The Virtual Observatory – enabling data access – key science drivers

Nicholas Walton

AstroGrid and Euro-VO Technology Centre Project Scientist

(Institute of Astronomy, University of Cambridge)

Photo: SALT

The Virtual Observatory

- The Challenge: Facilitate Better Science
  - Science: range of astronomy, solar to cosmology
  - Technical: global system
  - Political: global community
- Building a solution: The Virtual Observatory
  - standards
    - IVOA
    - GGF
  - implementations
- Context for this workshop
  - AstroGrid: an example VO implementation

The Challenge of Data

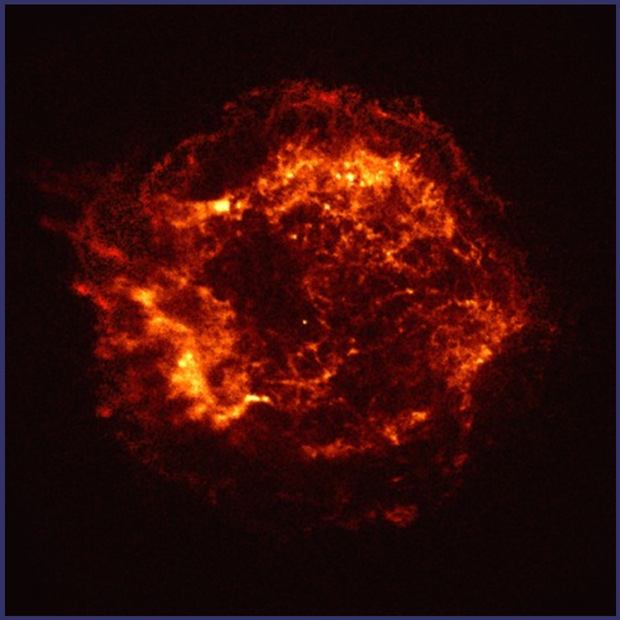
- Astronomy is an observational science
- Progress is made via understanding gained from the study of the cosmos
- Powerful observatories exist producing observational data across the wavelength domain
  - data comes in many formats
  - levels of complexity
- Data & applications held globally: USA, Europe, Asia
  - heterogeneous data archives
- Research partnerships are also global
- Connecting researchers with data and applications is the challenge for the Virtual Observatory

The Need for Virtual Observatories: Managing Technological Change

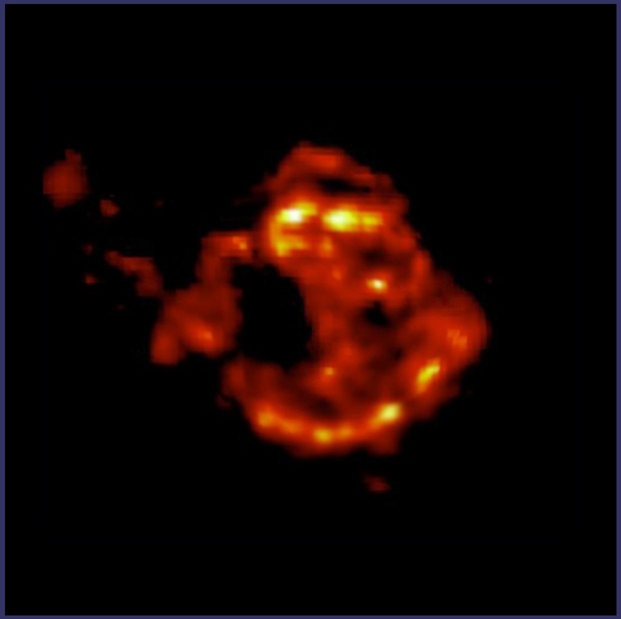
- The massive Growth of Data
  - Number + size of telescopes
    - Optical: ESO's 4x8m VLT, 2x8m Gemini
    - X-ray: XMM-Newton
    - sub-mm: ALMA
  - Increase in size and multiplex capabilities of instrumentation:
    - Infra-Red: VISTA > 100 GB/nights
    - Radio: e-Merlin > data rates ~320 Gbps
  - All sky at 0.1 arcsec – 100 TB

Supernova Remnant Cassiopeia-A – a 300 year old Supernova

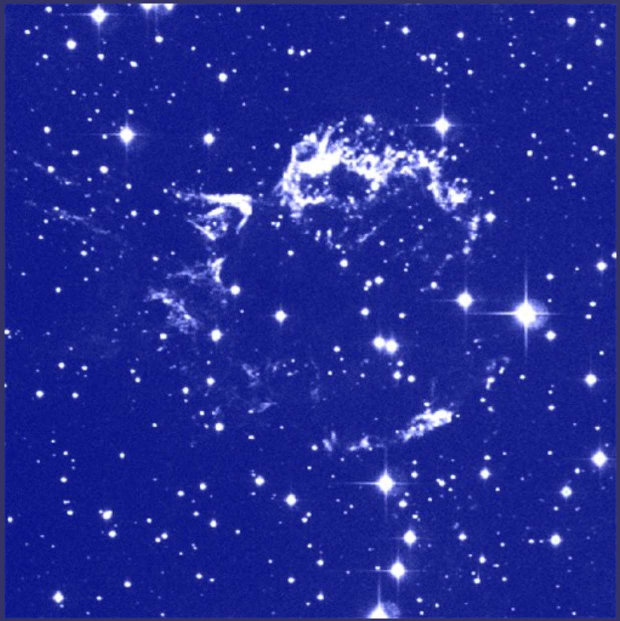
The Challenge and Opportunity of multi-Wavelength data:



