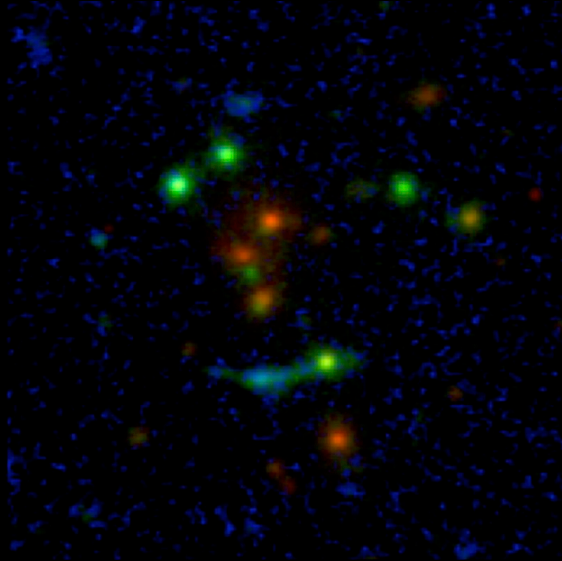


SDSS J2222+2745: The cluster-lensed sextuple quasar



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SGAS Collaboration: M. Gladders (Chicago), K. Sharon (Michigan), M. Bayliss (Harvard), E. Wuyts (MPE Garching), J. Rigby (NASA Goddard), M. Florian (Chicago), T. Johnson (Michigan),

+ L. Abramson (Chicago), B. Koester (Michigan), N. Groeneboom (Oslo)

T. Brinckmann, M. Kristensen, M. Lindholmer, A. Nielsen,
J.-K. Krogager, J. Fynbo (Copenhagen)

SGAS: SDSS DR7+DR8 results

(Gladders et al. 2015, in prep.)

Mean Score	#	%Complete	%Confirmed	#Lenses
2.5-3.0	30	100	100	30 (30)
2.0-2.5	39	99	92	36 (36)
1.5-2.0	101	97	77	78 (80)
1.0-1.5	281	100	26	73 (95)
				TOTAL 217 (241)

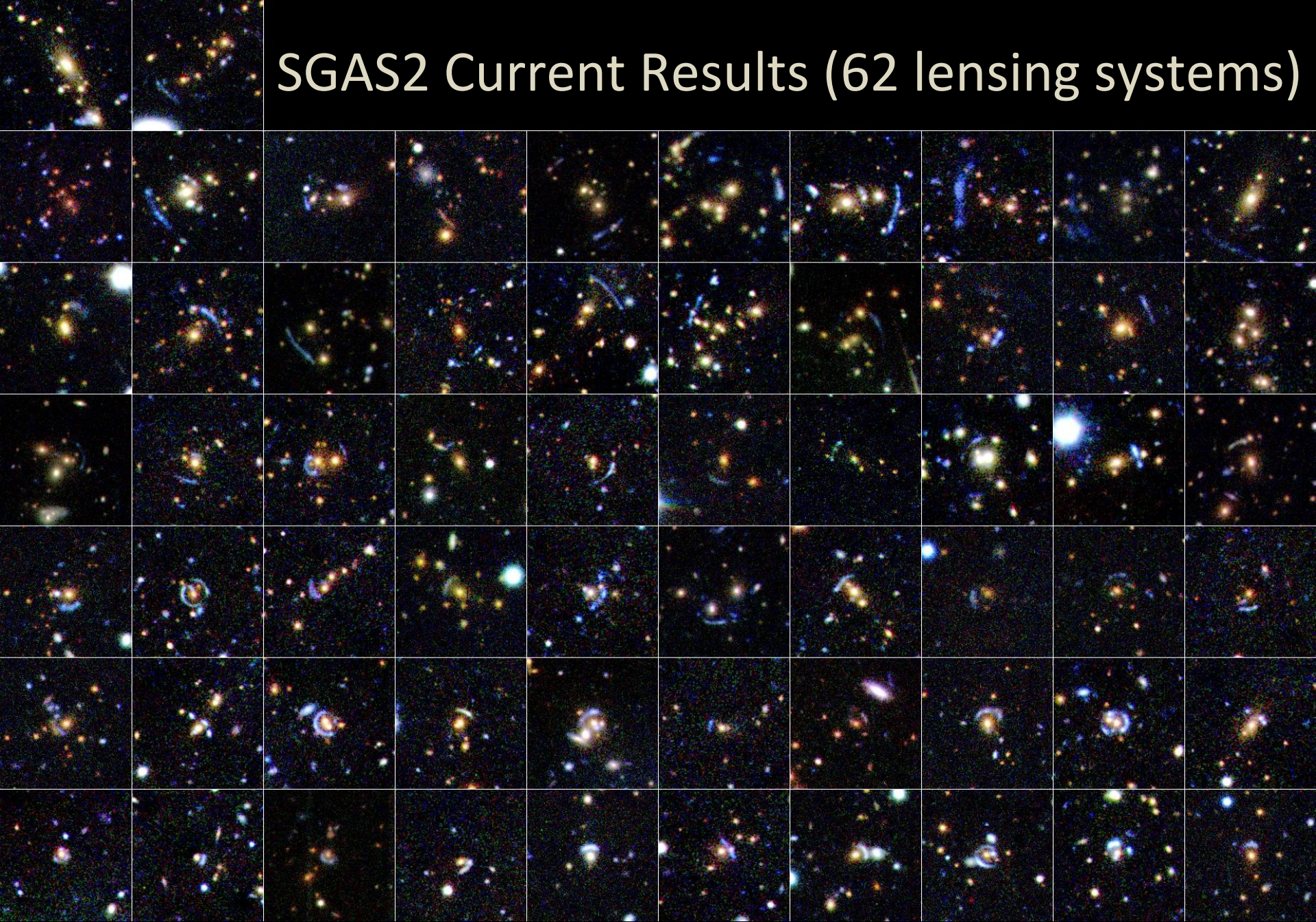
of Candidates
from Search

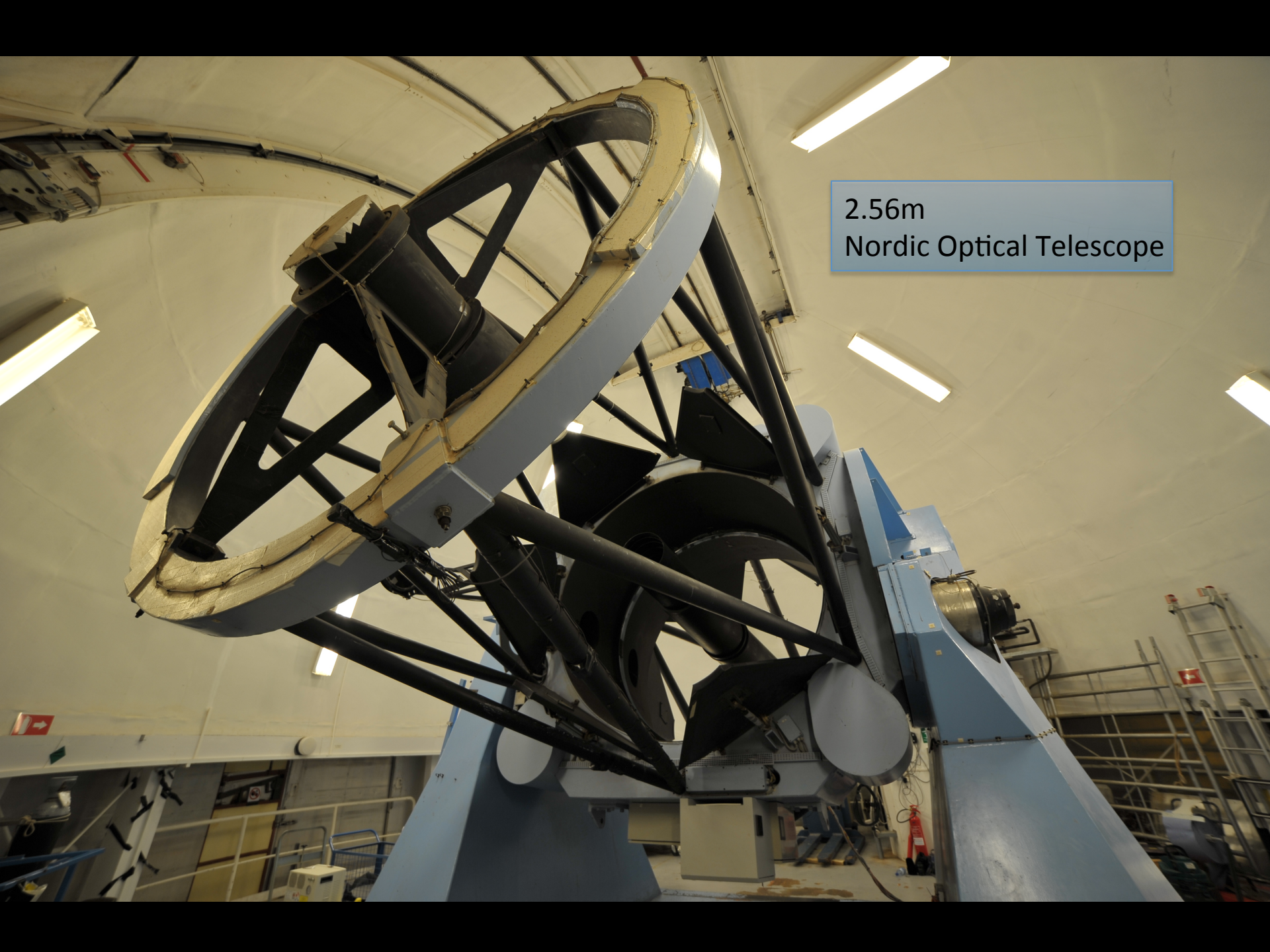
Completeness of
Follow-up

Fraction Confirmed
as Lensing

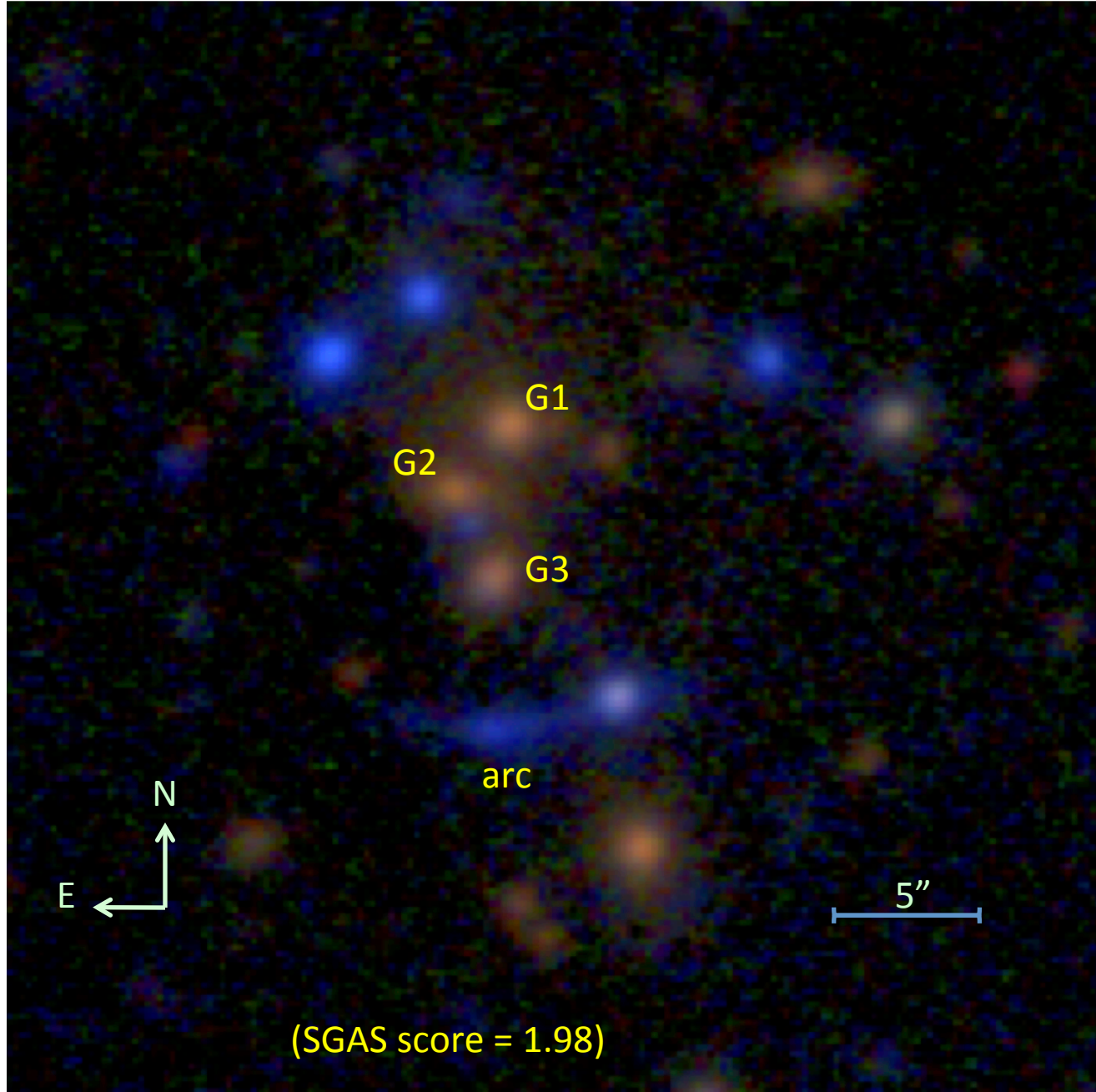
Total #Lenses
Found (corr. for
incompleteness)

