The Two Micron All Sky Survey

Roc Cutri and the 2MASS Team - November 2005

http://ipac.caltech.edu/2mass/

Skrutskie et al. 2006, AJ, 131, in press

UMASS

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2MASS Objectives

Technical Objective: To carry out a highly uniform, digital imaging survey of the entire sky in three near infrared bands

Science Goal: Produce an Image Atlas and Catalogs that will enable astronomers to:

– Trace luminous matter over the entire length of the Milky Way, probing largest structures of the Galaxy

– Construct the first all-sky photometric census of galaxies in the local universe to establish the foundations for measuring 3-D distribution of matter and mapping the Hubble flow out to z~0.1

– Have the statistical basis to search for rare but astrophysically important objects such as low mass stars/brown in the Solar neighborhood, globular clusters in the Galactic Plane and dust-obscured active galactic nuclei

Implementation

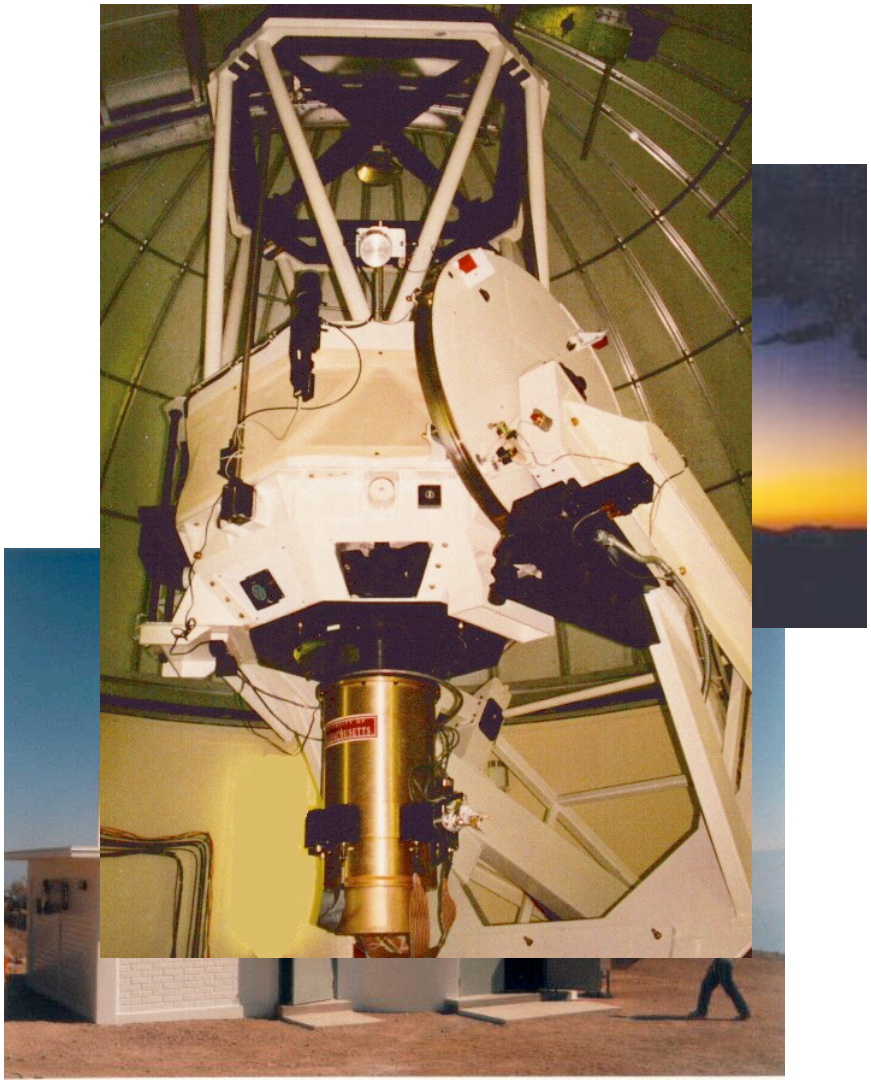
- Joint project of the Univ. of Massachusetts and IPAC/Caltech, funded primarily by NASA and NSF

- Identical, dedicated **1.3 m** telescopes at Mt. Hopkins and CTIO

- Cameras containing three NICMOS 3 arrays for simultaneous imaging in:
  - **J (1.24μm), H (1.66μm) and K_s (2.16μm)**

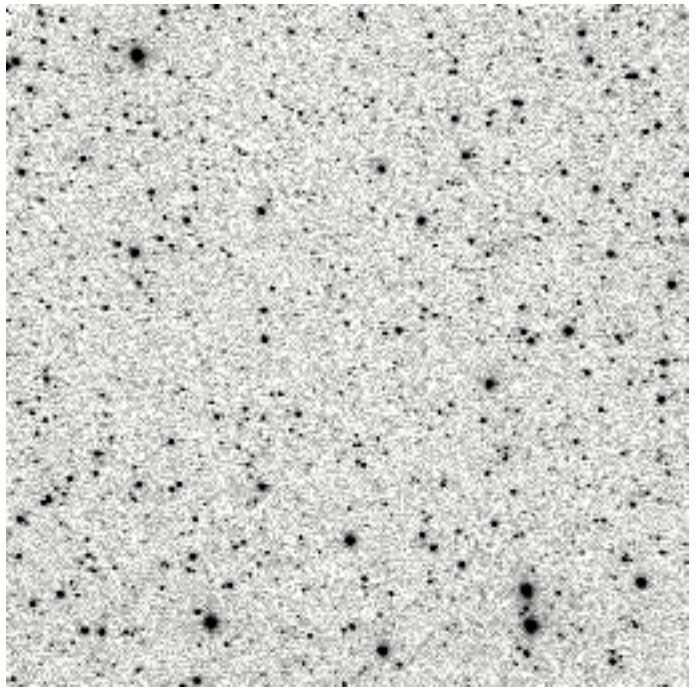
- **2"/pixel** - 8.5'x8.5' FOV

- Highly automated operation using pre-scripted nightly plan



Survey Strategy

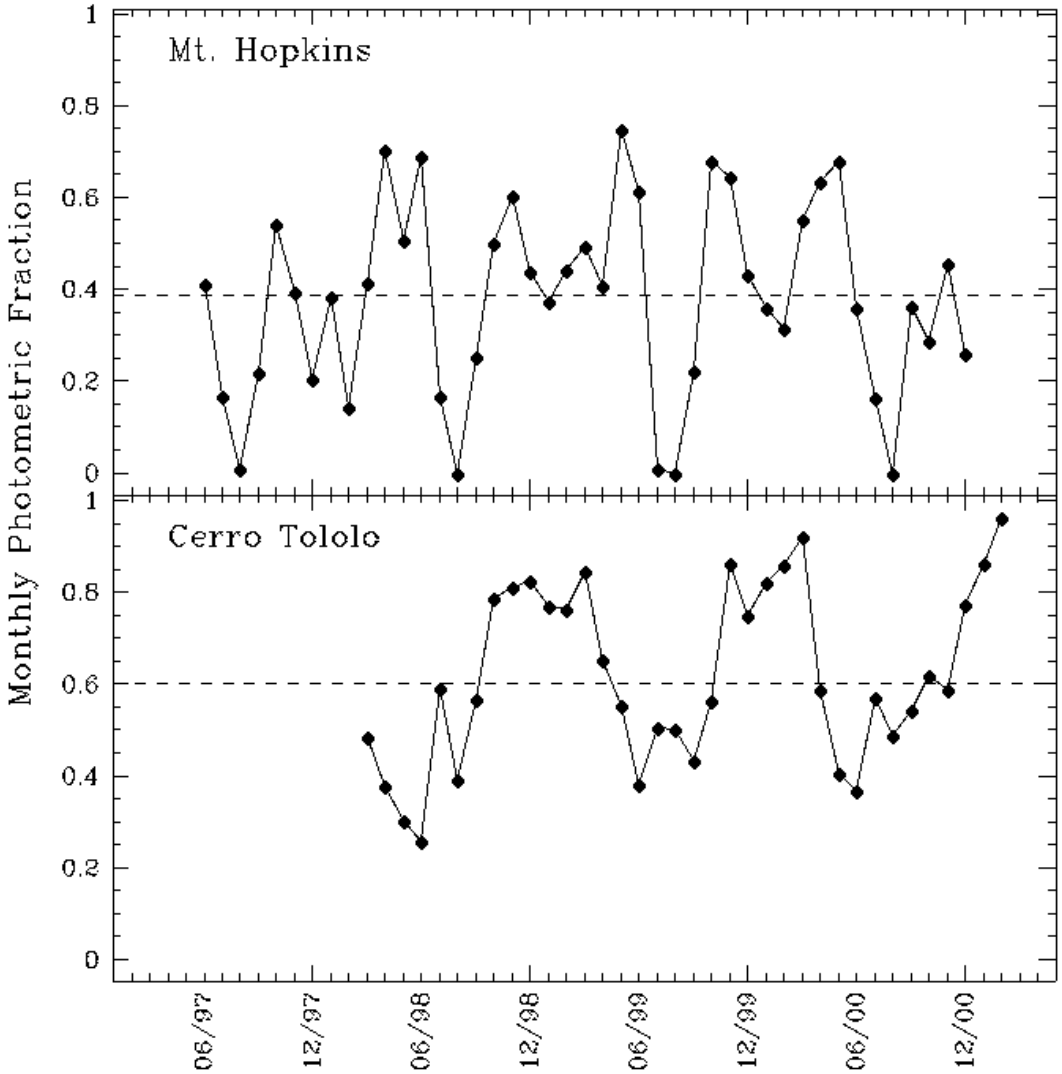
- Sky divided into 59,650 **Tiles** (6°x8.5')
- High efficiency **"freeze-frame" scanning**
  - Telescope scans in declination (1°/min)
  - Secondary freezes sky on focal planes for 1.5s
  - Two readouts at each position (0.05s & 1.3s)
  - Advance 1/6 frame (net 7.8s on each sky point)
  - Arrays rotated for sub-pixel sampling
- One scan yields **273 frames x 2 reads x 3 bands**
- 65 Tiles (**~60 deg^2**) scanned each average clear night