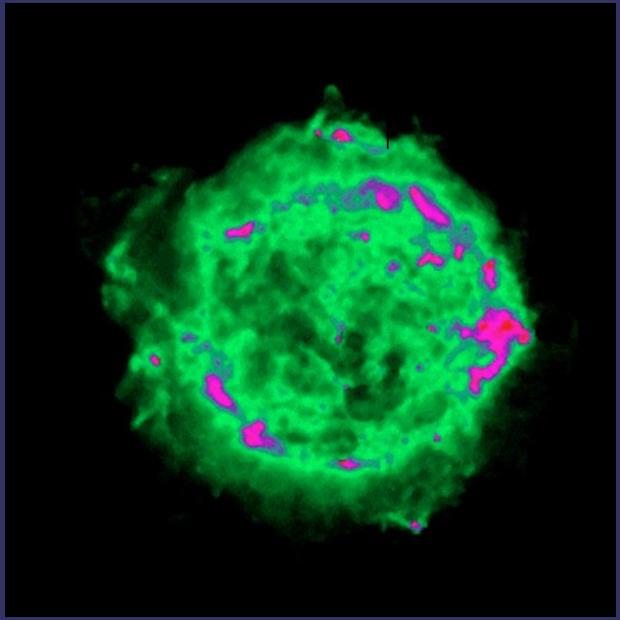
Shocks seen in the X-ray Chandra image



Dust shows in the IR



Heavy elements seen in the optical



Mapping e^{-}s in the magnetic field as revealed by Radio data

Images from Chandra Science Centre

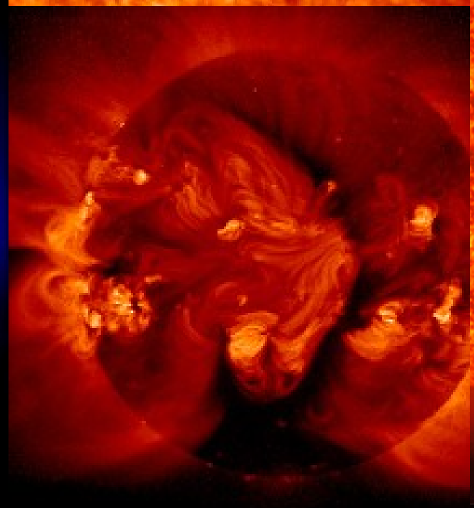
New & Improved Science from VO's: Space Weather

What happens to the Earth's magnetosphere during a coronal mass ejection ?

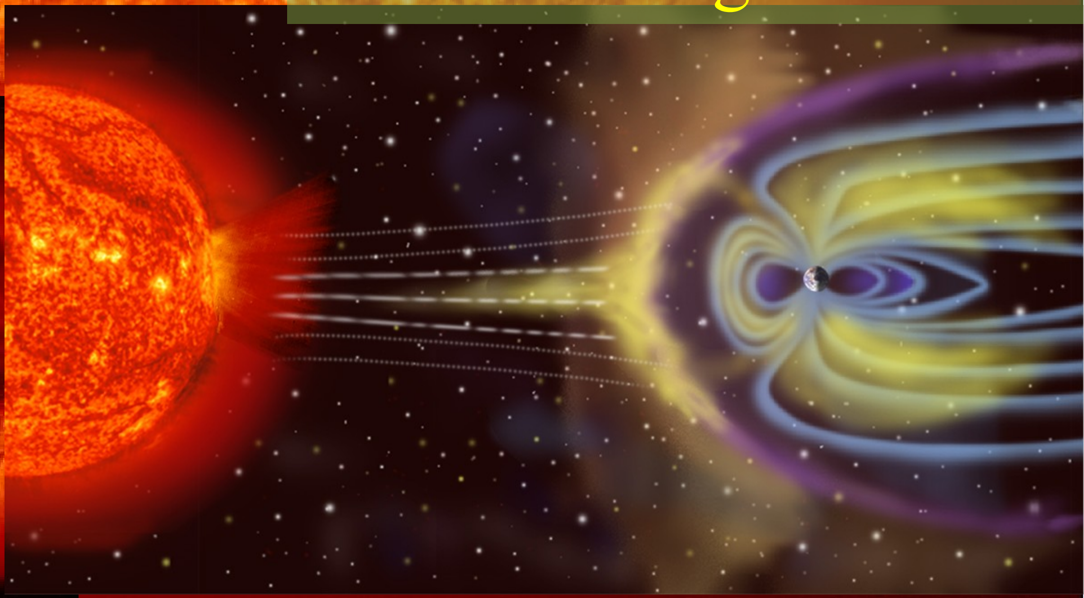
Event imaged by space based solar observatory

