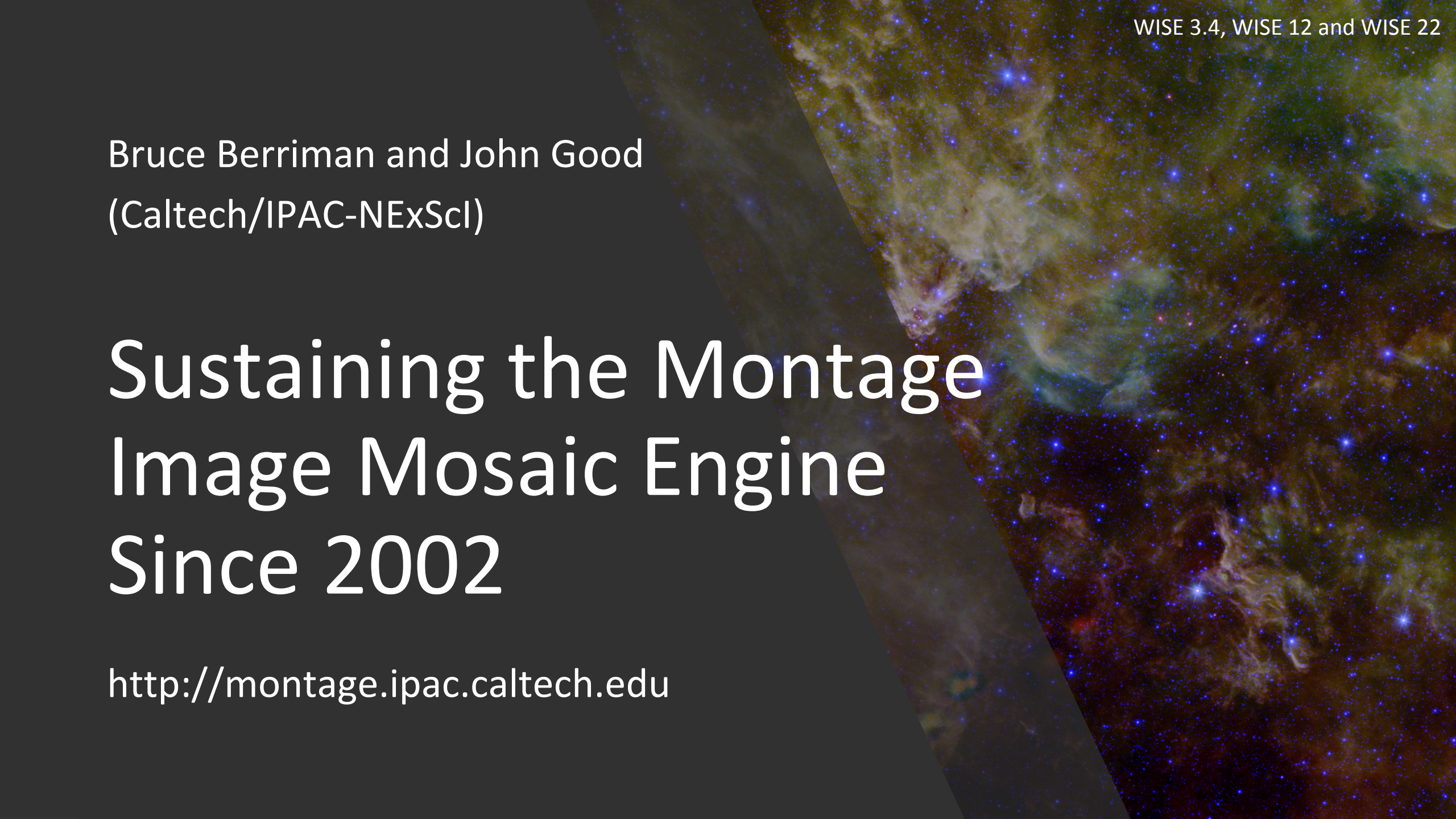



Bruce Berriman and John Good
(Caltech/IPAC-NExScI)

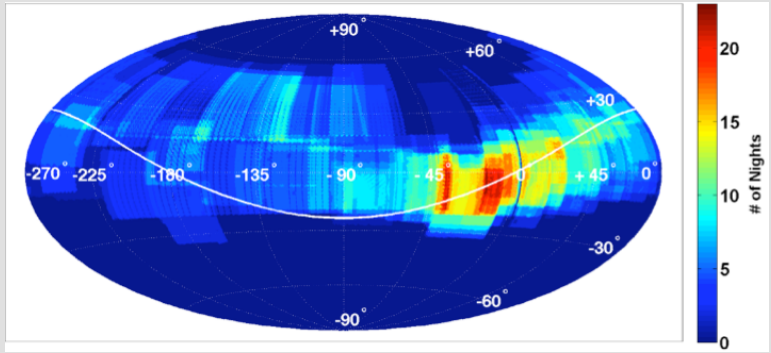
# Sustaining the Montage Image Mosaic Engine Since 2002

http://montage.ipac.caltech.edu

# Montage Has Found Wide Applicability

- Supporting detection of NEOs. *Vighh et al. 2015*
- Laser Raman scattering. *Vogt et al. 2017 Physical review*
- Supporting observation planning for JWST. *Beck et al. 2016, SPIE, 9910, 99101O*
- Analysis of barred galaxies discovered by Galaxy Zoo. *Kruk et al. 2018, MNRAS, 473, 4731*

**Co-registration of images in Lincoln Near Earth Asteroid Research Program (LINEAR)**

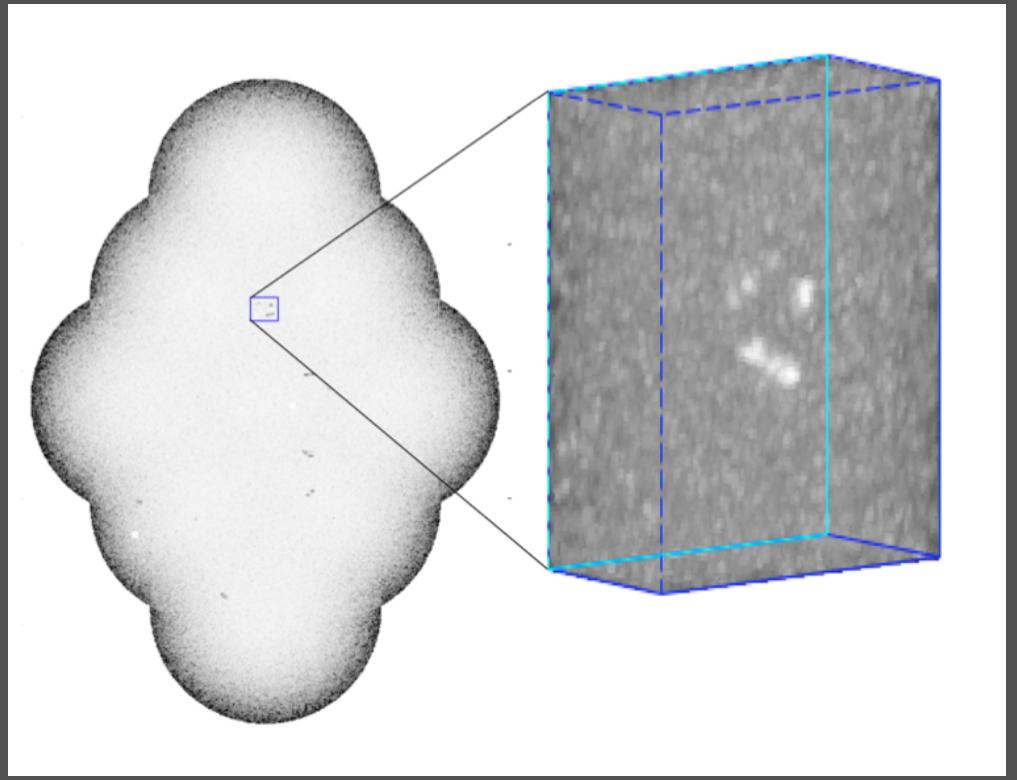



***Sky coverage April 2013 - November 2014***

- 83 objects reported to date.
- "Initial asteroid detection results using the Space Surveillance Telescope" Viggh et al., Aerospace Conference (2015) (DOI 10.1109/AERO.2015.7118951)