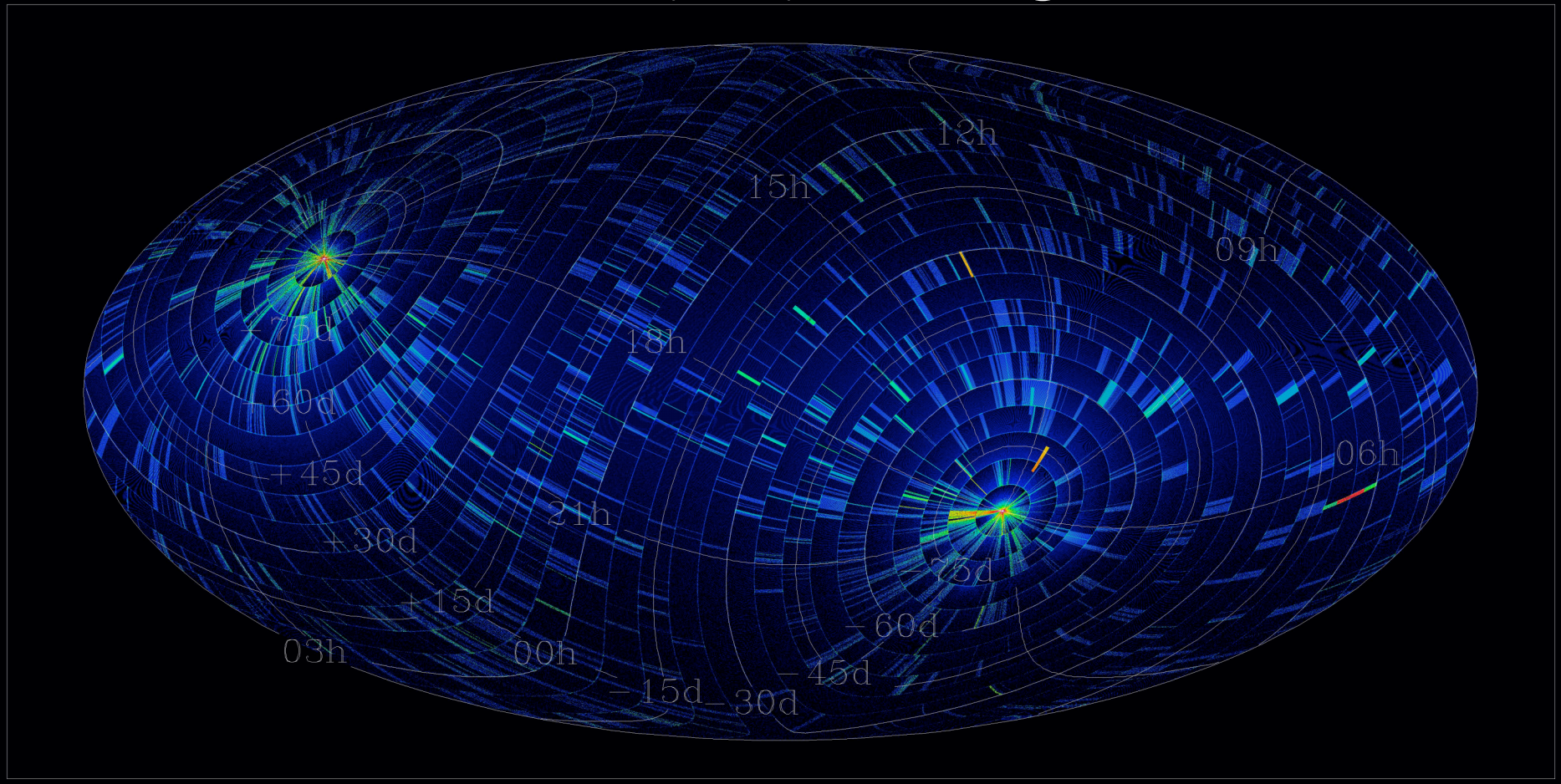
Sequence of 273 2MASS J-band frames from **Scan** of Abell 3627 region

Survey Operations

- Mt. Hopkins
  - **June 1997 - December 2000**
  - **42%** photometric
- CTIO
  - **March 1998 - February 2001**
  - **64%** photometric
- **24.5 TB** raw data collected
- Photometric data covering **99.998%** of the sky
  - 0.7 deg^2 in 21 small gaps



Survey Sky Coverage



- ~30% of the sky observed more than once
- Catalogs use only one epoch for uniformity
- Multi-epoch data to be released with *Extended Mission* products