SGAS2 Current Results (62 lensing systems)

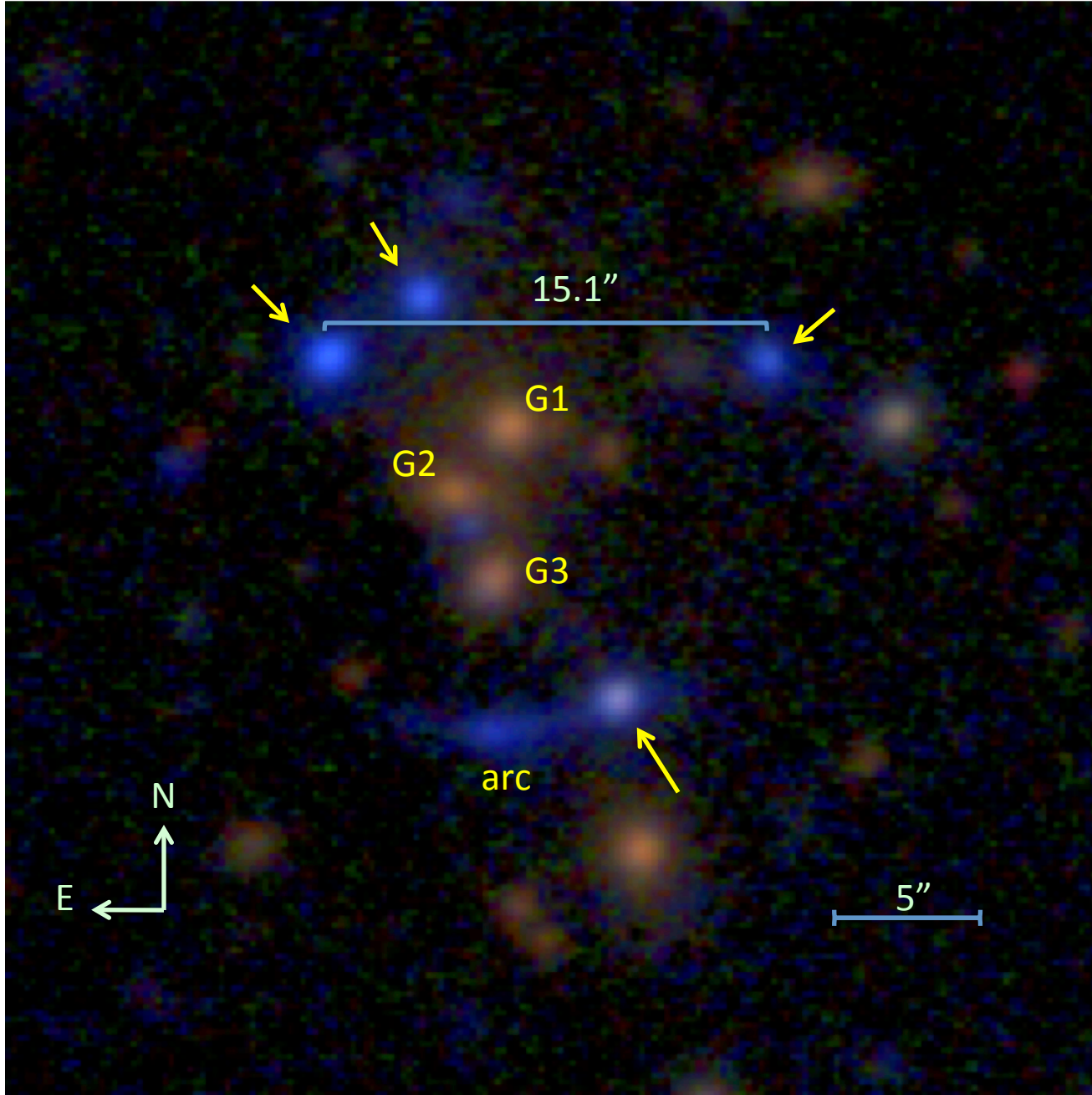




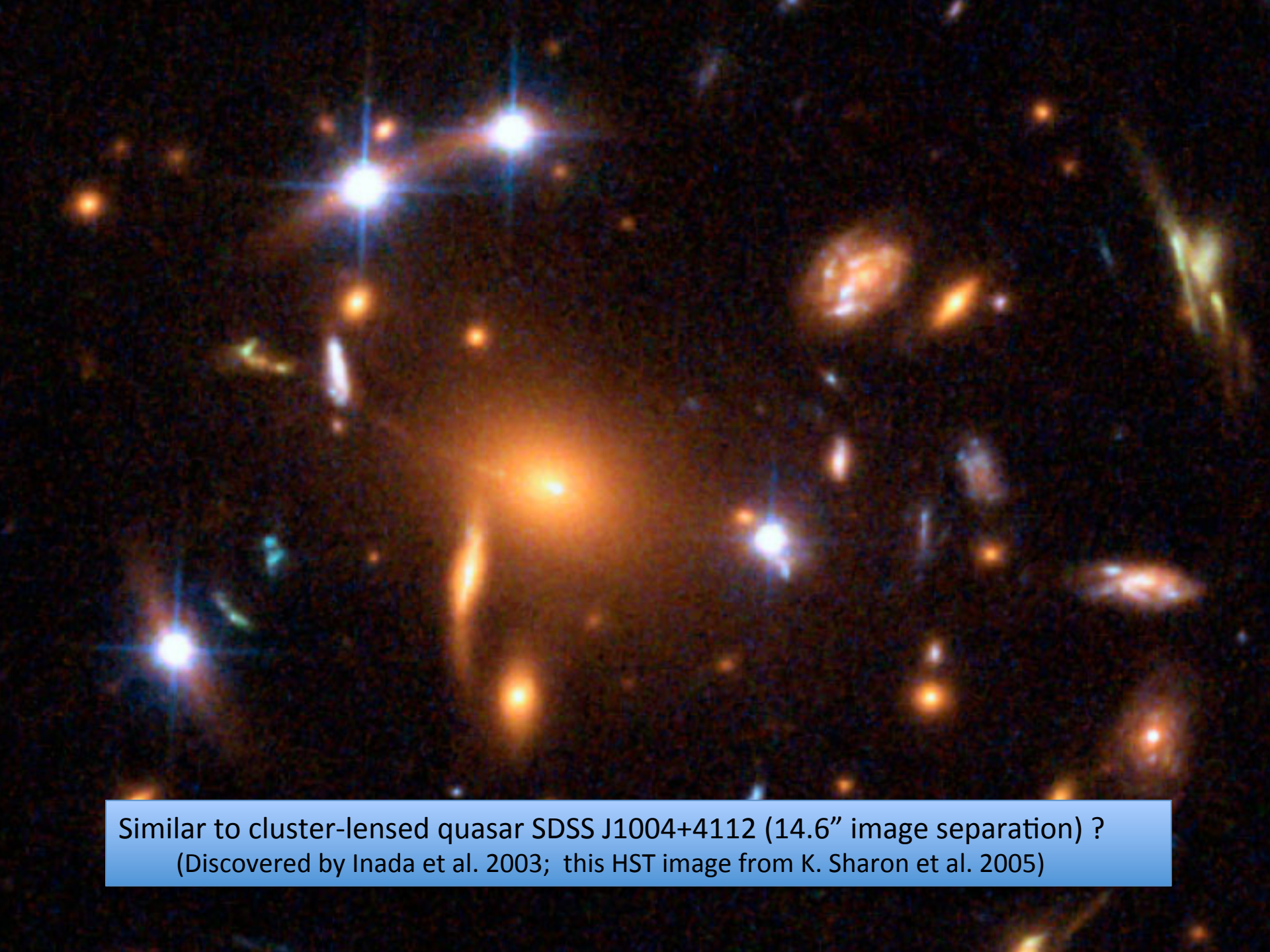
2.56m
Nordic Optical Telescope



SGAS (DR8) survey image from NOT (2x300s g, 2x150s r, 2x150s i)