# Integration Into Archives and Processing Environments

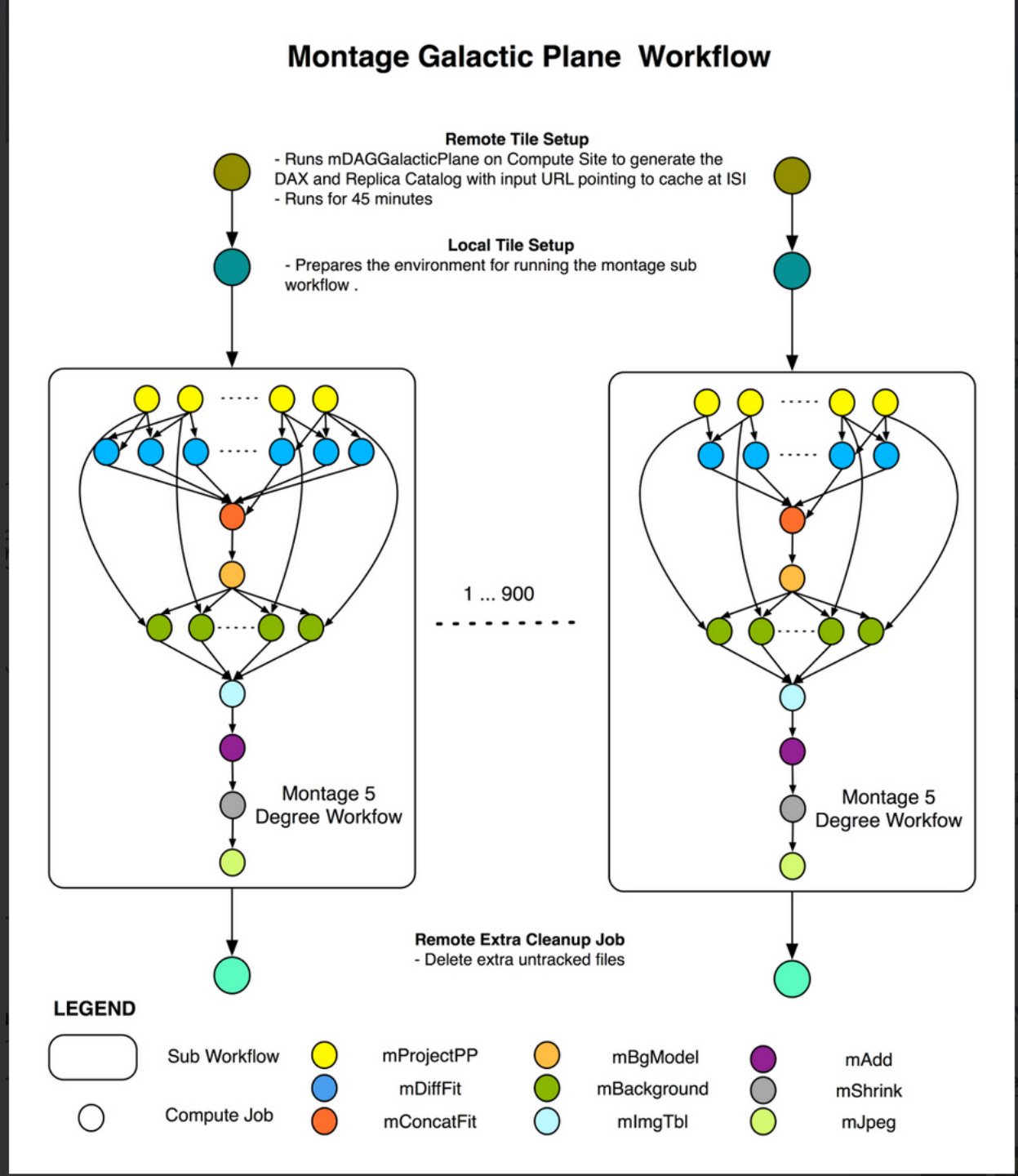
- The CSIRO ASKAP Science Data Archive
- AKARI
- Spitzer Space Telescope Legacy Programs …
- 27 prtojects to date



*800x1100x300 pixel image cube of IC 1459 galaxy group; 9 square degrees and a 240 km/s velocity range. Right: A 97x97x51 sub-cube around IC 5270 extracted using Montage. The sub-cube covers 24 arcmin on a side and 40 km/s.*

# Montage At Scale

- Development of cyber-infrastructure
  - 468 citations in IT literature since 2013. cf. 133 in astronomy
- Driver for development of Pegasus Workflow Manager.
- Used to create 16-wavelength Atlas of the Galactic Plane on AWS.



# Release History

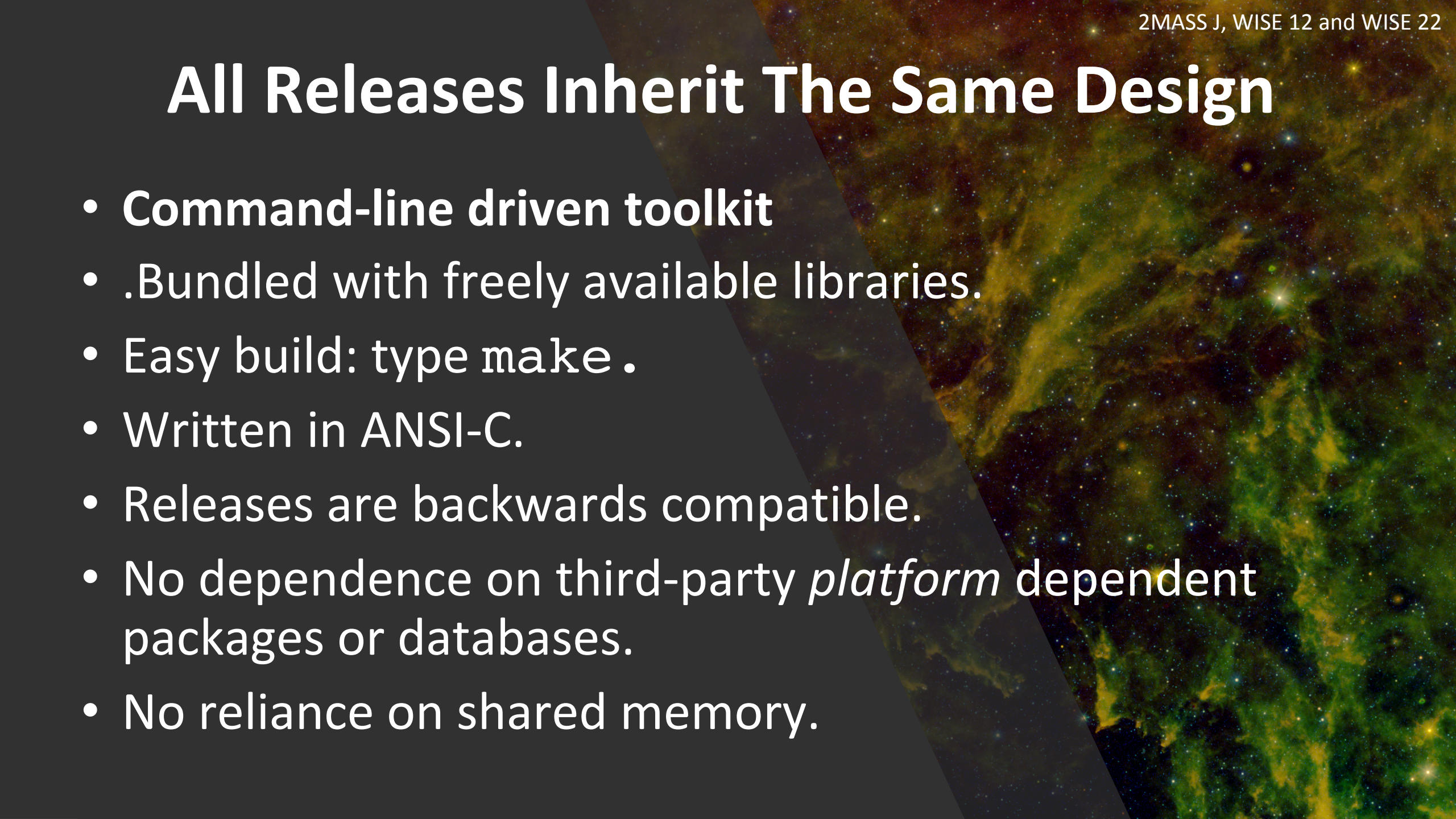
| | |
|---|---|
| **2002-2005: The NASA Years** | |
| Releases 1.0 – 2.2 | 2D mosaics. |
| **2006-2013: The (largely) Unsupported Years** | |
| Releases 3.0 -3.3 | Utilities. |
| **2014-2017: The NSF Years** | |
| Releases 4 -6 | Data cubes, HEALPix, WWT (TOAST), Fast reprojection, Visualization.<br>BSD 3-clause license. |