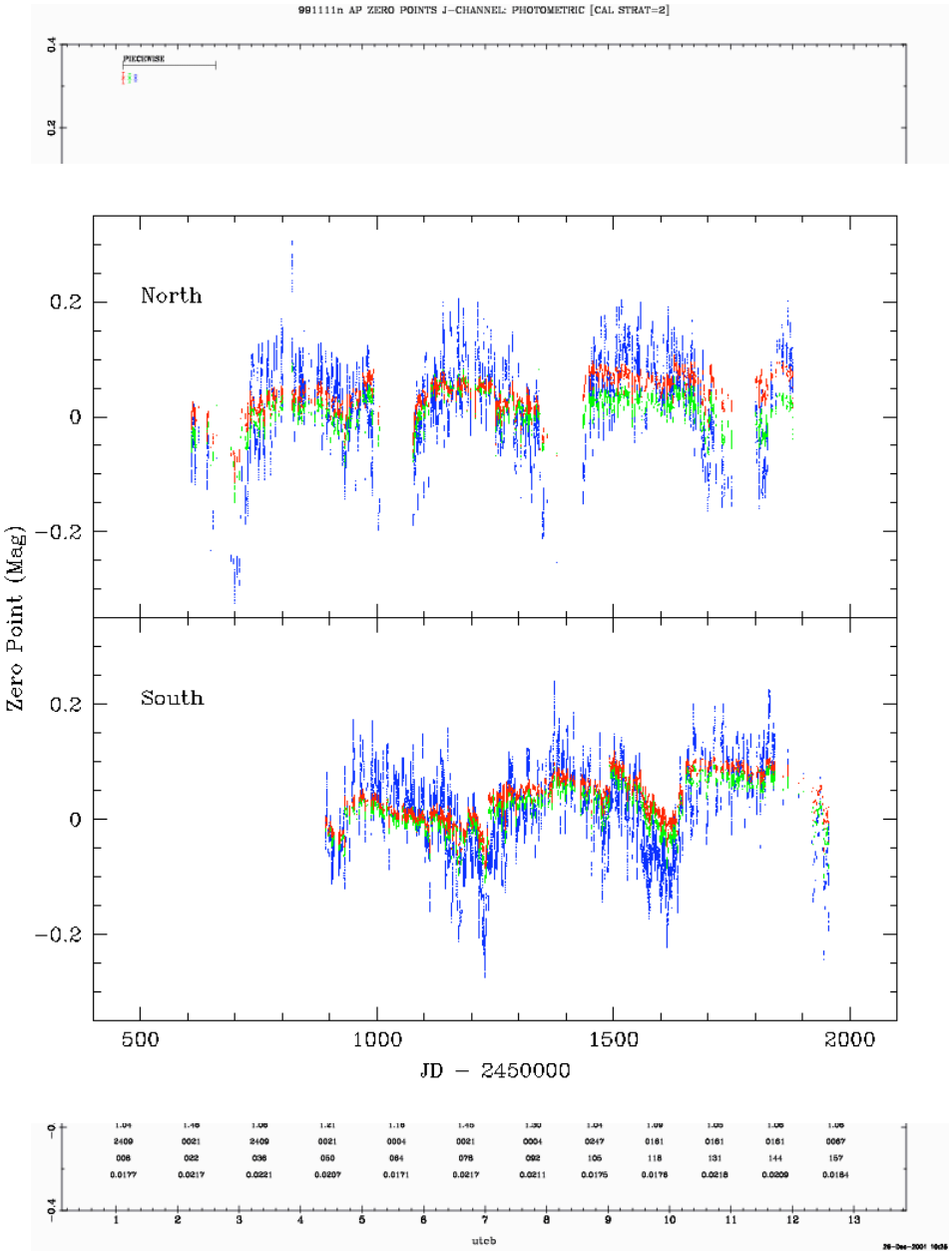
Photometric Calibration

- **Hourly observations** of one of 35 (8.5'x 1°) Calibration Fields
  - Scanned 6 times each visit
  - 5-8 different Tiles/night
  - 5-50 standard stars per field

- Nightly photometric transformations
  - **Zero point** fit to nightly observations
  - Atmospheric **extinction** derived from long-term statistics

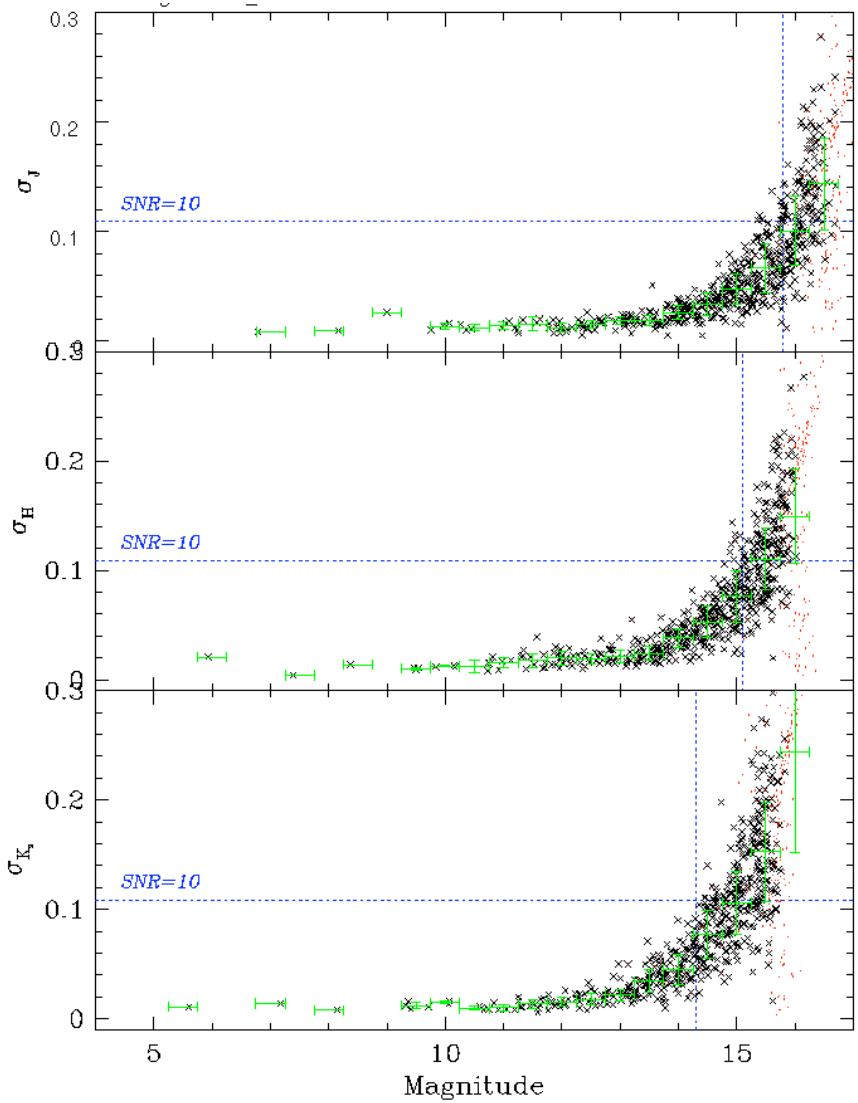
- Photometric uniformity
  - North/south observations tied via observations of the same **equatorial fields**
  - **Internal consistency** of standard star network (Nikolaev et al. 2000, AJ, 120, 3340)

- **<1-2% global zero point variation**, no systemmatic color drifts > 1%



Value of Touchstone Fields

- Cal fields observed **600-3700 times** during survey sampling all possible observing conditions
- **Instantaneous performance** monitoring for quality assurance
- Empirical relationship between **sensitivity** and seeing, background, transparency, etc. applied to general survey measurements



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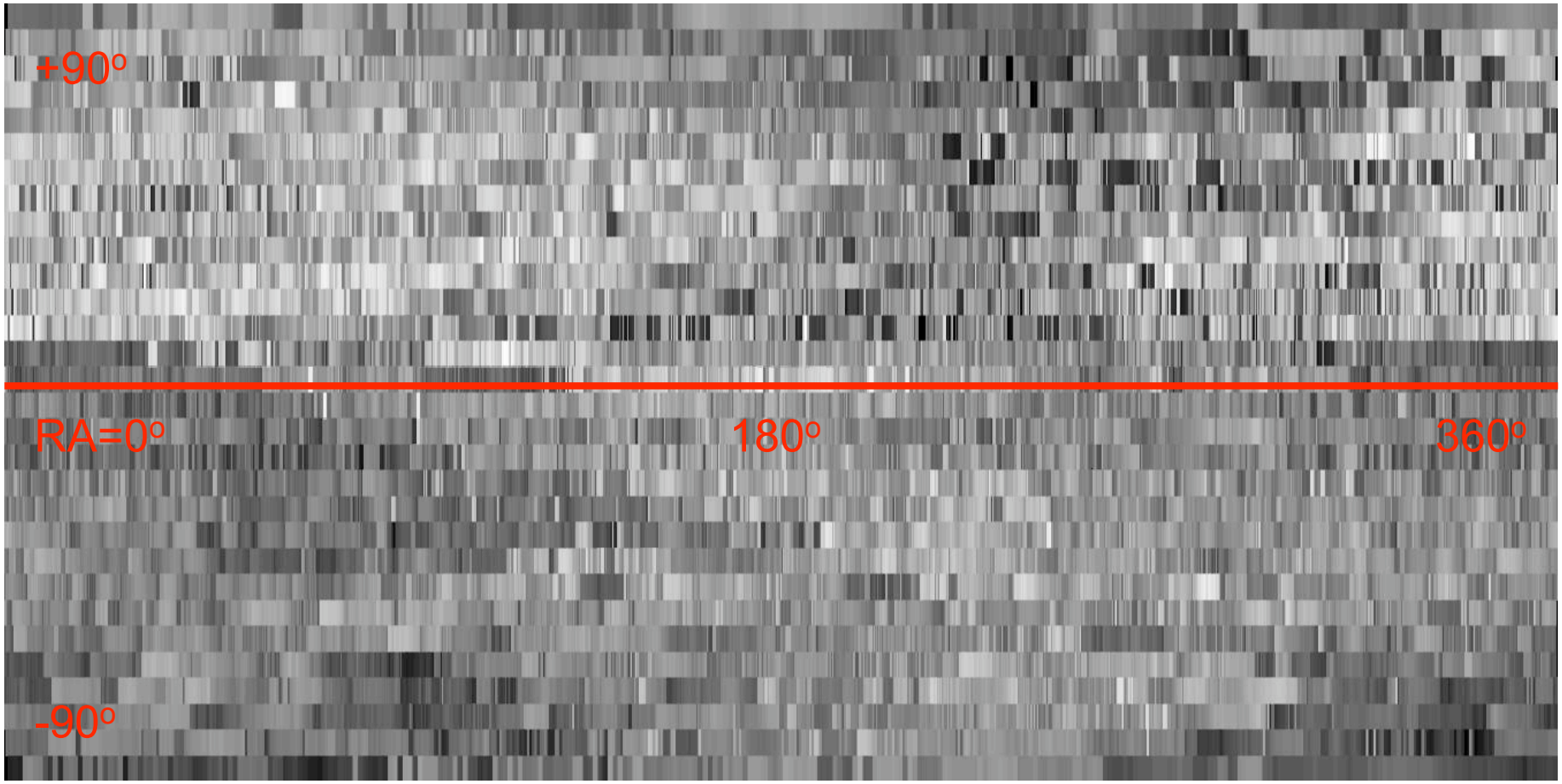
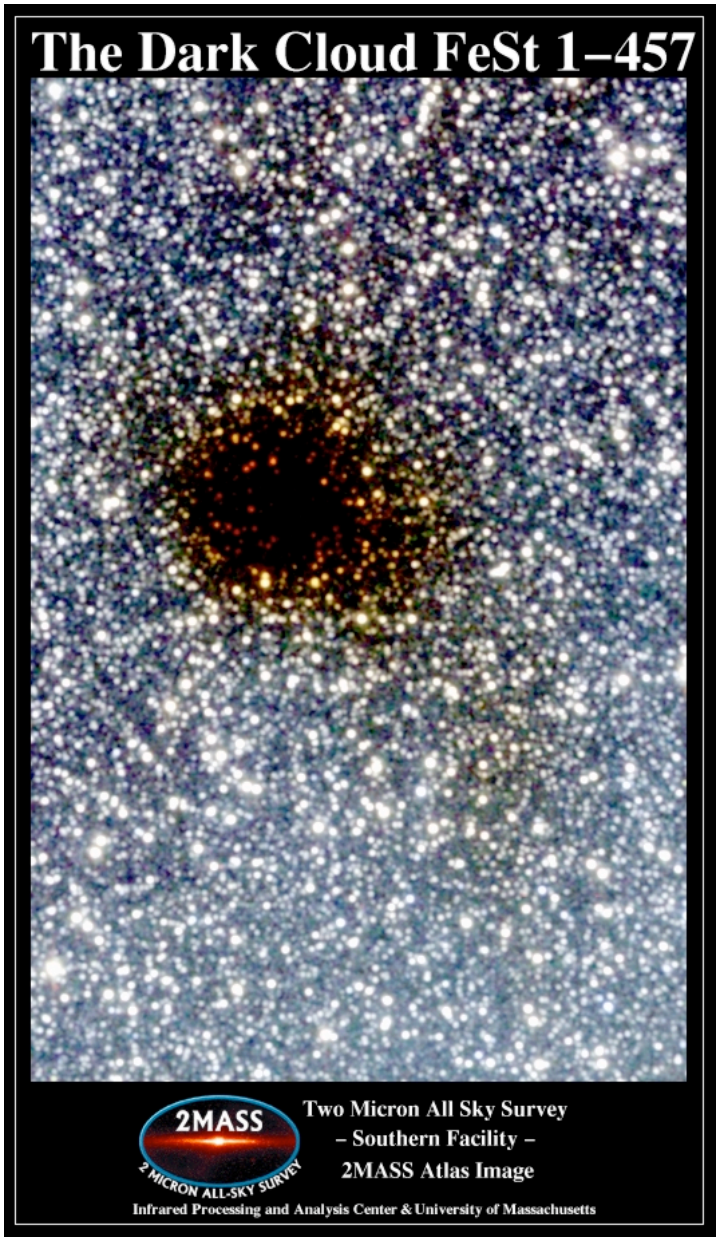


