Science in the Virtual Observatory

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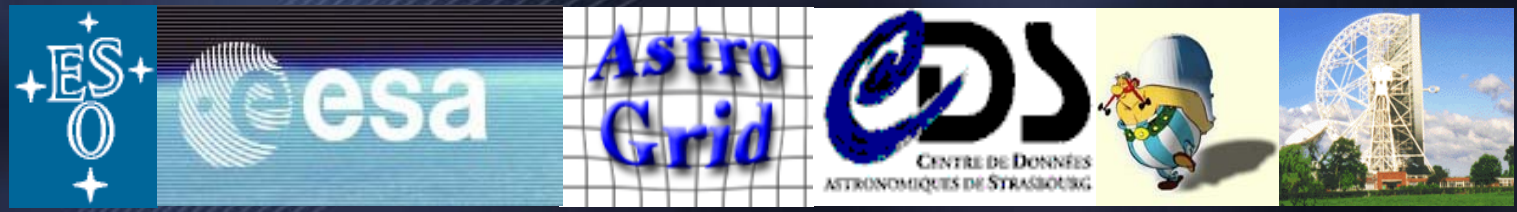
- VO as a science driver
- VO-Science in Europe: the AVO experience
- The AVO Science Reference Mission
- The future: science in the EURO-VO

Virtual Observatory

- An innovative, *evolving* system, which takes advantage of astronomical data explosion
- It will allow users to interrogate multiple data centres in a seamless and transparent way and to utilize at best astronomical data
- It will allow new *SCIENCE* by, e.g.,:
  - ✓ moving Astronomy beyond era of “classical” identification by combining **all** available information: data mining (increase observational efficiency) + statistical identification (less need for spectra)
  - ✓ permitting massive, remote computing on astronomical data, with analysis tools residing where the data are or in a VOStore

AVO

- Astrophysical Virtual Observatory Project: R&D on scientific requirements and technology for building the VO in Europe, 50% funded by European Community



- Phase A, 2001 - 2004/5 (*http://www.euro-vo.org*)
- Driven by strategy of **scientific VO annual demonstrations**
- Science Working Group established to provide scientific advice to AVO project
- Project completed; now EURO-VO

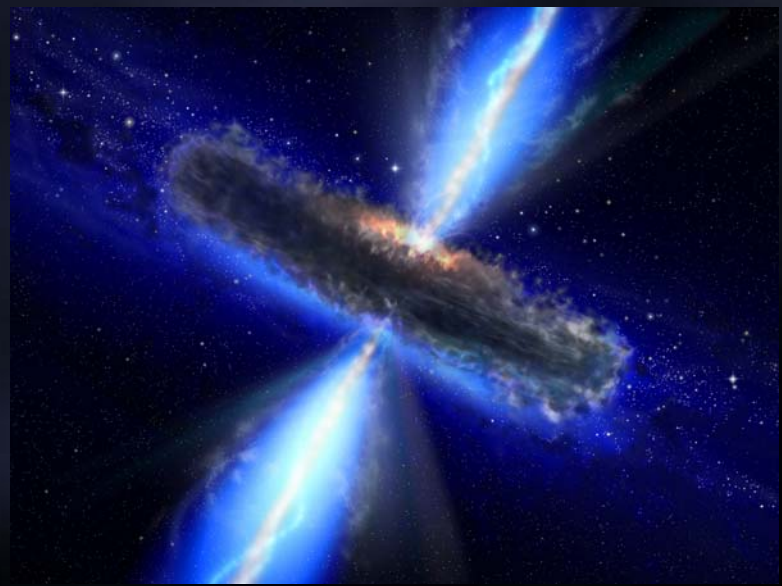
January 2004 AVO Demo Overview

- Two scenarios:
  - Extragalactic: **Obscured (Type 2) Quasars**
  - Galactic: **Classification of Young Stellar Objects (YSO)**
- Multiwavelength, heterogeneous, and complex data: VLA, CGPS, ISO, 2MASS, USNO, 2.2m/WFI, VLT/FORS, HST/ACS, XMM, and Chandra (images, spectra, and catalogues)
- Access to any **VO-compliant** data: seamless and transparent access to ESA ISO & XMM archives and ESO data products
- AVO: from First Light (2003 demo) to First Science!

VO First Science!