# Design Drives Sustainability

WISE 3.4, MSX 8.8 and WISE 22

# Simple Design Drives Long-term Sustainability

WISE 3.4, MSX 8.8 and WISE 22

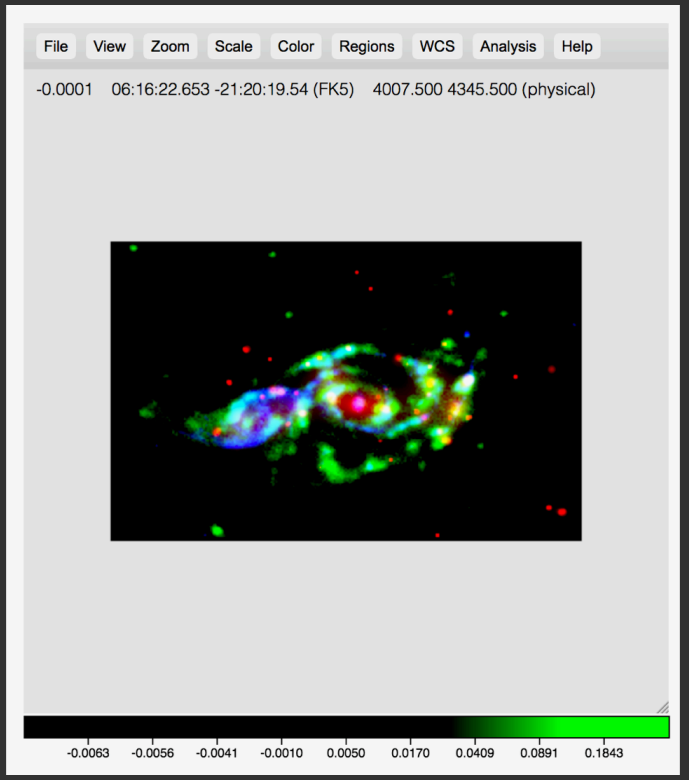



# All Releases Inherit The Same Design

- **Command-line driven toolkit**
- .Bundled with freely available libraries.
- Easy build: type `make`.
- Written in ANSI-C.
- Releases are backwards compatible.
- No dependence on third-party *platform* dependent packages or databases.
- No reliance on shared memory.

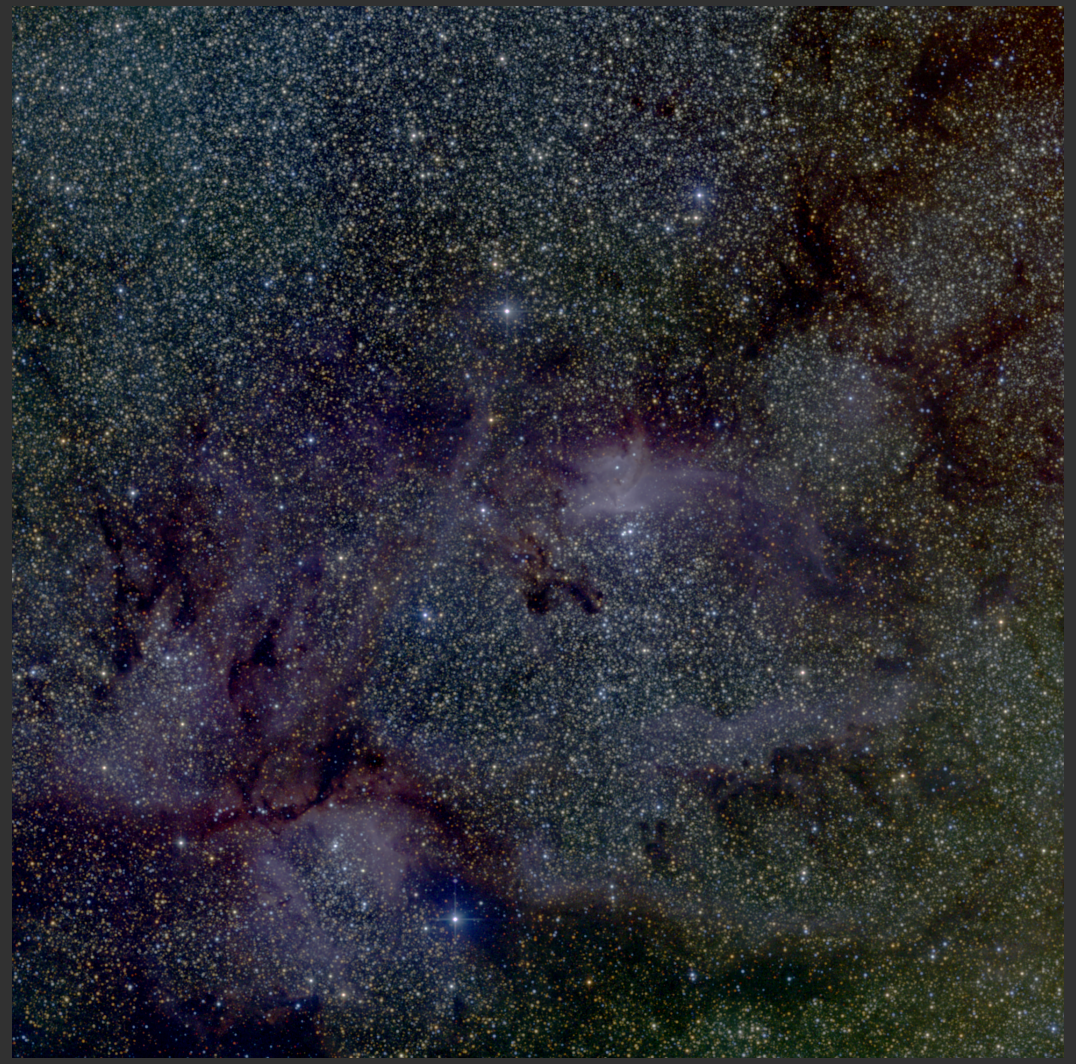
# Advances in Compilers: Common Code Base For Windows , *nix,  Macs, Javascript