Cartesian Sky Map of 2MASS Ks-band SNR=10 level (14.3 - 15.5 mag)

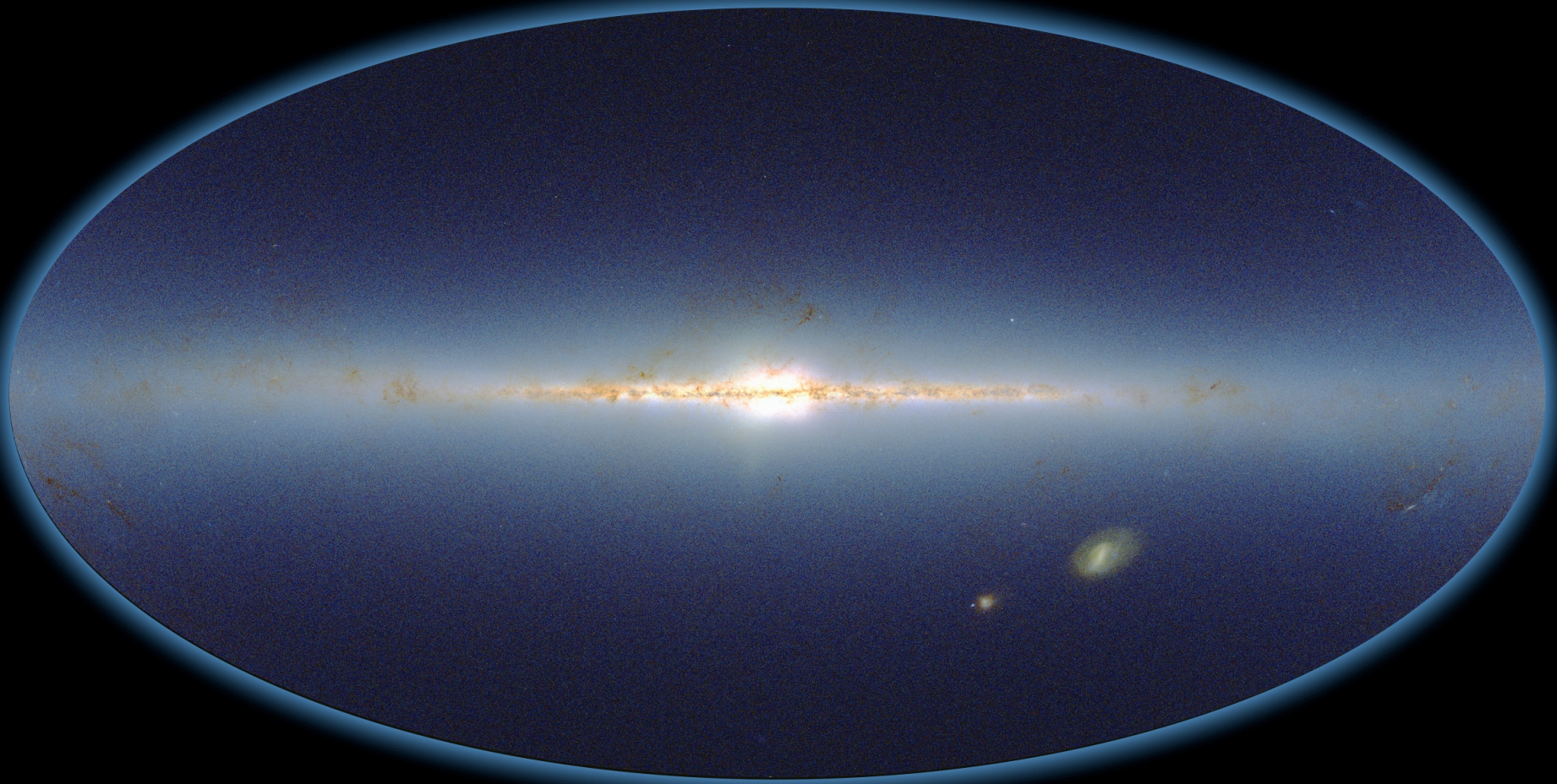
All-Sky Image Atlas

- **4,121,439** calibrated J, H, K_s images
- 512x1024 **1”/pix** FITS format
- 3-bands **registered**
- *Full-fidelity* Atlas Images available on-line via IRSA/2MASS Image Services

(http://irsa.ipac.caltech.edu/applications/2MASS/IM)

