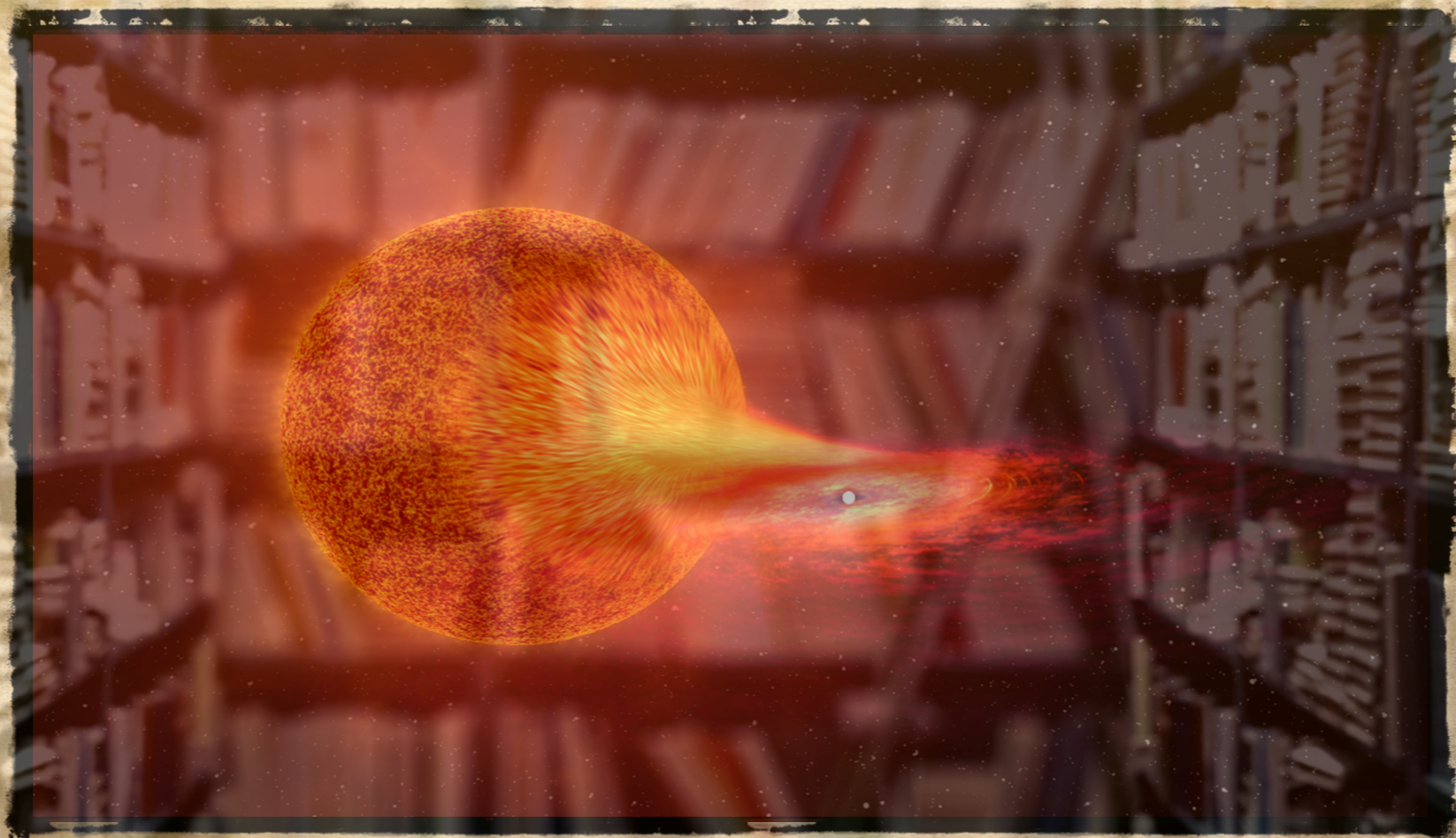


archival data retrieval and analysis in the time domain
(& accreting-only symbiotic binaries)

Adrian B. Lucy, STScI Fellow, Space Telescope Science Institute

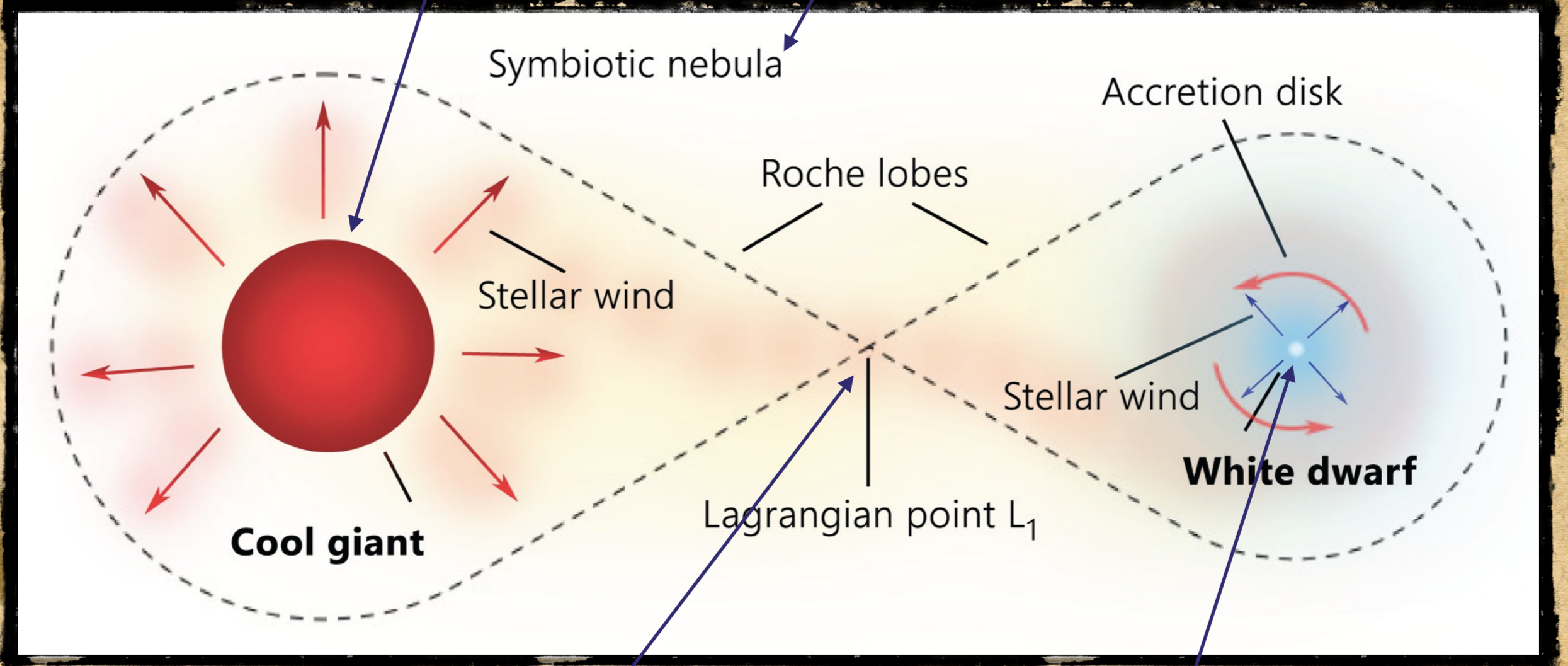


symbiotic binaries

cool evolved G–M (or S/C) I–III
(usually M III)
that has left the main sequence

dense wind of the cool giant,
illuminated by the hot component

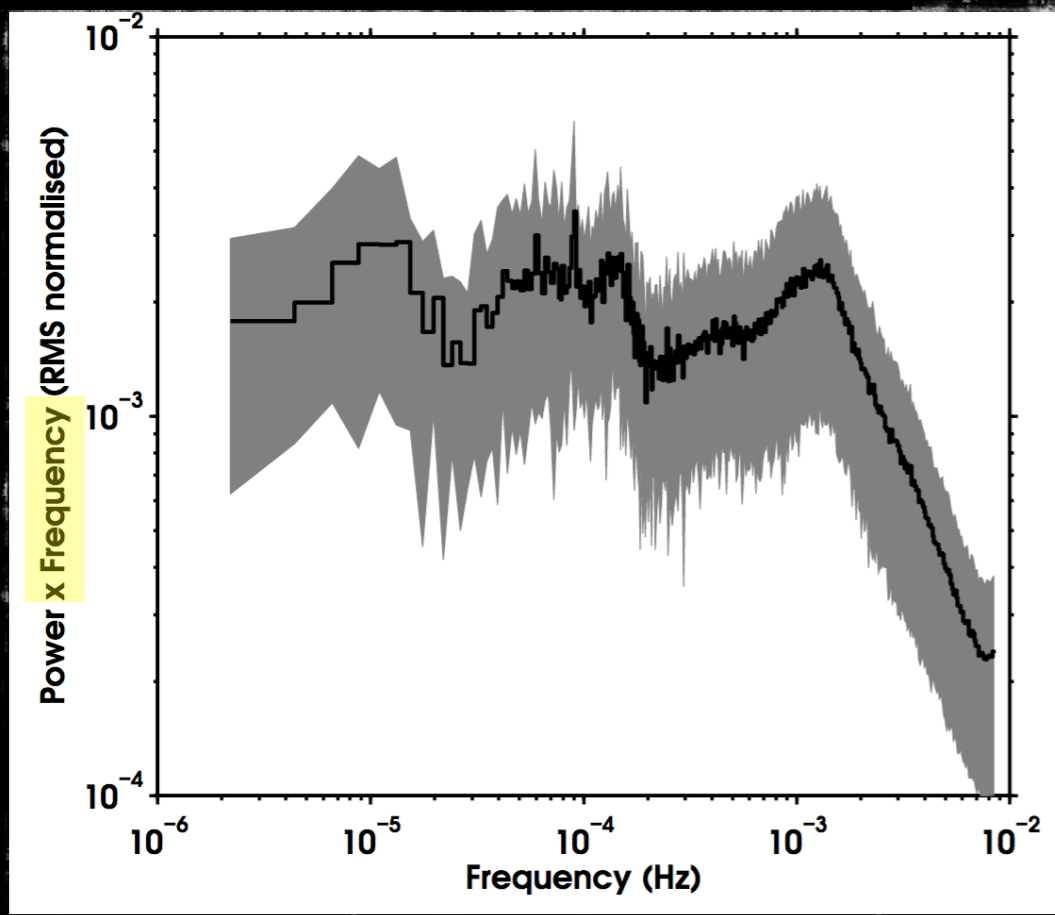
Merc et al. 2019



BHL wind accretion,
Roche lobe overflow,
or a hybrid (Mohamed & Pod. 2007)

accreting white dwarf (often shell burning),
or rarely an accreting neutron star,
or in principle an accreting black hole (e.g., ULXs),
or controversially an accreting main sequence star

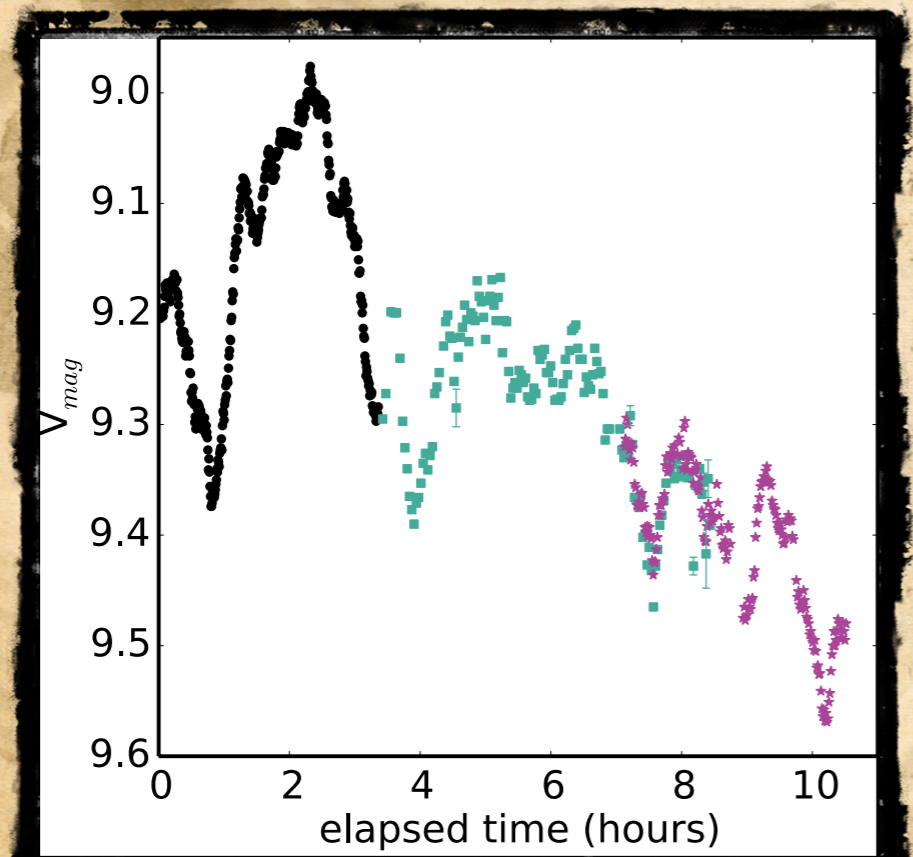
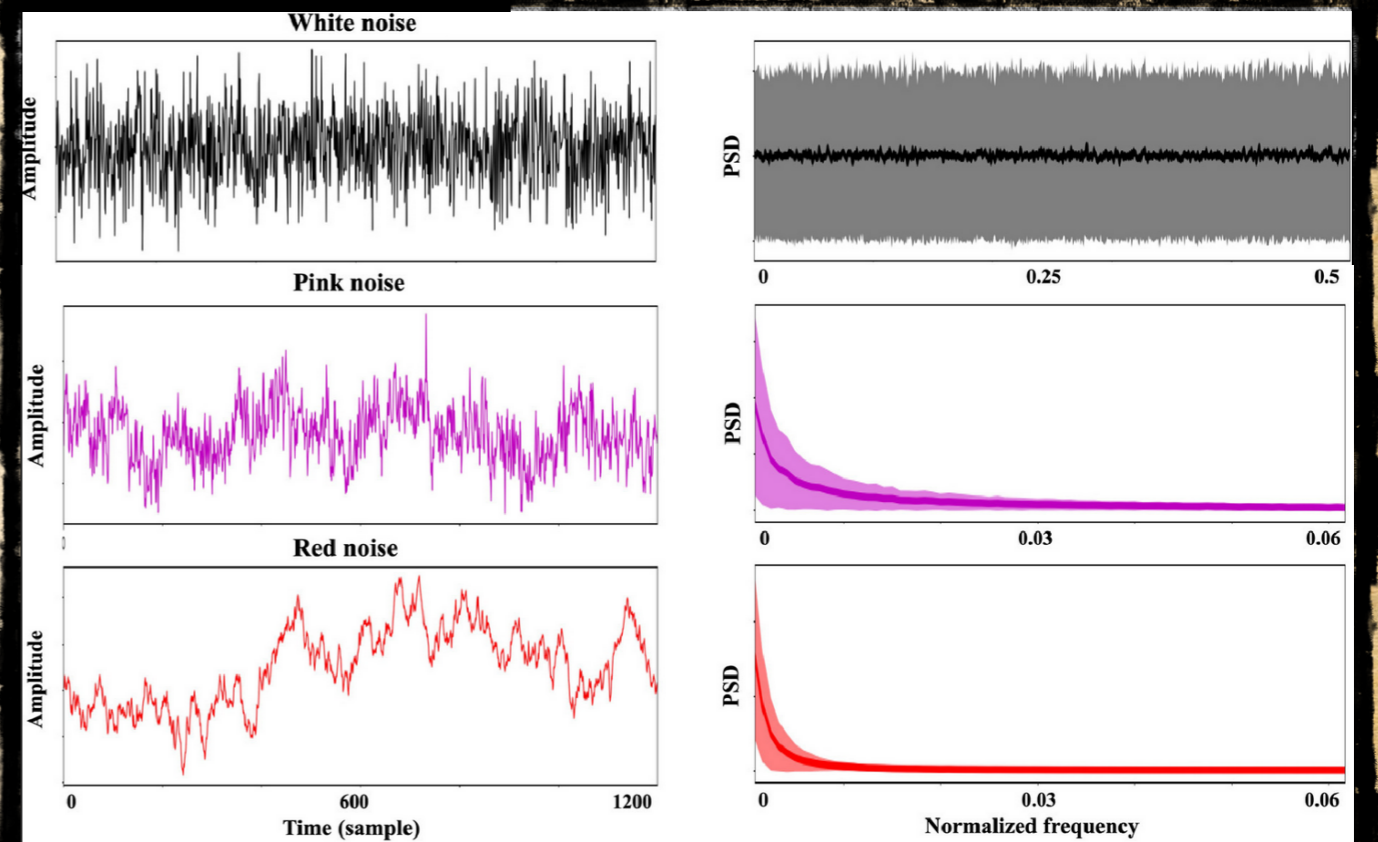
Scaringi et al. 2012 (PSD of a CV, MV Lyr)



Accretion disk flickering

Uttley et al. 2001, 2005; Scaringi et al. 2014, etc.

