Probing the relevant scales of star formation within strongly lensed galaxies at z=2-3

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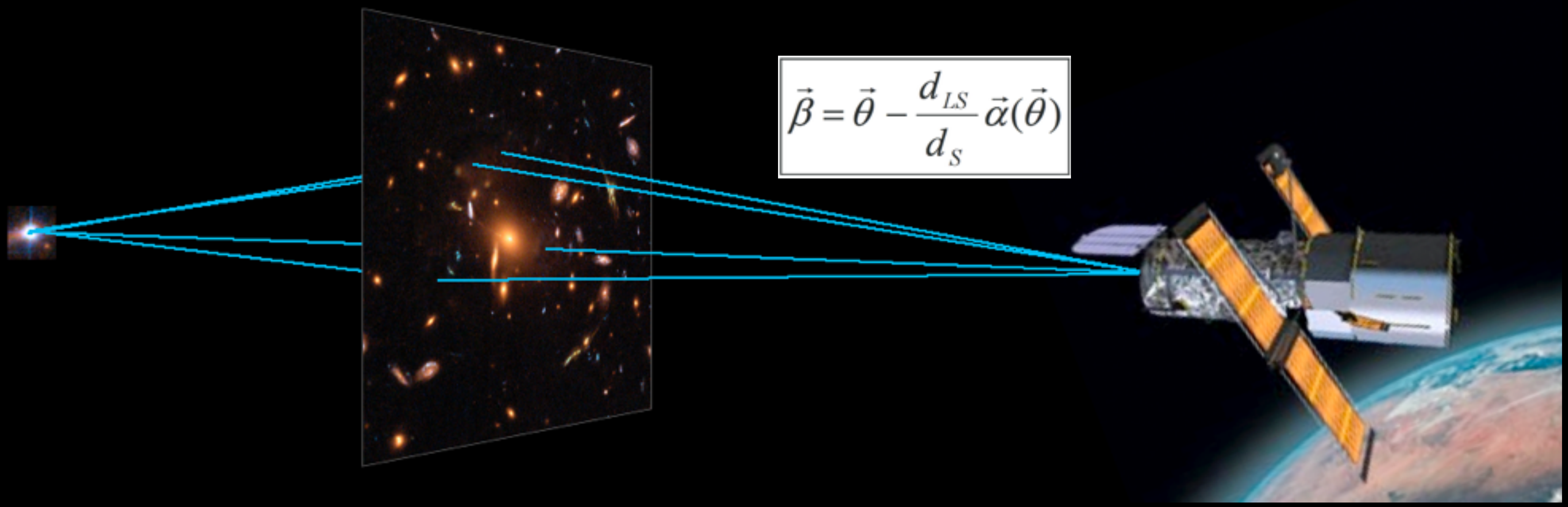
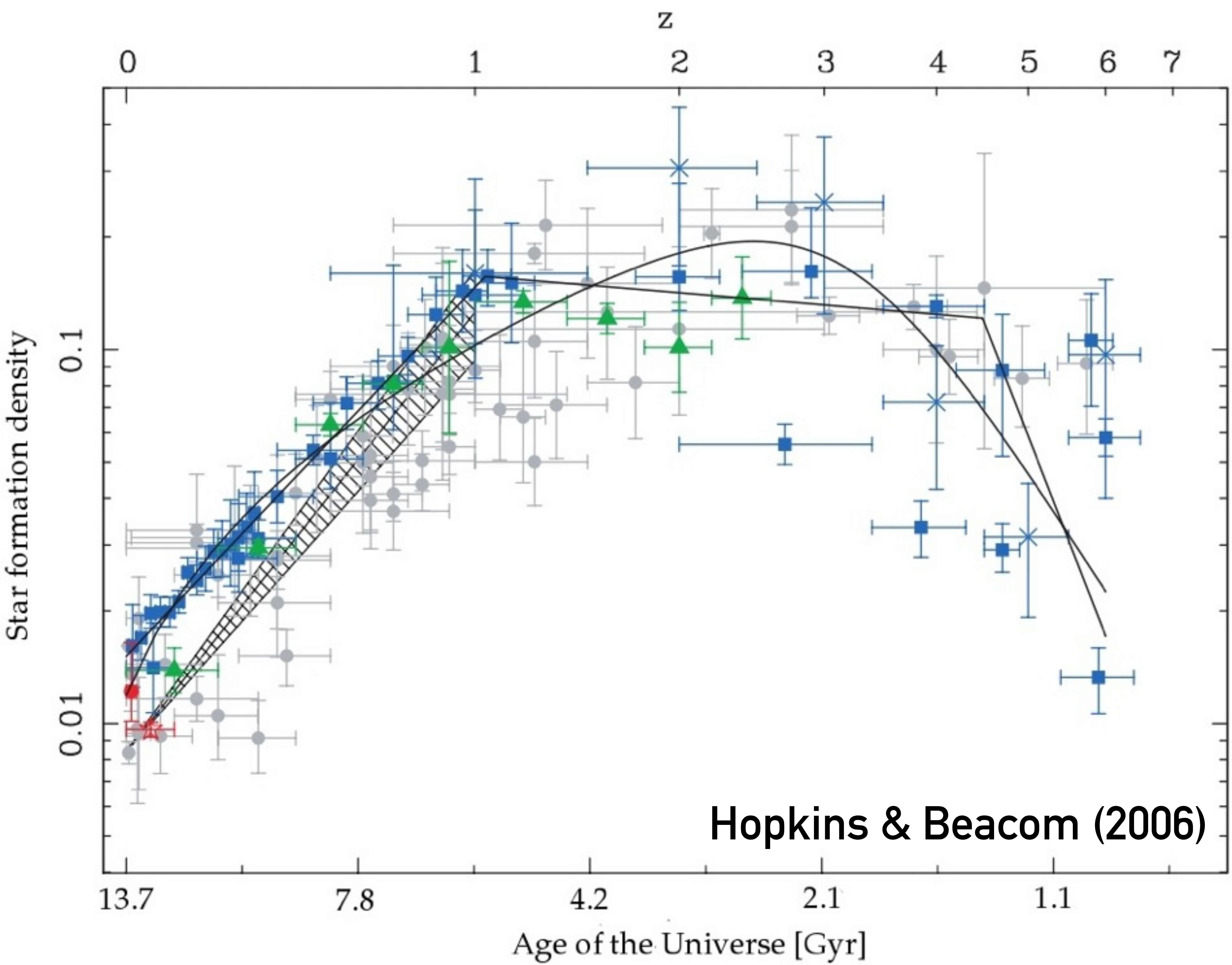
Jane Rigby (NASA Goddard)
Keren Sharon, Traci Johnson (University of Michigan)
Matt Bayliss (Harvard CFA)
Hakon Dahle (University of Oslo)

Strong Lensing 101

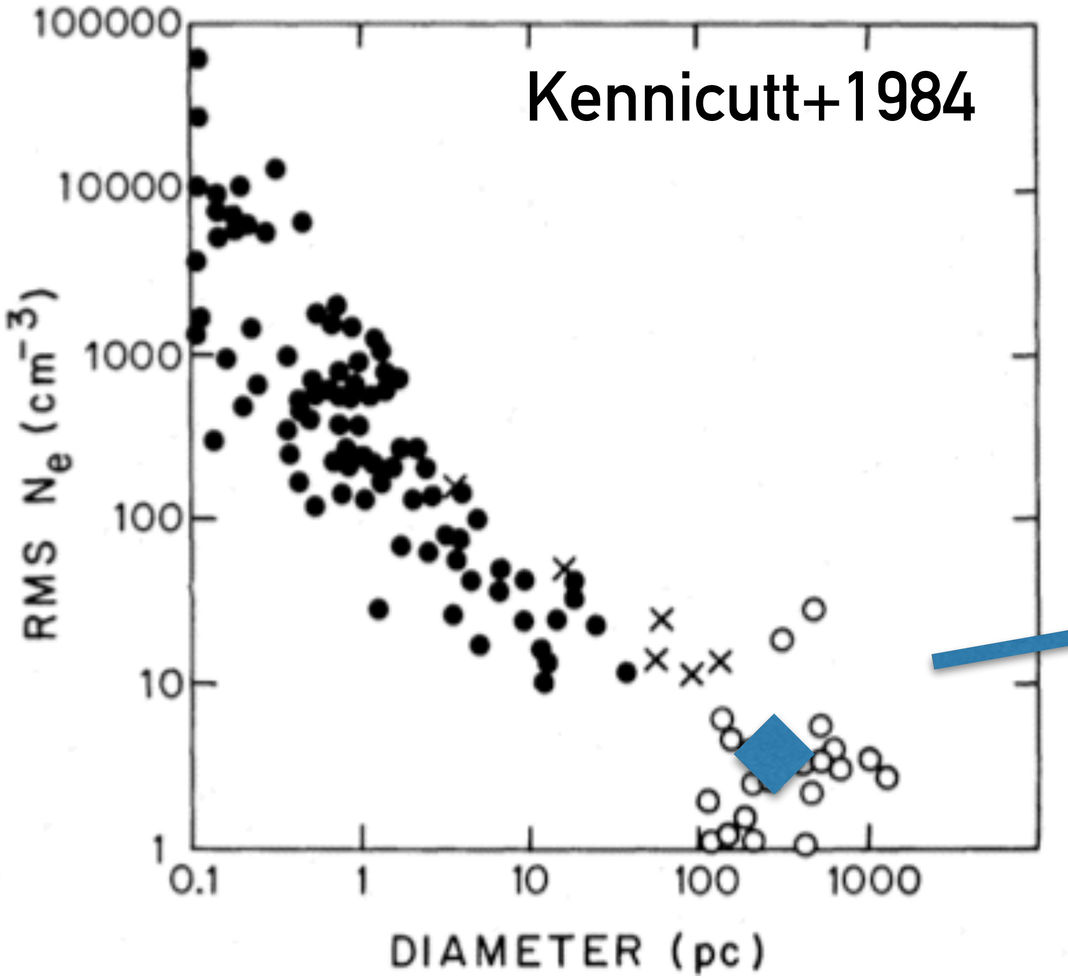


$$\vec{\beta} = \vec{\theta} - \frac{d_{LS}}{d_S} \vec{\alpha}(\vec{\theta})$$

- Mass distribution between source and observer deflects light
- you see multiple images of single background source
- sources appear stretched into giant arcs → higher spatial resolution
- lensing conserves surface brightness → magnification → higher S/N


z
0
1
2
3
4
5
6
7
Star formation density
0.1
0.01
13.7
7.8
4.2
2.1
1.1
Age of the Universe [Gyr]
Hopkins & Beacom (2006)