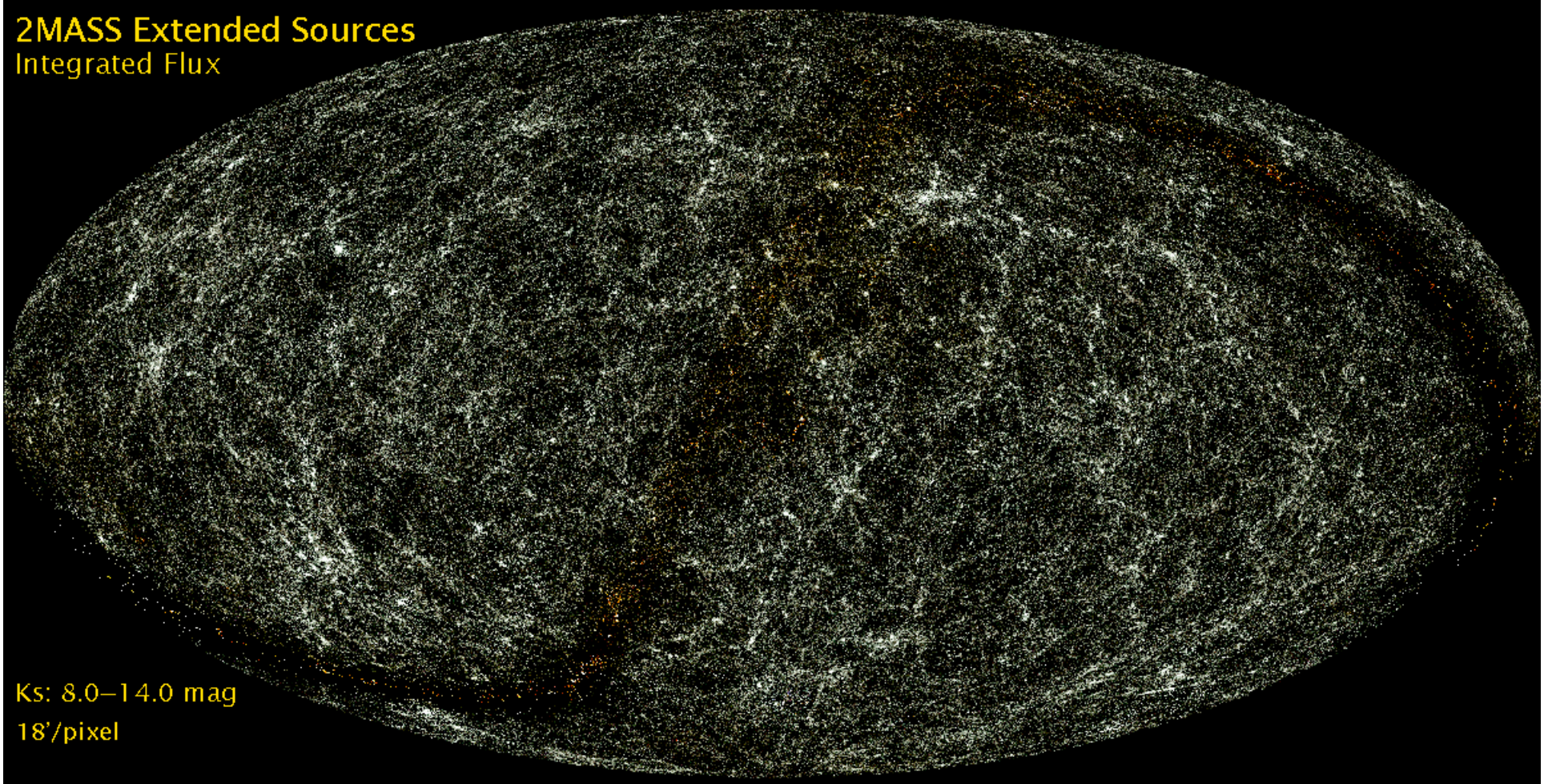


All-Sky Point Source Catalog (PSC)

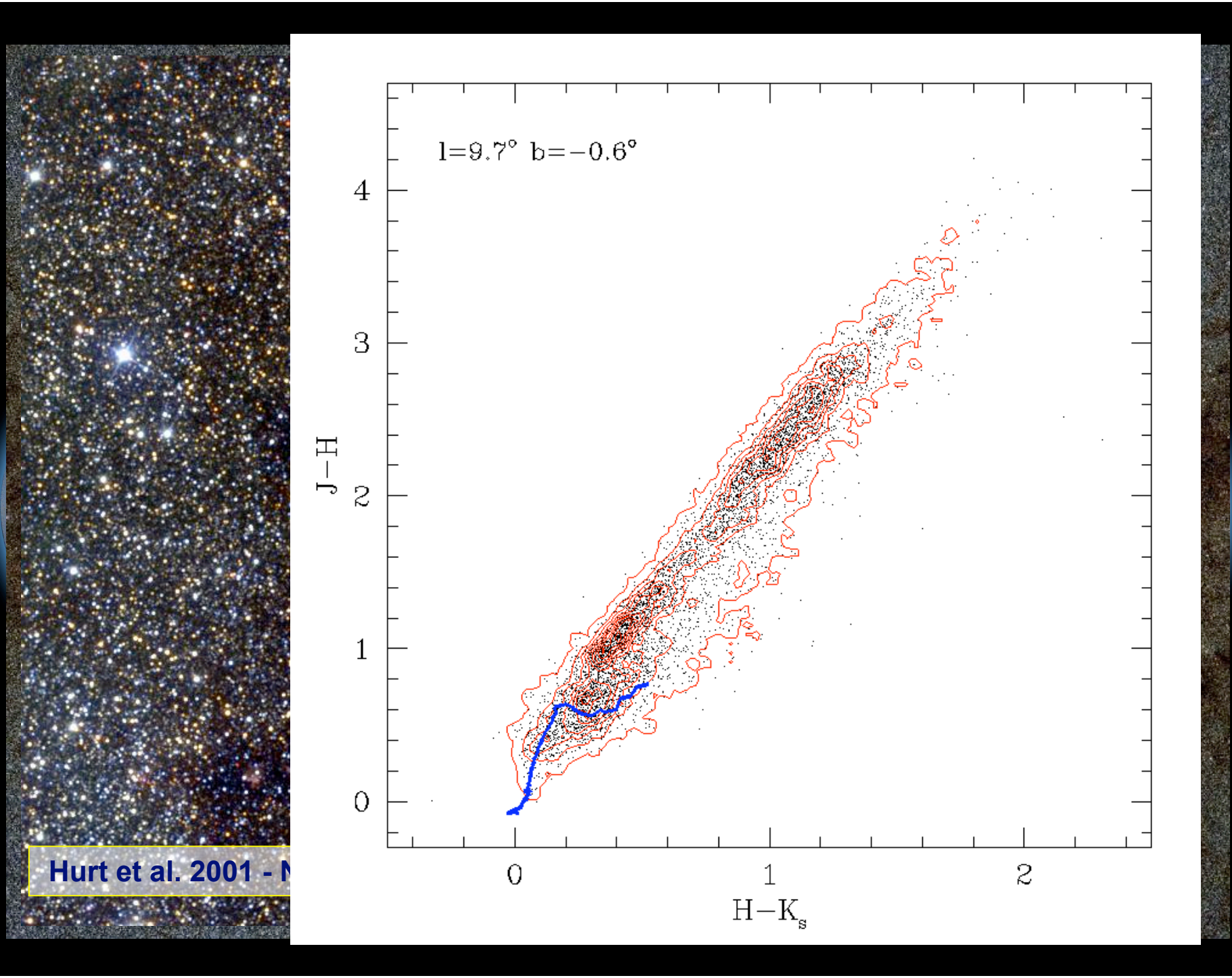


- Photometry & astrometry for **471 million srcs** (>95% MW stars)
- **~20 mags** dynamic range (-4.4< K_s<15.5)
- Complete to **SNR>10** for J<15.8, H<15.1, K_s<14.3 mag
- Astrometric accuracy: **~80 mas** wrt Tycho 2