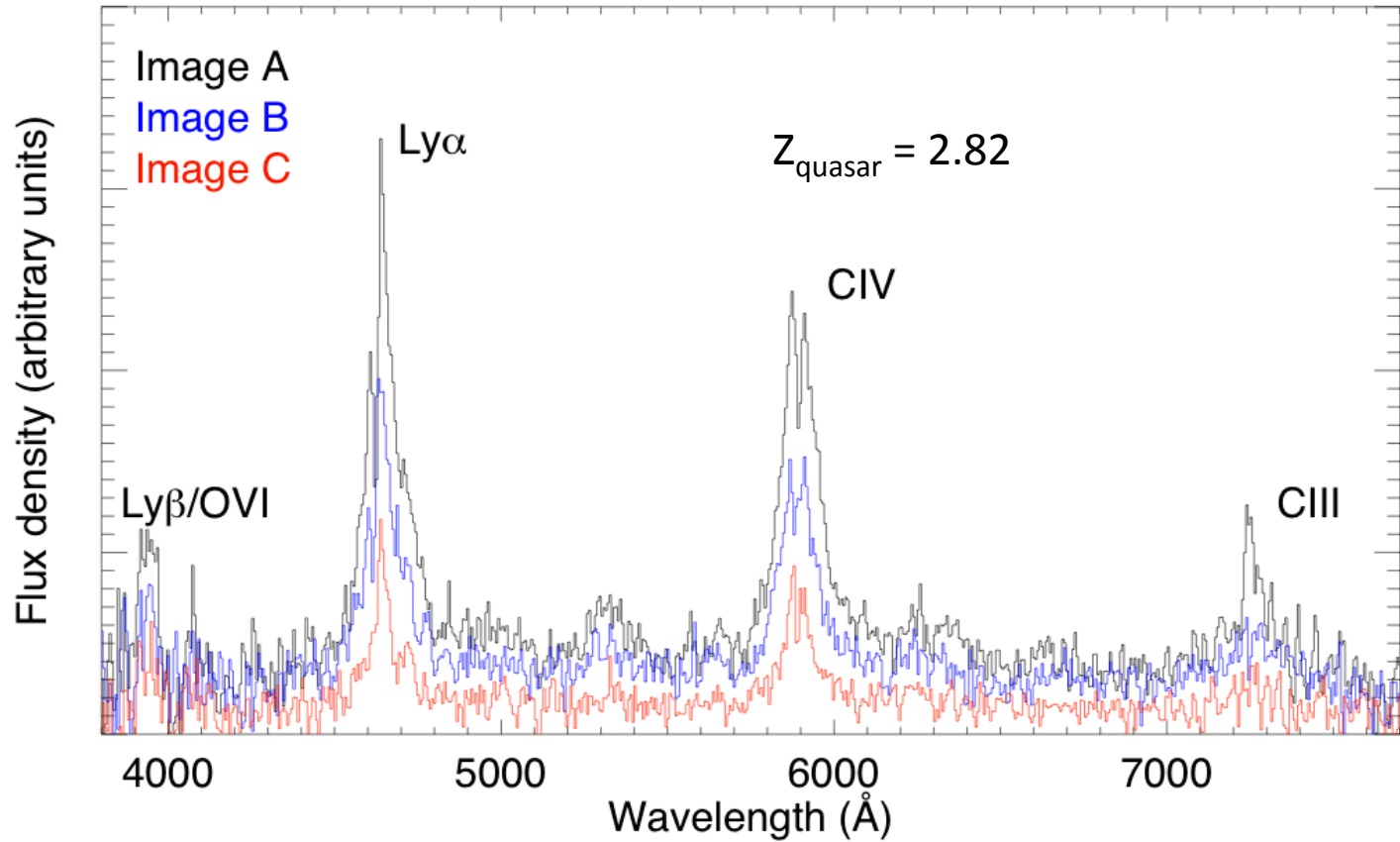


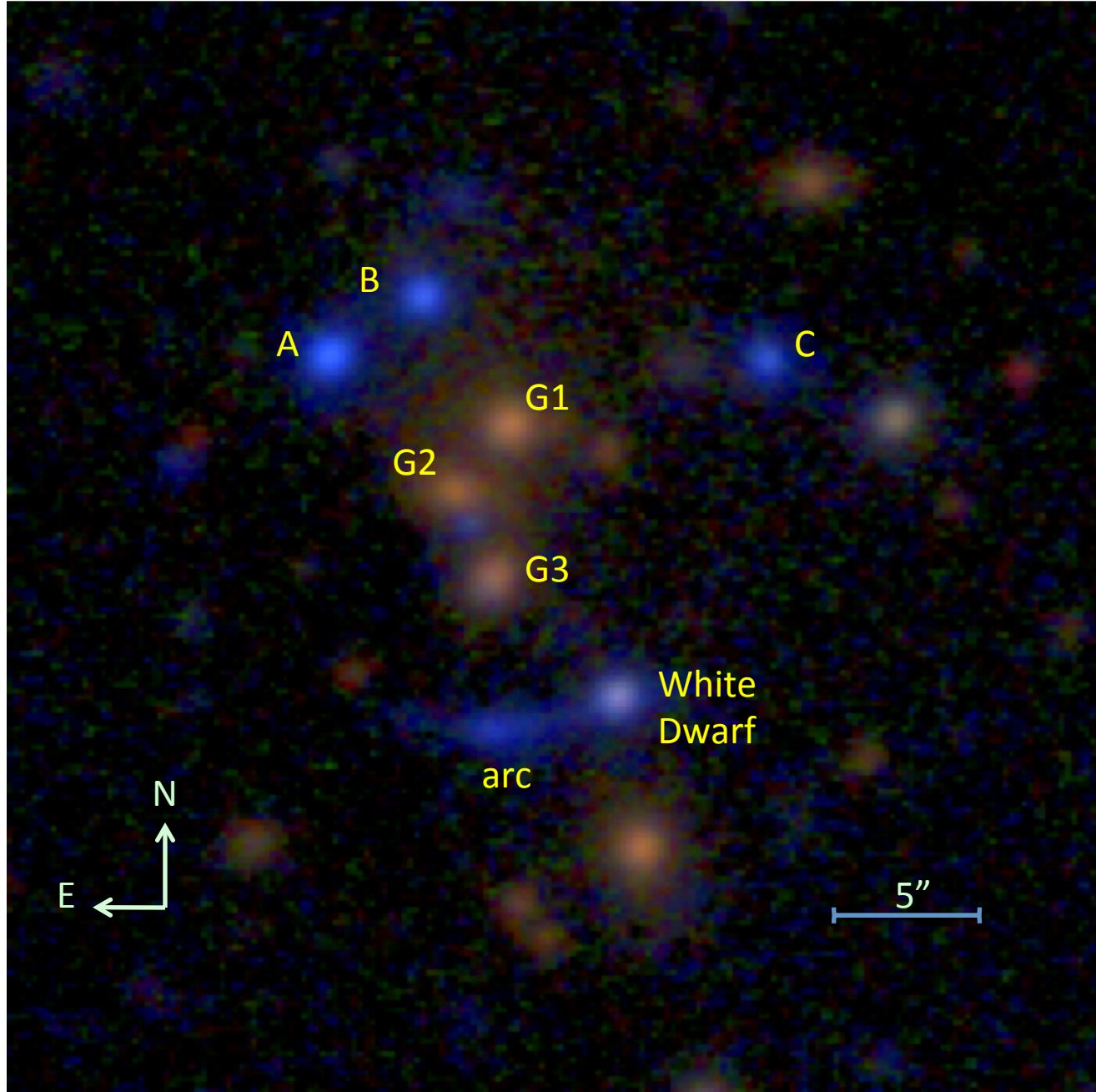
SGAS (DR8) survey image from NOT (2x300s g, 2x150s r, 2x150s i)



Similar to cluster-lensed quasar SDSS J1004+4112 (14.6'' image separation) ?
(Discovered by Inada et al. 2003; this HST image from K. Sharon et al. 2005)

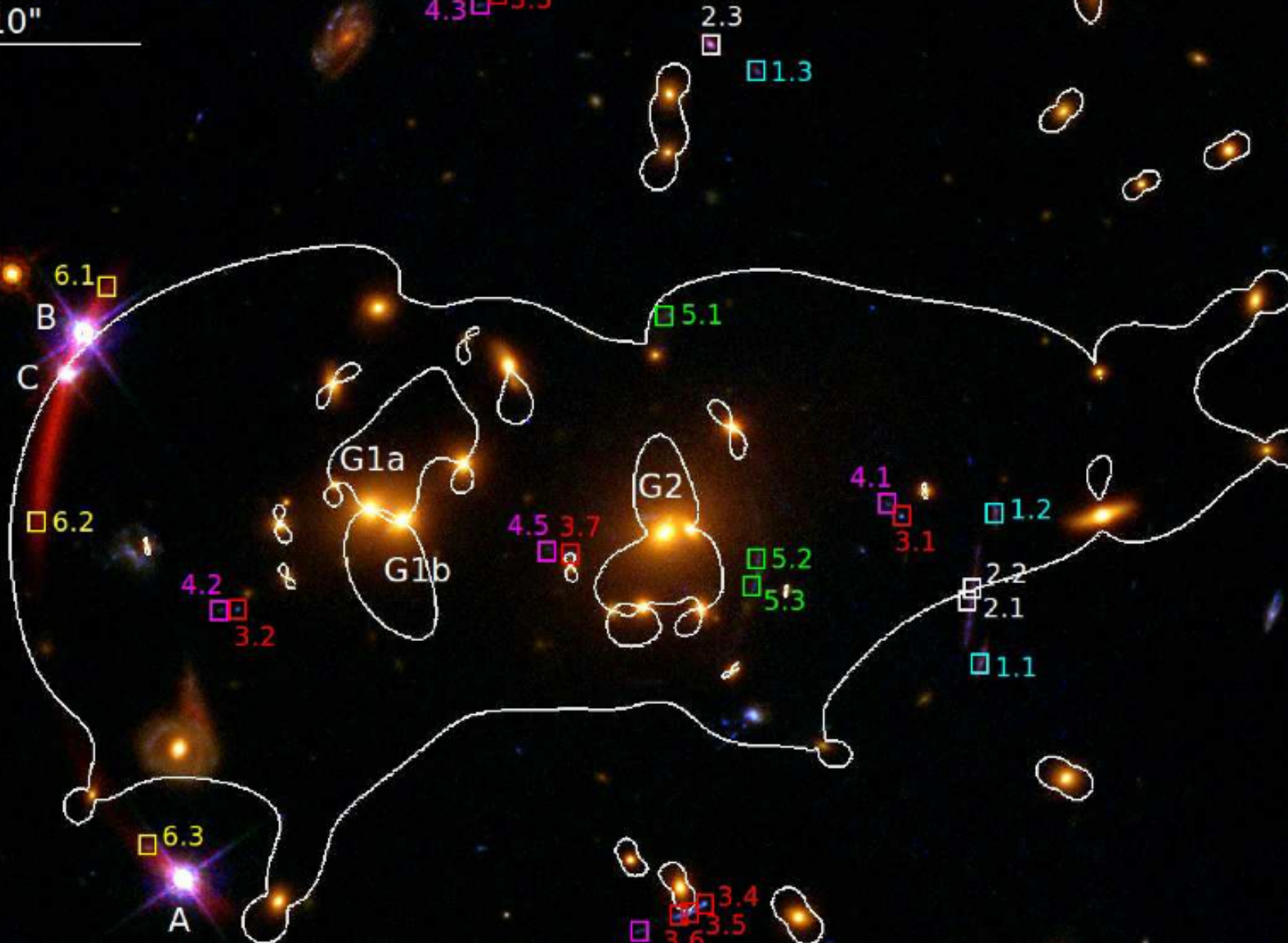
Initial lensing confirmation



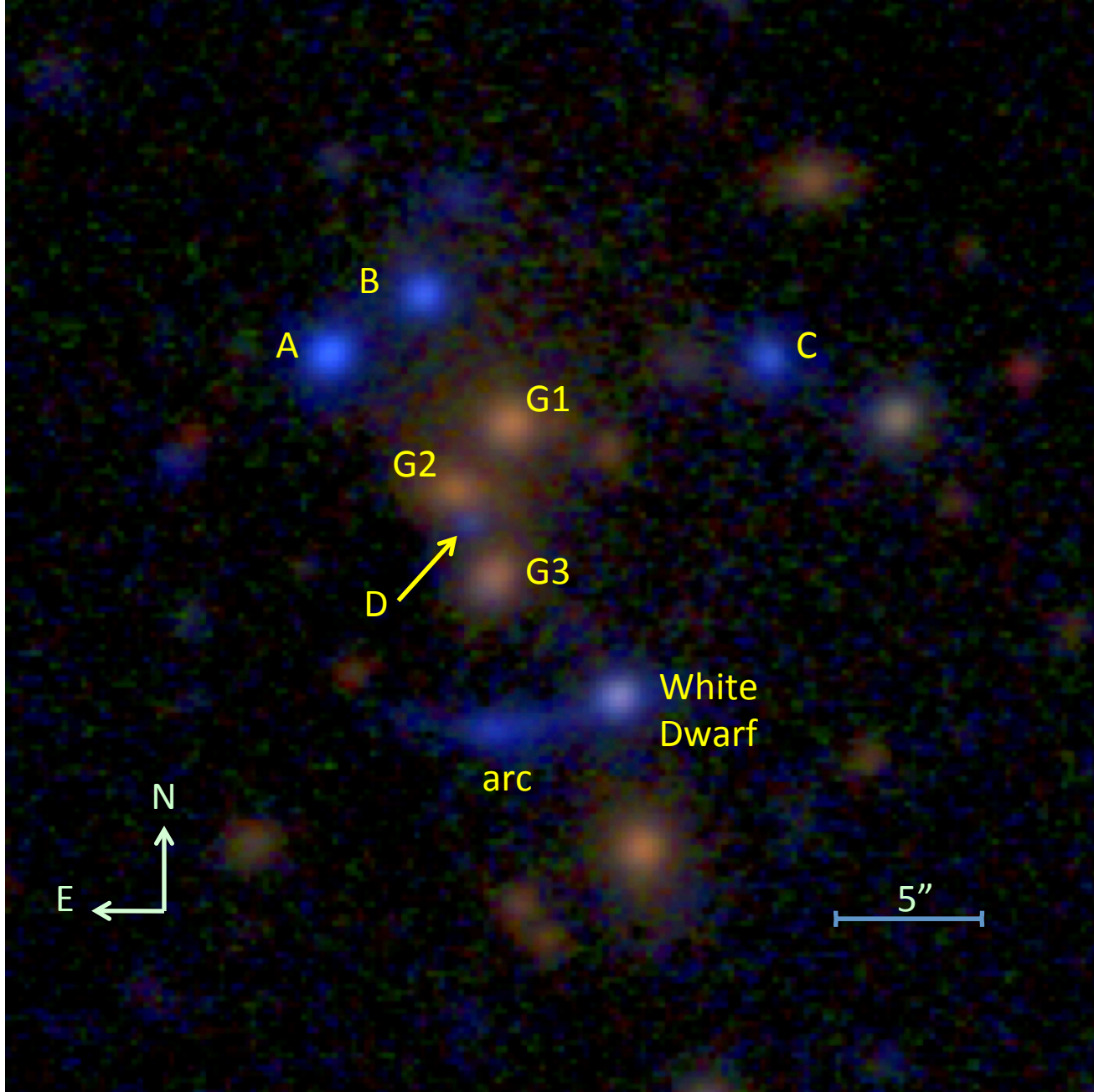


SGAS (DR8) survey image from NOT (2x300s g, 2x150s r, 2x150s i)

