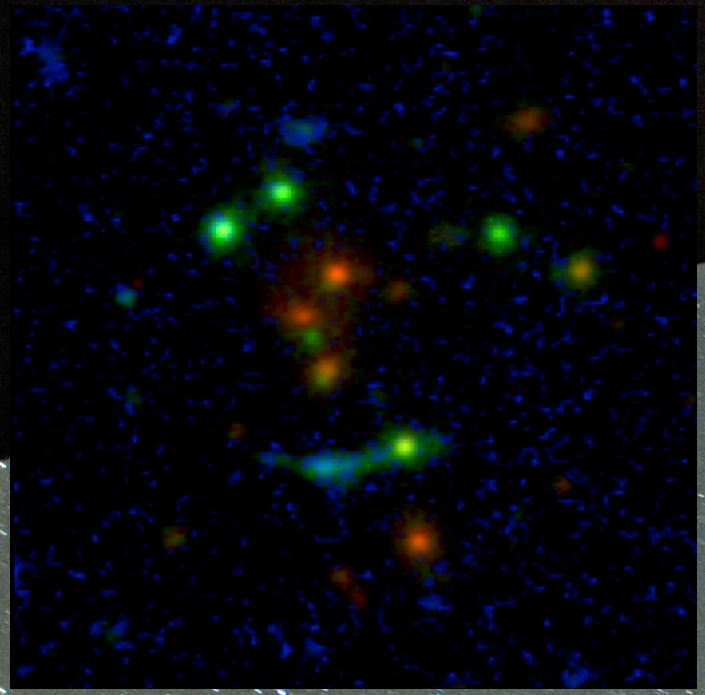


Discovery of a unique gravitational lens

- Playing to the strengths of NOT

Håkon Dahle (ITA, University of Oslo)

SDSS Giant Arcs Survey (SGAS)

Sloan Digital Sky Survey 2.5m telescope

SDSS Cluster Catalog

- ~ 70,000 galaxy clusters detected
- Photo-z's accurate to dz ~ 0.02
- 14,000 deg^2 in DR8 (Jan. 2011) 10 Gpc^3

- But SDSS imaging is too shallow (μ_g< 22 mag/□″) and seeing is too poor (FWHM ~ 1.4″) to confirm substantial #'s of arcs.
- Solution: Snapshot imaging survey of ~ 10^3 best lens candidates to z<0.55 from SDSS using the Nordic Optical Telescope.
- Probing ~ 70 times larger volume than any previous arc survey
- Currently working on extension to z<0.9 (SGAS2, ~0.25M l.o.s.)

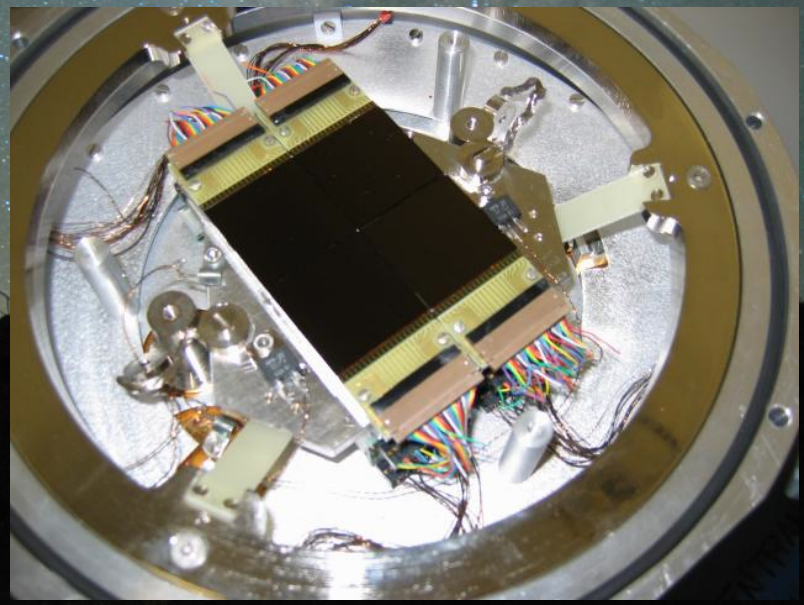
Visual search

M. Gladders (U. Chicago)

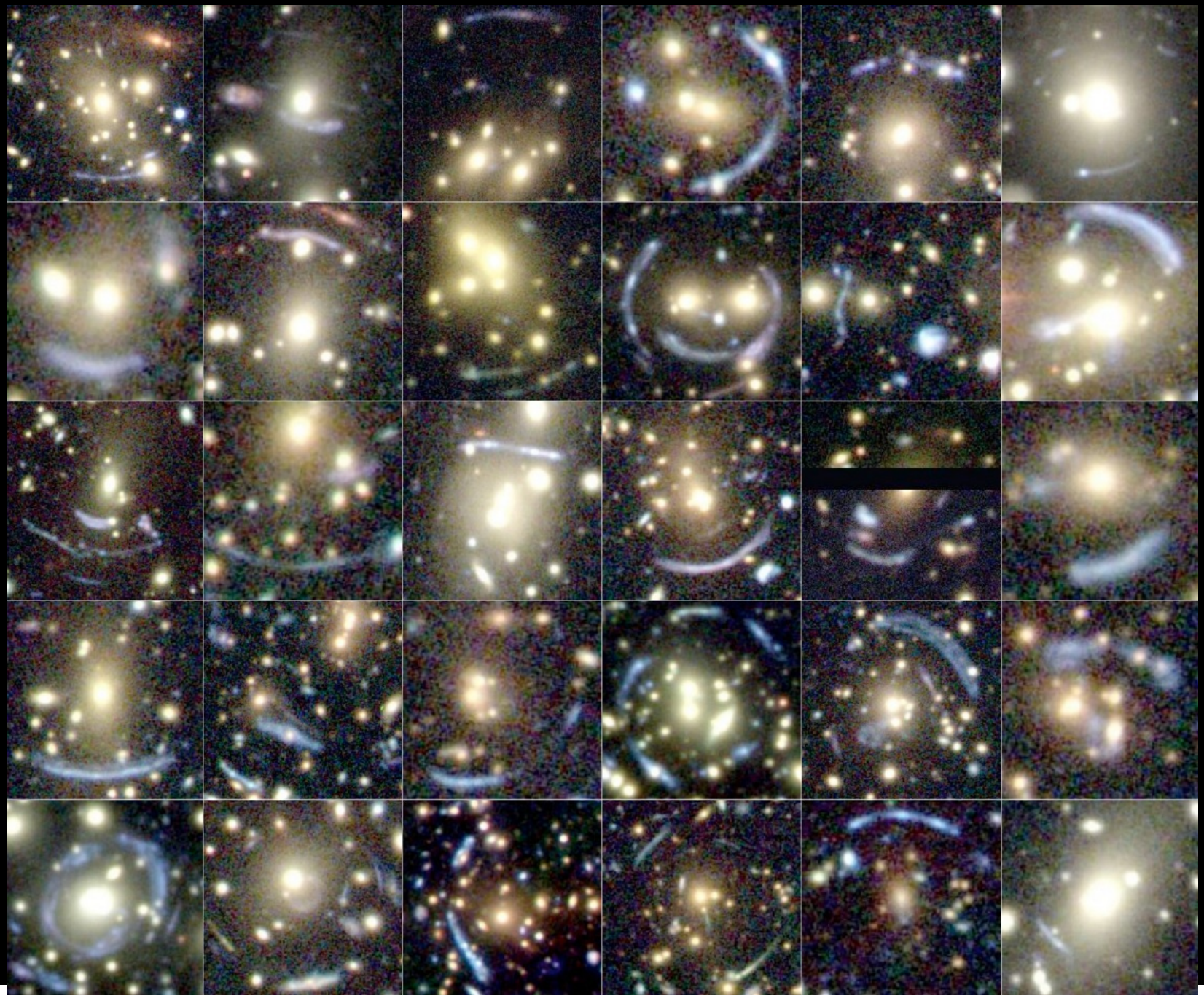
Why use NOT?

NOT + MOSCA ideally suited for strong lens survey:

- Blue sensitivity, throughput
- Small overheads for slewing and focusing
- Good image quality