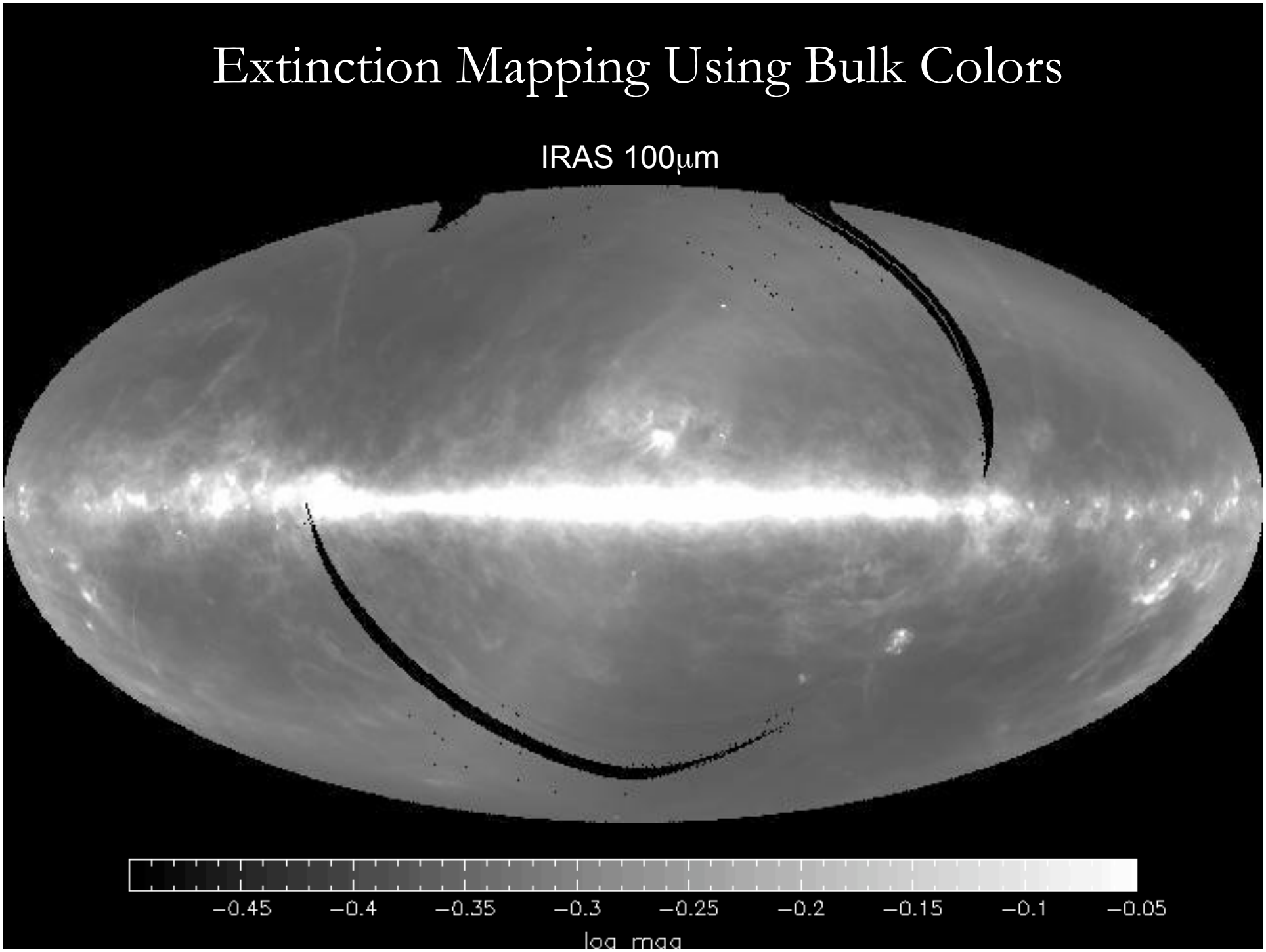
All-Sky Extended Source Catalog (XSC)



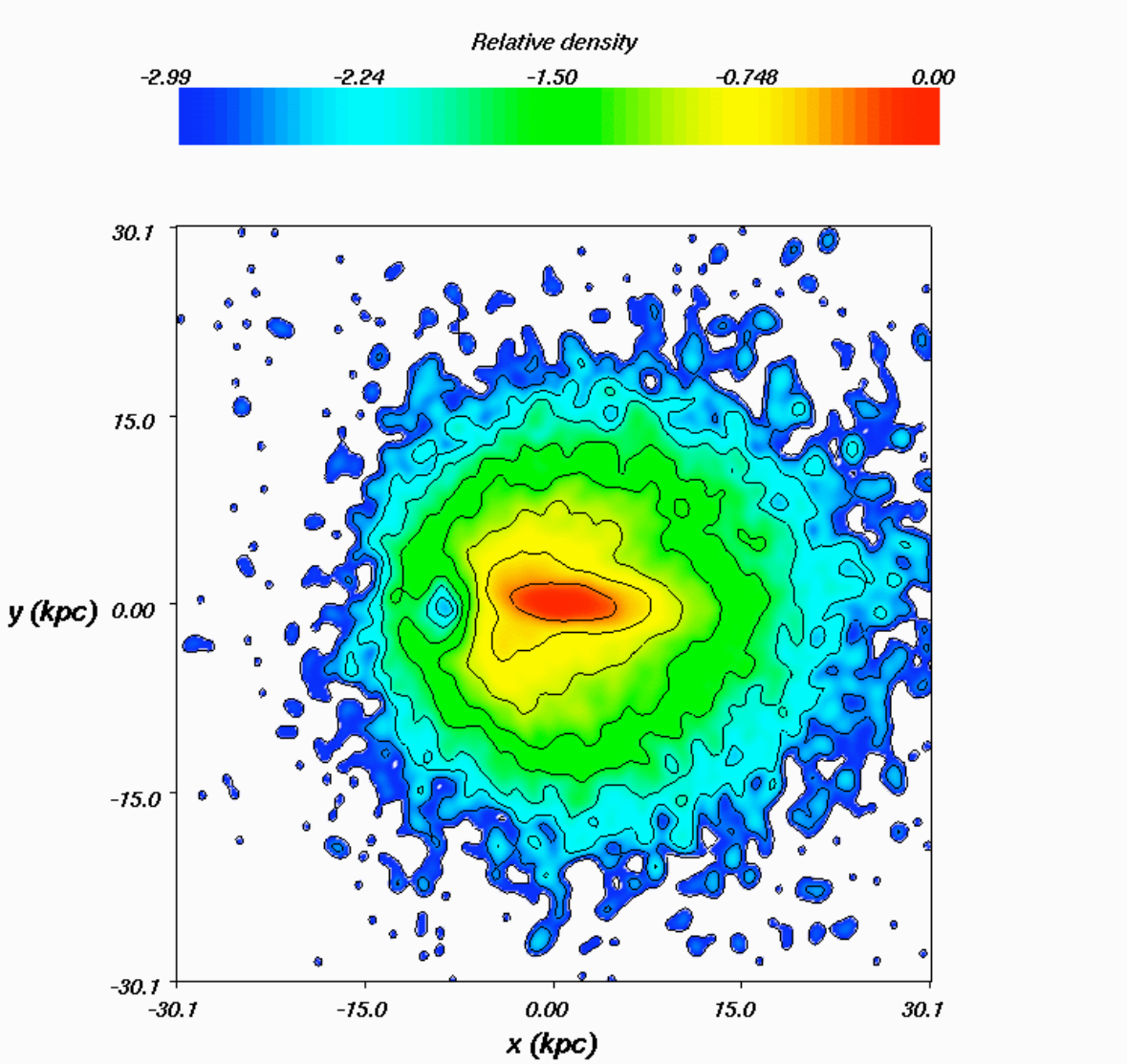
- Photometry, positions and shape info for **1.6 million resolved srcs** (~97% are z<0.1 galaxies)
- **~13.5 mags** dynamic range ($1.0<K_s<14.5$)
- 92% **Complete to K_s<13.5**
- Positional accuracy ~**0.8"** wrt FIRST


