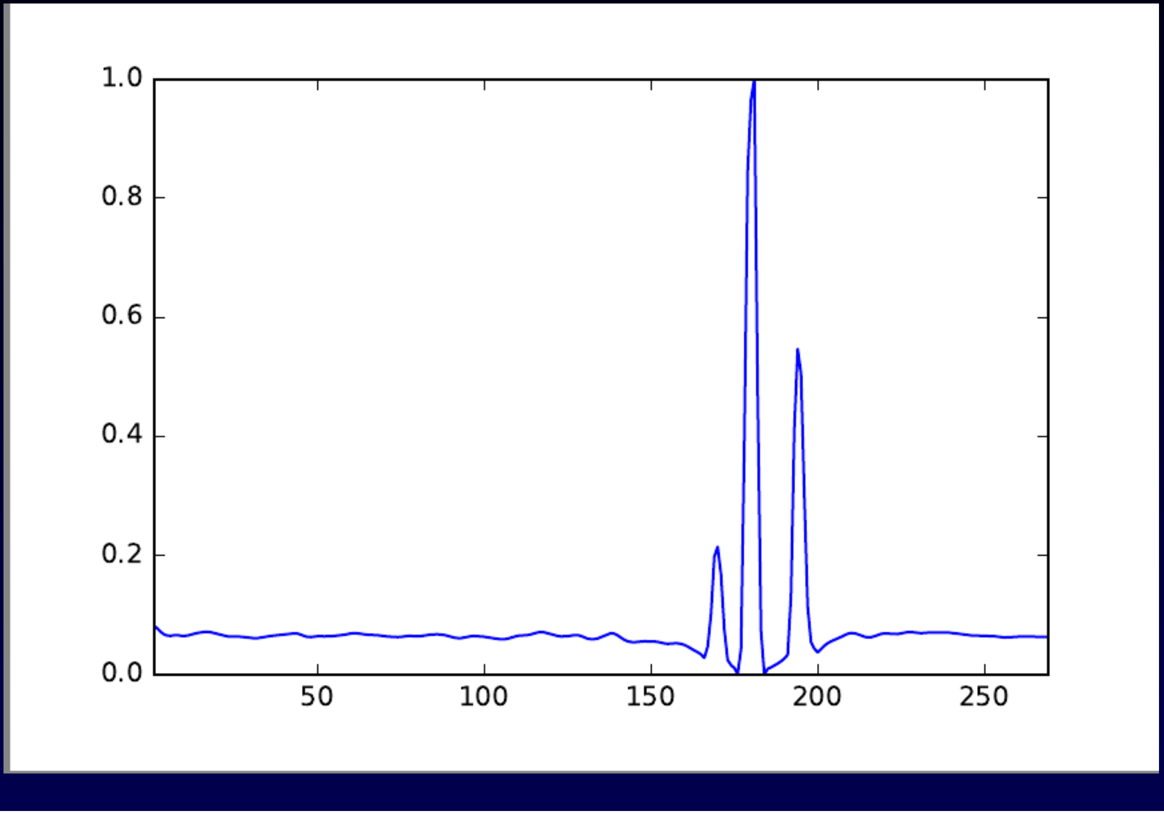


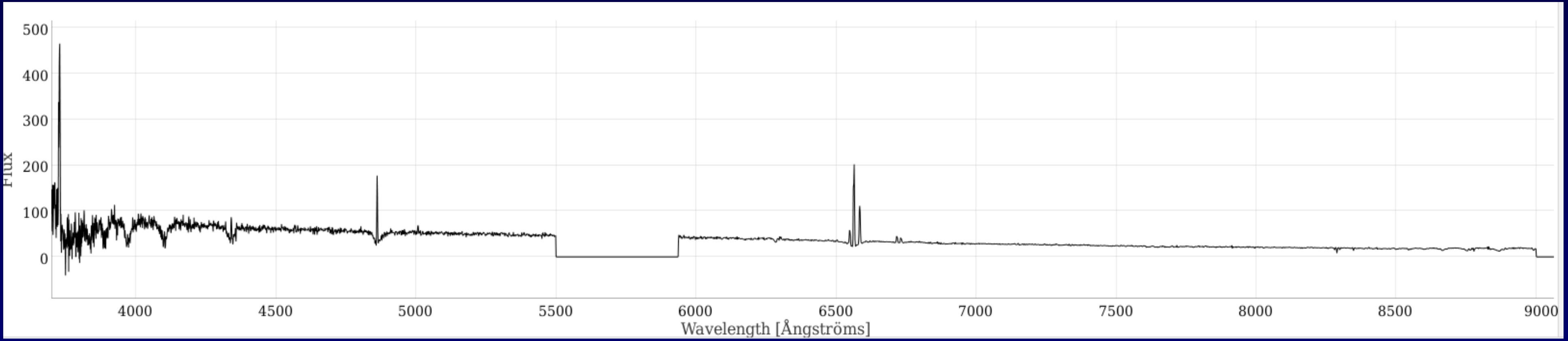


Yet Unknown Be Star



Be Candidates Foud