- Minimalist GNU for Windows (MinGW)
- Emscripten for Javscript




*3 color image of Cas A: Chandra (red), Spitzer (blue), and Galex (green), reprojected to Chandra (WCS).*

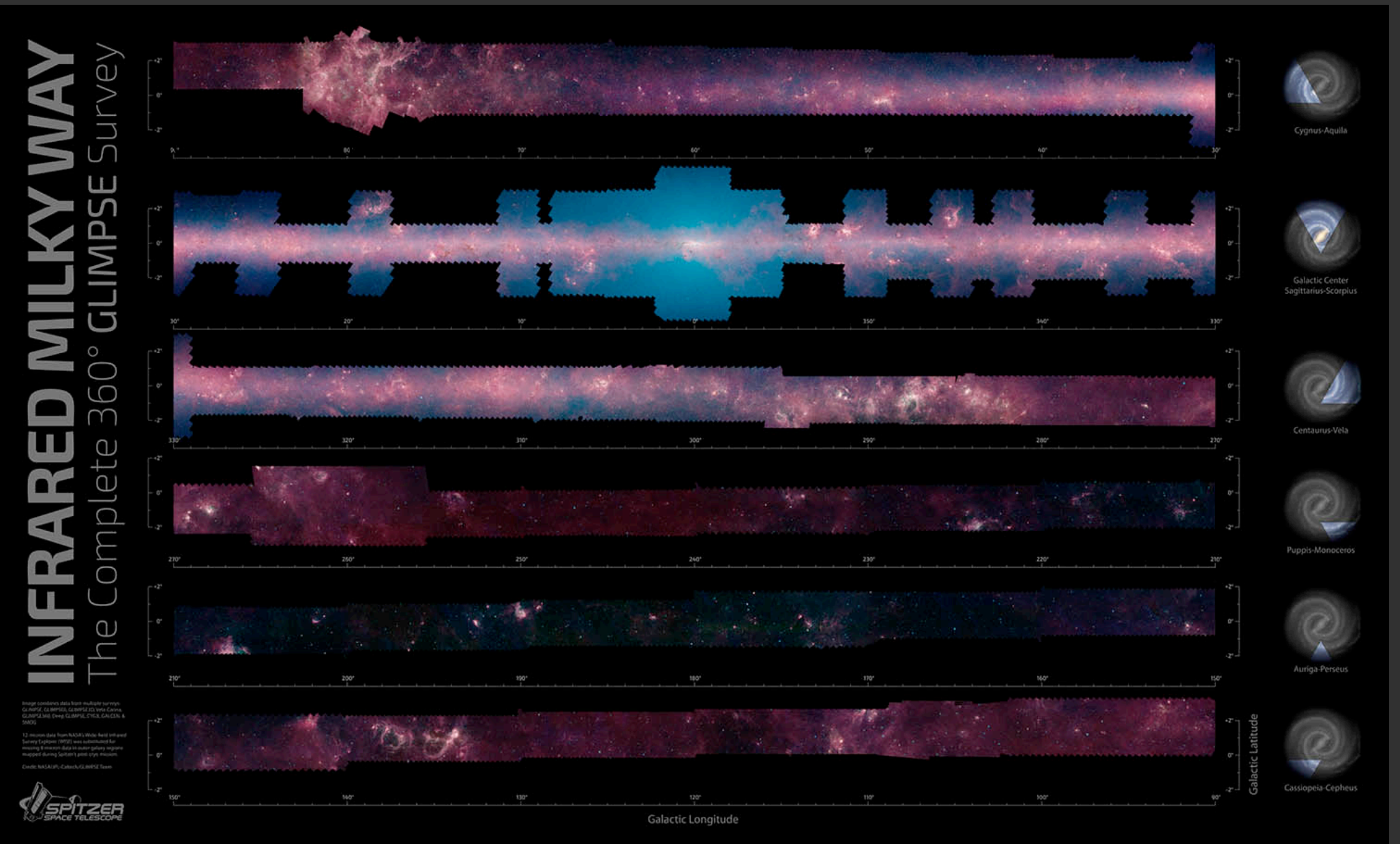
*NGC 6537, 2MASS, 3-color*



# Each module performs one task

- Analyze the geometry of input images  to derive geometry of output mosaic
- Re-project the input images.
  - Preserve the calibration and astrometric fidelity
- Model background images and rectify to a common level
- Co-add the processed images