l=9.7° b=−0.6°
J−H
H−K$_s$
0
1
2
3
4
0
1
2
Hurt et al. 2001 - N

Extinction Mapping Using Bulk Colors

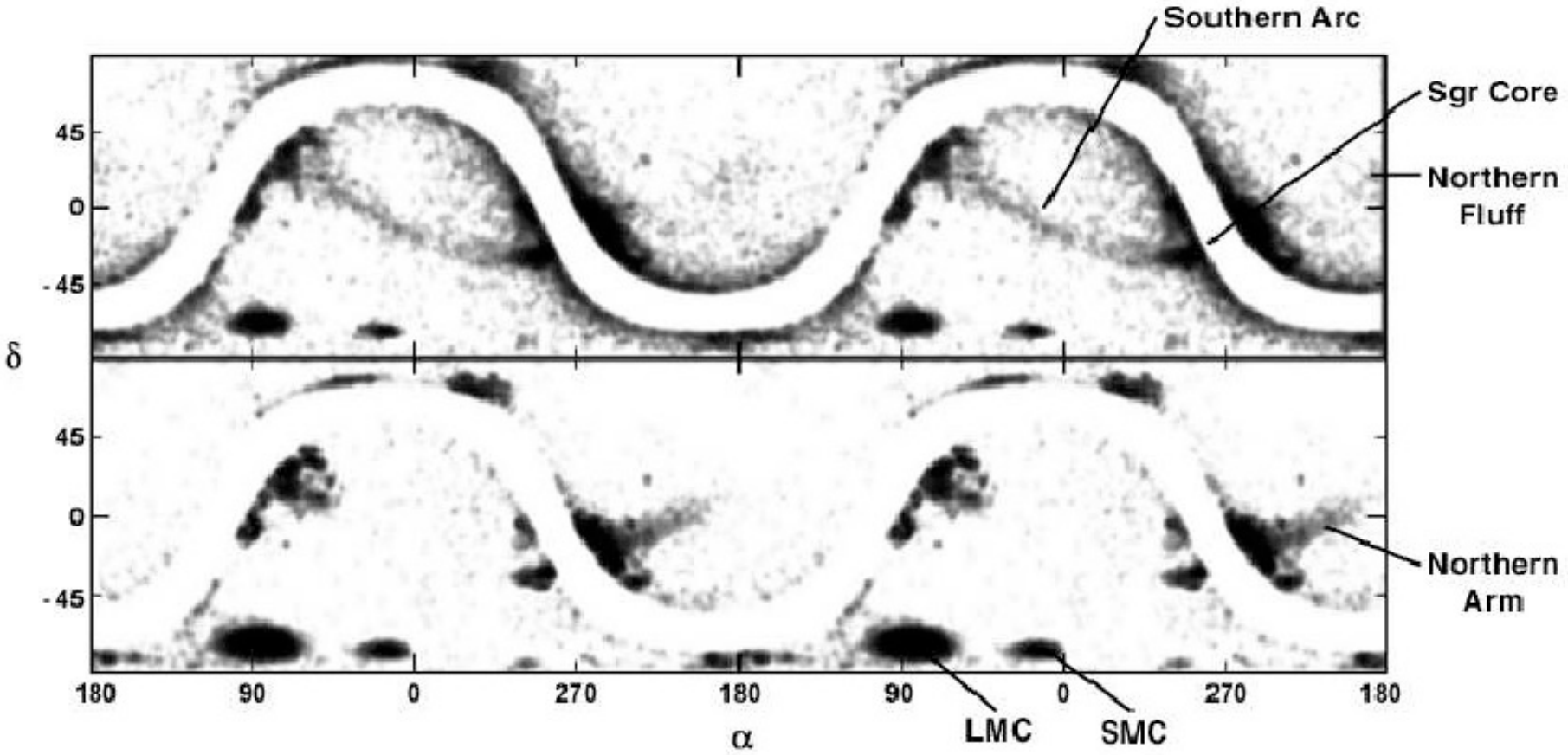


Tracing the Structure of the Milky Way

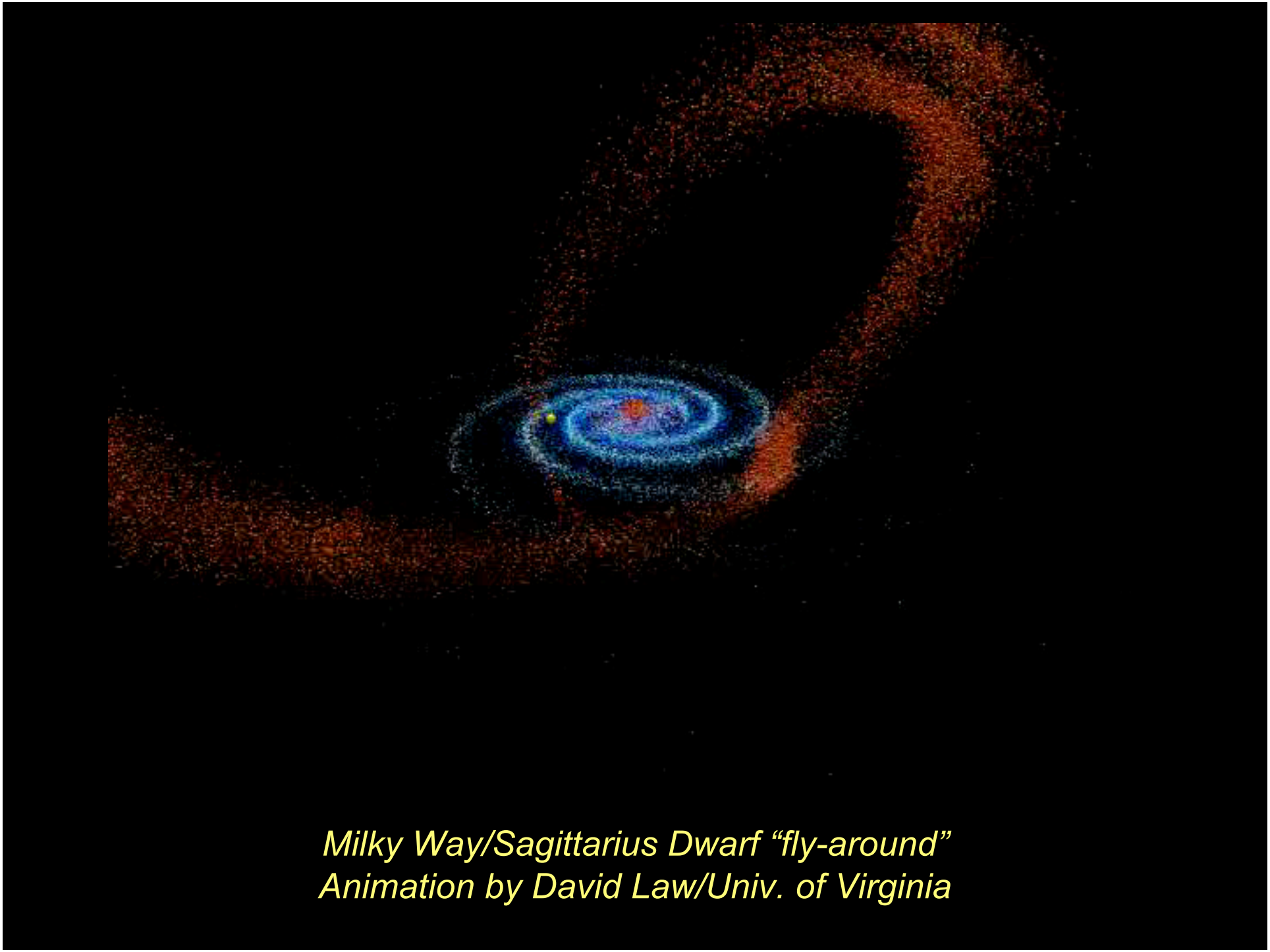


Skrutskie et al. 2001, BAAS, 33, 1437; Cole & Weinberg 2002, ApJ, 547, L43

Sagittarius Dwarf Tidal Stream

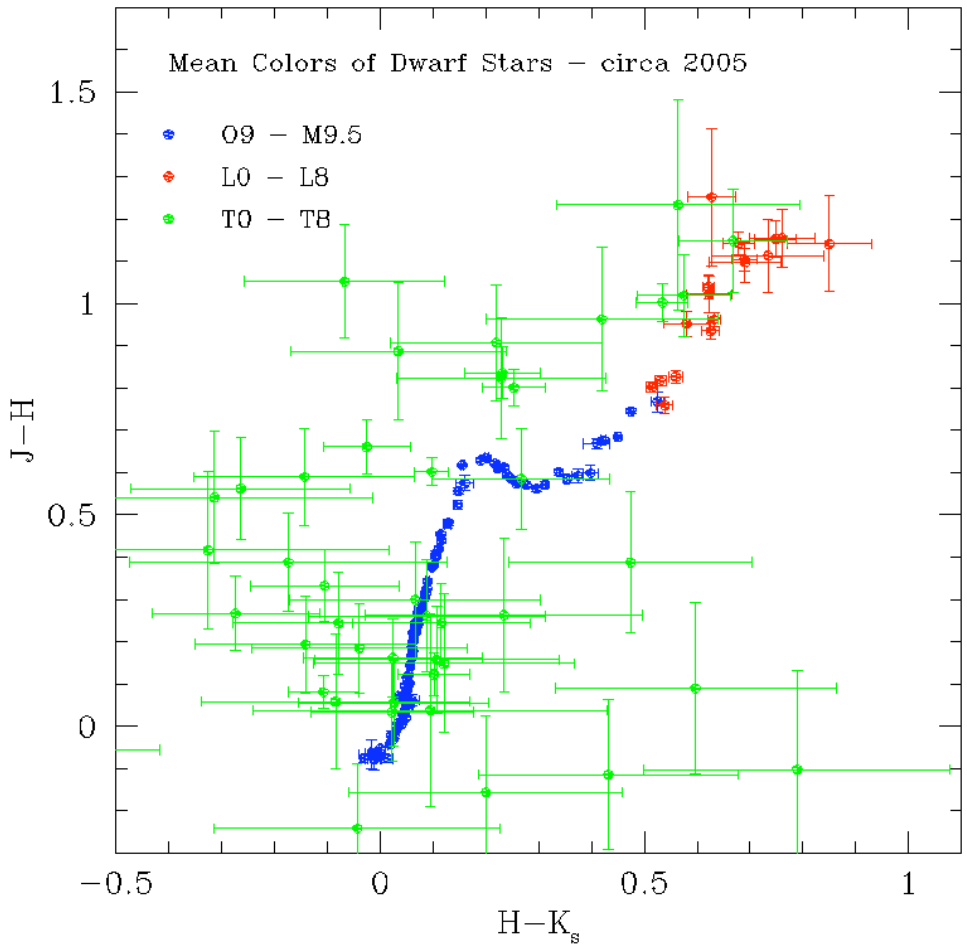


Majewski et al. 2003, ApJ, 599, 1082



Milky Way/Sagittarius Dwarf “fly-around”
Animation by David Law/Univ. of Virginia

Foundation for L and T Dwarfs



- Prior to 1994, latest main sequence star known was **M9.5**
- DENIS, SDSS and 2MASS provided long wavelength sensitivity, depth and sky coverage to find **rare, cooler objects**
- New spectral types - **L & T**
- Only problem is that they aren't rare!
- **>400** L dwarfs and **>60** T dwarfs now known

See new review by Kirkpatrick (2005 Ann.Rev.As.Ap.)