THE PHYSICAL SCALE OF STAR FORMATION



30 Doradus

380pc

local HII regions come in
a large range of sizes

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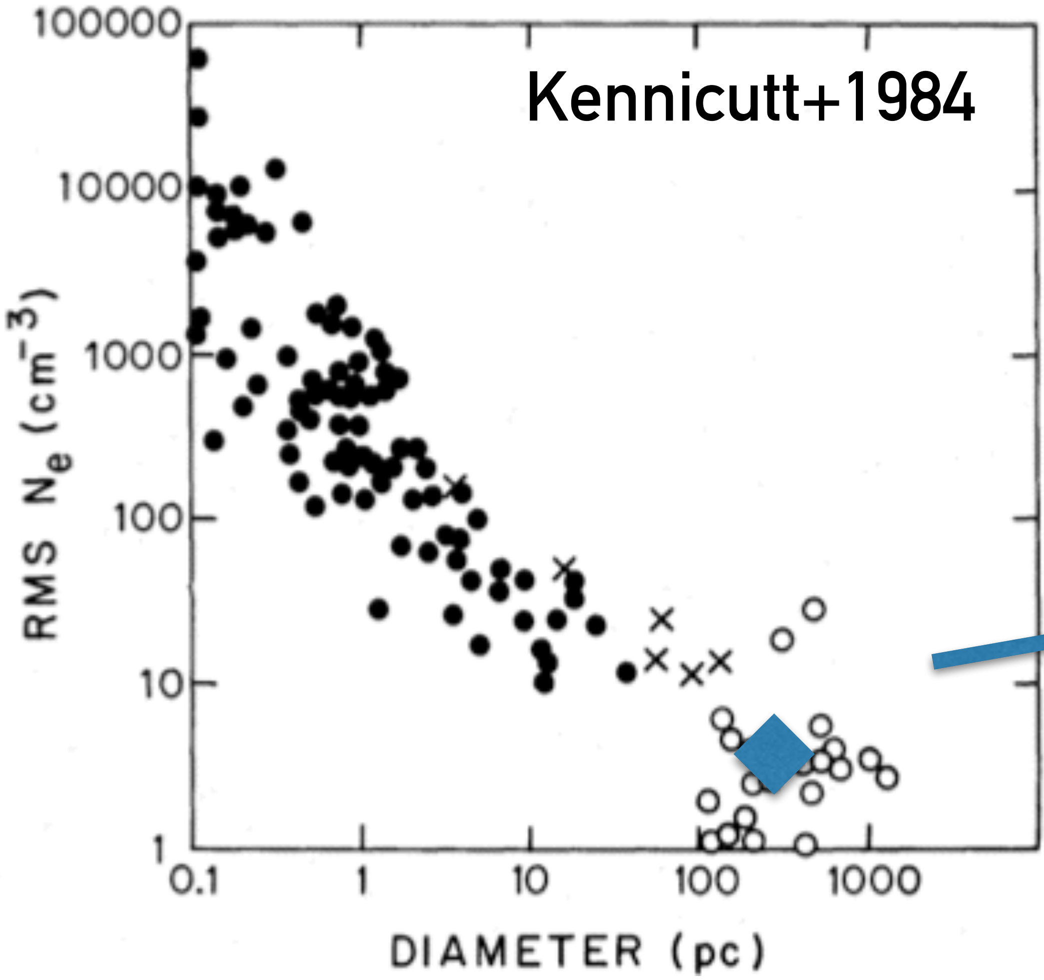

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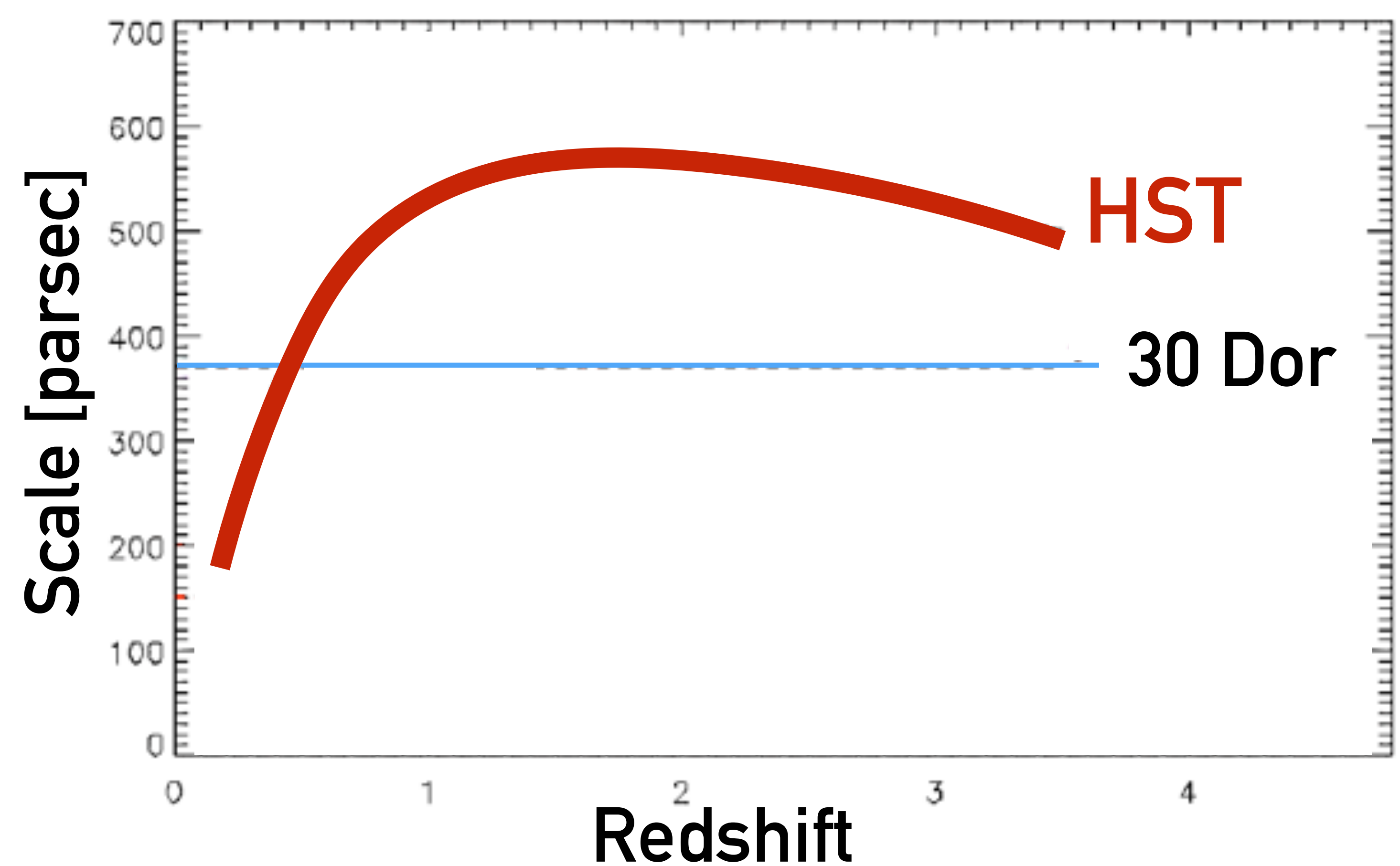

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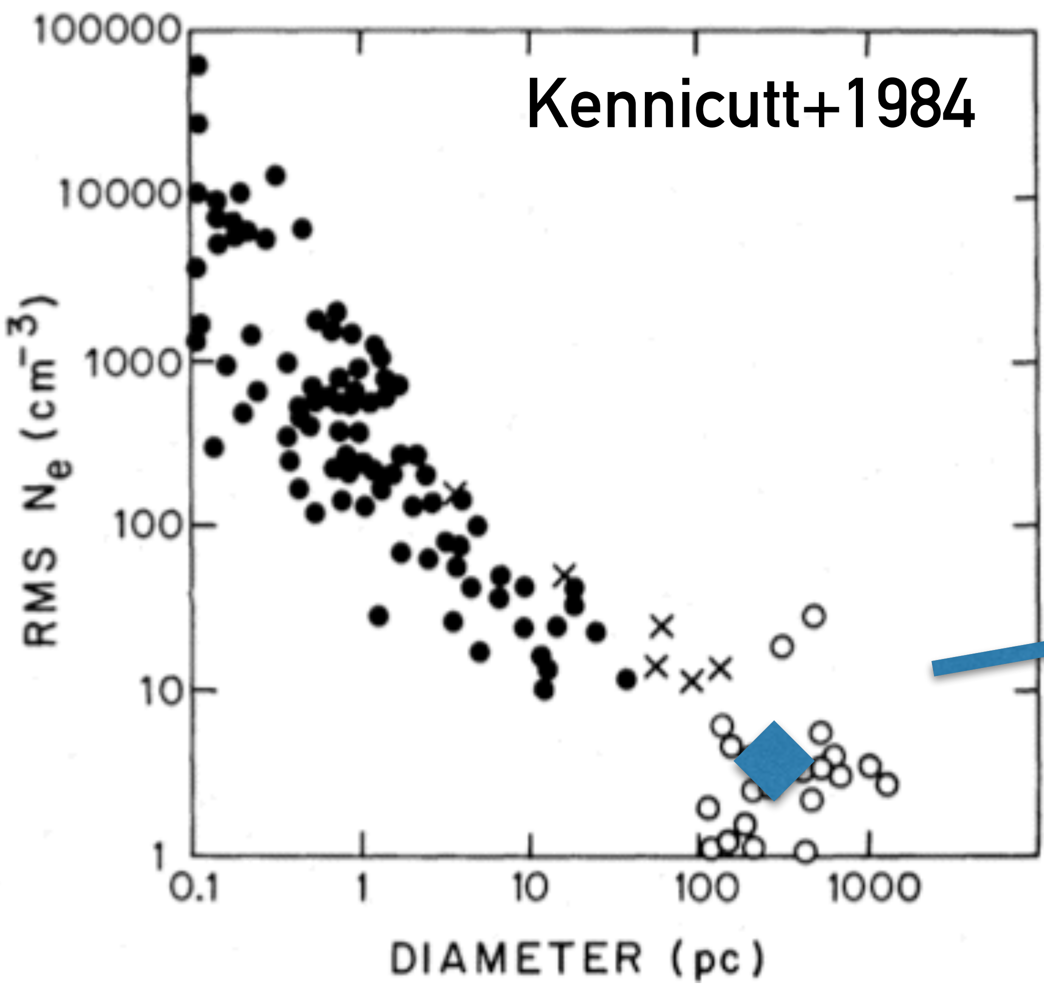