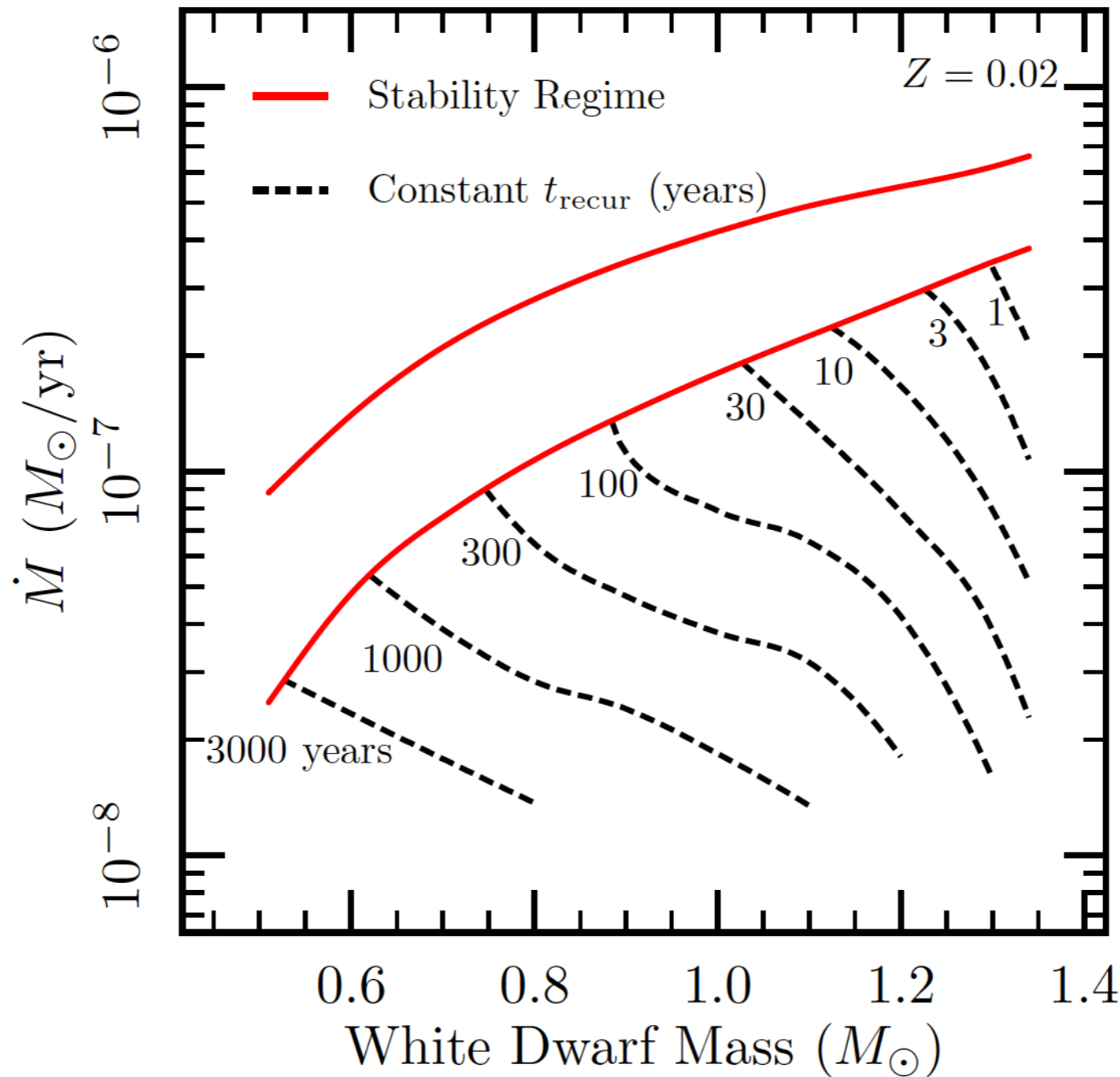
Omidvarnia et al. 2021



- obscuration mechanisms:
1. shell burning is too luminous
 2. cool giant is too luminous
 3. no accretion disk

burning vs. accreting only

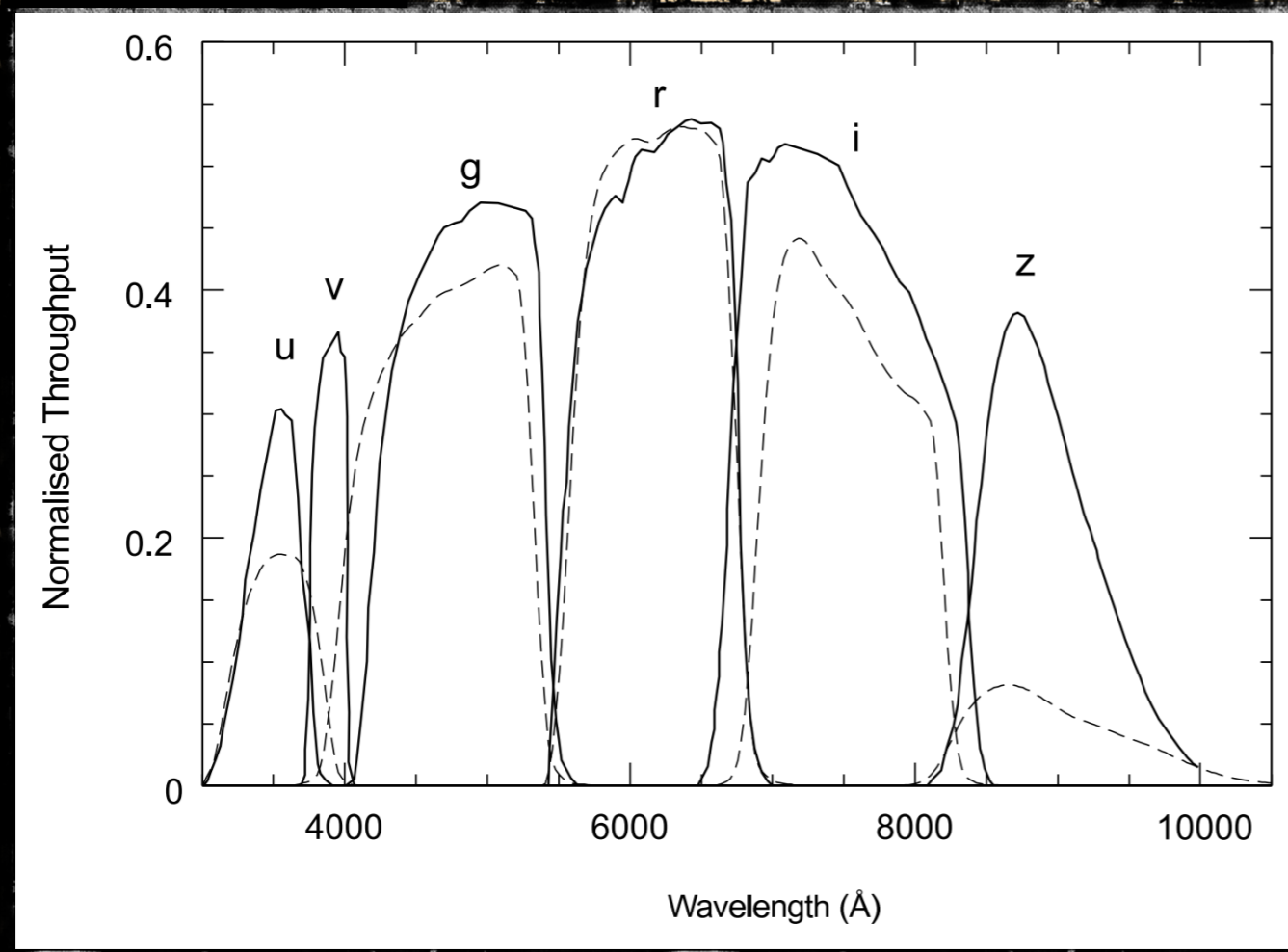
Wolf et al. 2013



accreting-only status before 2021:

only 10 or 11 optical flickerers, up to maybe another 10 UV flickerers, and 23 (overlapping with flickerers, and 9 are neutron star accretors) hard X-ray emitters

Murphy et al. 2009



Mukai et al. 2016

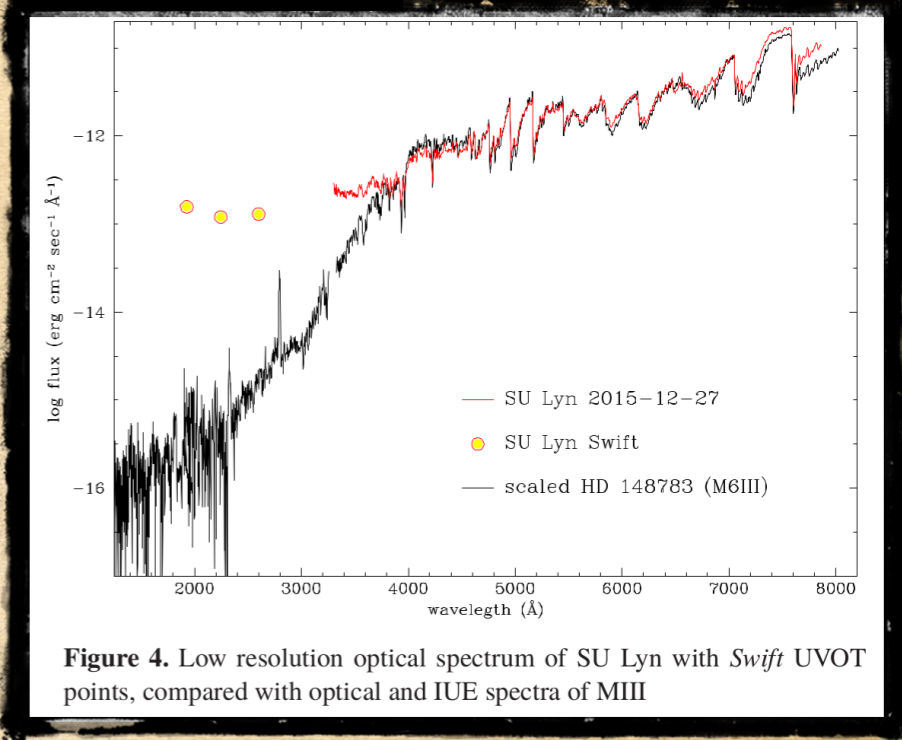
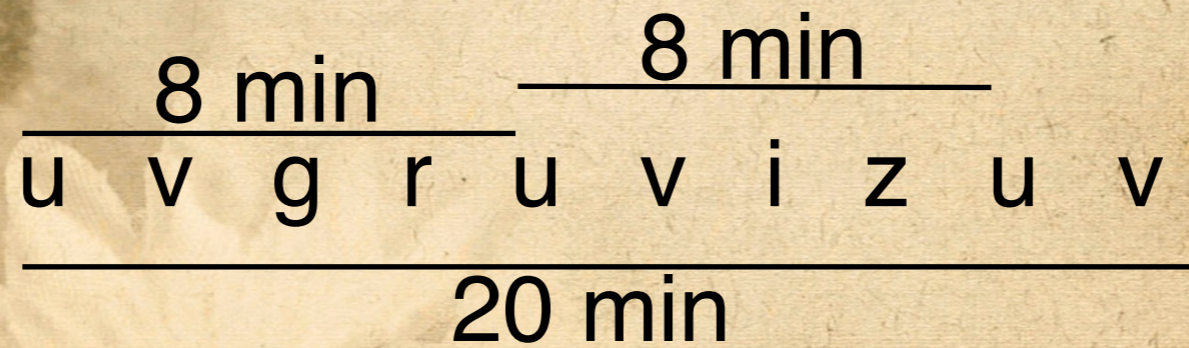


Figure 4. Low resolution optical spectrum of SU Lyn with *Swift* UVOT points, compared with optical and IUE spectra of MIII