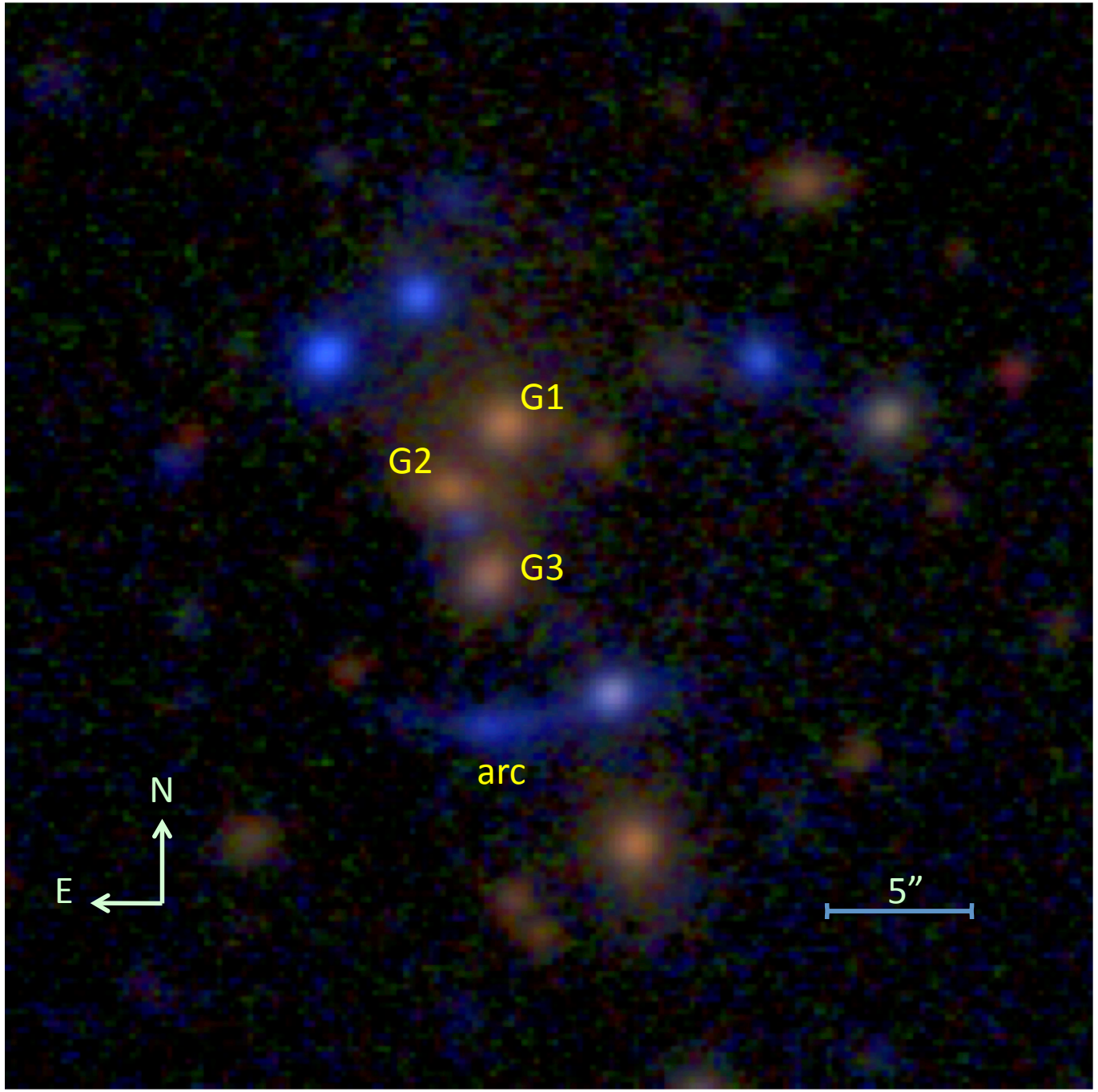


New Cluster Lenses

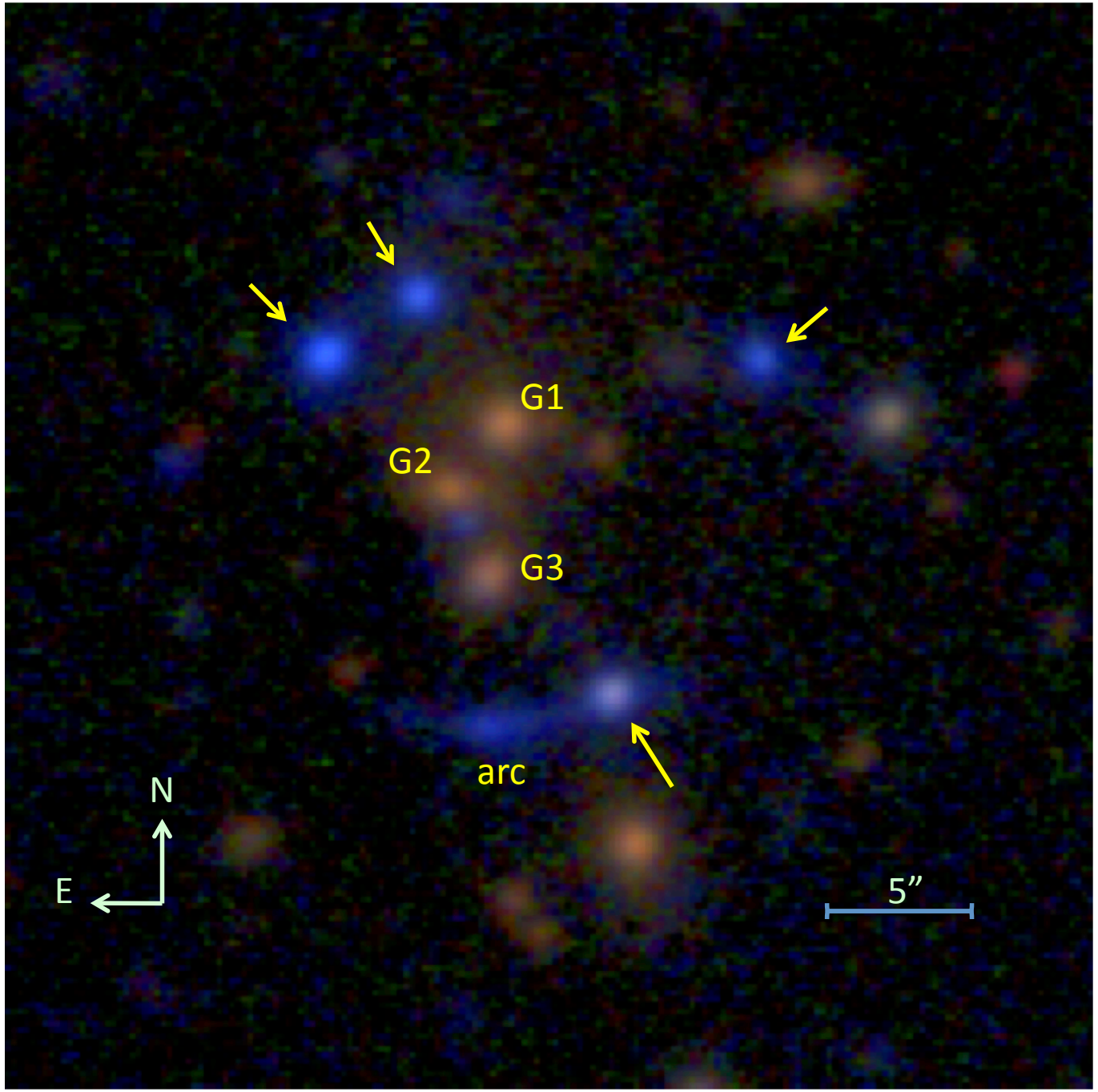


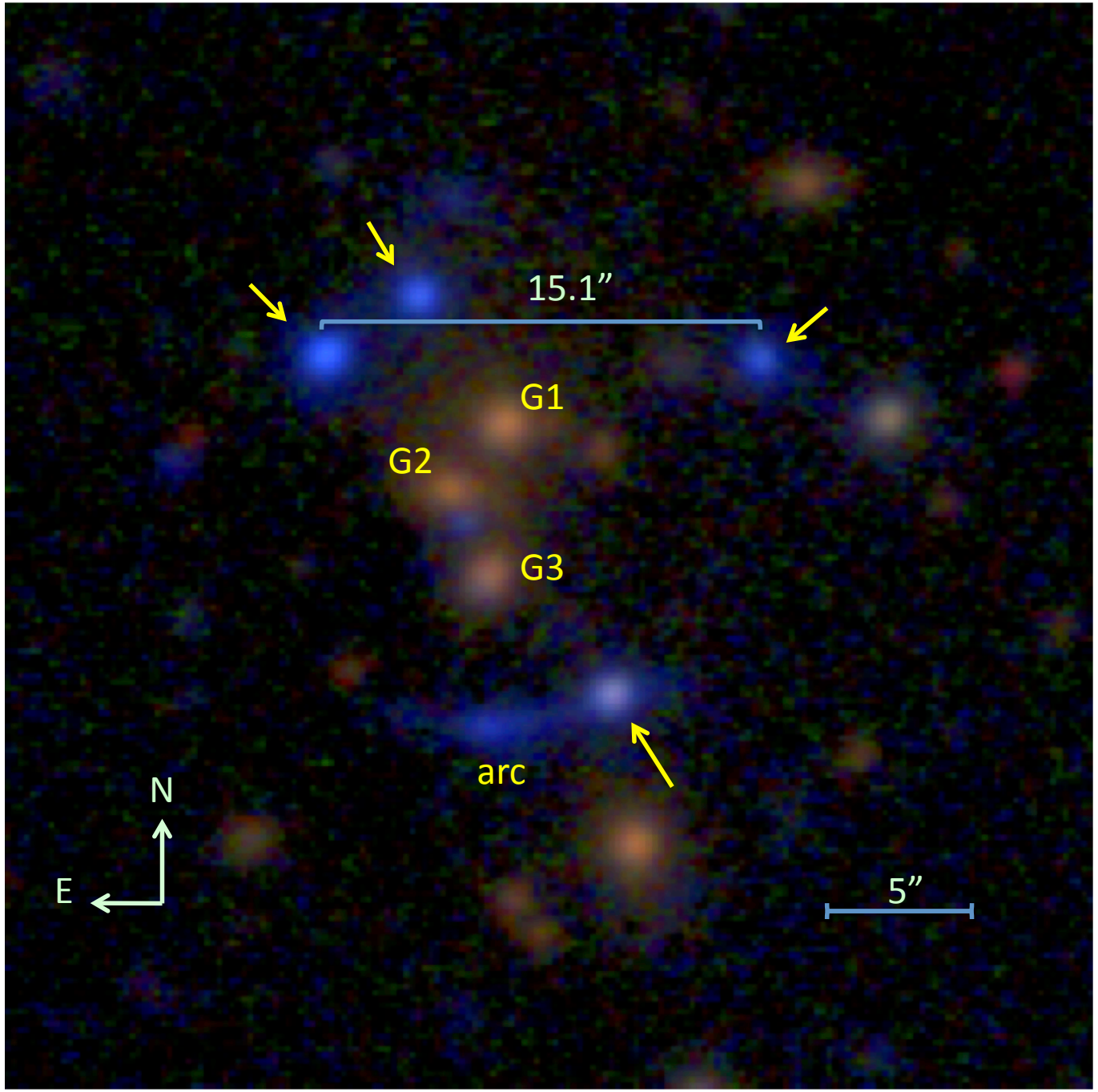
SGAS1 Survey

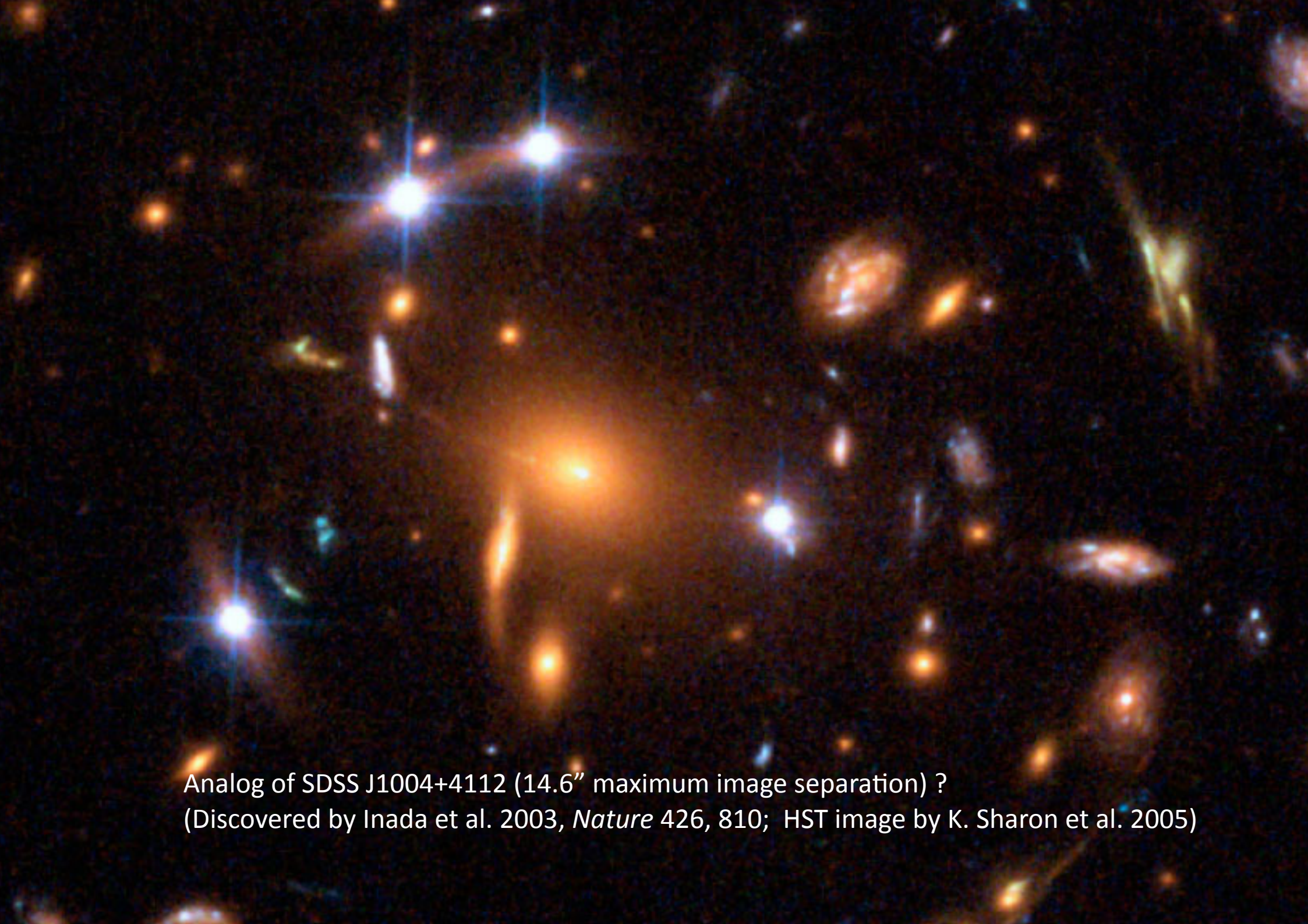
- ~1000 clusters imaged
- About 200 new cluster lenses discovered, including many spectacular systems
- The bright arcs we discover are ideally suited for spectroscopic follow-up!
- Spectroscopy to obtain arc redshifts at Gemini, Magellan, Keck, APO 3.5m, NOT…
- Wide-field imaging using Subaru Suprime-Cam (Oguri et al. 2012), weak lensing mass measurements
- HST Cycle 20 large programme (107 orbits) to image 73 arcs in 37 clusters, to spatially resolve star formation down to ~100pc @ z=1-3, + much else…