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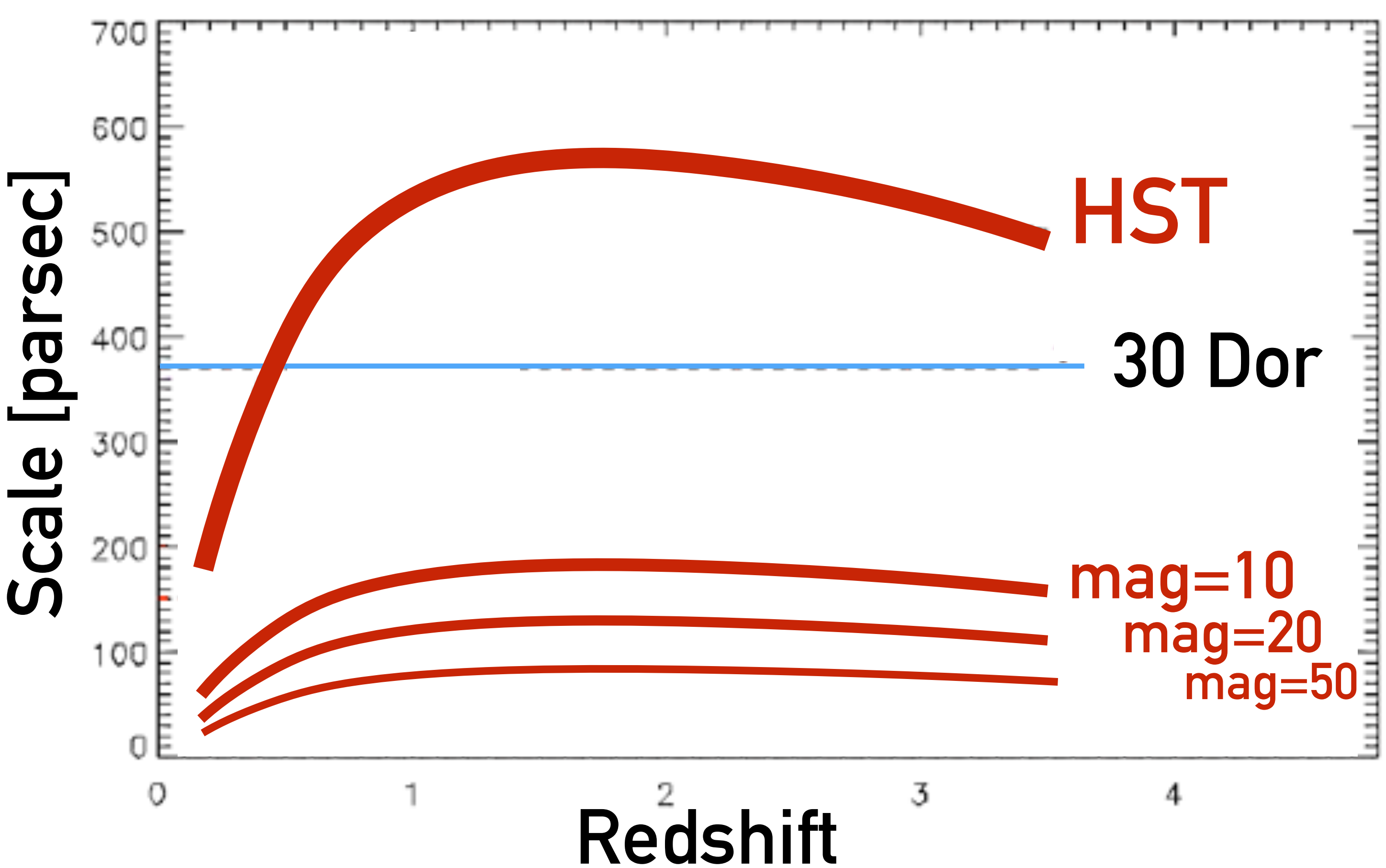
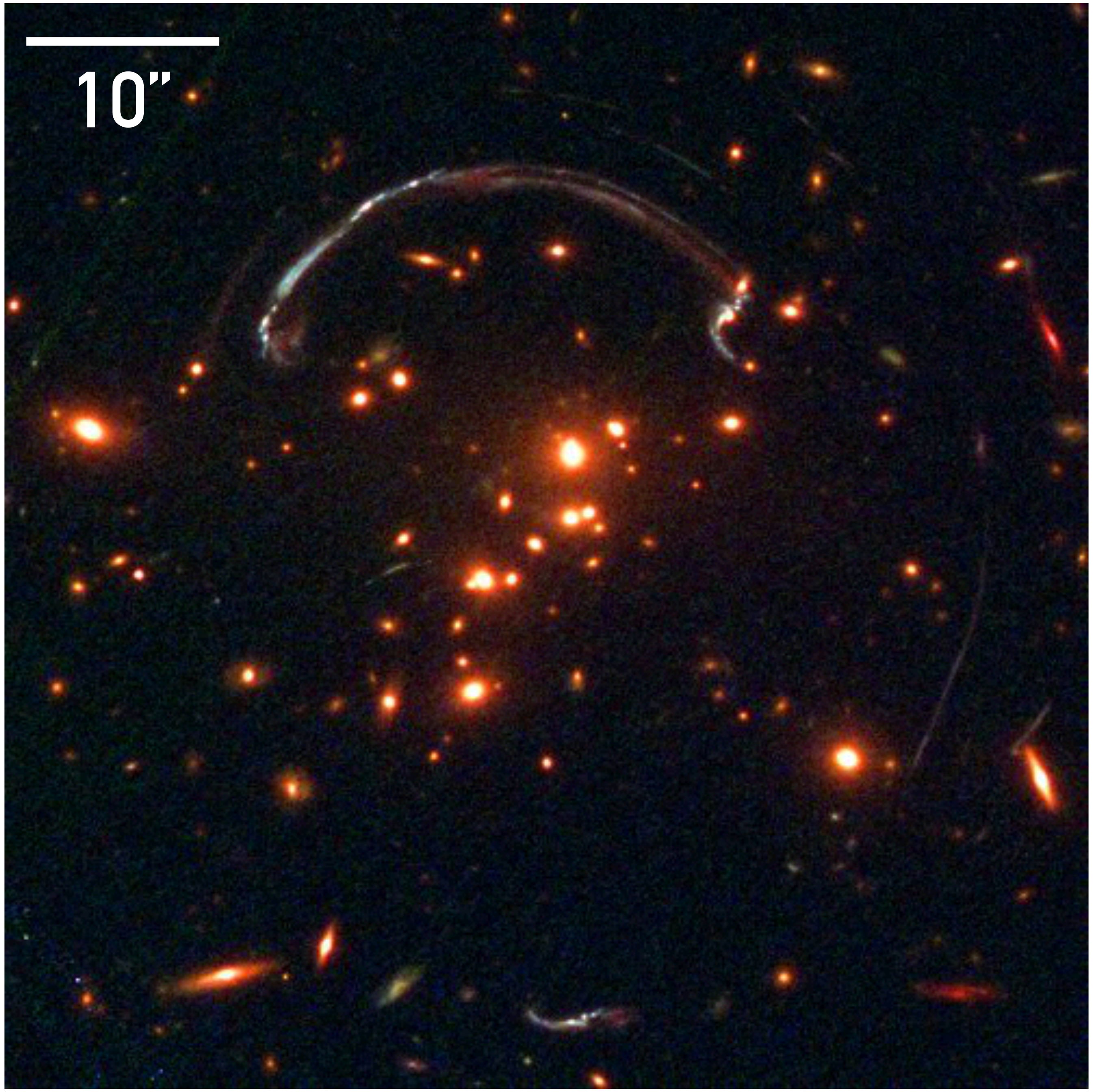


Only strong lensing can resolve SF on relevant physical scales ~100 pc

RCS0327: uniquely resolving a merger at z=1.7



The brightest distant lensed galaxy known

Wuyts+2010, Rigby+2012, Sharon+2012, Wuyts+2014, Whitaker+2014

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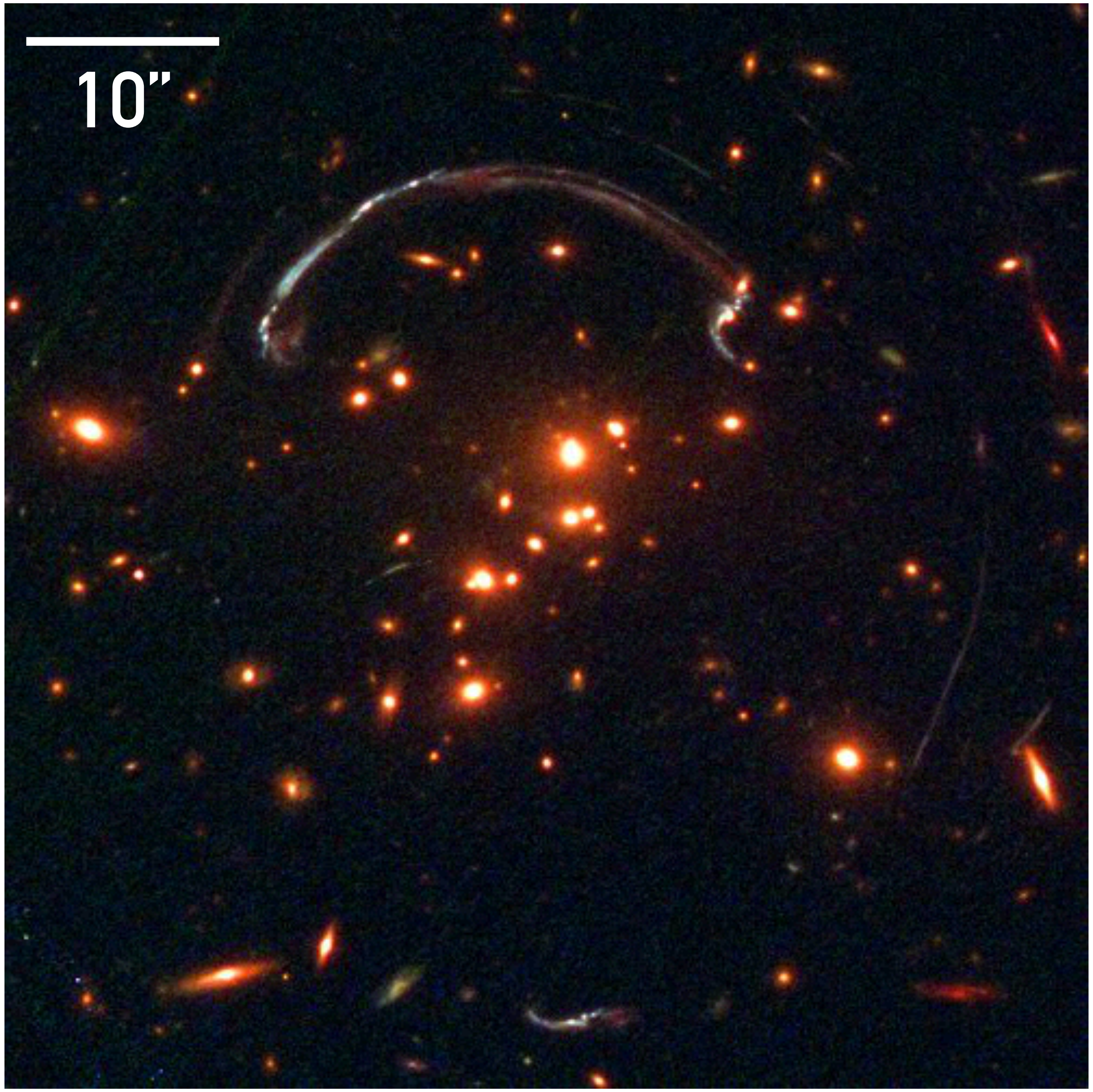

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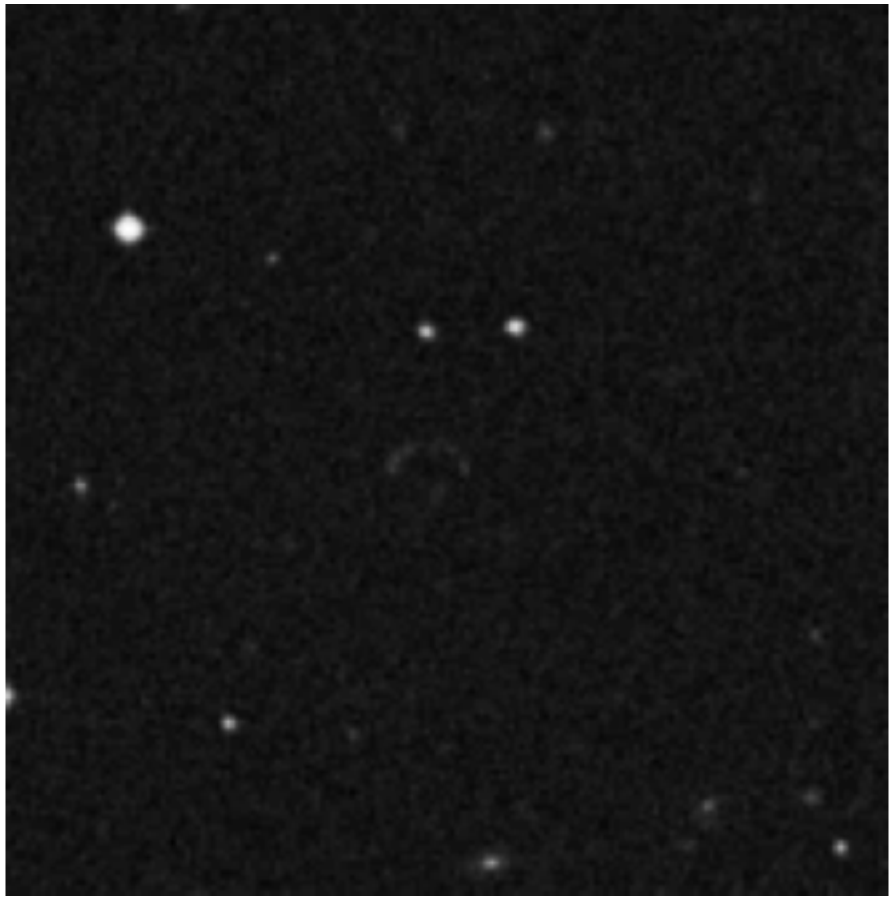

