First Science with the Virtual Observatory

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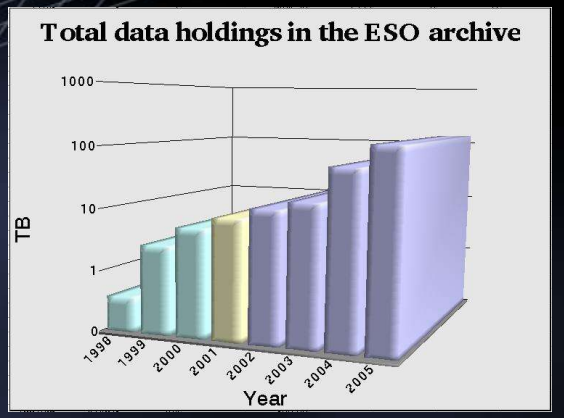
Outline

- Introduction to Virtual Observatories
- Science with the VO
  - Search for type 2 Quasars
  - AGB to PN transition objects
- Tools available now
- Virtual Observatory Future Outlook

Why do we need VO?



- Imminent Technical Challenges
  - Data volumes and rates
  - Major archives growing: Tbytes/yr
    - Doubling time: 6-12 months
    - Faster than Moore's Law (18 months)
    - Device access rates & last mile of thin wire are the real bottle necks

➔ *Take the computation to the data*

➔ *Ship the results, not the data*

Scientific Motivation

Multi-ůλ science requires

- Data from different telescopes
- Analysis tools
- on-line services
- archived information

to be *readily compatible*

Science drivers

- Find all info on a given set of objects
  - Defined by positions, colours, morphology,...
- Build SEDs from multi-archive data
  - Accounting for instrumental, sensitivity, aperture effects
- "*Outlier Science*" Multi-d parameter searches
- Compare LSS with *'virtually observed'* N-body simulations
- Re-analyse the SLOAN, MACHO
- Multi-λ census of AGN
- Build a survey to search for Cosmic Shear

Virtual Observatories

- VO = framework for interoperable systems
- VO Vision: *All Astronomy resources as if they were on your desktop*
- "*Observing the digital sky*"

Interoperability

- Common query language
- Uniform interfaces for diverse data
- Analysed by the same tools
- Astronomical interoperability
  - Coordinates, Units, photmetric systems, ...
  - Describing content in standard way
- The key to interoperability is the use of Standards

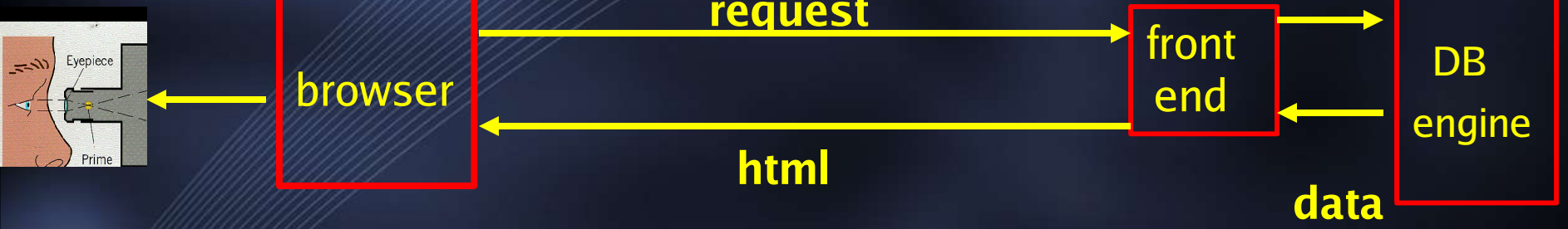
International Virtual Observatory Alliance

Member Organizations

Core Components

- Finding available data, services
  - Registries
- Accessing the data and services
  - Data Access layer protocols: SIA, SSA
  - Common query language: VOQL
  - Contents Description: Metadata, formats
  - Workflow: Linking services together

yesterday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Eyepiece
Prime
browser
front
end
DB
engine
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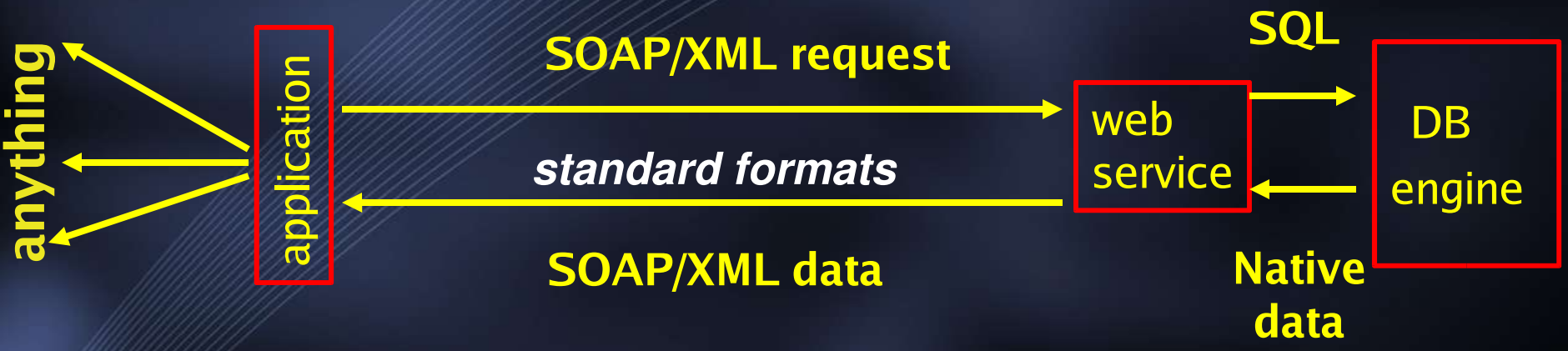
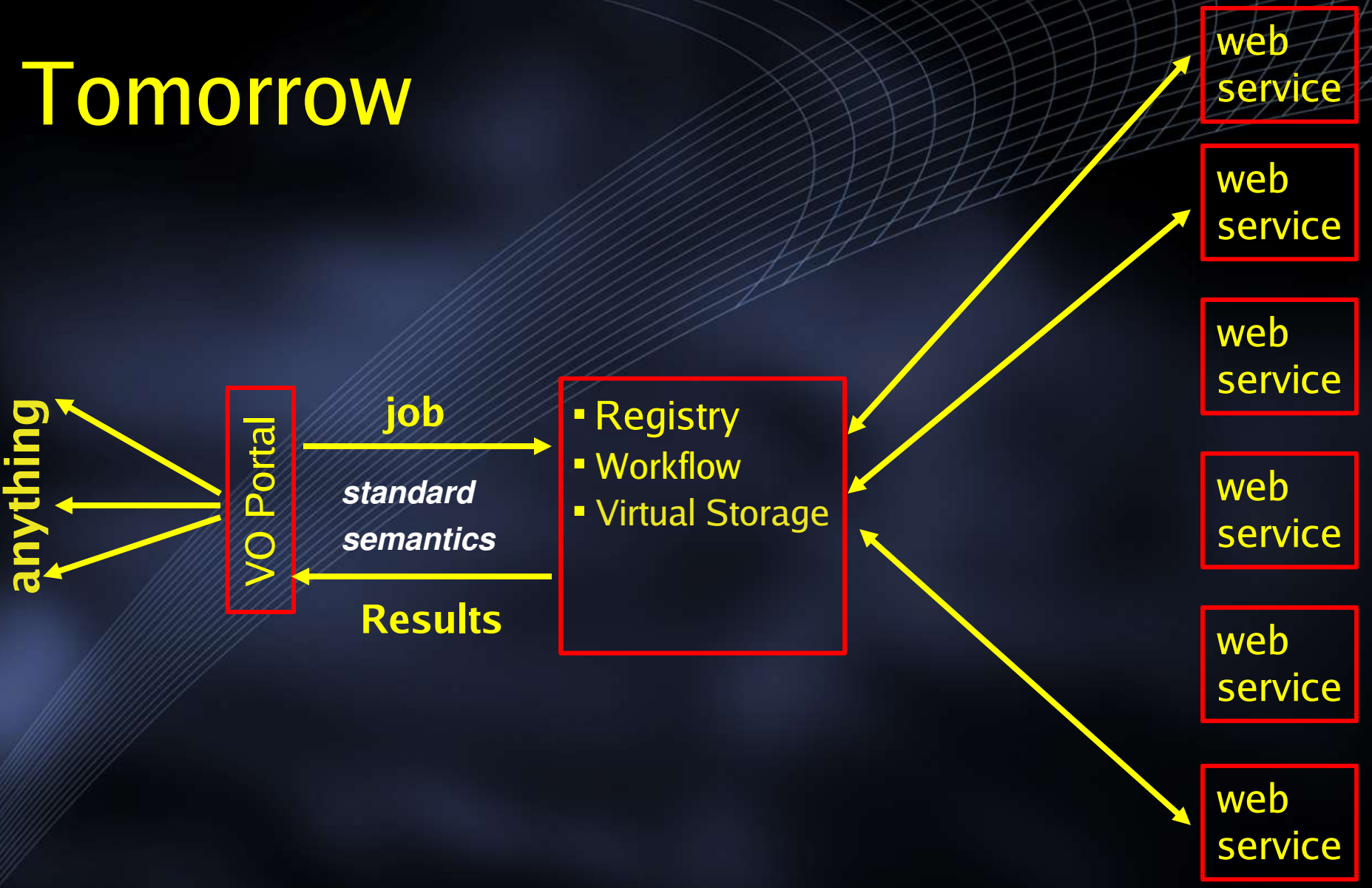
data

today


anything
application
SOAP/XML request
standard formats
SOAP/XML data
web service
SQL
DB engine
Native data

Tomorrow

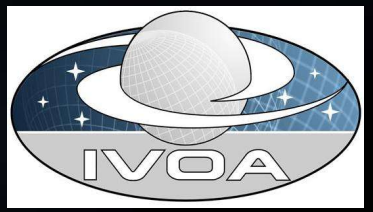

anything
VO Portal
job
standard
semantics
Results
Registry
Workflow
Virtual Storage
web service
web service
web service
web service
web service
web service

Standards

- Registry standards
  - Describing resources/services
- Simple Image/Specta Access Protocols
- Format standard: VOTable, (FITS)
- VO Query Language
- UCD: semantics
- Data Model
- Web Services – following IT industry

Status

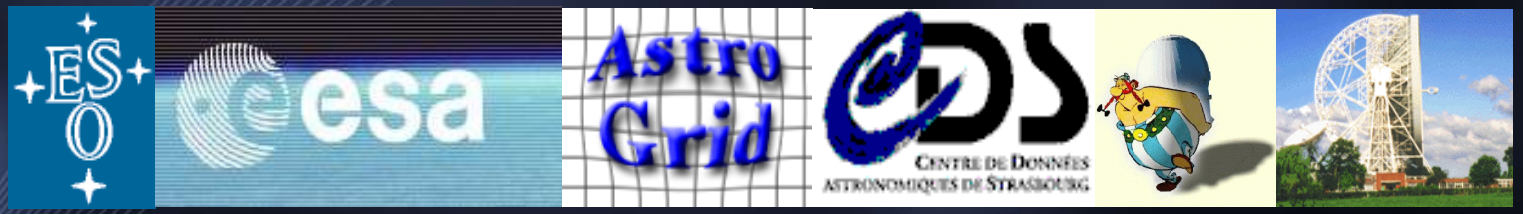
- Milestone: Phase-A studies finalised
  - AVO, AstroGrid, NVO
  - Moving on to building real services
- Prototype VO tools ➟ Scientific Results
  - Many projects/archives adopting standards
  - WWW growth effect starting



AVO

ASTROPHYSICAL VIRTUAL OBSERVATORY

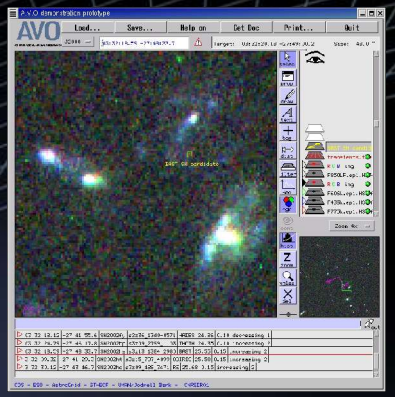
- R&D on scientific requirements and technology for building a VO
- 6 European organisations