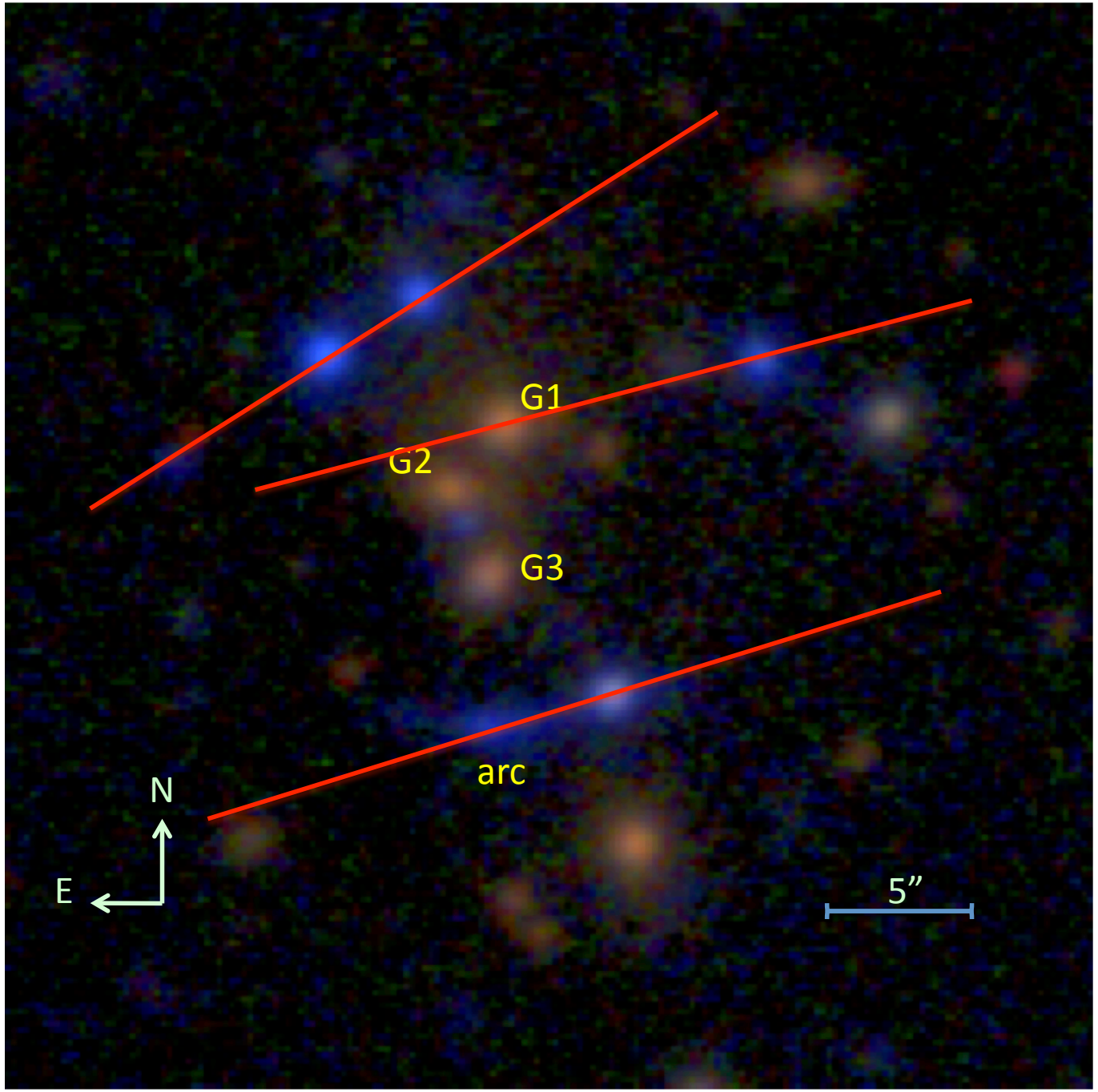
MOSCA SGAS survey image (2x300s g, 2x150s r, 2x150s i), September 2011


G1
G2
G3
arc
N
E
5”


15.1”
G1
G2
G3
arc
N
E
5”

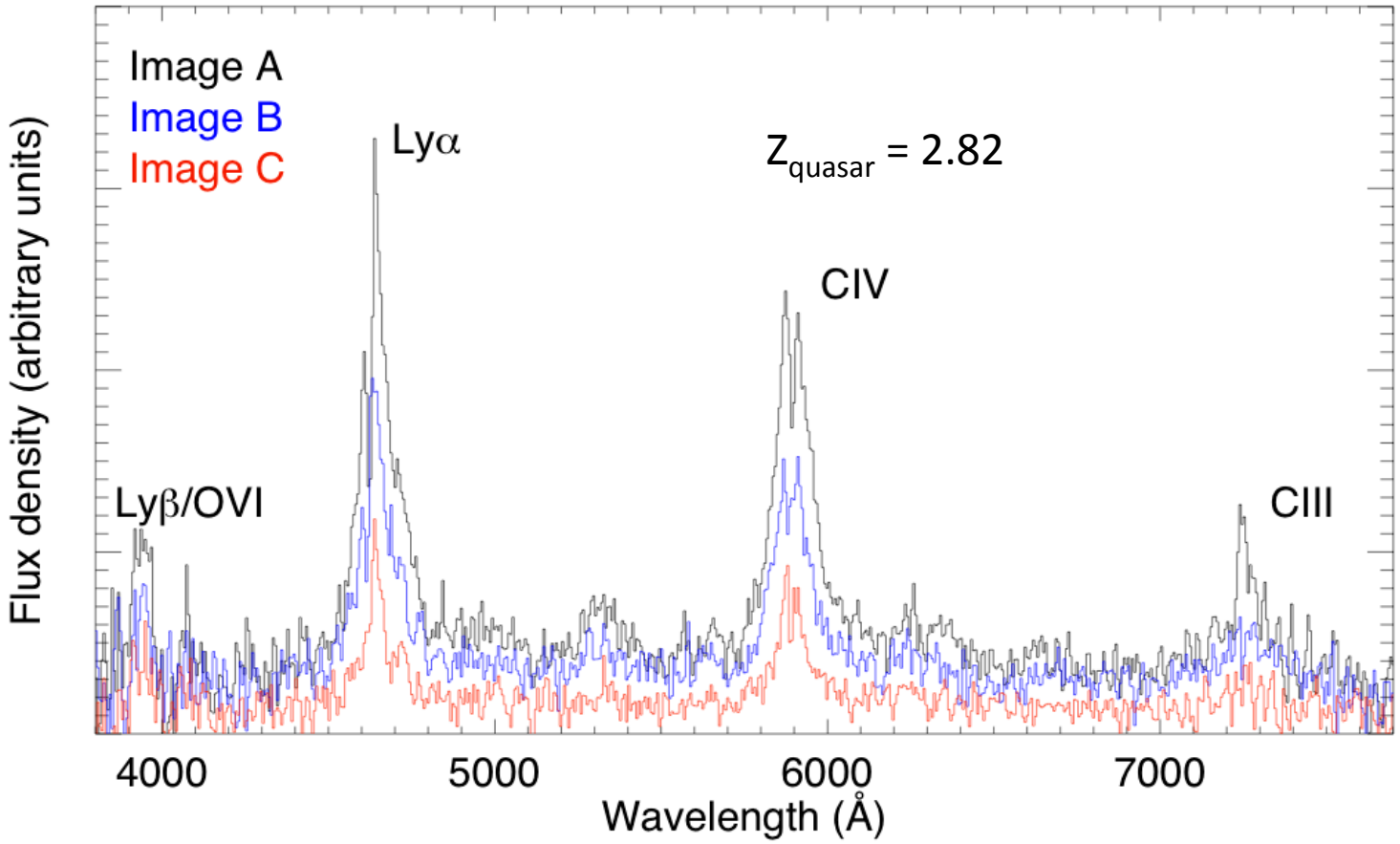


Analog of SDSS J1004+4112 (14.6” maximum image separation) ?
(Discovered by Inada et al. 2003, *Nature* 426, 810; HST image by K. Sharon et al. 2005)

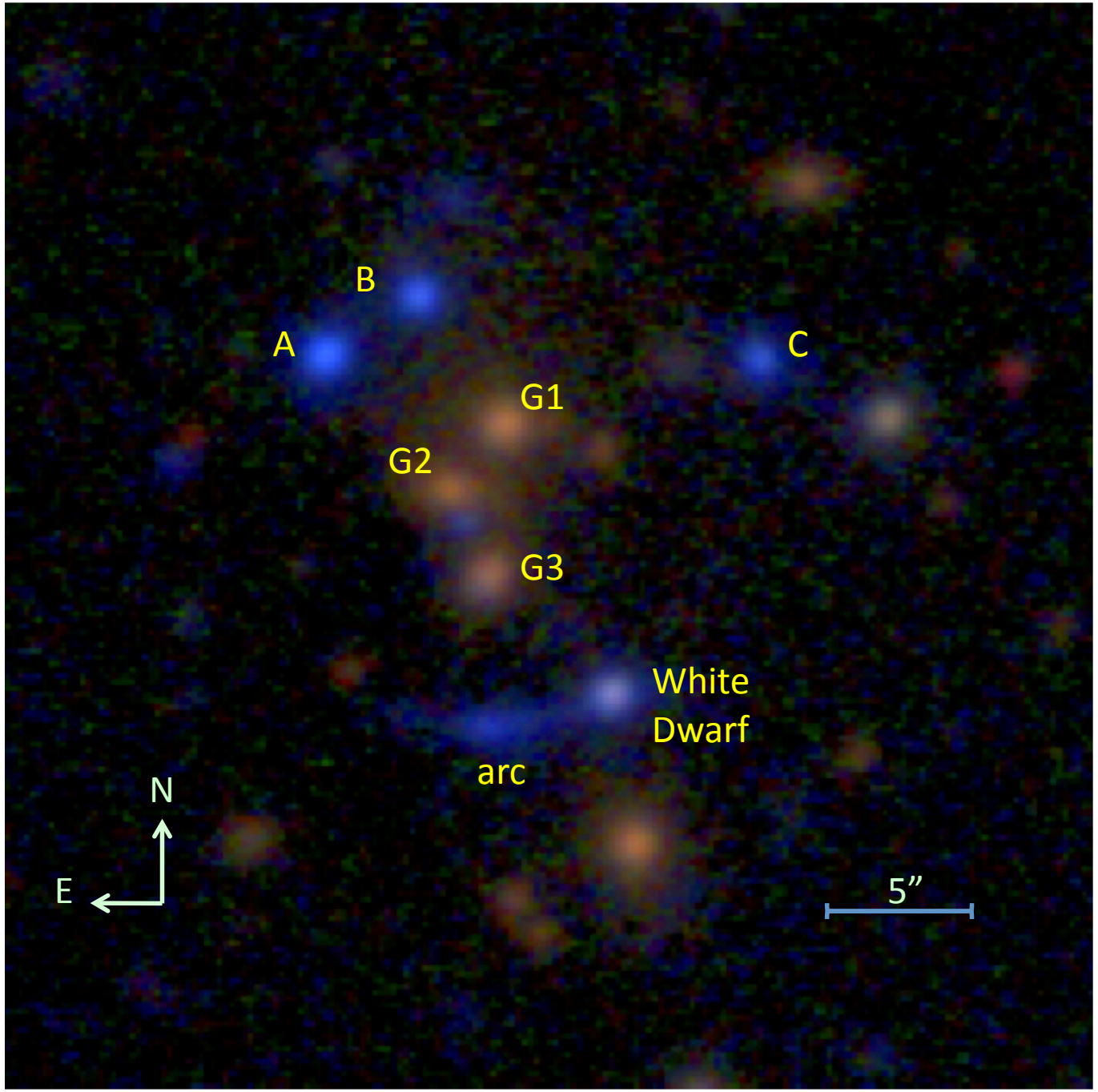


ALFOSC spectroscopy obtained in August 2012 during Copenhagen University observational astronomy course at NOT.

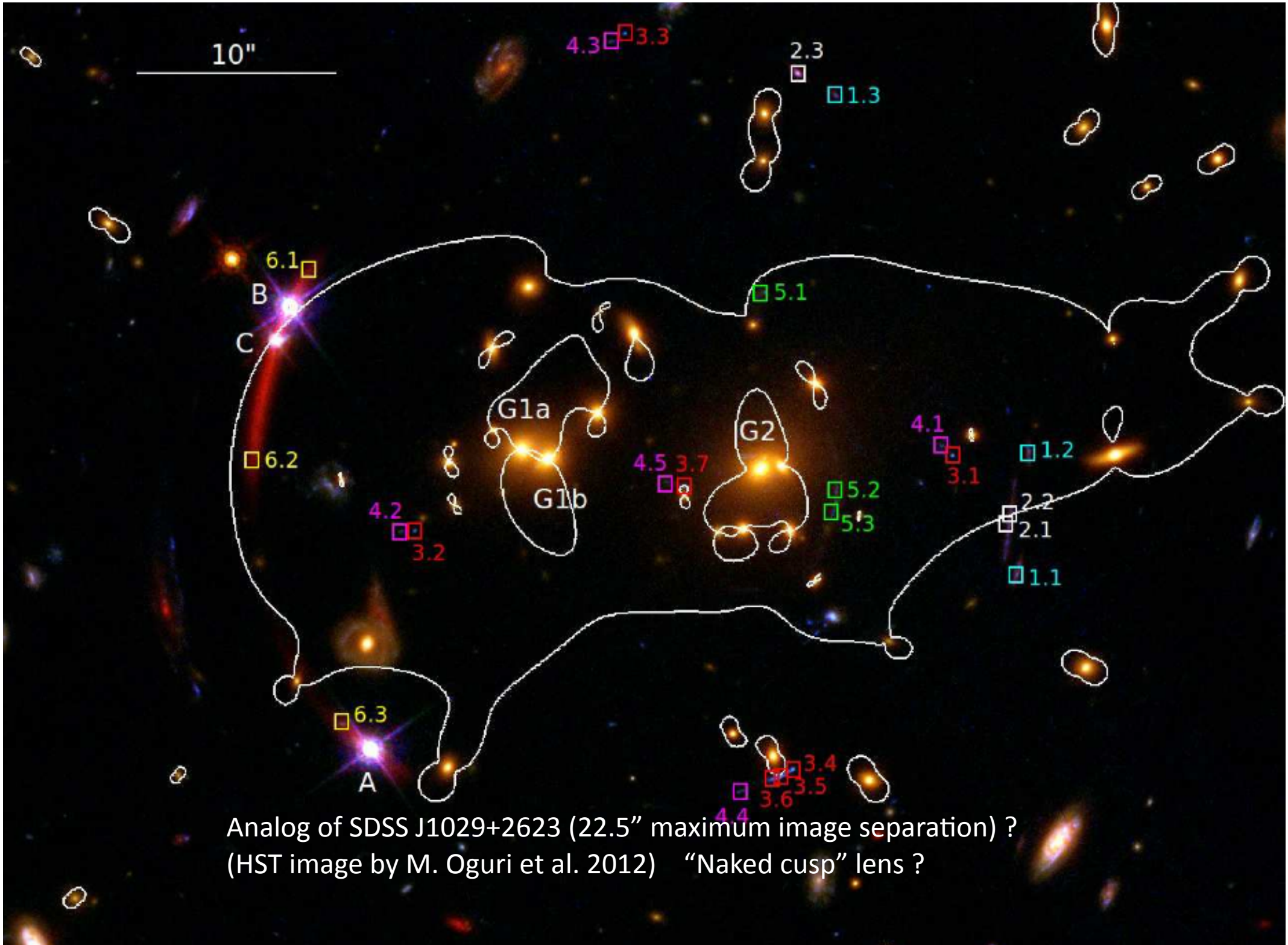
It’s a lens !!