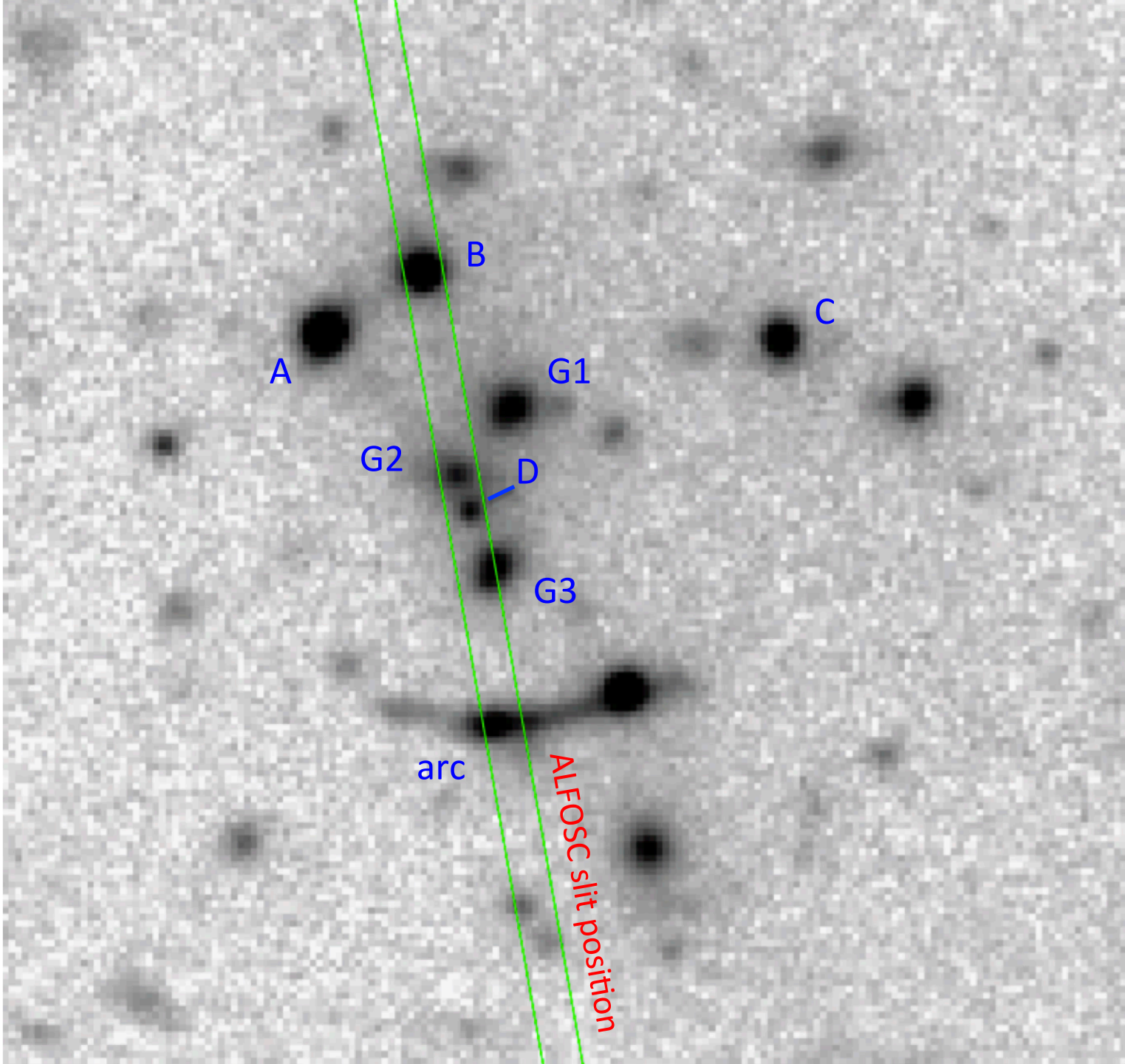
10"



Naked cusp lens, similar to SDSS J1029+2623 ? (largest image separation of 22.5")
(Discovered by Inada et al. 2006; HST image from Oguri et al. 2012)



SGAS (DR8) survey image from NOT (2x300s g, 2x150s r, 2x150s i)



A

B

C

G1

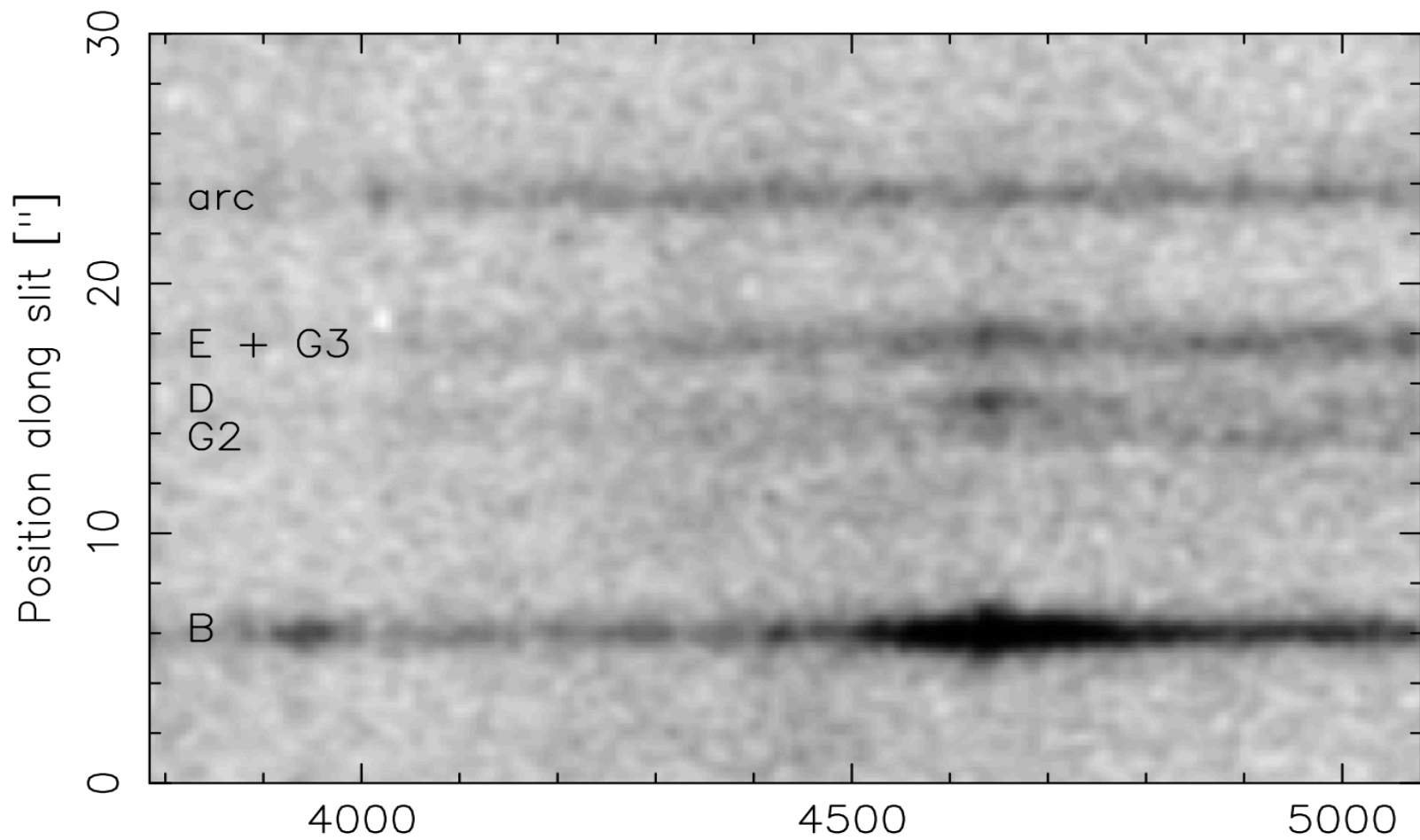
G2

D

G3

arc

ALFOSC slit position

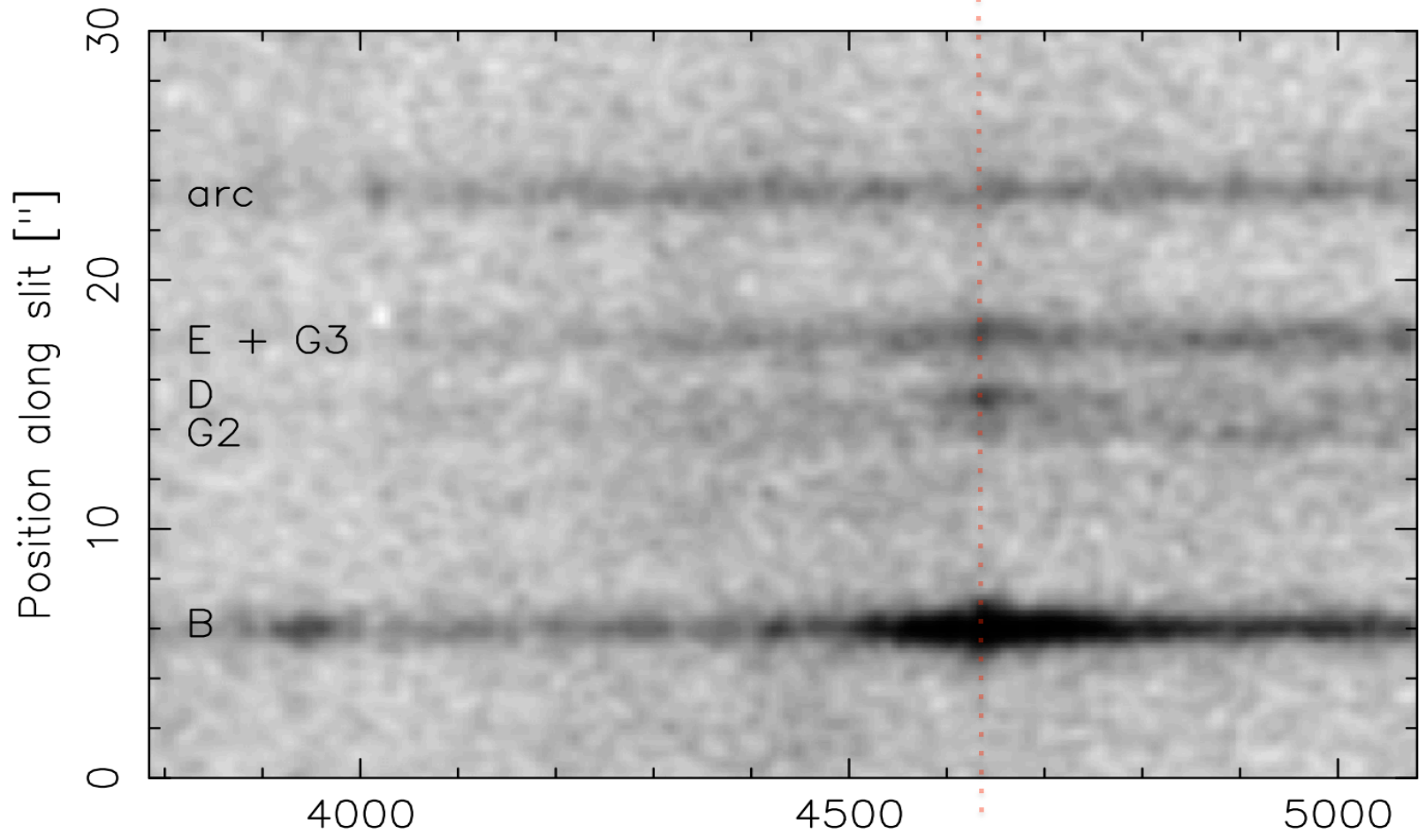


NOT/ALFOSC spectrum

λ [\AA]