# Montage As A Reprojection Engine



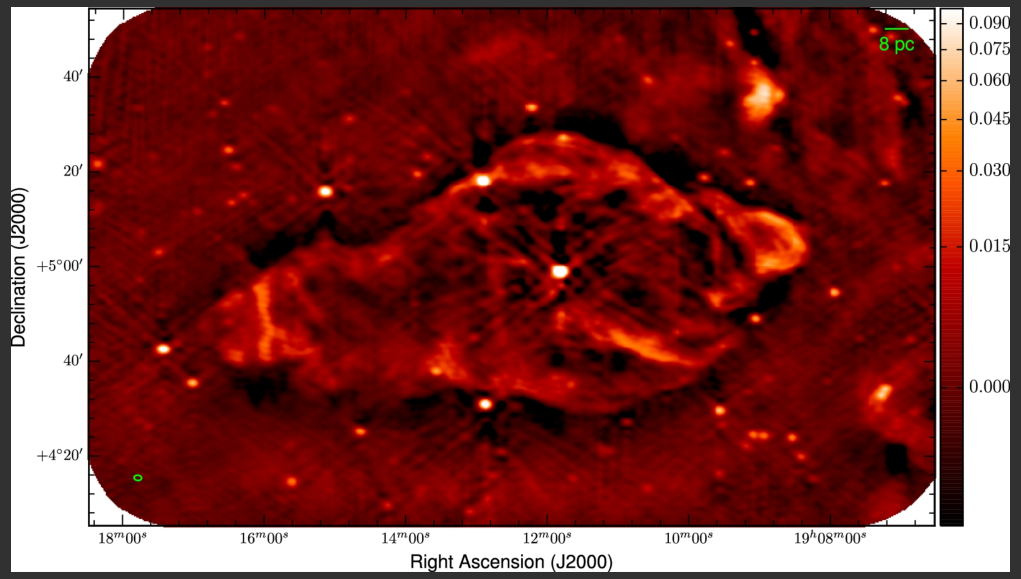

Meade et al 2014

# Background Rectification of 2MASS H-band images

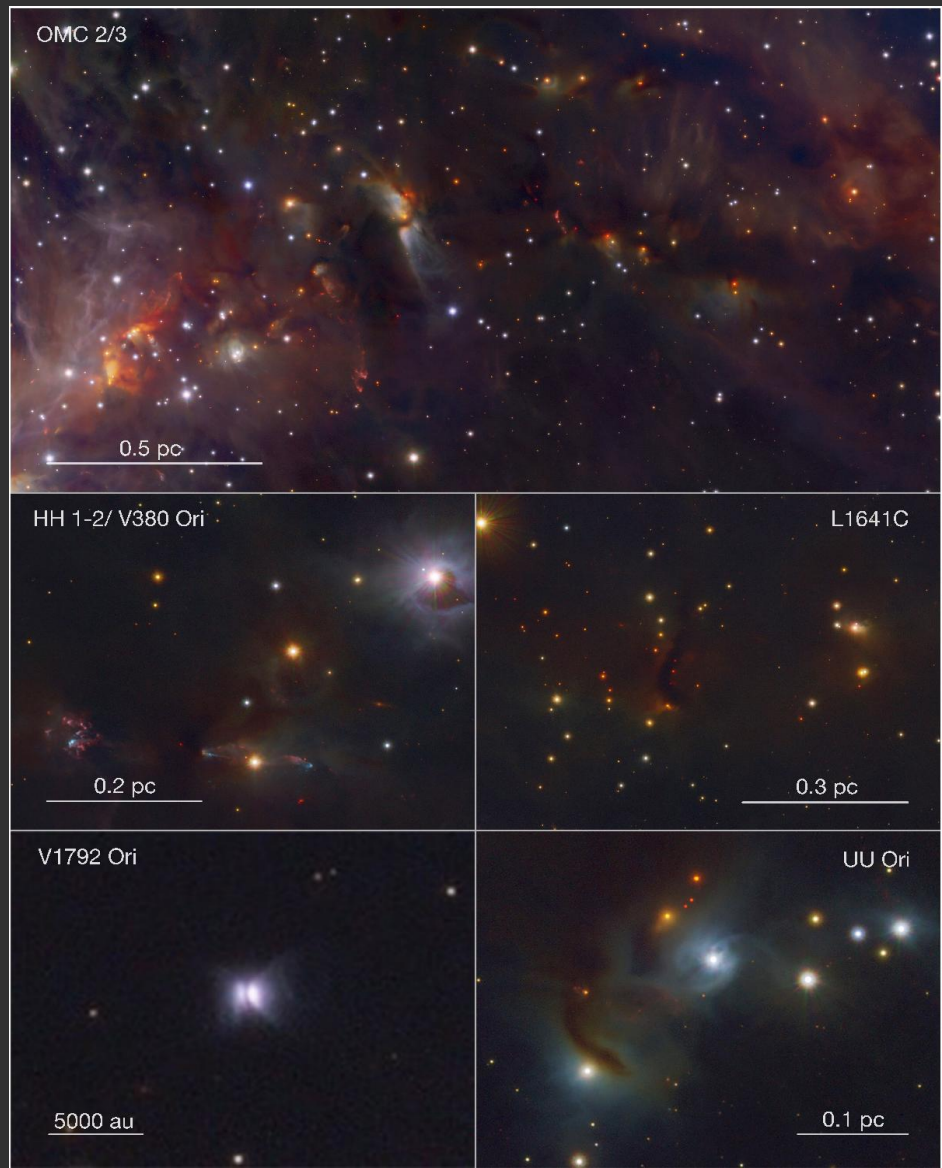
# Montage As A Background Rectification Engine

- Meingast et al. 2016. A & A , 587, A153
- Peters et al. 2016. MNRAS, 464, 1591
- Farnes et al. 2017. MNRAS, 467, 4777.

*A wide-field, wide-band, mosaicked, multifrequency synthesis image of the total intensity emission (Stokes I) from W50/ SS433. The image combines data over the frequency range from 1.4 to 3.1 GHz, with an effective bandwidth of 1.7 GHz .Farnes et al.*