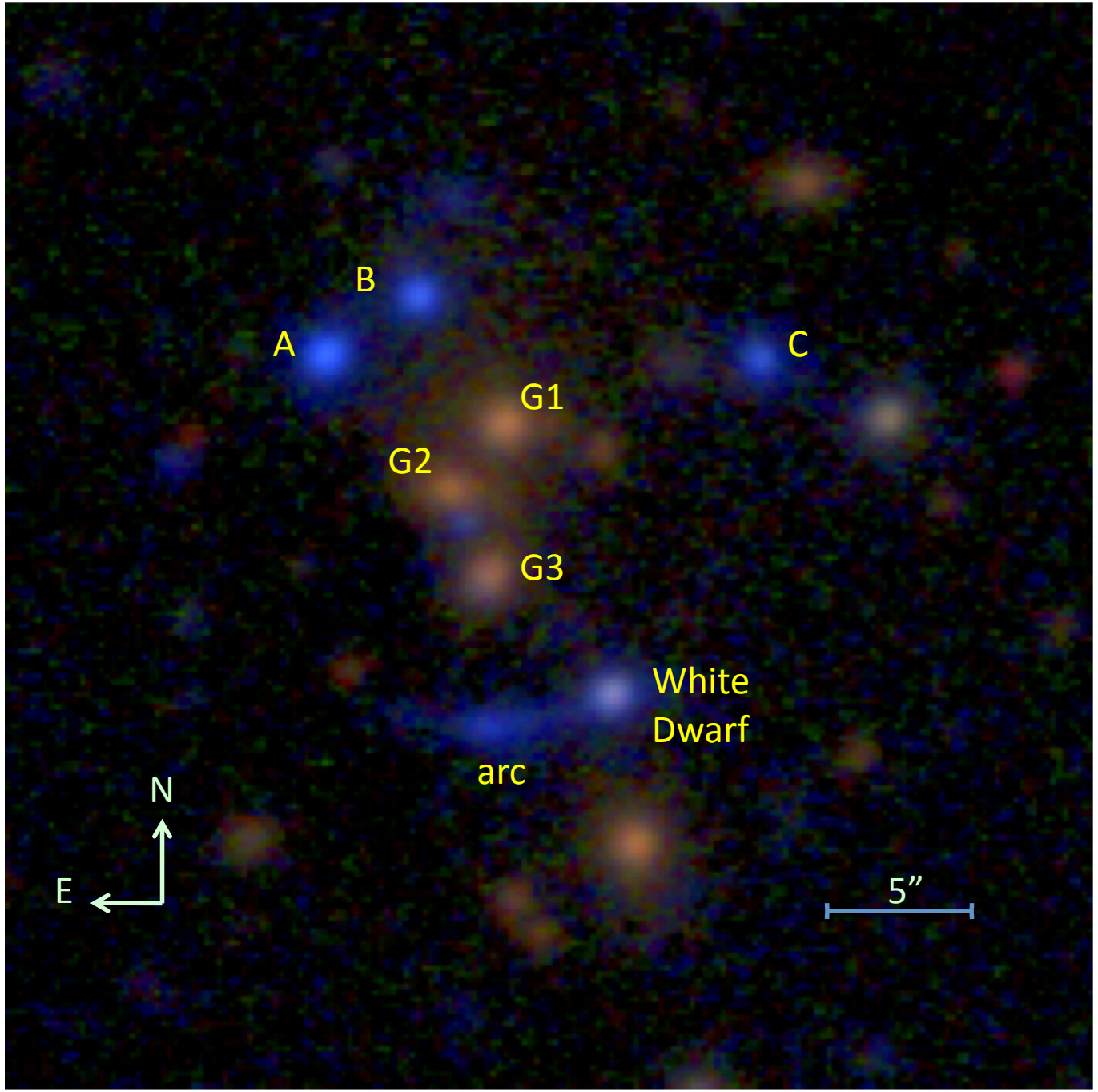
Johan Fynbo + Copenhagen students



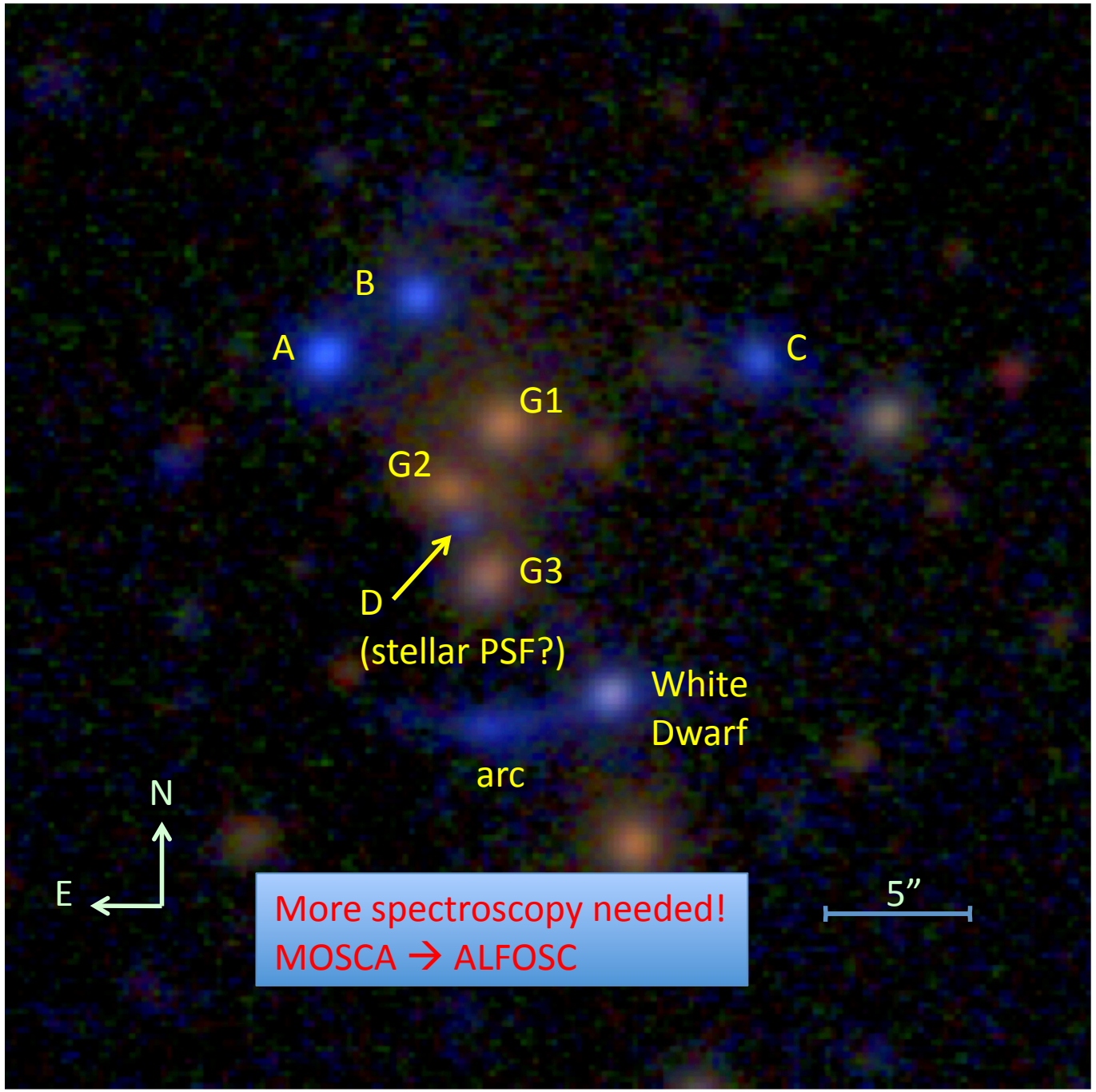
QSOlens

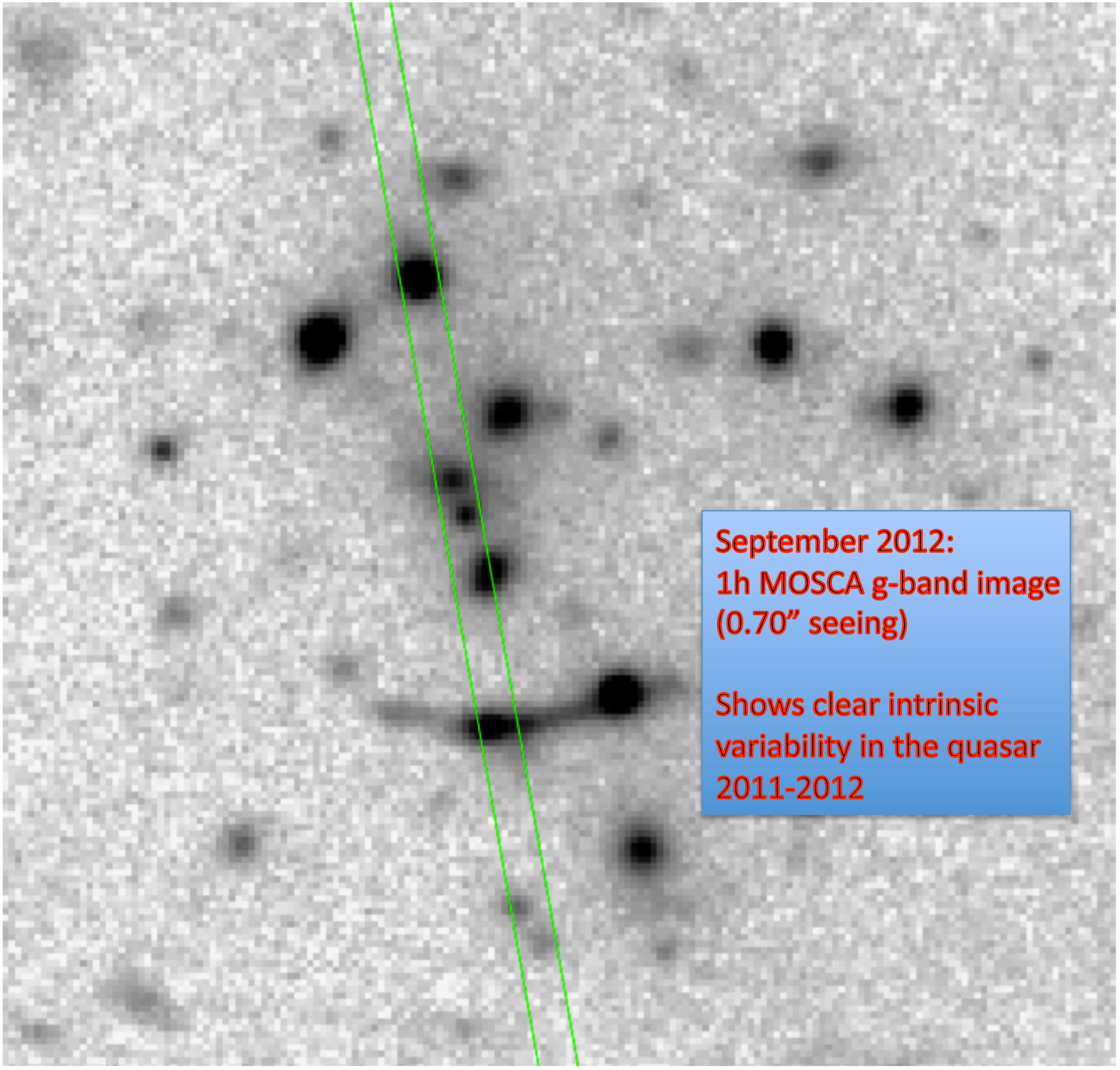


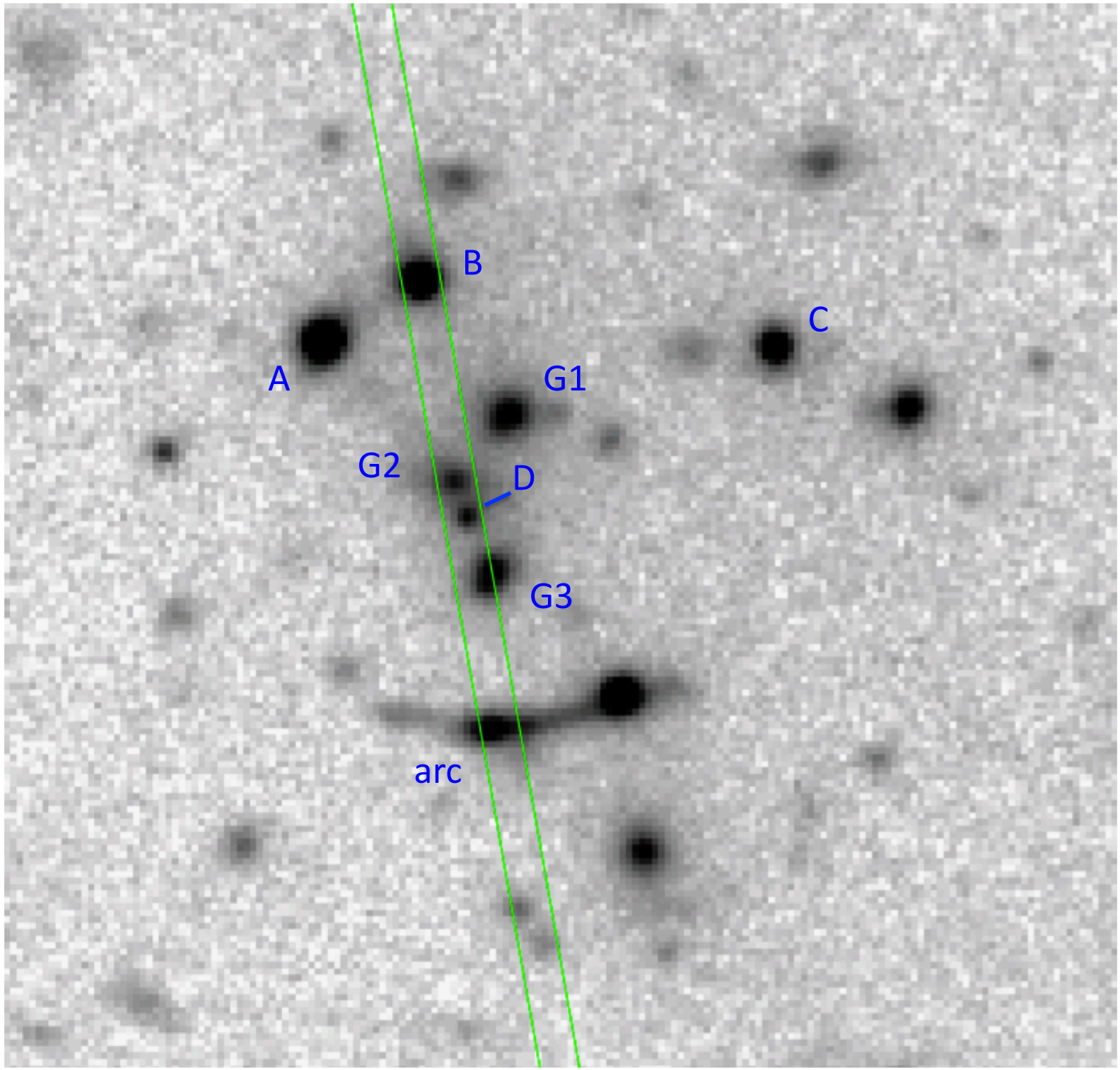
Analog of SDSS J1029+2623 (22.5” maximum image separation) ?