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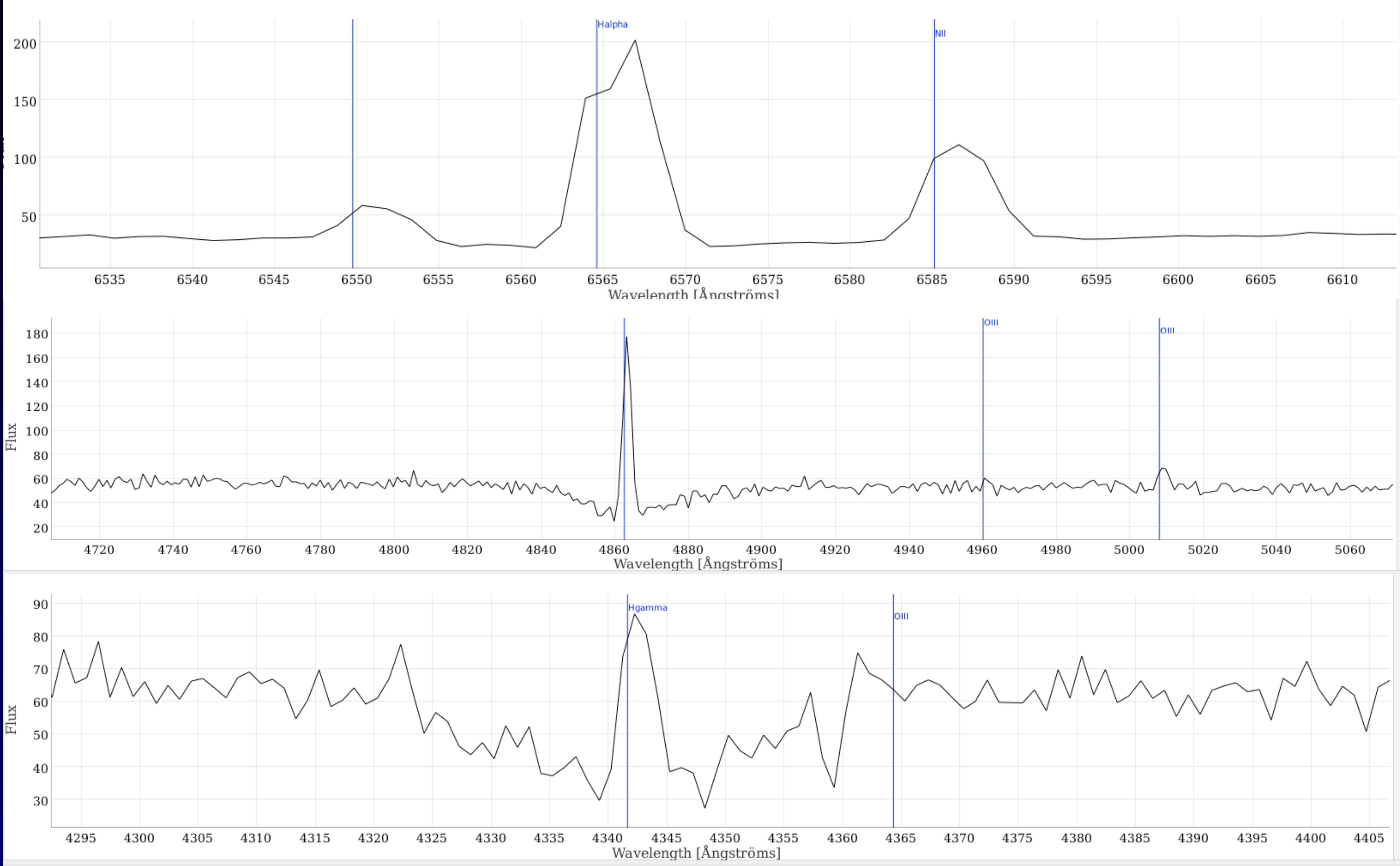
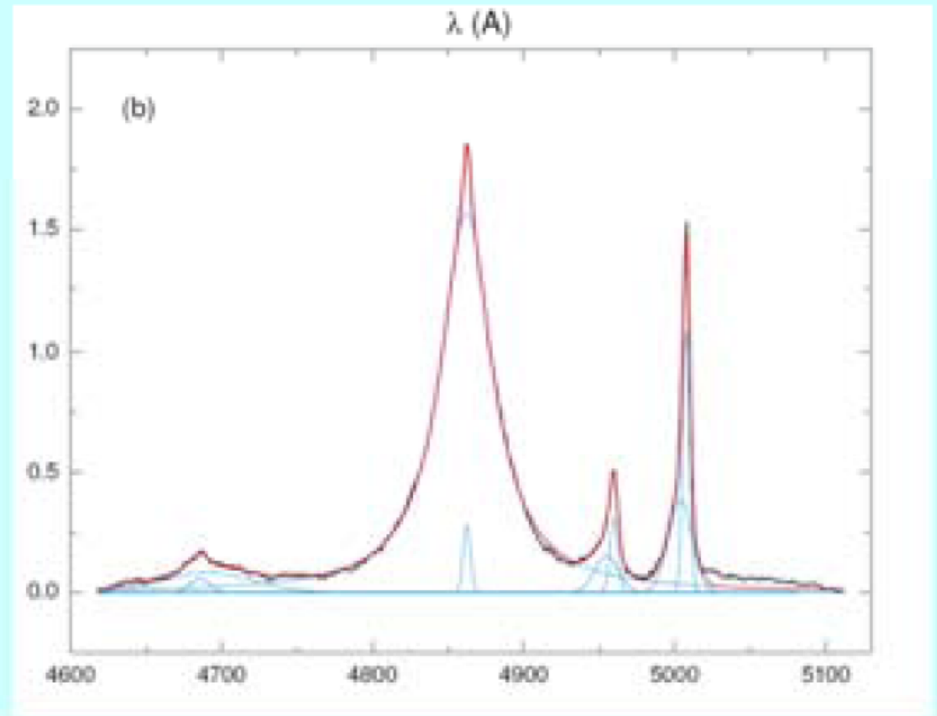