Dahle et al. 2013

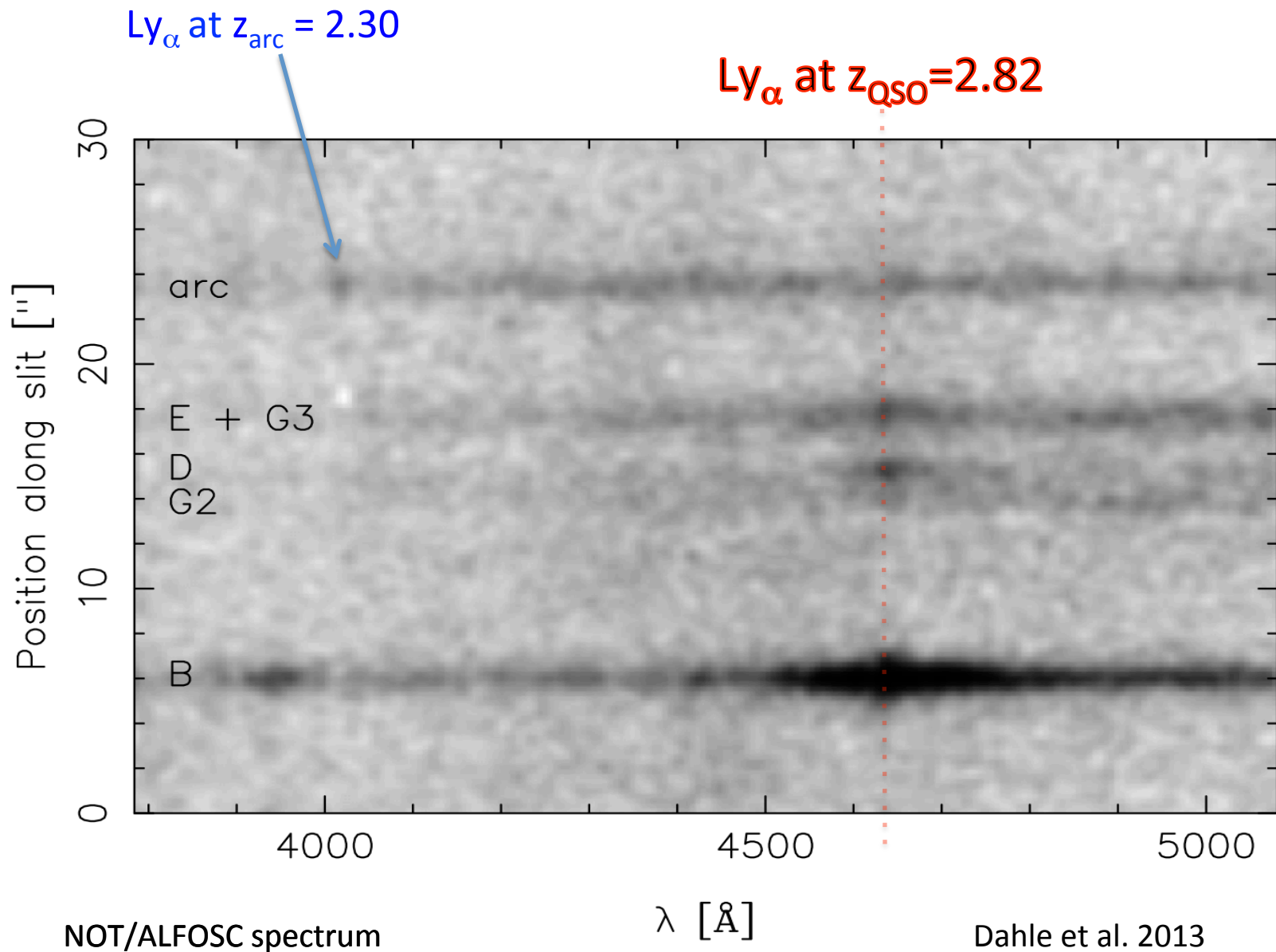
Ly_α at $z_{\text{QSO}}=2.82$



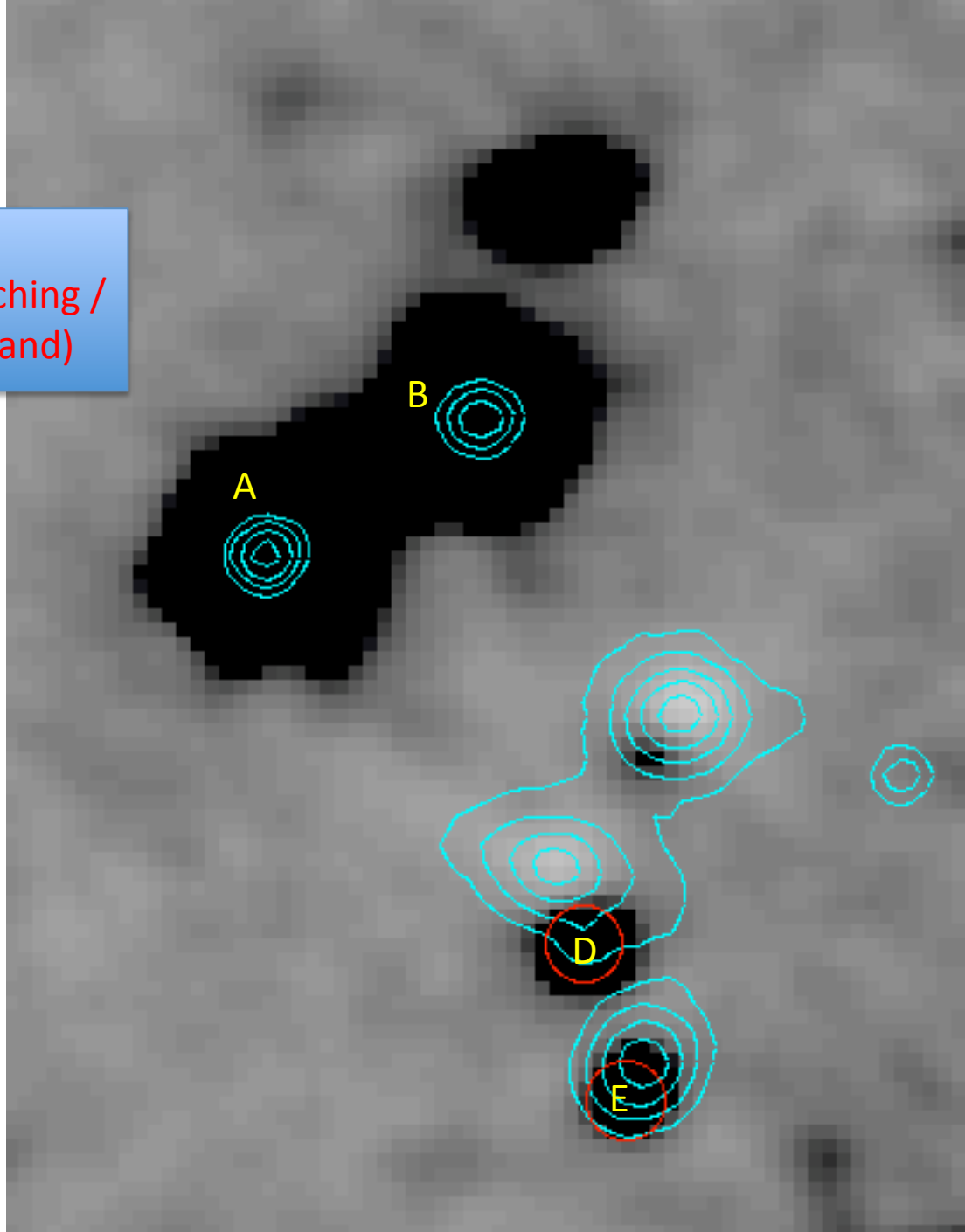
NOT/ALFOSC spectrum

λ [\AA]

Dahle et al. 2013



“g-i” image
(after PSF matching /
rescaling of i-band)



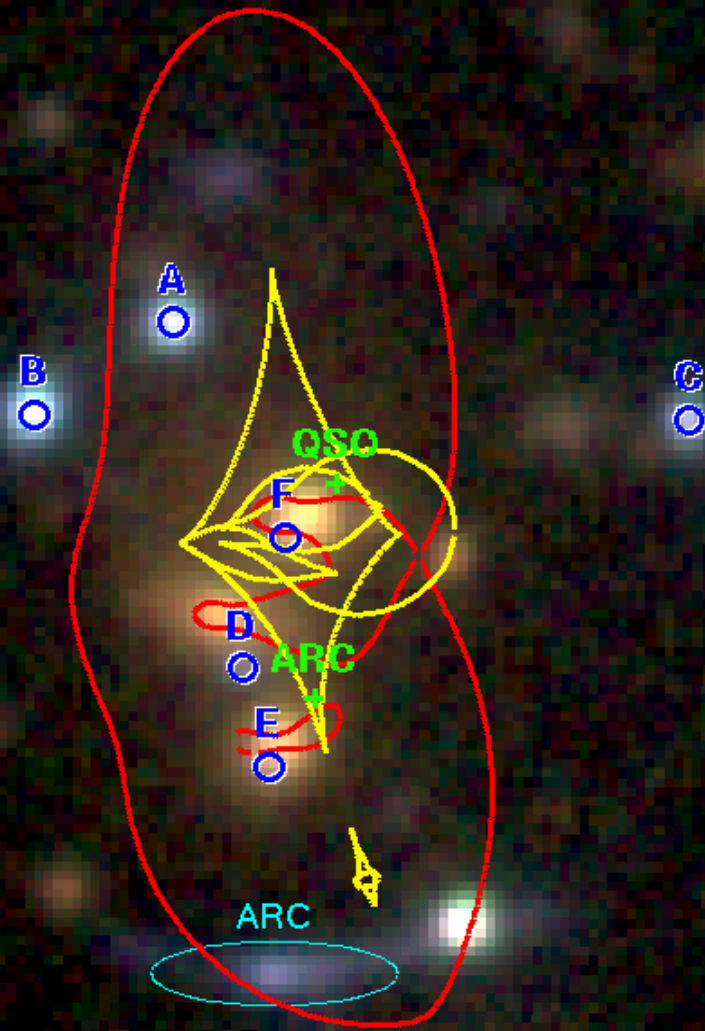
Lenstool model

Mass components :

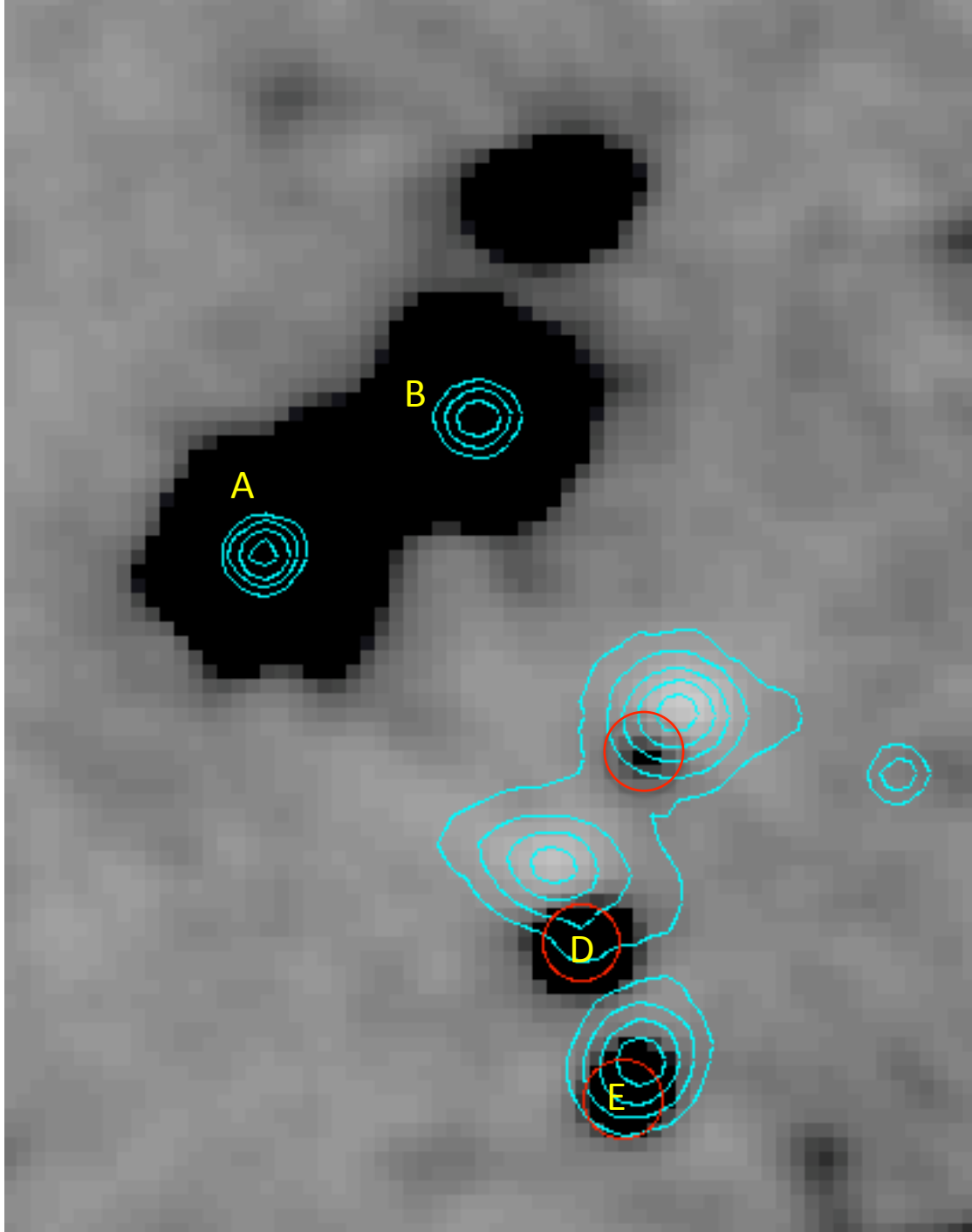
- **Cluster: Elliptical PIEMD model**
- **G1-G3 modeled separately (fixed pos., e , θ , r_s)**
- **Other cluster galaxies are modeled with velocity dispersion σ and scale radius r_s fixed by scaling relations**
- **Fit to image positions, $z_l=0.49$, $z_{\text{QSO}}=2.82$, $z_{\text{arc}}=2.30$**