(HST image by M. Oguri et al. 2012) “Naked cusp” lens ?

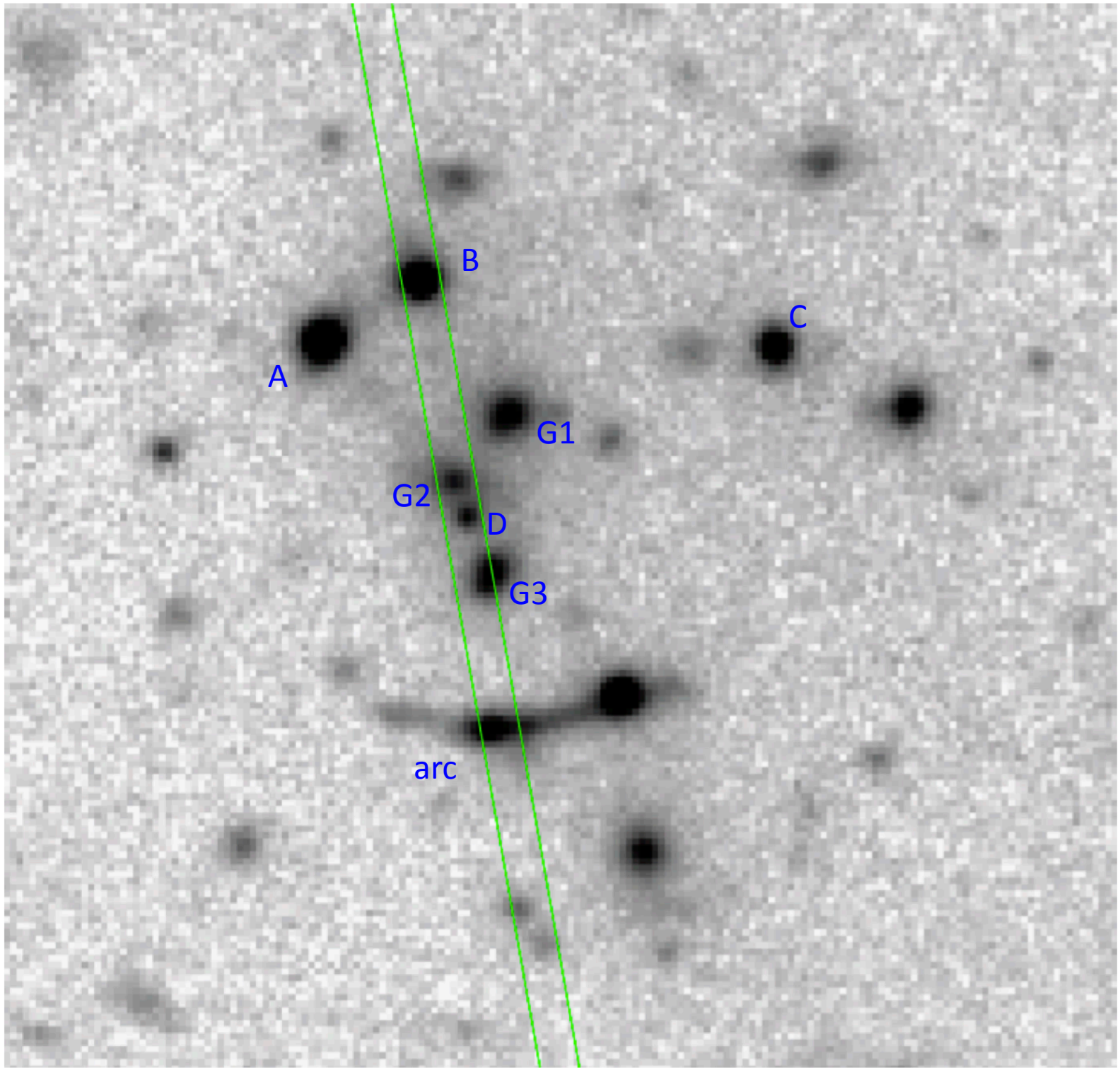


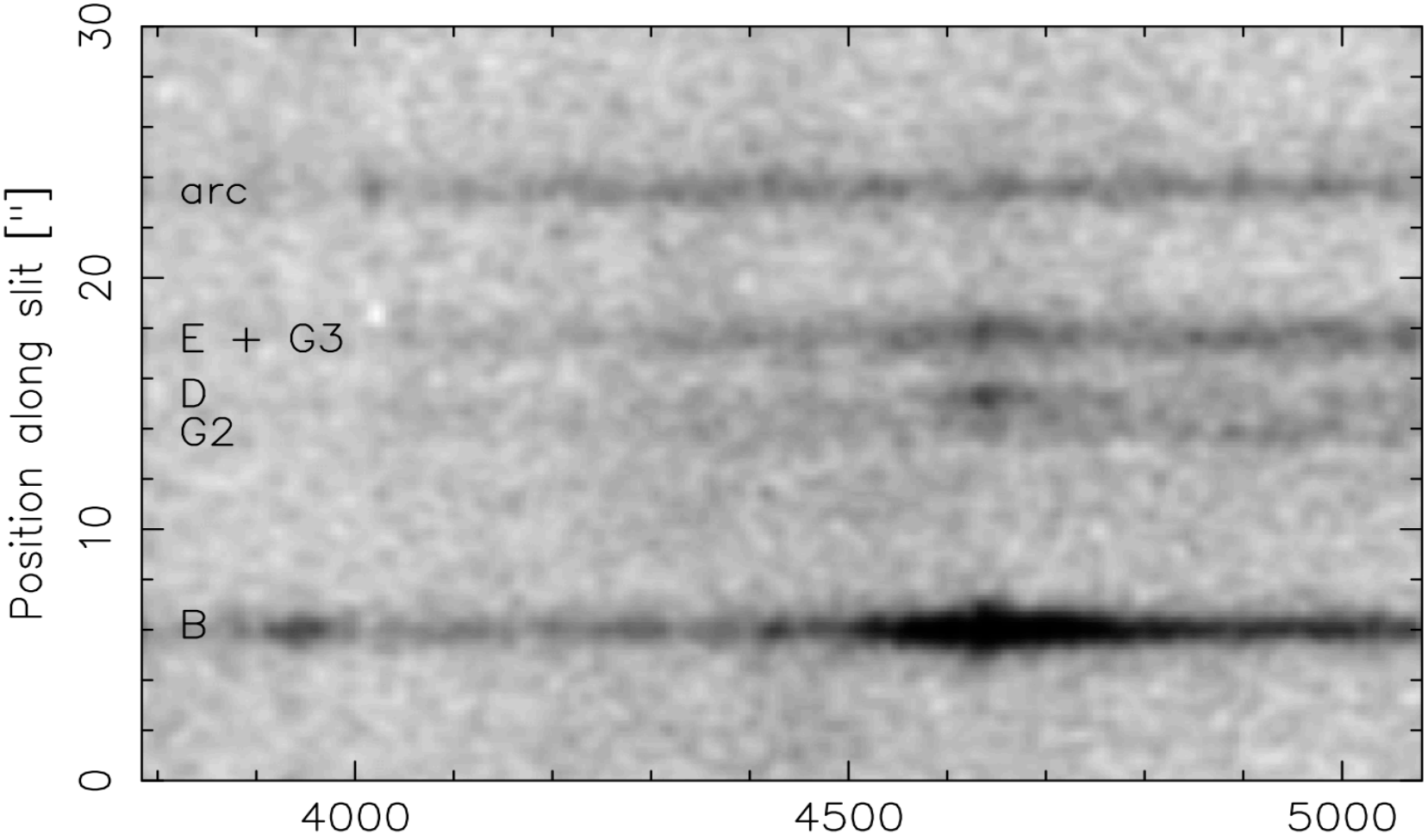
QSOlens


B
A
C
G1
G2
G3
D
(stellar PSF?)
White
Dwarf
arc
N
E
More spectroscopy needed!
MOSCA → ALFOSC
5”