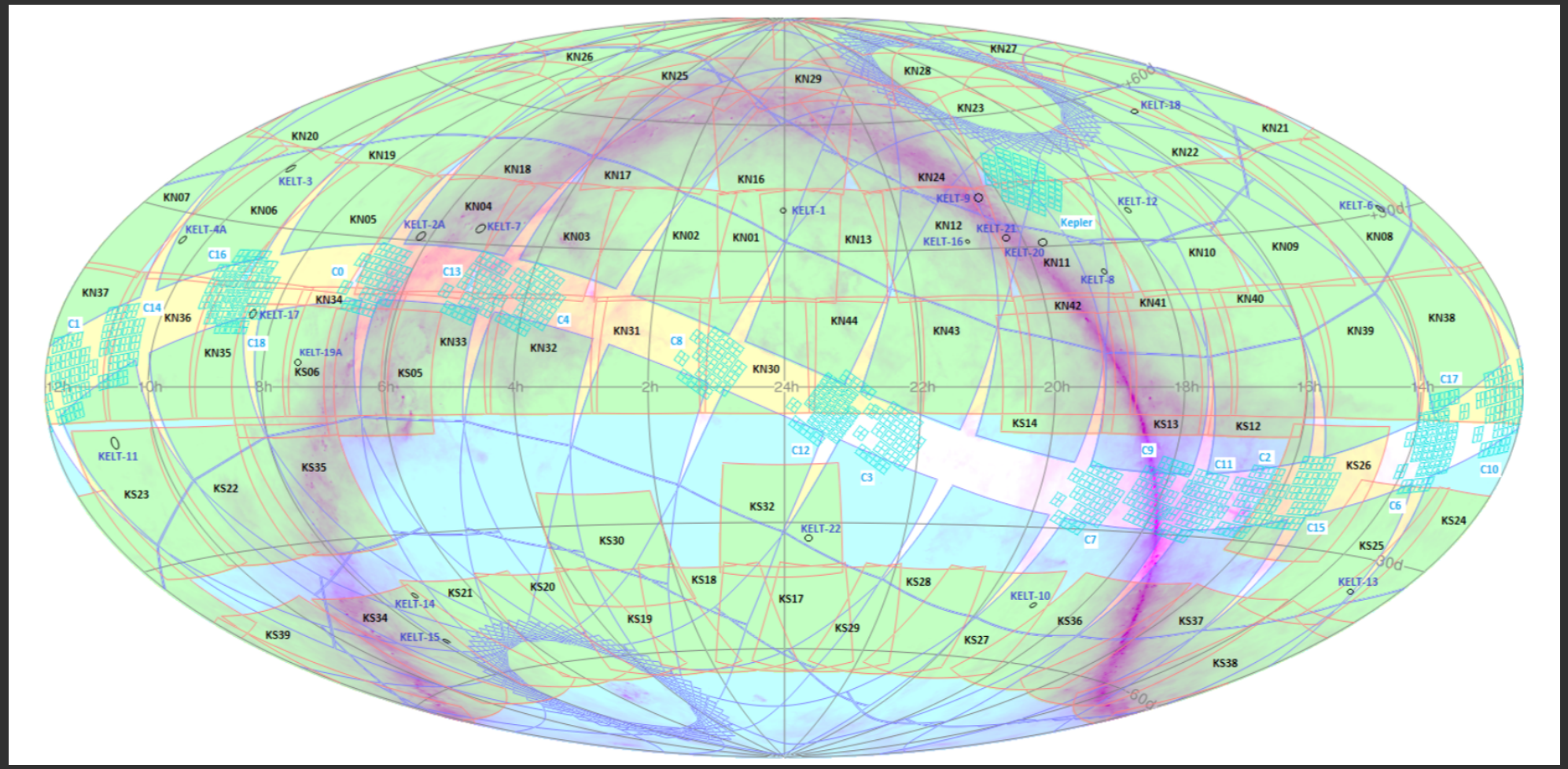



*Newly identified objects in the VISTA Orion A survey. Meingast et al*



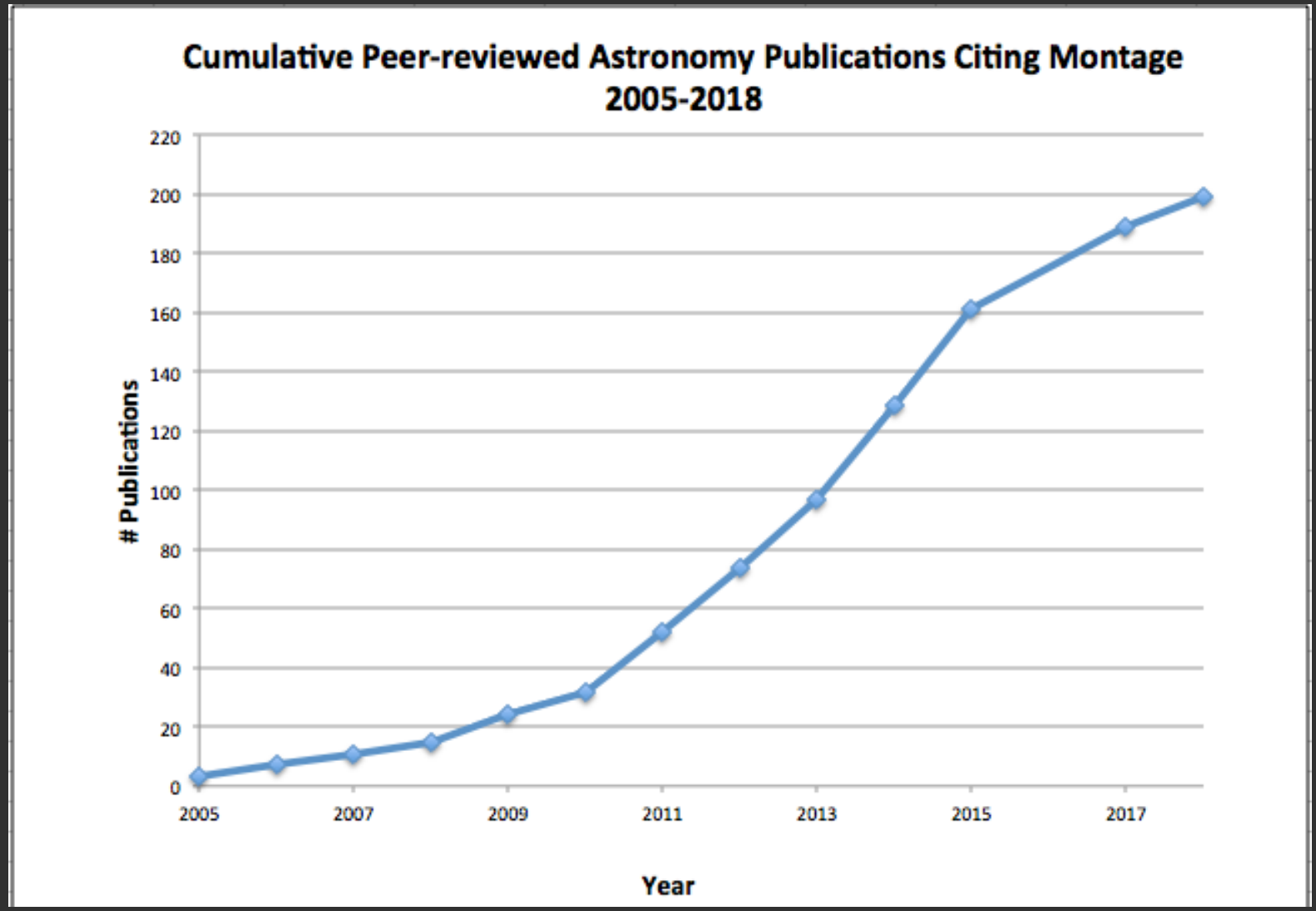
# Sky Graphics Engine

**Collins et al. (2018) AAS Journals submitted. *https://arxiv.org/abs/1803.01869***




See Berriman and Good, 2017, PASP, *PASP,* **129,** 058006

# Slow Uptake

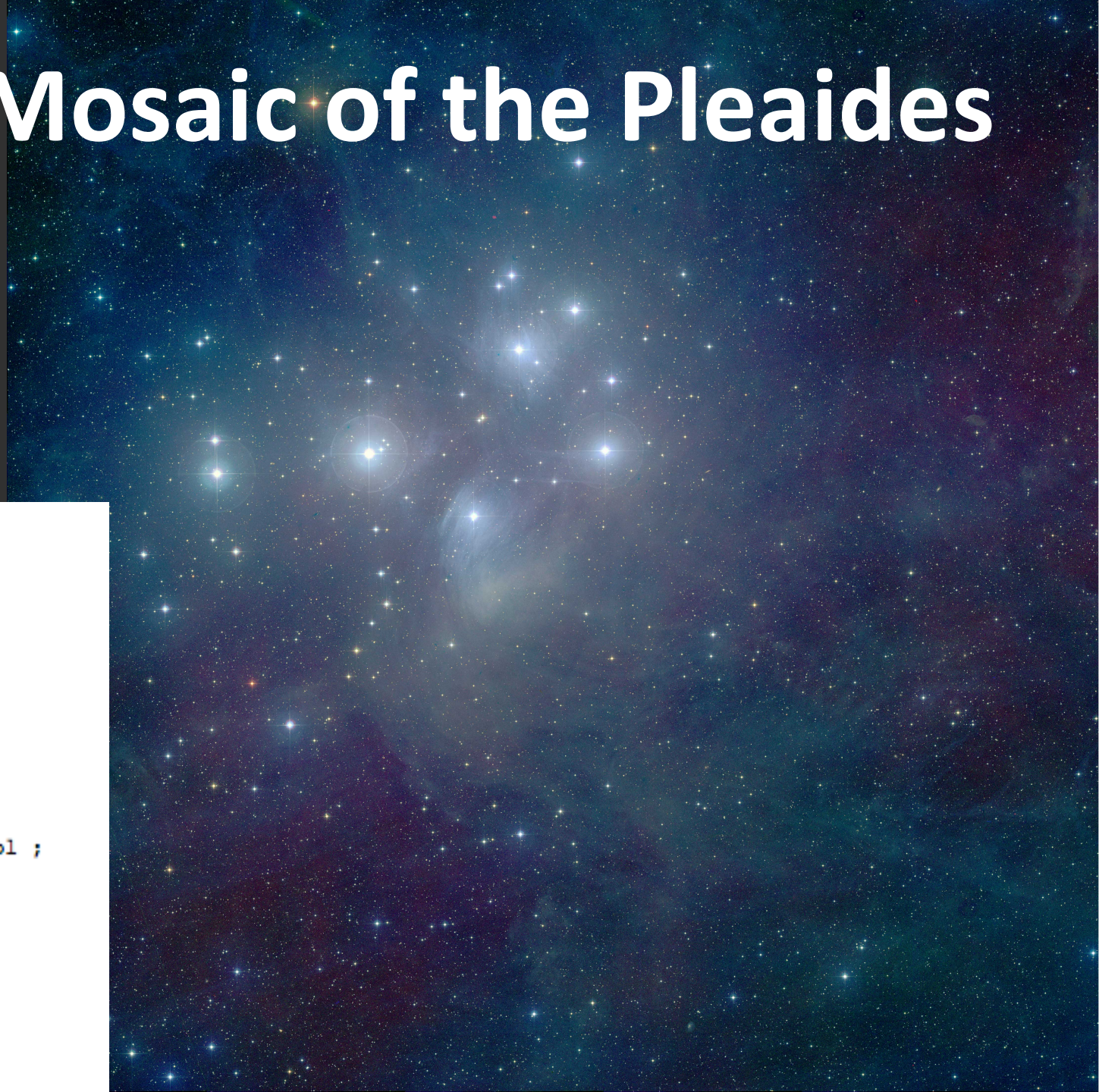

Cumulative Peer-reviewed Astronomy Publications Citing Montage
2005-2018
# Publications
220
200
180
160
140
120
100
80
60
40
20
0
2005
2007
2009
2011
2013
2015
2017
Year

The grumpier the user, the more valuable the suggestions.