The SkyMapper Southern Sky Survey (Main Survey, DR2)



building a sample of luminous red objects

$(J-K_s)_0 > 0.85$

$M_J < 0$

$J < 14.0$

No other SkyMapper source within 6 arcsec

SkyMapper $u_ngood > 0$, $v_ngood > 0$, $g_ngood > 0$

2MASS AAA data quality

Converged Bailer-Jones et al. (2018) distance exists

SkyMapper $class_star > 0.9$, $flags_psf = 0$, $nch_max = 1$

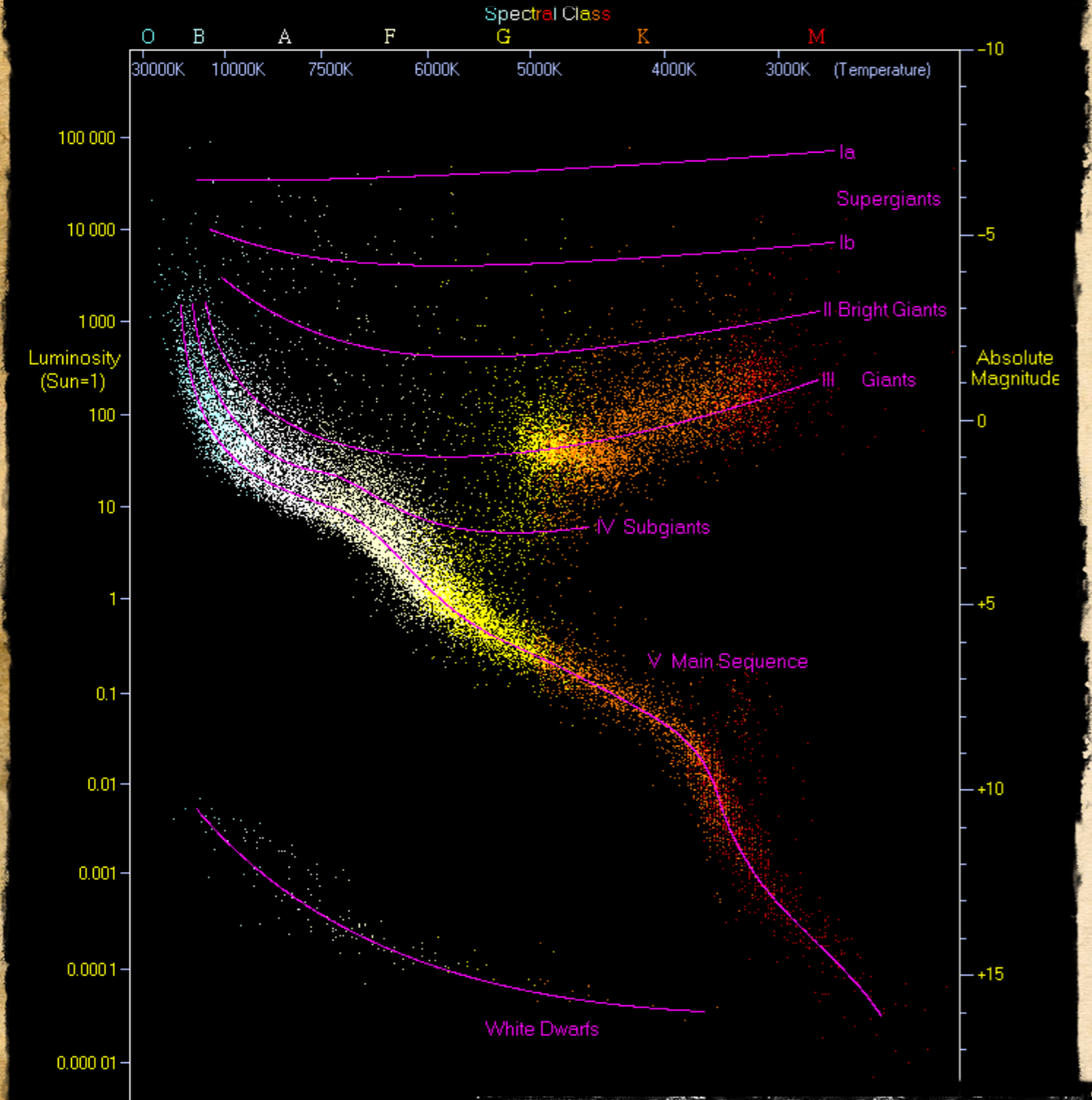
2MASS $gal_contam = 0$, $ext_key = 0$, $cc_flg = '000'$, $ext_key = 0$

2 arcsec crossmatch to 2MASS and Gaia

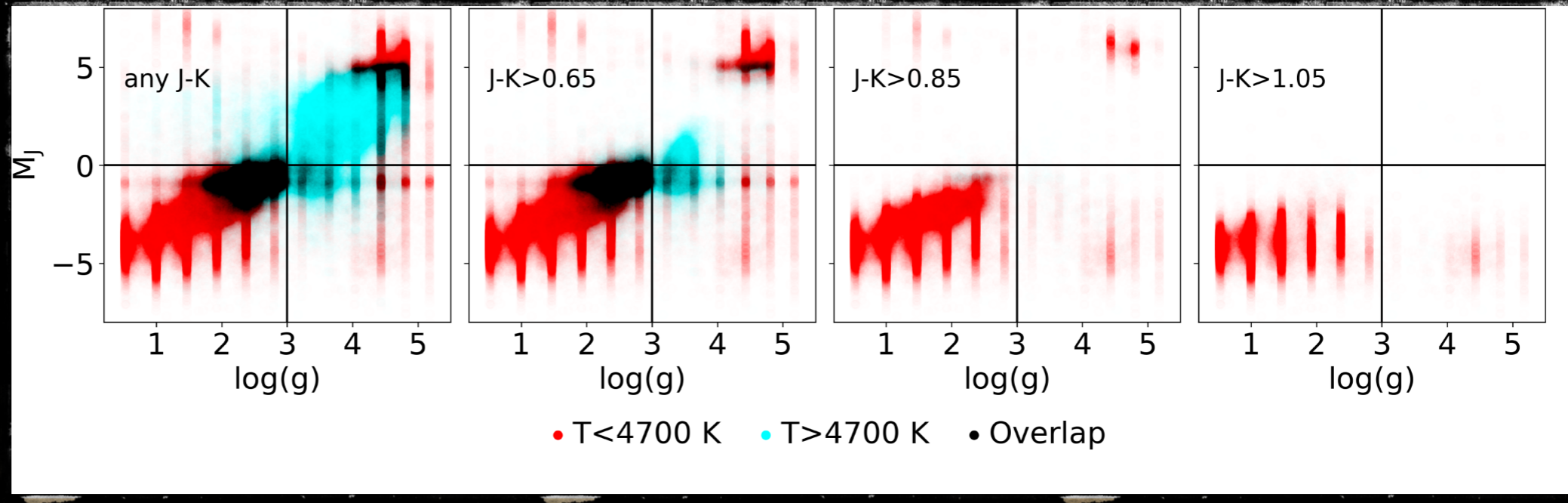
3 arcsec crossmatch to ALLWISE

And sufficient data to reconstruct ≥ 1 nightly color snapshot from individual measurements with SkyMapper $used_in_clip = True$ or $False$, but not null.

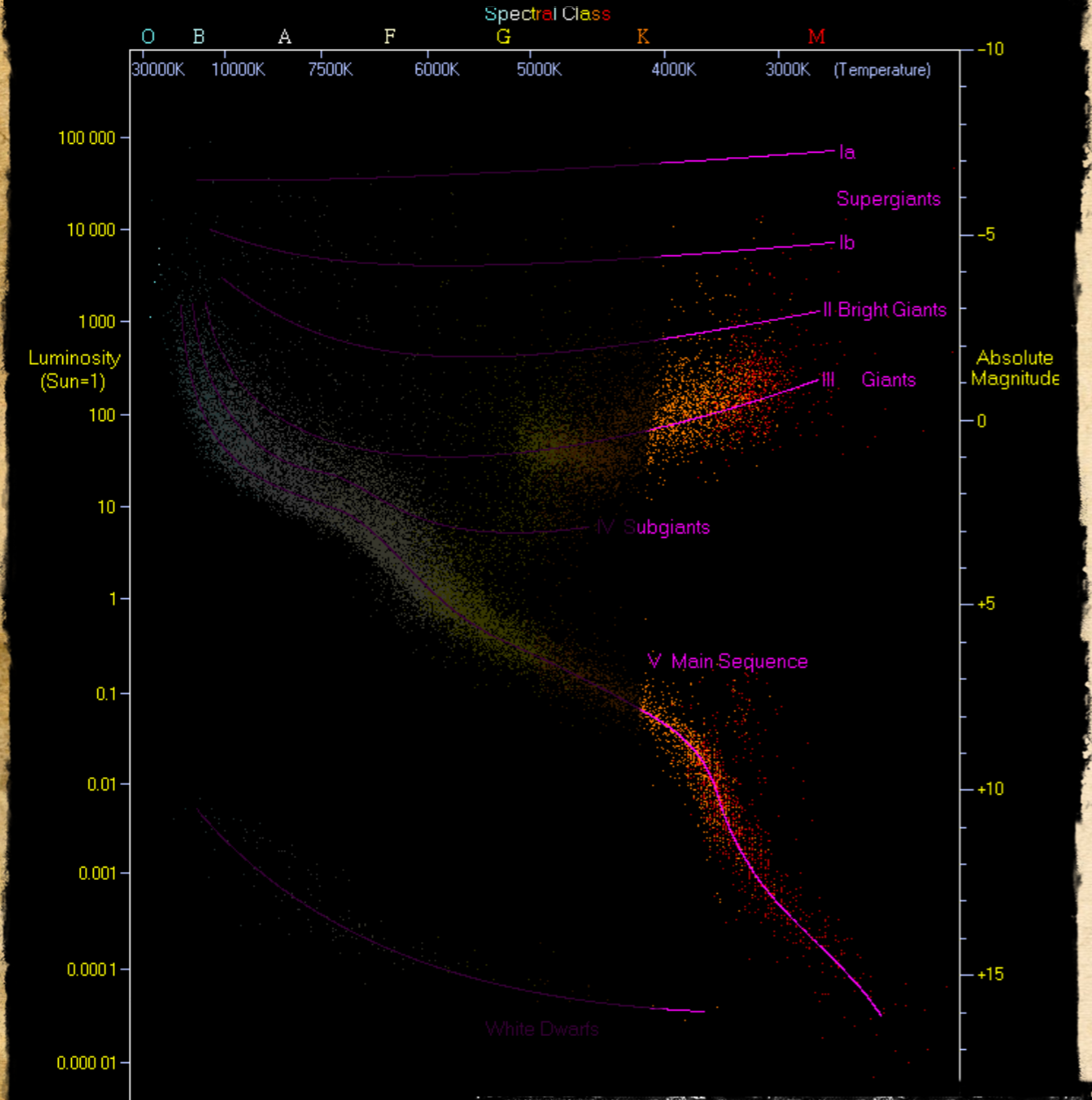
HR diagram by Richard Powell



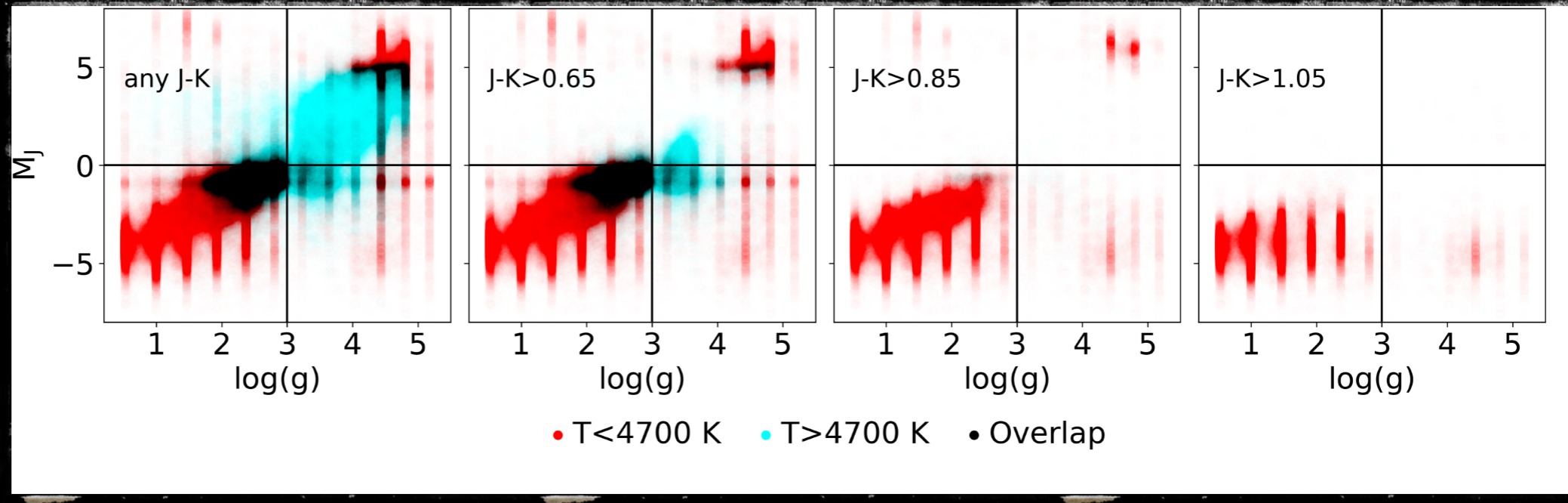
Tested on LAMOST and RAVE



HR diagram by Richard Powell



Tested on LAMOST and RAVE




```

SELECT
  m.object_id, g.source_id, m.raj2000,  m.dej2000, m.glon,
  m.glat, m.u_ngood, m.u_nclip, m.v_ngood, m.g_ngood,
  m.r_ngood, m.i_ngood, m.z_ngood, w.w1mpro, w.w1sigmpro,
  w.w2mpro, w.w2sigmpro, t.j_m, t.j_msigcom, t.h_m,
  t.h_msigcom, t.k_m, t.k_msigcom, m.u_psf, m.e_u_psf, m.v_psf,
  m.e_v_psf, m.g_psf, m.e_g_psf, m.r_psf, m.e_r_psf, m.i_psf,
  m.e_i_psf, m.z_psf, m.e_z_psf, m.prox, t.prox AS tprox,
  m.allwise_dist, g.parallax, g.parallax_error,
  g.astrometric_excess_noise, g.astrometric_excess_noise_sig,
  g.pmra, g.pmra_error, g.pmdec, g.pmdec_error, m.ebmvsfd
FROM
  dr2.master m
JOIN
  ext.twomass_psc t ON m.twomass_key=t.pts_key
JOIN
  ext.gaia_dr2 g ON m.gaia_dr2_id1=g.source_id
JOIN
  ext.allwise w ON m.allwise_cntr=w.cntr
WHERE
  m.twomass_dist < 2.0 /* cross-matching radii (arcsec) */
  AND m.gaia_dr2_dist1 < 2.0
  AND m.allwise_dist < 3.0
  AND m.prox > 6.0
  AND t.ph_qual = 'AAA' /* quality cuts */
  AND t.gal_contam = 0
  AND t.ext_key IS NULL
  AND t.cc_flg = '000'
  AND m.class_star > 0.9
  AND flags_psf = 0
  AND m.u_ngood > 0
  AND m.v_ngood > 0
  AND m.g_ngood > 0
  AND m.nch_max = 1
  AND (t.j_m - t.k_m) > 0.85 /* 2MASS initial color cut */
  AND t.j_m < 14.0 /* Select for high 2MASS SNR */

```

ADQL query in TOPCAT



```

SELECT
  m.object_id, g.source_id, m.raj2000, m.dej2000, m.glon,
  m.glat, m.u_ngood, m.u_nclip, m.v_ngood, m.g_ngood,
  m.r_ngood, m.i_ngood, m.z_ngood, w.wlmprow, w.wlsigmprow,
  w.w2mprow, w.w2sigmprow, t.j_m, t.j_msigcom, t.h_m,
  t.h_msigcom, t.k_m, t.k_msigcom, m.u_psf, m.e_u_psf, m.v_psf,
  m.e_v_psf, m.g_psf, m.e_g_psf, m.r_psf, m.e_r_psf, m.i_psf,
  m.e_i_psf, m.z_psf, m.e_z_psf, m.prox, t.prox AS tprox,
  m.allwise_dist, g.parallax, g.parallax_error,
  g.astrometric_excess_noise, g.astrometric_excess_noise_sig,
  g.pmra, g.pmra_error, g.pmdec, g.pmdec_error, m.ebmvsfd
FROM
  dr2.master m
JOIN
  ext.twomass_psc t ON m.twomass_key=t.pts_key
JOIN
  ext.gaia_dr2 g ON m.gaia_dr2_id1=g.source_id
JOIN
  ext.allwise w ON m.allwise_cntr=w.cntr
WHERE
  m.twomass_dist < 2.0 /* cross-matching radii (arcsec) */
  AND m.gaia_dr2_dist1 < 2.0
  AND m.allwise_dist < 3.0
  AND m.prox > 6.0
  AND t.ph_qual = 'AAA' /* quality cuts */
  AND t.gal_contam = 0
  AND t.ext_key IS NULL
  AND t.cc_flg = '000'
  AND m.class_star > 0.9
  AND flags_psf = 0
  AND m.u_ngood > 0
  AND m.v_ngood > 0
  AND m.g_ngood > 0
  AND m.nch_max = 1
  AND (t.j_m - t.k_m) > 0.85 /* 2MASS initial color cut */
  AND t.j_m < 14.0 /* Select for high 2MASS SNR */