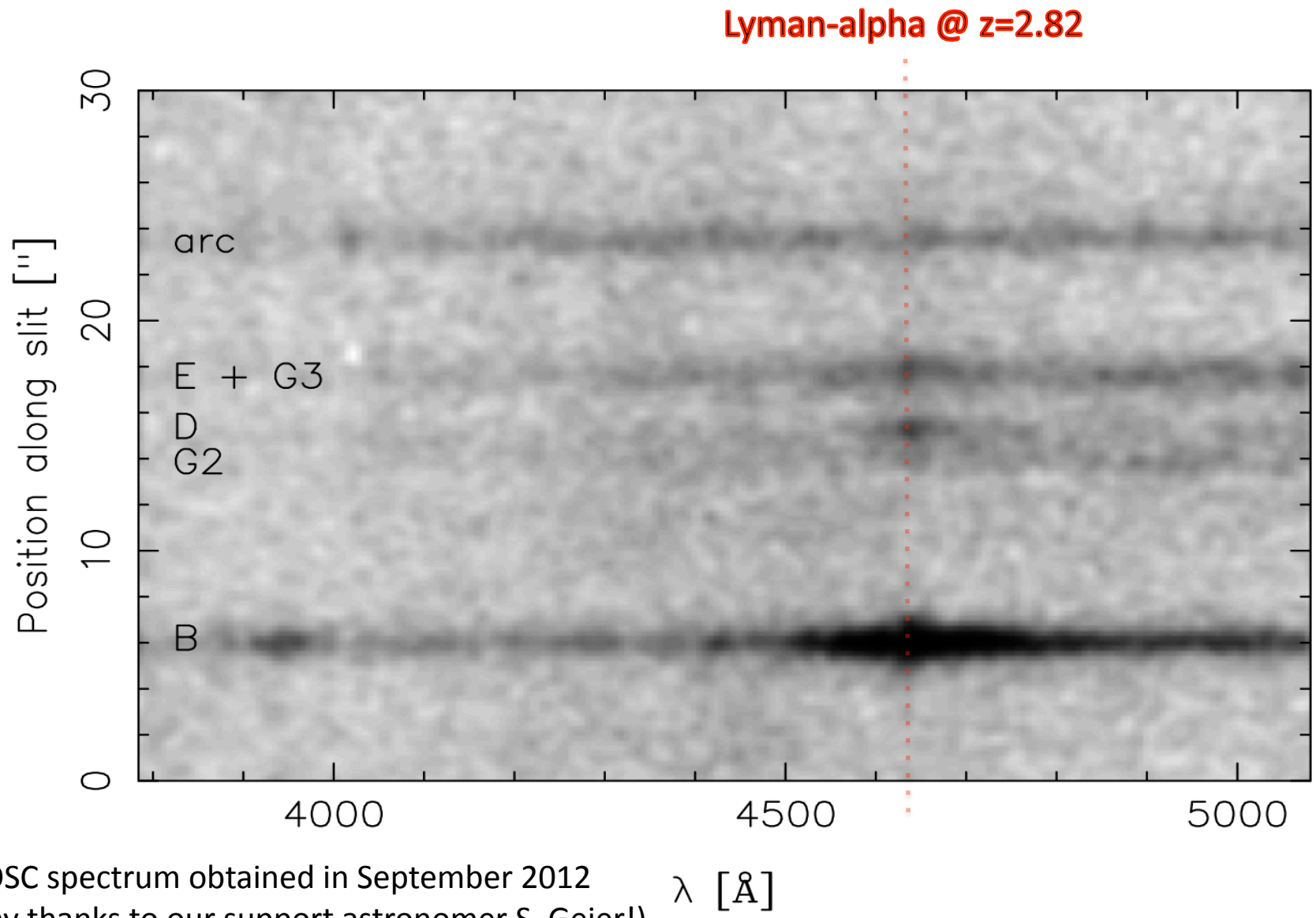

September 2012:
1h MOSCA g-band image
(0.70” seeing)
Shows clear intrinsic
variability in the quasar
2011-2012


B
C
A
G1
G2
D
G3
arc


B
C
A
G1
G2
D
G3
arc



ALFOSC spectrum obtained in September 2012
(many thanks to our support astronomer S. Geier!)



ALFOSC spectrum obtained in September 2012
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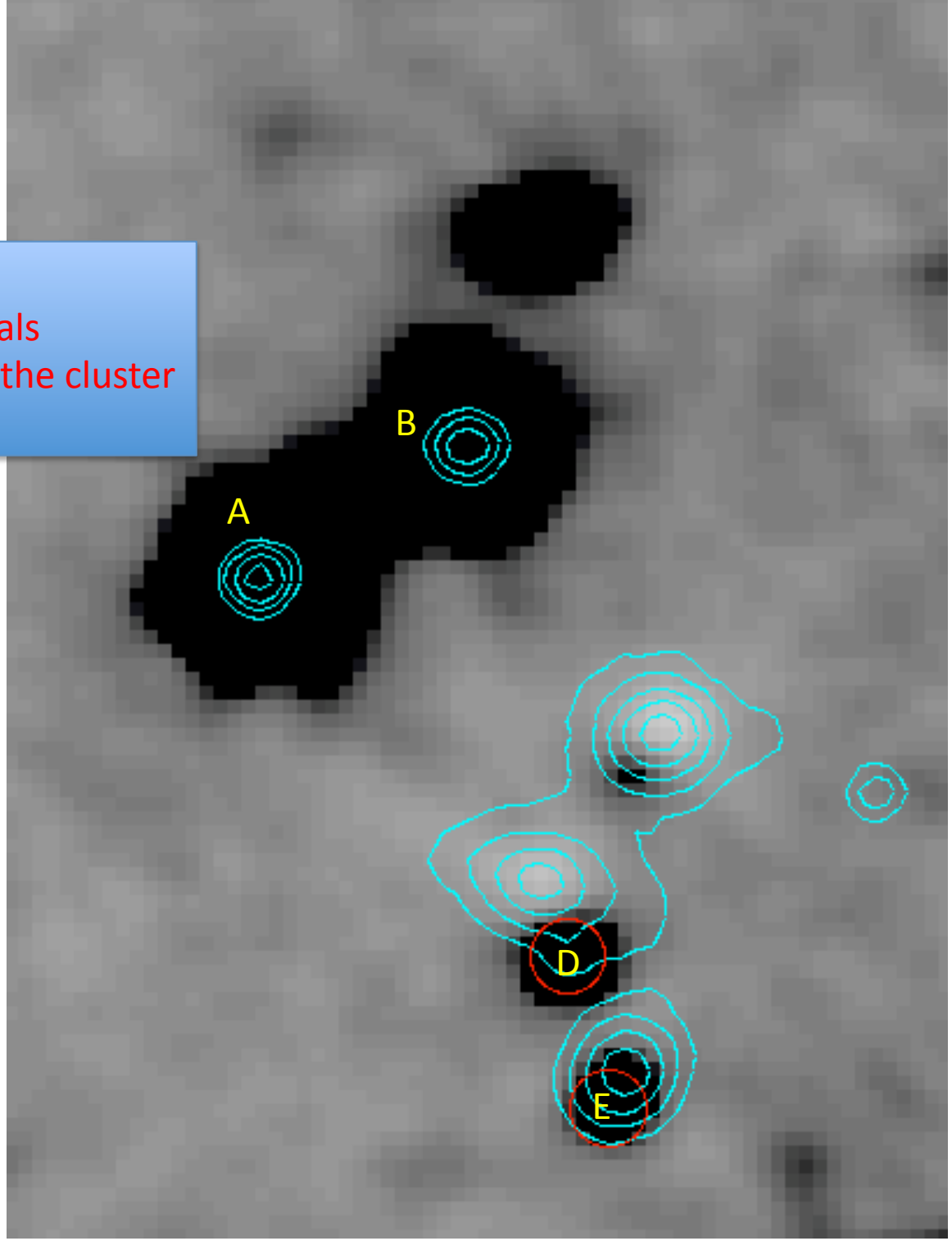
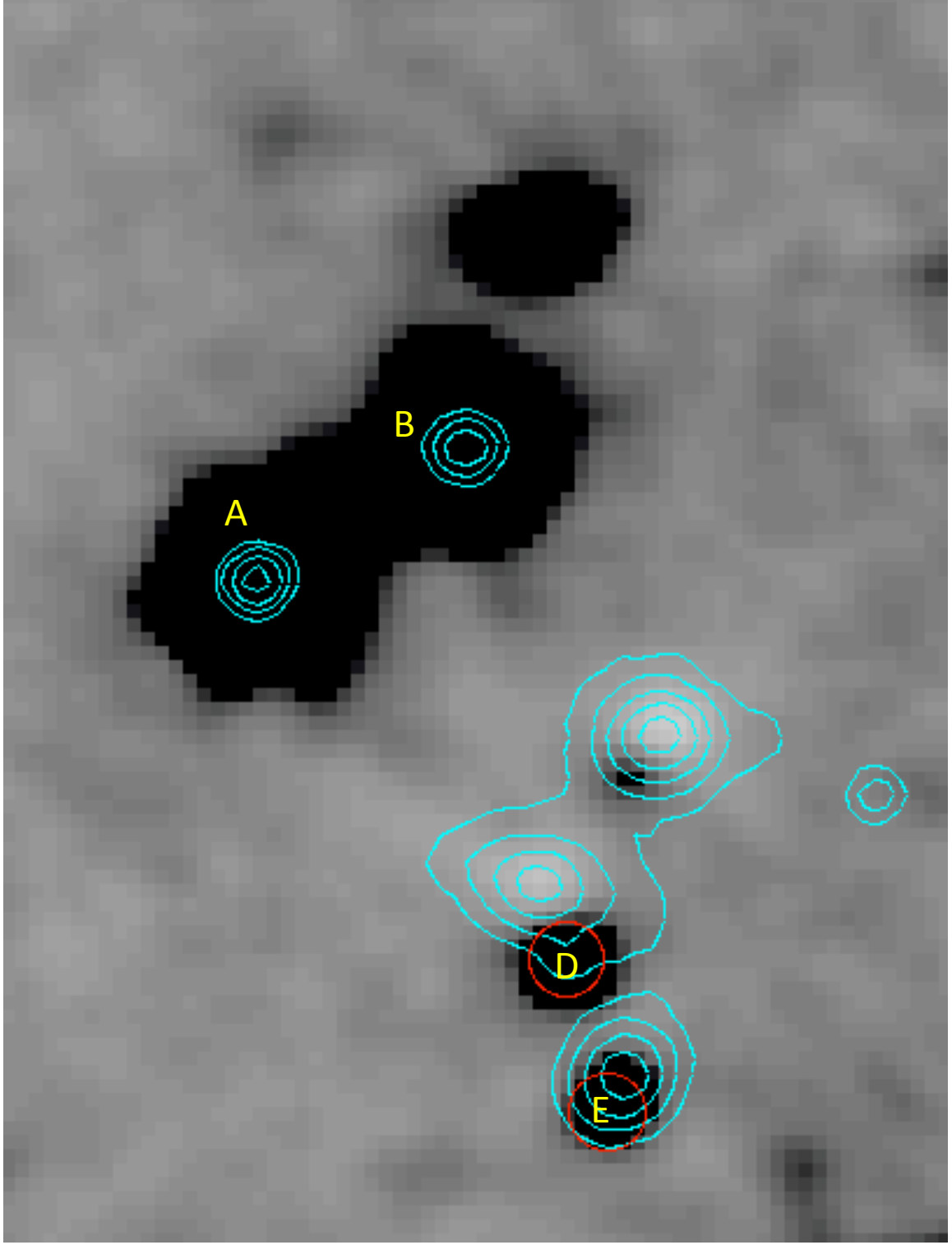
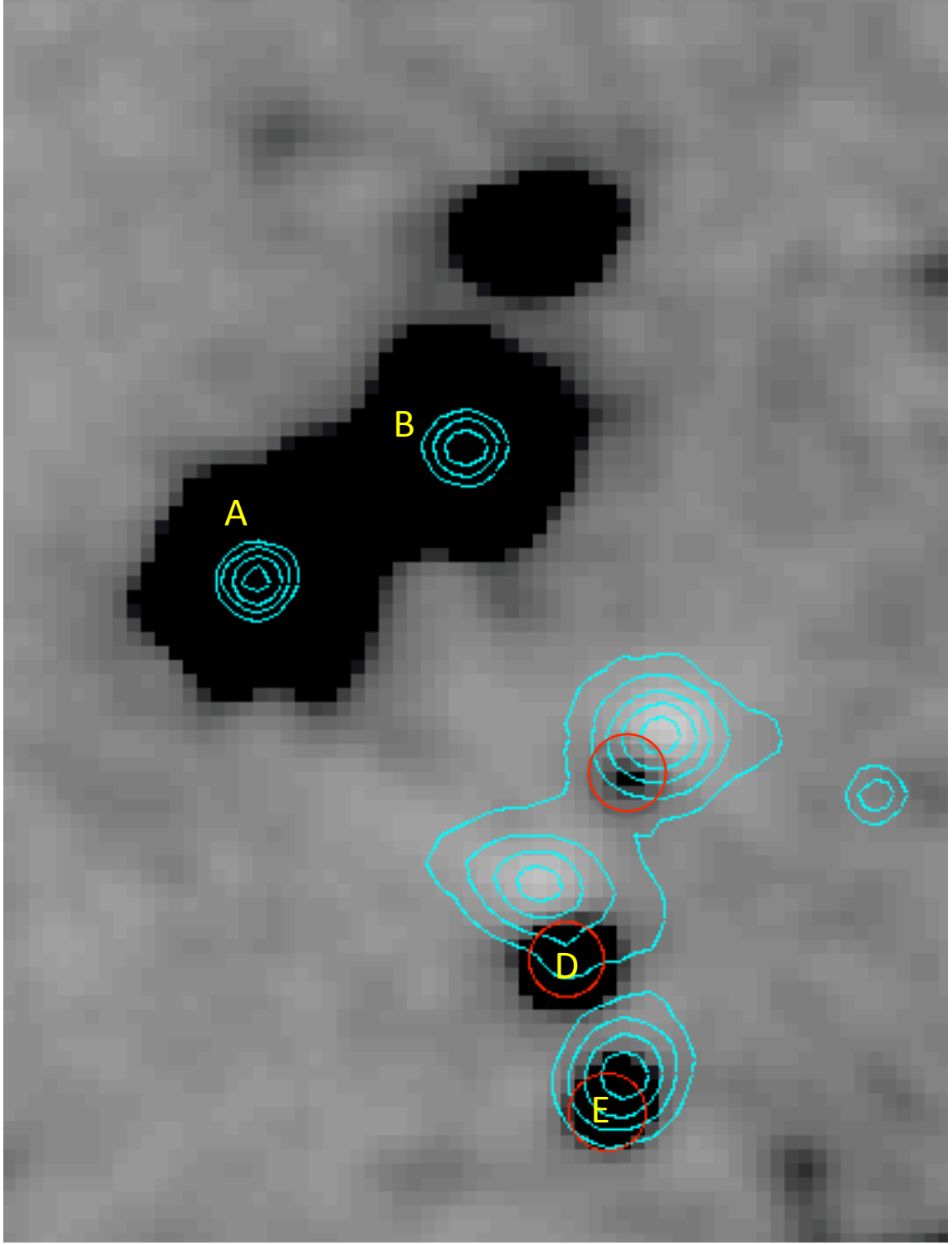