Structure of the Local Universe

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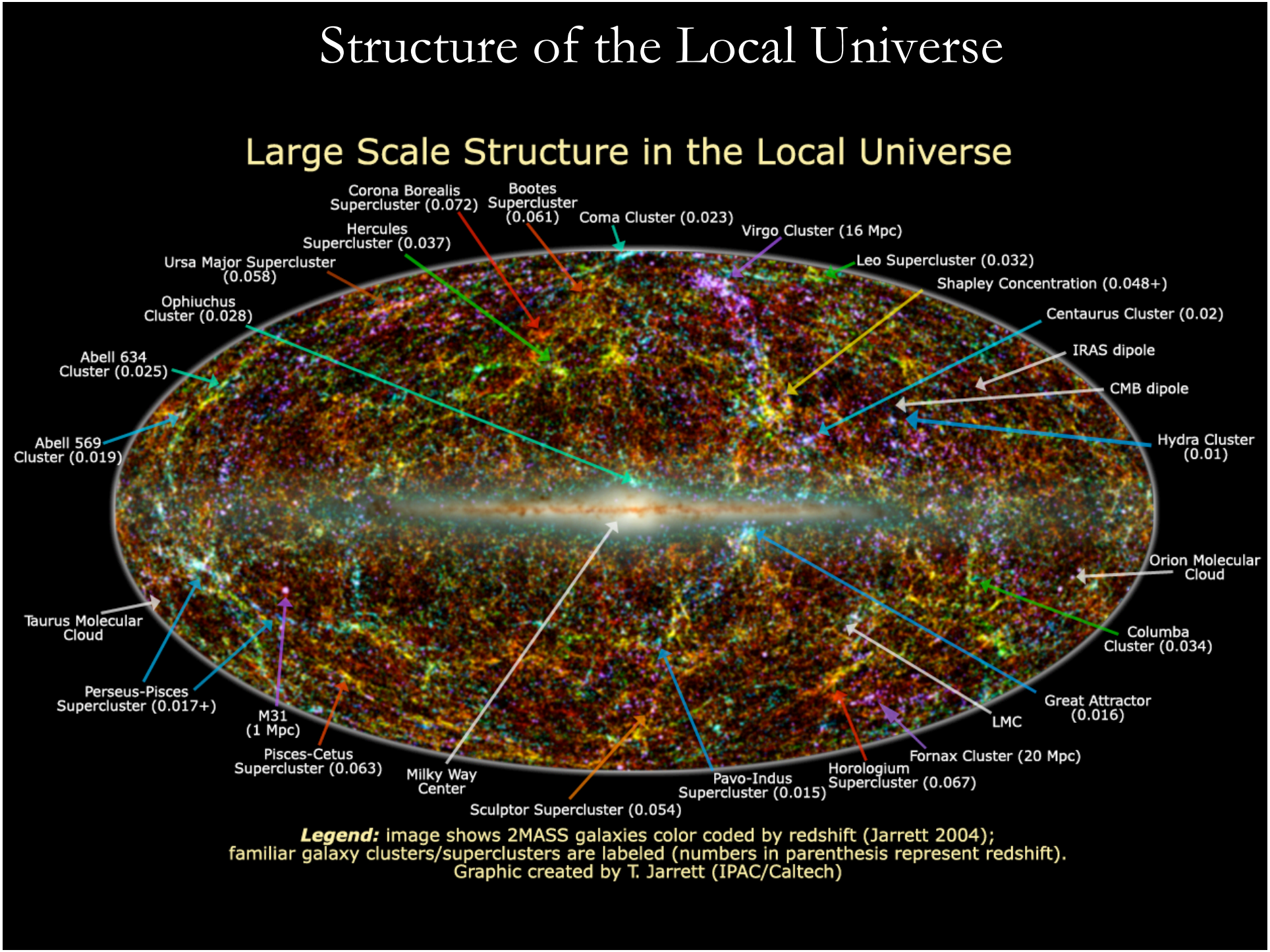
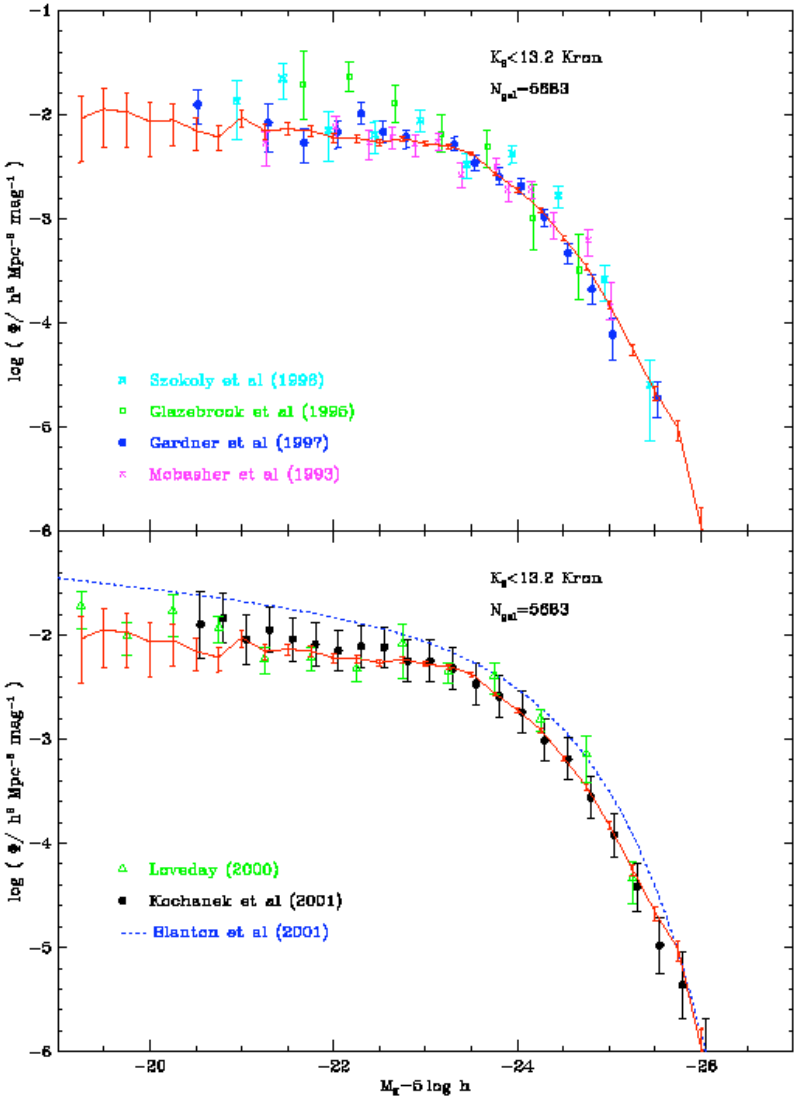


Galaxy Luminosity Function

- *XSC + redshift surveys*
  - *ZCAT (Kochanek et al. 2001, ApJ, 560, 566)*
  - *2dFGRS (Cole et al. 2001, MNRAS, 326, 255)*
- Schechter function
  - M*(K) = -23.4
  - Late type more numerous
- M/L => mass function
  - M^*_{stars} = 3-7 x 10^{10} h^{-2} M_o
  - Ω_{stars} = 1.6-2.9 x 10^{-3}



Defining Characteristics

- Well-defined, concise set of performance requirements from beginning
  - Sky coverage, photometric and astrometric accuracy, completeness, reliability, uniformity
- Prototyping
- Touchstone calibration fields to impose uniformity, monitor performance
- High throughput data processing system with extensive validation
- Staged data releases, with planned reprocessing ("You can't get it right the first time")
  - "Early" data releases take on a life of their own, though
- Well-characterized, understandable, documented data products
- Good access tools (bulk distribution, on-line via *IRSA*, *CDS*, etc)
- Legacy - ***2MASS data used in >1200 refereed publications***