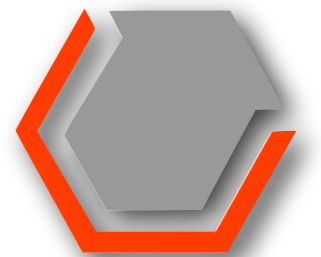# DES Strong Lens Searches

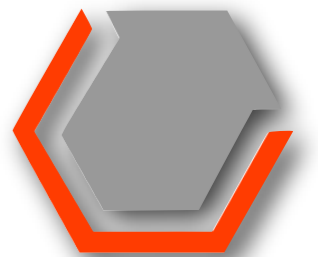## Strong Lens Program and Follow-up at Gemini South

- science goals

- search strategies

- follow-up from Gemini South

B. Nord (with Liz Buckley-Geer, Huan Iin)
DES Chicagoland Meeting at Argonne
2014.12.9

DES Strong Lens Searches

Strong Lens Program and Follow-up at Gemini South

- science goals

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Science Goals

- <u>Dark energy</u>

  - Lenses with background sources at multiple redshifts (e.g., H_0 from ratio of distance measures)

  - Lensed transients - quasars and supernovae (e.g., H_0 from gravitational time delays)

  - Massive clusters

- <u>Dark matter</u>

  - mass profiles on scales from individual galaxies to massive clusters.

- <u>Galaxy evolution</u>

  - The high red-sensitivity of DECam CCDs, along with the grizY filter set means we will be sensitive to high-redshift Lyman Break galaxies (e.g., g-band dropouts at z~4 or r-band dropouts at z~5).

Forecasts

- Current predictions are based on extrapolations from the literature. We are currently refining some of these using simulations.

- Expect ~**1000 lenses** in DES with 18" > Einstein Radius > 2"

  - 200 of those would contain giant arcs (with arc length-to-width ratio > 8)

  - based on extrapolations from the CFHTLS Strong Lensing Legacy Survey (using the 54 systems with rank 3 and above from More et al. 2012).

- Expect to find a sample of ~**120 lensed quasars**

  - 2nd image has i < 21 (for a double), including 20 high information-content quads where the 3rd brightest image has i < 21 (Oguri & Marshall 2010)

Search Strategies

- SVA1 Visual Search: Multiple scanners looked at each field and targets were rank-ordered
  - Galaxy-/group-scale: all wide-field and SN field tiles
  - Cluster-scale: all known SPT clusters and RedMapper clusters
- Y1 Data and Beyond
  - Introduce automated arc-finding
  - Working with the Space Warps team to do a targeted search around DES LRGs using citizen scientists starting with the Y1 data release
  - Continue to examine RedMaPPer and SPT clusters
  - Catalog searches looking for blue objects in association with LRGs: very successful strategy in SDSS but does require good de-blending in the object detection step
- Transients: QSOs and SNe
  - We have a DES External Collaboration called STRIDES (*STR*ong lensing *I*nsights into *D*ark *E*nergy *S*urvey)
  - Use a combination of color selection, morphology and variability
    - Wide separation lenses using a color selection
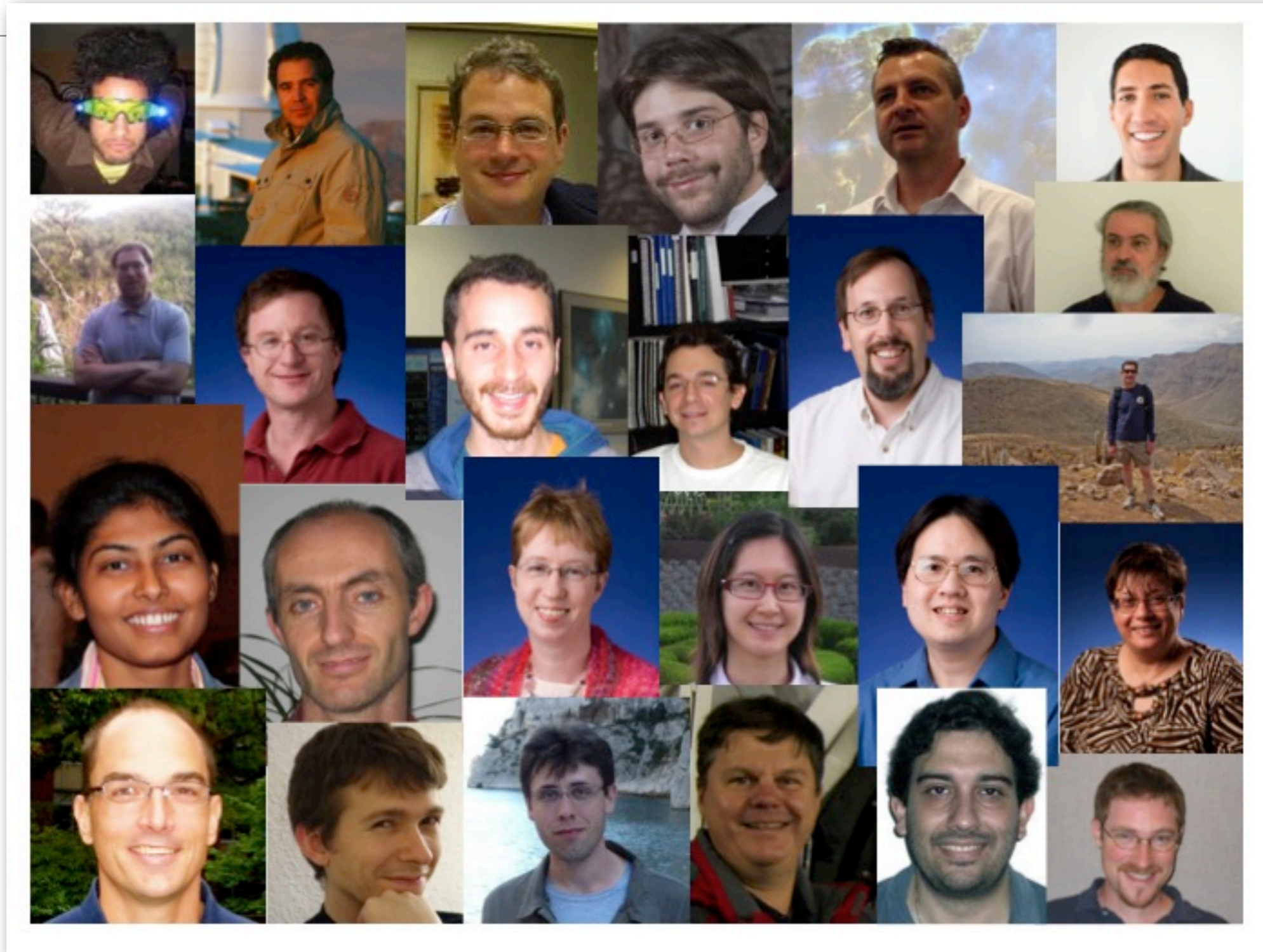   - color selection + morphology plus machine learning variability selection

Follow-up plans

- Currently focusing on spectroscopic confirmation
- <u>OzDES program</u>
    - in the SN fields using AAT/AAOmega – suitable for bright targets r ≤ 22.5 (5 fibers per pointing for lensing targets)
- <u>Magellan</u>
    - currently 1-2 nights per semester through the University of Chicago using IMACS
- <u>Gemini</u> Large and Long Program (GLLP)

GLL Program and Candidates

- **~1000** visually identified lensing candidates in SVA1 (and a bit of Y1), performed by the DES strong lensing group

- Gemini Large and Long Program Proposal (led by L. Buckley-Geer):

  - <u>Targets</u>: **60** Strong Lens candidates; 50 photo-z calib targets per field

  - <u>Award</u>:

    - 276 hours in total through 2016B

    - 80 hours in B semesters, 12 hours in A semesters

    - Band 2 has overall lower completion rates than Band 1, although your participation in Priority Visitor Observing should promote higher completion.

- **2014B Semester**

  - **80 hours and 6 nights at Gemini (Oct 19 - 24, 2014)**

Collaborators

Gemini Set-up

- New GMOS South Hamamatsu detectors: improved red-sensitivity

- R150 (red) grating + GG455 filter for 4500-10000A wavelength coverage.