- First refereed astronomical paper enabled via end-to-end use of VO tools and systems: "*Discovery of optically faint obscured quasars with Virtual Observatory tools*", Padovani, Allen, Rosati, & Walton, 2004, A&A, 424, 545

ESA/ESO Press release May 28 2004



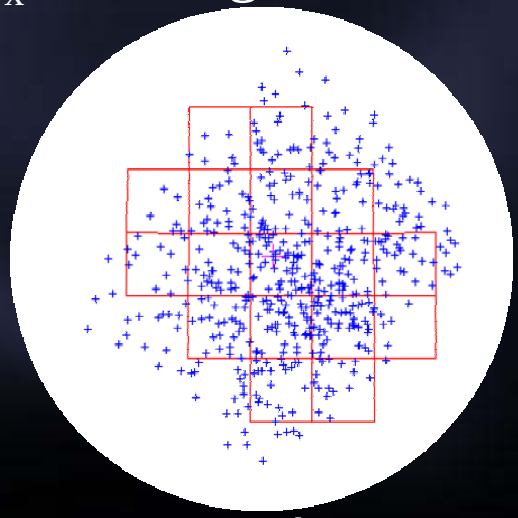
The AVO Prototype

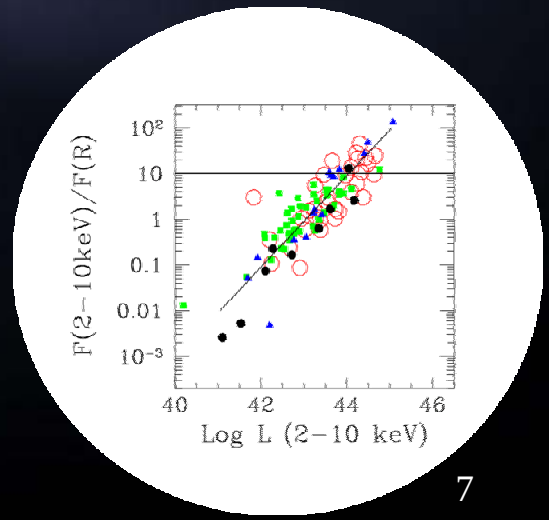
- Evolution of Aladin (Centre de Donnés astronomiques de Strasbourg [CDS])
- Downloadable Java application
  (http://www.euro-vo.org/twiki/bin/view/Avo/SwgDownload)
- Extensible toolset with plug-ins which allows easy access to images (manipulation), spectra, catalogues, with overlays, plotting facilities, catalogue extraction, and a cross-correlation utility [ASTROGRID, VOIndia, STScI]
- Interoperable with other VO tools