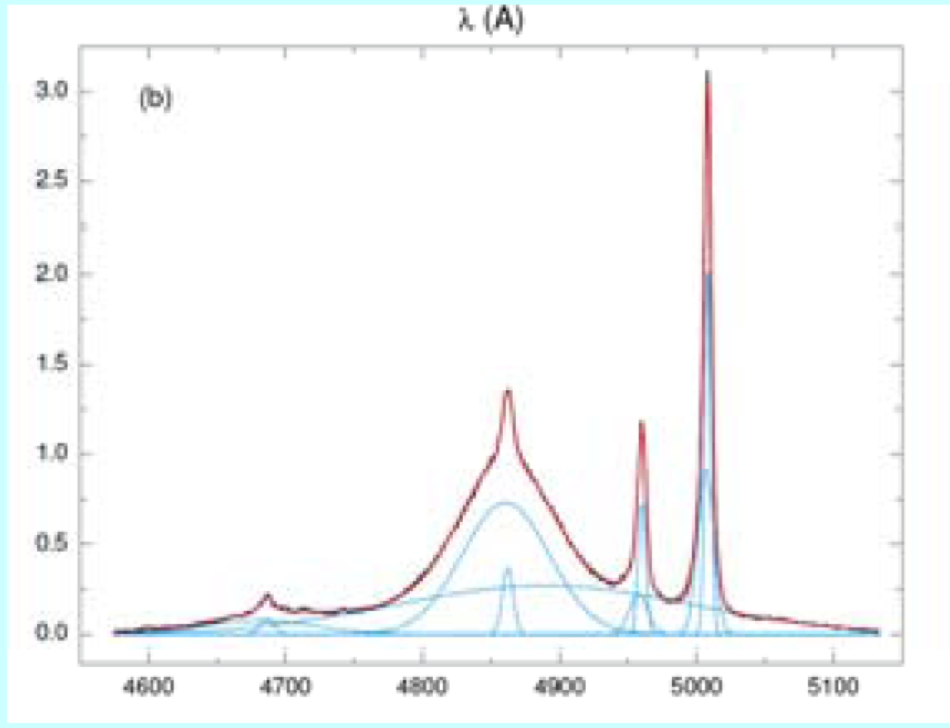


AGN Populations



Population A



Population B

Sulentic et al. 2002