Digitized Sky Survey
archive.eso.org/dss/dss

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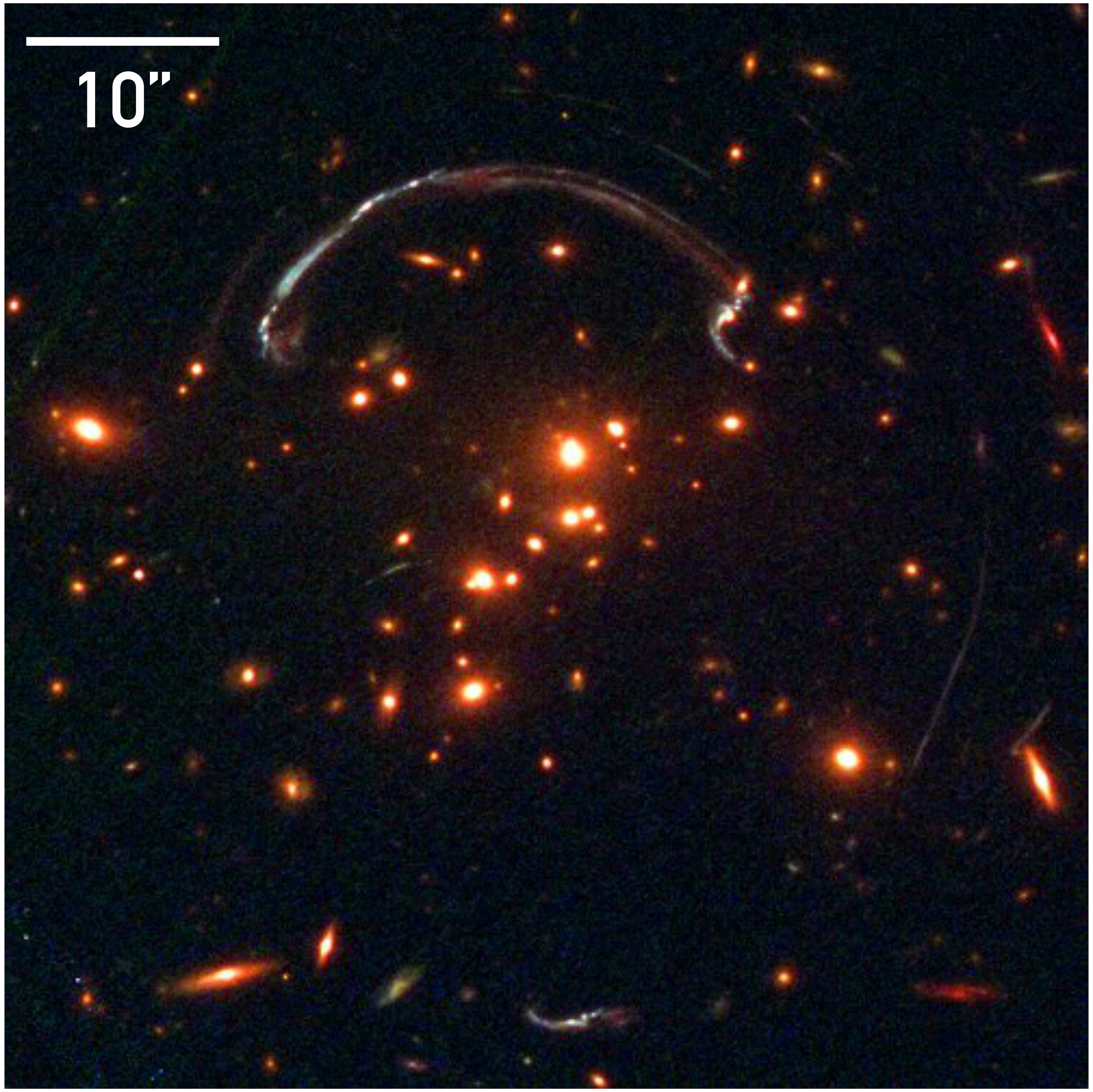

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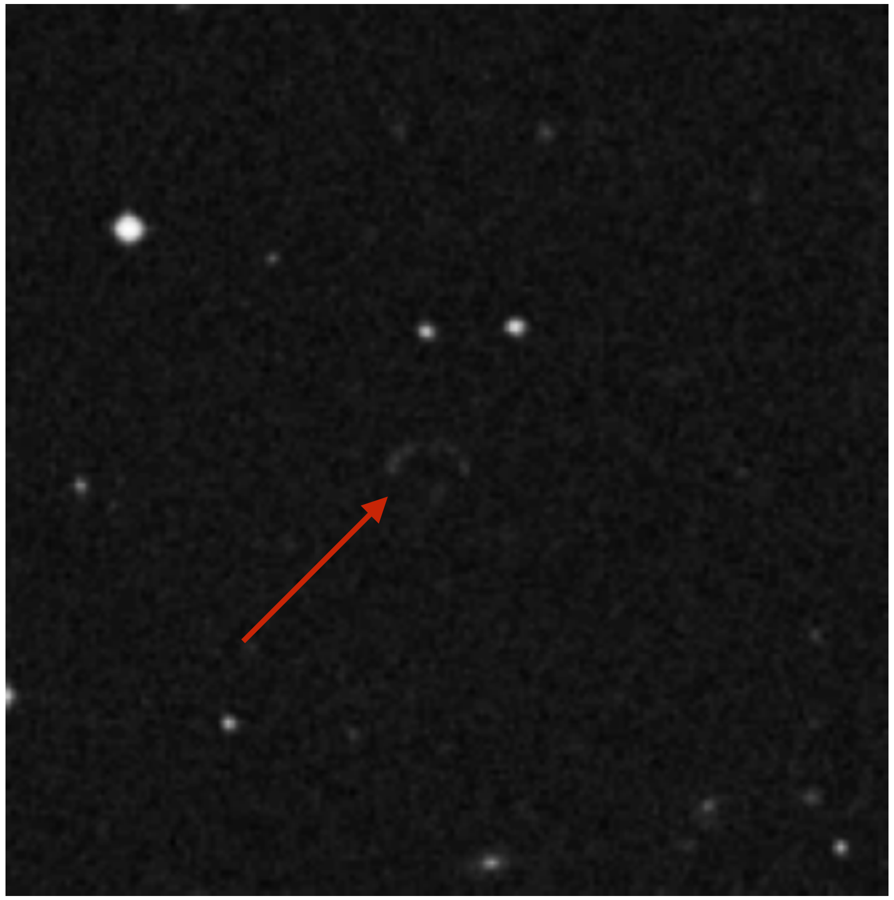

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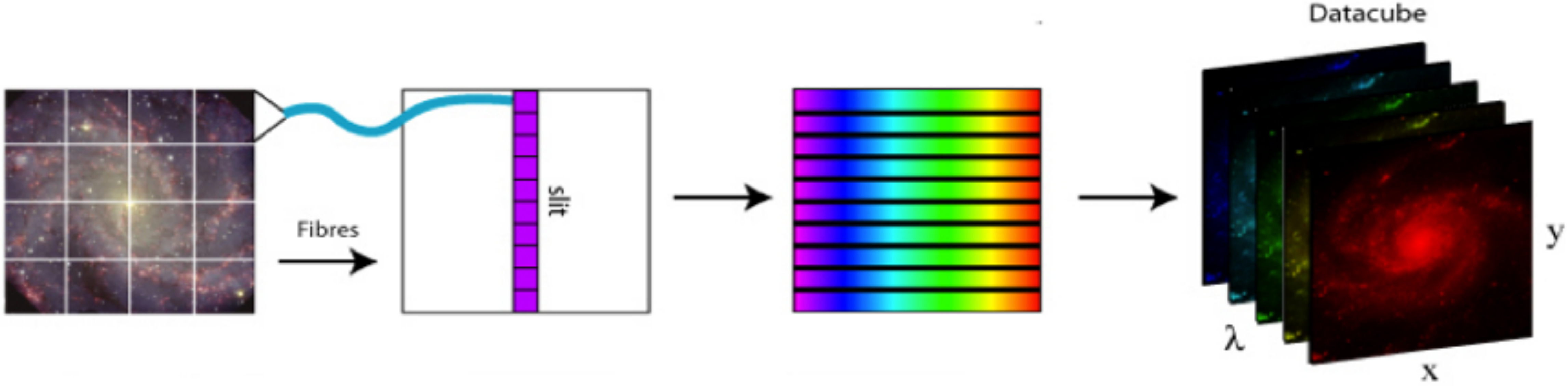
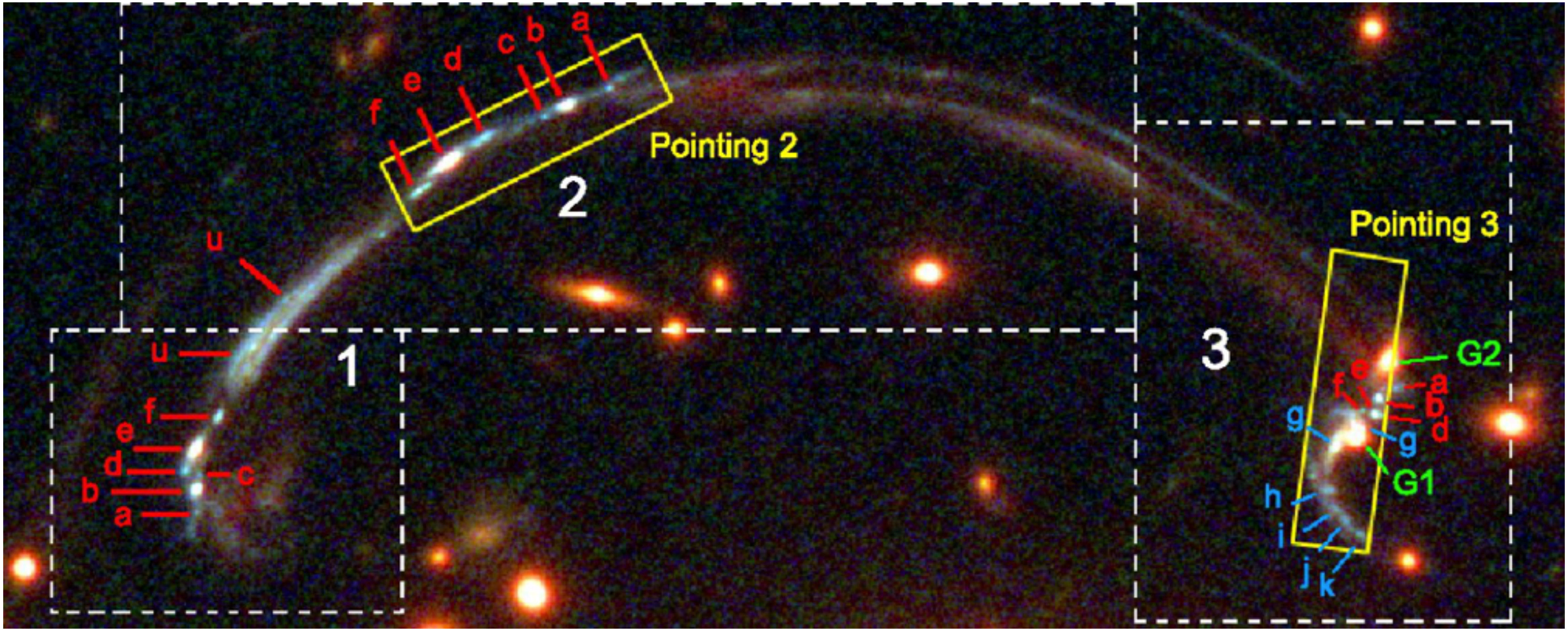
KECK/OSIRIS + AO IFU observations