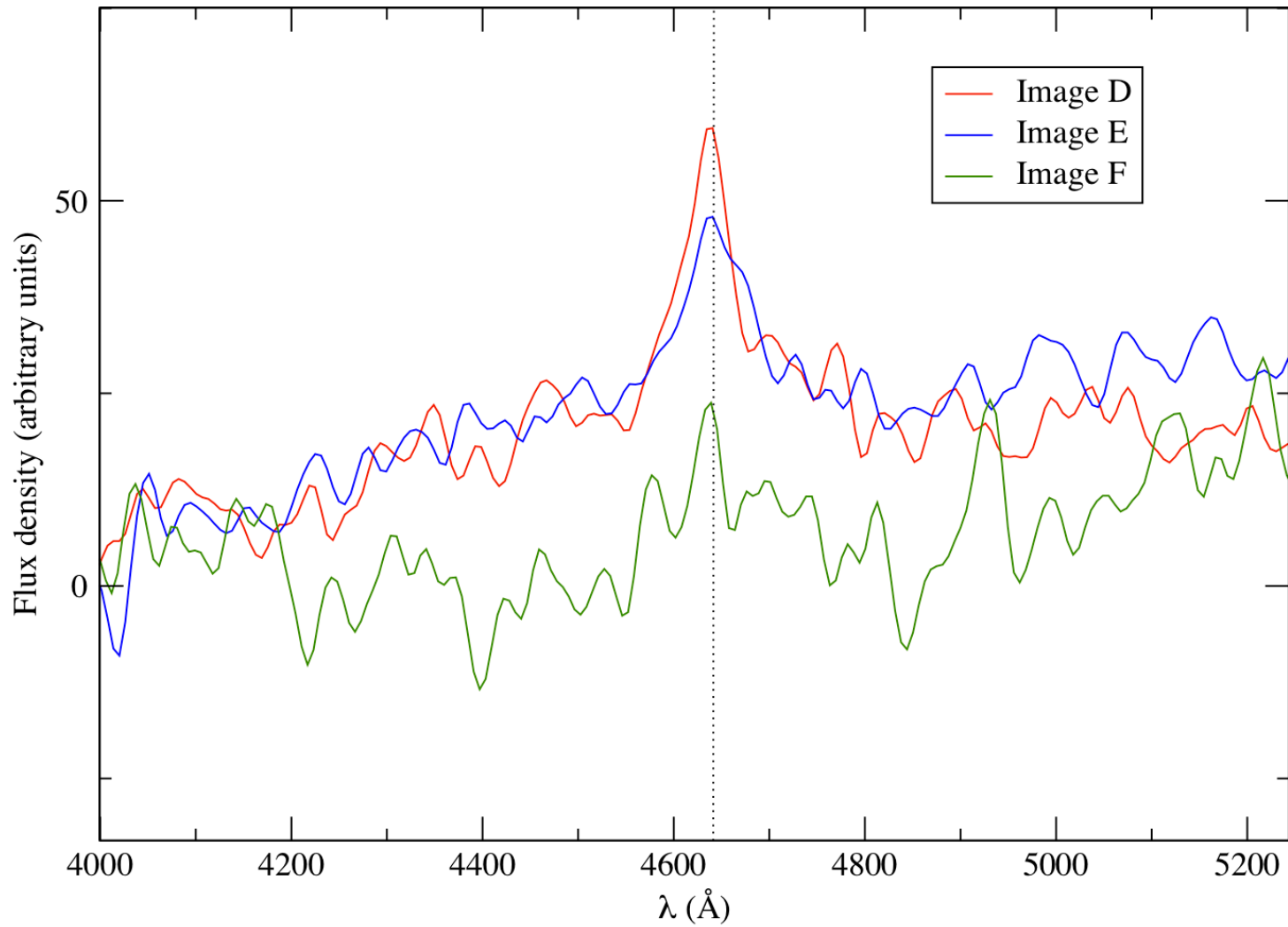


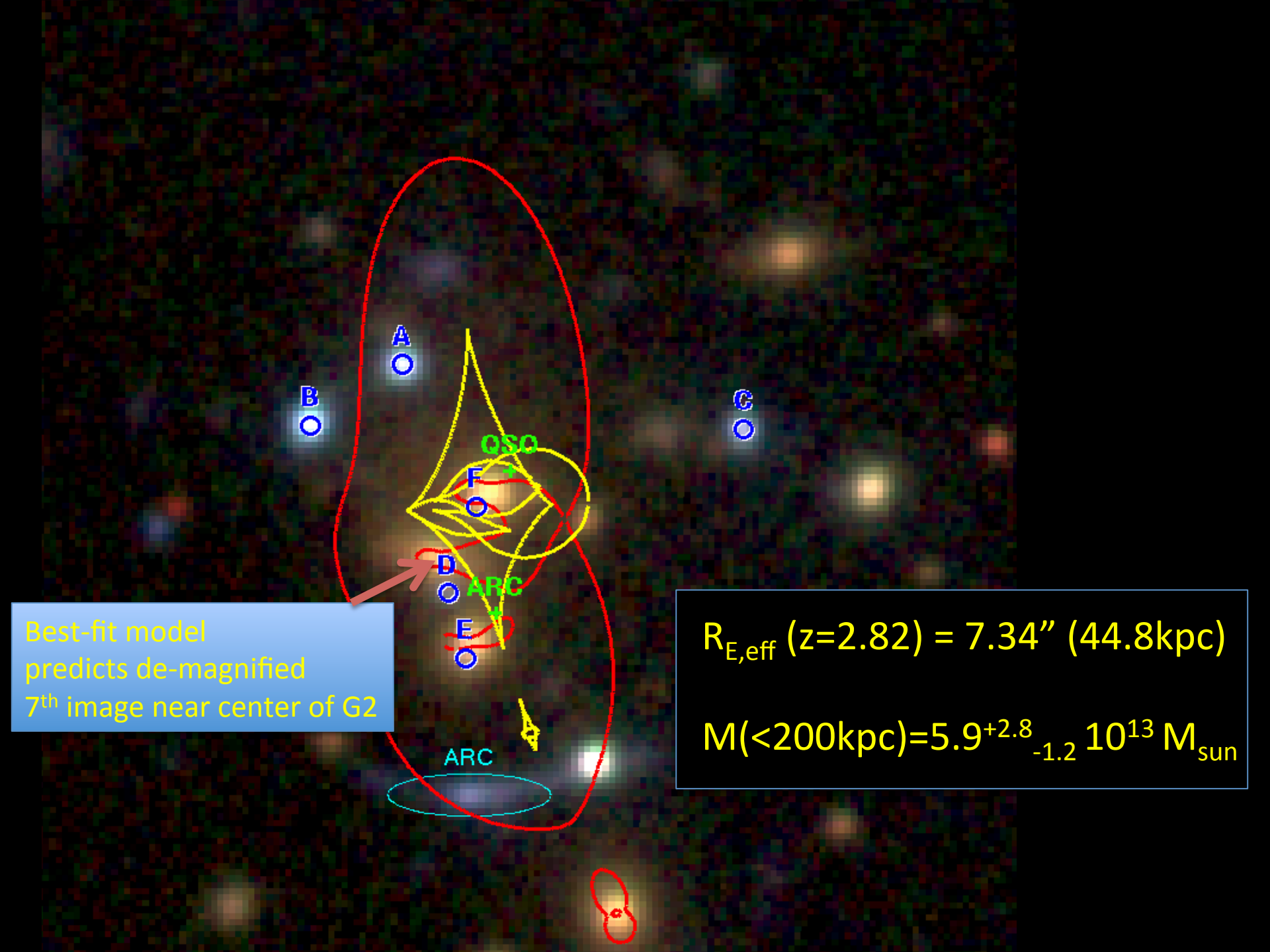
(Some models) predicted two additional quasar images, near G1 and G2



(Dahle et al. 2013)

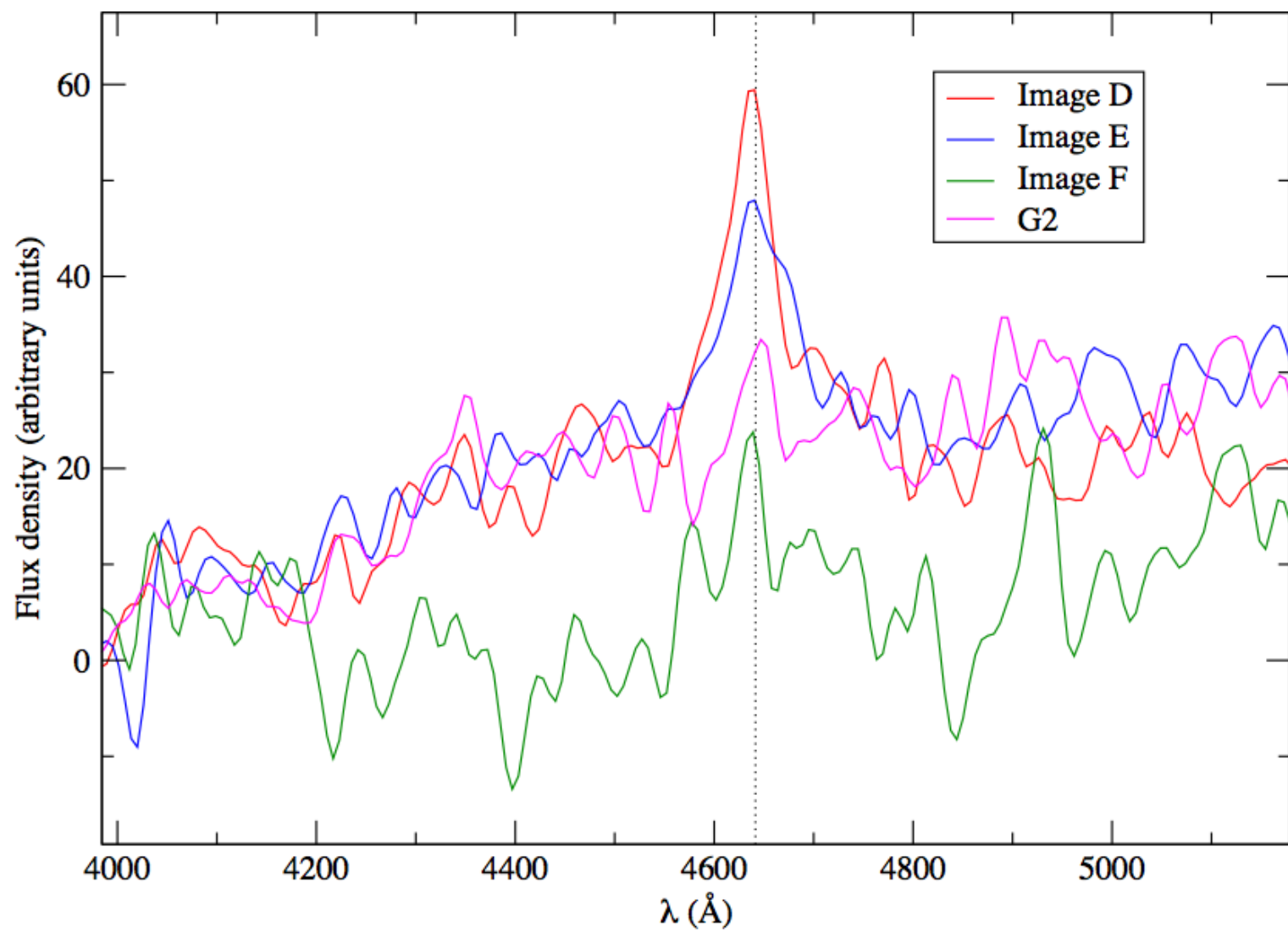






Best-fit model predicts de-magnified 7th image near center of G2

$$R_{E,\text{eff}} (z=2.82) = 7.34'' (44.8\text{kpc})$$
$$M(<200\text{kpc}) = 5.9^{+2.8}_{-1.2} 10^{13} M_{\text{sun}}$$