"g-i" image:
Positive residuals
are bluer than the cluster
galaxies
A
B
D
E

Strong Lens modeling

Parametric (Lenstool; Jullo et al. 2007) strong lens model with multiple components:

- **Cluster: Elliptical PIEMD model**
- **G1-G3 modeled separately**
- **Other cluster galaxies (assuming empirical scaling relations between galaxy mass and light)**
- **Fit to multiple image positions, given our measured redshifts**
- **Some models predict additional quasar images near G1, G2**


A
B
D
E


A
B
D
E

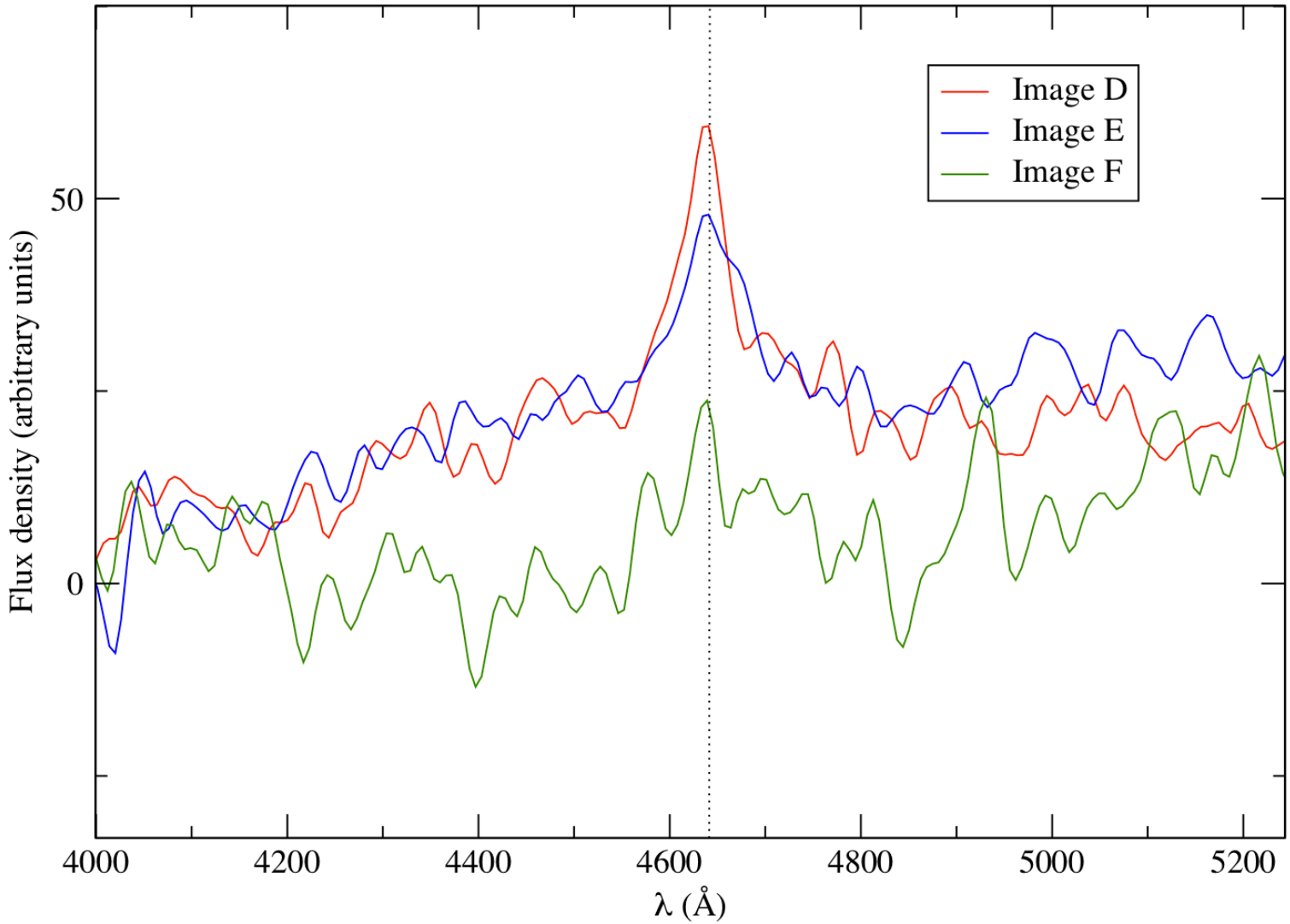
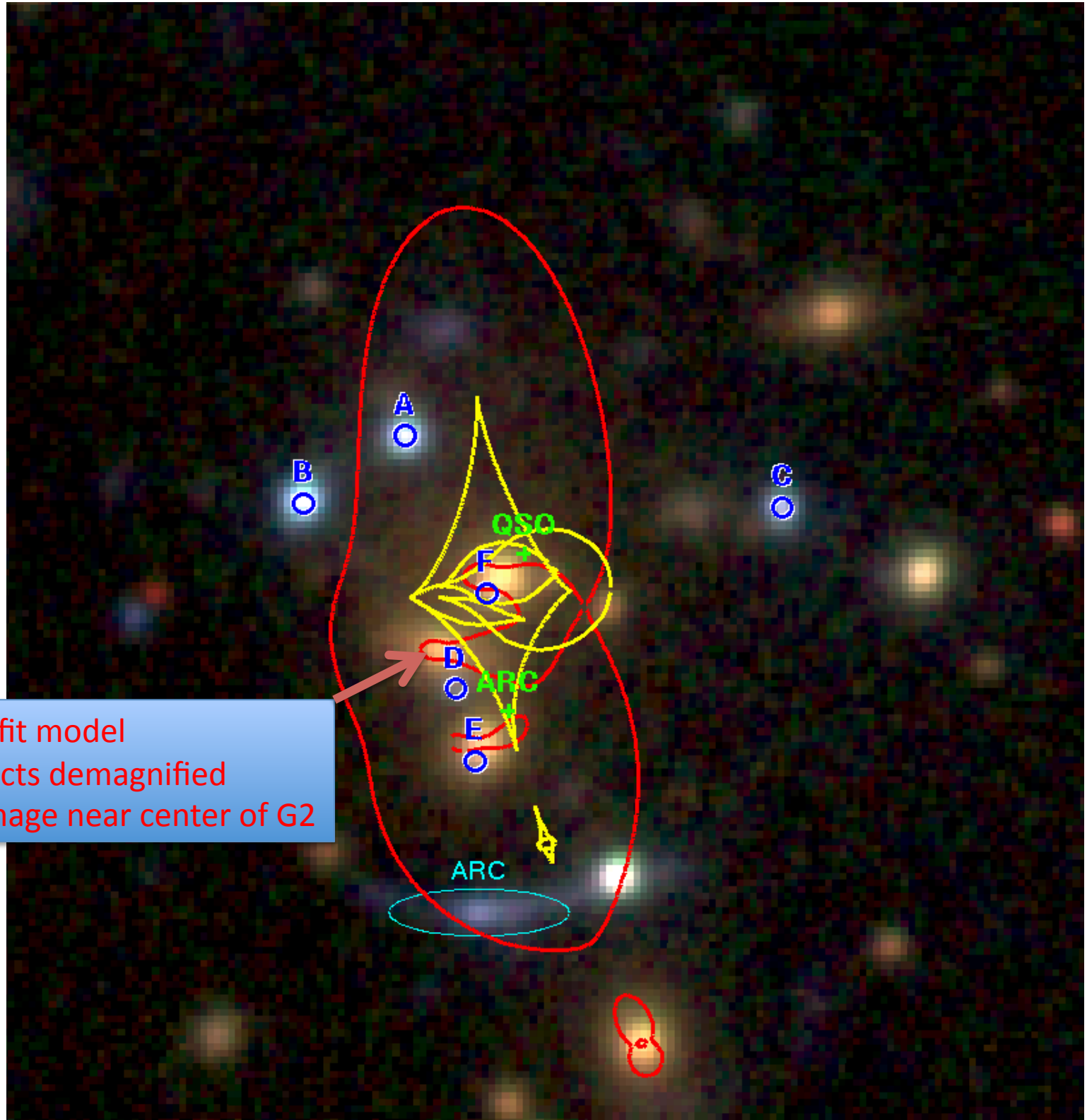
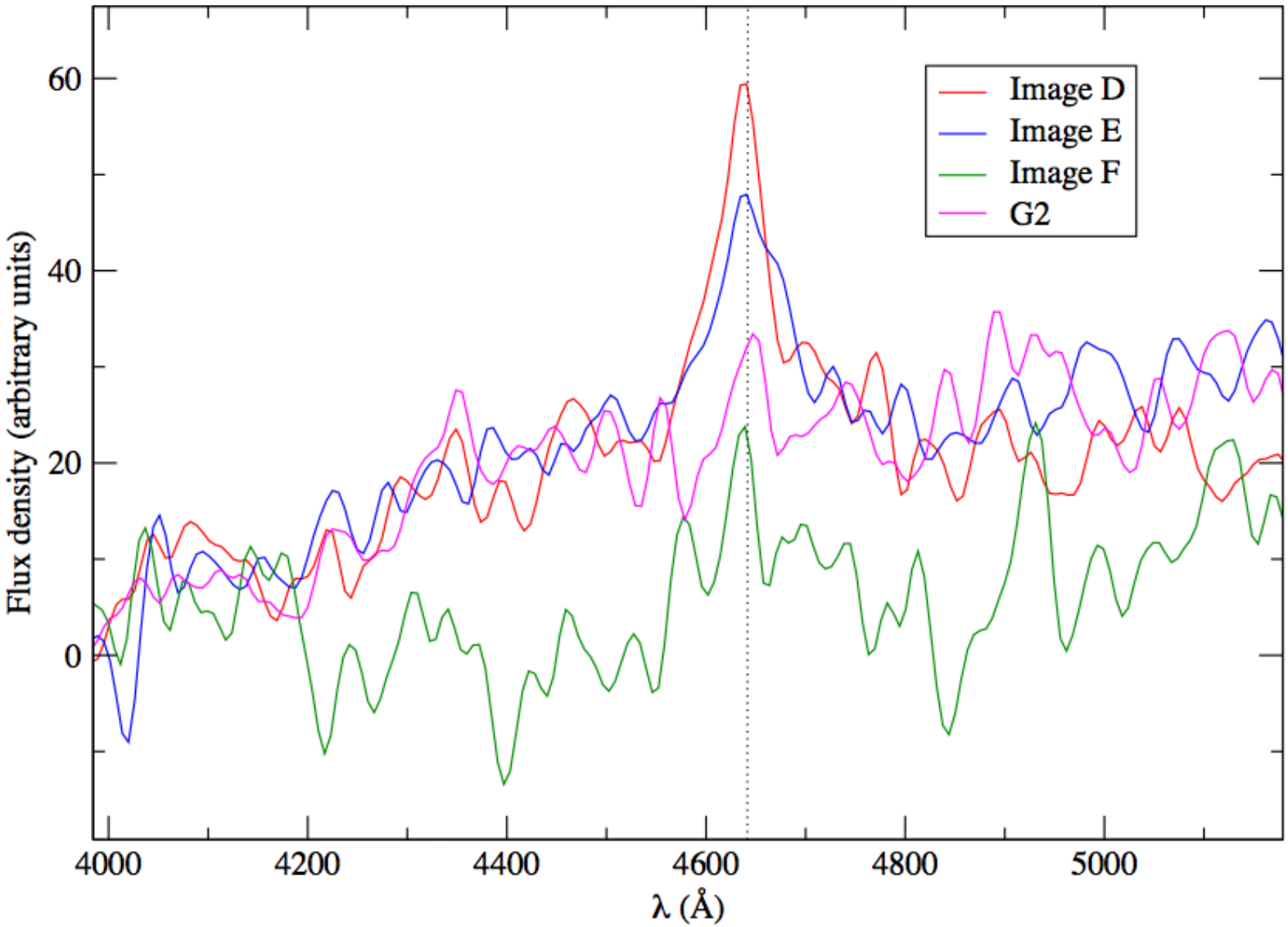
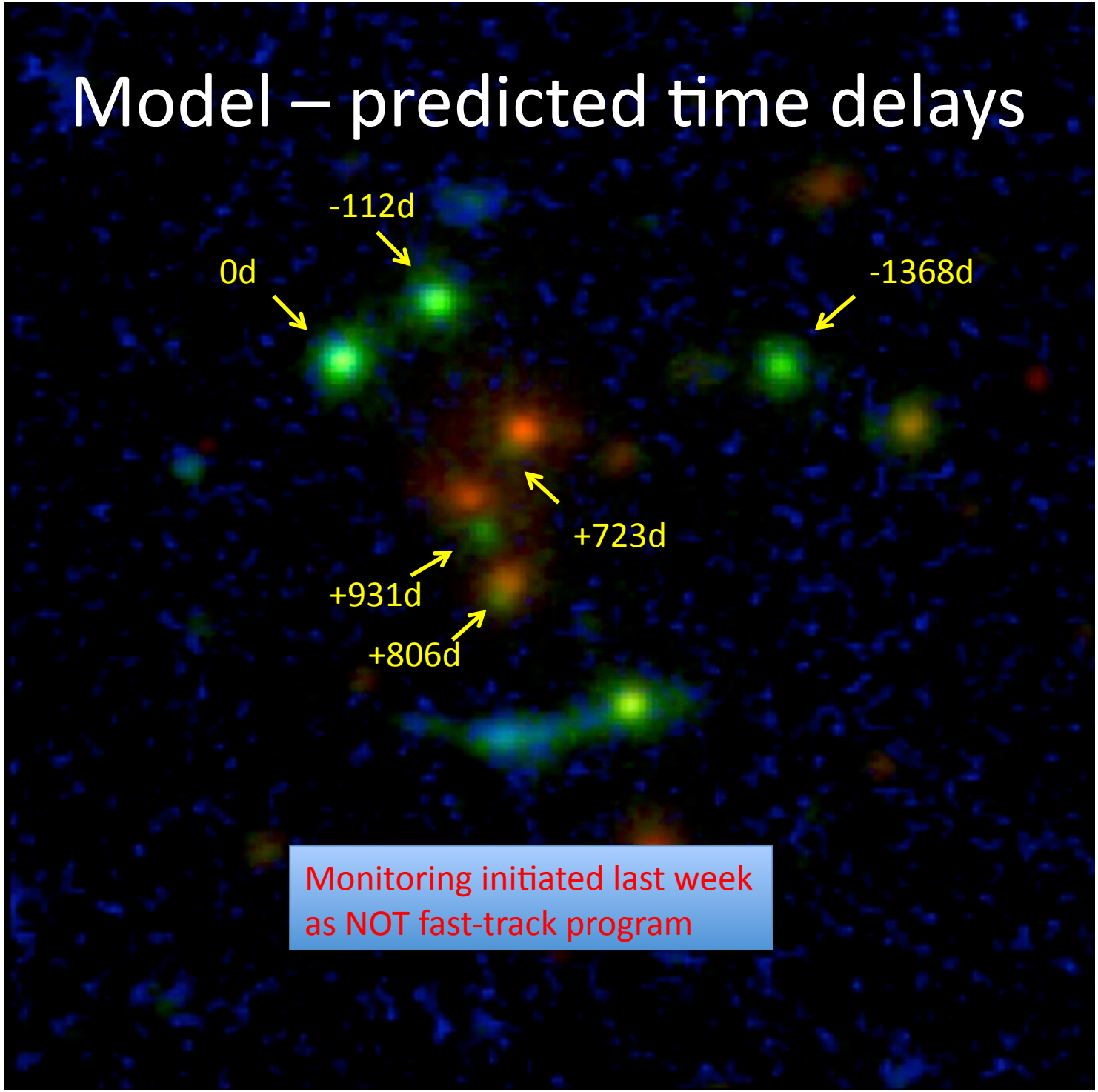