- 3 yr phase-A, 2001-2004/5
- Driven by strategy of scientific VO demonstrations

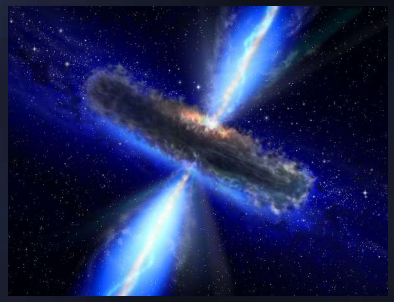
Demo 2003: First Light

VO Visualisation and Data Discovery



Demo 2004: First Science

Searching for type 2 Quasars using Virtual Observatory tools

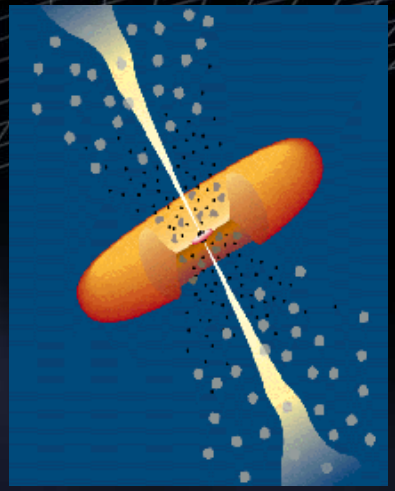


Demo 2005

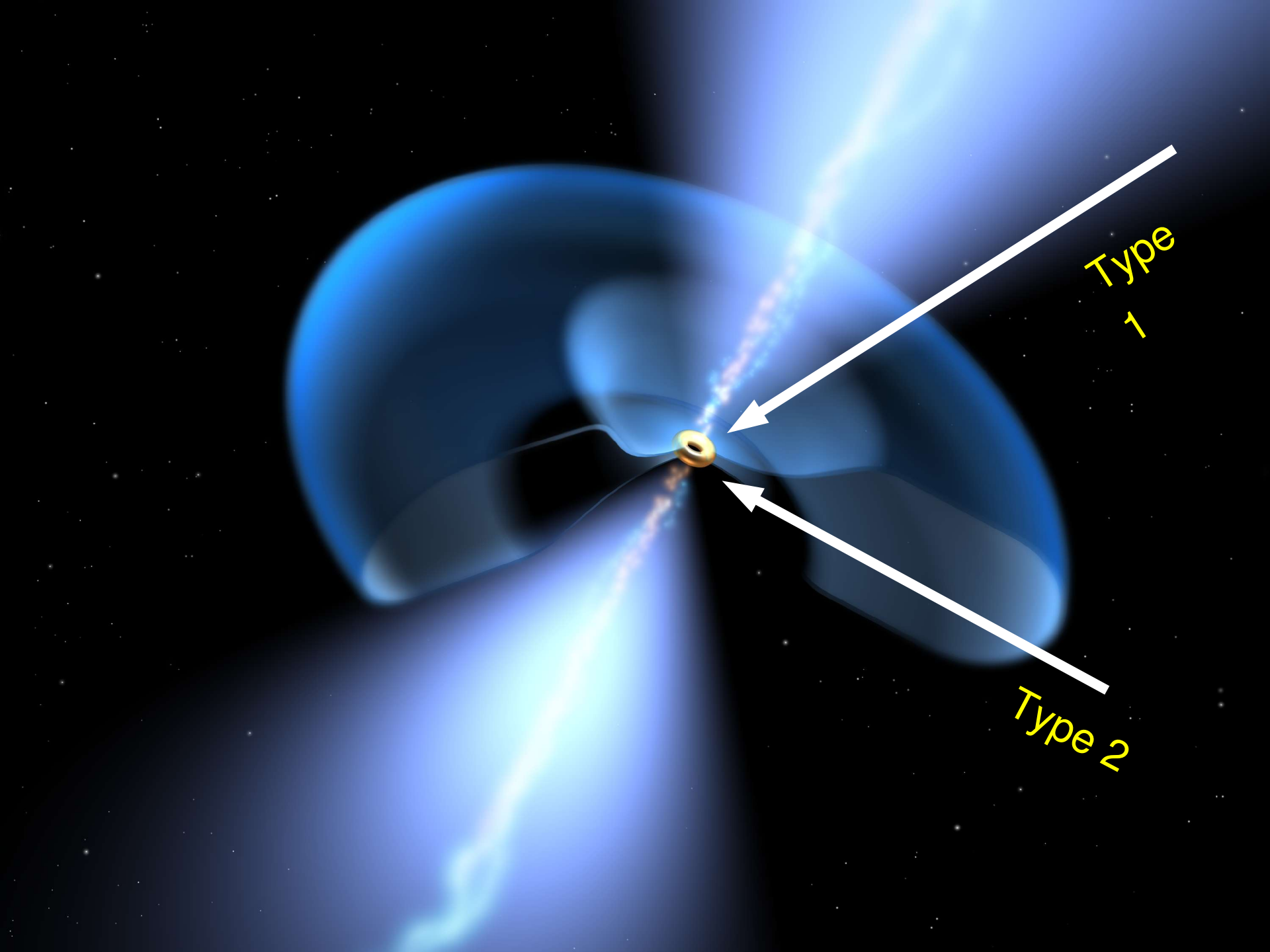
AGB to Plantary Nebulae transition

Workflow: SEDs to Models

AGN Unified Model



- Different types of AGN explained by the physics of the
  - Black hole
  - Accretion disk
  - Jet and
  - Torus
- Convolved with the geometry of the viewing angle
- Urry & Padovani (1995), Jaffe et al. (2004)

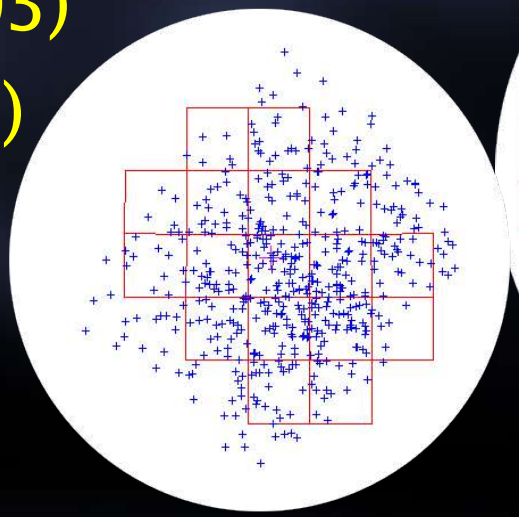

Type 1
Type 2

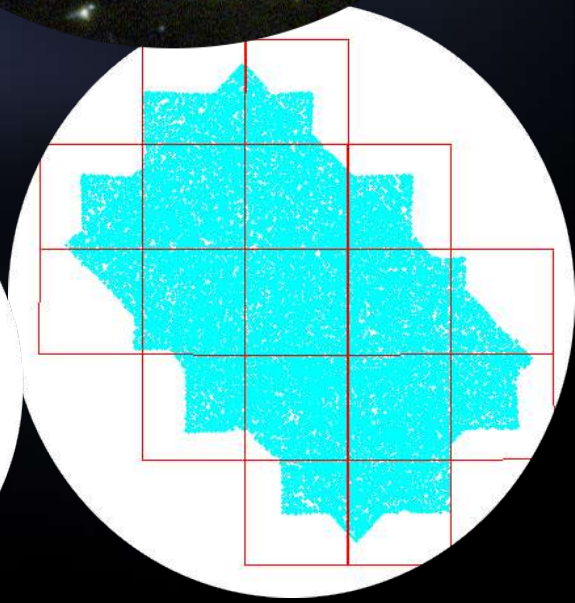
Type 2 AGN

- Local *low power* type 2s : Seyfert 2s
- High power counterparts: QSO 2 (*type 2 quasars)*, difficult to find.
- Heavily reddened and fall through optical/UV selection
- However...
  - Hard X-rays can penetrate the torus

Data

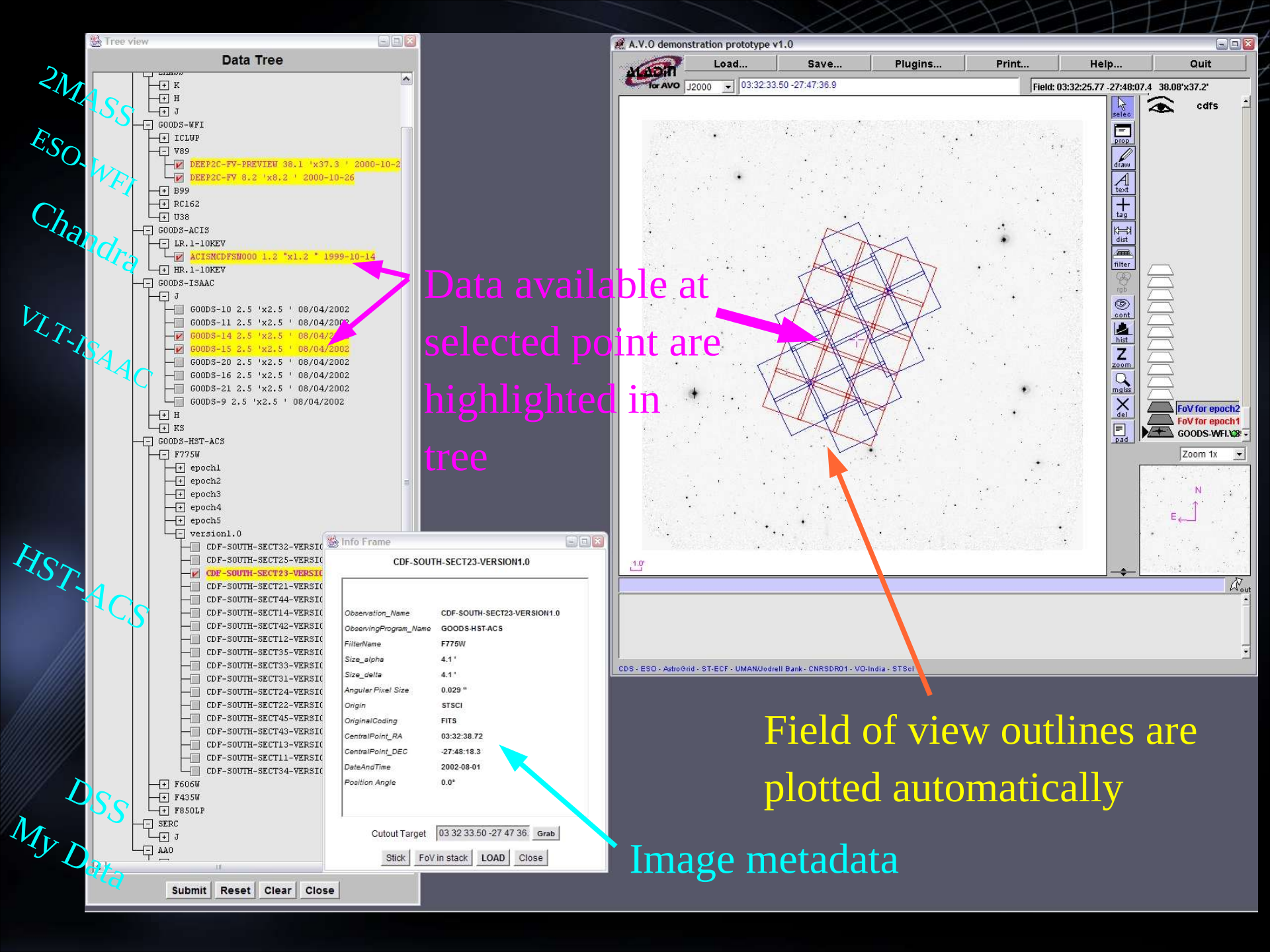
- GOODS: *Bviz* Images & Catalogues
  - CDF-S (+UDF), HDF-N : 61647 sources
- Deep X-ray Chandra Catalogues
  - Alexander et al. 2003
  - HDF-N 2Ms (503)
  - CDF-S 1Ms (326)





AVO prototype

- Registry of services (GLU)
- CDS Aladin interface
  - Interactive manipulation of image and catalogue data
  - “Portal” for access to services/data
- Cross-matching service for catalogues
- Conventions for accessing remote data
- Remote calculations
- Interoperable with other VO tools