Effect detected later by satellites and ground radar

SOHO/EIT – EUV

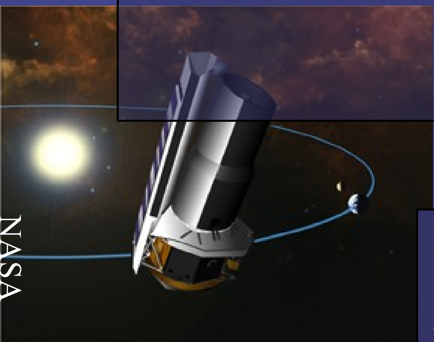


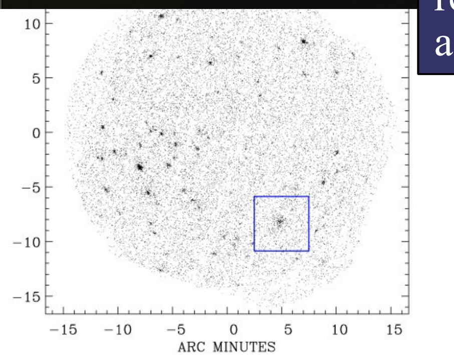
Yohkoh – Xray

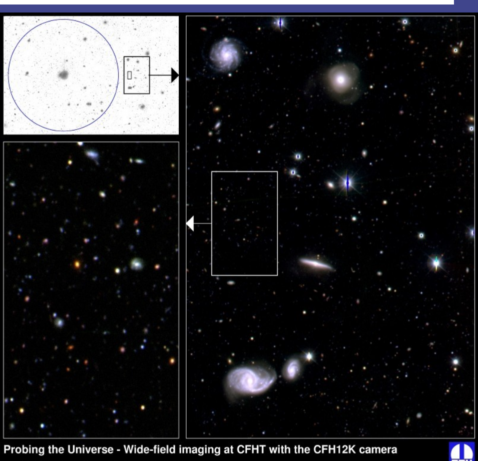


NASA: Living With a Star – http://lws.gsfc.nasa.gov

New & Improved Science: Cosmology

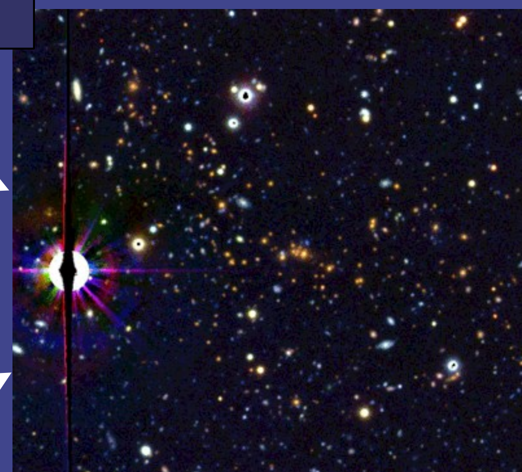






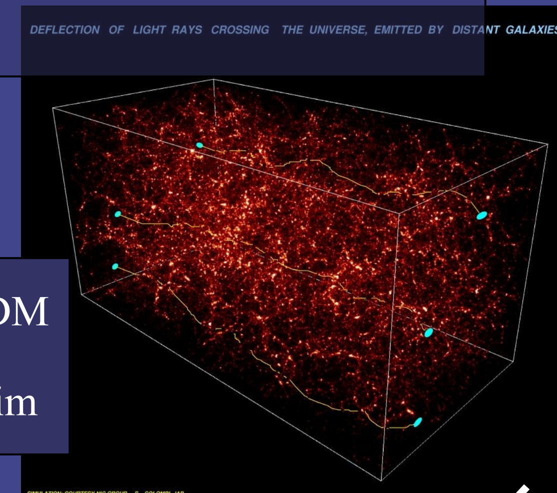
Multiple large image sources: registration & association

Automatic cluster finding techniques

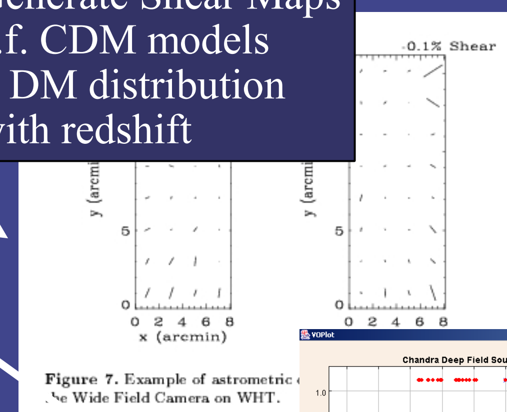


X-ray cluster: Chandra X-ray (Mullis) overlaid on a deep BRI image (Clowe & Luppino).

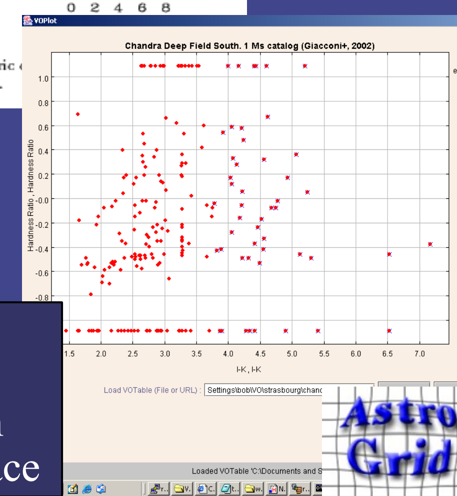
Multi-TB λCDM models, e.g. Millennium Sim



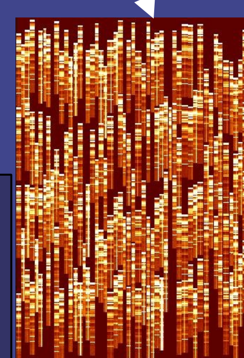
Generate Shear Maps c.f. CDM models > DM distribution with redshift



Remove star correlate gal with z



Source ID from multiplexed spectral data



Colour-Colour relationships classification in multi-phase space

Science Challenge

- Multi-Wavelength data required
  - key science: e.g. planets, large scale structure, galaxy formation: all needs a combination of data
- More data required
  - survey telescopes create ~TB/night
- More use of database organised resources used

System needs to be fast and easy for the astronomer to use and affordable for the data providers to operate

System use drives increased (sustainable) funding for operations and development of data access system

Solutions: a Flexible Framework

- Create a system that recognises:
  - no one data provider or repository: thus data interoperability
  - application provision
- Requires
  - a system built upon agreed interoperability standards
- Exploits
  - wider IT developments: Grid and WS technologies
    - power of XML/ SOAP etc
  - access to high speed networks
    - but note: backbones ~10Tb/s, desktops ~100Mb/s
  - reduced costs of h/w: all data now on spinning disks