WISE 3.4, MSX 8.8 and WISE 22

# Sample Script: A Mosaic of the Pleaides

*Courtesy: Inseok Song*



```
#!/bin/bash
# Pleiades Image creation BASH script.
# Inseok Song, 2007
for bands in DSS2B DSS2R DSS2IR; do echo Processing ${bands};
mkdir $bands;
cd $bands;
mkdir raw projected;
cd raw;
mArchiveList dss ${bands} "56.5 23.75" 3 3 remote.tbl;
mArchiveExec remote.tbl;
cd .. ;
mImgtbl raw rimages.tbl ;
mProjExec -p raw rimages.tbl ../pleiades.hdr projected stats.tbl ;
mImgtbl projected pimages.tbl ;
mAdd -p projected pimages.tbl ../pleiades.hdr ${bands}.fits ;
cd .. ;
done

mJPEG -blue DSS2B/DSS2B.fits -1s 99.999% gaussian-log \
      -green DSS2R/DSS2R.fits -1s 99.999% gaussian-log \
      -red DSS2IR/DSS2IR.fits -1s 99.999% gaussian-log \
      -out DSS2_BRIR.jpg
```

# Image of M51:  Jupyter Notebook Prototype

## MontagePy mViewer

The Montage toolkit is primarily involved in reprojecting, background matching, and mosaicking astronomical images but it also has fairly sophisticated tools for image display (PNG/JPEG generation). This notebook entry shows the basics of using mViewer to create afull-color image from three wavelength bands that have already been reprojected and mosaicked.

First, lets import mViewer from the Montage package.

In [22]:
```
from MontagePy.main import mViewer

help(mViewer)
```

```
Help on built-in function mViewer in module MontagePy.main:

mViewer(...)
    mAdd enerates a JPEG image file with overlays from a FITS file (or a set of three FITS files in color).

    Parameters
    ----------
    cmdstr : str
        The command string (arguments or JSON).
    outFile : str
        Output PNG/JPEG.
    mode : int, optional
        Type of the command string: Type of the command string: 0 for JSON file, 1 for JSON, 2 for 'command' string.
    outFmt : str, optional
        'png' or 'jpeg'.
    fontFile : str, optional
        Font file for labeling (overrides default)
    debug : int, optional
        Debugging flag.
```

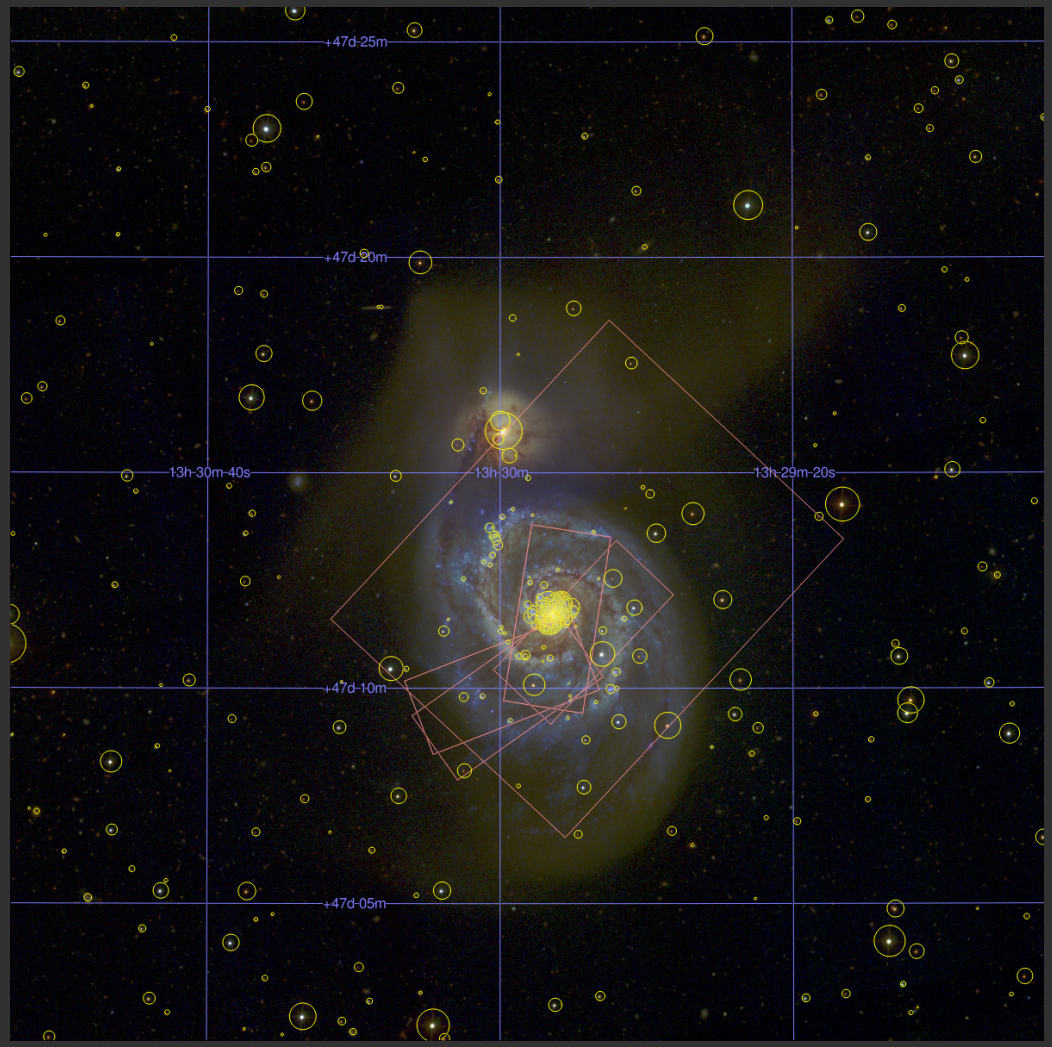
The Montage toolkit contains dozens of utilities. Two that are often used along with mViewer are mShrink to rescale the input images and mSubimage to cut out sections. All of Montage is available through the MontagePy.main module.