2MASS
ESO-WFI
Chandra
VLT-ISAAC
HST-ACS
DSS
My Data
Tree view
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RC162
U38
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epoch4
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F850LP
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ObservingProgram_Name GOODS-HST-ACS
FilterName F775W
Size_alpha 4.1 '
Size_delta 4.1 '
Angular Pixel Size 0.029 "
Origin STSCI
OriginalCoding FITS
CentralPoint_RA 03:32:38.72
CentralPoint_DEC -27:48:18.3
DateAndTime 2002-08-01
Position Angle 0.0°
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
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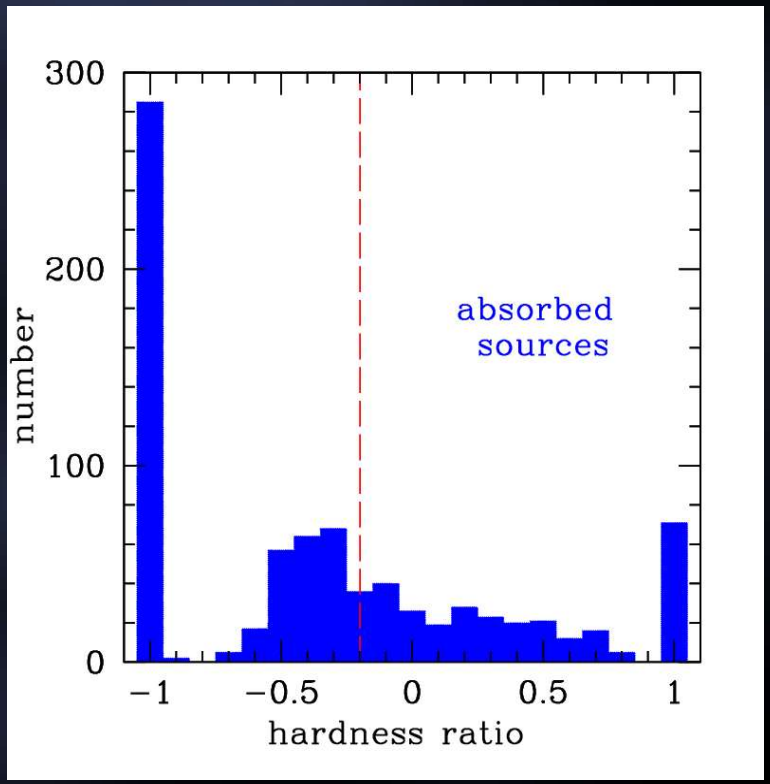
03:32:33.50 -27:47:36.9
Field: 03:32:25.77 -27:48:07.4 38.08'x37.2'
cdfs
FoV for epoch2
FoV for epoch1
GOODS-WFI
Zoom 1x
CDS - ESO - AstroGrid - ST-ECF - UMAN/Jodrell Bank - CNRSDR01 - VO-India - STScI
Field of view outlines are plotted automatically
Image metadata

Method

- Select candidates based on two key physical properties of Type 2 AGN:
  - Obscured – absorbed
    - Chandra X-ray catalogues
  - High power – to be classed as AGN
    - Empirical relation for Lx using flux(2-10 keV) / flux(R-band)

Absorbed sources

- HardnessRatio
  HR=(H-S)/(H+S)
  S = 0.5 – 2.0 keV
  H = 2-8 keV
- Type 2 AGN have HR > -0.2
- Increasing z makes sources appear softer therefore discard some high-z type 2s
- 294 absorbed sources (CDF-S: 104, HDF-N:190)

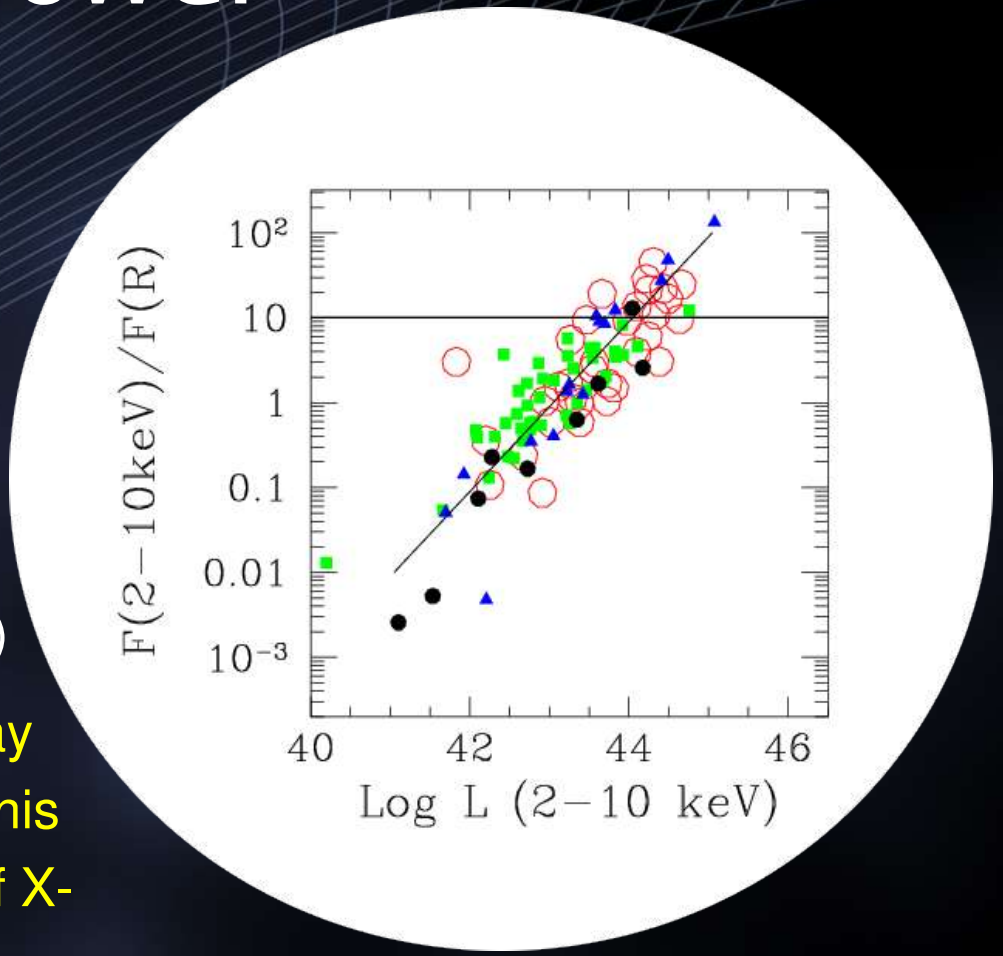


Optical counterparts

- X-match absorbed sources with GOODS *z*-band catalogs
- Detect and correct for systematic shift
- Take positional uncertainty into account
  - (Match distance)/error < 1
  - Most match distances < 1.25”
  - False match estimate: 8 – 15%
- Almost all (HDF-N, CDF-S) X-ray sources have optical counterparts

Estimate X-ray Power

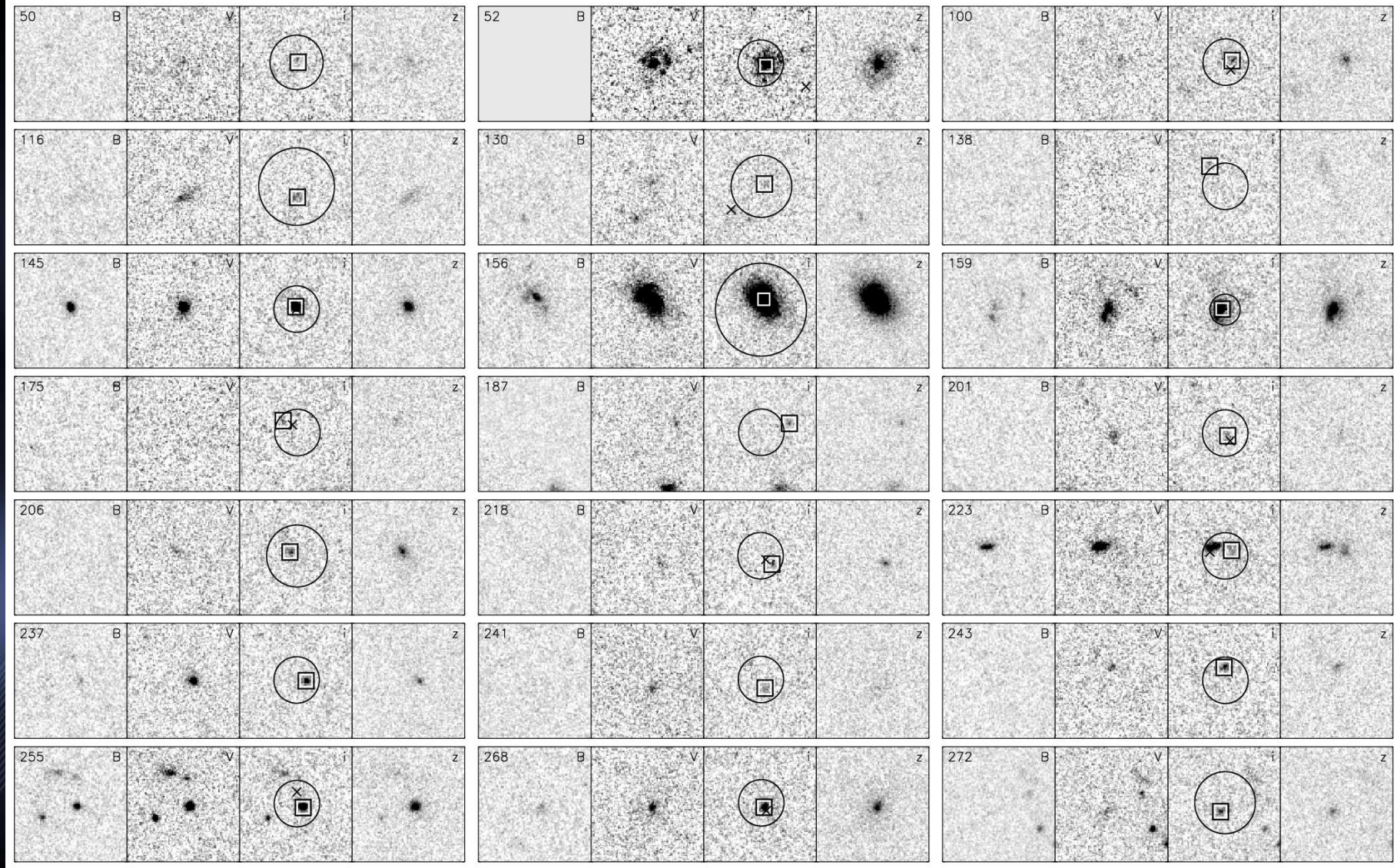
- Fiore et al. (2003) relation for type 2 objects
- flux(2-10 keV) / flux(R)
  ~ L(nucleus) / L(host galaxy R)
- Since R luminosity (unlike X-ray power) show modest scatter, this flux ratio is a good estimator of X-ray power



Log L(2-10 keV) = Log f(2-10 keV)/f(R) + 43.05 (erg s^{-1})

Type 2 AGN candidates: CDF-S

B V *i* *z*



Results

- 147 type 2 AGN
- 27% of the 546 X-ray sources
- But some of these sources are already known...
  - Spectroscopically classified as type 2 AGN
    - Szokoly et al. (2004)
    - Barger et al. (2003)

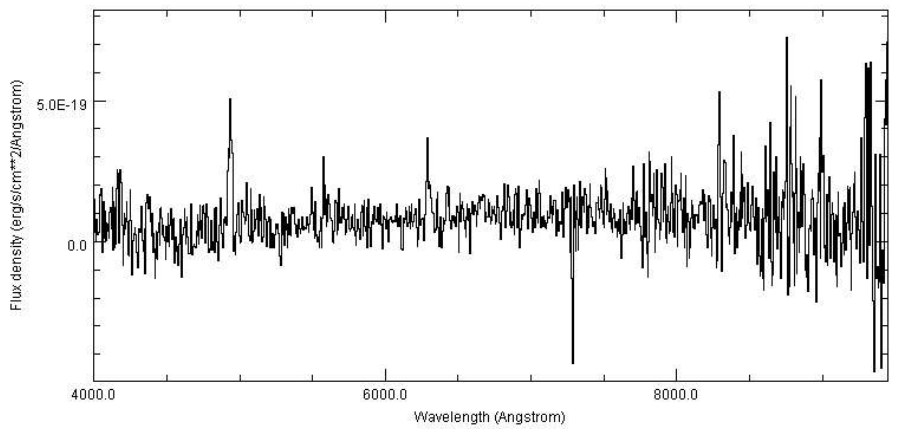
/bin/xfors?format=fits&specid=cdf_027

File Cursor Window Help

X axis: WAVELENGTH | Y axis: FLUX | 8374.499 | -5.730355E-19 | Print

Space Telescope Science Institute — Operated for NASA by AURA

Grid off | Auto | Smooth | Fit | Units



Pan

FORS2 ld spectrum GOODS J033214-274825
FORS2 ld spectrum GOODS J033214-274825
FORS2 ld spectrum GOODS J033214-275124
FORS2 ld spectrum GOODS J033214-275257
FORS2 ld spectrum GOODS J033214-275258
FORS2 ld spectrum GOODS J033215-274633
FORS2 ld spectrum GOODS J033217-275113
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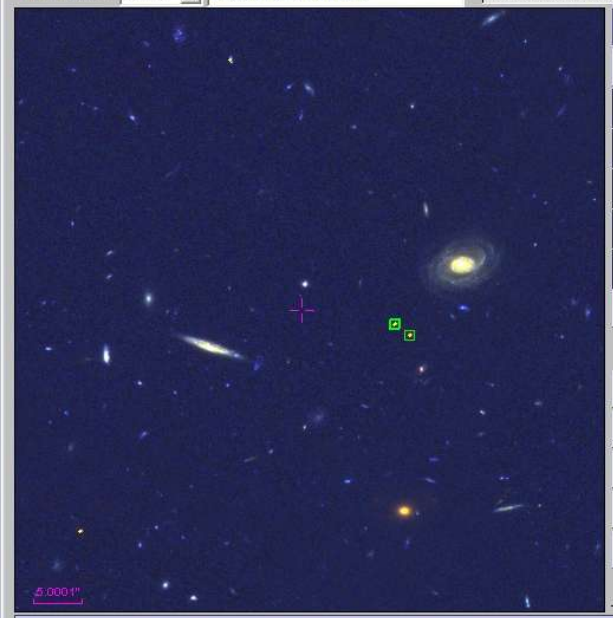
FORS2 ld spectrum GOODS J033218-274718
FORS2 ld spectrum GOODS J033218-274743
FORS2 ld spectrum GOODS J033218-274850