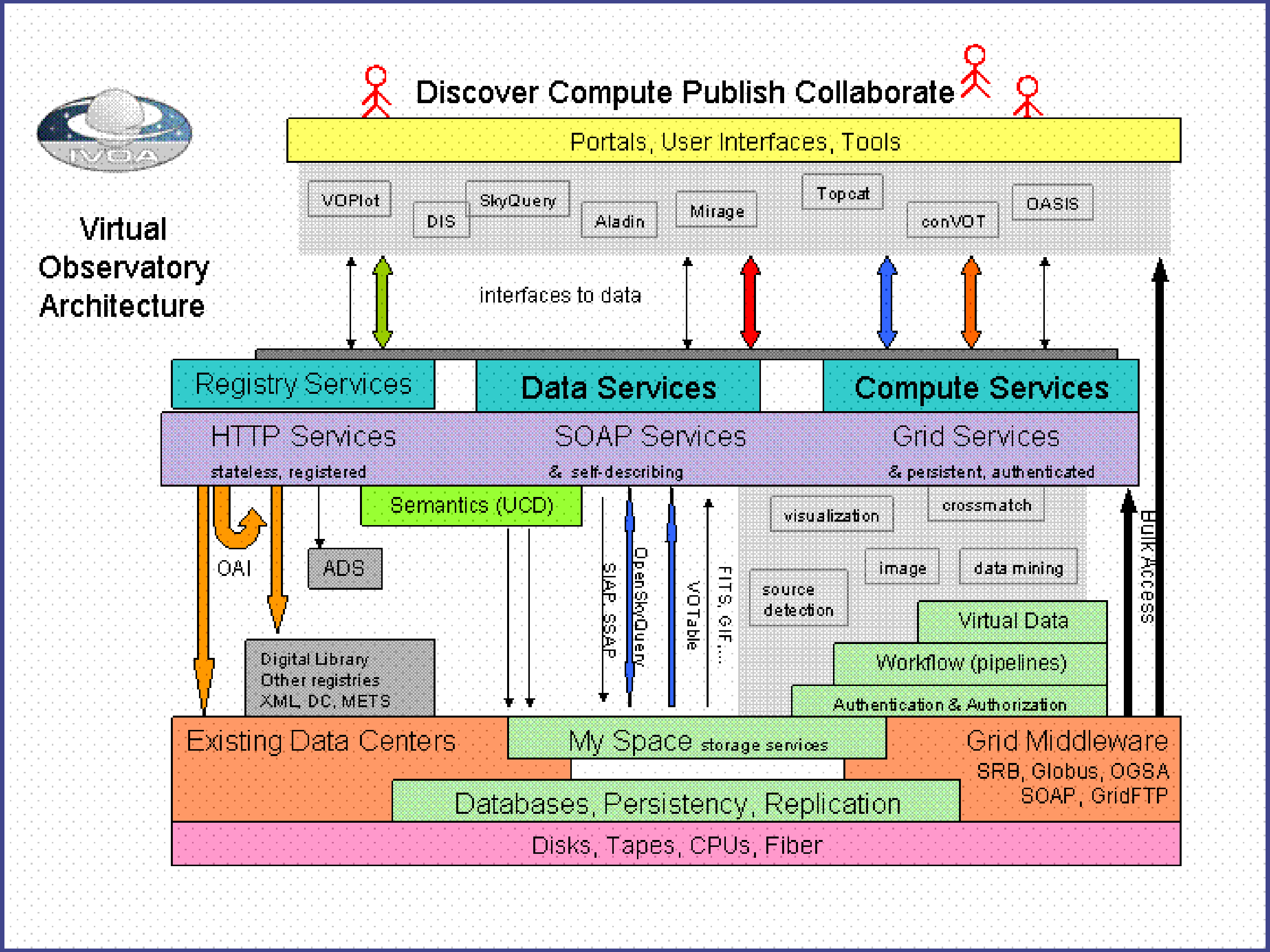
Building the Virtual Observatory:

Global scope
International partnerships
Agreeing interoperability standards
Building regional implementations
Based on new computational technologies
Deployed on the fastest networks

IVOA: Stds Enabling Interoperability

- The International Virtual Observatory Alliance http://www.ivoa.net
- A global partnership
- Projects represent global astronomy data providers
- IVOA a forum for interoperability standards
- VO projects build on these standards
- Global reach

IVOA Architecture Analysis



Analysis of a VO:

- Multi-layer
- Complex
- User interfaces thru a portal
- Astro-apps interface to a VO abstraction layer
- Lower level middleware provided by the 'grid' world
  - e.g. SRB
- Hardware at bottom layer

IVOA has working groups to address 'astro' specific 'boxes'

Ref: IVOA Architecture Overview: Williams et al, 2004
IVOA Note 2004-06-14:
http://www.ivoa.net/Documents/Notes/IVOArch/IVOArch-20040615.html

VO Standard Areas

- Standard vocabulary (semantics)
- Standard ontology describing how terms are related
- Standard data model (encoding format) for each type of measurement
- Standard query language for issuing spatial, temporal, and semantic queries across the catalogs.
- Standard access services for retrieving catalog records or image cutouts.
- Standard mechanisms for interacting with storage systems (VOSpace)
- Standard authentication/ authorisation mechanisms
- Standard event notification services.

IVOA Working Groups: http://www.ivoa.net/forum

- Registry:
  - how to 'register' resources: concept of VOResources
- Data Access Layer:
  - Standards for remote data access: e.g. SIAP, SSA
- Data Model:
  - Standards for the actual data: e.g. XML'ing of FITS
- VO Query Language:
  - Standards for 'astro' database access: e.g. Openskyquery, 'circle'
- Unified Content Descriptors: std Vocabulary
  - Standards for common ways of describing data: metadata
- VOTable:
  - XML representation of tabular data
- Grid & Web Services:
  - Interfaces to Grid and Web Service stds: e.g. 'Heartbeat'