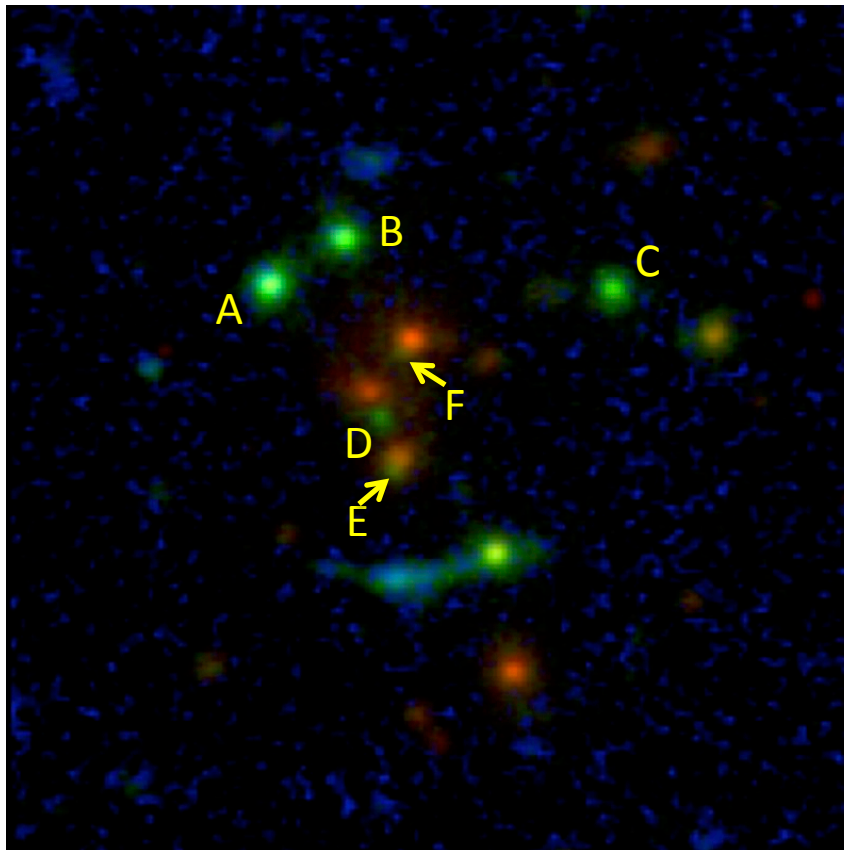
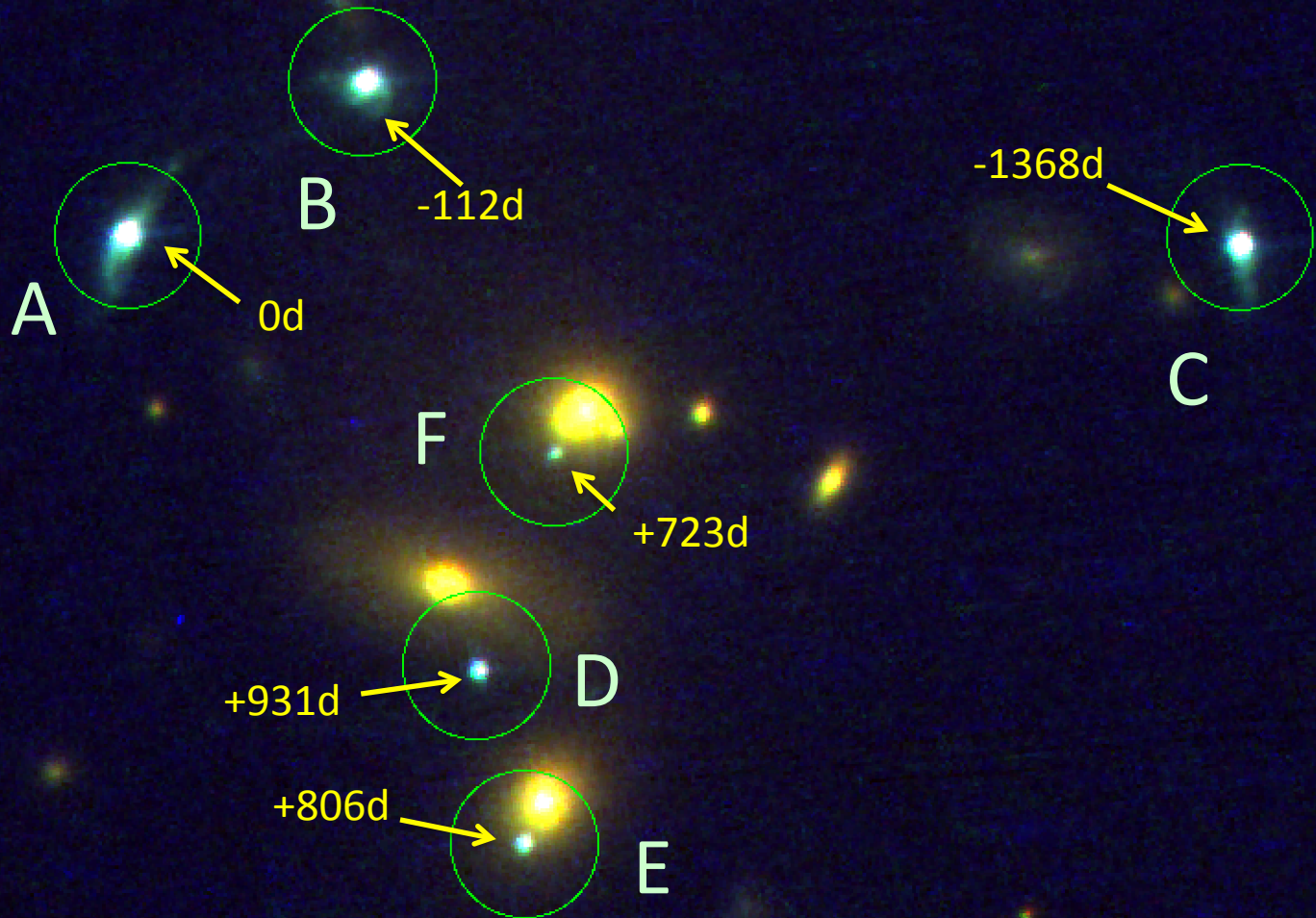
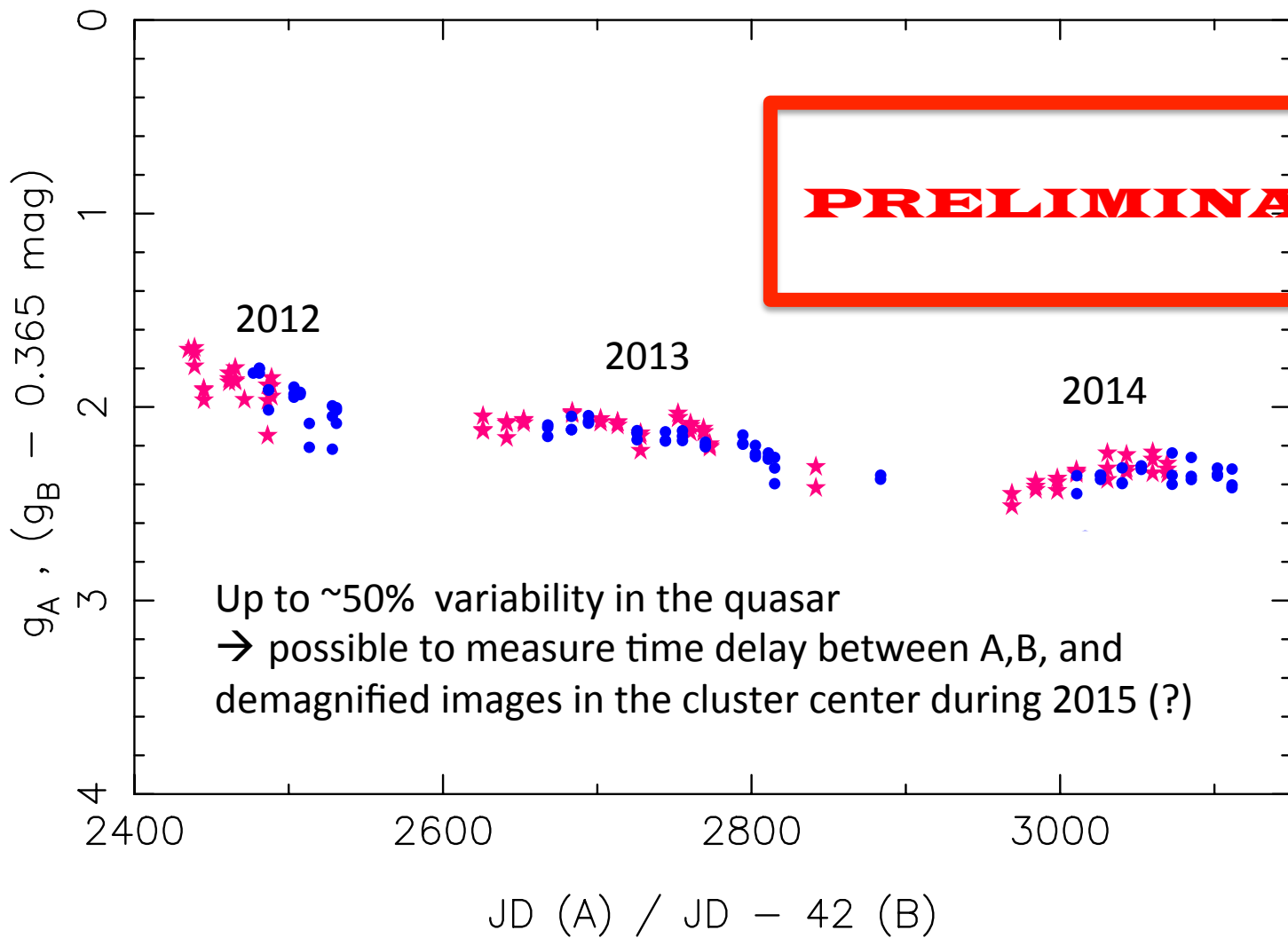


Image	Magnitude (i)	Magnification	Time Delay [days]
A	20.95 ± 0.01	4.7 (+3.5)(-1.6)	$\equiv 0$
B	21.31 ± 0.01	5.3 (+4.6)(-1.6)	-112 (+158)(-225)
C	21.90 ± 0.01	2.4 (+1.1)(-0.3)	-1368 (+456)(-344)
D	23.78 ± 0.08	0.7 (+0.3)(-0.2)	931 (+237)(-233)
E	23.96 ± 0.08	0.6 (+0.3)(-0.2)	806 (+370)(-224)
F	24.55 ± 0.07	0.5 (+0.5)(-0.2)	723 (+223)(-161)

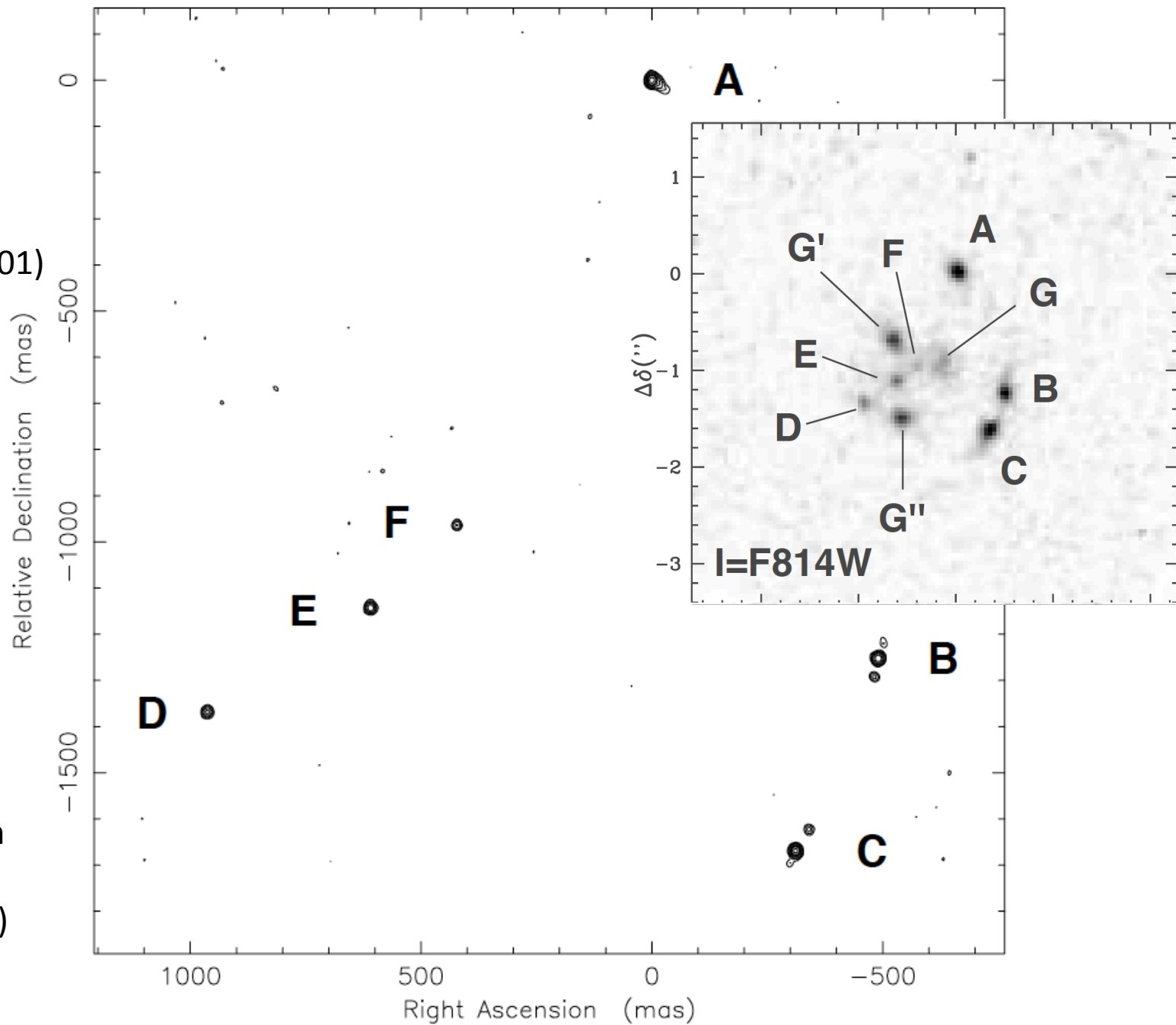
Model – predicted time delays



NOT monitoring program
(ongoing since October 2012)



B1359+154:
6-image AGN,
lensed by
compact group
(Rusin et al. 2001)