Submit | Reset | Clear | Close

A.V.O demonstration prototype v1.0

Load... | Save... | Plugins... | Print... | Help... | Quit

Aladin for AVO | J2000 | 03:32:39.67 -27:48:50.5 | Field: 03:32:40.38 -27:48:49.2 1.03'x1.03'



Spectra.05 | szokoly_cat. | Selected sou | Absor.. 100% | Selected sou | HR_fi.. 100% | J/AJ/126/539 | FoV for version | RGB img | GOODS-HST- | GOODS-HST- | GOODS-HST- | fields.xml | GOODS-WFI.V2

Zoom 1/4x

Spectrum	FORS2 ld spectrum GOODS J033239-274850	53.1652972222222	-27.8140630555556
Spectrum	FORS2 ld spectrum GOODS J033239-274851	53.1648288888889	-27.8143688888889
Spectrum	FORS2 ld spectrum GOODS J033239-274851	53.1648288888889	-27.8143688888889
Spectrum	FORS2 ld spectrum CDF 027	53.1652916666667	-27.8140277777778

CDS - ESO - AstroGrid - ST-ECF - UMAN/Jodrell Bank - CNRSDR01 - VO-India - STScI

GIMP

Known sources

- Remove known sources from candidates, and use as a check on the L_x estimation method
- Identified by X-match with Szokoly et al. (2004) CDF-S, and Barger (2003) HDF-N.
- Check of estimated L_x

$\langle \log L_{x,est} \rangle = 42.57 \pm 0.08$ compared to

$\langle \log L_x \rangle = 42.49 \pm 0.09$

...consistent

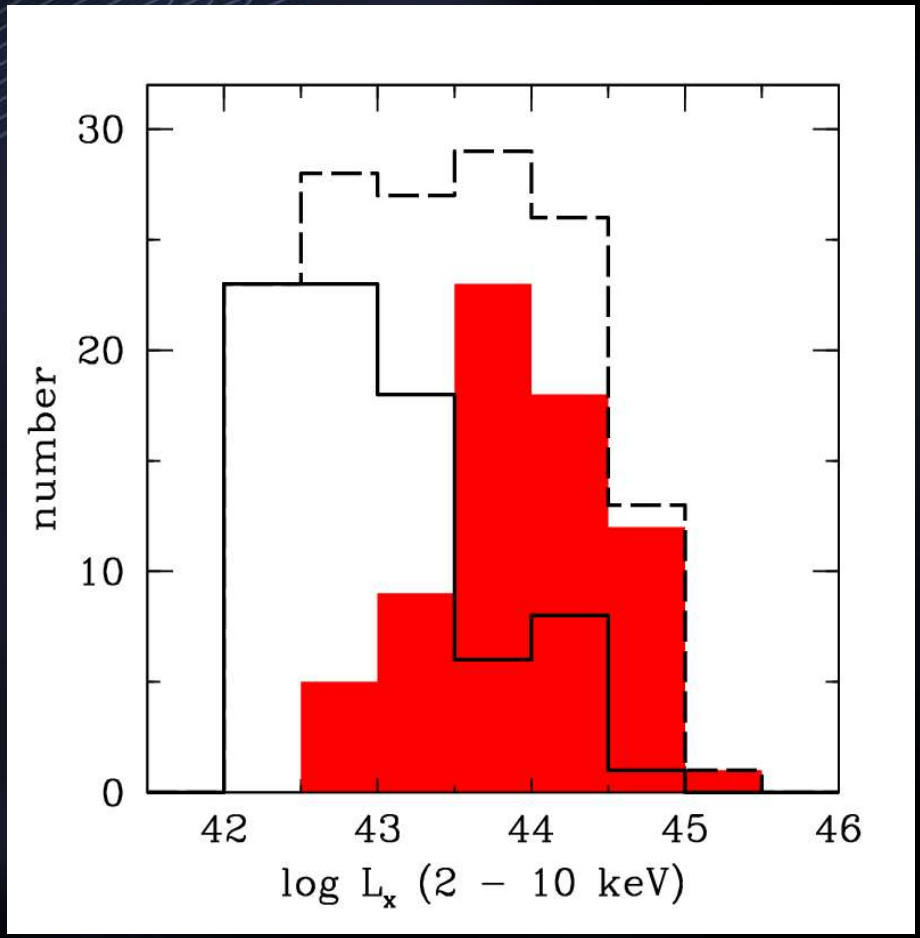
Results : NEW Type 2 AGN

- 68 new type 2 AGN candidates
- 31 have $L_X > 10^{44}$ erg s^{-2} : QSO 2
  - Only 9 previously known in GOODS fields

- Now 40 QSO 2s: Quadrupled the QSO 2s in the GOODS fields !

Luminosity distribution

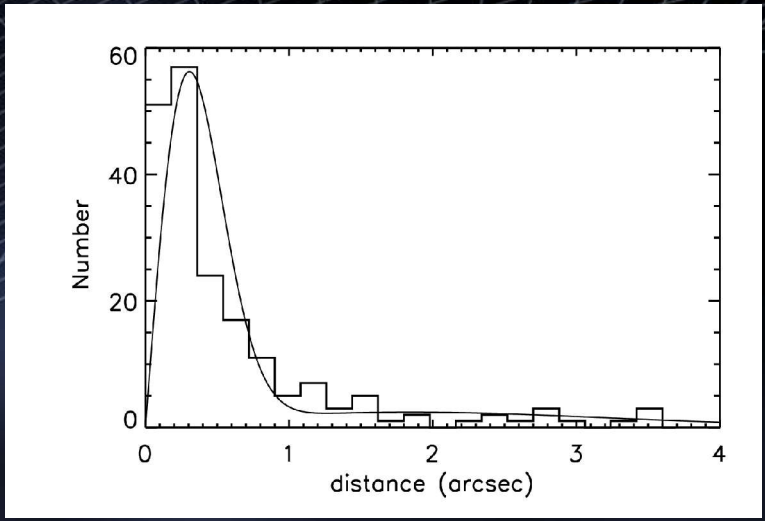
- New type 2 AGN
- Fills a gap luminosity distrib.
- AGN 2 $\langle z_{est} \rangle \sim 2.9$
- QSO 2 $\langle z_{est} \rangle \sim 3.7$



QSO 2 surface density

- >330 QSO2 deg^{-2} (down to 10^{-15} erg $cm^{-2}s^{-1}$)
- Consistent with Perola et al (2004) predictions for >10^{-14} erg $cm^{-2}s^{-1}$
- ~5x higher than predictions for faint flux limits
  - Gandhi et al. (2004) predicts 19 deg^{-2}
  - We find ~ 100 deg^{-2}
- Resolved X-ray background : 10±2%
  down to f(2-8keV)=10^{-15} erg $cm^{-2}s^{-1}$

False Match Rate



- Fit X-match distances to model
- Expected match rate D

$$N_1\Phi(d,\lambda) + N\Phi(d,\lambda)\left[\frac{1+2\pi\lambda\sigma^2}{2\pi\lambda\sigma^2}\exp\left(-\frac{d^2}{2\sigma^2}\right) - 1\right] \quad \text{(A.1)}$$

2-d Poisson distribution

$$\Phi(d,\lambda) = 2\pi\lambda d\exp(-\pi\lambda d^2)$$

True matches

$$\alpha = \frac{N}{2\pi\lambda\sigma^2}\Phi(d,\lambda)\exp\left(-\frac{d^2}{2\sigma^2}\right)$$