```

Pre-matched (but no pre-match
for Bailer-Jones Bayesian
distances)

```

SELECT
  m.object_id, g.source_id, m.raj2000, m.dej2000, m.glon,
  m.glat, m.u_ngood, m.u_nclip, m.v_ngood, m.g_ngood,
  m.r_ngood, m.i_ngood, m.z_ngood, w.w1mpro, w.w1sigmpro,
  w.w2mpro, w.w2sigmpro, t.j_m, t.j_msigcom, t.h_m,
  t.h_msigcom, t.k_m, t.k_msigcom, m.u_psf, m.e_u_psf, m.v_psf,
  m.e_v_psf, m.g_psf, m.e_g_psf, m.r_psf, m.e_r_psf, m.i_psf,
  m.e_i_psf, m.z_psf, m.e_z_psf, m.prox, t.prox AS tprox,
  m.allwise_dist, g.parallax, g.parallax_error,
  g.astrometric_excess_noise, g.astrometric_excess_noise_sig,
  g.pmra, g.pmra_error, g.pmdec, g.pmdec_error, m.ebmvsfd
FROM
  dr2.master m
JOIN
  ext.twomass_psc t ON m.twomass_key=t.pts_key
JOIN
  ext.gaia_dr2 g ON m.gaia_dr2_id1=g.source_id
JOIN
  ext.allwise w ON m.allwise_cntr=w.cntr
WHERE
  m.twomass_dist < 2.0 /* cross-matching radii (arcsec) */
  AND m.gaia_dr2_dist1 < 2.0
  AND m.allwise_dist < 3.0
  AND m.prox > 6.0
  AND t.ph_qual = 'AAA' /* quality cuts */
  AND t.gal_contam = 0
  AND t.ext_key IS NULL
  AND t.cc_flg = '000'
  AND m.class_star > 0.9
  AND flags_psf = 0
  AND m.u_ngood > 0
  AND m.v_ngood > 0
  AND m.g_ngood > 0
  AND m.nch_max = 1
  AND (t.j_m - t.k_m) > 0.85 /* 2MASS initial color cut */
  AND t.j_m < 14.0 /* Select for high 2MASS SNR */

```

from survey documentation:
chose larger of the two

```

SELECT
  m.object_id, g.source_id, m.raj2000,  m.dej2000, m.glon,
  m.glat, m.u_ngood, m.u_nclip, m.v_ngood, m.g_ngood,
  m.r_ngood, m.i_ngood, m.z_ngood, w.w1mpro, w.w1sigmpro,
  w.w2mpro, w.w2sigmpro, t.j_m, t.j_msigcom, t.h_m,
  t.h_msigcom, t.k_m, t.k_msigcom, m.u_psf, m.e_u_psf, m.v_psf,
  m.e_v_psf, m.g_psf, m.e_g_psf, m.r_psf, m.e_r_psf, m.i_psf,
  m.e_i_psf, m.z_psf, m.e_z_psf, m.prox, t.prox AS tprox,
  m.allwise_dist, g.parallax, g.parallax_error,
  g.astrometric_excess_noise, g.astrometric_excess_noise_sig,
  g.pmra, g.pmra_error, g.pmdec, g.pmdec_error, m.ebmvsfd
FROM
  dr2.master m
JOIN
  ext.twomass_psc t ON m.twomass_key=t.pts_key
JOIN
  ext.gaia_dr2 g ON m.gaia_dr2_id1=g.source_id
JOIN
  ext.allwise w ON m.allwise_cntr=w.cntr
WHERE
  m.twomass_dist < 2.0 /* cross-matching radii (arcsec) */
  AND m.gaia_dr2_dist1 < 2.0
  AND m.allwise_dist < 3.0
  AND m.prox > 6.0
  AND t.ph_qual = 'AAA' /* quality cuts */
  AND t.gal_contam = 0
  AND t.ext_key IS NULL
  AND t.cc_flg = '000'
  AND m.class_star > 0.9
  AND flags_psf = 0
  AND m.u_ngood > 0
  AND m.v_ngood > 0
  AND m.g_ngood > 0
  AND m.nch_max = 1
  AND (t.j_m - t.k_m) > 0.85 /* 2MASS initial color cut */
  AND t.j_m < 14.0 /* Select for high 2MASS SNR */

```

tested first on symbiotics w/
with extended nebulae/jets,
hence no 2mass prox
constraint

```

SELECT
  m.object_id, g.source_id, m.raj2000, m.dej2000, m.glon,
  m.glat, m.u_ngood, m.u_nclip, m.v_ngood, m.g_ngood,
  m.r_ngood, m.i_ngood, m.z_ngood, w.w1mpro, w.w1sigmpro,
  w.w2mpro, w.w2sigmpro, t.j_m, t.j_msigcom, t.h_m,
  t.h_msigcom, t.k_m, t.k_msigcom, m.u_psf, m.e_u_psf, m.v_psf,
  m.e_v_psf, m.g_psf, m.e_g_psf, m.r_psf, m.e_r_psf, m.i_psf,
  m.e_i_psf, m.z_psf, m.e_z_psf, m.prox, t.prox AS tprox,
  m.allwise_dist, g.parallax, g.parallax_error,
  g.astrometric_excess_noise, g.astrometric_excess_noise_sig,
  g.pmra, g.pmra_error, g.pmdec, g.pmdec_error, m.ebmvsfd
FROM
  dr2.master m
JOIN
  ext.twomass_psc t ON m.twomass_key=t.pts_key
JOIN
  ext.gaia_dr2 g ON m.gaia_dr2_id1=g.source_id
JOIN
  ext.allwise w ON m.allwise_cntr=w.cntr
WHERE
  m.twomass_dist < 2.0 /* cross-matching radii (arcsec) */
  AND m.gaia_dr2_dist1 < 2.0
  AND m.allwise_dist < 3.0
  AND m.prox > 6.0
  AND t.ph_qual = 'AAA' /* quality cuts */
  AND t.gal_contam = 0
  AND t.ext_key IS NULL
  AND t.cc_flg = '000'
  AND m.class_star > 0.9
  AND flags_psf = 0
  AND m.u_ngood > 0
  AND m.v_ngood > 0
  AND m.g_ngood > 0
  AND m.nch_max = 1
  AND (t.j_m - t.k_m) > 0.85 /* 2MASS initial color cut */
  AND t.j_m < 14.0 /* Select for high 2MASS SNR */

```

Asynchronous!

```

SELECT
  m.object_id, g.source_id, m.raj2000, m.dej2000, m.glon,
  m.glat, m.u_ngood, m.u_nclip, m.v_ngood, m.g_ngood,
  m.r_ngood, m.i_ngood, m.z_ngood, w.wlmprow, w.wlsigmpro,
  w.w2mprow, w.w2sigmprow, t.j_m, t.j_msigcom, t.h_m,
  t.h_msigcom, t.k_m, t.k_msigcom, m.u_psf, m.e_u_psf, m.v_psf,
  m.e_v_psf, m.g_psf, m.e_g_psf, m.r_psf, m.e_r_psf, m.i_psf,
  m.e_i_psf, m.z_psf, m.e_z_psf, m.prox, t.prox AS tprox,
  m.allwise_dist, g.parallax, g.parallax_error,
  g.astrometric_excess_noise, g.astrometric_excess_noise_sig,
  g.pmra, g.pmra_error, g.pmdec, g.pmdec_error, m.ebmvsfd
FROM
  dr2.master m
JOIN
  ext.twomass_psc t ON m.twomass_key=t.pts_key
JOIN
  ext.gaia_dr2 g ON m.gaia_dr2_id1=g.source_id
JOIN
  ext.allwise w ON m.allwise_cntr=w.cntr
WHERE
  m.twomass_dist < 2.0 /* cross-matching radii (arcsec) */
  AND m.gaia_dr2_dist1 < 2.0
  AND m.allwise_dist < 3.0
  AND m.prox > 6.0
  AND t.ph_qual = 'AAA' /* quality cuts */
  AND t.gal_contam = 0
  AND t.ext_key IS NULL
  AND t.cc_flg = '000'
  AND m.class_star > 0.9
  AND flags_psf = 0
  AND m.u_ngood > 0
  AND m.v_ngood > 0
  AND m.g_ngood > 0
  AND m.nch_max = 1
  AND (t.j_m - t.k_m) > 0.85 /* 2MASS initial color cut */
  AND t.j_m < 14.0 /* Select for high 2MASS SNR */

```

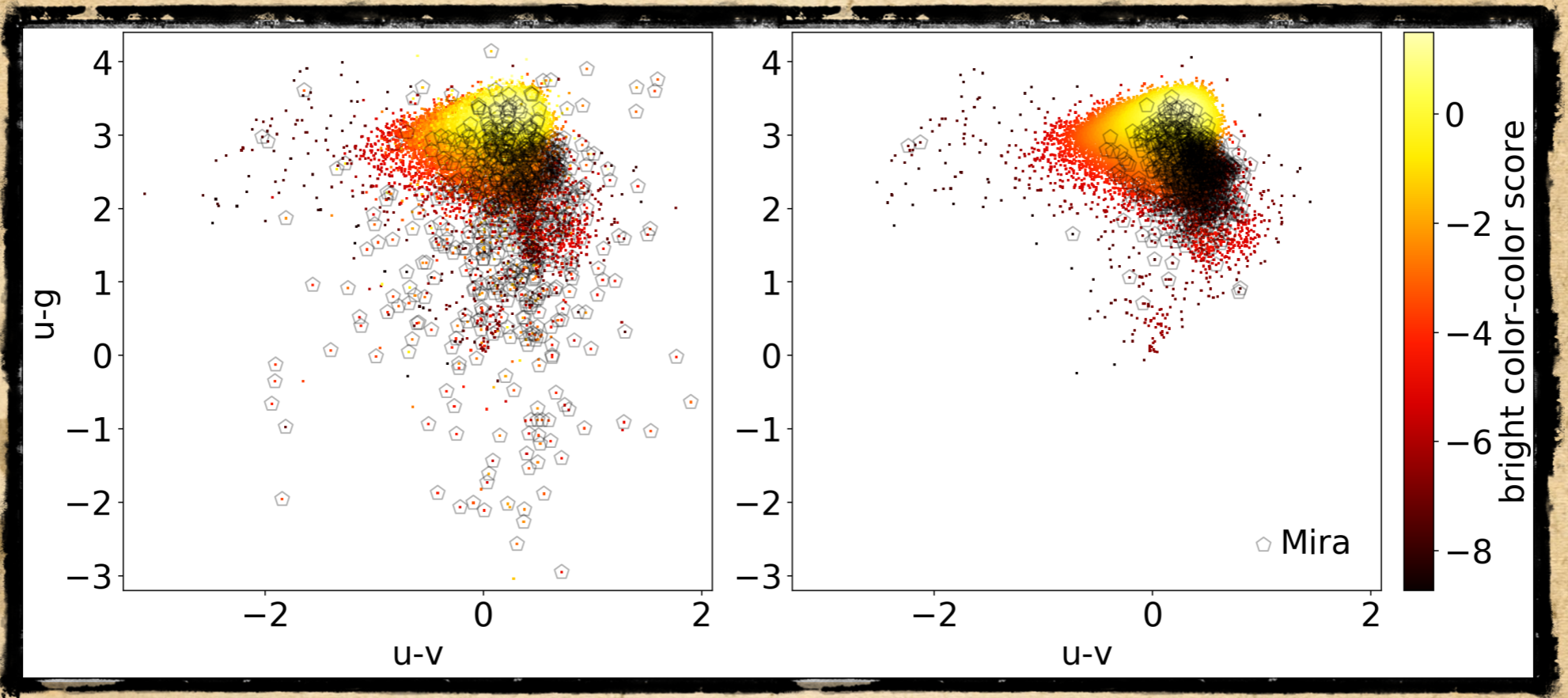
No distance cut here

*TAP query: from [Bailer-Jones et al. 2018 catalog of Bayesian distances] join [local table] on [Gaia source ID from SkyMapper pre-match]

*with ARI-Gaia TAP endpoint, because it accepted table uploads up to 1 million rows (now 10 million)

*Sped up by retrieving only indexed columns
*otherwise it timed out!

*only 13 out of 71 known symbiotics with *uv* photometry were cut by the cuts described up until now



- *need to get variability and recalculate colors from full photometry table of individual measurements
- *don't want to retrieve individual measurements for millions of M dwarfs, so need to incorporate distances into selection
- *SkyMapper didn't have Bailer-Jones distances in the schema
- *SkyMapper TAP endpoint doesn't accept table uploads
- *so, need a workaround...