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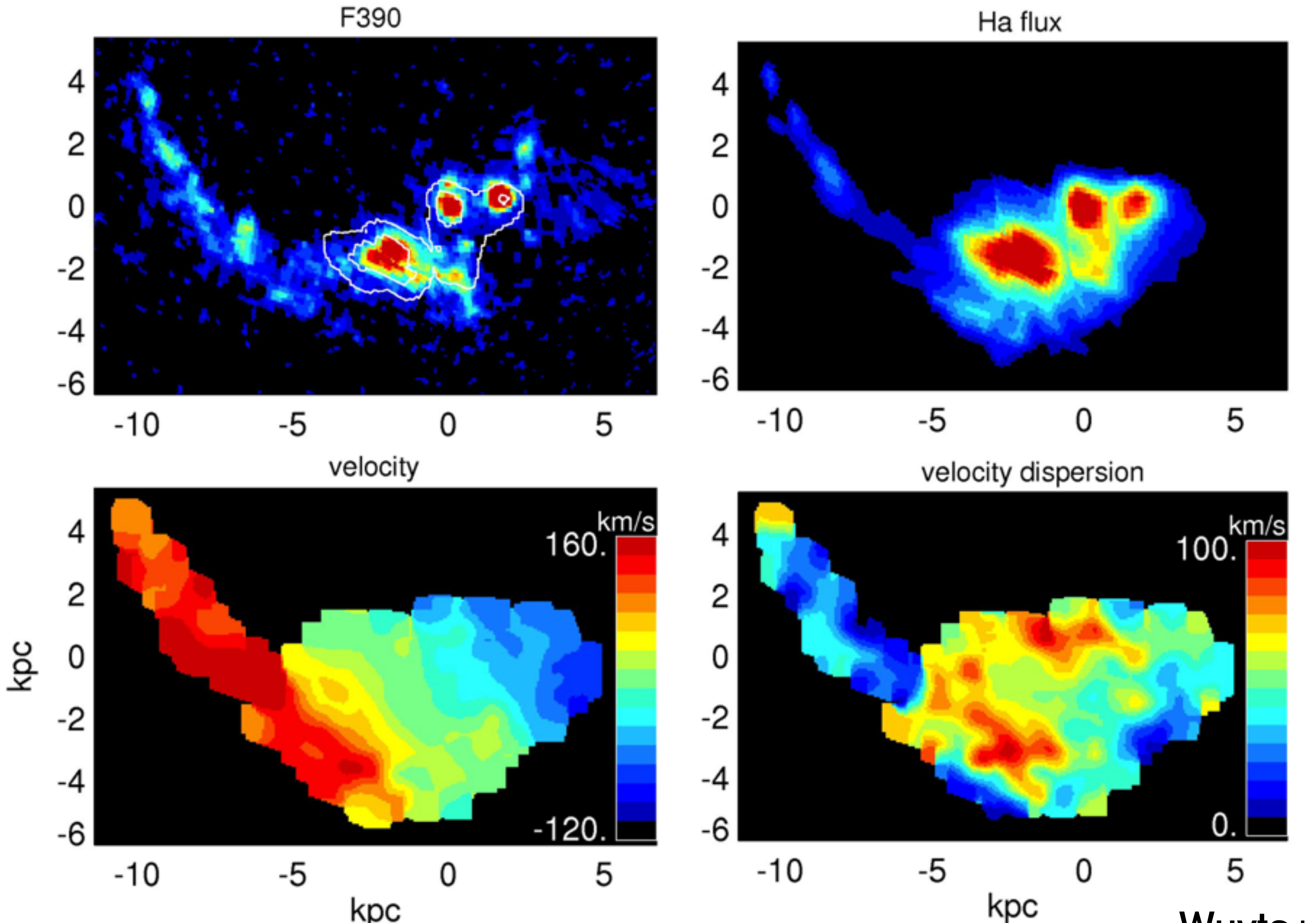
SOURCE-PLANE IMAGES for POINTING 3



Wuyts+2014

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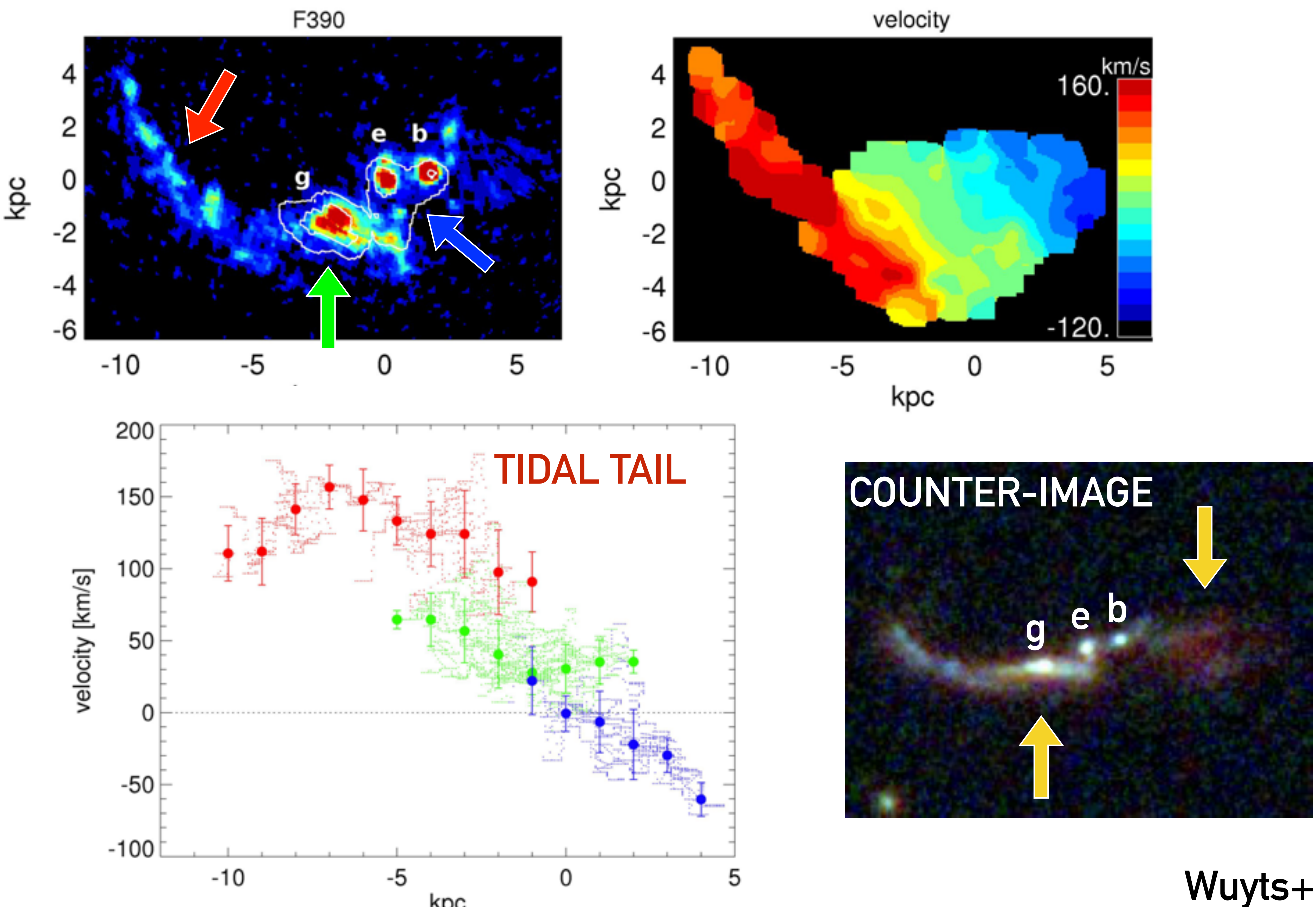

Wuyts+2014

SLOAN GIANT ARCS SURVEY

SDSS DR7 10.000 deg^2
40.000 galaxy clusters/groups
$0.1<z<0.55$

VISUAL EXAMINATION

0. no evidence of lensing
1. likely not a strong lens, but not unambiguous
2. a likely strong lens, but not certain
   (faint and/or questionable geometry)
3. an almost certain strong lens

images scored multiple times → track completeness

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FOLLOW-UP (DEEPER & BETTER SEEING)

<score>	#lenses	follow-up	confirmed	total#
2.5-3.0	33	100%	33 (100%)	33
2.0-2.5	39	100%	30 (77%)	30
1.5-2.0	135	93%	53 (43%)	58
1.0-1.5	304	65%	55 (28%)	95

171 confirmed
strong lenses

216 after correcting
for follow-up incompleteness

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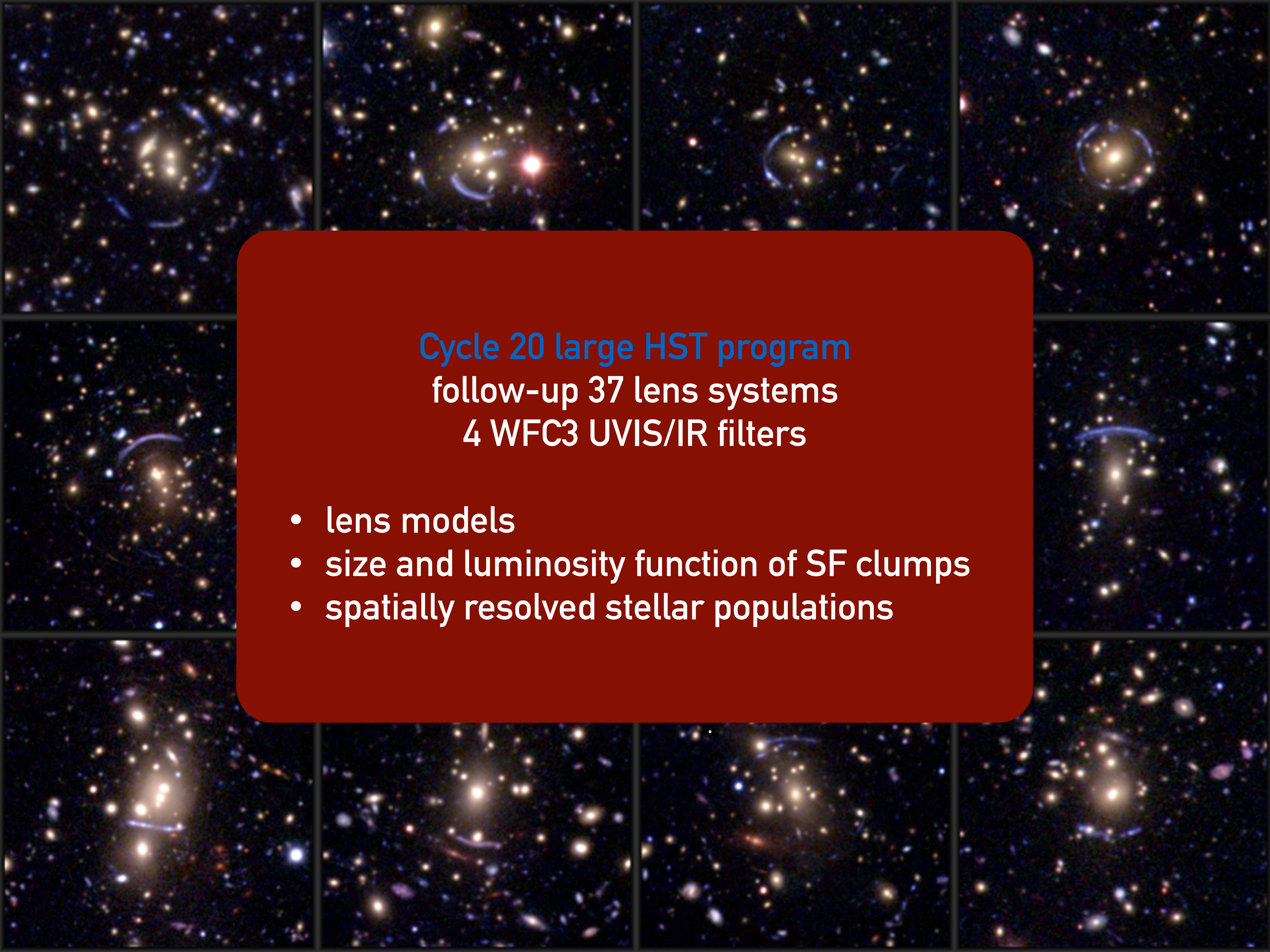
Gladders+2015, in prep



Cycle 20 large HST program

follow-up 37 lens systems
4 WFC3 UVIS/IR filters

- lens models
- size and luminosity function of SF clumps
- spatially resolved stellar populations