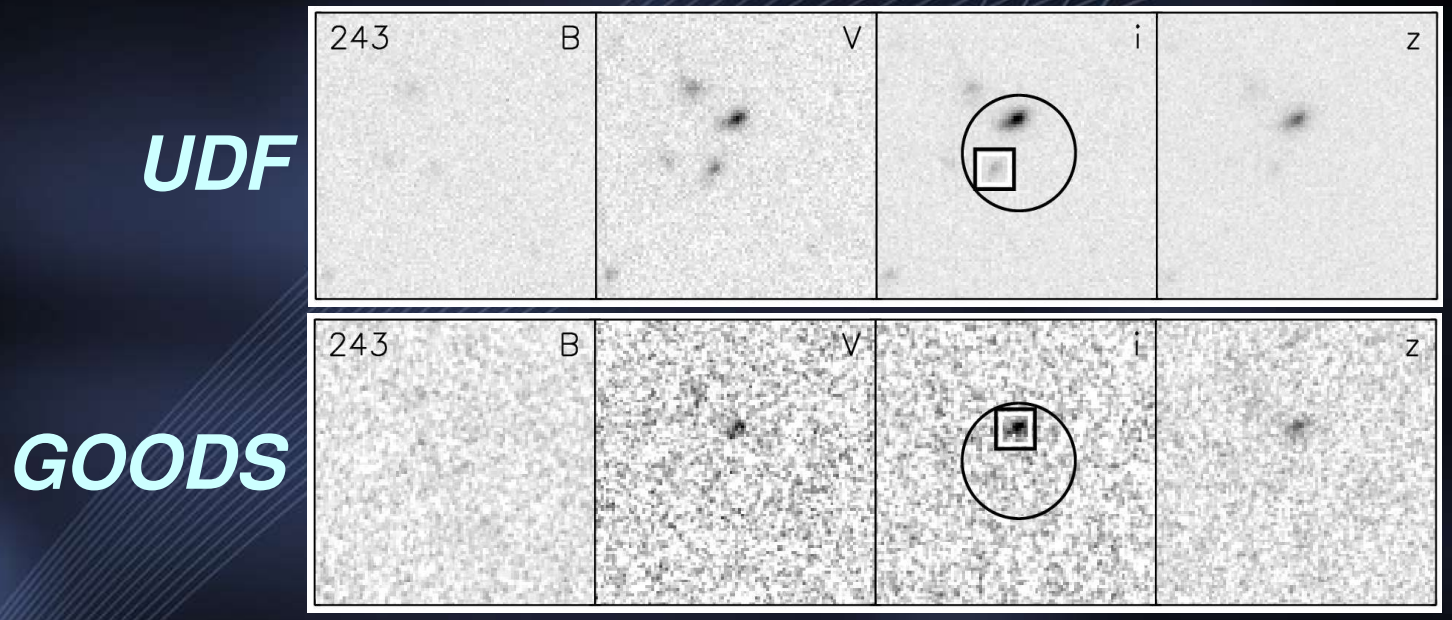
True partner, but correctly assigned

$$\beta = N\Phi(d,\lambda)\exp\left(-\frac{d^2}{2\sigma^2}\right)$$

No counterpart, but have been matched

$$\psi = (N_1 - N)\Phi(d,\lambda)$$

Ultra Deep Field

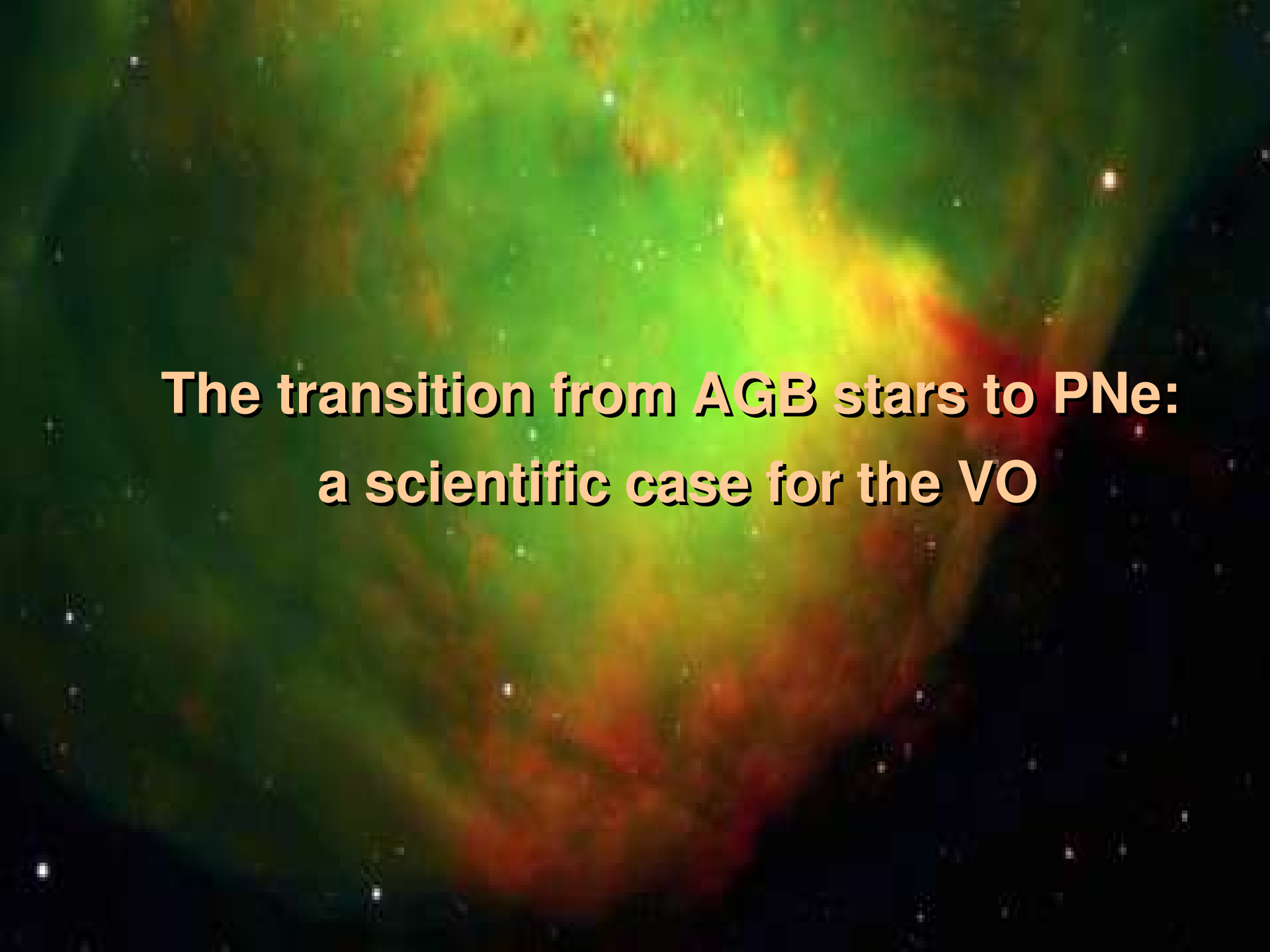


- 3 AGN-2 candidates fall within UDF
- 1 has closer, fainter optical counterpart in UDF

Science Conclusions

- Using
  - the deepest Chandra X-ray, and HST imaging
  - & Empirical estimator for Lx we find
- 68 New type 2 AGN
- 31 Qualify as QSO 2, z~4
- Many more QSOs than predicted

Published: Padovani, Allen, Rosati, Walton A&A 2004


The transition from AGB stars to PNe:
a scientific case for the VO

The transition from AGB stars to PNe

- Late evolutionary stages of low- and intermediate mass stars (1 - 8 $M_\odot$)

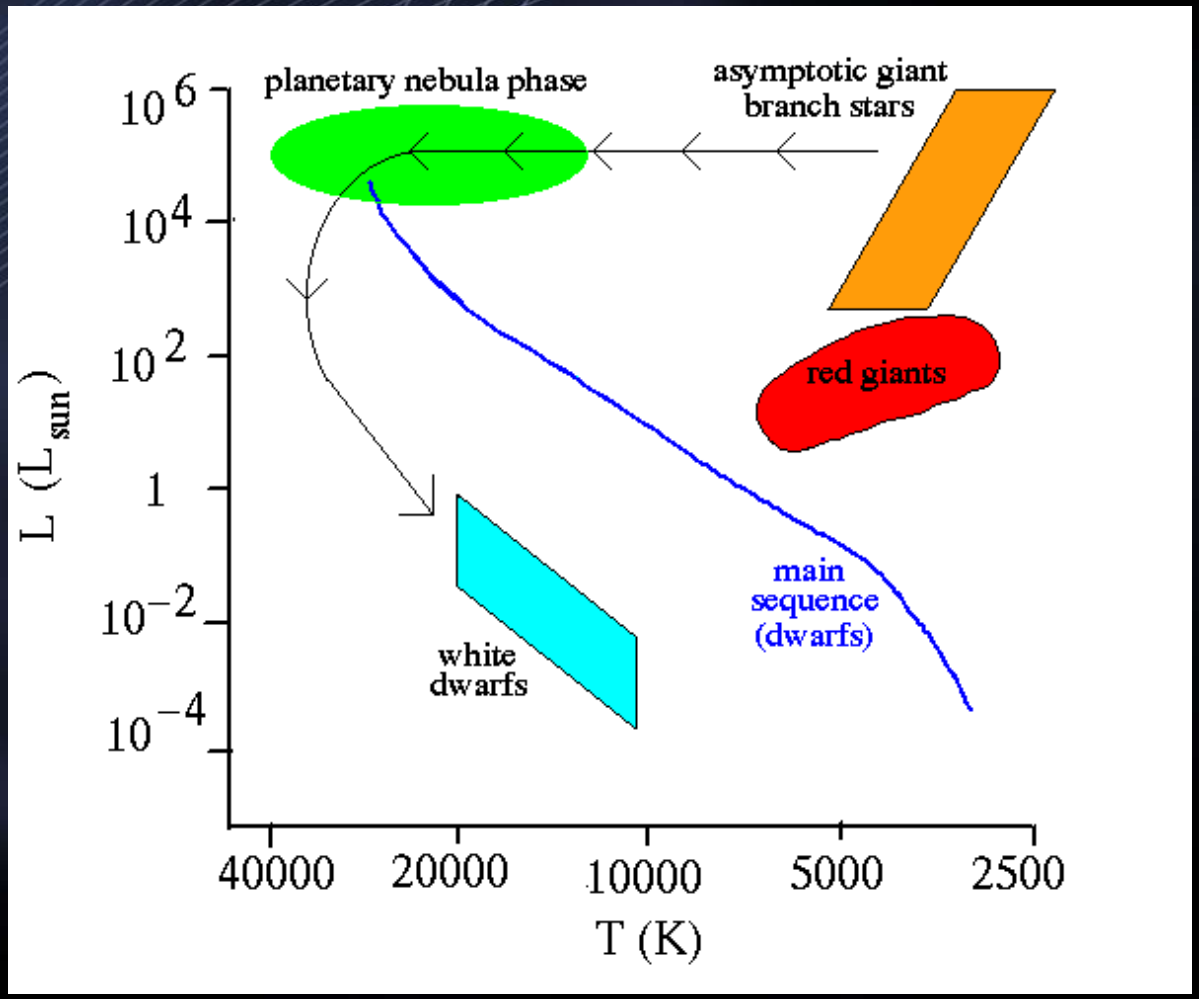
- Short transition times
  (~10^3 - 10^4 yr)
- Recent AGB mass loss
  (up to 10^{-4} $M_\odot$/yr)

⇓

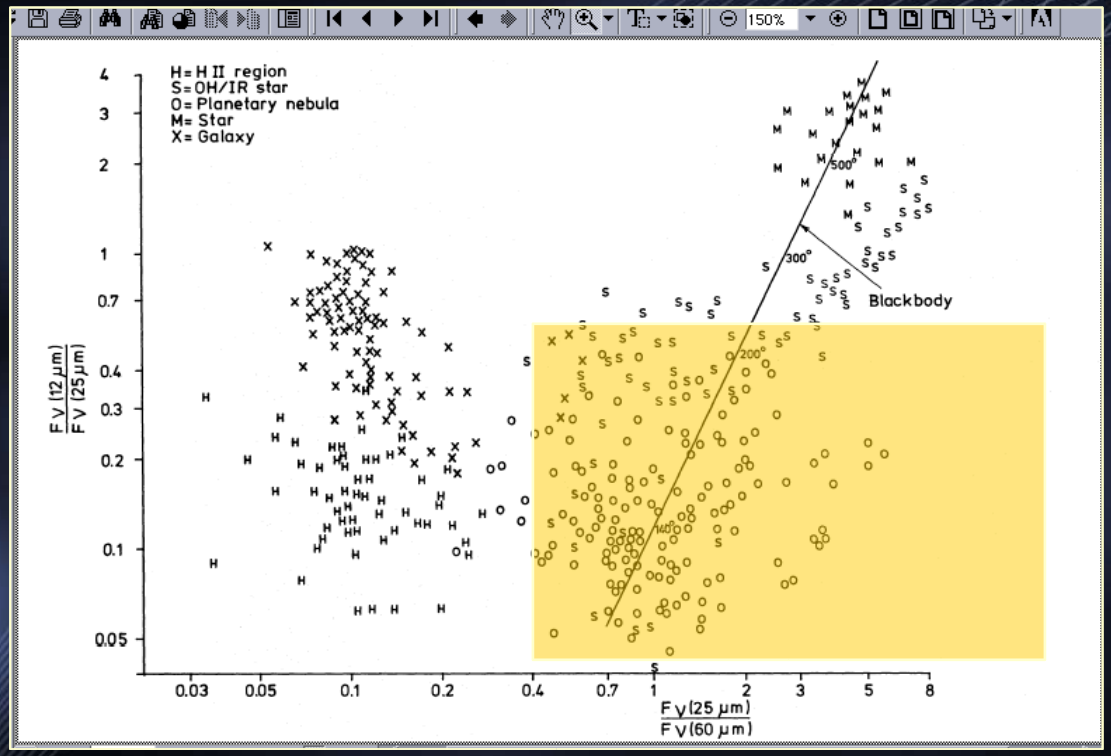
- Few objects in this phase

- Many are heavily obscured
  in the optical

⇓



Search for new transition sources using IRAS



Pottasch et al. 1988; Preite Martinez 1988; García-Lario 1992

All-sky survey
250,000 Sources
12, 25, 60, 100 μm

PNe show characteristic IRAS colours

… ***but unidentified sources in the IRAS two colour diagram were found to be transition sources rather than typical PNe***

IVOA

AVO
ASTROPHYSICAL VIRTUAL OBSERVATORY

An ideal case for the AVO

- X-match catalogues (MSX and IRAS) containing ~10^5 – 10^6 sources
- Catalogue manipulation: select/filter/add columns (A-C, D-60)
- Query SIMBAD or other Vizier catalogues with lists containing ~ 10^4 sources to search for yet unidentified sources and/or get a classification for the identified ones
- Create color-color diagrams where the position of different classes of sources can be visualized
- On-the-fly display SEDs of specific sources including ALL available data in catalogues/data archives (spectroscopy+photometry) for automated classification or modelling

Query by List

Remote Cross-Matching:

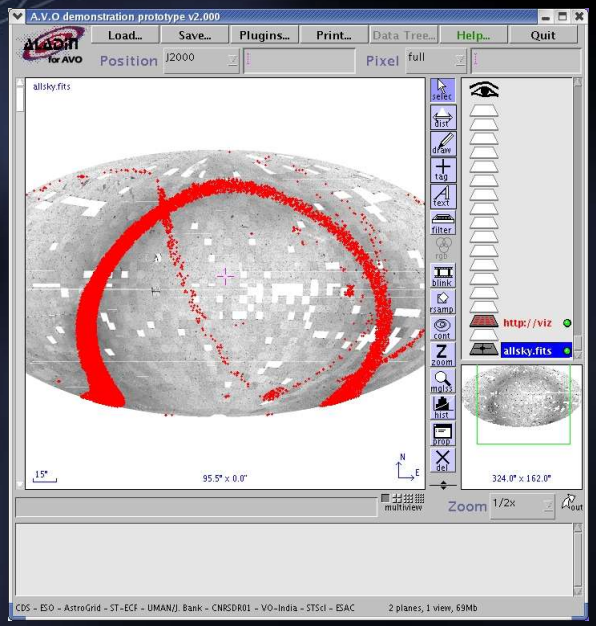
'bringing the computation to the data'

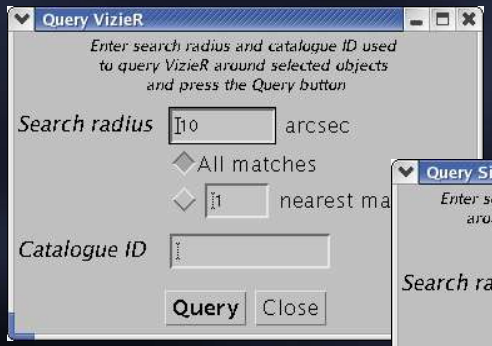
Multiple Cone Searching:

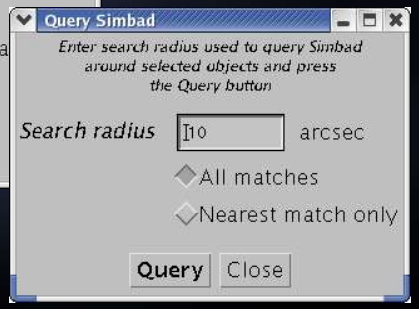
'stream-lining batch requests'

Supports X-Match for sparse or complex distributions of sources

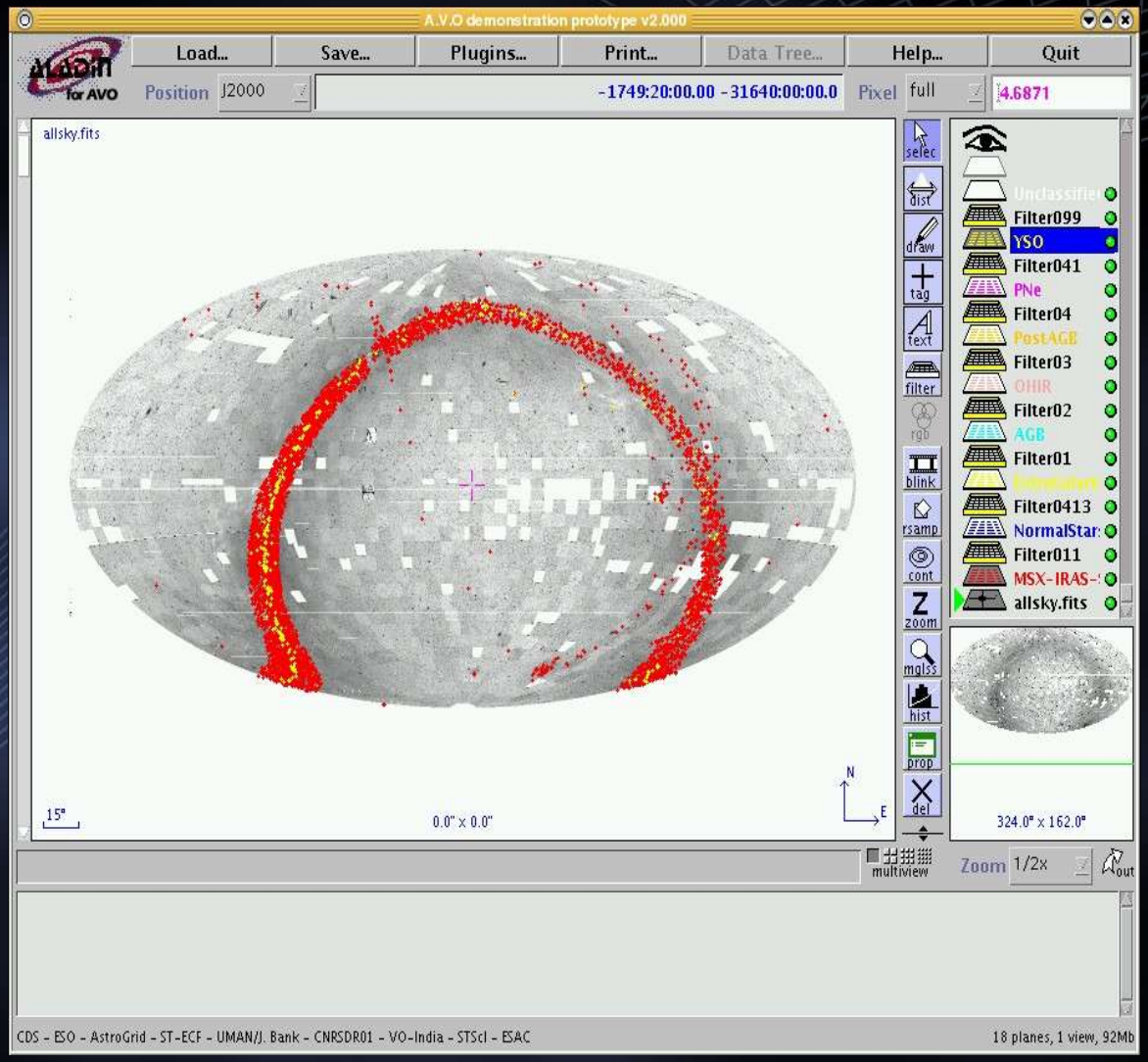
- >10^5 sources
- e.g. Entire IRAS







VizieR & SIMBAD

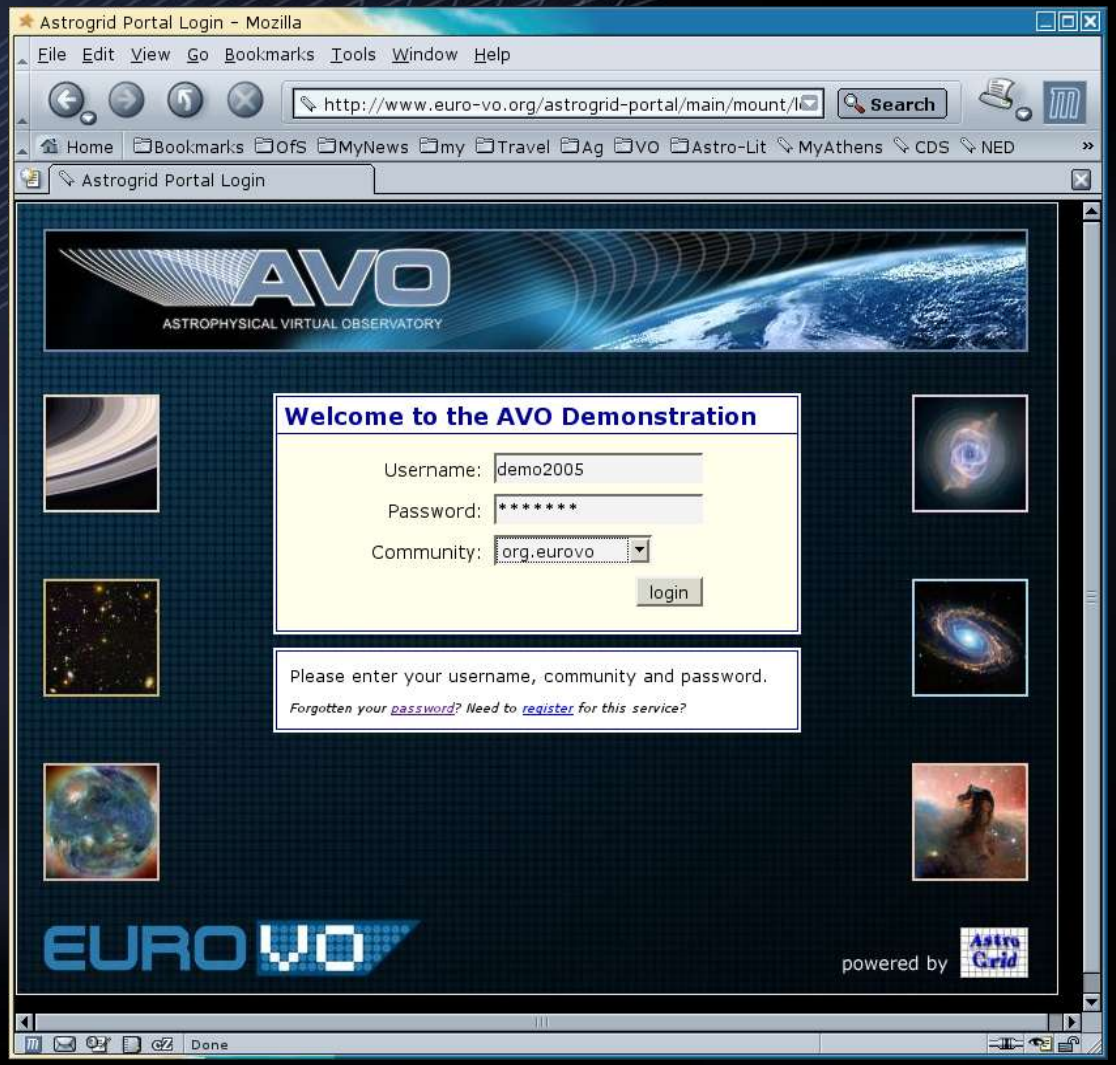

A.V.O demonstration prototype v2.000
Load...
Save...
Plugins...
Print...
Data Tree...
Help...
Quit
Aladin for AVO
Position
J2000
-1749:20:00.00 -31640:00:00.0
Pixel
full
4.6871
allsky.fits
select
dist
draw
tag
text
filter
rgb
blink
rsamp
cont
zoom
mglss
hist
prop
del
Unclassifie
Filter099
YSO
Filter041
PNe
Filter04
PostAGB
Filter03
OHIR
Filter02
AGB
Filter01
Filter0413
NormalStar
Filter011
MSX-IRAS-
allsky.fits
15"
0.0" x 0.0"
N
E
324.0" x 162.0"
multiview
Zoom
1/2x
out
CDS - ESO - AstroGrid - ST-ECF - UMAN/J. Bank - CNRSDR01 - VO-India - STScI - ESAC
18 planes, 1 view, 92Mb