*multiple cone search (Multicone) in TOPCAT, crossmatching our sample to the SkyMapper dr2.photometry TAP cone-search endpoint with a right outer join

*separated into pieces to avoid timing out the multicone query

*downloaded full dr2.image table (needed date of observation)

*joined our full table of measurements (millions of rows) to the image table, locally in TOPCAT

*+quality control cuts

*then computed, for each object, a weighted average of nightly u-v and u-g colors in pandas

Multiple Cone Search Parameters

Cone Search URL:

Input Table:

RA column: (J2000)

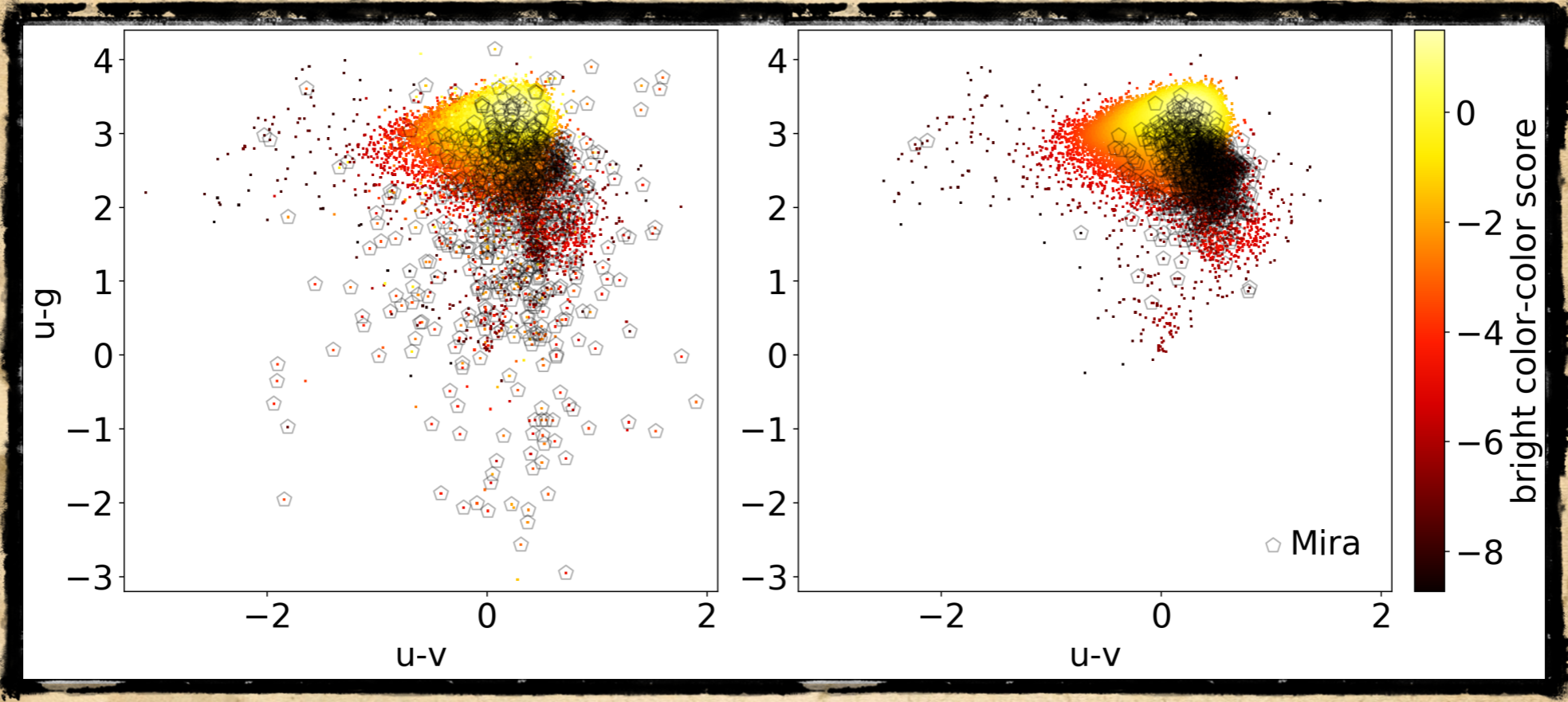
Dec column: (J2000)

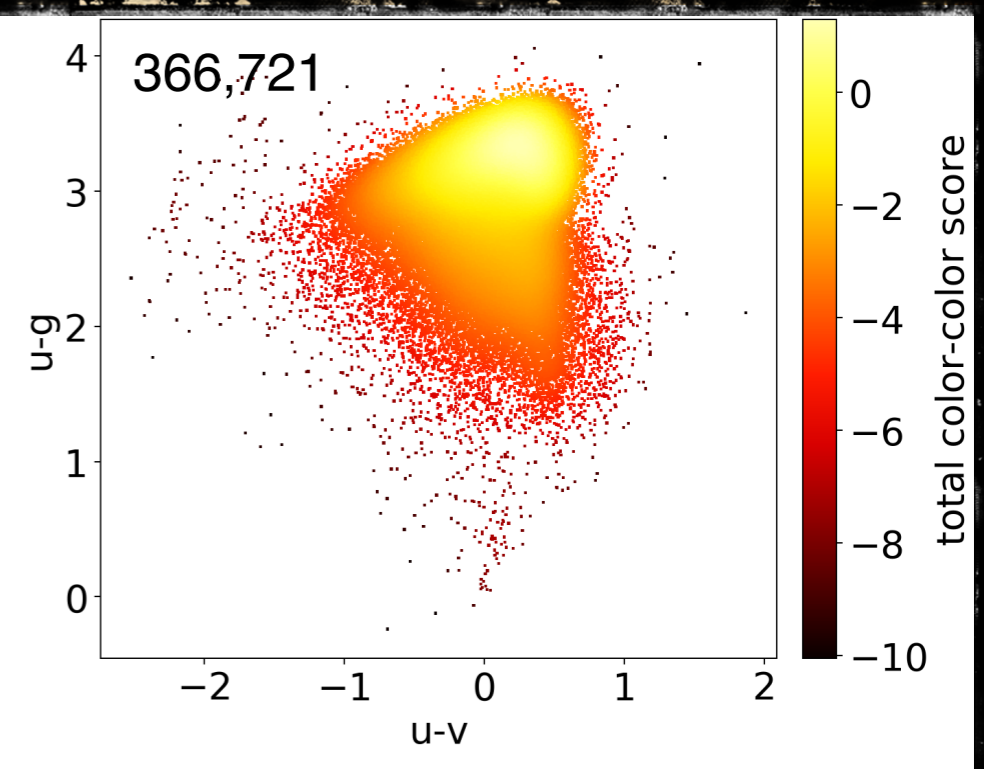
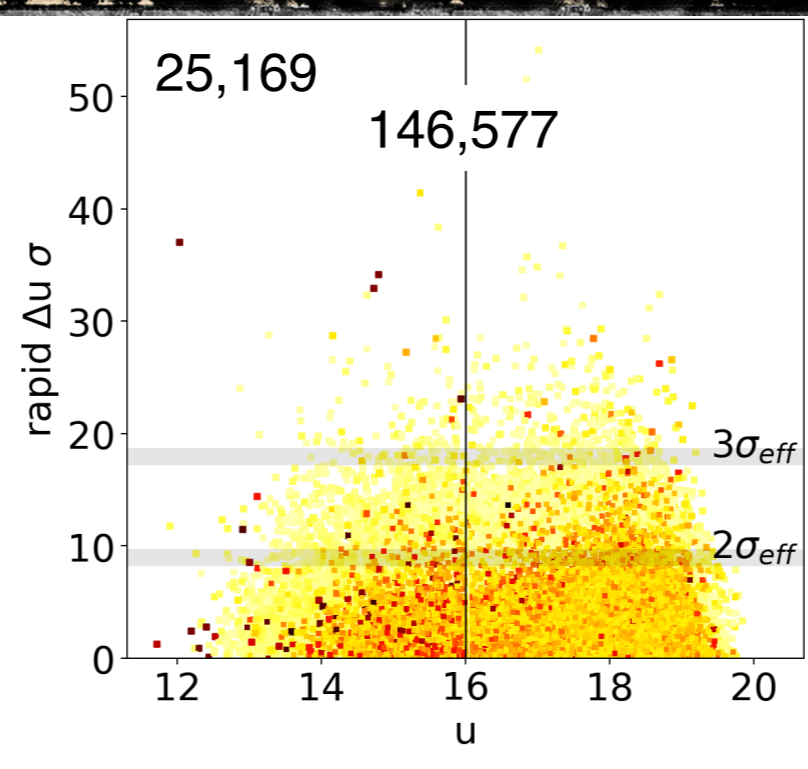
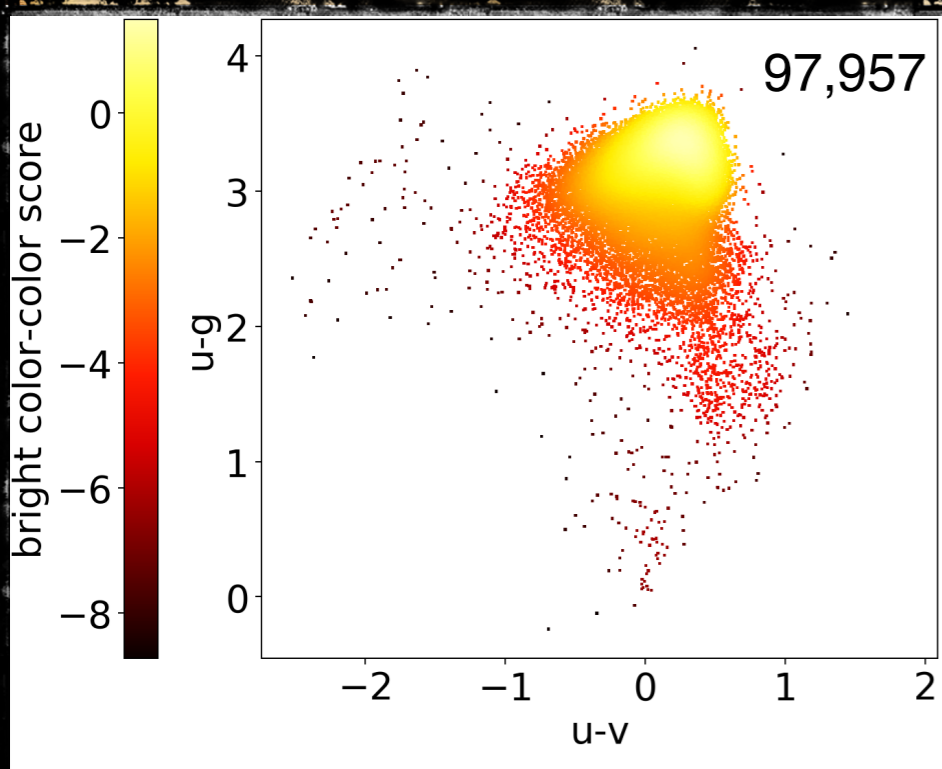
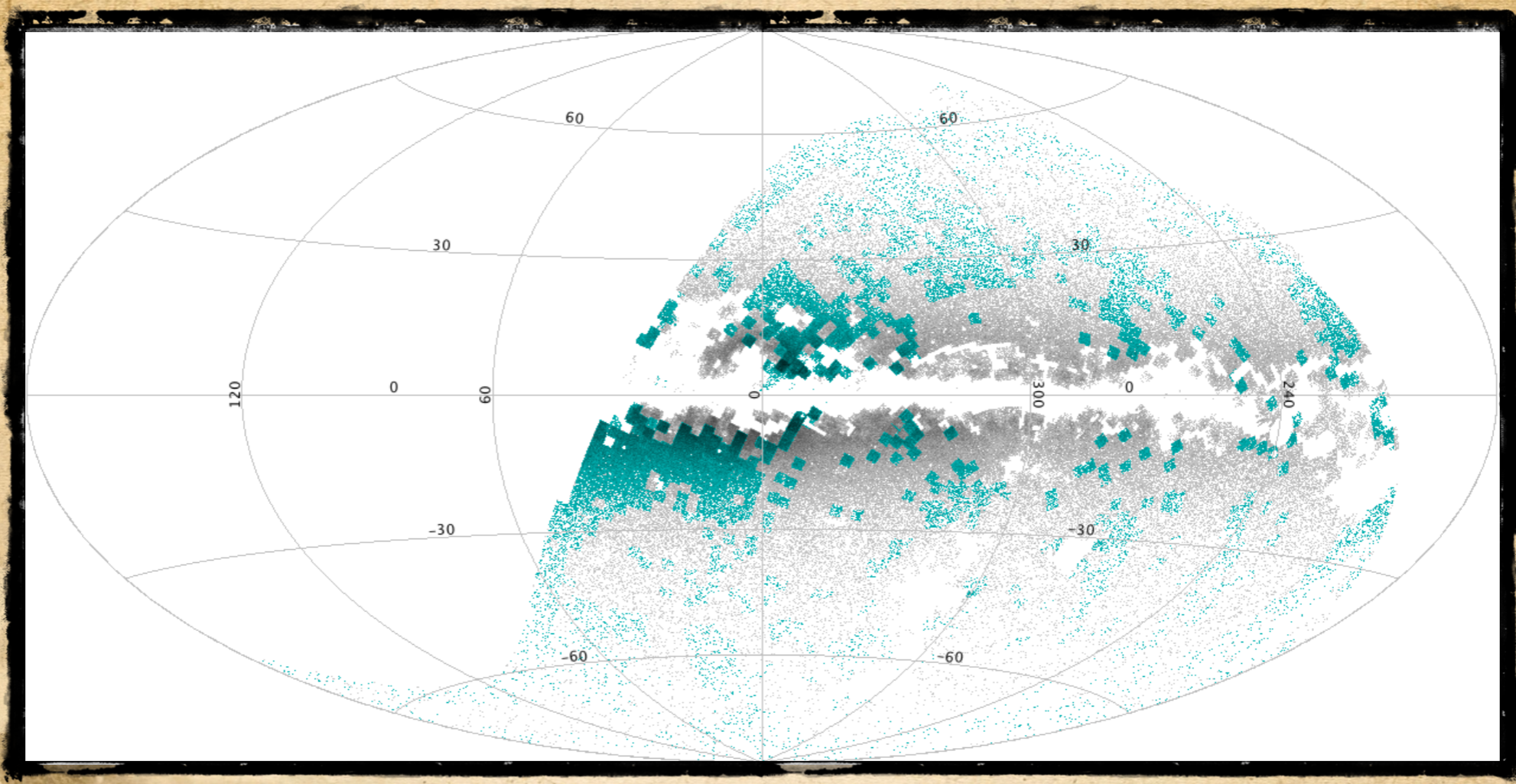
Search Radius column:

Verbosity:

Output Mode: New joined table with all matches

Parallelism: Add subset for matched rows



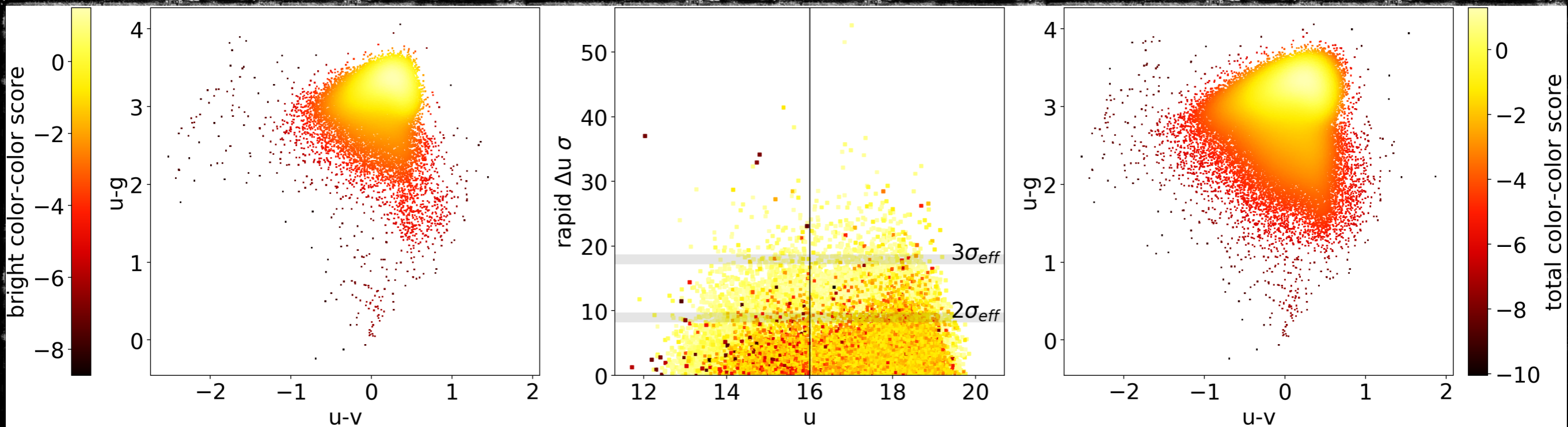


rapid Δu σ of an object is the maximum of

$$\frac{|u_i - u_j|}{\sqrt{(e_mag_psf)_i^2 + (e_mag_psf)_j^2}}$$

for i, j in exposures $[u_1, u_2, u_3]$ of a single Main Survey $u_1 v g r u_2 v i z u_3 v$