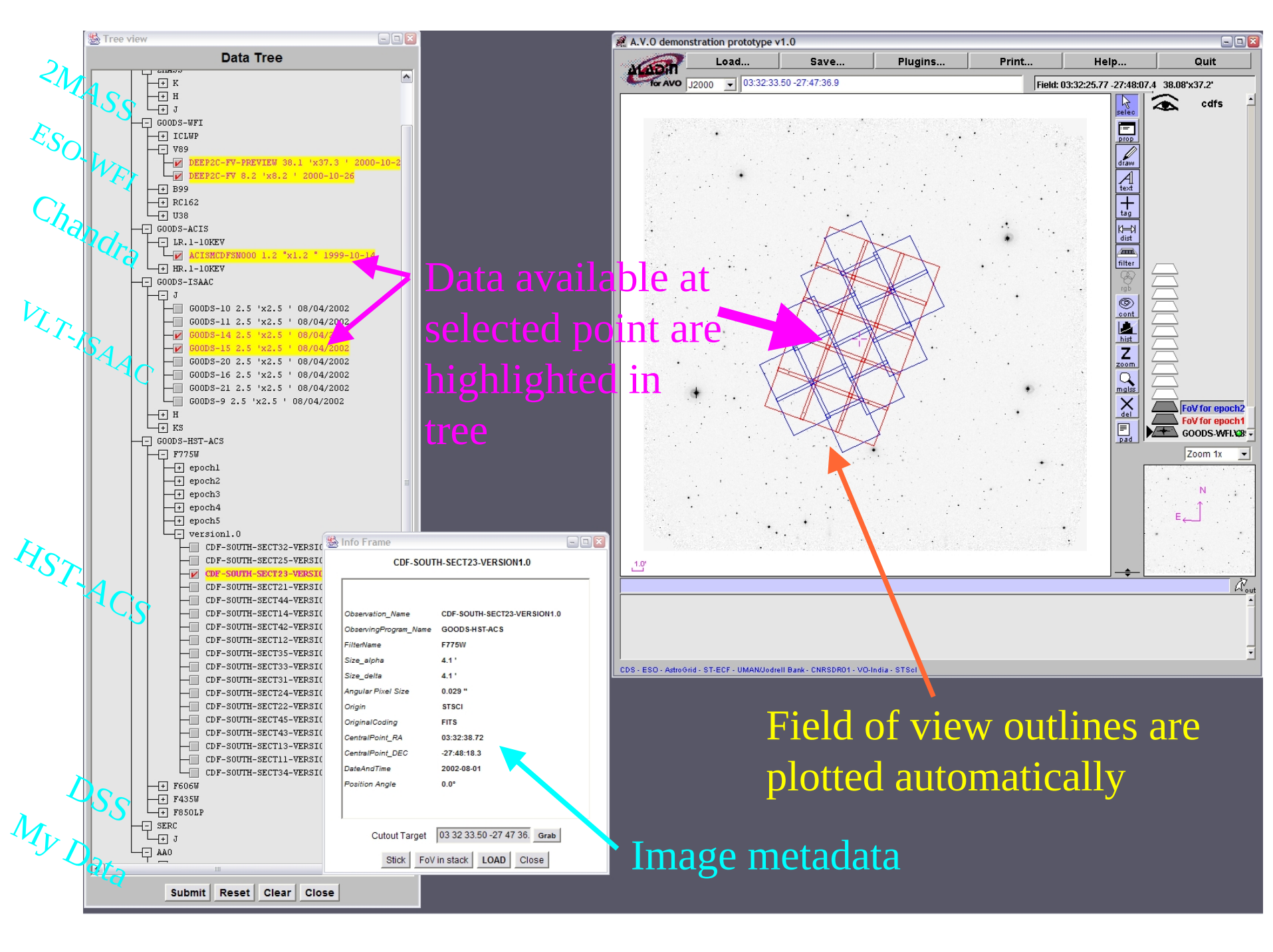
Discovery of QSO 2s with VO tools

- GOODS HST/ACS data & catalogues
- Chandra X-ray catalogues
- Select absorbed X-ray sources
- Cross-match X-ray and optical
- Check against spectroscopy
- Apply empirical estimator for Lx:

$L_x > 10^{42}$ erg/s: **AGN 2**; $L_x > 10^{44}$ erg/s: **QSO 2**



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ESO-WFI
Chandra
VLT-ISAAC
HST-ACS
DSS
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AAO
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DateAndTime 2002-08-01
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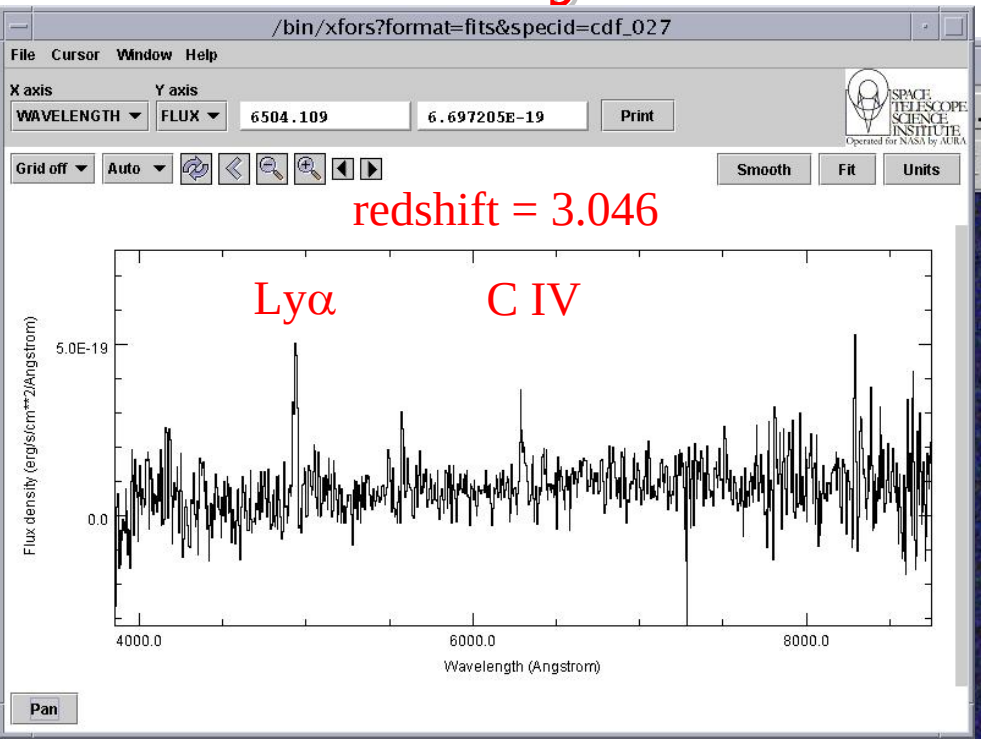
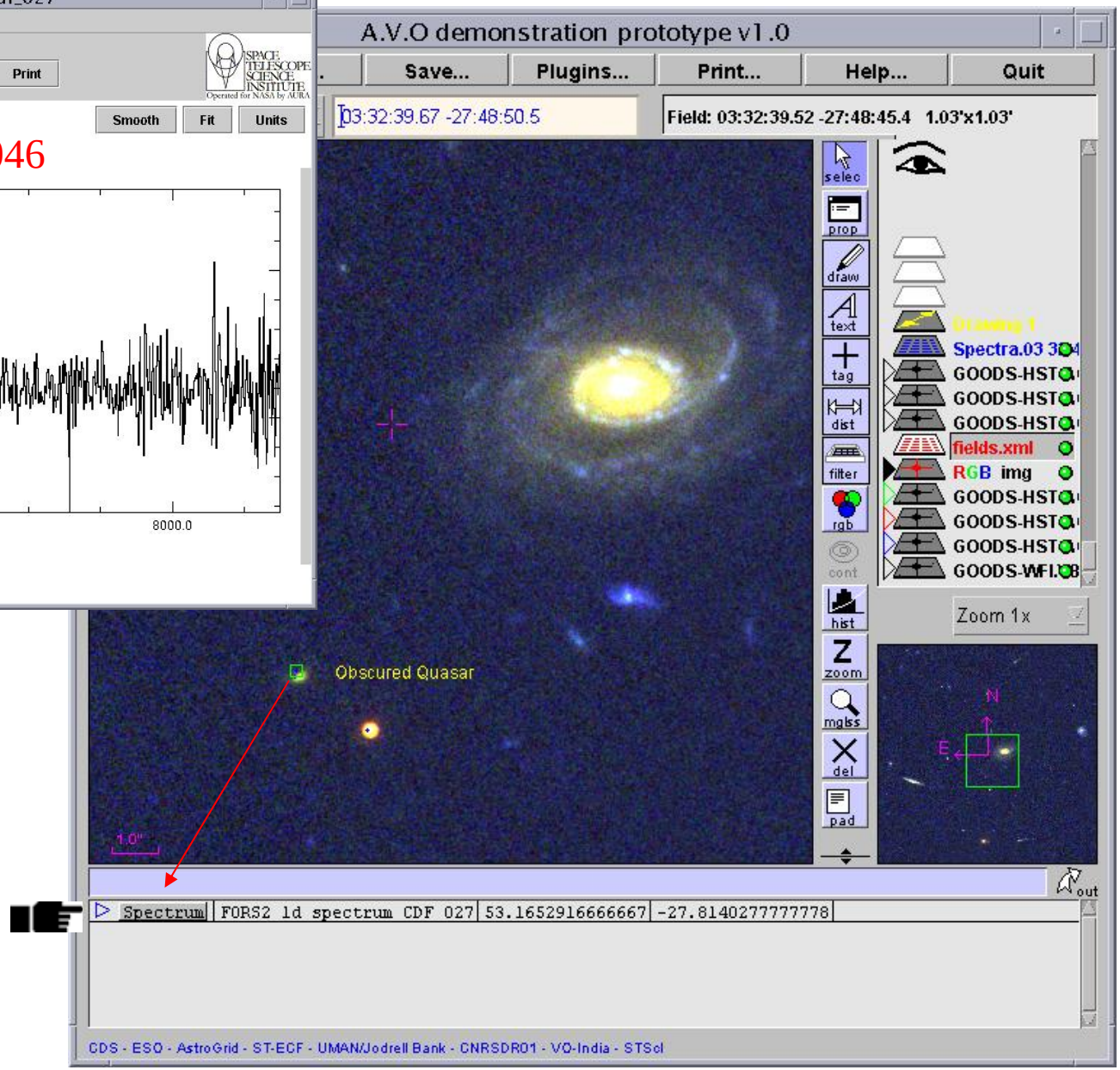
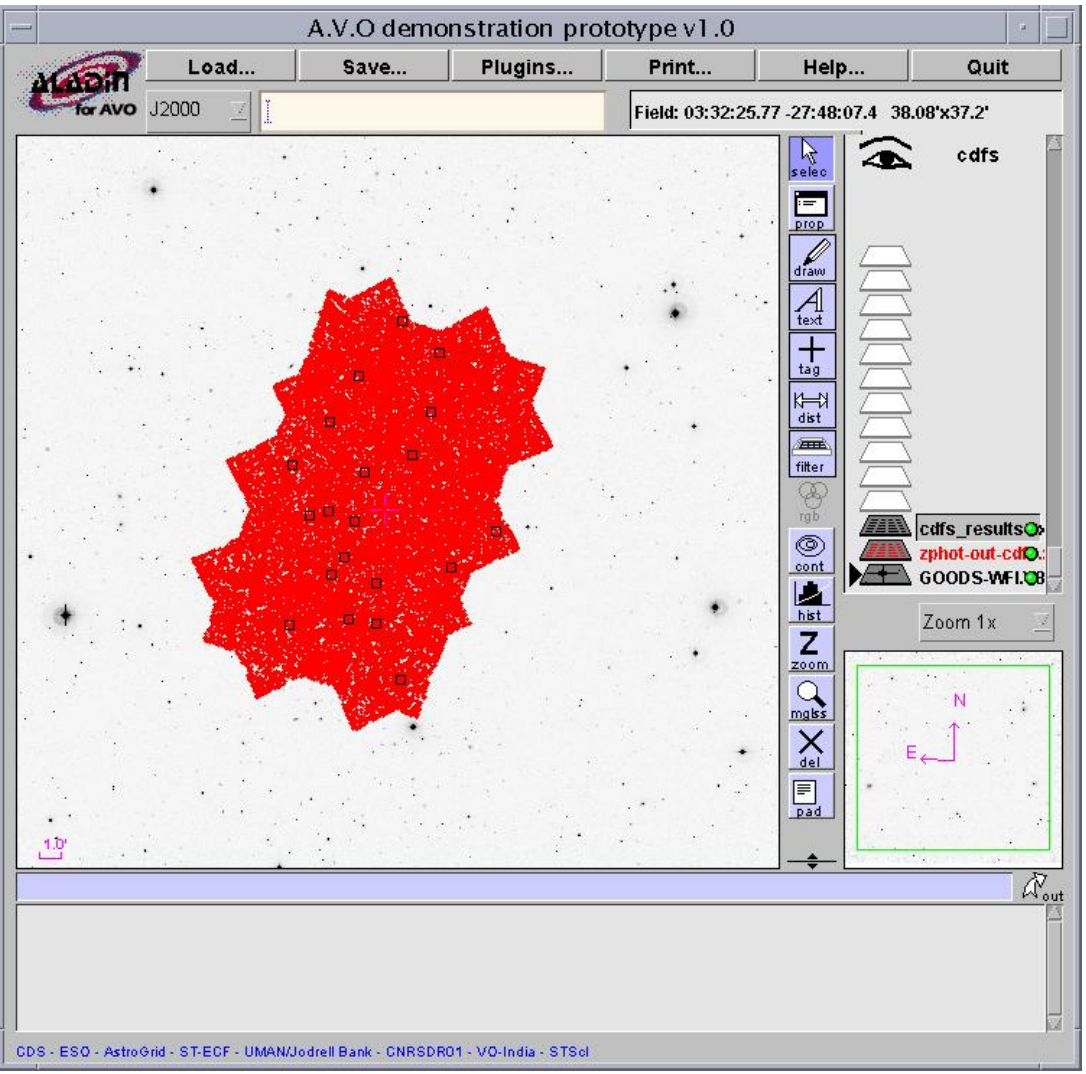
Cutout Target 03 32 33.50 -27 47 36.
Grab
Stick
FoV in stack
LOAD
Close
Data available at selected point are highlighted in tree
A.V.O demonstration prototype v1.0
Load...
Save...
Plugins...
Print...
Help...
Quit
for AVO
J2000
03:32:33.50 -27:47:36.9
Field: 03:32:25.77 -27:48:07.4 38.08'x37.2'
cdfs
FoV for epoch2
FoV for epoch1
GOODS-WFI
Zoom 1x
CDS - ESO - AstroGrid - ST-ECF - UMAN/Jodrell Bank - CNRSDR01 - VO-India - STScI
Field of view outlines are plotted automatically
Image metadata