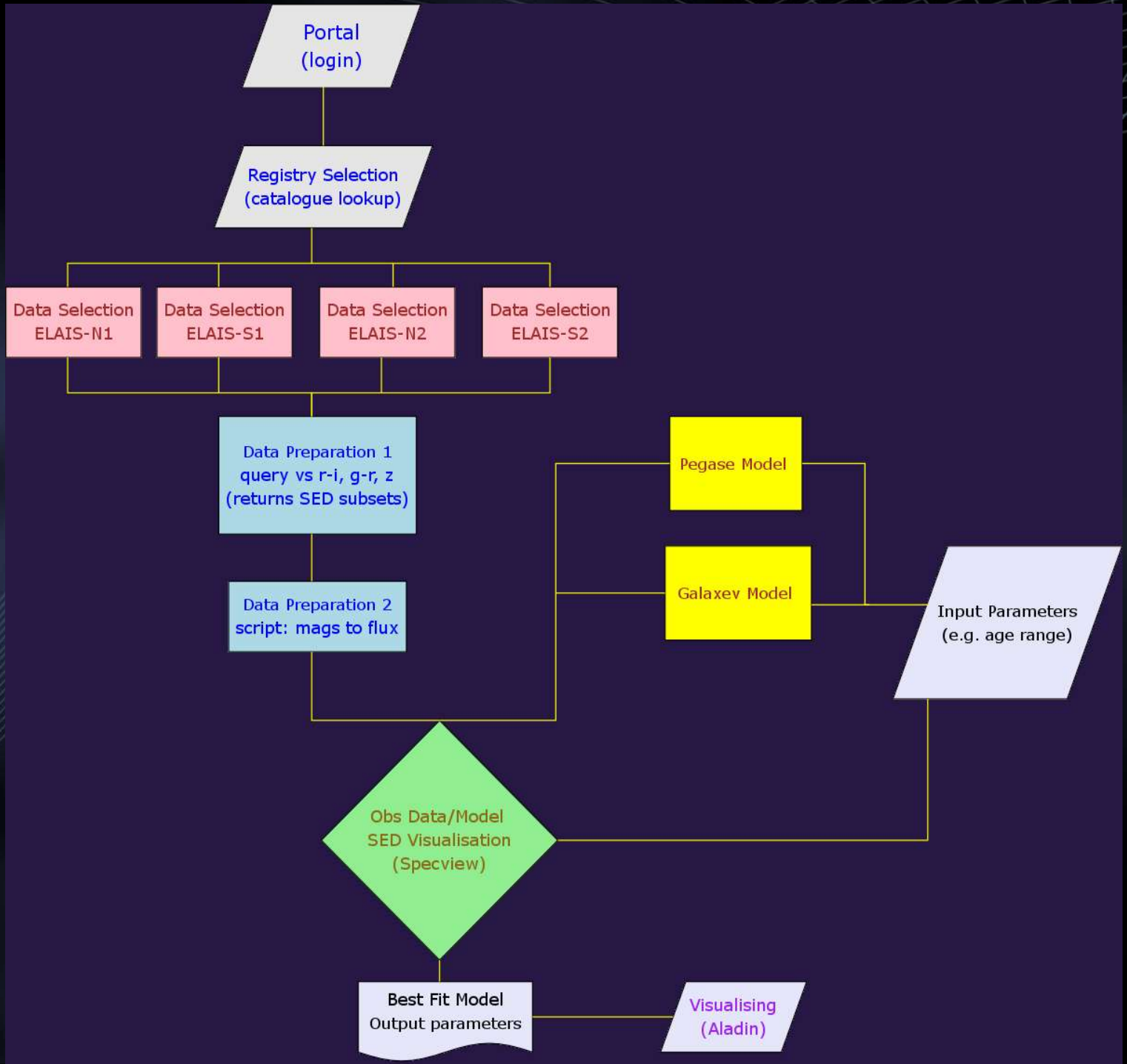
Candidate transition sources

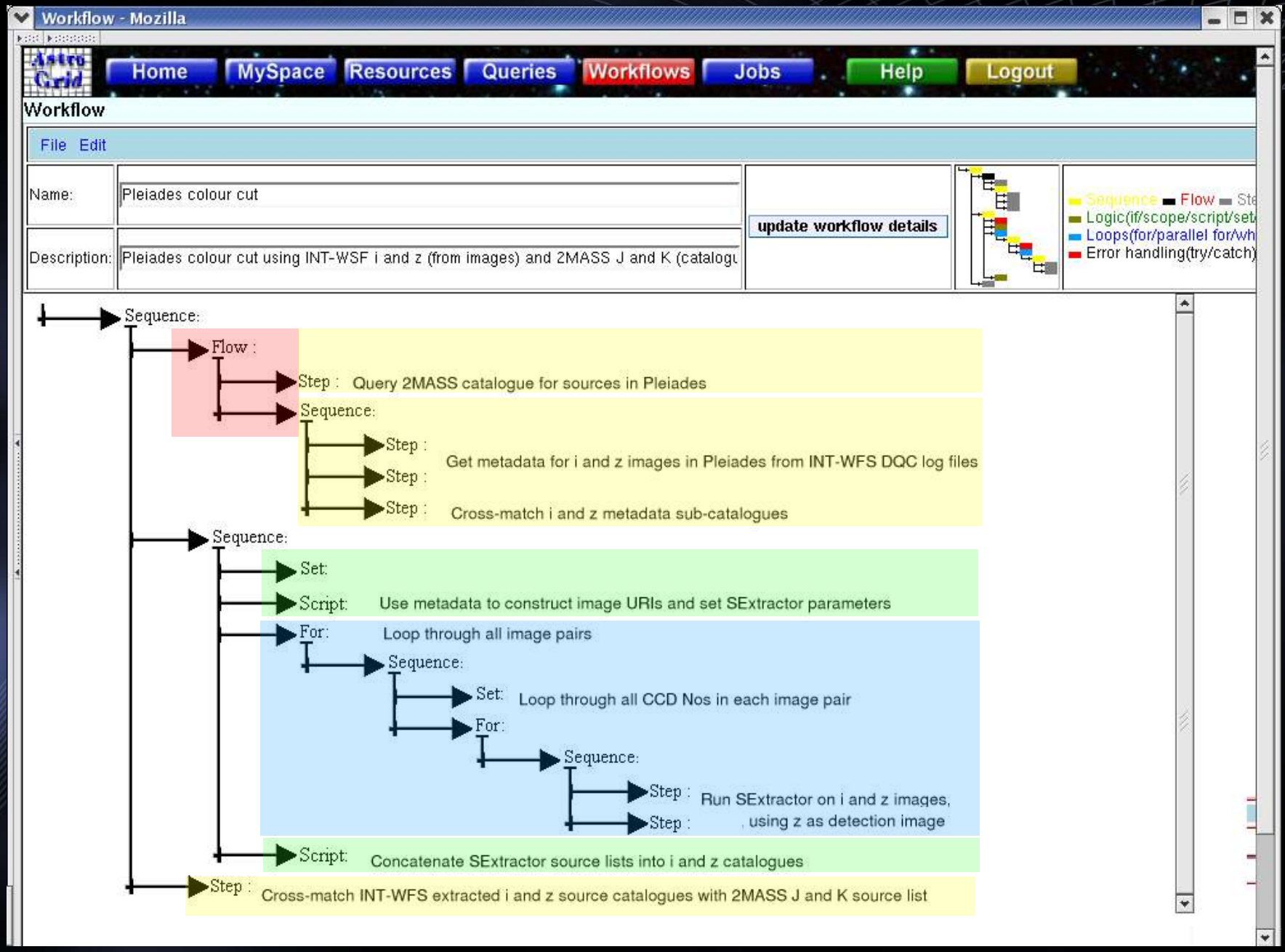
- 132 classified sources [A-C]≥0.7, 0.0≤ [D-60]≤2.5:
  - 0.8% each normal stars, extragalactic objects
    - 2 objects - probably misclassified!
  - 1.5% very red AGB stars (Miras, Carbon stars etc.)
  - 10.6% OH/IR stars, 27.3% post AGB stars
  - 50% Planetary Nebulae
    - exceptionally reddened - young/obscured Pne
  - 9.1% Young Stellar Objects
    - use 2MASS or exclude |b|≤2 to reduce contamination
- 103 unclassified sources
  - 89.4% probability of being in AGB-PNe

Bleeding edge aspects of the AVO demo

- Workflow
- VO sign-on
- Virtual Storage
- VO-enabled applications
  - Sextractor, Hyper-z, Pegase, Galaxev




Portal
(login)
Registry Selection
(catalogue lookup)
Data Selection
ELAIS-N1
Data Selection
ELAIS-S1
Data Selection
ELAIS-N2
Data Selection
ELAIS-S2
Data Preparation 1
query vs r-i, g-r, z
(returns SED subsets)
Data Preparation 2
script: mags to flux
Pegase Model
Galaxev Model
Input Parameters
(e.g. age range)
Obs Data/Model
SED Visualisation
(Specview)
Best Fit Model
Output parameters
Visualising
(Aladin)


Workflow - Mozilla
Home
MySpace
Resources
Queries
Workflows
Jobs
Help
Logout
Workflow
File Edit
Name:
Pleiades colour cut
Description:
Pleiades colour cut using INT-WSF i and z (from images) and 2MASS J and K (catalogu
update workflow details
Sequence
Flow
Logic(if/scope/script/set
Loops(for/parallel for/wh
Error handling(try/catch)
Sequence:
Flow :
Step : Query 2MASS catalogue for sources in Pleiades
Sequence:
Step :
Step :
Step :
Get metadata for i and z images in Pleiades from INT-WFS DQC log files
Cross-match i and z metadata sub-catalogues
Sequence:
Set:
Script: Use metadata to construct image URIs and set SExtractor parameters
For: Loop through all image pairs
Sequence:
Set: Loop through all CCD Nos in each image pair
For:
Sequence:
Step :
Step :
Run SExtractor on i and z images,
using z as detection image
Script: Concatenate SExtractor source lists into i and z catalogues
Step : Cross-match INT-WFS extracted i and z source catalogues with 2MASS J and K source list

Portal
(login)

Registry Selection
(catalogue lookup)

Data Selection
ELAIS-N1

Data Selection
ELAIS-S1

Data Selection
ELAIS-N2

Data Selection
ELAIS-S2

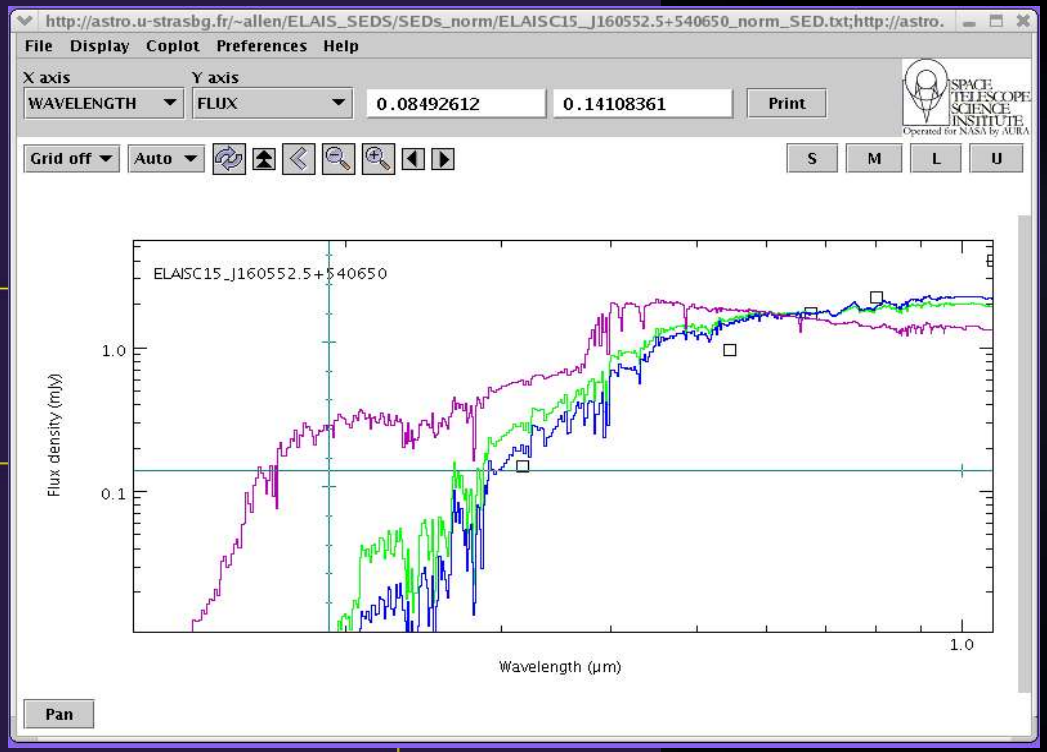
Data Preparation 1
query vs r-i, g-r, z
(returns SED subsets)

Data Preparation 2
script: mags to flux

Obs Data/Model
SED Visualisation
(Specview)

Best Fit Model
Output parameters

Visualising
(Aladin)