— — \rightarrow effective σ at 99.7%, 95.5%



CDS Upload X-Match

Remote Table

VizieR Table ID/Alias:

Name:

Alias:

Description:

Row Count:

Coverage:

Local Table

Input Table:

RA column:

Dec column:

Match Parameters

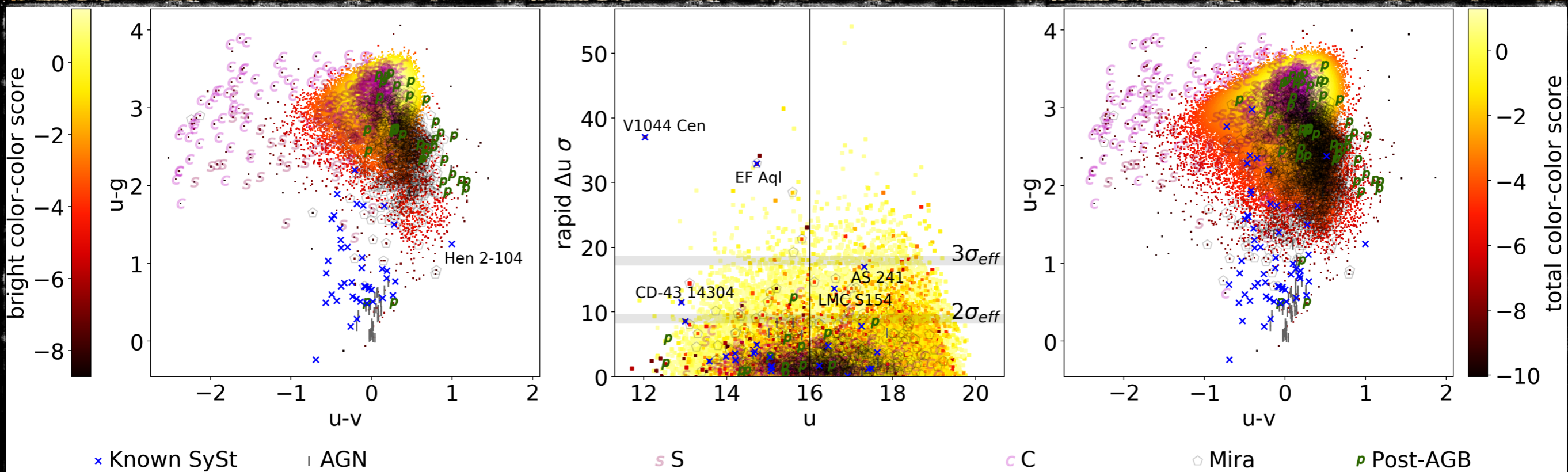
Radius:

Find mode:

Rename columns:

Block size:

SIMBAD crossmatch



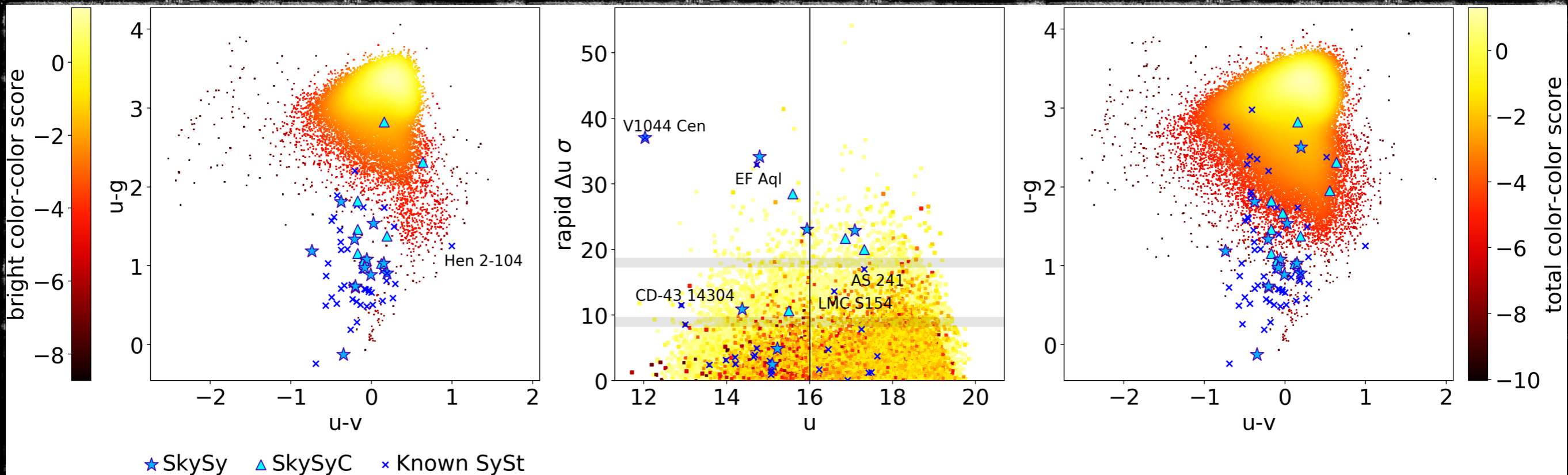
12 confirmed symbiotics (SkyMapper Symbiotics = SkySy) + 10 candidates (SkyMapper Symbiotic Candidates = SkySyC)

SkySyC criteria:

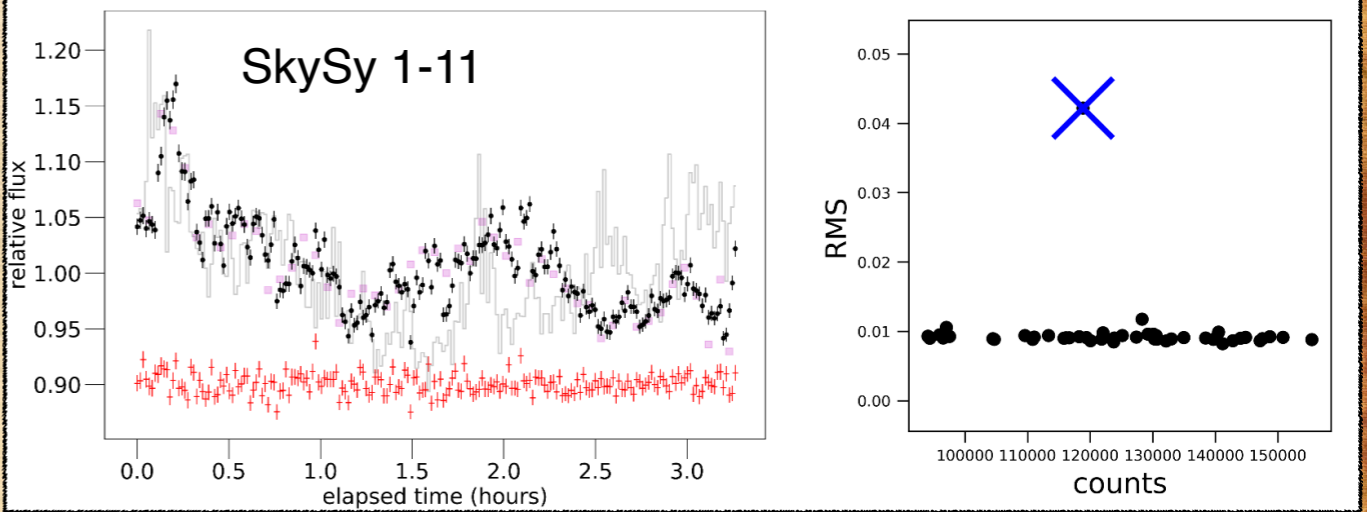
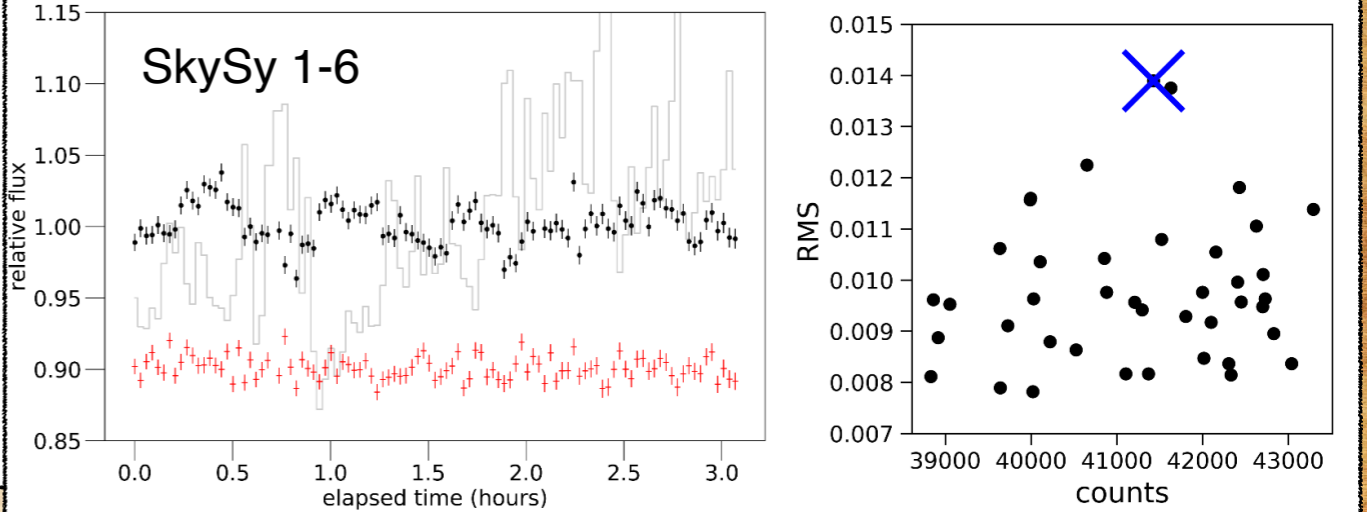
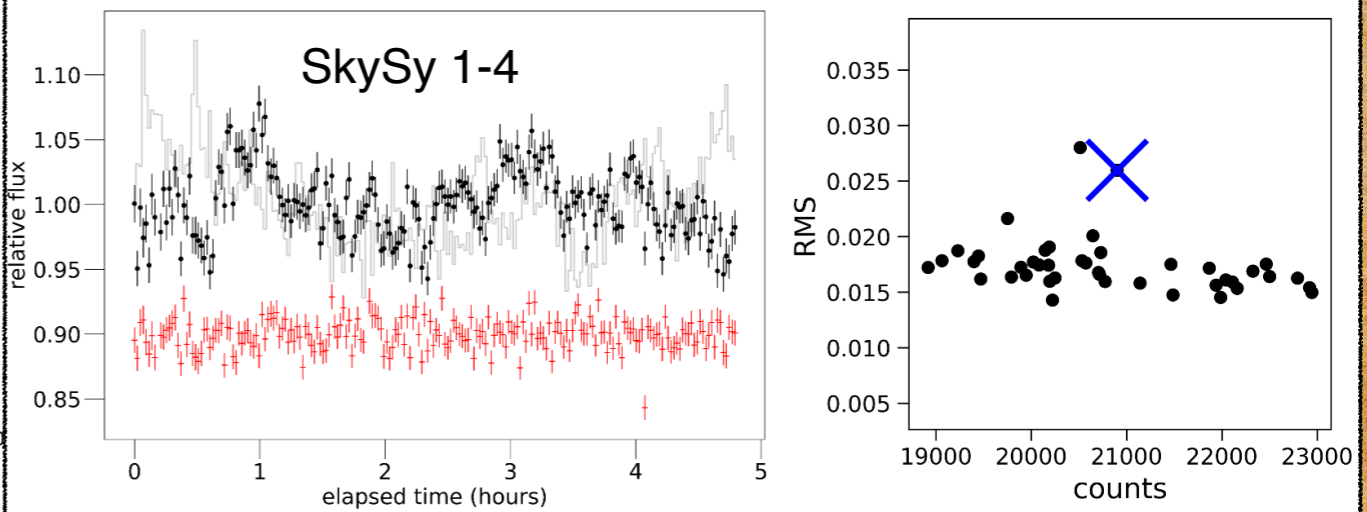
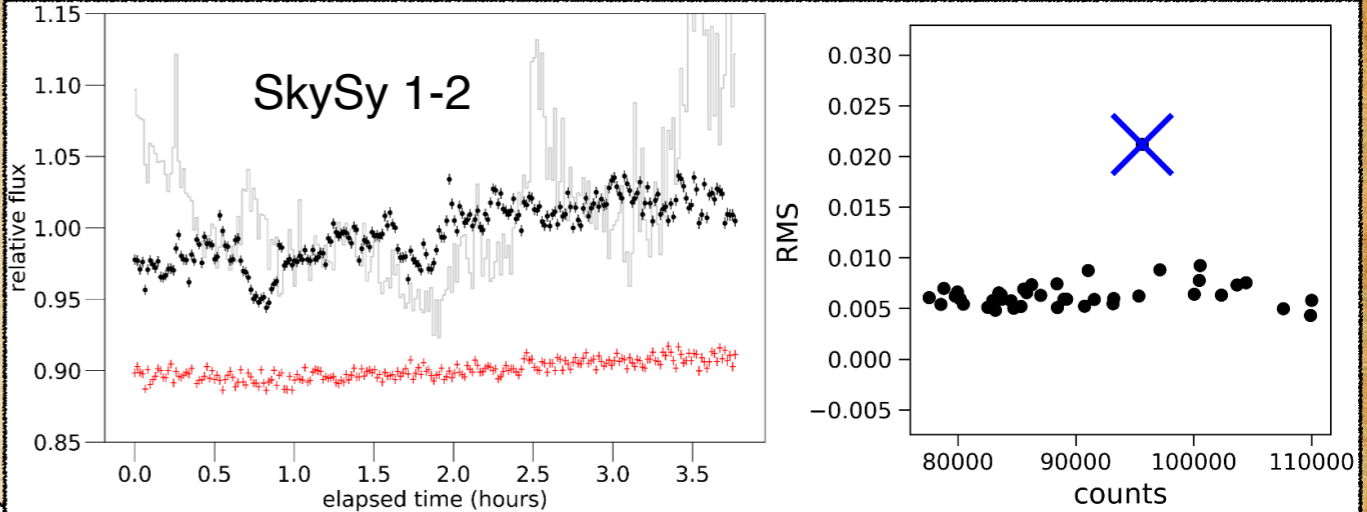
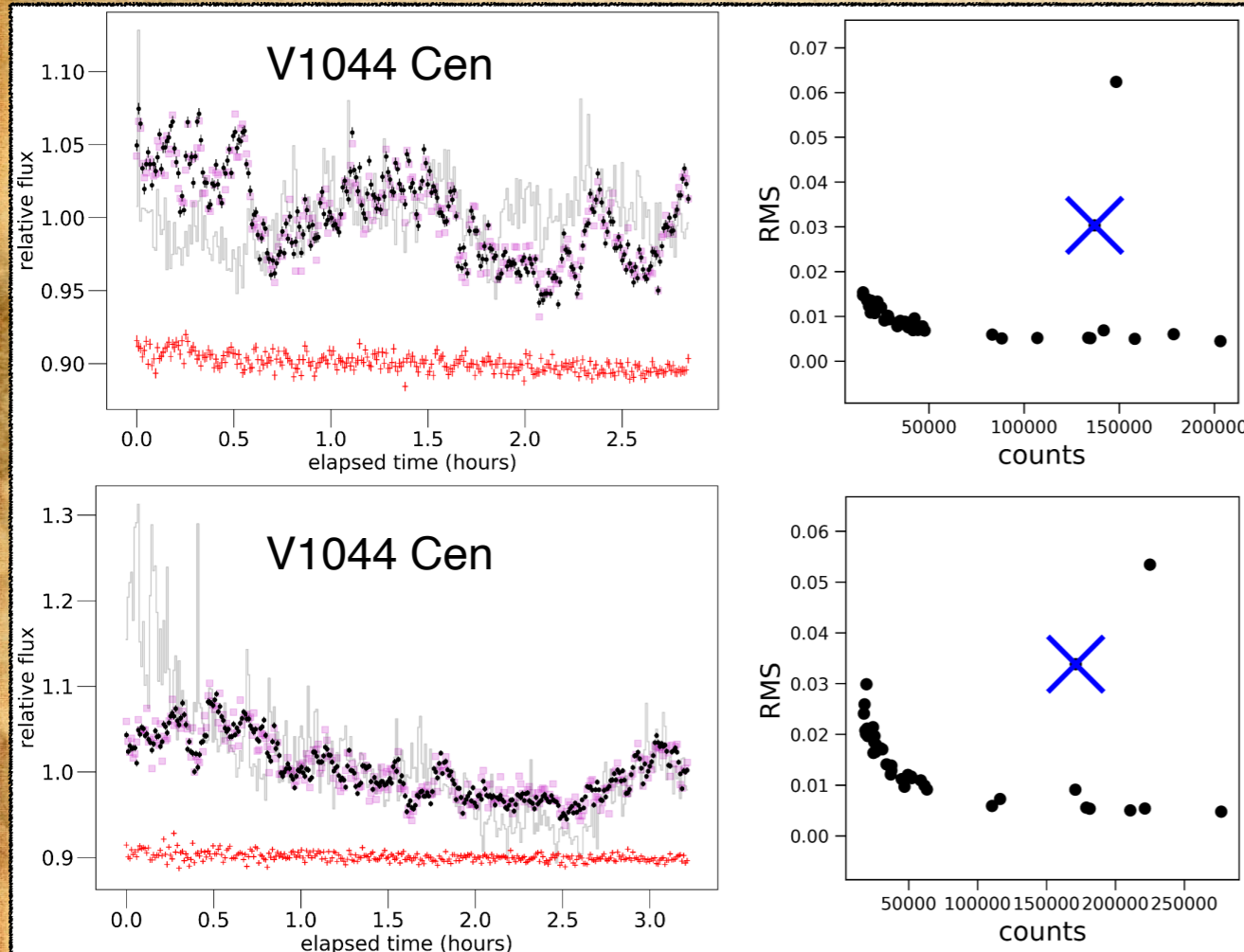
- cool giant
- Balmer alpha flux $>$ all higher order Balmer lines
(after extinction correction)
- not an S/carbon star OR has He I
(see Castelaz et al. 2000)