Background Sources

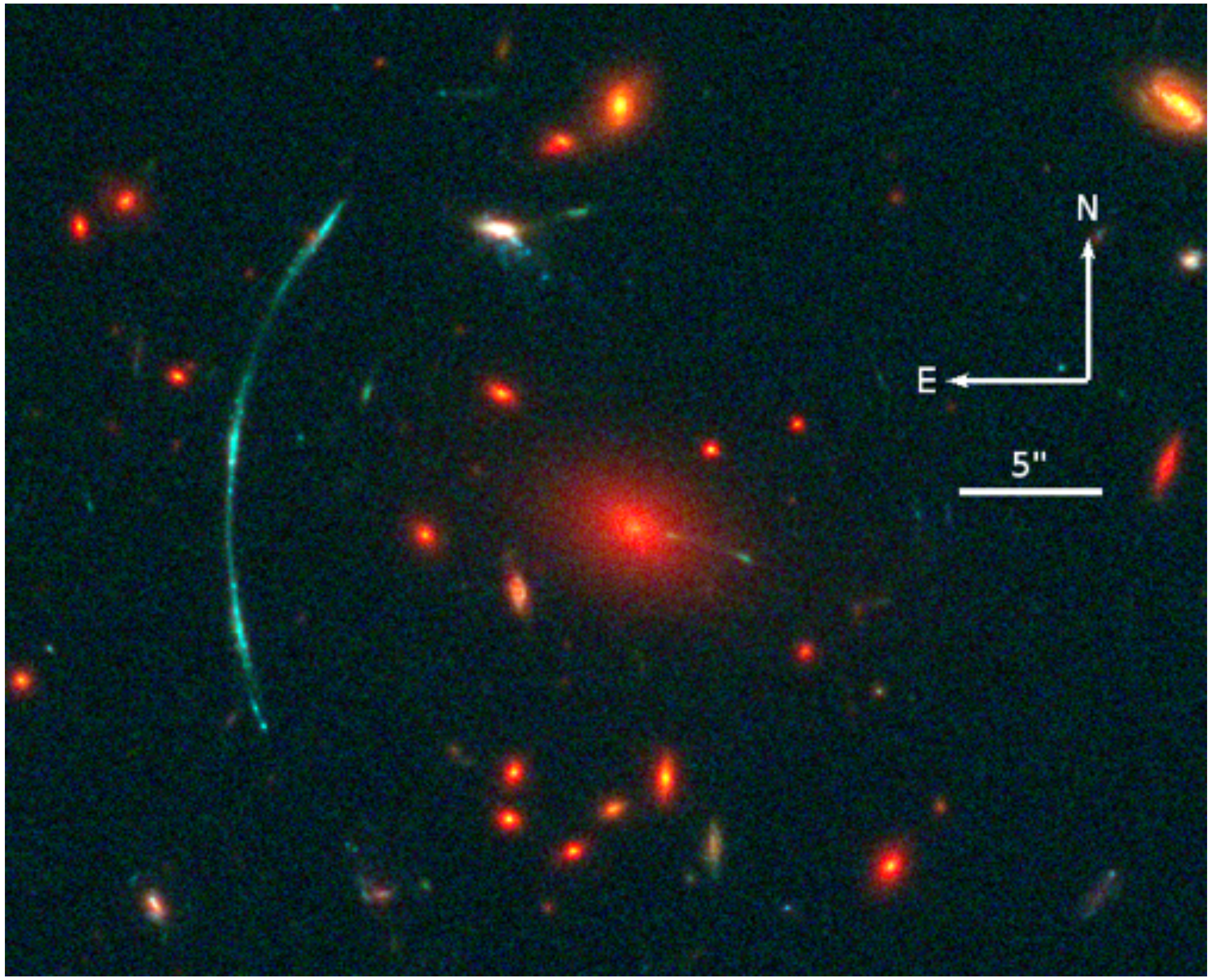
Bayliss+2010,2011ab,2014a - Dahle+2013 - Gladders+2013 - Koester+2010 - Rigby+2012,2014 - Sharon+2012 - Whitaker+2014 - Wuyts+2010,2012ab,2014

Lens systems

Bayliss2014b - Blanchard+2013 - Gralla+2011 - Oguri+2009,2012 - Sharon+2014 - Tremblay+2014

THE PHYSICAL SCALE OF STAR FORMATION

SGAS J1110+6459 z=2.481



Johnson+2014, in prep

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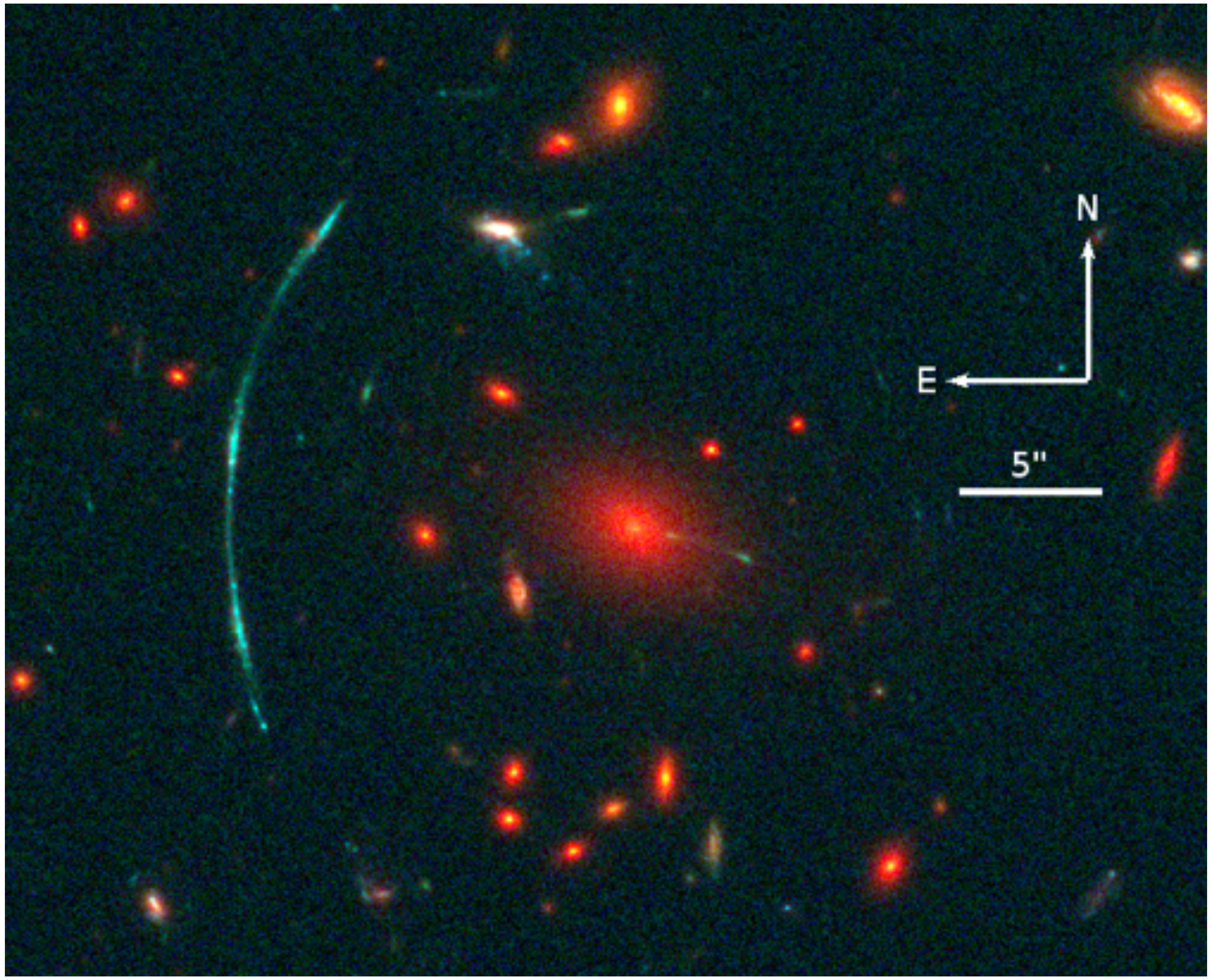

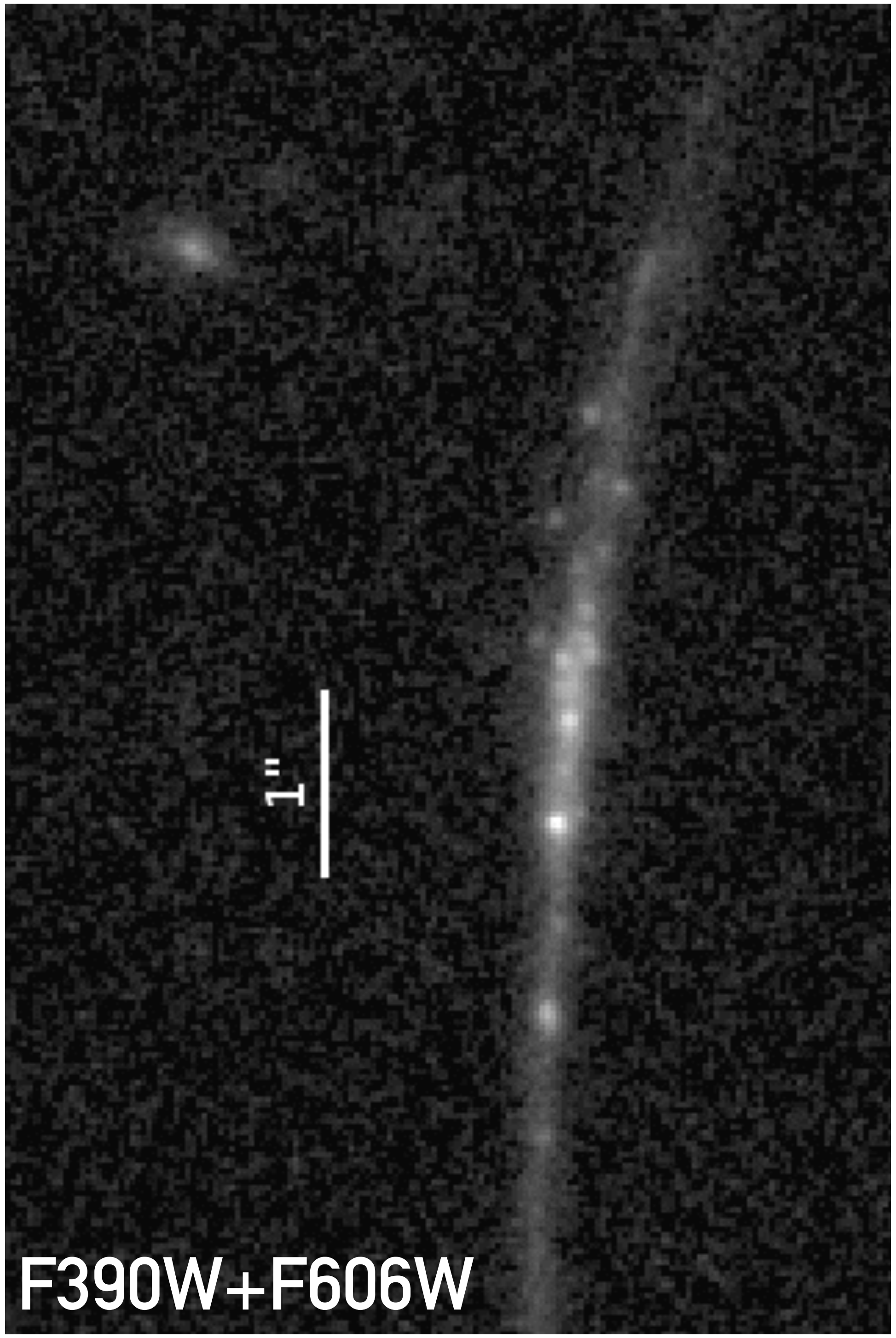

VERY CLUMPY
clump sizes in the source plane?