January 2004: AVO First Science





January 2004: AVO First Science



31 <u>new</u> QSO 2 (68 new type 2 AGN) in GOODS CDFS+HDFN

x 4 increase!

$N(f_x > 10^{-15}$ c.g.s.) $\geq$ 330/deg^2

faint: <R>~ 27, beyond spectroscopy even at VLT/Keck

VO Science!

- AVO has done cutting-edge science by exploiting the data beyond “classical” identification limits (R > 25)
- AVO provides “statistical” identification of sources using multiwavelength information
- VO tools enable astronomers to reach into new areas of parameter space with little effort
- “AVO should enable everyone to compete with the GOODS team (on their data)”

  [G. Gilmore, SWG meeting, June 2002]

January 2005 AVO Demo Overview

- Two scenarios:
  - Galactic: **Asymptotic Giant Branch to Planetary Nebulae Transition** (strong science case, Spectral Energy Distribution building from archival data)
  - Extragalactic: **Star Formation Histories in Galaxies** (new VO computing concepts: towards the Grid; access to theoretical models)
- Multiwavelength, heterogeneous, and complex data: VLA, MERLIN, Spitzer, ISO (spectra and images), MSX, IRAS, 2MASS, WFS, HST/WFPC2, FUSE, IUE, plus Vizier catalogues
- Another VO paper to be written (Bayo, Garcia-Lario, Sierra, et al.)!

AGB stars to PNe

Late evolutionary stages of low- and intermediate mass stars (1 - 8 M_o)

- Short transition times (~10^3 - 10^4 yr)
- Recent AGB mass loss (up to 10^{-4} M_o/yr)