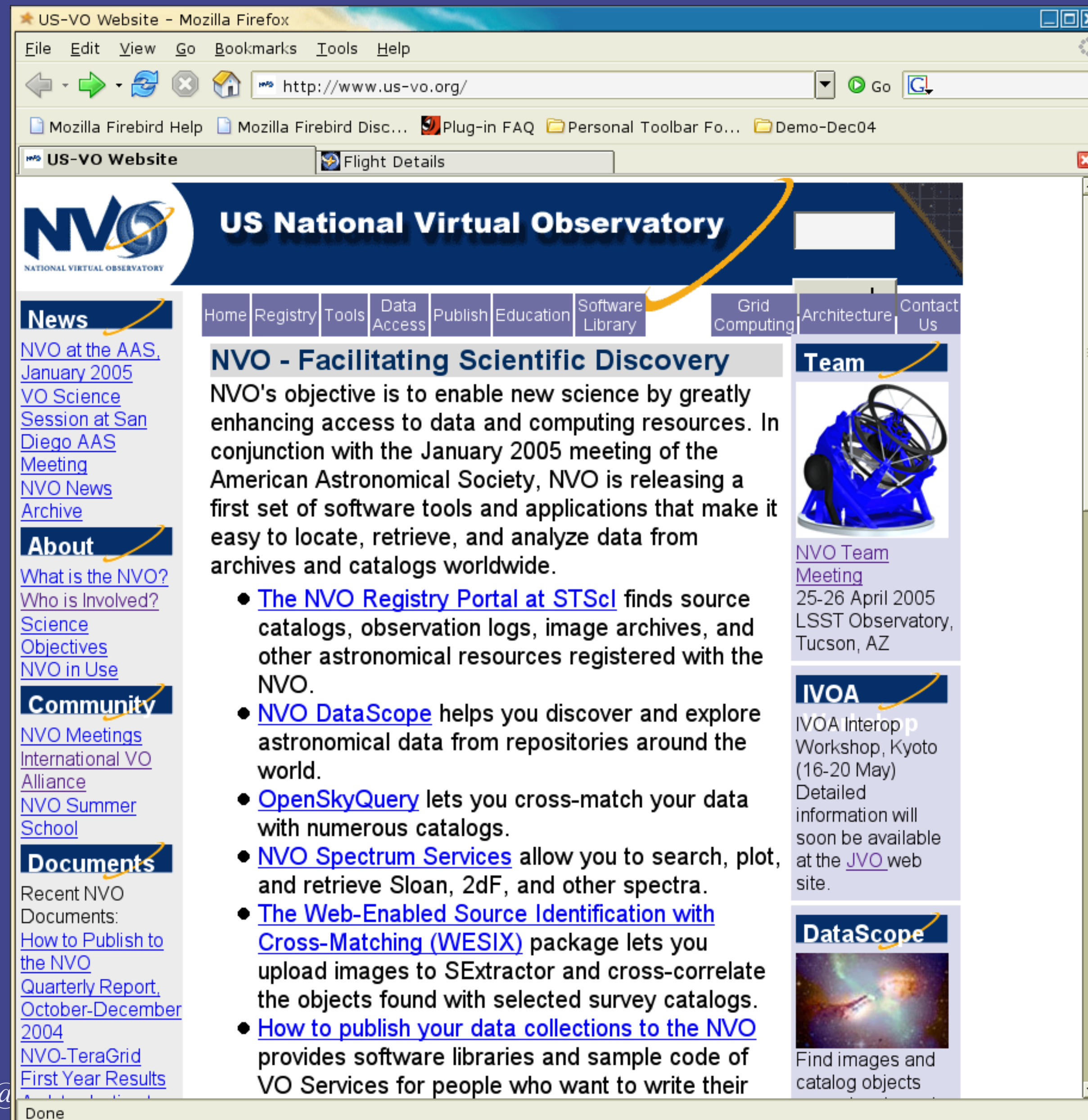
GGF and Astronomy

- Current IVOA implementations largely utilise web services, however GGF standards are becoming relevant in a number of areas:
  - Authorisation
  - Transport, e.g. GridFTP
  - Persistent Storage
  - Job Submission
- Use of grid service standards actively under investigation by a number of VO projects
  - AstroGrid
  - USA's NVO

Science Driven Virtual Observatories

US-VO: NVO http://www.us-vo.org

- Partnership of major data/ compute centres in the USA:
  - IPAC, NASA-HESARC, NASA-JPL, NRAO, NOAO, SDSS, SAO, STScI
  - SDSC, NCSA, Pittsburgh
  - Globus, MS
- Webservices based
- Initially tools
  - Now moving to an architecture

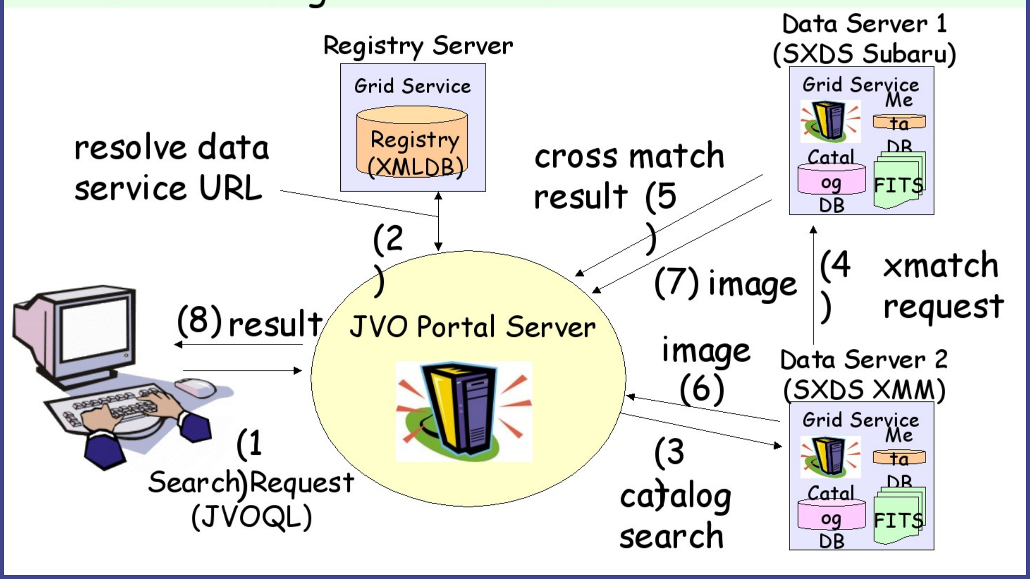


Japan-VO: JVO http://jvo.nao.ac.jp

- Partners
  - NAOJ, JAXA, ICRR, Ochanomizu U, Osaka U, Titech, Fujitsu
  - Data from Suburu, Astro-F, Nobeyama, Alma
- 1st JVO prototype based on Globus Toolkit 2 – 'grid'
- 2nd JVO prototype based on GT3 – grid services, improved performance