Johnson+2014, in prep

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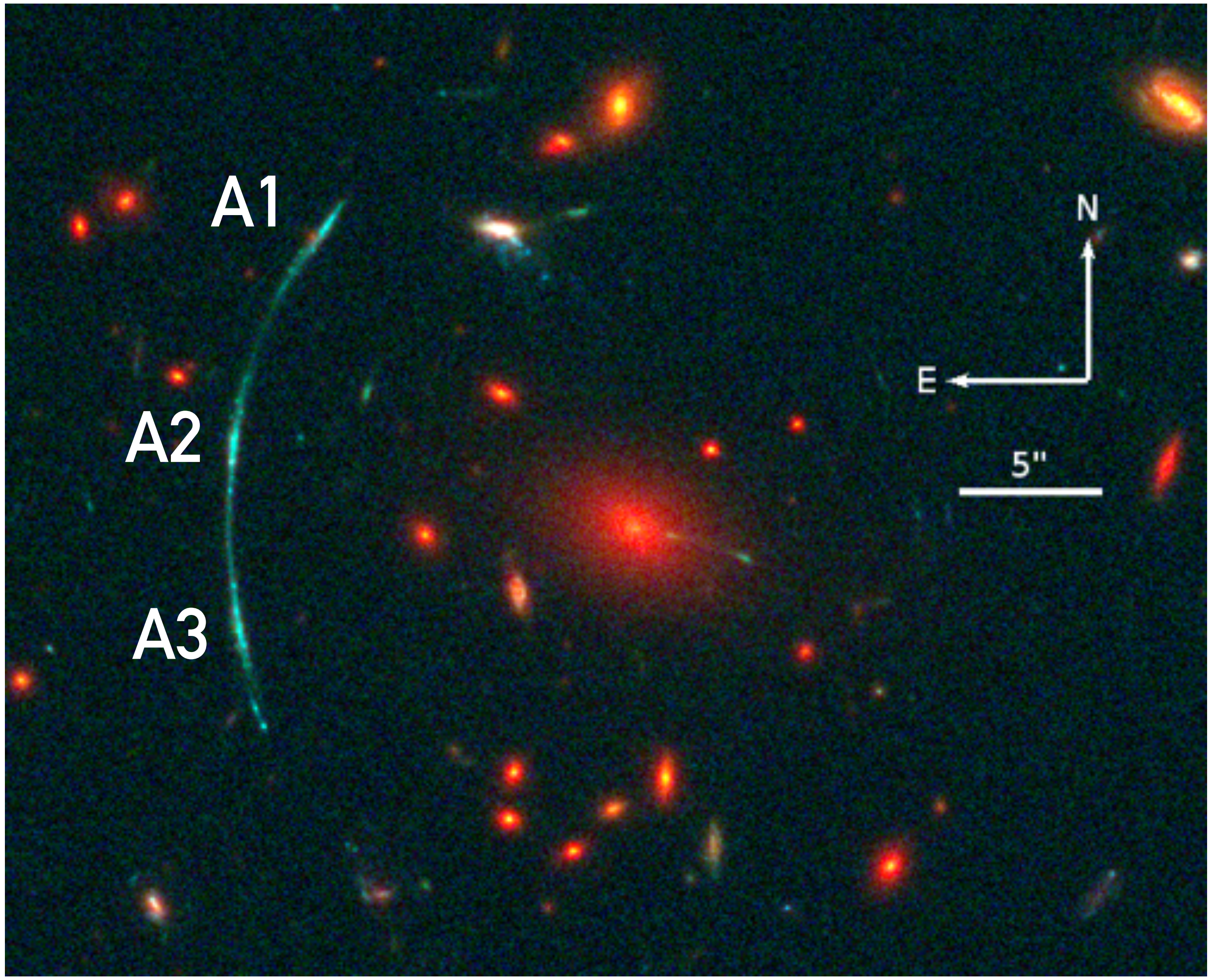
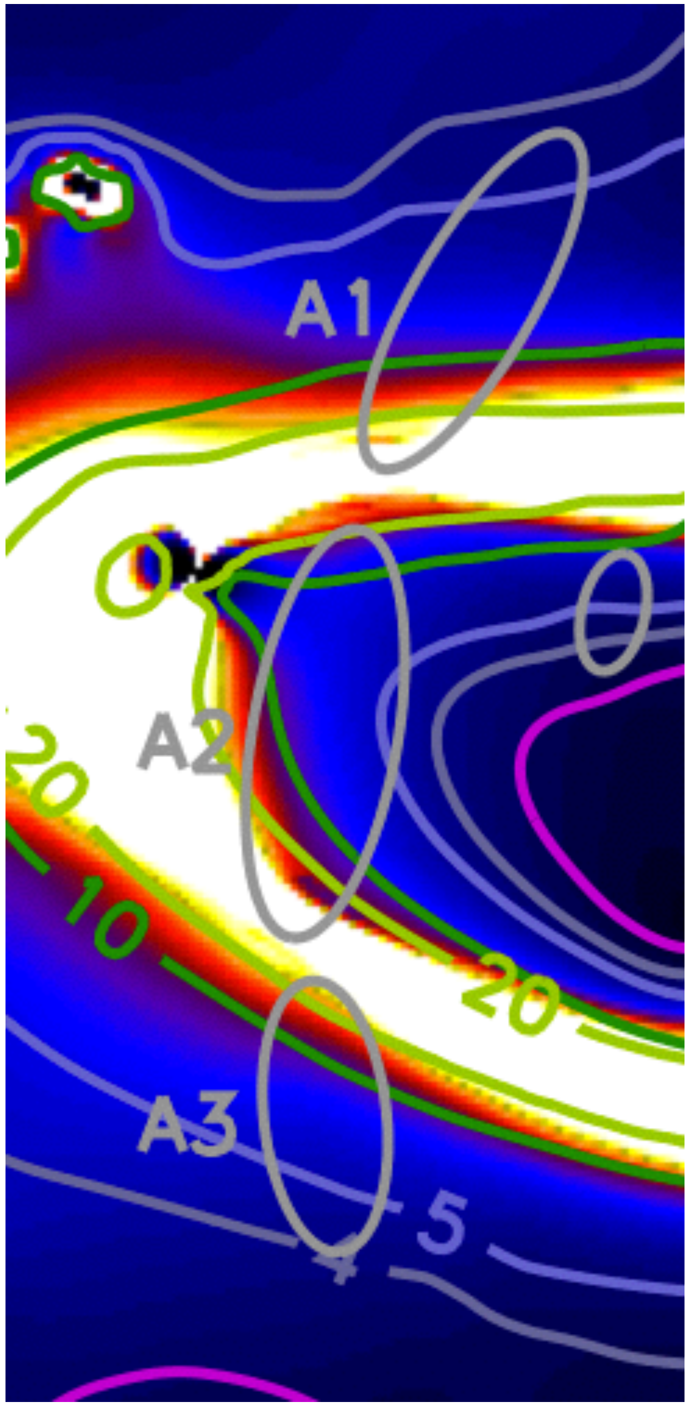
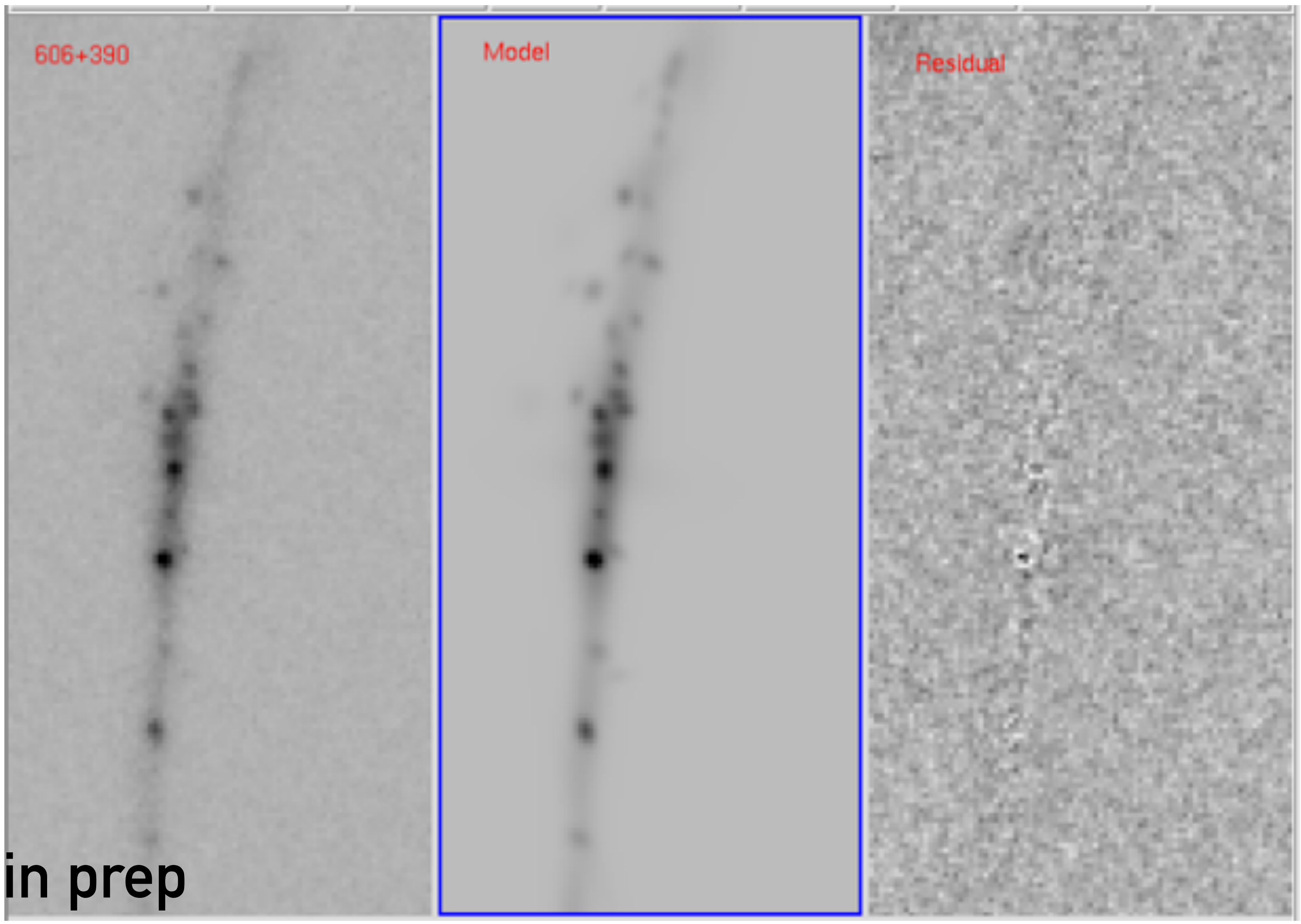




μ~5-10x across arc
(20% statistical uncertainty)

Johnson+2014, in prep

1. Construct a GALFIT model of the clumps in the image plane
2. Trace the clump positions to the source plane
3. Create a model of the clumps in the source plane
    - Gaussian, flux scaled by magnification
    - clump size = free parameter
4. Ray trace the model to the image plane
5. Convolve with the instrument PSF
6. Compare the result with the image plane GALFIT model
7. Repeat 3-6 while iterating on the clump sizes to minimize the residuals



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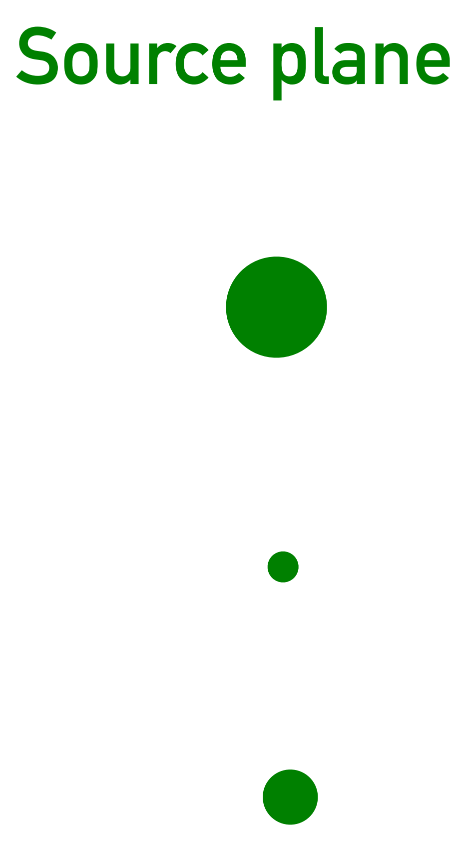