SkySy criteria:

- cool giant and AT LEAST ONE of the following:
 1. emission from >35 eV ion (traditional)
 2. extensively validated optical flickering
 3. unambiguous X-ray photons above 2.4 keV



At least 20% of the true population of symbiotics will have optical flickering detectable through SkyMapper.



*What data do I need for my science to work?

*How many output rows do I expect? / how much data do I want to download? Can I split it easily into parts? Do I have the space for it? Does it need to be asynchronous?

*What do the database schema look like? Which columns are indexed?

*Do I need to cross-match to external catalogs? What external data is already available in the schema or through the interface I'm using?

*Do I need/want to be able to cross-match to local tables (table uploads)?

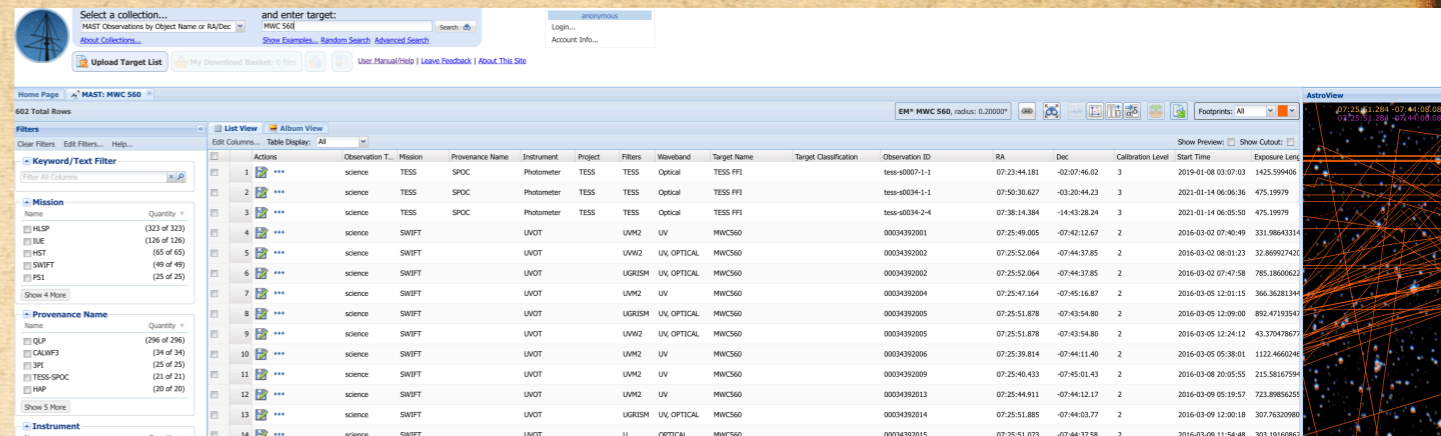
*What is the email address of the archive's help desk?

The MAST ecosystem

*disclaimers

The MAST ecosystem: data exploration on browser

1. Portal (incl. VO): <https://mast.stsci.edu/portal/Mashup/Clients/Mast/Portal.html>

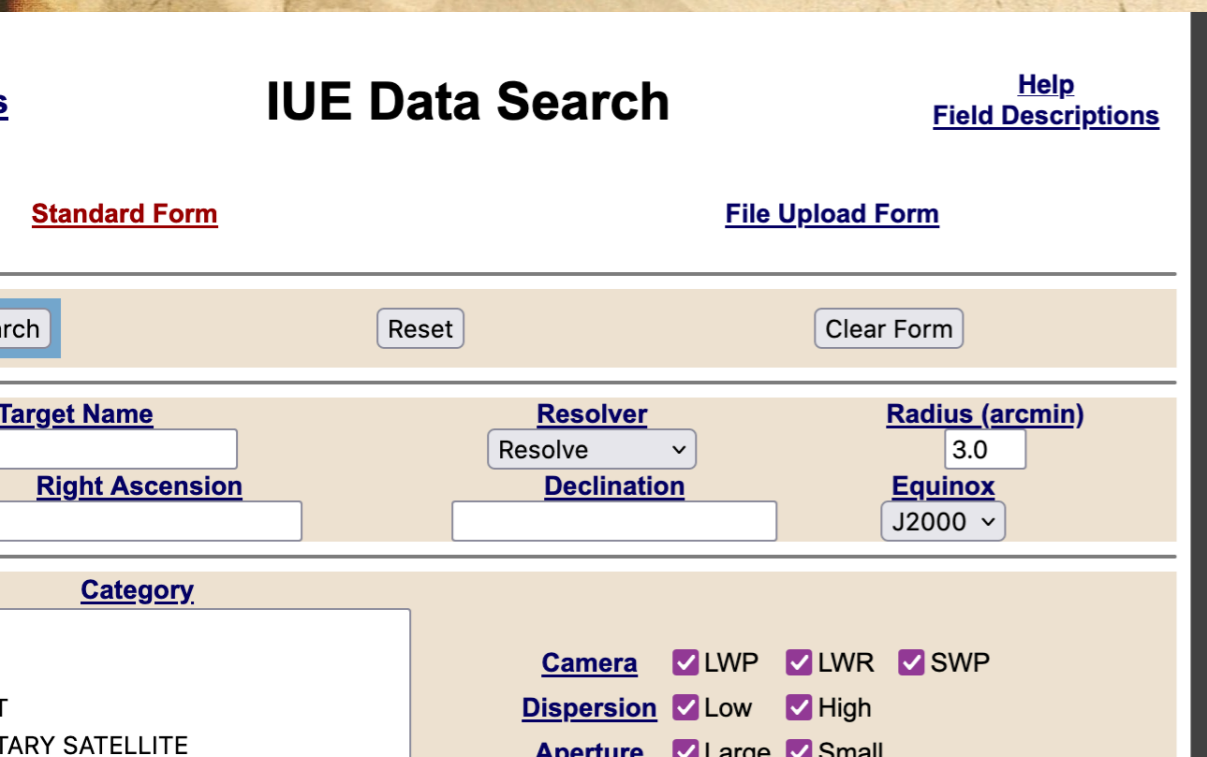


The screenshot shows the MAST data exploration interface. It features a search bar at the top, a navigation menu, and a main table of observations. The table has columns for Observation ID, Mission, Provenance Name, Instrument, Project, Filters, Wavelength, Target Name, Target Classification, Observation ID, RA, Dec, Calibration Level, Start Time, and Exposure Length. The table is currently displaying 14 rows of data.

Observation ID	Mission	Provenance Name	Instrument	Project	Filters	Wavelength	Target Name	Target Classification	Observation ID	RA	Dec	Calibration Level	Start Time	Exposure Length
tes-0007-1-1	science	TESS	SPOC	Photometer	TESS	Optical	TESS FFI		tes-0007-1-1	07:23:44.181	-02:07:46.02	3	2019-01-08 03:07:03	1425.599406
tes-0034-1-1	science	TESS	SPOC	Photometer	TESS	Optical	TESS FFI		tes-0034-1-1	07:50:30.627	-03:20:44.23	3	2021-01-14 06:06:36	475.19979
tes-0034-2-4	science	TESS	SPOC	Photometer	TESS	Optical	TESS FFI		tes-0034-2-4	07:38:14.384	-14:43:28.24	3	2021-01-14 06:05:50	475.19979
00034392001	science	SWIFT	UVOT			UV	MWC560		00034392001	07:25:49.005	-07:42:12.67	2	2016-03-02 07:40:49	331.9864314
00034392002	science	SWIFT	UVOT			UV	MWC560		00034392002	07:25:52.064	-07:44:37.85	2	2016-03-02 08:01:23	32.869927426
00034392003	science	SWIFT	UVOT			UV	MWC560		00034392003	07:25:52.064	-07:44:37.85	2	2016-03-02 07:47:58	785.1860062
00034392004	science	SWIFT	UVOT			UV	MWC560		00034392004	07:25:47.164	-07:45:16.87	2	2016-03-05 12:31:15	366.3628134
00034392005	science	SWIFT	UVOT			UV	MWC560		00034392005	07:25:51.878	-07:43:54.80	2	2016-03-05 12:39:00	892.4719354
00034392006	science	SWIFT	UVOT			UV	MWC560		00034392006	07:25:51.878	-07:43:54.80	2	2016-03-05 12:24:12	43.37047867
00034392007	science	SWIFT	UVOT			UV	MWC560		00034392007	07:25:39.814	-07:44:11.40	2	2016-03-05 05:38:01	1122.4660246
00034392009	science	SWIFT	UVOT			UV	MWC560		00034392009	07:25:40.433	-07:45:01.43	2	2016-03-08 20:05:55	215.58167594
00034392013	science	SWIFT	UVOT			UV	MWC560		00034392013	07:25:44.911	-07:44:12.17	2	2016-03-09 05:19:57	723.8986255
00034392014	science	SWIFT	UVOT			UV	MWC560		00034392014	07:25:51.885	-07:44:03.77	2	2016-03-09 12:00:18	307.76320986
00034392015	science	SWIFT	UVOT			UV	MWC560		00034392015	07:25:51.073	-07:44:17.58	2	2016-03-09 11:54:48	303.15166862

2. Mission search forms: <https://archive.stsci.edu/searches.html#missions>

3. High Level Science Products



The screenshot shows the IUE Data Search form. It includes a search bar, a 'Reset' button, and a 'Clear Form' button. The form has several input fields and dropdown menus for 'Target Name', 'Right Ascension', 'Declination', 'Equinox', 'Resolver', and 'Radius (arcmin)'. There are also checkboxes for 'Camera', 'Dispersion', and 'Aperture' with options like 'LWP', 'LWR', 'SWP', 'Low', 'High', 'Large', and 'Small'.

IUE Data Search [Help](#) [Field Descriptions](#)

[Standard Form](#) [File Upload Form](#)

Search

Target Name

Right Ascension

Declination

Equinox

Resolver

Radius (arcmin)

Camera LWP LWR SWP

Dispersion Low High

Aperture Large Small

The MAST ecosystem: data exploration on browser

3. High Level Science Products (Available in the portal too when possible)

High Level Science Products are observations, catalogs, or models that complement, or are derived from, MAST-supported missions. These include Hubble (HST), James Webb (JWST), TESS, PanSTARRS, Kepler/K2, GALEX, Swift, XMM, and others. HLSPs can include images, spectra, light curves, maps, source catalogs, or simulations. They can include observations from other telescopes, or data that have been processed in a way that differs from what's available in the originating archive. All HLSPs are public immediately with no proprietary periods. Use the filters below to discover HLSP. [Search HLSP by coordinates or filenames on MAST Classic](#). Or, see all HLSPs in a [simplified, searchable table](#).

Contribute HLSPs

HLSP filter

Keyword (HLSP, PI, etc.)

Object Type

Mission

Product Type

SUBMIT

Items per page: 15 (190 total)

◀◀ First ◀ Previous 1 2 3 4 5 Next ▶▶ Last ▶▶

EXOMAST

SEARCH

Search by planet, object of interest or TESS TCE

[View Table of Exoplanets](#)

MAST

Search for extragalactic observations and catalog data from MAST high-level science products (HLSP). Download results for further analysis or quickly view detailed information by individual galaxy—aggregated data, image cutouts, observed SEDs, and observations from [CANDELS](#), [GOODS](#), [HFF-DEEPPSPACE](#), [3D-HST](#).

Search by

Select an HLSP.

survey= | | |

Select an observed field. [See field footprints](#).

region= | | | | |

Pick a specific region for more catalog options.

catalog= | |

+ Add condition Add a parameter to filter by. [See parameter descriptions](#).
* Different catalogs have different parameters.