Euro-VO Tool highlights

Aladin – multiview

HST ACS
Ultra Deep
Field

variable size
cutouts
generated from
loaded images

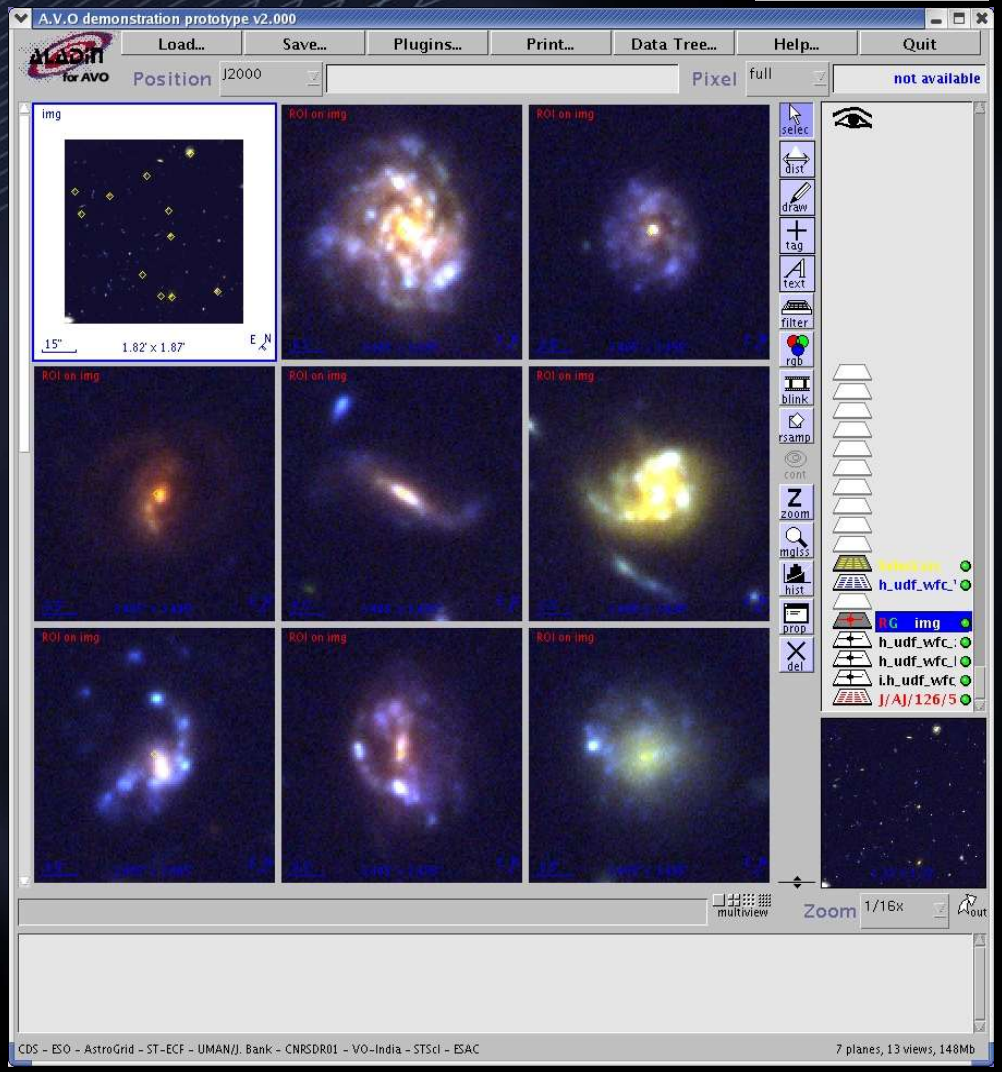
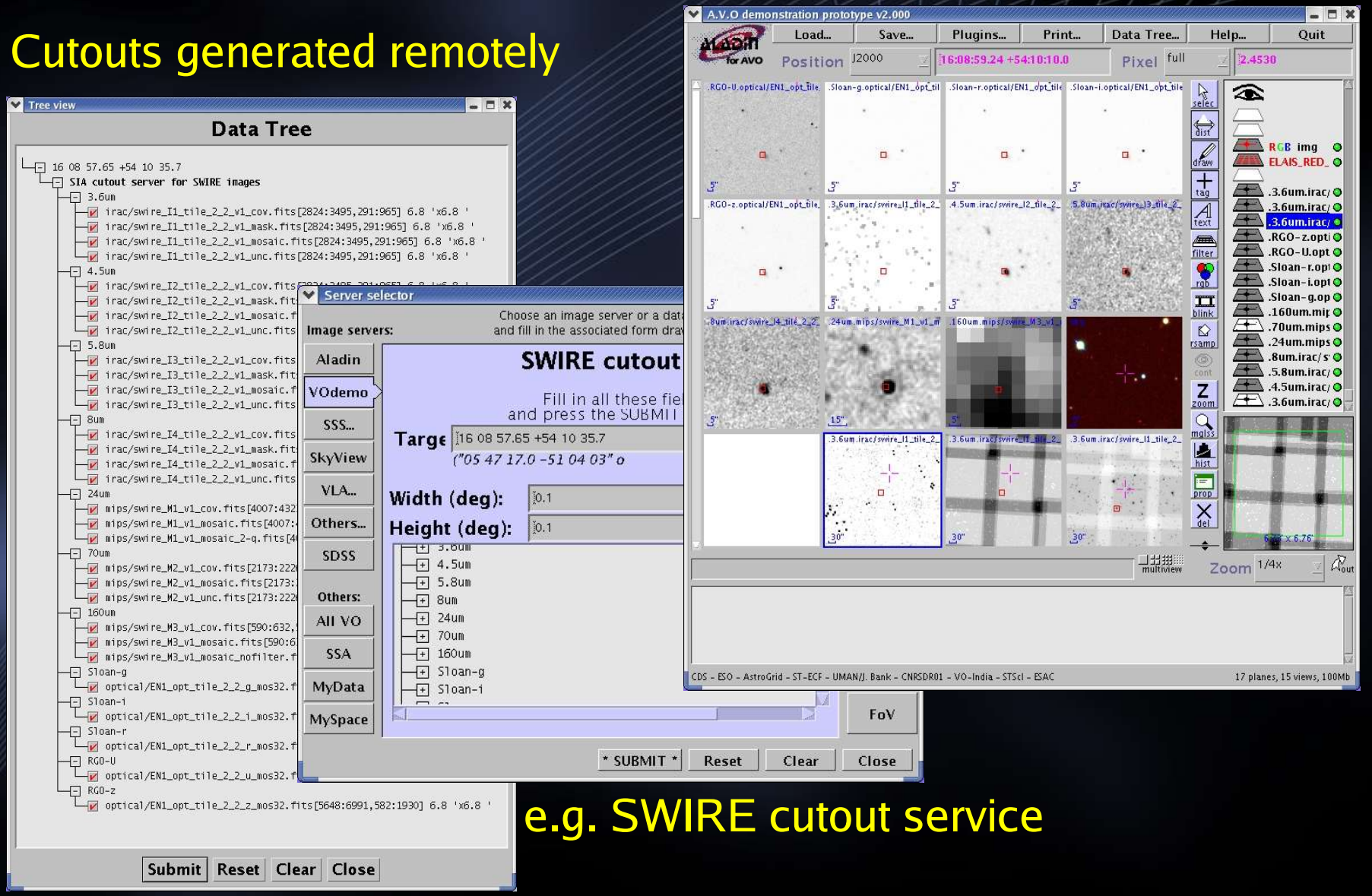


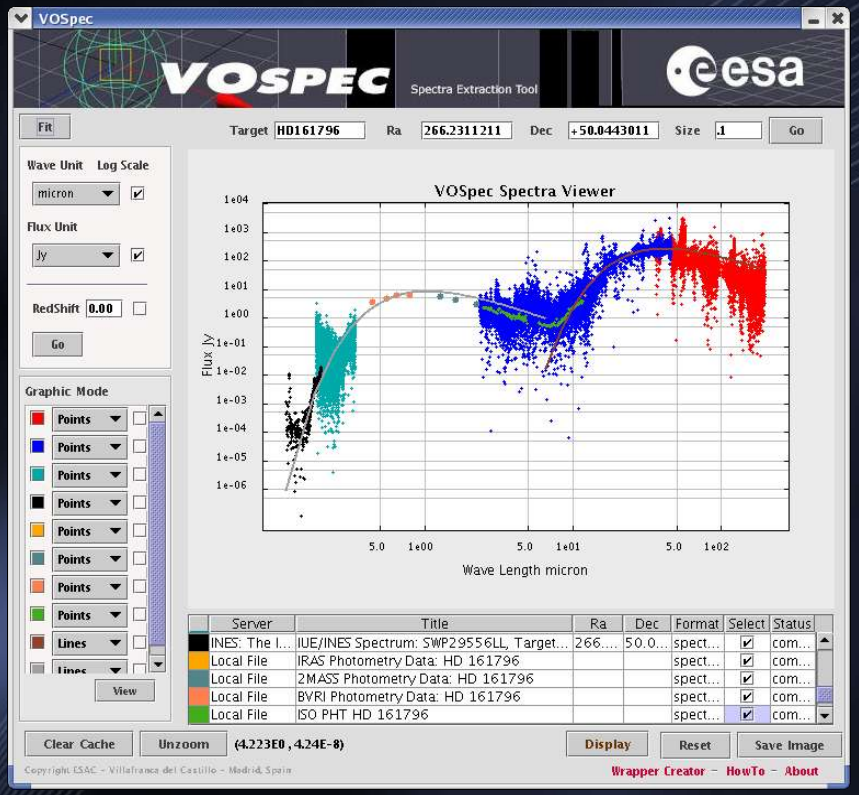
Image Cutout Services

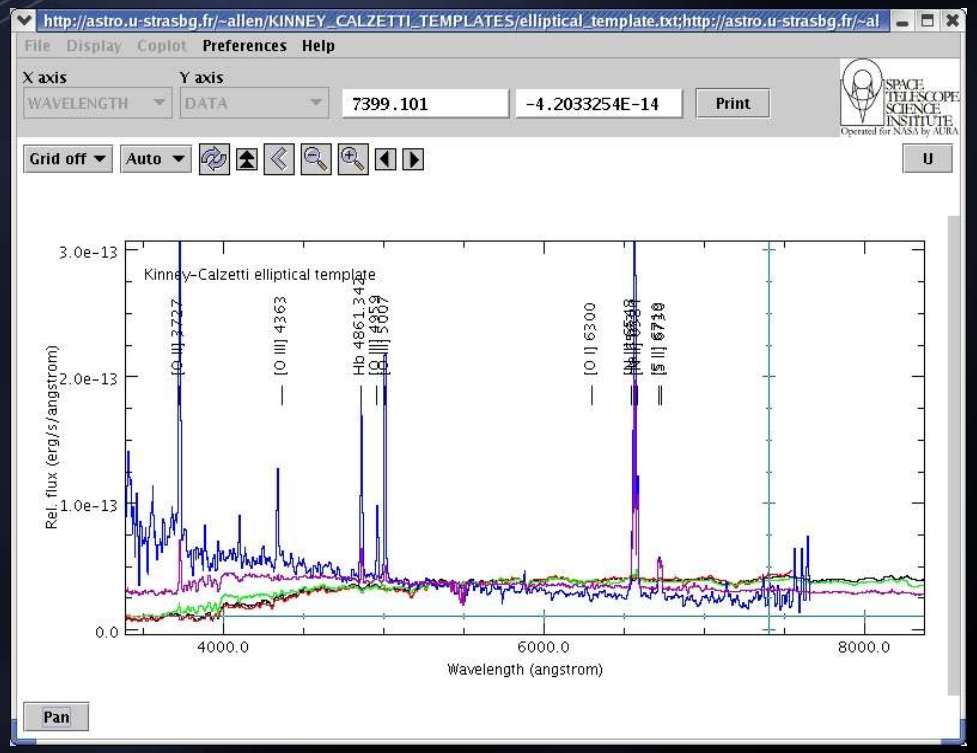
Cutouts generated remotely

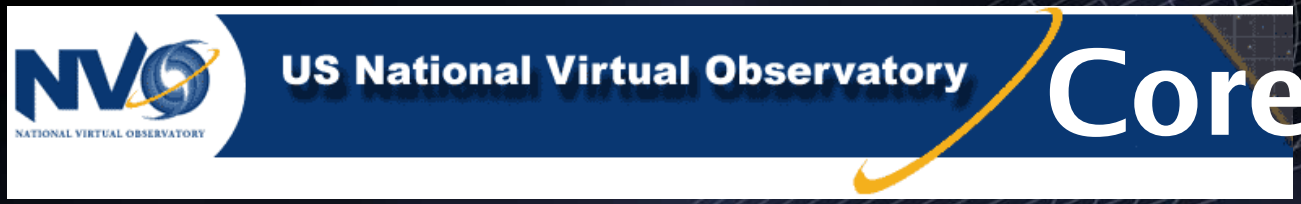


e.g. SWIRE cutout service

Multi-archive spectra, model fitting







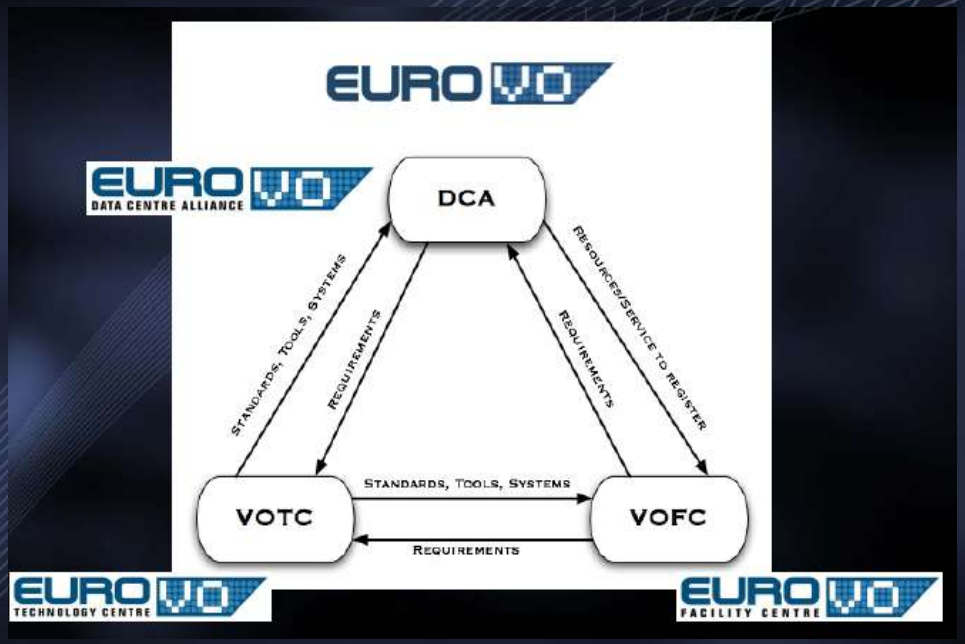
Core Services

- Registry
- Datascope
  - Multi-archive data query
- Spectrum Services
  - SDSS, 2dF, filter curves, upload
- Open SkyQuery
  - Multi-database X-match
- NVO Publishing
  - Make your data VO accessible
- Source Identification
  - Upload images, ID, X-match

www.france-vo.org

Colloque d'ouverture de l'Action Specifique OV France
4 au 7 avril, IAP

- Particular Interests and Strengths in:
- Spectroscopic Data
- Theoretical modeling
- + CDS VO services



Reaching out to data providers:

Workshop on VO standards and systems for data Centres and Large Projects

ESO, June 27- July 1

VO Science Outlook

- First Science enabled by the first VO interoperability gains
  - Scalable Data Access
  - Catalogue/image manipulation
    - X-match, filtering, link to original data
- Next:
  - TB data, 10^9 object science
  - Theory-VO, Multi-ůλ data fusion
  - Workflow linking of services

VO tools

- Prototype tools available
  - www.euro-vo.org
  - www.ivoa.net
  - cdsweb.u-strasbg.fr

Credits

- Some slides were copied and modified from
  - A. Lawrence
  - P. Benvenuti
  - P. Garcia-Lario
  - A. Richards
  - P. Quinn