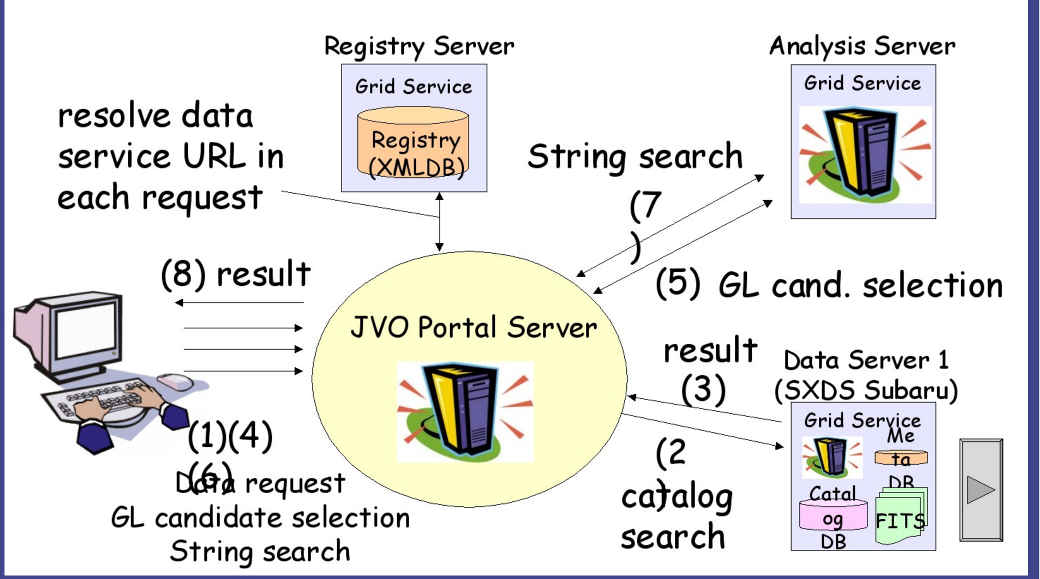
Demo 1: Cross match & Image request

Cross match of the optical and X-ray catalogs of SXDS and image retrievals.



Demo 2: Cosmic String Search

Data request to the SXDS optical catalog, GL candidate selection, String search by pattern recognition.



AstroGrid: UK's Virtual Observatory

Empowerment of scientists

- Improve the quality, ease, speed and cost effectiveness of on-line astronomy
- Make comparison and integration of data seamless
- Removing barriers to multi-wavelength astronomy
- Enable acces to very large data sets

Project: 2001-2007: key data and resource providers in consortium

Euro-VO: VOTC Technology Centre

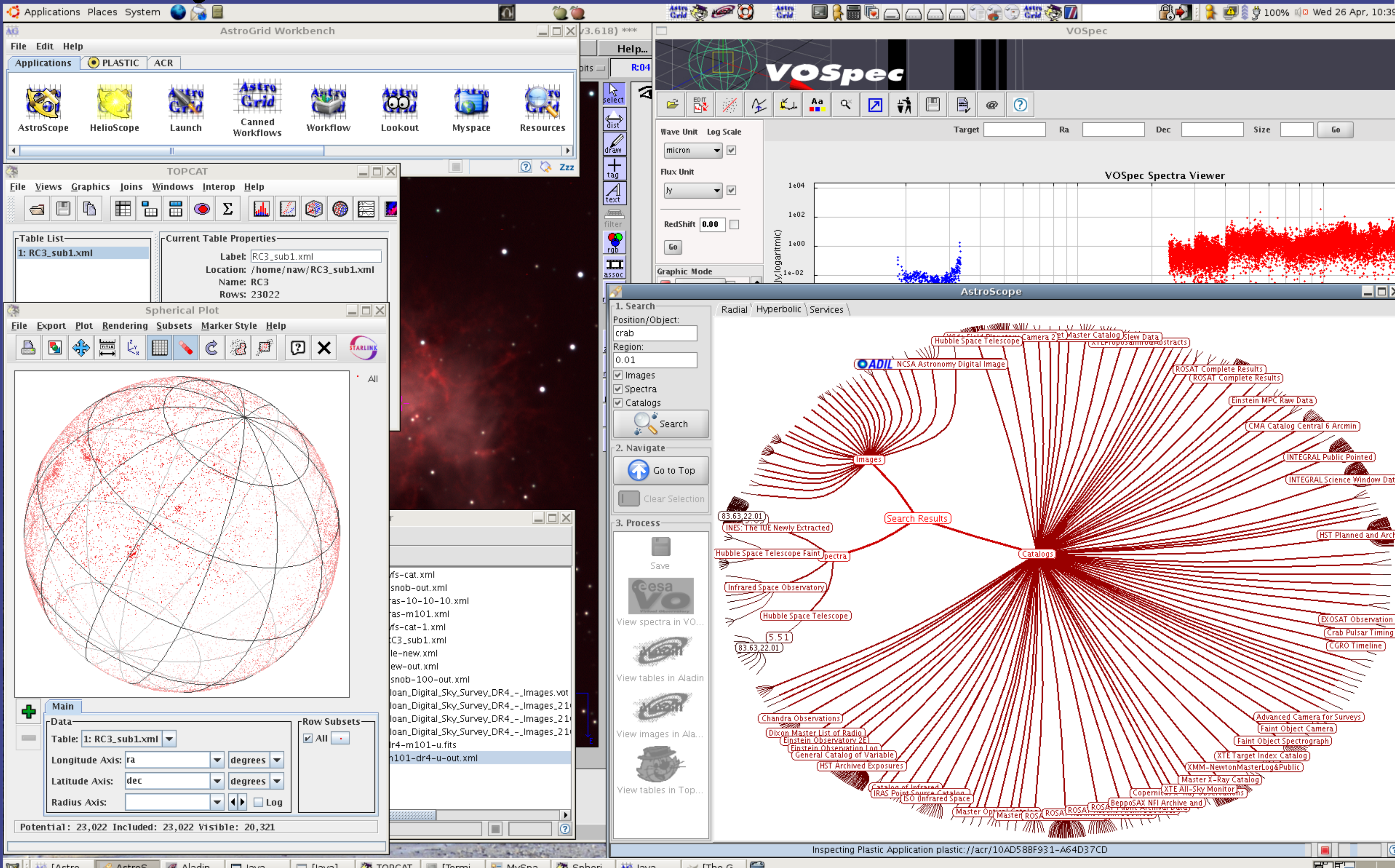
Infrastructure, new tools, resource discovery, data mining+visualisation

AstroGrid: An example implementation

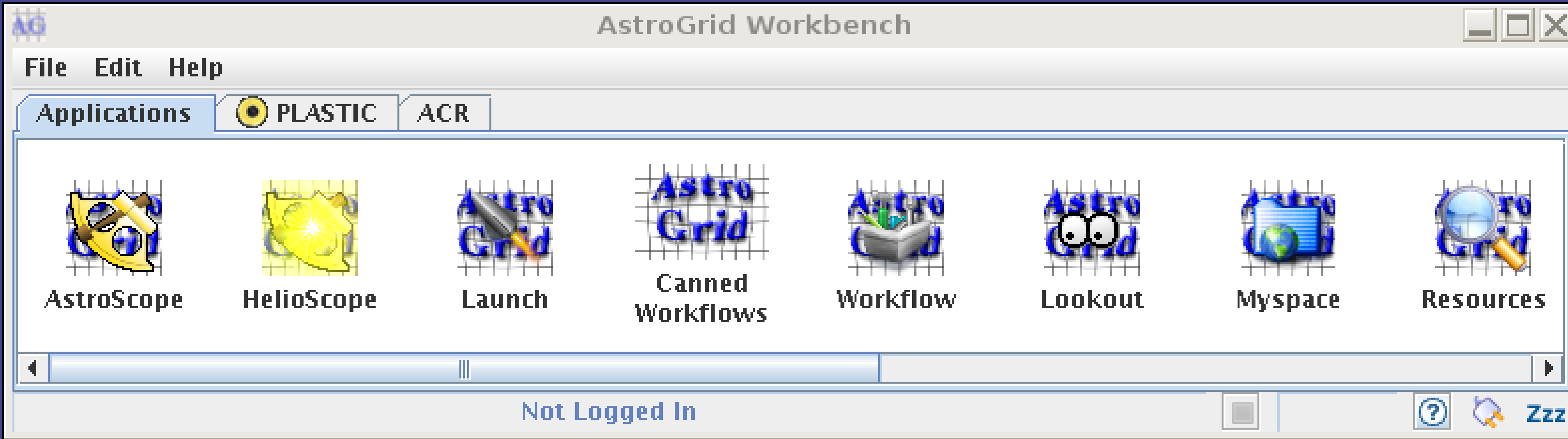
AstroGrid 2006.2 Release: Apr 2006

http://www.astrogrid.org/launch

AG System



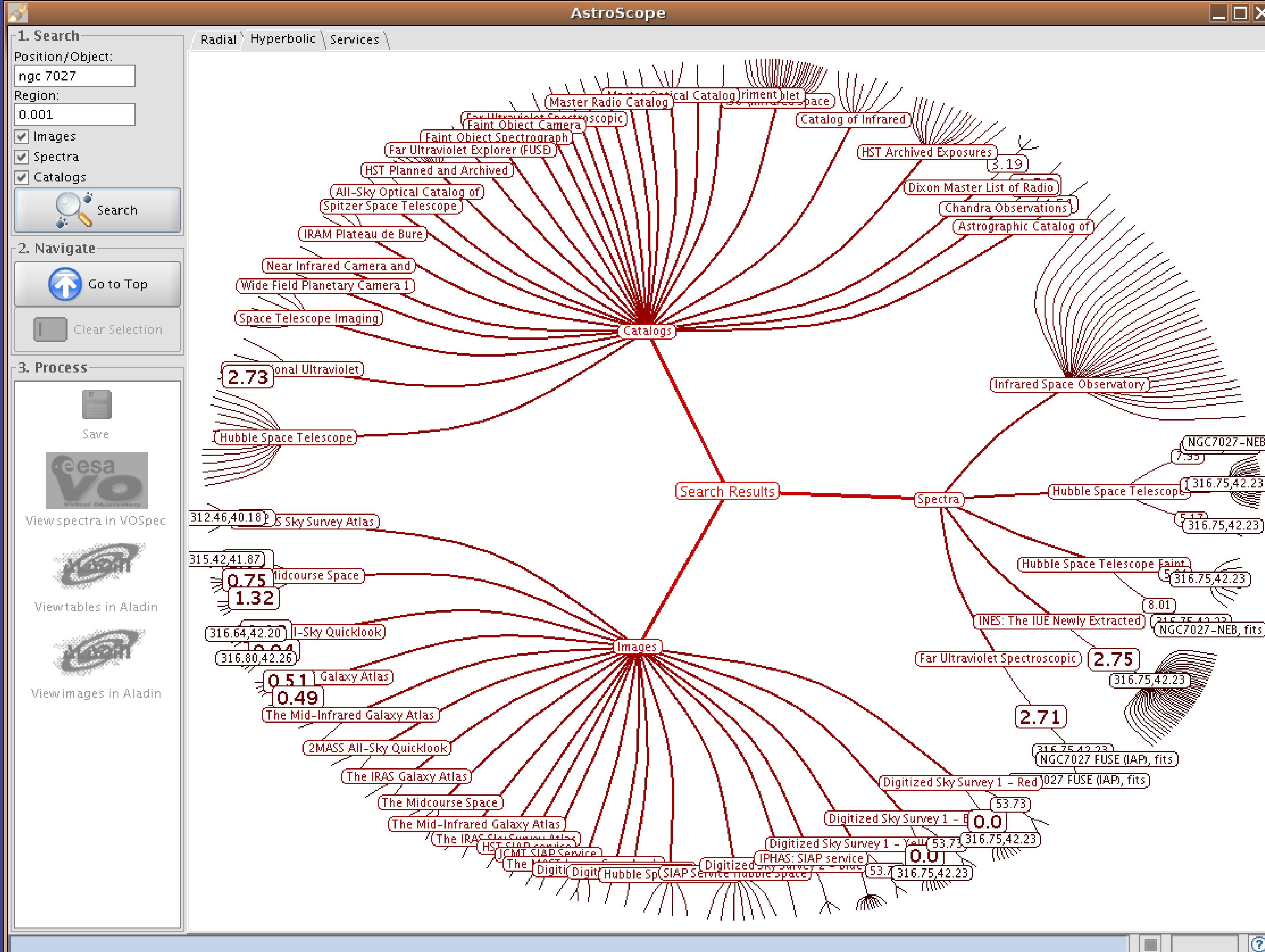
AstroGrid Workbench
Applications
PLASTIC
ACR
AstroScope
HelioScope
Launch
Canned Workflows
Workflow
Lookout
Myspace
Resources
TOPCAT
Table List
1: RC3_sub1.xml
Current Table Properties
Label: RC3_sub1.xml
Location: /home/naw/RC3_sub1.xml
Name: RC3
Rows: 23022
Spherical Plot
Main
Data
Table: 1: RC3_sub1.xml
Longitude Axis: ra
Latitude Axis: dec
Radius Axis:
Row Subsets
Potential: 23,022 Included: 23,022 Visible: 20,321
VOSpec
Wave Unit
Log Scale
micron
Flux Unit
Jy
RedShift
Graphic Mode
Target
Ra
Dec
Size
Go
VOSpec Spectra Viewer
AstroScope
1. Search
Position/Object:
crab
Region:
0.01
Images
Spectra
Catalogs
Search
2. Navigate
Go to Top
Clear Selection
3. Process
Save
View spectra in VO...
View tables in Aladin
View images in Ala...
View tables in Top...
Radial
Hyperbolic
Services
Search Results
Images
Catalogs
Inspecting Plastic Application plastic://acr/10AD58BF931-A64D37CD