SEARCH

The MAST ecosystem: programmatic interfaces

1. Default: *astroquery.mast (<https://astroquery.readthedocs.io/en/latest/mast/mast.html>)
 - python
 - extensive functionality, but can't access all metadata
 - output row limits for some things

The MAST ecosystem: programmatic interfaces

2. Need more access to metadata?

*MAST API, i.e. mashup API (<https://mast.stsci.edu/api/v0/>, https://mast.stsci.edu/api/v0/_services.html)

- more complex

- output row limit of about 500,000

- access to more, but not all, metadata (e.g., for CAOM, https://mast.stsci.edu/api/v0/_caomfields.html)

*http get (https://archive.stsci.edu/vo/mast_services.html#GET)

*CAOM TAP query (<https://vao.stsci.edu/caomtap/querymanager.html>)

- all CAOM (cross-mission) metadata

- VO-compatible

- ADQL queries

- large, async queries

The MAST ecosystem: programmatic interfaces

3. Need to cross-match to other archives AND portal shows the data you need is available for VO service? Virtual Observatory TAP endpoints (<https://archive.stsci.edu/virtual-observatory>)

4. Very large/complex query, $>10^6$ output rows, need to upload your own large table for crossmatch? Check if your data is available in CasJobs:

- SQL

- can handle larger, async queries

- HLSPs, Kepler, TESS, 2MASS, PanSTARRS,

MAST Query / CasJobs

Home Help Tools Query History MyDB Import Groups Output Profile Queues

Table (optional)	Task Name
HLSP_471UC	
HLSP_ASPIC	My Query
HLSP_ASPIC	
HLSP_ATLAS_REFCAT2	
HLSP_GSWLC	
HLSP_KG_RADII	

The MAST ecosystem: cloud interfaces

1. TIKE is a good approximation of the Roman science platform

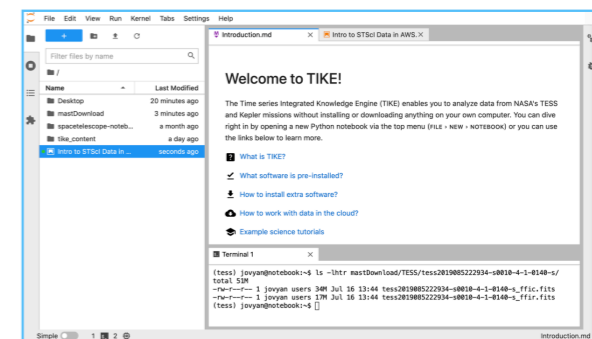
<https://timeseries.science.stsci.edu/>

The Timeseries Integrated Knowledge Engine (TIKE): cloud-based user interface for analysis of TESS mission data.

TIKE Science Platform

Coming in 2021! (stay tuned)

- Over 20 pre-installed community software packages
- Tutorials and example notebooks
- JupyterHub service in same region as MAST AWS Public Datasets: free, high bandwidth to TESS data



MAST AWS TESS data now free to transfer

<https://registry.opendata.aws/collab/stsci/>

- MAST AWS data no longer uses "requestor pays"
- Astroquery (>= 0.4.2) and other clients no longer need AWS credentials
- High-throughput data access anywhere (cloud or not)

We can use astroquery.MAST to search and filter data products, return the S3 paths, and download them.

For astroquery >= 0.4.2, no AWS account is required

```
from astroquery.mast import Observations

#Identify a few Sector 18 FFIs
select = Observations.query_criteria(selectable="FFI", mission="TESS", sector="18")
products = Observations.get_product_list(select)
filtered = Observations.filter_products(products, filters=[{"productSubDescription": "FFI", "only": True}])

#Print (len(filtered)) products
print(len(filtered))

#Return the AWS S3 locations (URLs)
Observations.enable_cloud_dataset(provider="AWS")
urls = Observations.get_urls(filtered)
print(urls)

INFO: Using the S3 STScI public dataset [astroquery.mast.cloud]
s3://stsci-public-aws-public/ffis/0018/2019/0054-1/tes2019080222934-0018-4-1-0140-0_ffis.fits

#Download a few example products
manifest = Observations.download_products(products[:2], cloud_only=True)

Downloading URL s3://stsci-public-aws-public/ffis/0018/2019/0054-1/tes2019080222934-0018-4-1-0140-0_ffis.fits to
./mastDownload/TESS/tes2019080222934-0018-4-1-0140-0_ffis.fits [Done]
Downloading URL s3://stsci-public-aws-public/ffis/0018/2019/0054-1/tes2019080222934-0018-4-1-0140-0_ffis.fits to
./mastDownload/TESS/tes2019080222934-0018-4-1-0140-0_ffis.fits [Done]

#Print local file location
print(manifest)

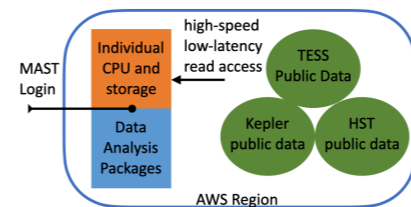
Local Path
...
./mastDownload/TESS/tes2019080222934-0018-4-1-0140-0_ffis.fits
./mastDownload/TESS/tes2019080222934-0018-4-1-0140-0_ffis.fits
```

Initial focus on timeseries analyses, e.g. TESS, Kepler

Pre-installed Python packages

- Core scientific packages: numpy, scipy, matplotlib, pandas.
- Core astronomy packages: astropy, astroquery, pyvo.
- Data analysis packages: emcee, george, celerite.
- TESS- or Kepler-focused packages: lightkurve, astrocut, everest.
- Machine learning: tensorflow, scikit-learn.
- Cloud tools: awscli, boto3, s3fs.

Quickly visualize TESS & Kepler data



Computing adjacent to MAST AWS datasets

Access TESS data without transferring it over internet

The table below shows the typical time it takes to sequentially download 30 TESS Full Frame Images (~1 GB) in different environments. These results are a snapshot obtained at a single point in time on Feb 3, 2021.

Environment	Data location	Client	Time	Speed	Diff
TIKE platform	AWS	boto3	9s	907 Mbps	1x
TIKE platform	AWS	httpx	16s	510 Mbps	2x
TIKE platform	MAST	httpx	1m13s	112 Mbps	8x
WiFi	AWS	boto3	5m49s	23 Mbps	39x
WiFi	AWS	httpx	11m31s	12 Mbps	77x
WiFi	MAST	httpx	14m05s	10 Mbps	94x

STScI is hiring!

e.g. Scientist to support TESS archive (Aug 20, 2021) <https://jobregister.aas.org/ad/144258c4>

[Link to full STScI Job board](#)



Greg Snyder
Susan Mullally, Geert Barentsen (NASA Ames), Clara Brasseur, Scott Fleming, Joshua Peek, Ivelina Momcheva, Andrew Cortese, Michael Fox, Michael Gough, Brian Hayden, Ru Kein, Jacob Matuskey, Todd Miller, Christine Slocum



The MAST ecosystem: [cloud interfaces](#)

2. cloud data access APIs and cutout services/APIs/libraries
TBD

-can be demonstrated from within TIKE

-Currently available:

*astroquery.mast AWS cloud services, now free! (<https://astroquery.readthedocs.io/en/latest/mast/mast.html>)

*prototype client-side cutout library in a branch of Astrocut:
<https://github.com/spacetelescope/astrocut/tree/s3-support>

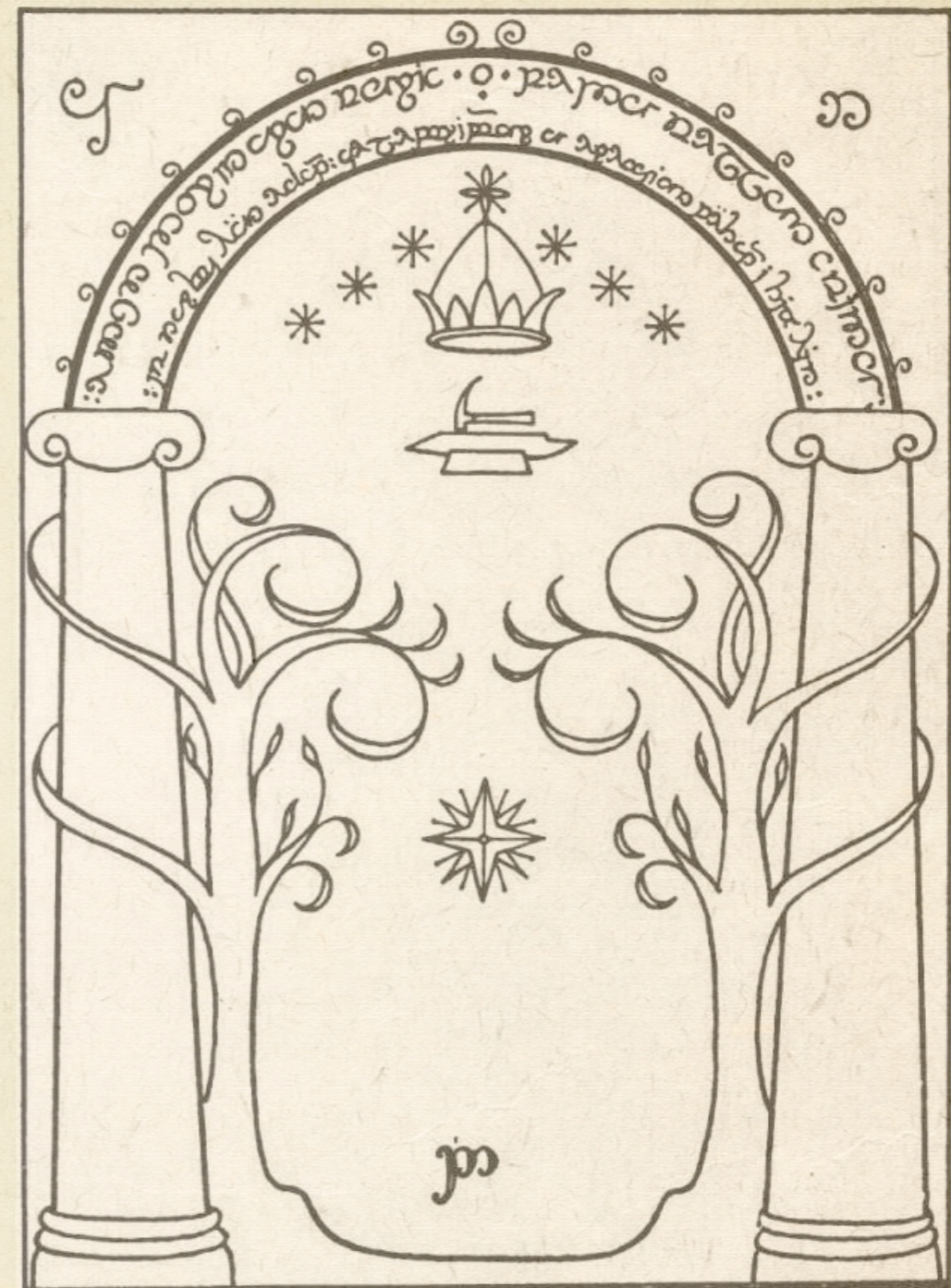
???

‘What does the writing say?’ asked Frodo, who was trying to decipher the inscription on the arch. ‘I thought I knew the elf-letters, but I cannot read these.’

‘The words are in the elven-tongue of the West of Middle-earth in the Elder Days,’ answered Gandalf. ‘But they do not say anything of importance to us. They say only: *The Doors of Durin, Lord of Moria. Speak, friend, and enter.* And underneath small and faint is written: *I, Narvi, made them. Celebrimbor of Hollin drew these signs.*’

‘What does it mean by *speak, friend, and enter*?’ asked Merry.

‘That is plain enough,’ said Gimli. ‘If you are a friend, speak the password, and the doors will open, and you can enter.’



Here is written in the Feänorian characters according to the mode of Beleriand: Ennyn Durin Aran Moria: pedo mellon a minno. Im Narvi hain echant: Celebrimbor o Eregion teithant i thiwhin.

???

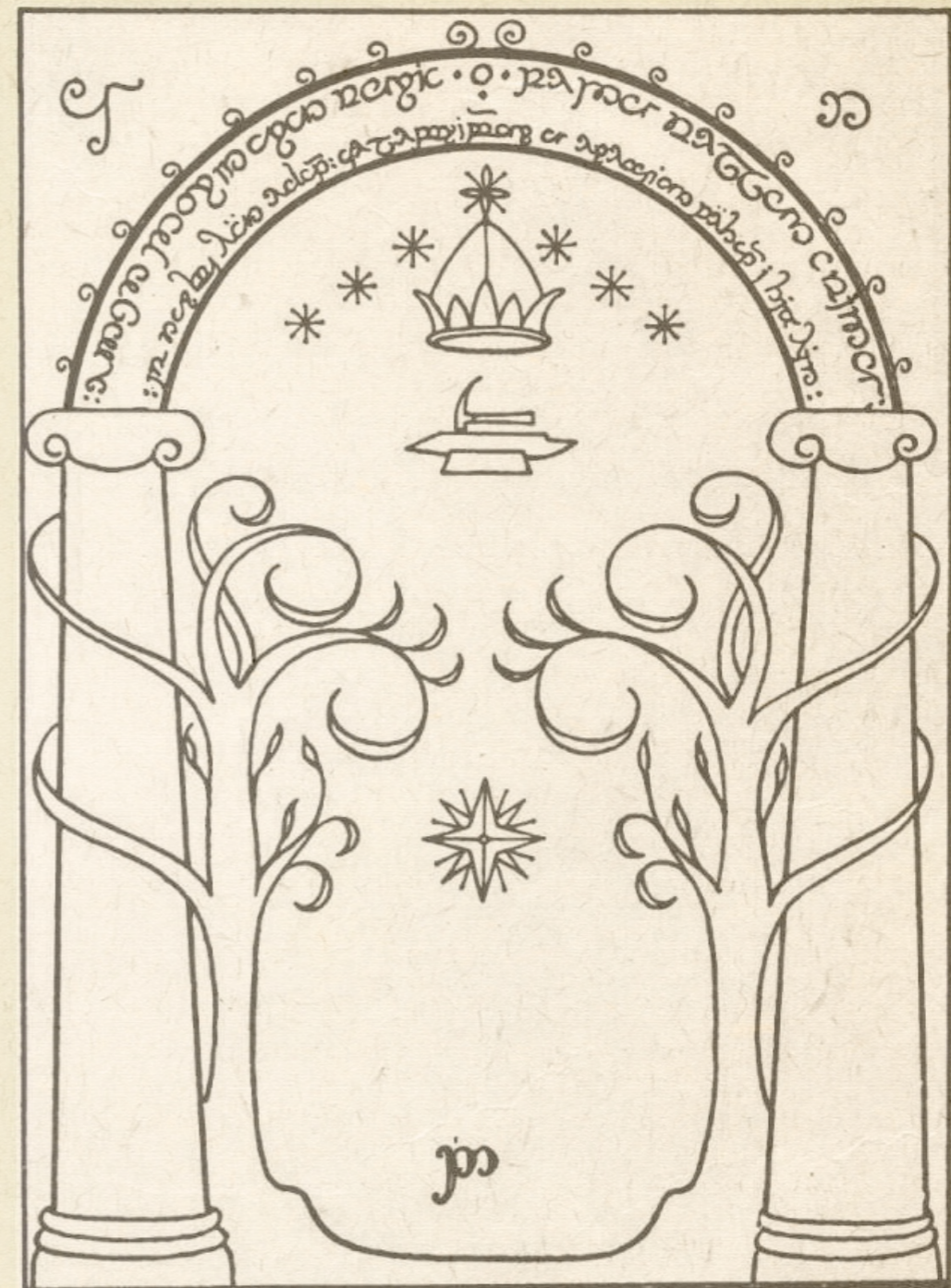
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alucy@stsci.edu

Symbiotic/SkyMapper work at 2021 PhDT.....17L

Symbiotic collaborators: J. Sokoloski, G. J. M. Luna, K. Mukai, H. Breytenbach, D. Buckley, S. Potter, P. Woudt, P. Groot, B. Paul, N. Nuñez, A. Howell, C. Wolf, R. Manick, M. Shara, D. Zurek

Thank you to everyone at MAST and STScI who has helped me during my onboarding.