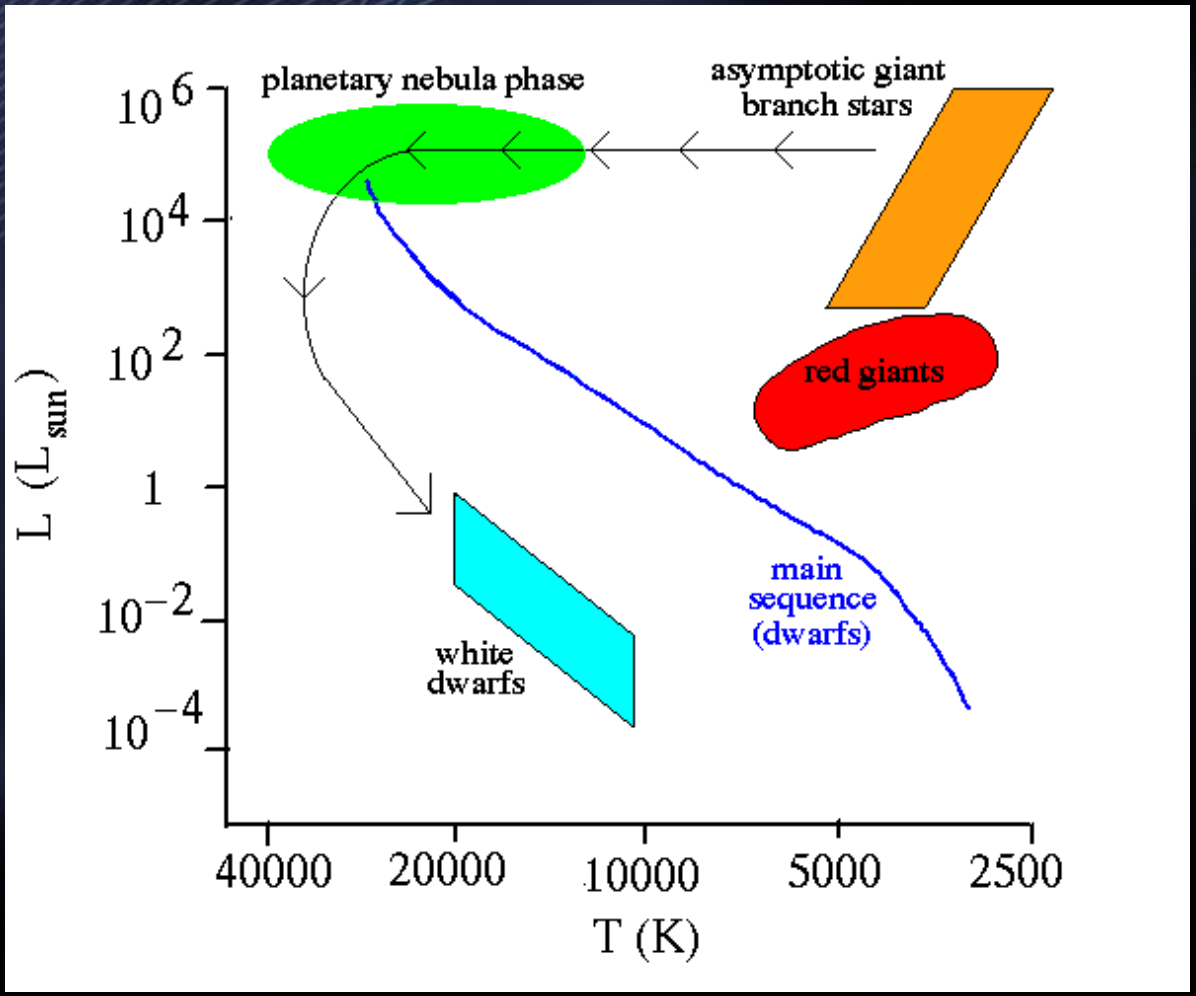
⇓

- Few objects in this phase (≈1/1,000,000)

- Many are heavily obscured in the optical

⇓

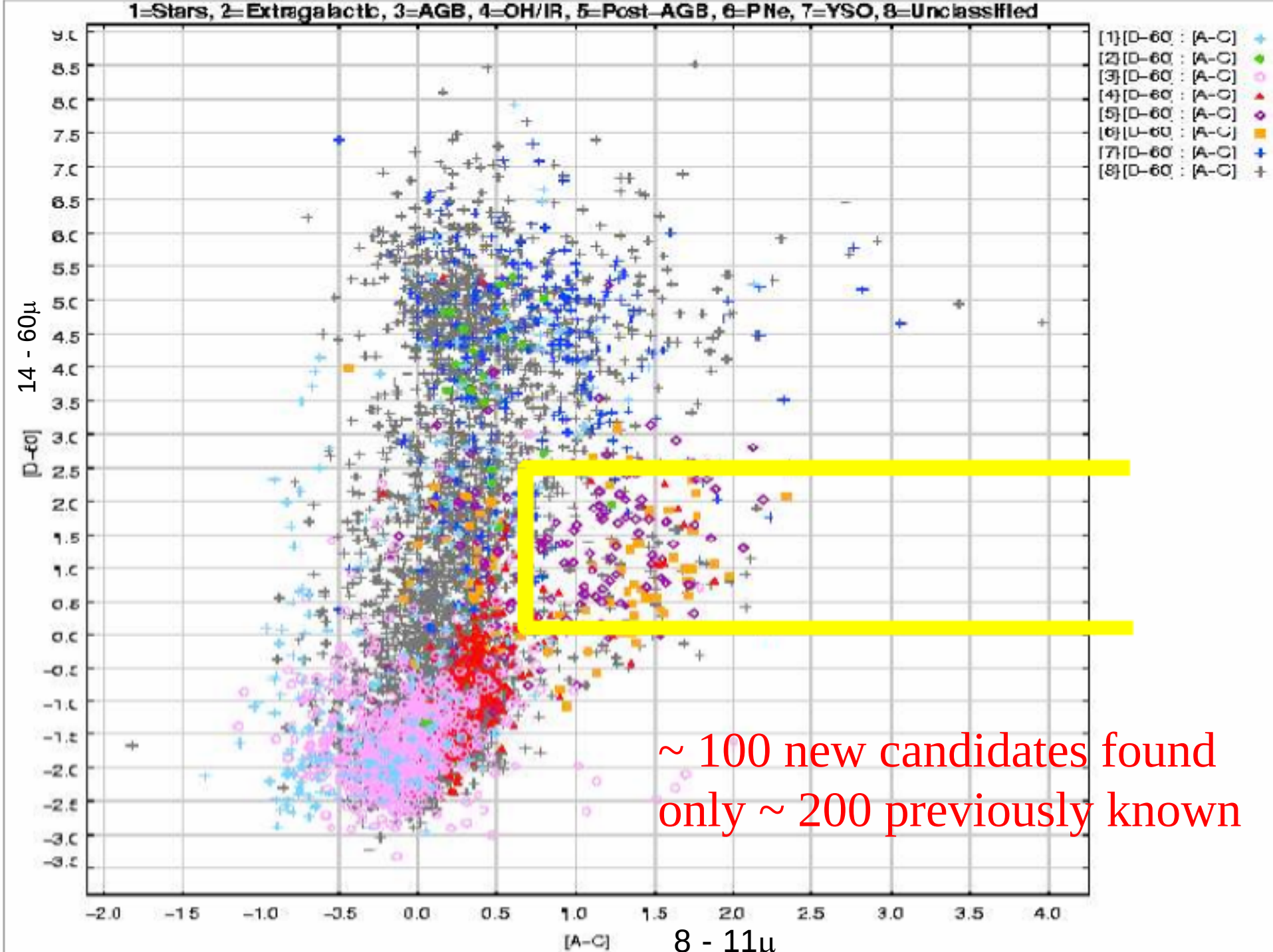
- Need for systematic surveys using infrared data