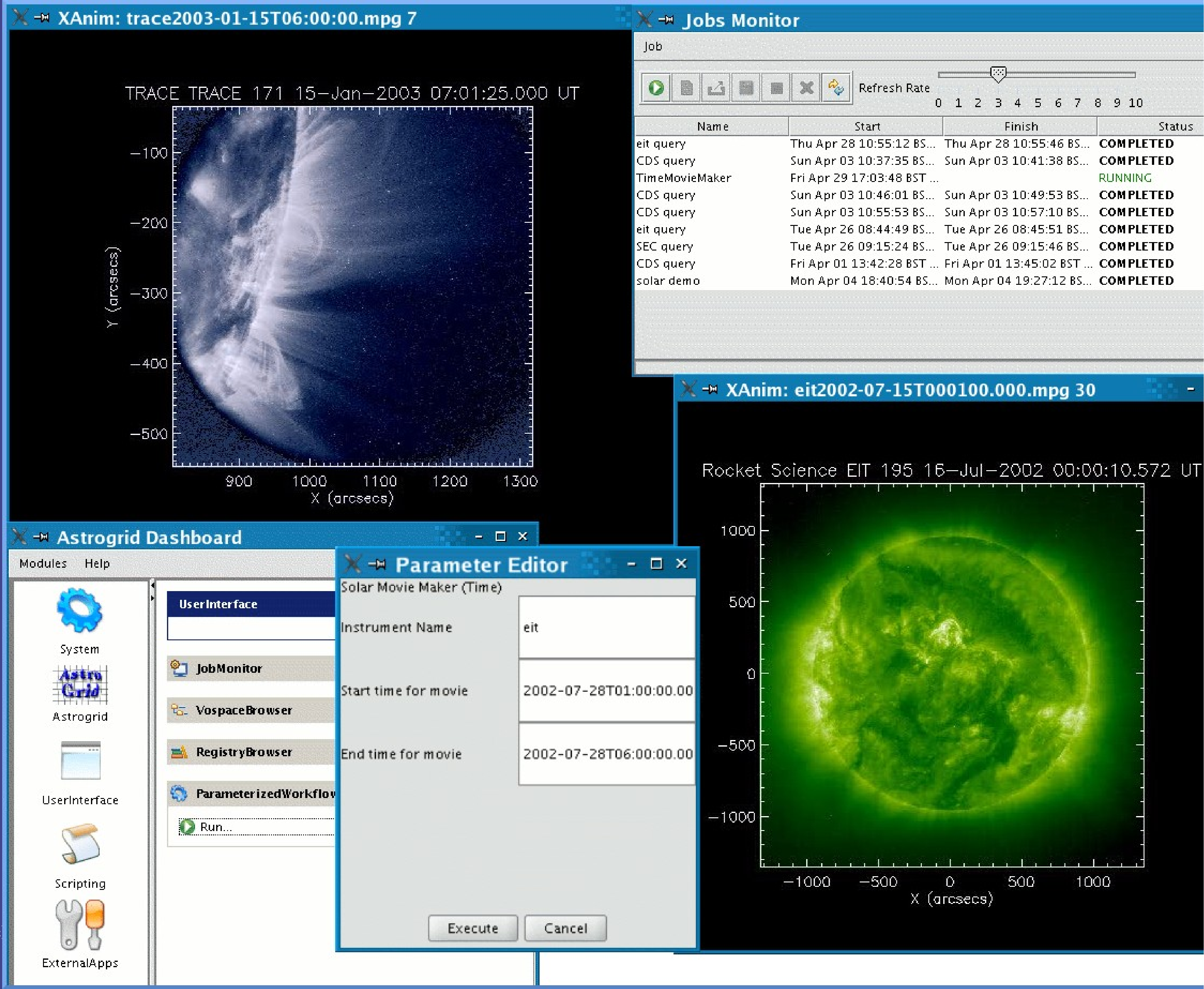
Workbench

- User Interface to VO services
- Delivery via Java Webstart technology
- Components
  - Registry
  - Find Data
  - Work with Apps
  - Workflows
  - Client Visualisation
- Enables Science

Find Information: AstroScope



Solar Movie Maker



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Wider Relevance

- Use of IVOA stds vs use of more generic GGF stds
  - implementations in use – supporting large data flows, complext computational environments
- Comparison with other domains, e.g. Medical
  - workflows and application environment
  - server based system with plugable clients for data visualisation
    - potential use from medicine to literature
- Supporting People Systems and Technical Systems
- Following talks and presentations look at specific areas where GGF standards may have relevance in supporting the construction of the Virtual Observatory

Closing

- The Virtual Observatory is developing a science driven infrastructure to allow access to distributed data and applications required to perform analysis and interpretation
  - 2006 is the year of rollout of significant systems in the USA, Europe, Asia and the UK
- Key Links
  - Astro-RG @ GGF: https://forge.gridforum.org/projects/astro-rg/
  - IVOA: http://www.ivoa.net
  - AstroGrid: http://www.astrogrid.org
  - NVO: http://www.us-vo.org
  - Euro-VO: http://www.euro-vo.org