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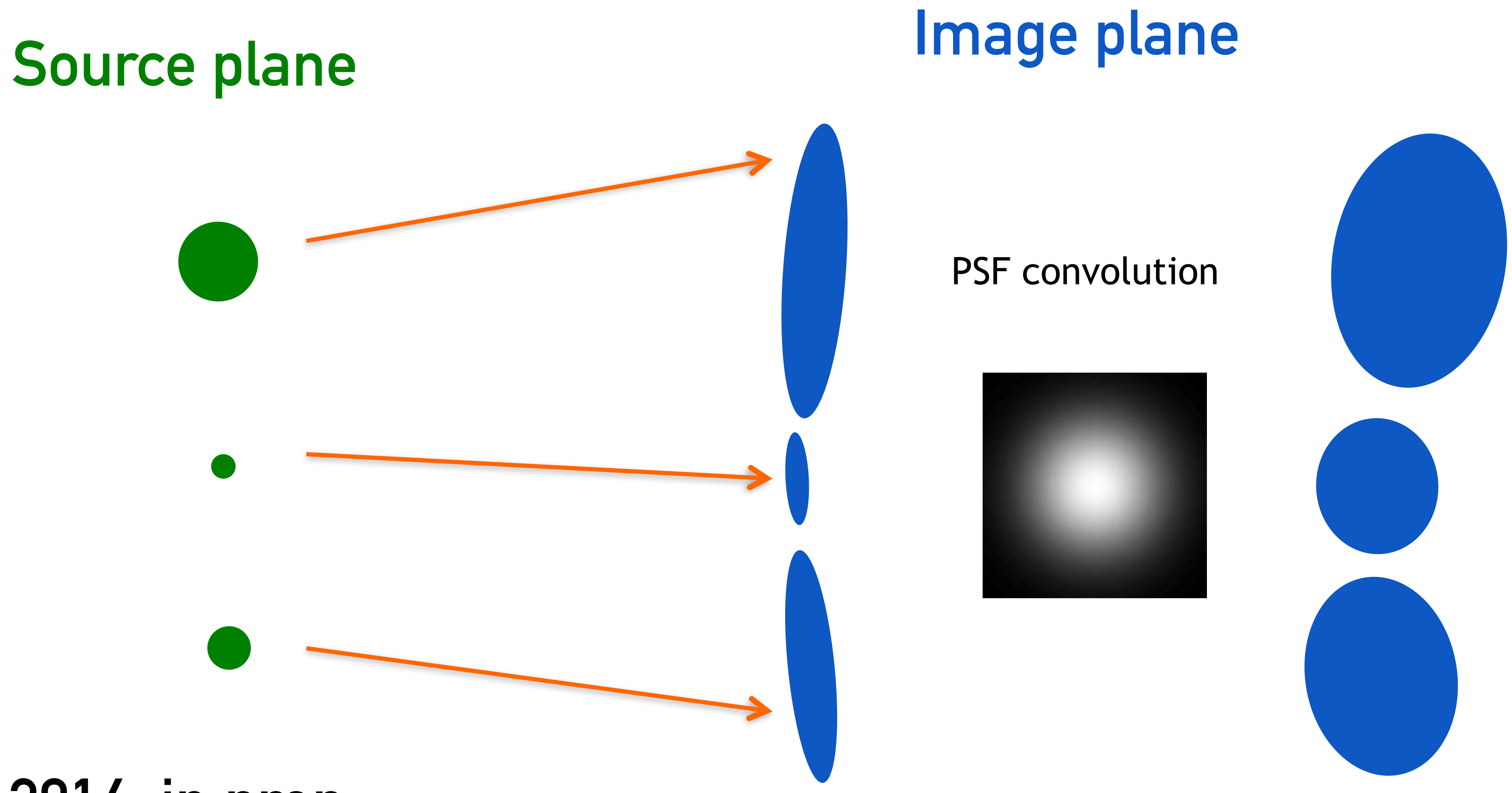

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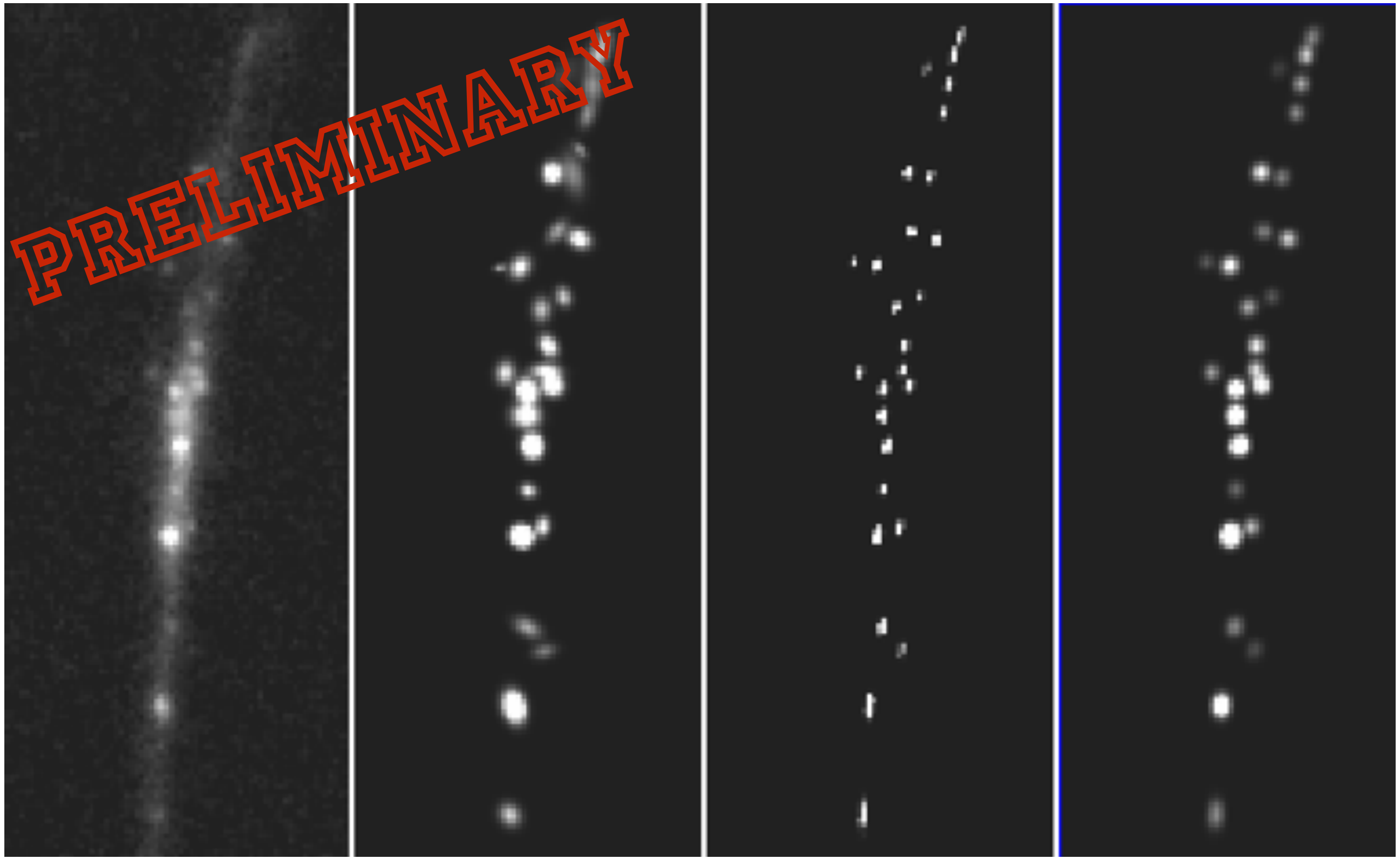
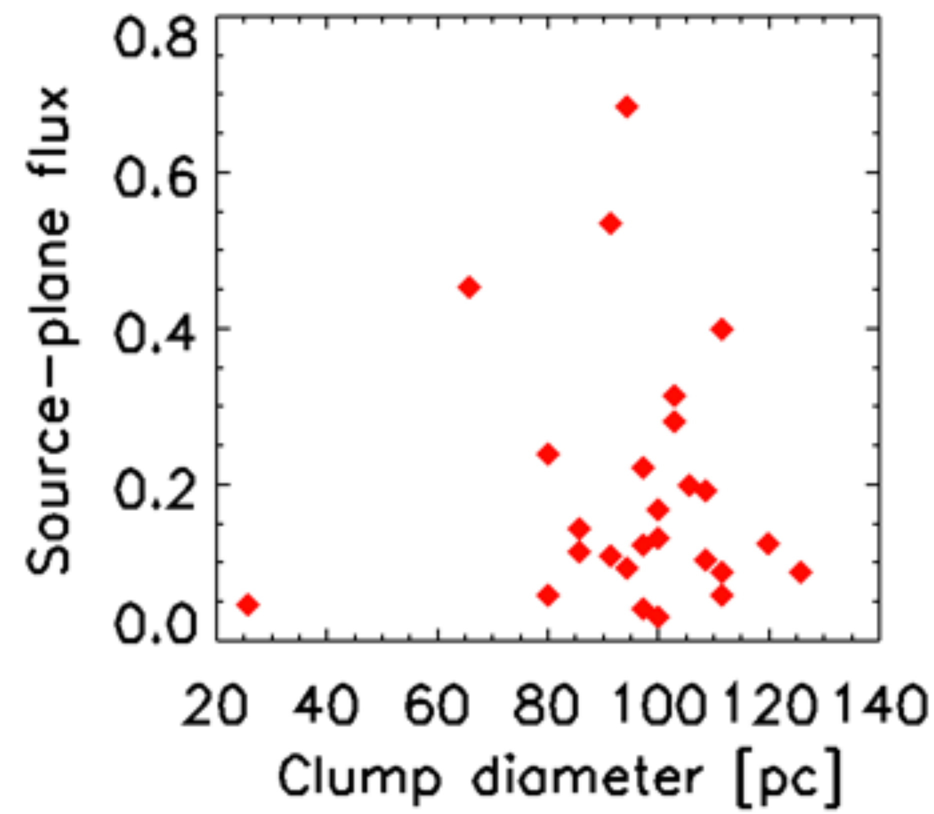
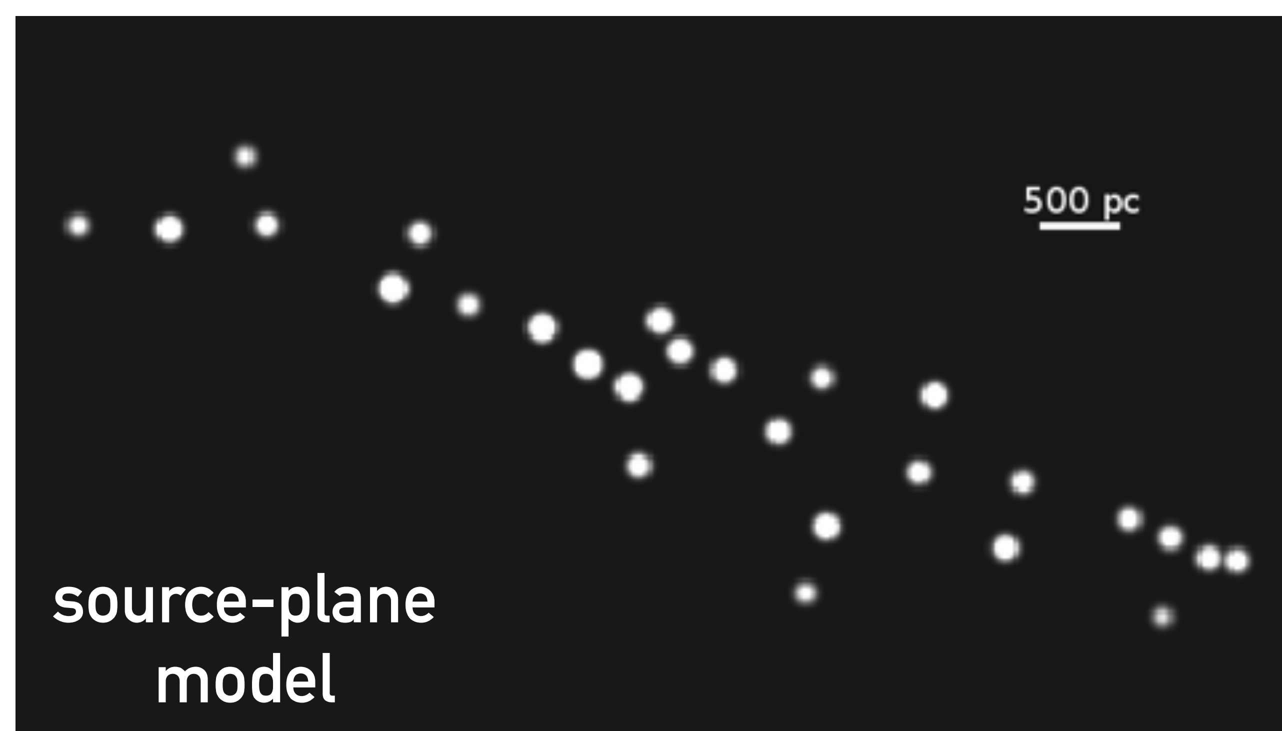


Data F390W+F606W | GALFIT model clumps only | source-plane model, ray-traced to image plane | convolved with PSF

clump diameter 80-120pc





Johnson+2014, in prep

poster-child RCS0327: merger at z=1.7
brightest distant lensed galaxy known
kinematics reveals ongoing interaction

Sloan Giant Arcs Survey
216 lens systems in SDSS DR7
completeness and purity quantified

SGAS1110 at z=2.481
>20 clumps, diameters 80-120pc
resolving the physical scales of SF