(courtesy of Pedro Garcia Lario)

AGB stars to PNe

- Strategy: use large IR catalogues (IRAS and Midcourse Space Experiment [MSX]) to identify colours characterising various classes of sources as given by SIMBAD and then find objects with no published identification in the region of parameter space typical of transition sources.
- Steps:
  - Select high-quality detections in IRAS (~ 70k) and MSX (~ 50k) catalogues
  - Cross-correlate MSX and IRAS lists
  - Calculate 8 - 11μ and 14 - 60μ colours
  - Query SIMBAD to get source classification
  - Identify region in two-colour diagram dominated by post-AGB and PNe objects
  - Unclassified sources in the same region $\Rightarrow$ new transition candidates


1=Stars, 2=Extragalactic, 3=AGB, 4=OH/IR, 5=Post-AGB, 6=PNe, 7=YSO, 8=Unclassified
[1][D-60] : [A-C]
[2][D-60] : [A-C]
[3][D-60] : [A-C]
[4][D-60] : [A-C]
[5][D-60] : [A-C]
[6][D-60] : [A-C]
[7][D-60] : [A-C]
[8][D-60] : [A-C]
14 - 60μ
[D-60]
[A-C]
8 - 11μ
~ 100 new candidates found
only ~ 200 previously known

The AVO Science Reference Mission

- The Science Reference Mission (SRM) defines key scientific results that the full-fledged (Phase B) EURO-VO should achieve when fully implemented.
- It consist of ten science cases, with related requirements, against which the success of the EURO-VO will be measured.
- Put together with input from the AVO Science Working Group.

The AVO Science Reference Mission

What is the Science Reference Mission (SRM)? The SRM is a definition of the key scientific results that the full-fledged, Phase B, EuroVO should be able to achieve when fully implemented. It will consist of a number of science cases, with related requirements, against which the success of the EuroVO will be measured.

Contents:

SRM document

- preliminary version (.pdf)

SRM Cases

- Circumstellar Disks (.txt)
- Intermediate Velocity Clouds (.txt)
- Which Star will go Supernova next? (.txt)
- Initial Mass Function (low masses) (.txt)
- Initial Mass Function (high masses) (.txt)
- Low and intermediate mass stars contribution to the ISM (.txt)
- Galaxy Formation and Evolution (.txt)
- Build-up of Supermassive Black Holes (.txt)
- Formation and Evolution of Galaxy Clusters (.doc)
- Correlation of CMB background, radio/mm, and optical/NIR Galaxy Surveys (.txt)

EURO-VO Science

- EURO-VO funding situation still not well-defined, only VO-Tech (a VO-TC project) funded
- There will be a EURO-VO external science body, whose composition will soon be finalized
- More complex role than AVO SWG given the tri-partite nature of EURO-VO: Data Centre Alliance, Technical Centre, and the Facility Centre

EURO-VO and the Community

- AVO has reached out to the European astronomical community mostly through the SWG, plus papers and articles (ESO Messenger, ST-ECF & EAS Newsletters)
- EURO-VO will reach out to the data providers through a dedicated workshop at ESO (June 27 - July 1)
- We also plan to start having a presence at JENAM/EAS meetings, to contact directly (and get feedback from) astronomers (as the NVO does at the AAS)

Summary

- The Virtual Observatory is a science driver!
- One of AVO's top priorities has been the pursuit of astronomy through:
  - Three science demonstrations
  - Journal and conference astronomical papers
  - A Science Reference Mission
- AVO has produced REAL science tools, which can be (and are!) used for astronomical research:
  - AVO prototype is a very flexible toolset with plug-ins which allow easy access to images, spectra, and catalogues
  - ASTROGRID's workflow builder and MySpace are at cutting edge of VO development
- EURO-VO's plans not fully defined yet; but science will certainly play a major role!