  - **[OII]** @ $z < 1.7$

  - **Hβ** @ $z < 1.0$
    Lyα @ $z \sim 2.7$–7.2

  - **Lyα** @ $z \sim 2.7 - 7.2$
    CIV @ $z \sim 2.0 - 6.7$

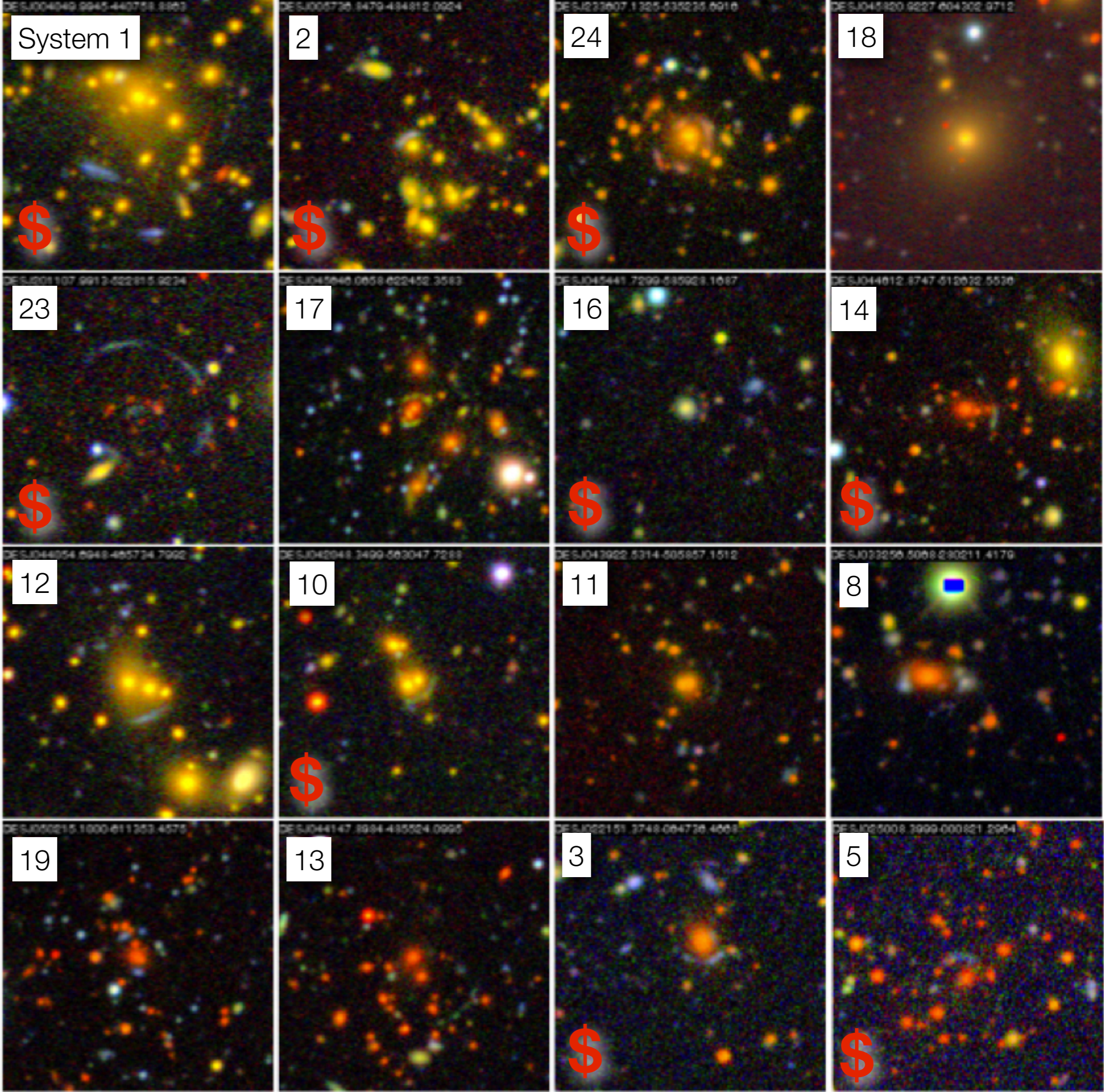- B600 (blue) grating for 3250A to 6250A

  - **Lyα** @ $z > 2.0$

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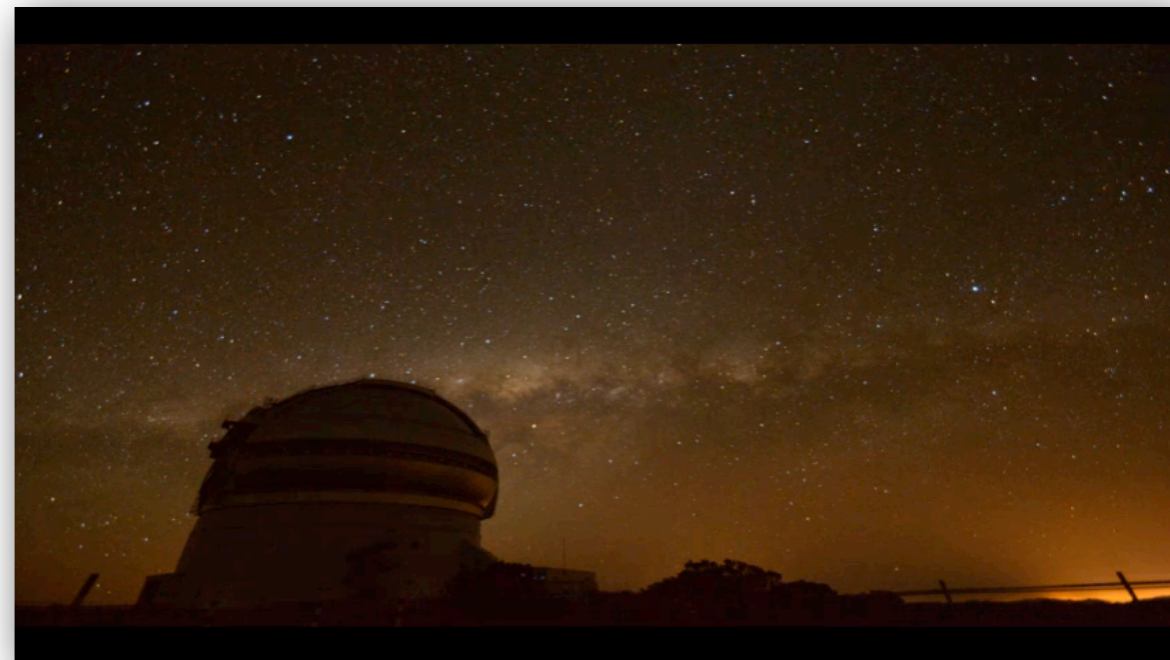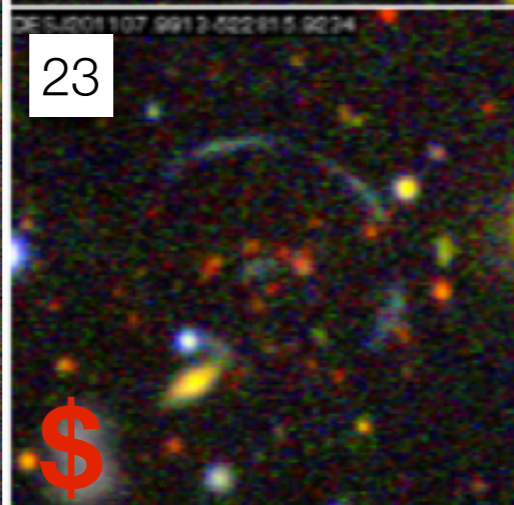
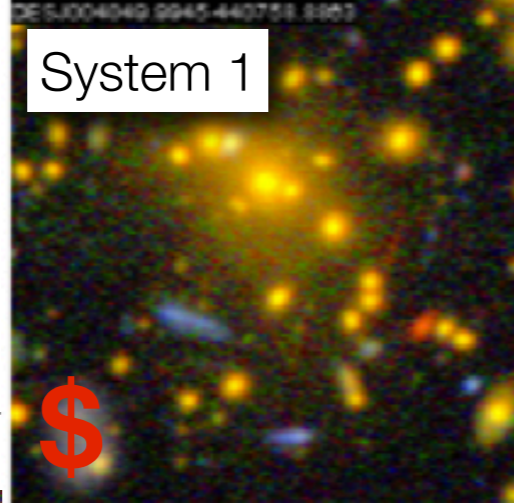- B600 (blue) grating for 3250A to 6250A

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Candidates
(2014B)
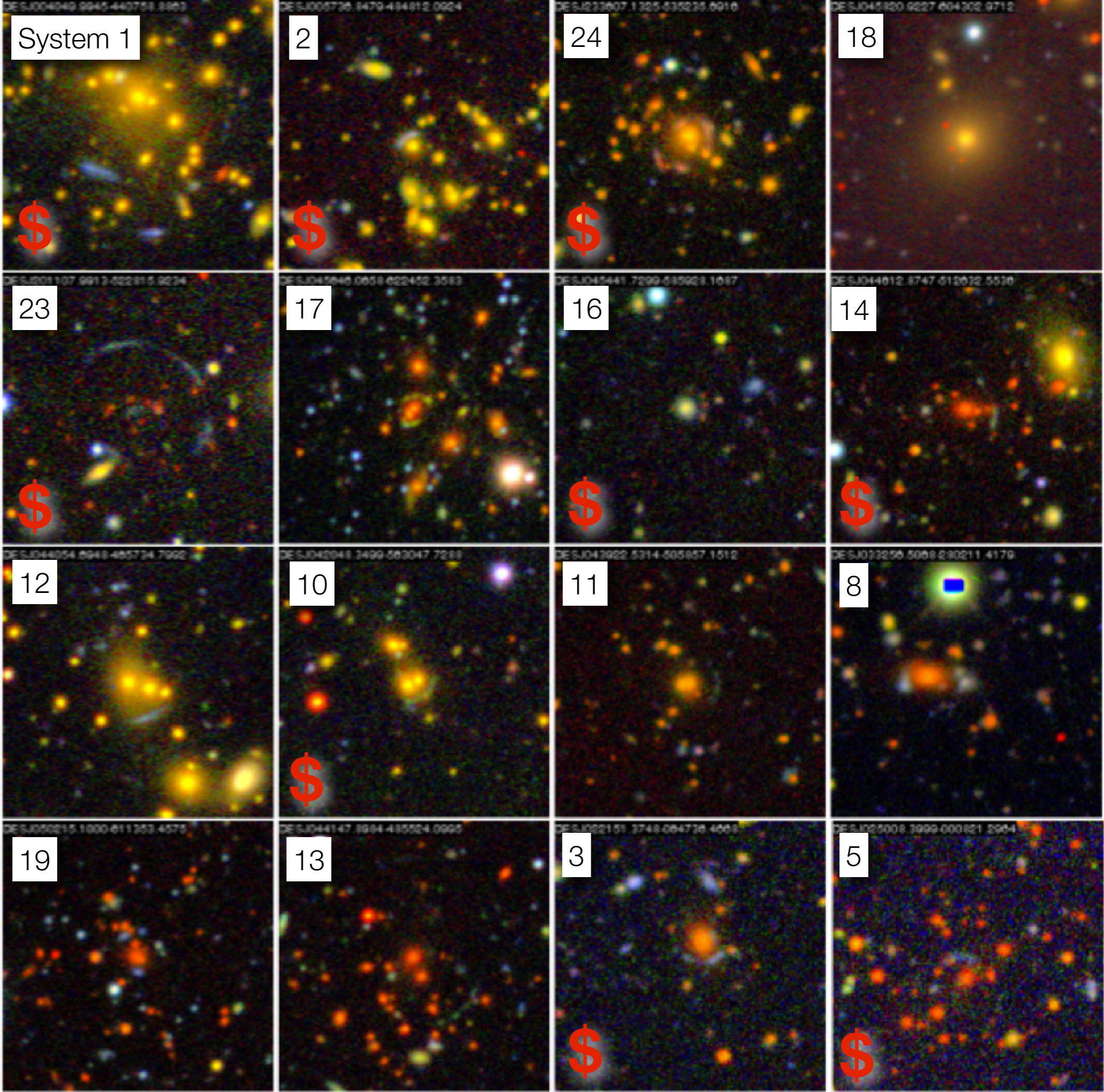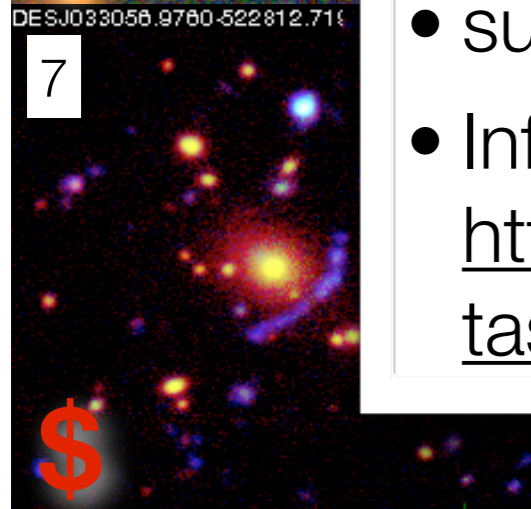
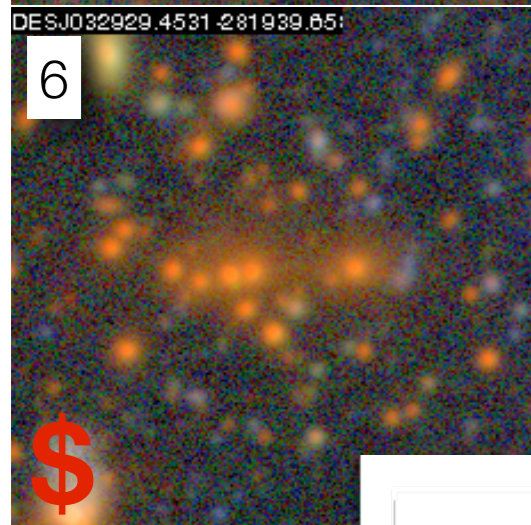- **$**: observed (13)
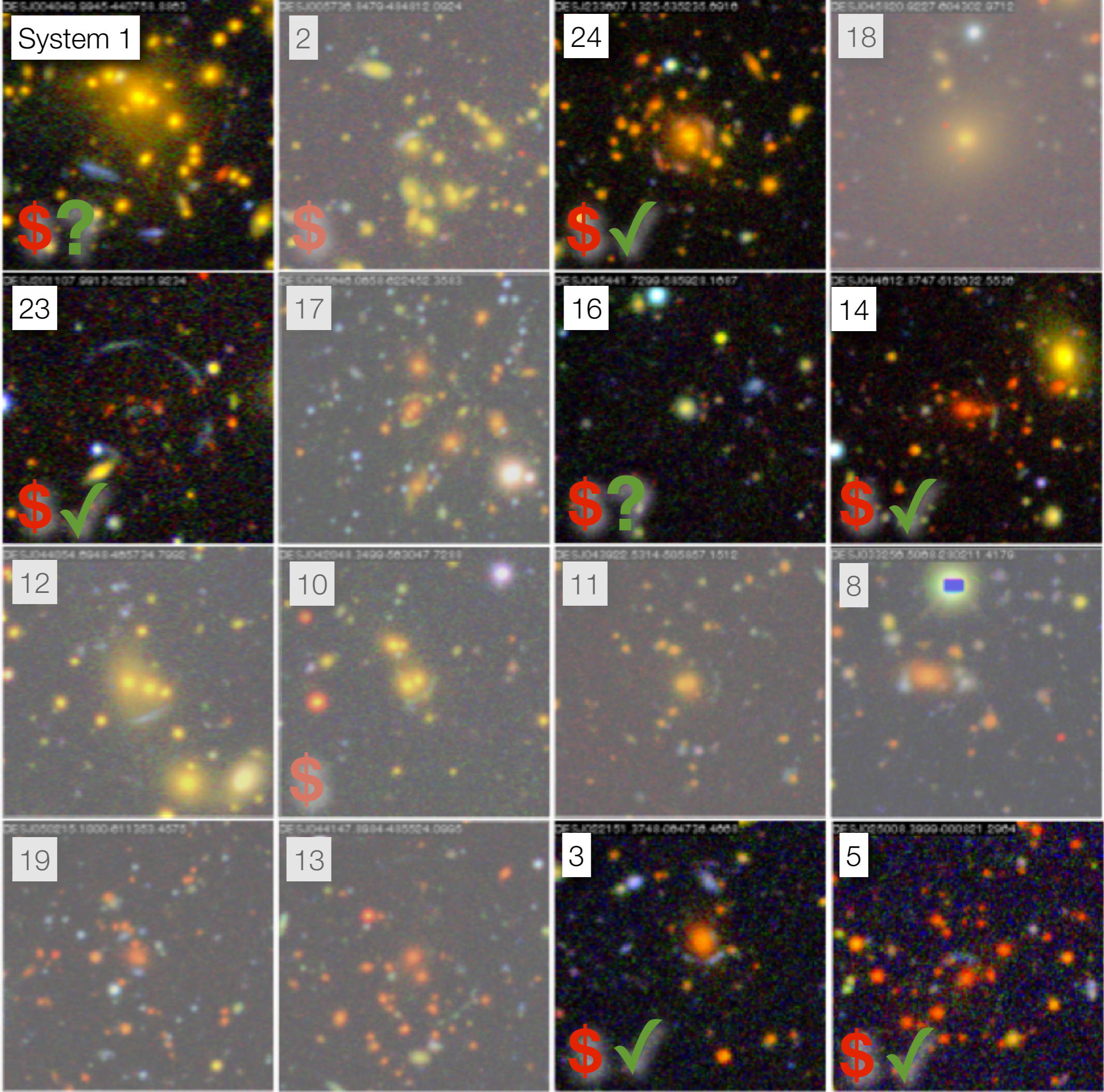
Candidates
(2014B)

- **$**: observed (13)

Candidates
(2014B)
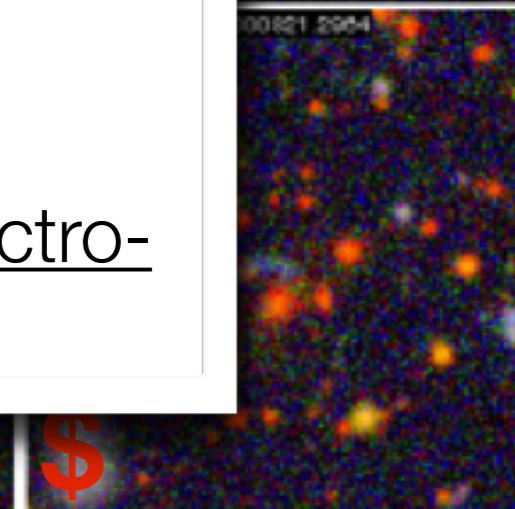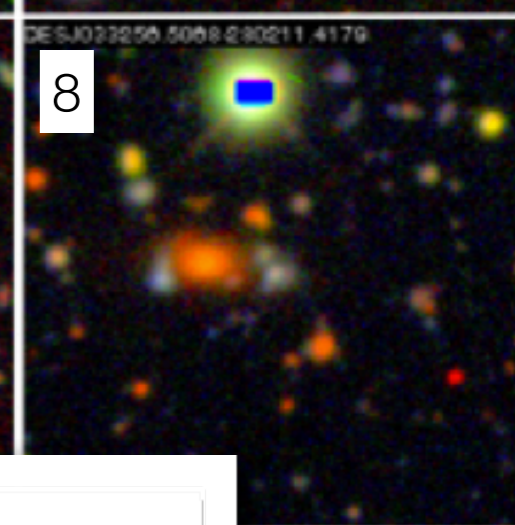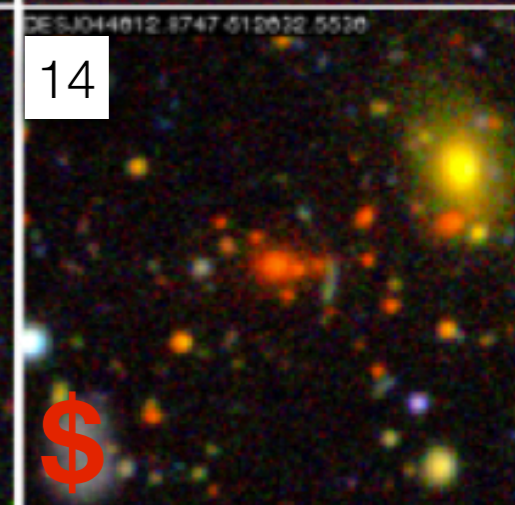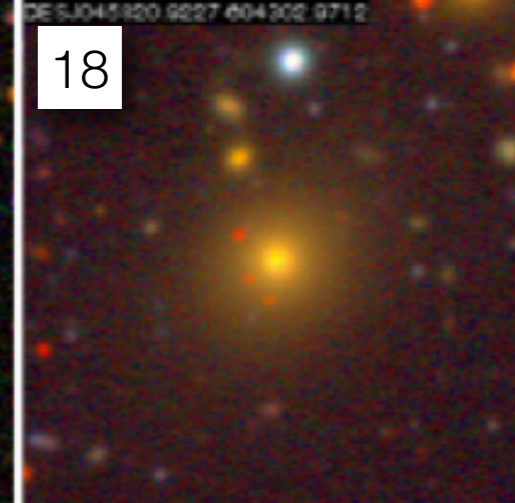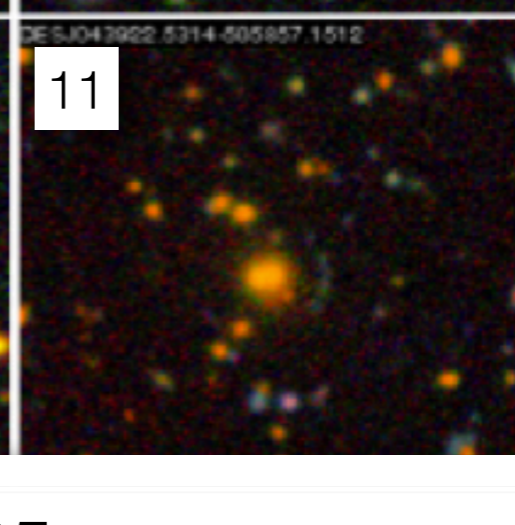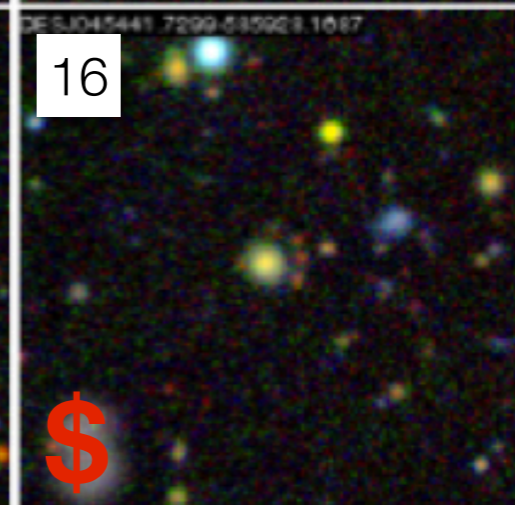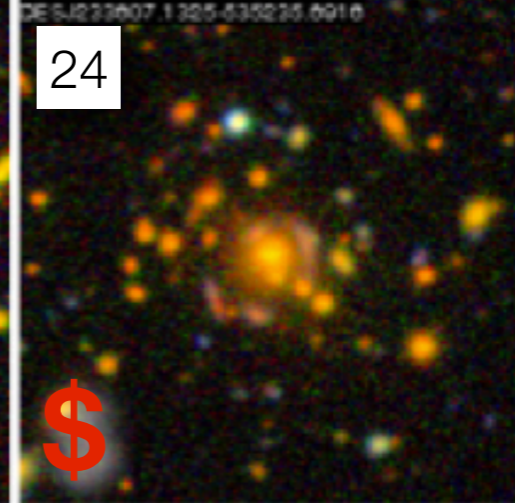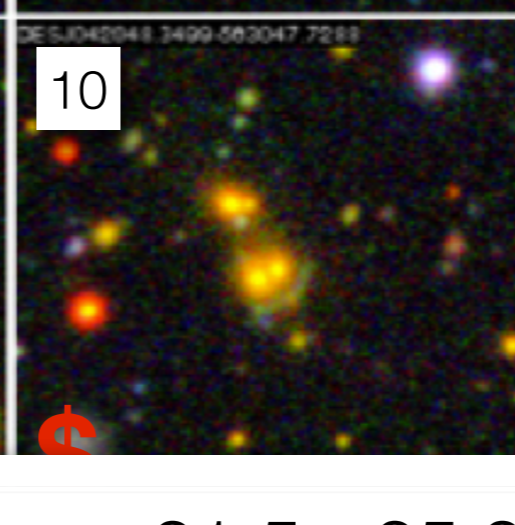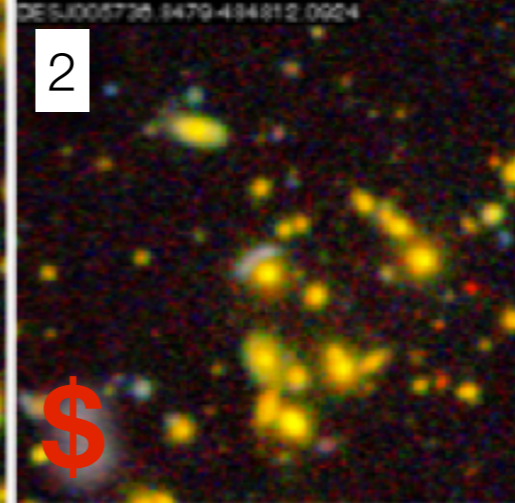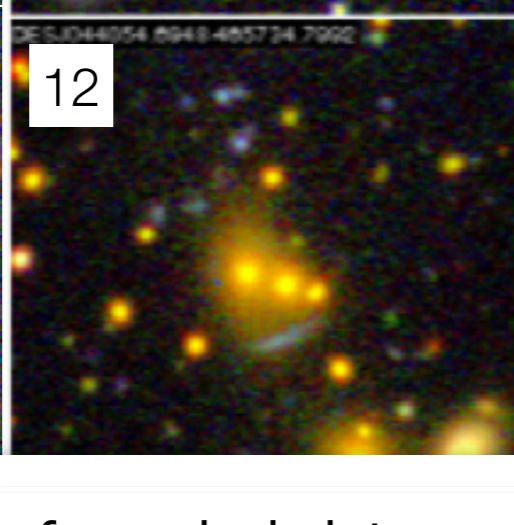
- **$:** observed (13)

surface brightnesses: 21.5 - 25.25

- Info on all the lens targets is here:
  https://cdcvs.fnal.gov/redmine/projects/des-spectro-task/wiki/Gemini_Target_List

- **$:** observed (13)
- ✓ : probable lensing systems (5)

From Candidate to Redshift

- Reduction (IRAF):

  - the usual basic *image reduction*: bias, flats, CR rejection, stacking

  - *Spectroscopic reduction*:

    - Identify and Calibrate lines (using CuAr lamps)

    - transform pixel to wavelength

    - 2D science -> 1D science spectrum

    - redshift extraction

- Preliminary Reductions performed while at Gemini

  - Identified features that reveal objects are likely lens systems (**6** "probably" and **1** unlikely):

    - 1, 3, 5, 14, 16(x), 23, 24

  - developed *PyRAF* code to help with automation (uses json input file): this *might* be better than copy-paste-replace method with IRAF; may be particularly useful for 100's of photo-z targets
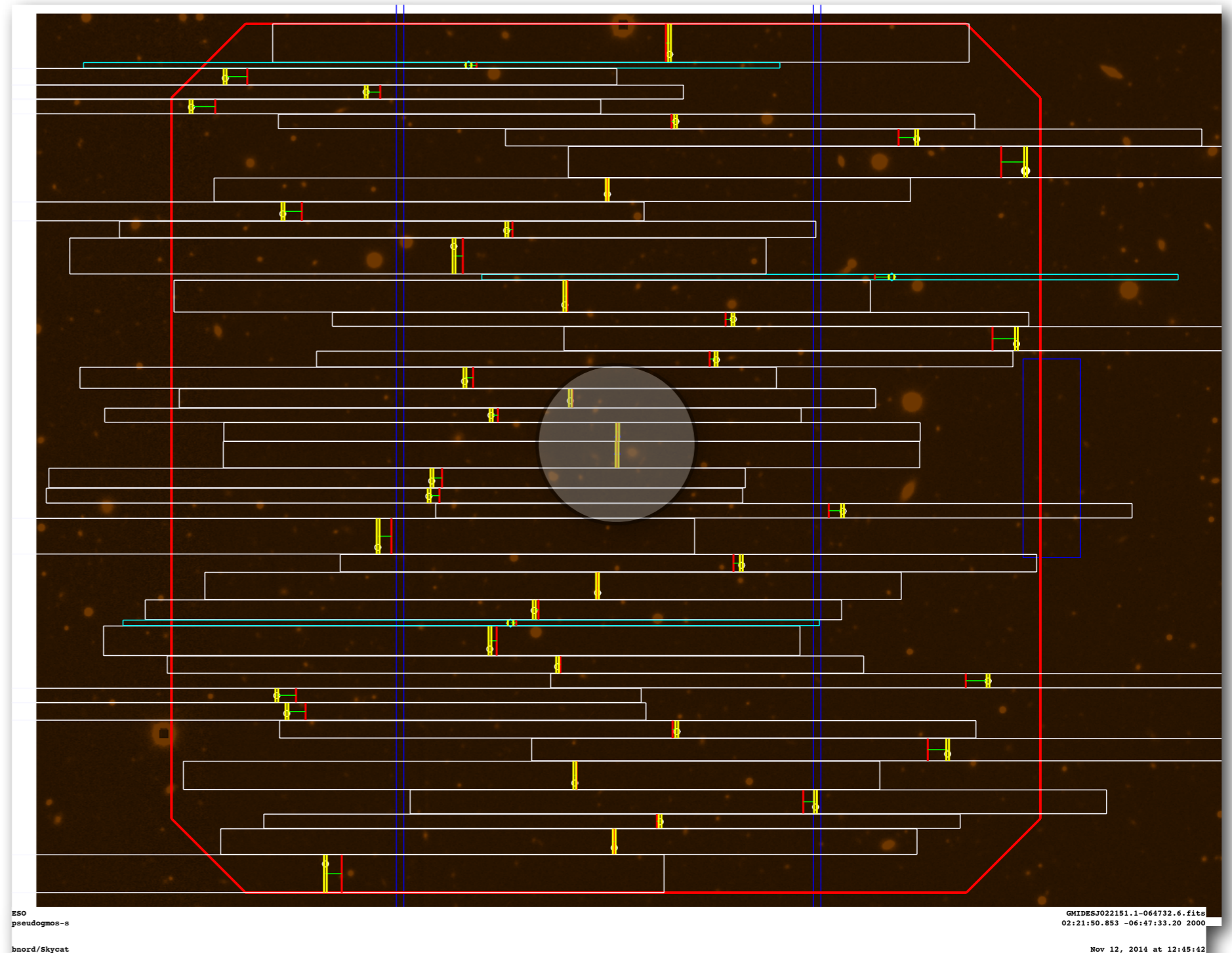
System 3 (DESJ022148.2-064600.4)
DES Image and Mask

- blue vertical lines: **chip gaps**

- red irregular octagon: **field of view**

- cyan horizontal bars: **acquisition stars**

- white horizontal bars: **extent of slit dispersion**

- yellow short vertical or slanted lines: **slit** (some slanted to get more of object)
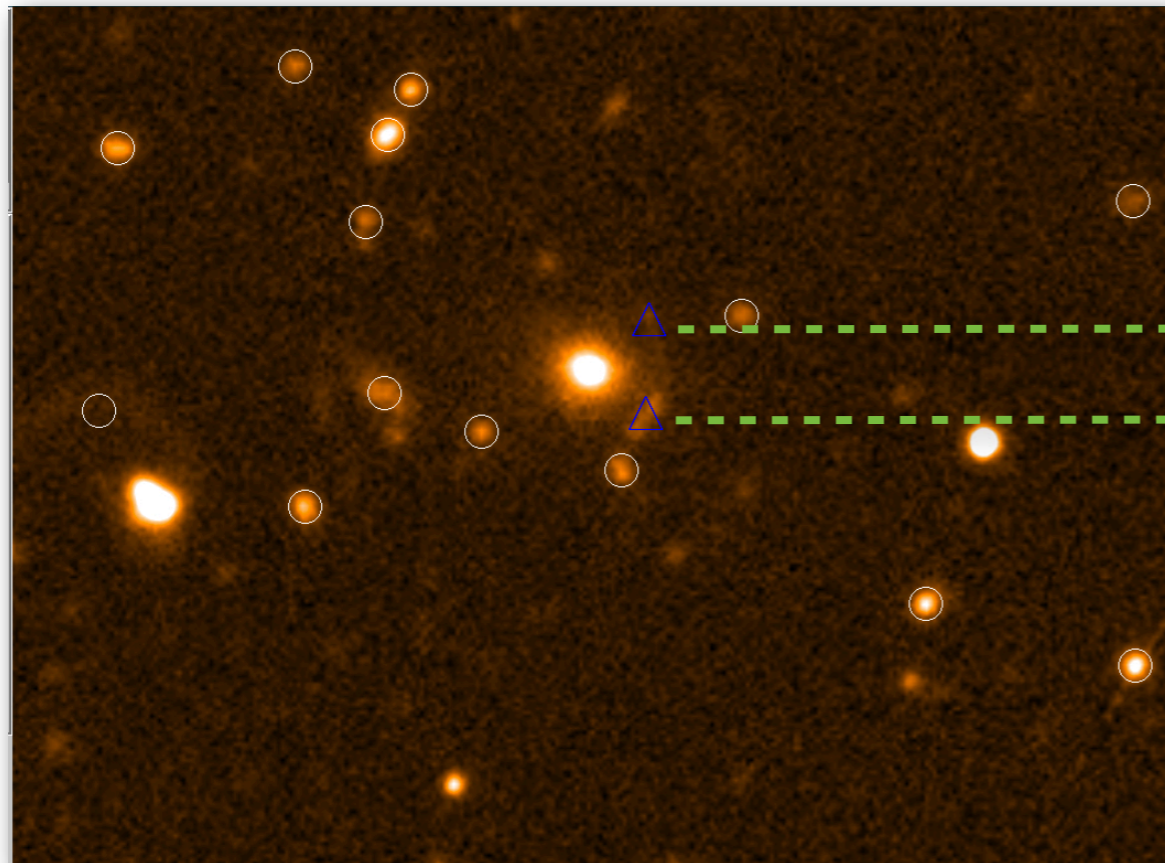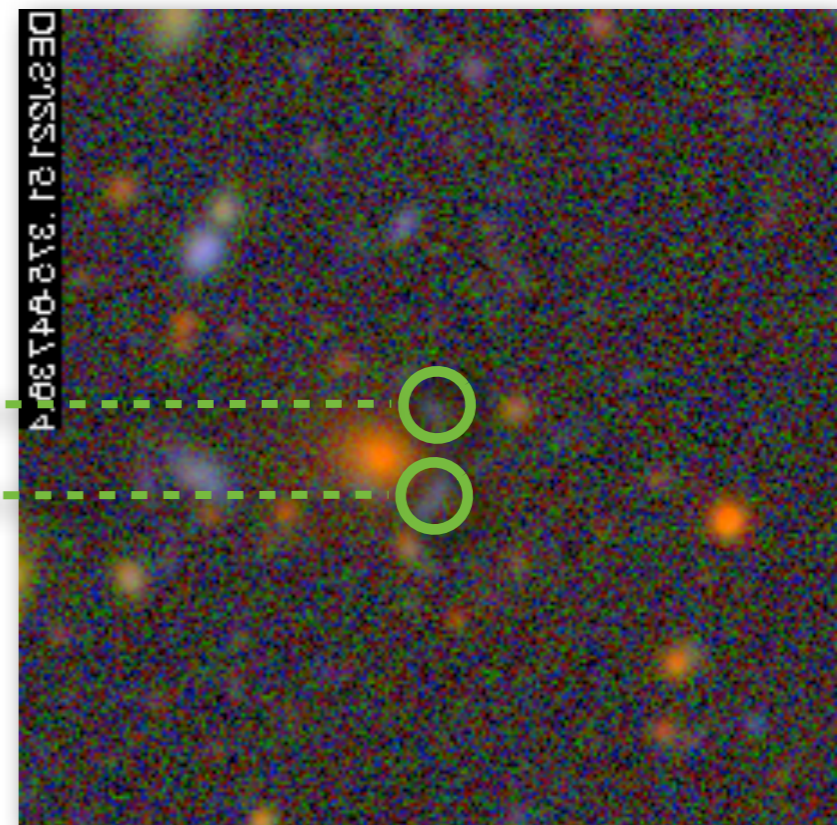
System 3 (DESJ022148.2-064600.4)
Object-Slit Alignment

Matching original image to slit mask.

Green circles show sources

blue triangles show sources

Images on left (for mask-making) are created
with gmmps

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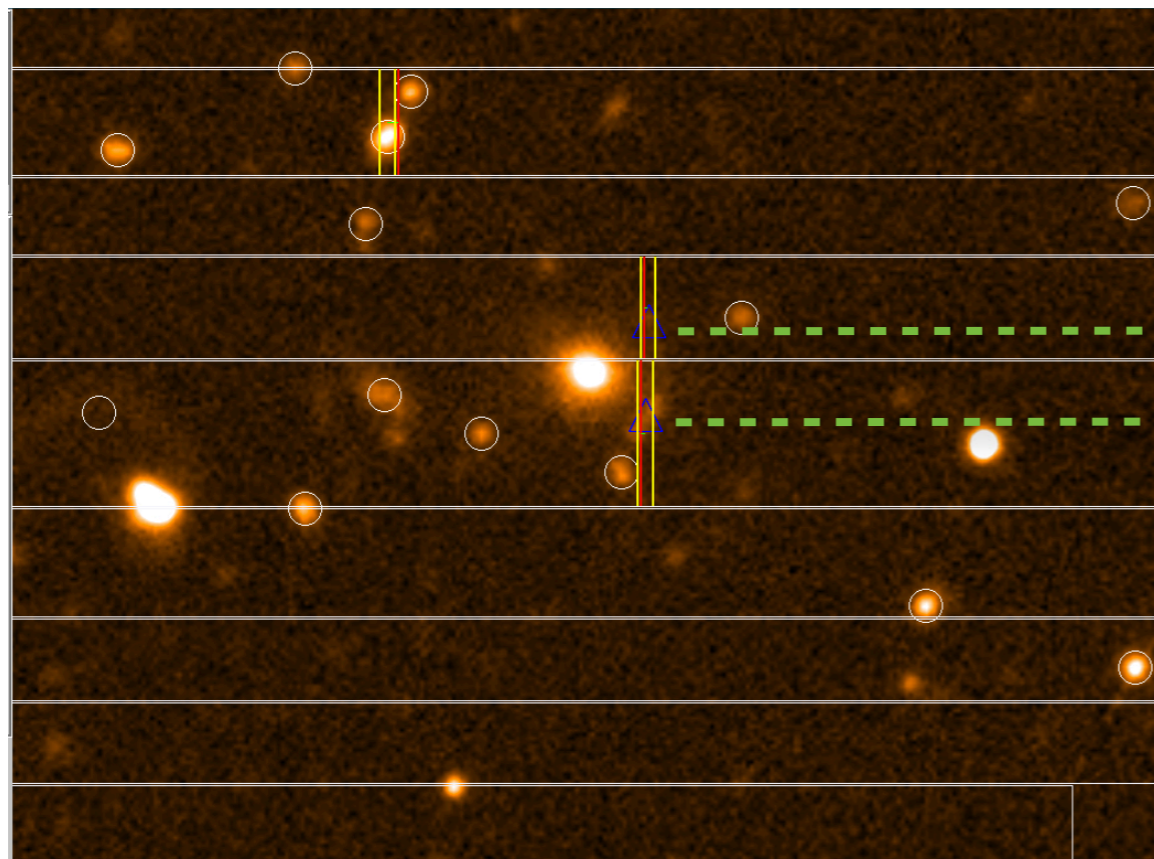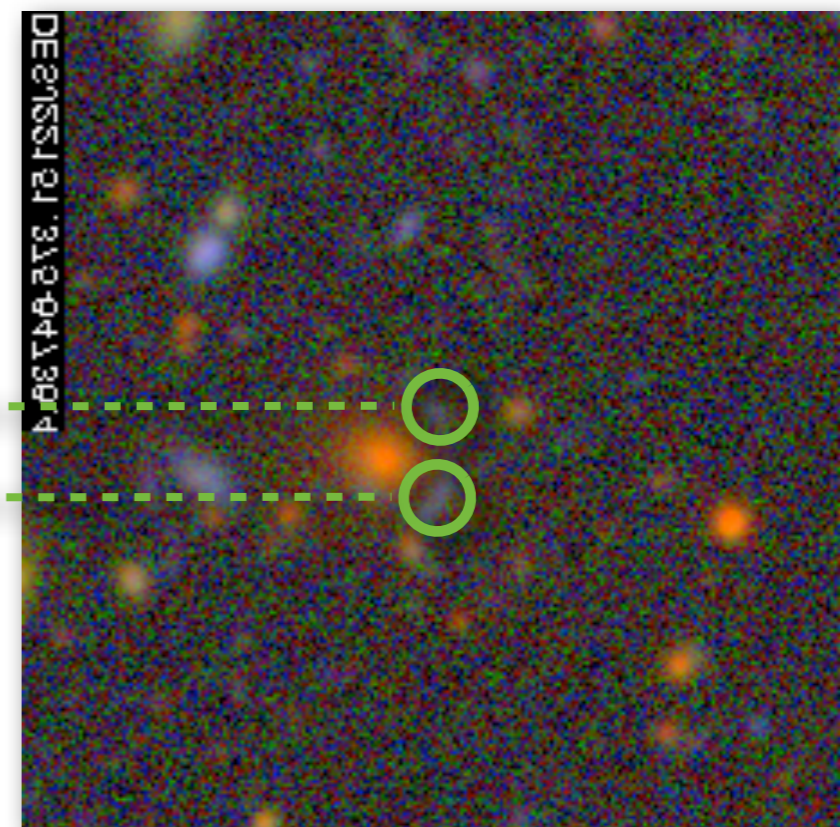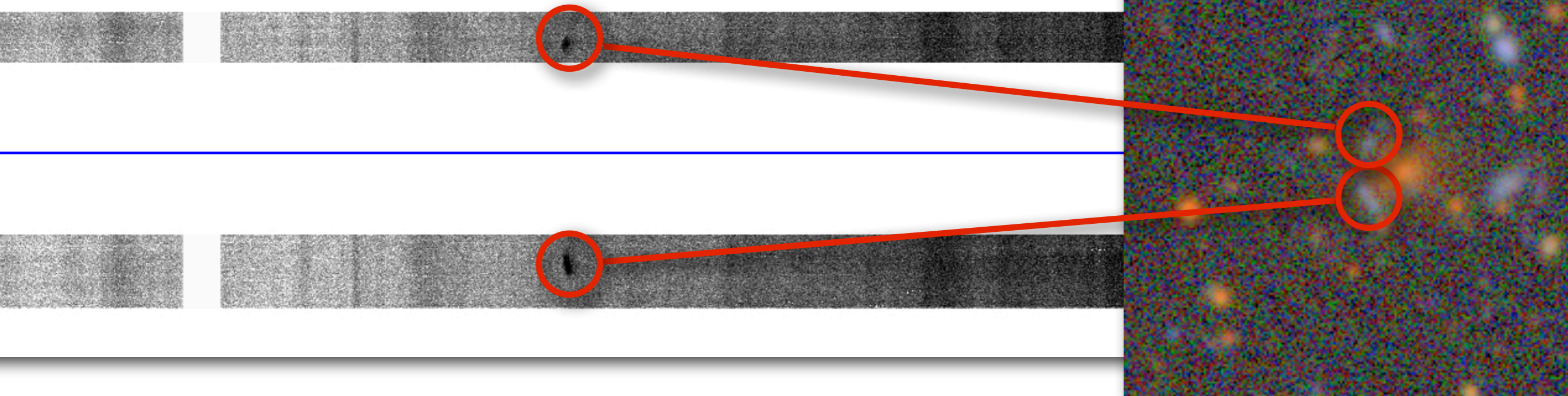Images on left (for mask-making) are created with gmmps

System 3 (DESJ022148.2-064600.4)
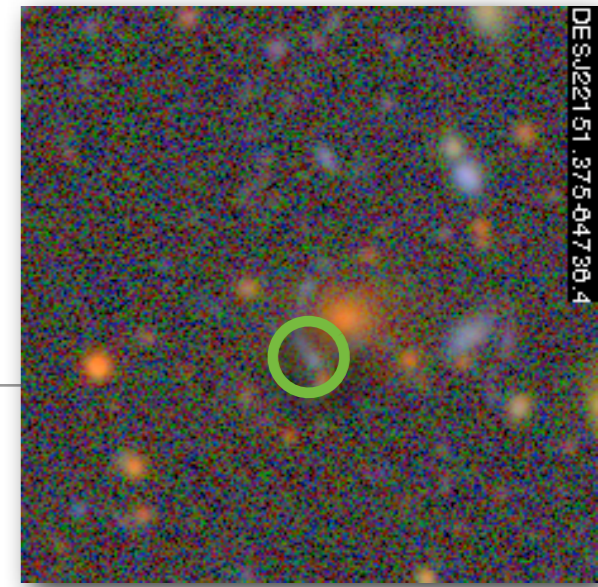## 2D spectra

These *are* the ~~droids~~
smudges you are looking for.

- **darkest** full lines: sky emission
- **slightly dark** horizontal line across full image: object continuum
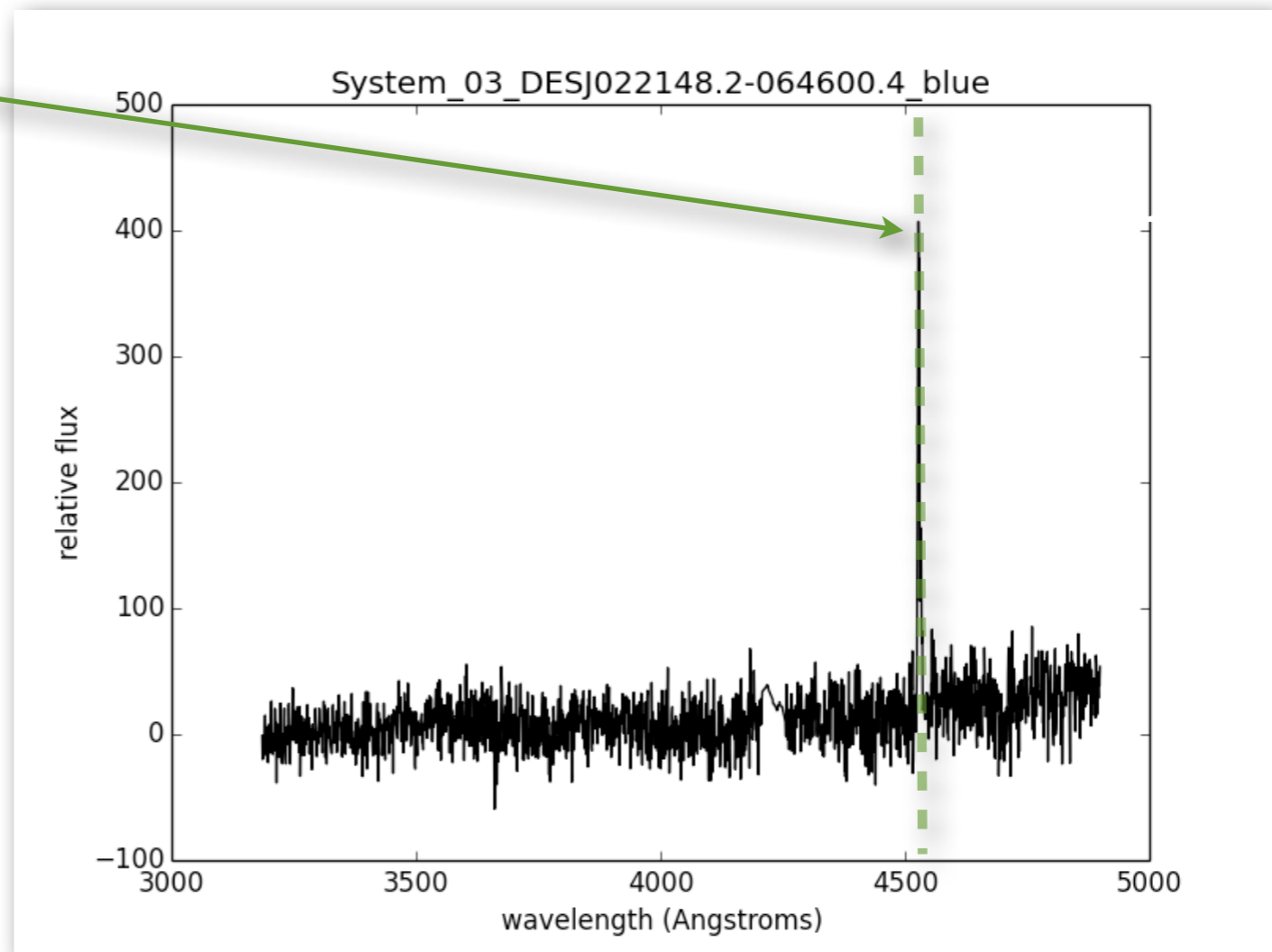- **small smudge** to near left chip gap (white block)

System 3 (DESJ022148.2-064600.4)
Spectral Features (blue grating)

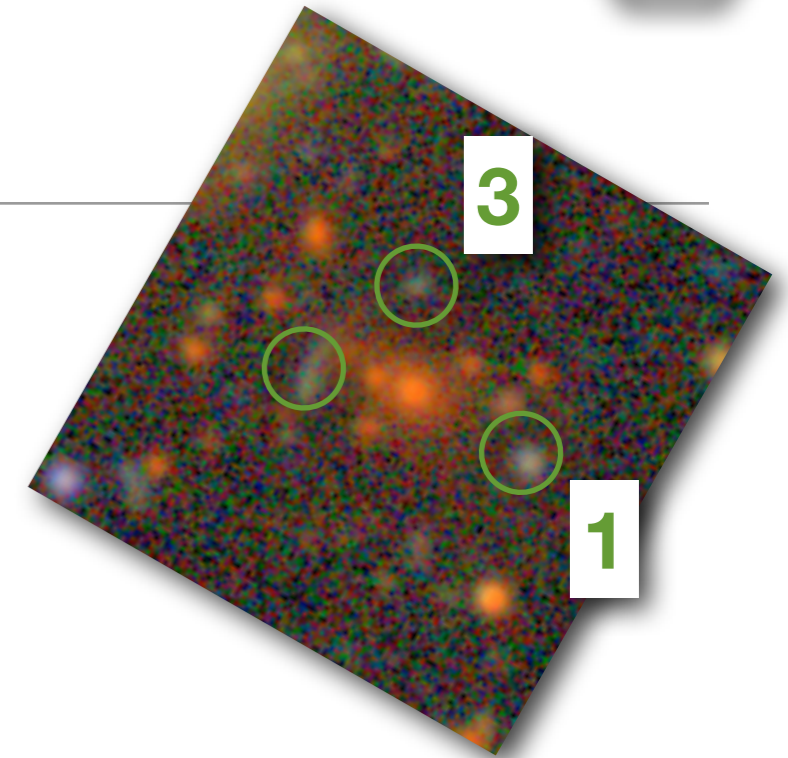

- Slit 2:
  - line: Lyα
  - source @ z = 2.72

status:
probable

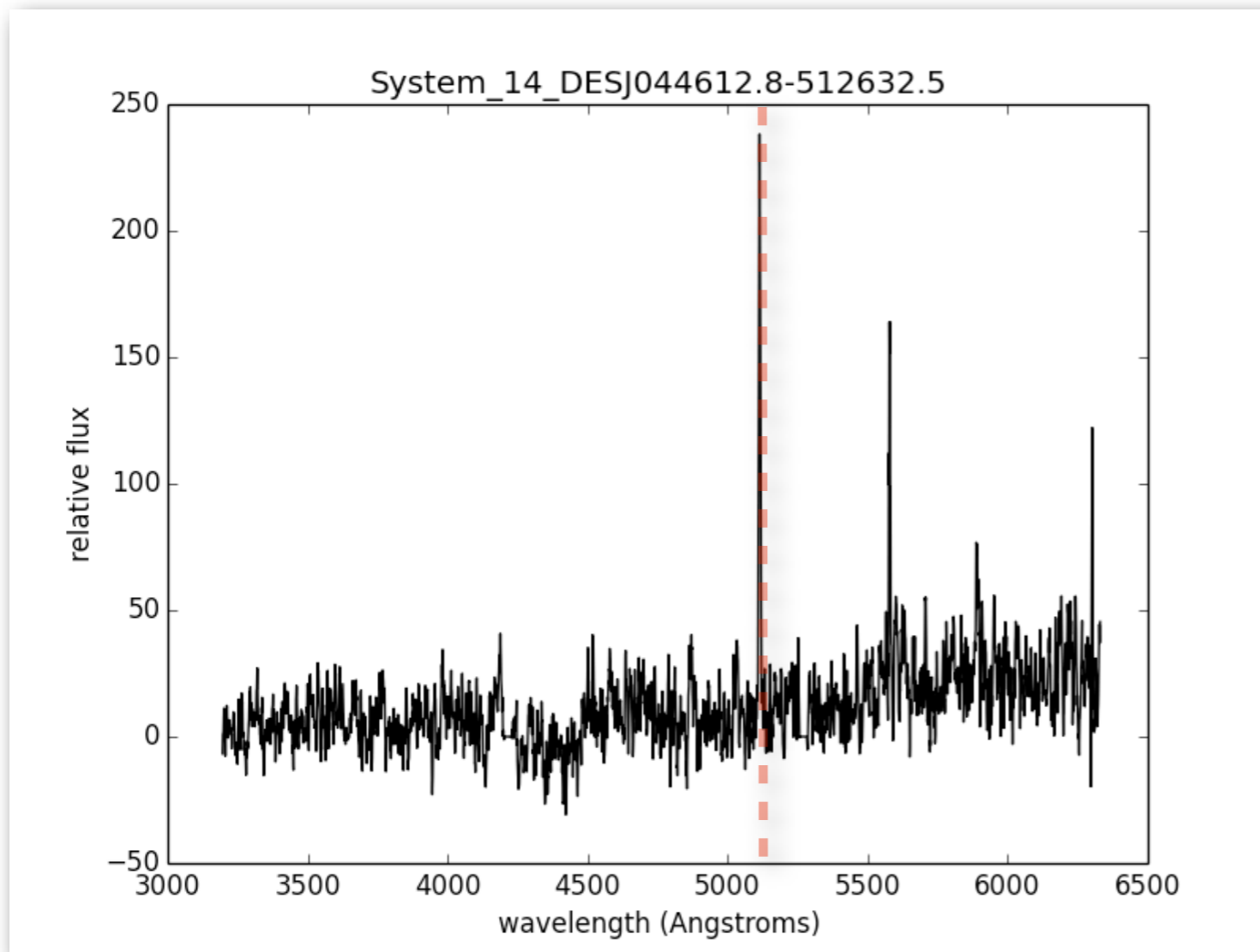# System 14 (DESJ044612.8-512632.5)
Spectral Features (blue grating)

- <u>Slits 1 and 3:</u>
  - line: $\lambda \sim 5200\text{Å}$ (Lyα)
  - z = 3.28
- lensing cluster at z = 0.7

3
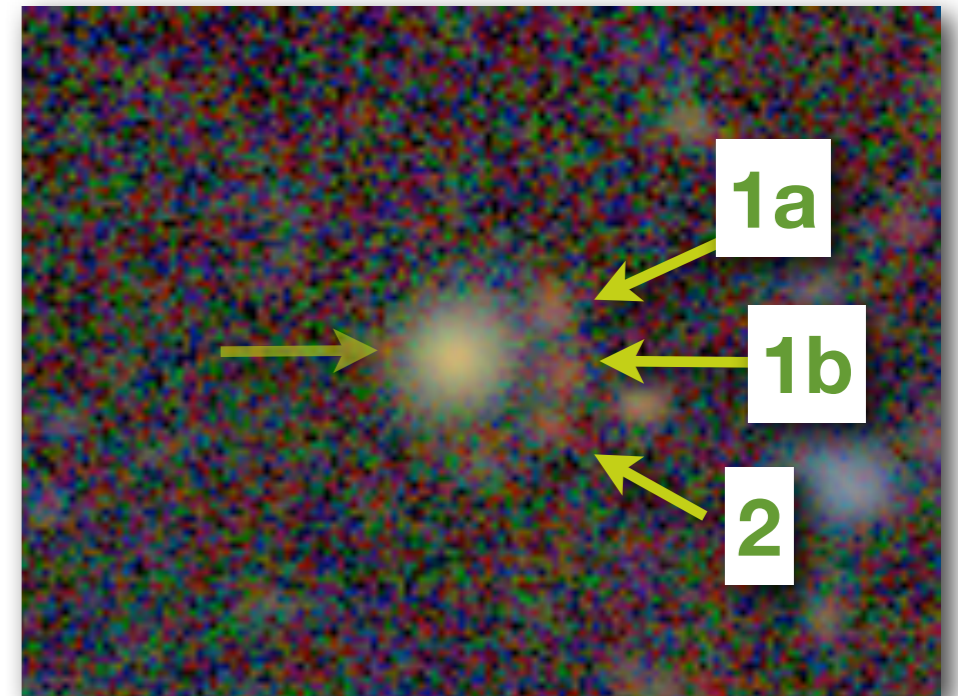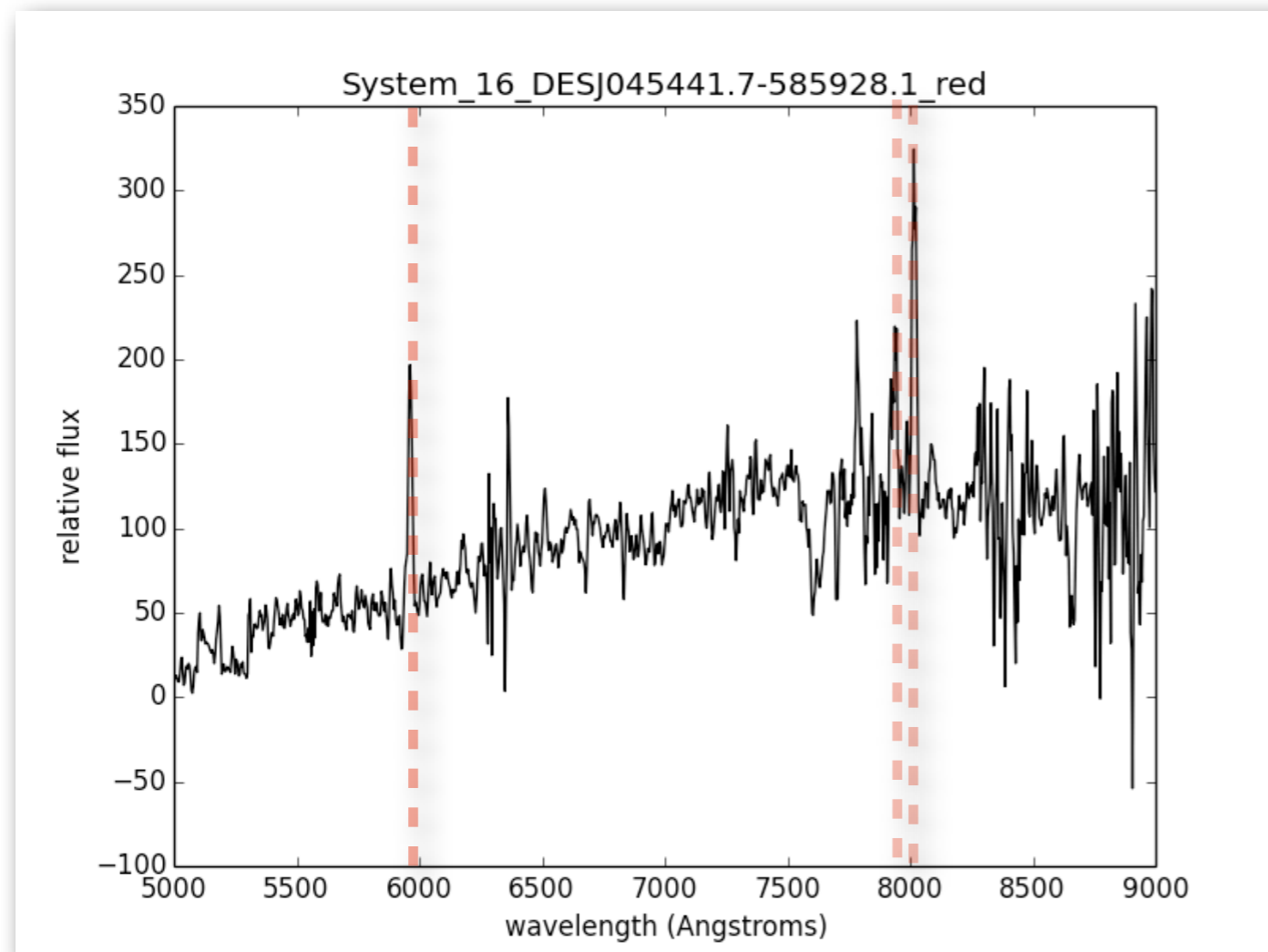
1

status:
  secure

System_14_DESJ044612.8-512632.5

System 16 (DESJ045441.7-585928.1)
Spectral Features (red grating)

- slit 1a:
  - $\lambda = 5963$Å (O_{3727}); 7934/8011Å ([OIII] 4959/5007Å)
- slit 1b: continuum, no lines
- slit 2: no continuum

System_16_DESJ045441.7-585928.1_red

- putative lens @ z ~ 0.3
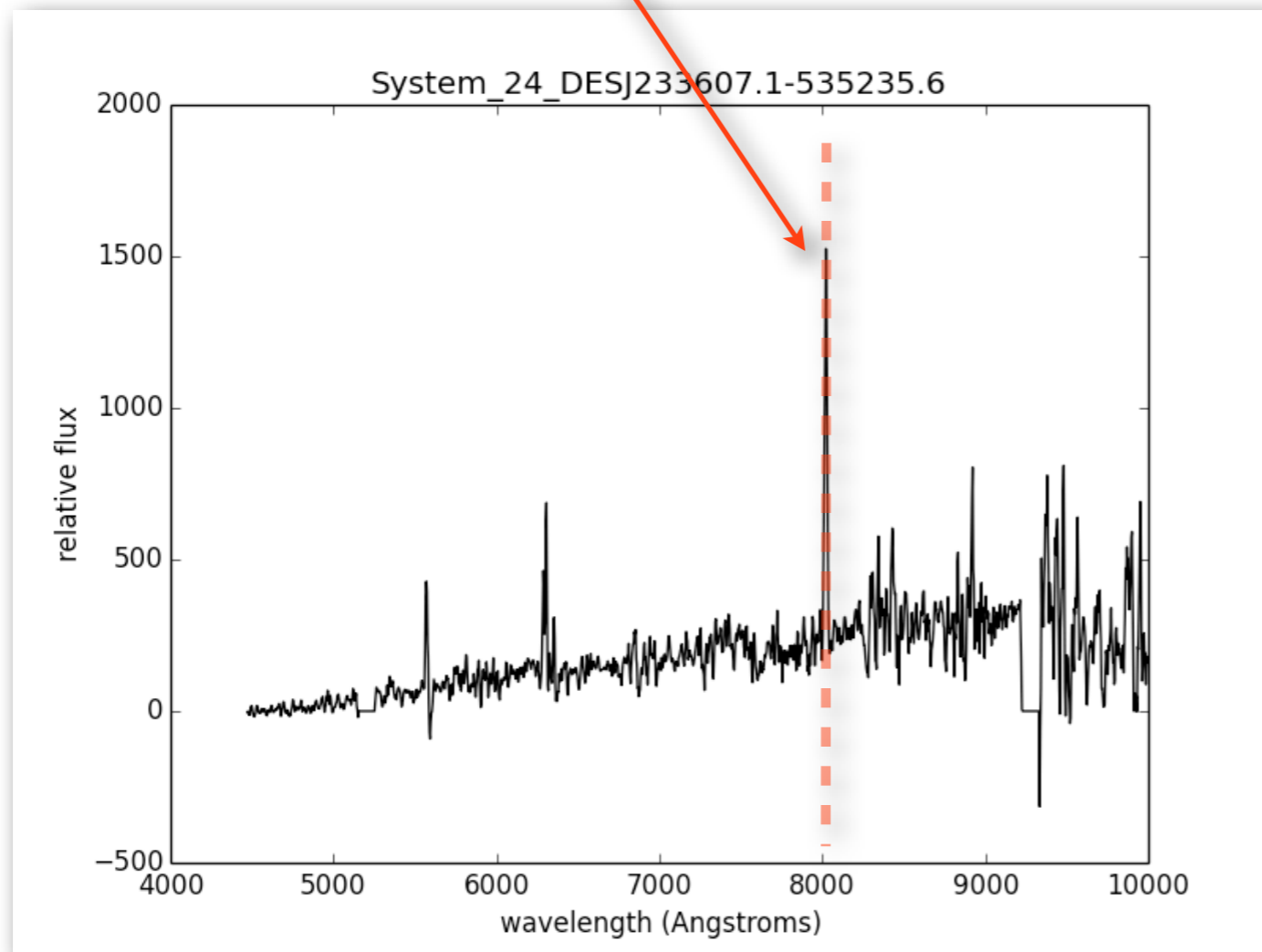- putative source z = 0.6
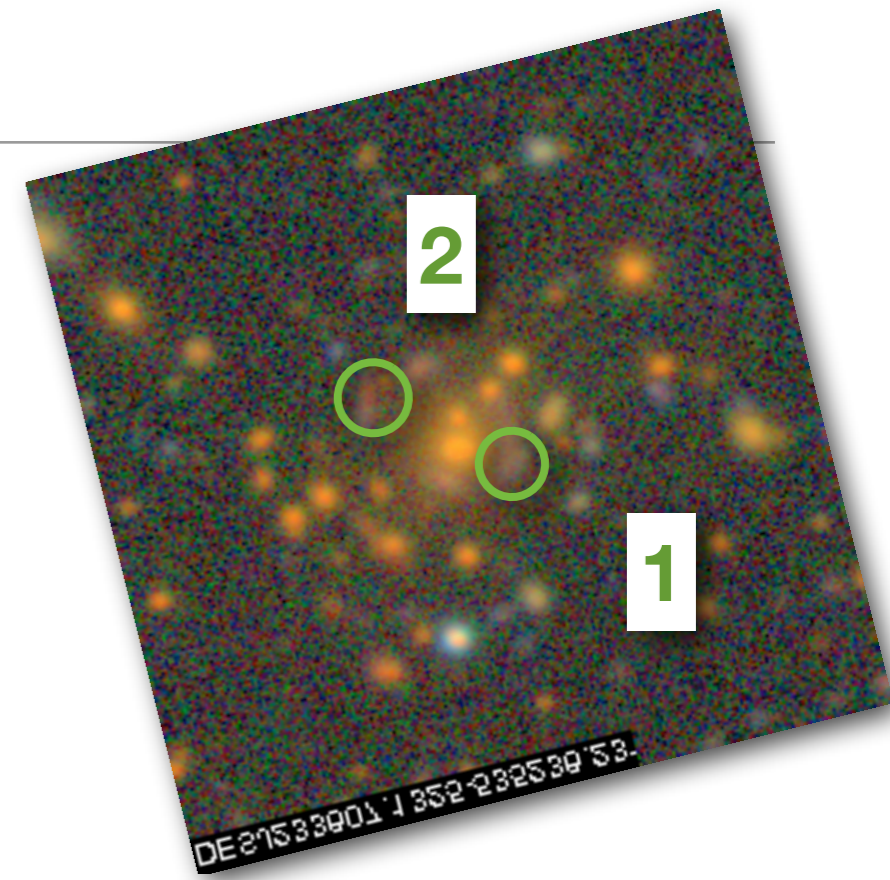
status:
  unlikely; probably a chance projection evidence (only features in one object, would be in all if a lens).

System 24 (DESJ233607.1-535235.6)
Spectral Features (red grating)

- <u>slit 1:</u> z = 0.897

- <u>slit 2:</u> z = 1.15 [OII]

- <u>lens:</u> z = 0.53

Known cluster from Souther Cosmology Survey, using Mosaic imager (Menentau et al., 2010)

<u>status:</u>
  secure

Summary

- <u>Lens count</u>

  - 6 systems are *probably* lenses: 1, 3, 5, 14, 23, 24

  - 1 systems are *probably not* lenses: 16

  - remaining candidates require further image reduction: e.g., stacking may reveal features

- <u>Automation</u> of image and redshift reductions with *PyRAF* has promise. There a are few hurdles: e.g., automated line calibration

- <u>Overall progress</u>

  - A number of interesting lensing candidates from the Science Verification data

    - Spectroscopic follow-up with our Gemini South LLP, AAT and Magellan

    - Starting some modeling using the DES images

  - The Y1 data release should yield:

    - Lots more arc candidates

    - First lensed QSO candidates

  - Increasing organization in our approach to analysis, data management and science output