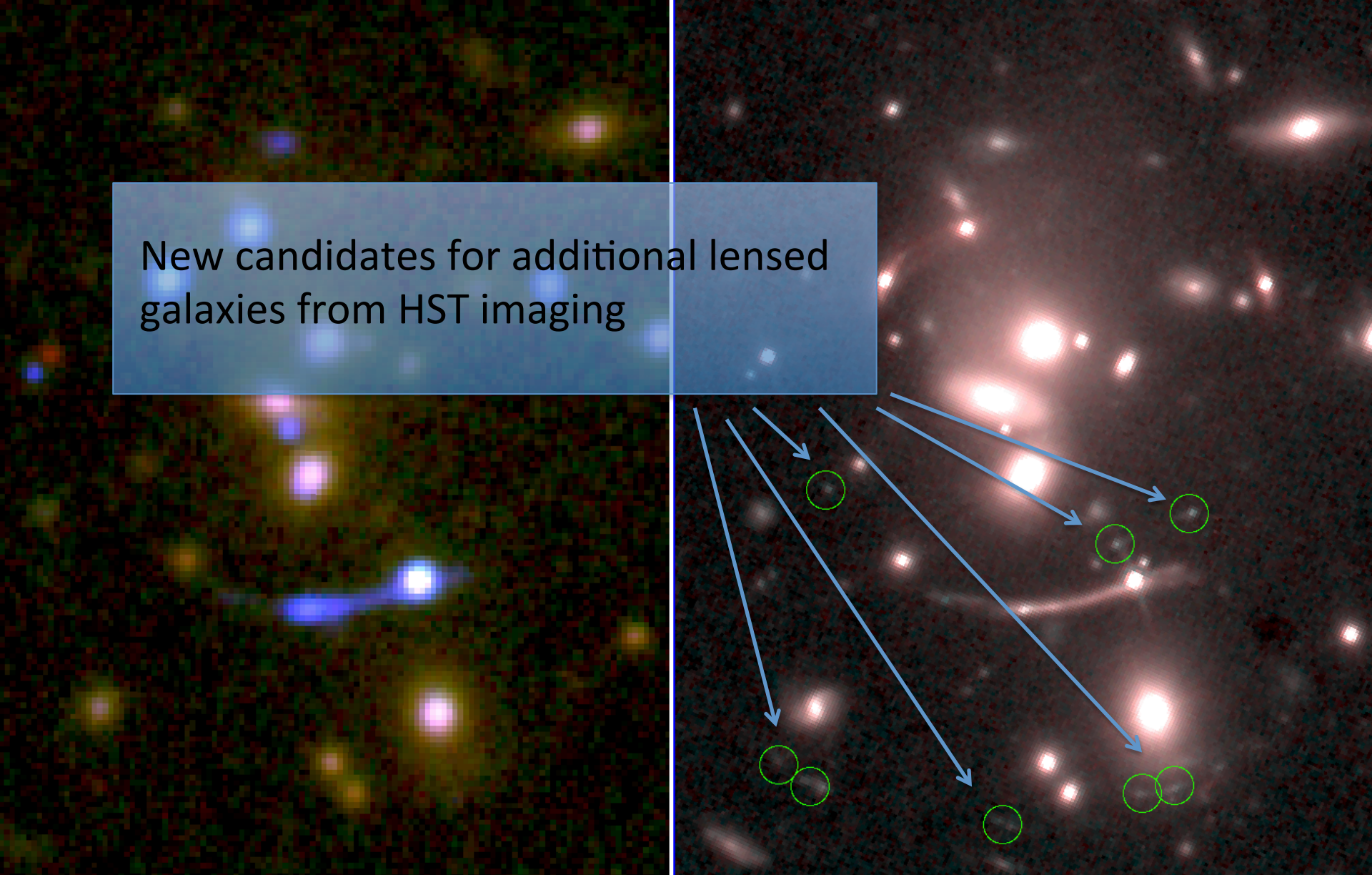


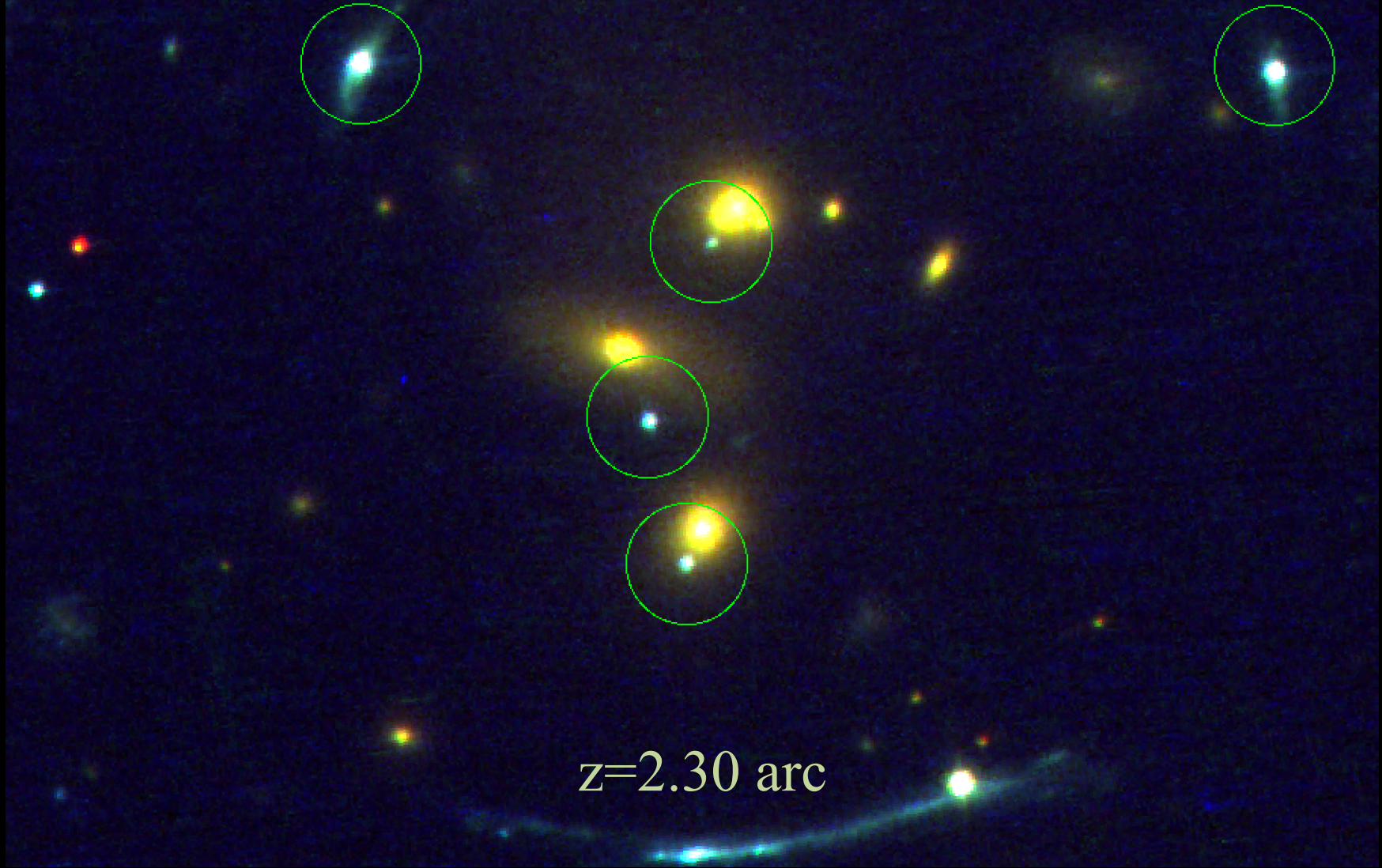
1.7'' separation
 $z_s = 3.253$
 $z_l \sim 1$ (3 galaxies)

New candidates for additional lensed galaxies from HST imaging

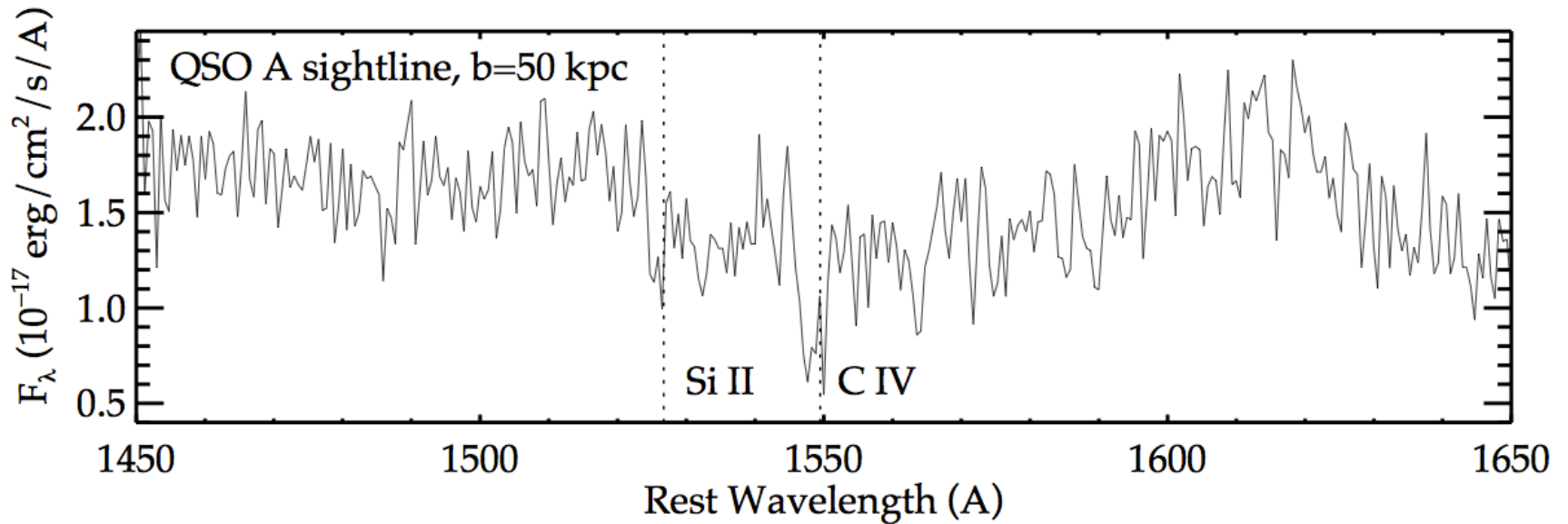
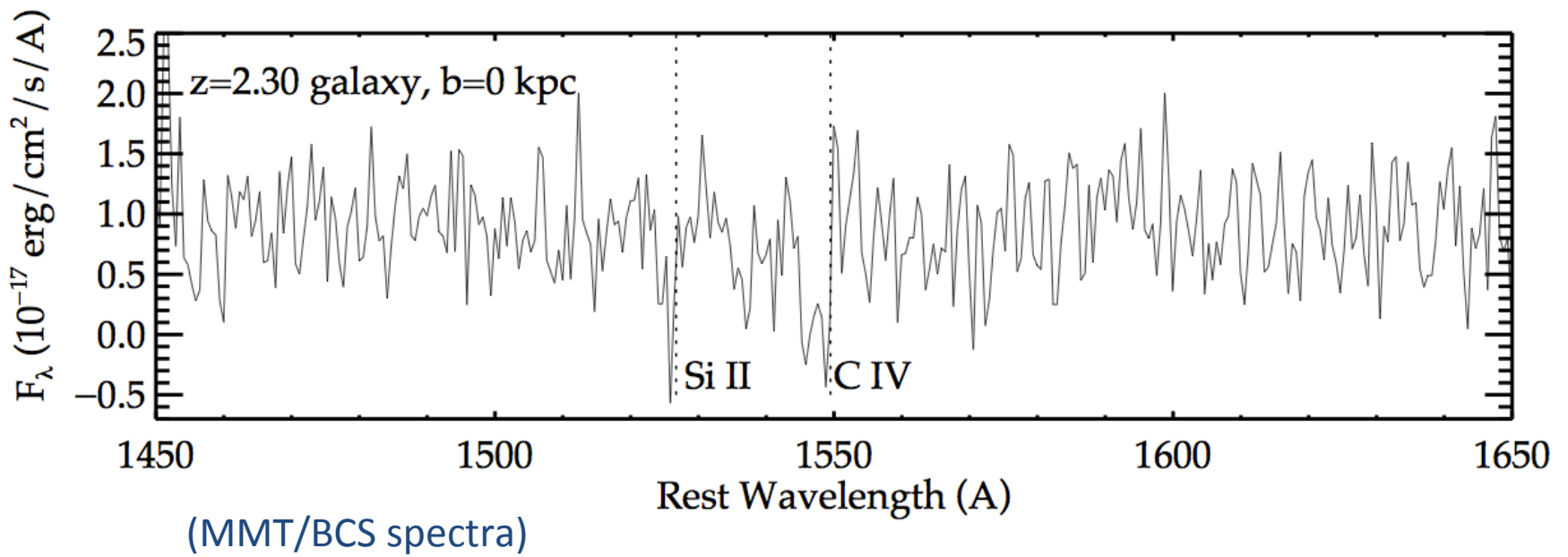
NOT/MOSCA gri

HST/WFC3 F110W, F160W





(cf. SGAS talk by E. Wuyts yesterday)



Stark et al. (2013): Ly_{α} , Si II, C IV absorption in the QSO image A spectrum, from the circumgalactic medium around the $z=2.30$ lensed arc, at $b \sim 50$ kpc

--> Kinematics and chemical composition of outflows in $z=2.30$ galaxy

Future work

- **Spectroscopy of fainter multiply lensed galaxies found in HST images**
- **Additional time delays from NOT monitoring campaign**
- **Confirmation of 7th image would put constraint on mass of SMBH in G2 (cf. Inada et al. 2008 constraint in SDSS J1004+4112 from 5th image)**
- **Chandra 70ksec TBD in Cycle 16 [PI: D. Pooley] to measure anomalous optical/X-ray flux ratios**
- **See also Misawa et al. 2013, 2014 (resolved 3D picture of clumps in QSO outflow winds in SDSS J1029+2623)**