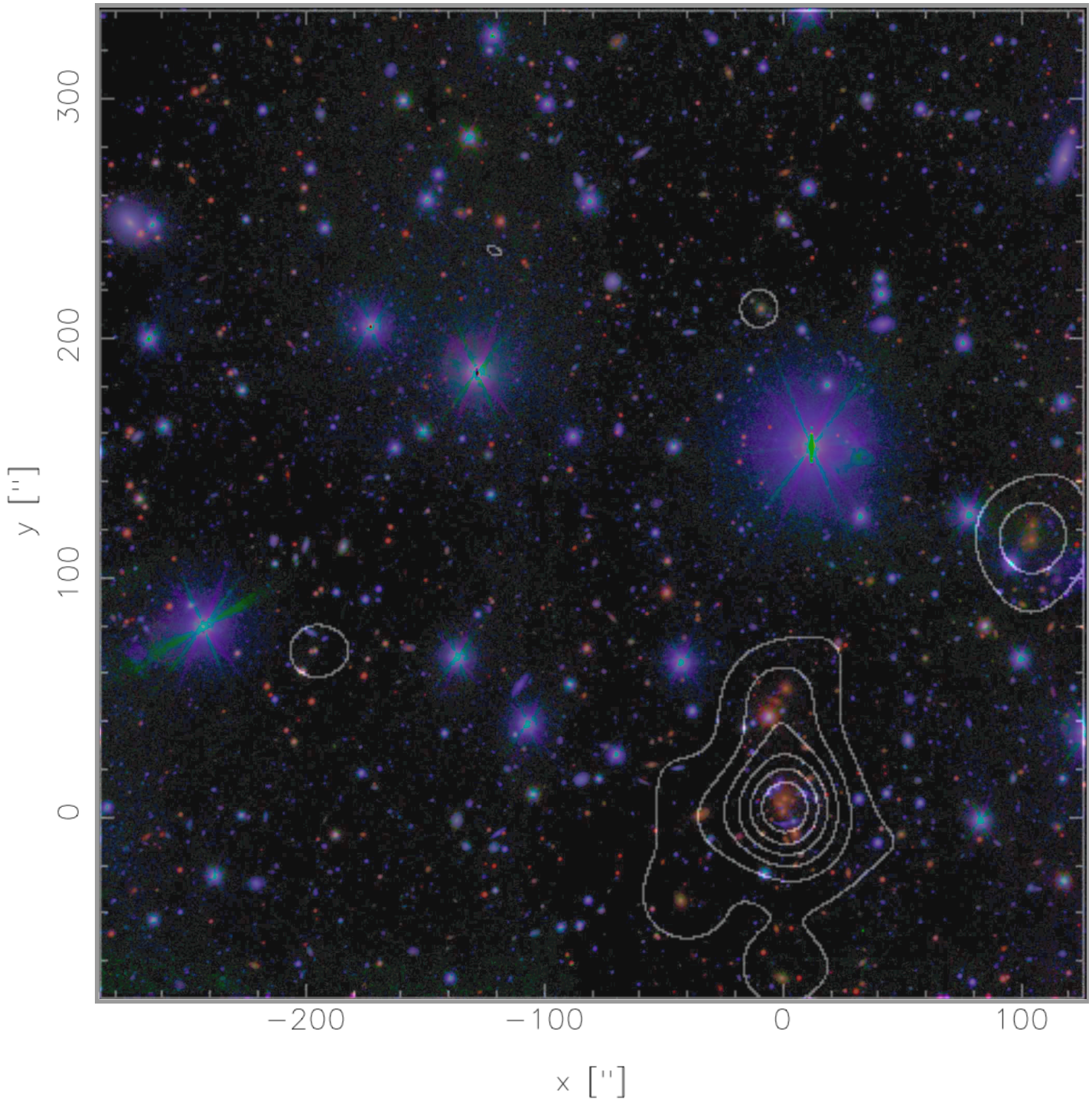
Image D
Image E
Image F
50
0
Flux density (arbitrary units)
4000
4200
4400
4600
4800
5000
5200
λ (Å)


A
B
C
QSO
F
D
ARC
E
ARC
Best-fit model
predicts demagnified
7th image near center of G2



Dahle et al. 2012, in prep.


Model – predicted time delays
-112d
0d
-1368d
+723d
+931d
+806d
Monitoring initiated last week
as NOT fast-track program


300
200
100
0
y ['']
−200
−100
0
100
x ['']

Why is this important ?

1. **Very good constraints on the mass distribution in a cluster core from quasar image positions and time delays**
2. **It is very unlikely to find this kind of lens system in SDSS! From theory, 1% of strongly lensed quasars are expected to show 6 or more images. This is consistent with observations for galaxy-scale lenses (1 known case out of ~100 know lenses), but for cluster-scale lenses it is now 1/3 !!**

This work has made use of…

- **Traditional visitor mode (on-site decisions possible)**
- **Fast-track program (getting monitoring started quickly)**
- **Service mode**
- **Informal Nordic network (much due to NOT)**
- **Dedicated (and flexible!) NOT staff**
- **Enthusiastic students**

SDSS J2222+2745: DISCOVERY OF A GRAVITATIONALLY LENSED SEXTUPLE QUASAR WITH MAXIMUM IMAGE SEPARATION OF 15.″1. *

H. Dahle[1,2], M. Gladders[3,4], K. Sharon[5], (SGAS TEAM MEMBERS), N. Groeneboom[1], T. E. Brinckmann[6], M. T. Kristensen[6], M. O. Lindholmer[6], A. Nielsen[6], J.-K. Krogager[6], J. P. U. Fynbo[6]

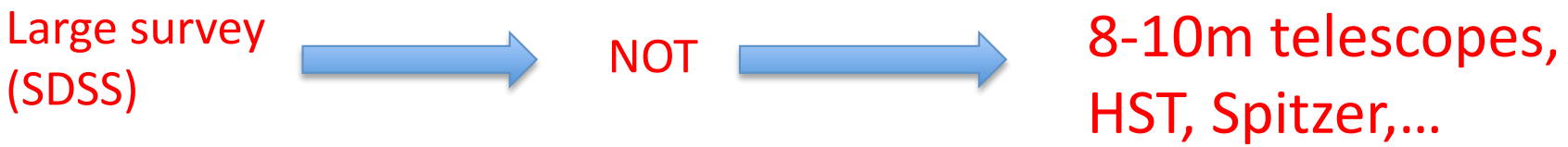
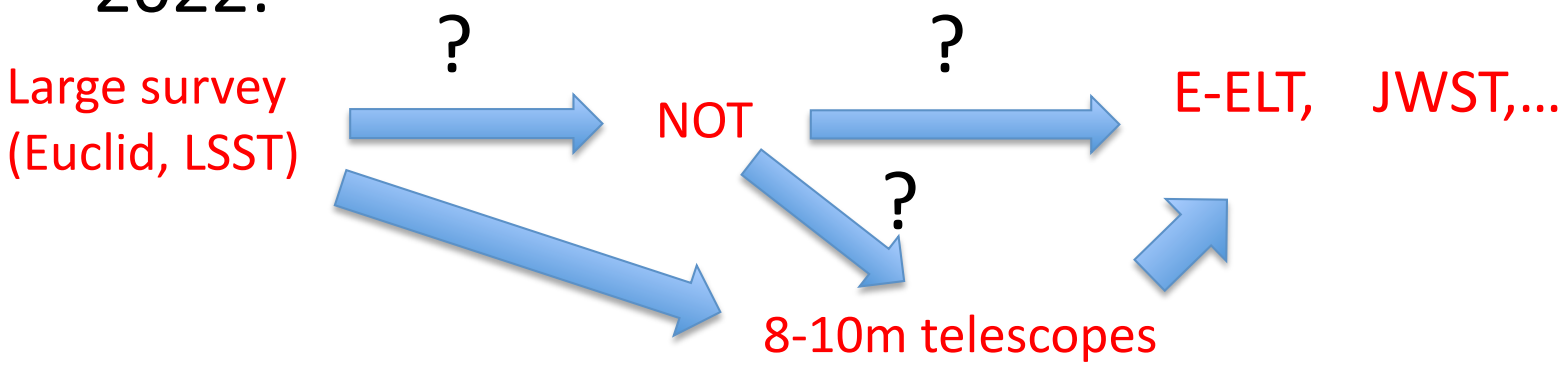
ApJ in prep: draft date October 23, 2012

ABSTRACT

We report the discovery of a unique gravitational lens system, SDSS J2222+2745, producing five spectroscopically confirmed images of a $z_s = 2.82$ quasar lensed by a foreground galaxy cluster at $z_l = 0.49$. We also present photometric and spectroscopic evidence for a sixth lensed image of the same quasar. The maximum separation between the quasar images is 15.″1. The lens system was discovered in the course of the Sloan Giant Arcs Survey, in which we identify candidate lenses in

NOT as target filter

What we are doing now:



~2022: