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From Discovery to Innovation...

The Virtual Observatory: The Future of Astrophysics Data Handling

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With support from the Canadian Space Agency

Astronomy and Astrophysics

Does fairly well in information technology

- Has excellent online literature services
  - ADS Abstracts
  - Journals
  - Preprints
- Has a good history of data archiving
- Has reasonable data access policies
- BUT
  - As a scientist it is frustrating and time-consuming to locate suitable data and data quality is often sub-standard

A Brief History of Data Archiving in Astronomy

History

- NASA has been a driving force in data archiving for astronomy
- Canada-France-Hawaii Telescope (CFHT) was a pioneer in archiving data from ground-based observatories
- Digital Revolution in astronomy happened in the 1980's

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The Canadian Astronomy Data Centre

History

- Canadian Astronomy Data Centre was created in 1986
- Astronomers and Computer Scientists
- supported by the Canadian Space Agency
- original mandate: to serve Hubble Space Telescope

CADC Firsts

- First web interface in astronomy
- Previews of data
- On-the-fly calibration
- Advanced image processing

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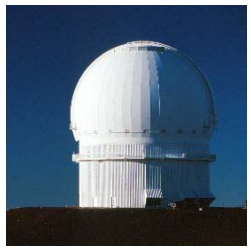
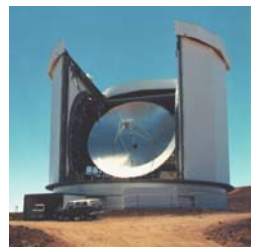
Current Collection at CADC

Hubble Space Telescope



Canada-France-Hawai'i Telescope
Hawai'i



James Clerk Maxwell Telescope
Hawai'i

Dominion Radio Astrophysical Observatory
British Columbia

Gemini North Telescope
Hawai'i

Gemini South Telescope
Cerro Pachón, Chile

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The Canadian Astronomy Data Centre

- Many Services
  - Digitized Sky Survey
  - Archive Inter-operability
- Meta-Data Catalogues
  - 19 databases
  - 80,000,000 rows
  - 34 gigabytes
- Data Files
  - 12,000,000 files
  - 20 terabytes

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A Brief History of Data Archiving in Astronomy

- Archiving is a word that does not adequately describe the activities, capabilities, and functions of data centres
  - Store,protect,catalogue, facilitate access, lobby for open data policy
  - Lobby for effective handling of data and metadata
  - Develop processing pipelines to add value
  - Execute processing on request

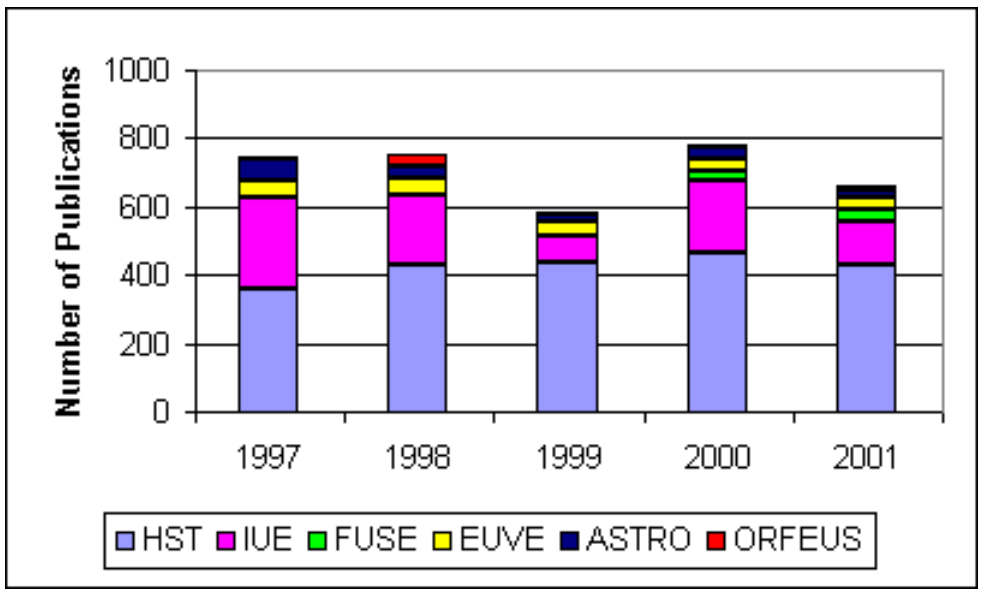
A Brief History of Data Archiving in Astronomy

Do astronomers publish research based on archival data?

Scientific Impact of Multi-Mission Archive at Space Telescope Science Institute

- ***~10% of the most-cited papers in the ISI database are based on MAST archival data***
- Over 600 papers/year with HST and other archives
- HST Data: Retrieval rate is 4 times the ingestion rate
- Over 30,000 datasets requested per month (over 8,000 are non-HST data); ~400,000 web hits per month

From Megan Donahue STScI



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International VO initiatives

- Massive homogeneous survey datasets are being created
  - Sloan Digital Sky Survey
  - 2MASS infared survey
  - Canada-France-Hawaii Legacy Survey
- Multi-wavelength survey datasets can be constructed
- Network bandwidth is increasing
- Astronomers have embraced many online services
- Funding agencies are receptive

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NVO

Astro Grid

AVO
ASTROPHYSICAL VIRTUAL OBSERVATORY

New types of science will be possible with new modes of data access

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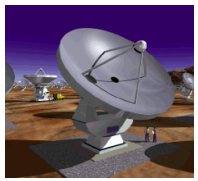
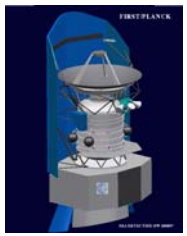
The Virtual Observatory



ALMA

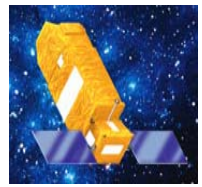


FIRST

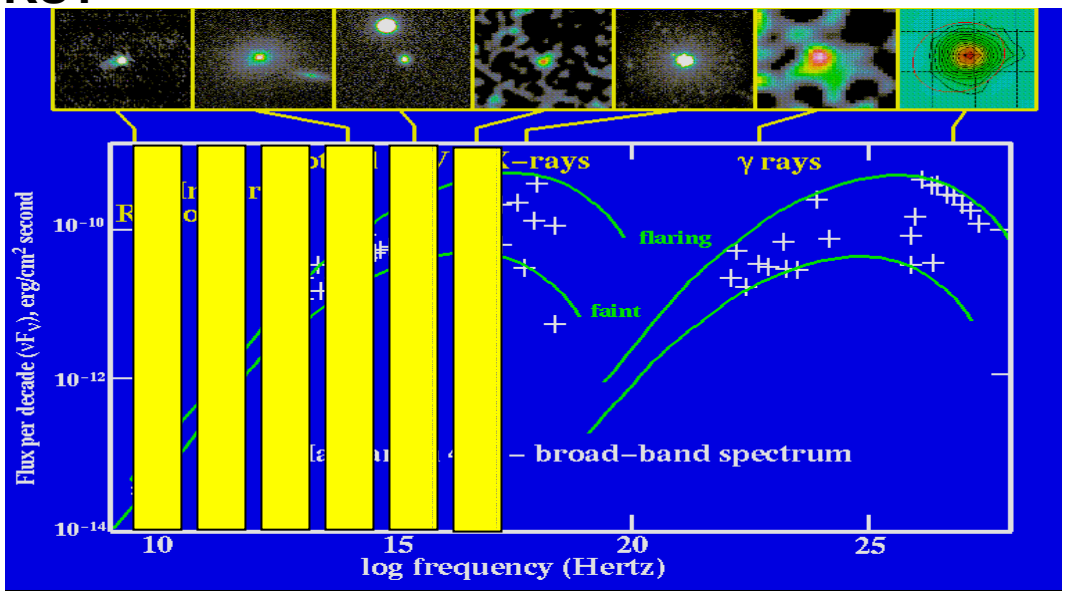
NGST

GEMINI

CFHT



FUSE



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International initiatives: Different strokes for different folks

- Major initiatives in Canada, the United States, the European community, the United Kingdom. (Australia, India, Russia)
- Each VO group has their own view of what it means to produce a VO and what the priorities should be.

- U.S.: A high-level distributed infrastructure, tools.
- U.K.: Several thrusts: data pipelines, ontology, data mining
- Europe: VO closely associated with operational data centers and other groups
- Canada: VO is within the Canadian Astronomy Data Centre

- Data-centric versus infrastructure-centric views

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Definition

The Virtual Observatory will be said to exist when astronomers can successfully execute scientific queries that seamlessly cross archive boundaries and wavelength boundaries, can combine the returned datasets in a way that permits their joint processing, and can achieve this without the need to understand engineering-level details of the instrument that produced the returned datasets.

- Discussions of online toolsets, grid computing, distributed datasets, etc. are implementation details.
- “Observatory” implies that the product is pixel data
- Are analysis tools and catalogues legitimate products?
- The Virtual Observatory needs to be defined in terms of capabilities delivered to scientists (the users).

Convergence ?

- Despite the differences in viewpoint at this early stage of the VO game, the approaches will converge as projects become reality.
- Interoperability
- Standards
- Integration

- But there need to be new investments in data archiving centres to match the investment in higher level infrastructure.
- POTENTIAL CONTENT CATASTROPHE FOR VO

Data Policy in Astronomy

Standard Practice

- Proprietary period of 1-2 years during which only the proposer of the observations may access those data
- Some data is calibrated and much is not
- Data quality is an issue
- Metadata completeness is an issue
- Metadata quality is an issue

Data Policy: Dark clouds on the horizon

- Past history
  - Canada has benefited enormously from open data access (and facility access) policies of the United States
    - Data access: Largely NASA
    - Facility access: NOAO and many others

- NASA has been very progressive

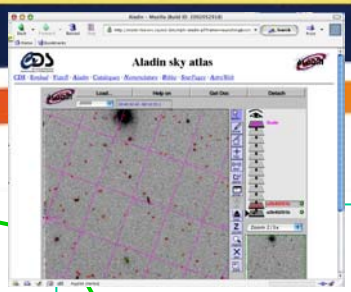
- Many facilities have had no channels to access data (NOAO) , some do not save and protect data (e.g., Keck telescopes: U. California and California Institute of Technology)

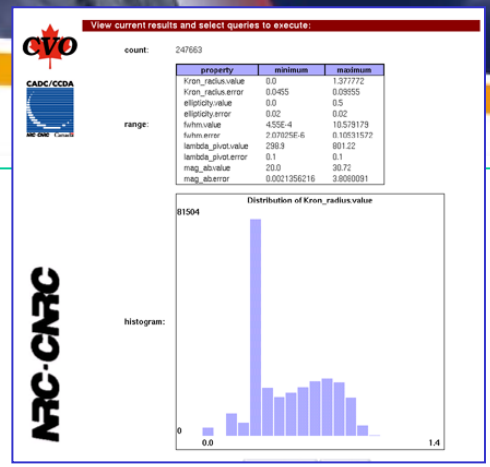
- Europe has been very progressive: BUT now the archives of the European Southern Observatory are CLOSED to astronomers outside of Europe.

Data Policy: Dark clouds on the horizon

- Present-day data policies are very mixed:
  - Tension between observatory operations and archiving needs
- Canada has been progressive
  - Canada-France-Hawaii Telescope archives since 1980s
    - Data quality has been fair
- Canada and Chile were the leading forces in creating an archive for the Gemini telescopes (partners U.S., U.K., Canada, Argentina, Chile, Brazil, Australia)
- Canada and France are considering a long (~ 3 years) proprietary period for the CFHT Legacy Survey

CVO Architecture





Archives

Archives publish to the VO

Web interface to archive

VoPix

VoSrc

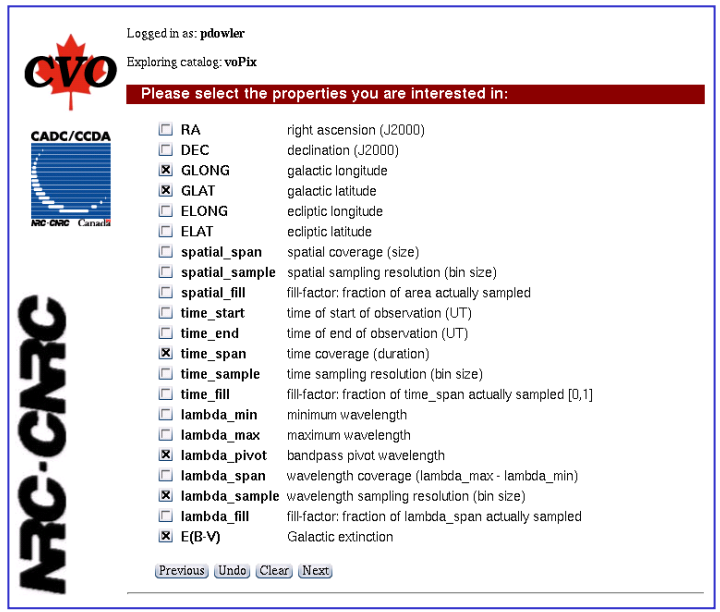
VoProc

CVO is a software layer above the archive level

CVO Goals

The CVO system provides a view on archive content:

- High-level
- Scientific descriptors
- Not instrument specific
- Integrates different archive content



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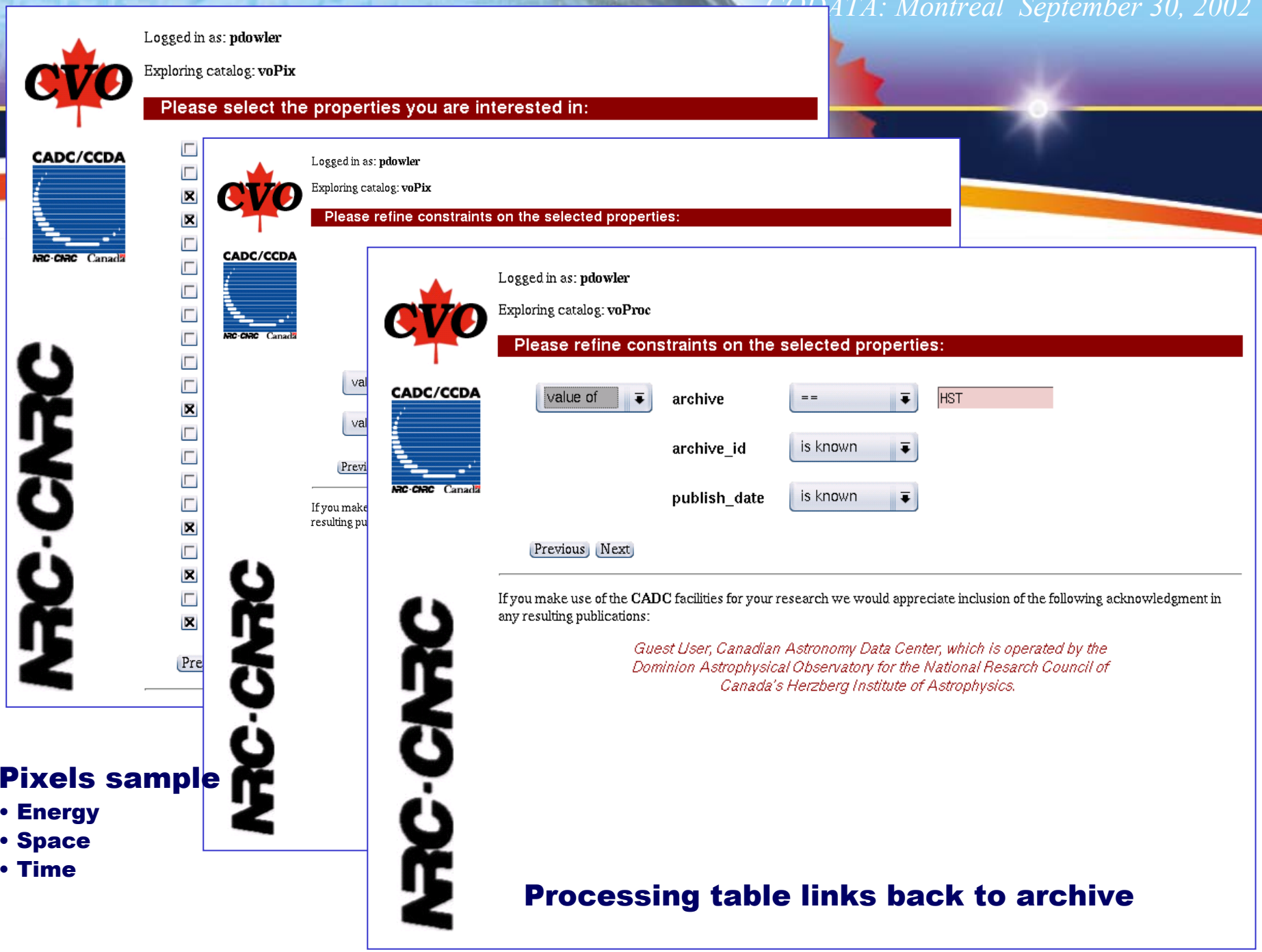


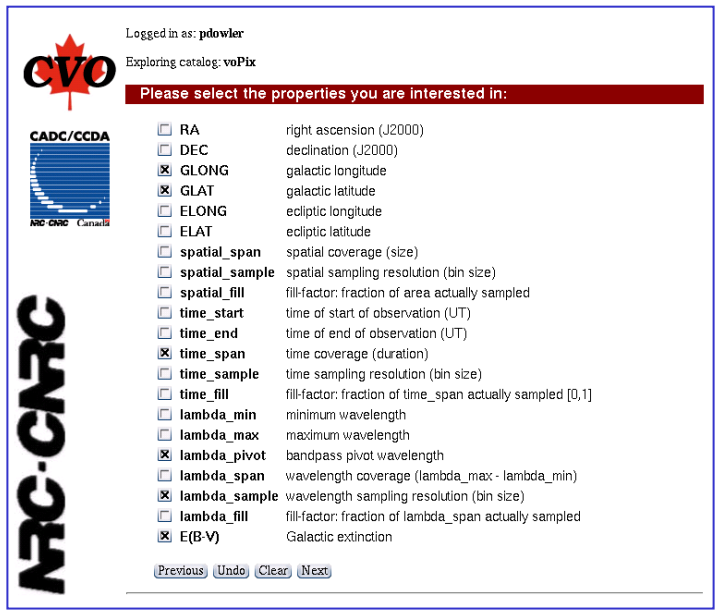
Pixels sample

- **Energy**
- **Space**
- **Time**

Processing table links back to archive

CVO Ultimate Goal

Multi-wavelength, hierarchical *object* catalogues are a representation of the state of our understanding of the universe.



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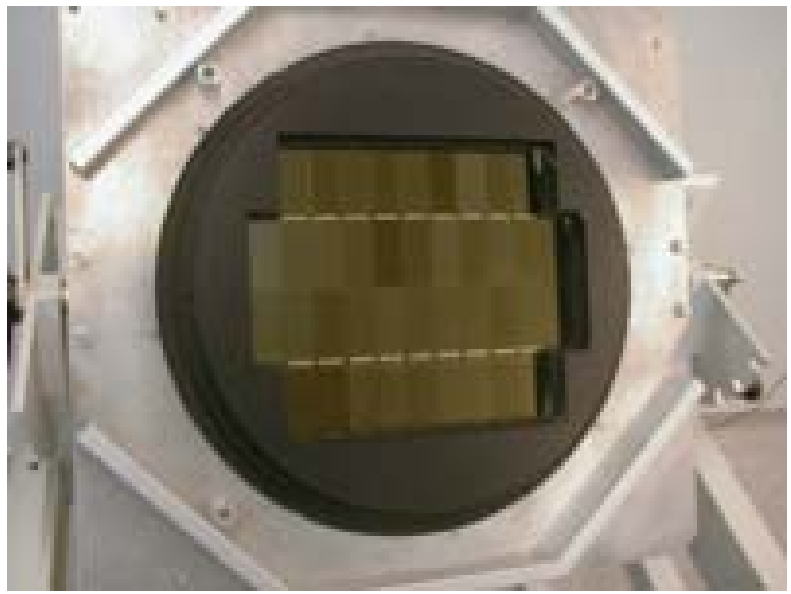
CFHT Legacy Survey: VO Content

CFHT MegaCam

- A 40 CCD camera
  - 320 Megapixels
  - 1 square degree on the sky
- Raw Data Rate
  - 720 megabytes per image!
  - 100 gigabytes per night!
  - 20 Terabytes per year!



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CFHT Legacy Survey

- SCIENCE
  - ***Determine the fate of the universe***

- Data Policy
  - Data are released immediately to the Canadian and French communities and to the world after a proprietary period

CFHT Legacy Survey

CFHT Legacy Survey

- Partnership between CFHT (Hawaii), CADC (Victoria),TERAPIX (Paris), CDS (Strasbourg)
- Science: Supernovae, Weak Lensing, Kuiper Belt

- 5 years / 500 nights
- 20 Terabytes per year
- 50 million objects with high-quality imaging
- Processed image products and catalogues
- 100 Terabyte project

Data Distribution via network

- 150 Mbps ***continuously*** for 5 years
- CANET/BCNET
- Need Gbit network

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CFHTLS: Storage and Processing

- DVD jukeboxes
  - 4.7 Gbytes/disk
  - 16 $/Gbyte
  - 11.5 Tbytes/m^2
  - 6 jukeboxes/year
  - 3,900 disks/year
- High overhead
  - Operationally
  - Physical space

CFHTLS: Storage and Processing

- Spinning disks
  - 20 Terabytes in each rack
- Processing
  - 20 1.5 GHz CPUs in each rack
- Cost effective
- Effective use of space
- Reliability ???

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Conclusions

Astronomy and Astrophysics

- Virtual Observatory recognizes the value and effectiveness of good information management in astrophysics
- Astronomy has a good IT foundation to build upon
- Funding agencies are receptive
- Data access policies need to be monitored for problems
- Virtual Observatory needs to invest in both infrastructure and in data

THE END

A Brief History of Data Archiving in Astronomy

Outline

- History and CADC
  - I will neglect NASA and concentrate on what I know
    - CFHT archived their digital data in the 1980's
    - Plates were taken home but remained the property of the observatory which never recalled them
  - Hubble Space Telescope opened doors in archiving for optical astronomers
  - Archiving is a word that has outlived its usefulness
    - Archive functions: Store,protect,catalogue, facilitate access, lobby for open data policy
    - Non-archive functions: Develop processing pipelines to add value
  - Archive Status: Do astronomers do research with archival data? YES HST examples
    - Deliver the archive over and over/ Megan's publication numbers

Outline

- Virtual Observatory initiatives: IVOA
  - Definition of the VO
  - Different strokes for different folks
  - High-level infrastructure
  - Where's the data?
  - There need to be data-centric initiatives also
  - THE GOALS ARE WELL-ALIGNED