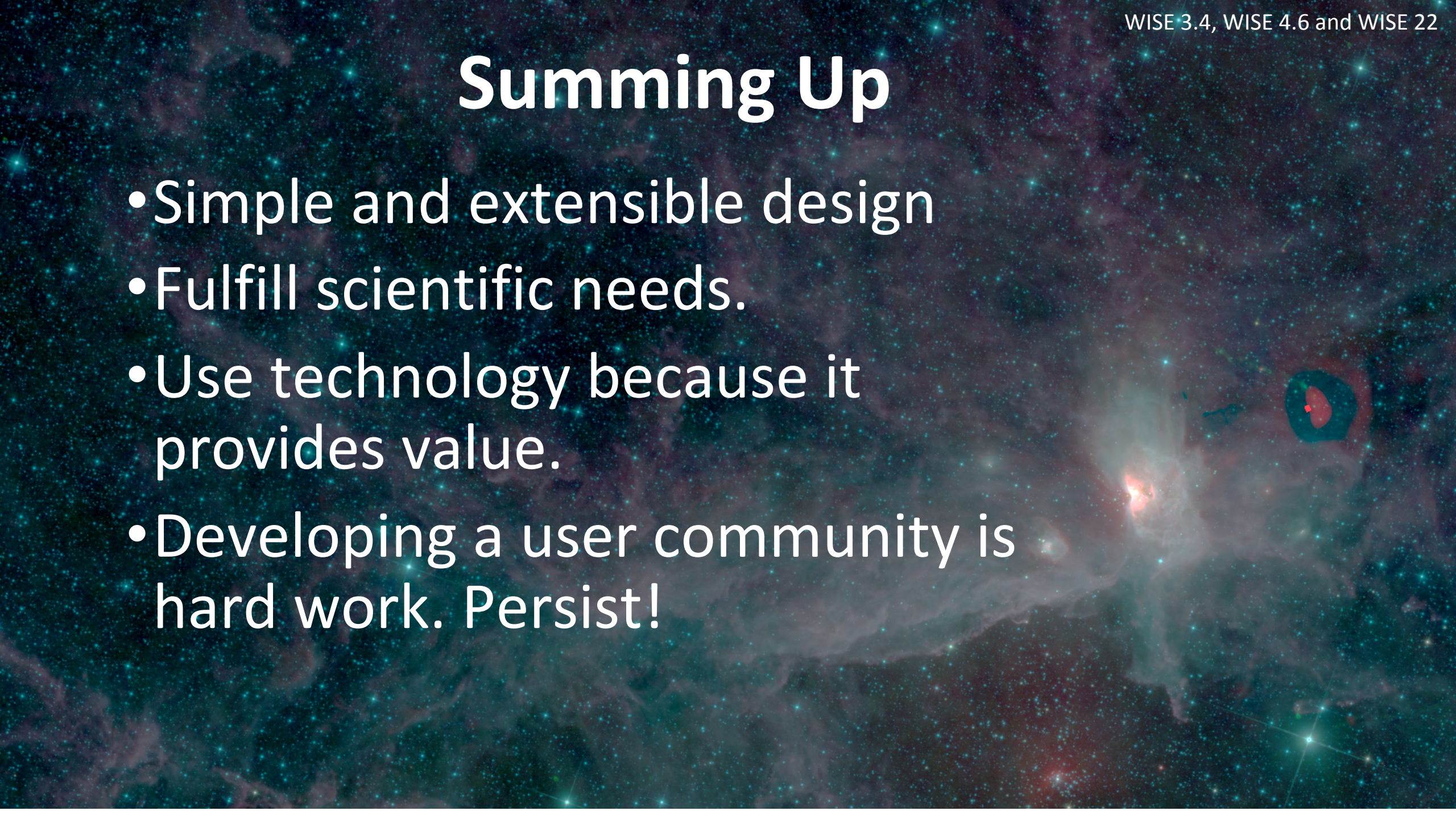
### JSON control

The number of arguments to mViewer is a little large for a standard keyword list so we will be using a JSON rendering of the parameters as the driver. This could be in the form of a file but we will use a JSON string. This will require us to set the 'mode' parameter for mViewer to 1 when we use it below.

Here we create the JSON as a simple string (note the triple quotes which let us make this a multi-line with embedded quotes, *etc.*) Since this is an active notebook, you can modify this as you like to adjust the final image.

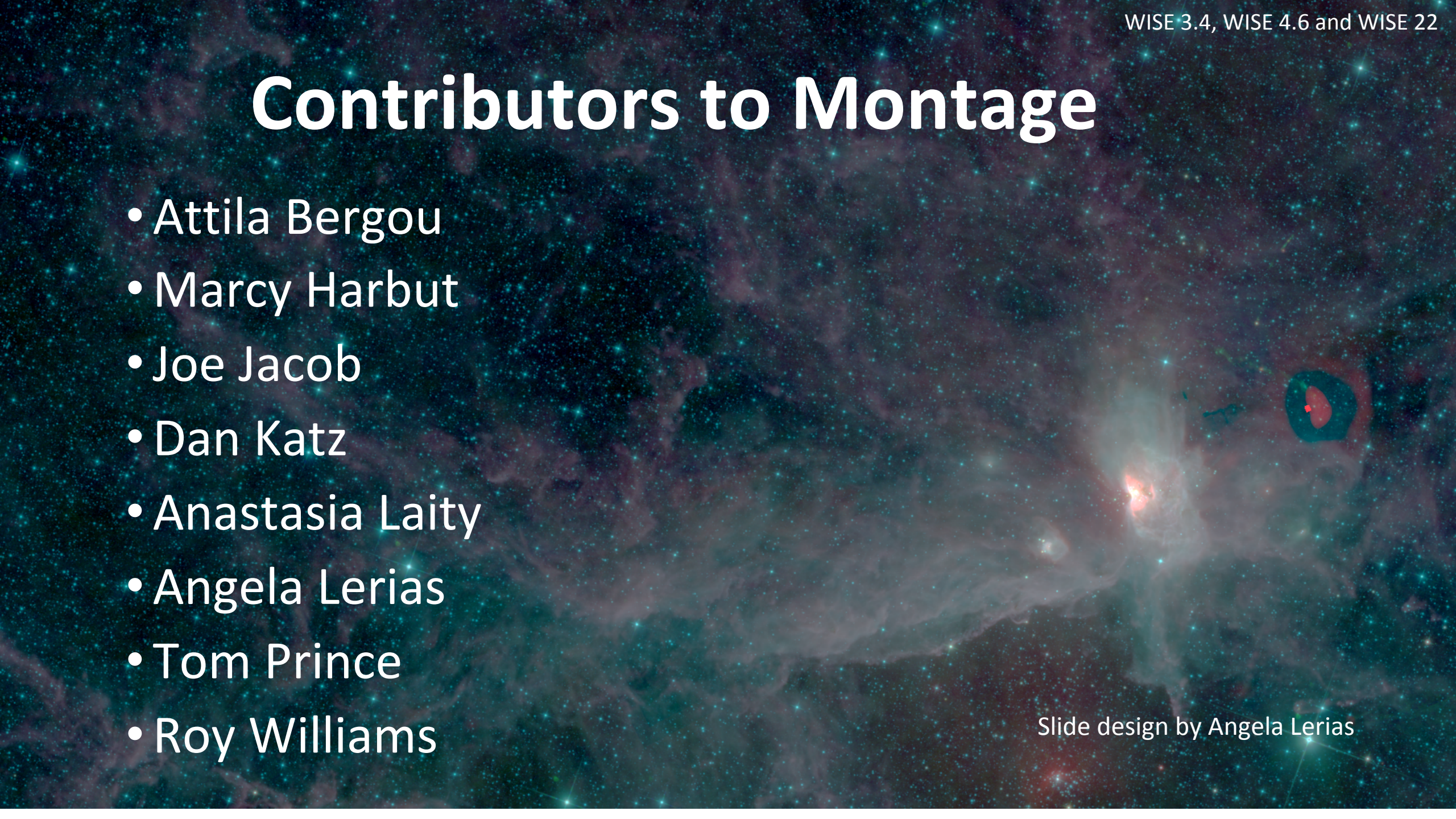
In [23]:
```
imgjson = """
{
   "image_file":"viewer.png",
   "image_type":"png",
   "true_color":1.50,
   "font_scale":1.1,

   "blue_file":
   {
      "fits_file":"data/fits/SDSS_u.fits",
      "stretch_min":"-0.1s",
      "stretch_max":"max",
      "stretch_mode":"gaussian-log"
   },
```






# Summing Up

- Simple and extensible design
- Fulfill scientific needs.
- Use technology because it provides value.
- Developing a user community is hard work. Persist!




# Contributors to Montage

- Attila Bergou
- Marcy Harbut
- Joe Jacob
- Dan Katz
- Anastasia Laity
- Angela Lerias
- Tom Prince
- Roy Williams

Slide design by Angela Lerias