

# HEROES: Strong lensing of Lyman-alpha emitters

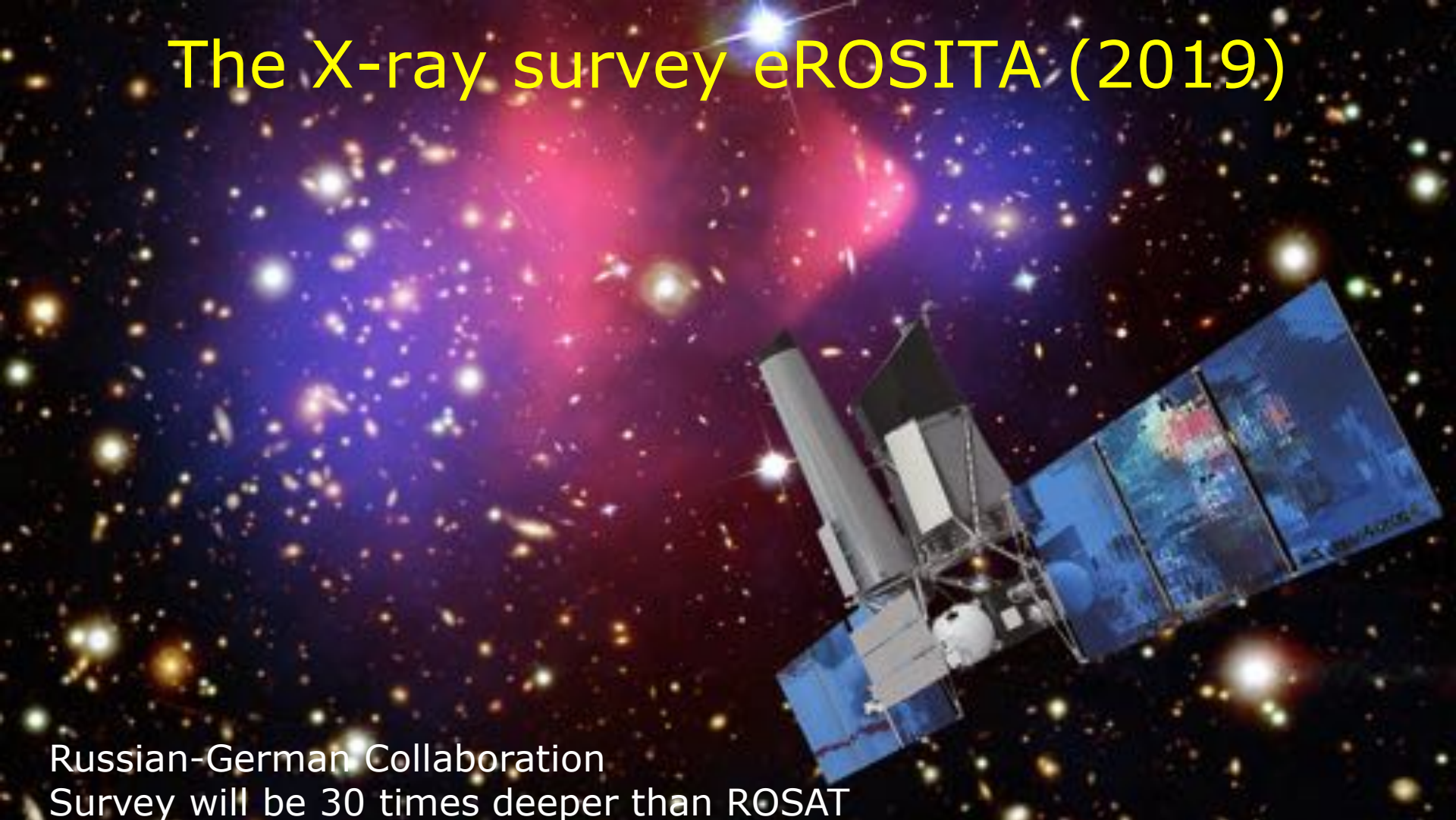
Günther Hasinger

ESAC Science Seminar, 28. June 2018



# The X-ray survey eROSITA (2019)

Russian-German Collaboration  
Survey will be 30 times deeper than ROSAT





## Former and current PI

Peter Predehl and G. H. with eROSITA in MPE cleanroom.

Currently eROSITA is at Lavochkin in Moscow

Launch is foreseen on April 6, 2019



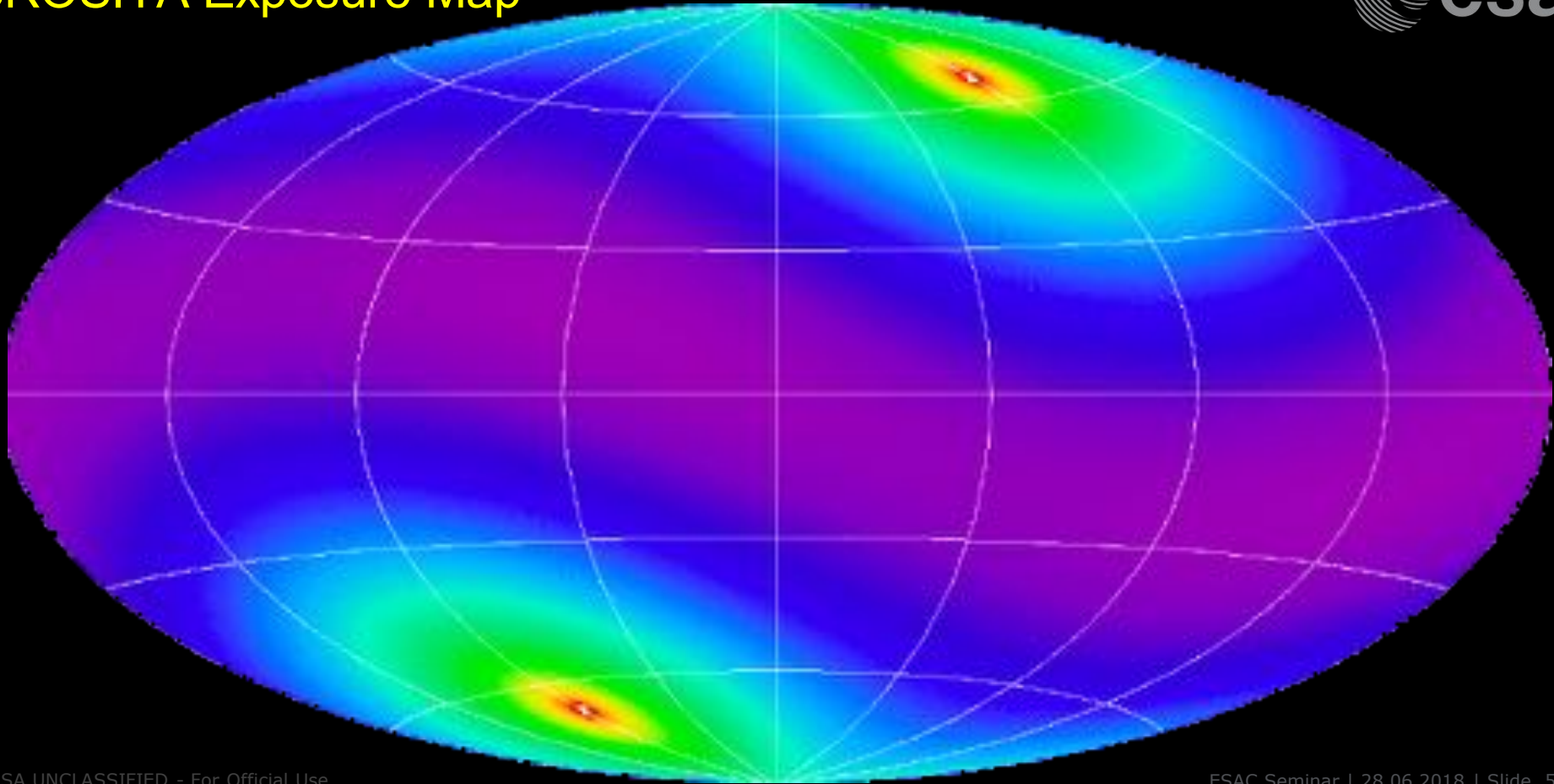
# X-ray technology from Germany/Italy



X-ray mirrors and CCD X-ray detectors are based on the XMM-Newton technology, further developed at the Max-Planck-Institute for extraterrestrial Physics with MPI Halbleiterlabor and Medialario

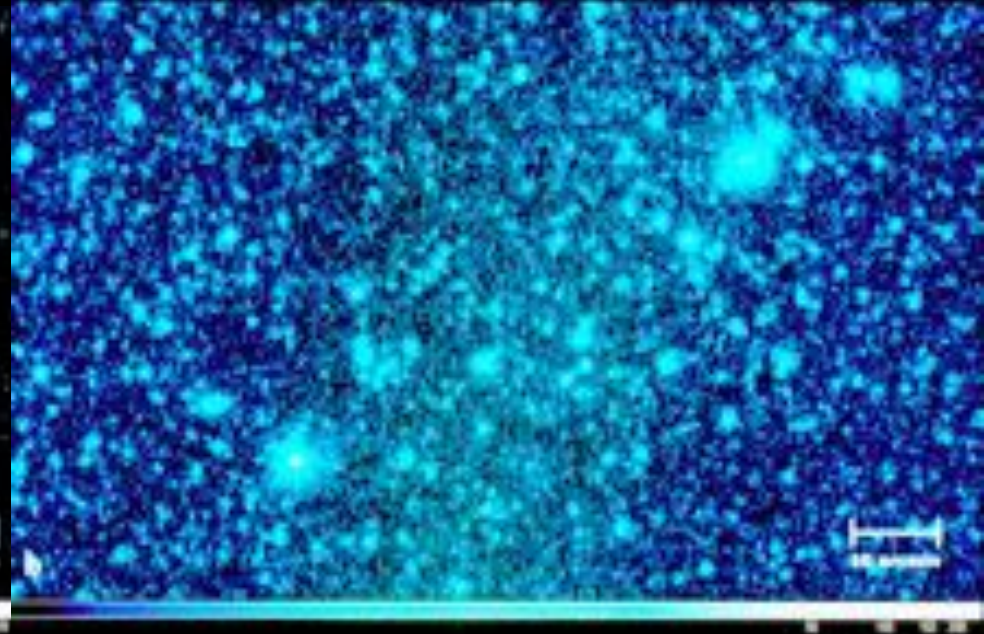


# eROSITA Exposure Map





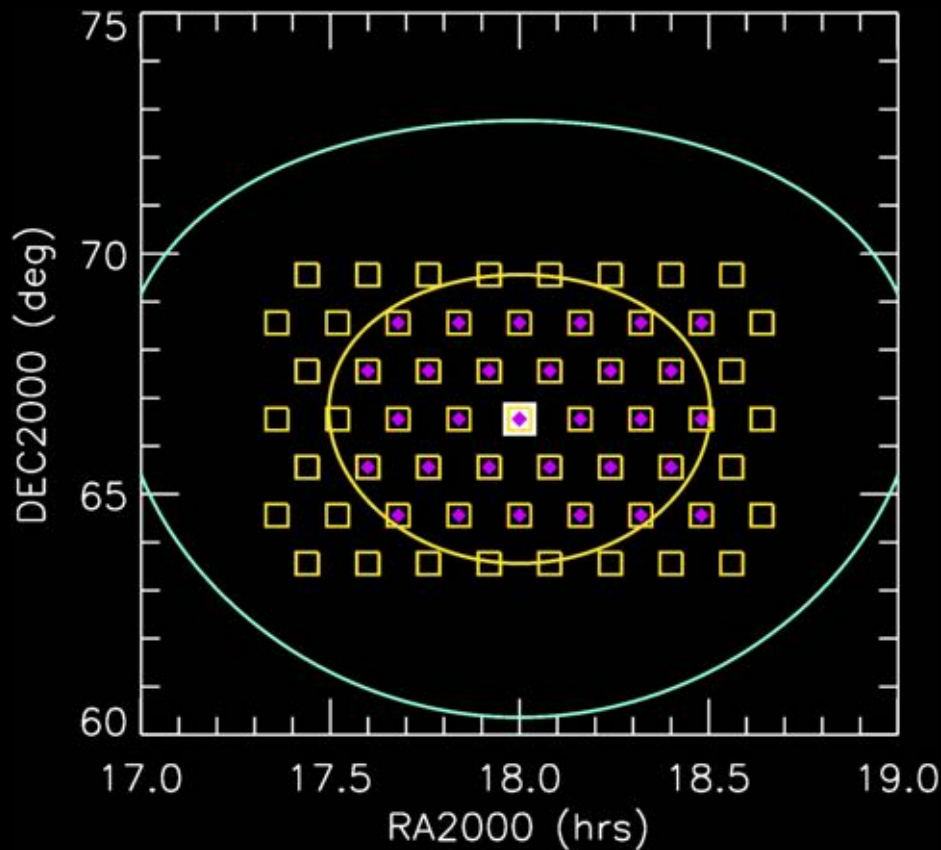
All-Sky (2 ksec)



Deep Survey (30 ksec)

Clusters of galaxies clearly recognizable as diffuse X-ray sources

# The Hawaii EROsita Ecliptic-pole Survey



Subaru Hyper  
SuprimCam, CFHT  
coverage in  
U,g,r,i,z,y,NB821,  
NB916,J

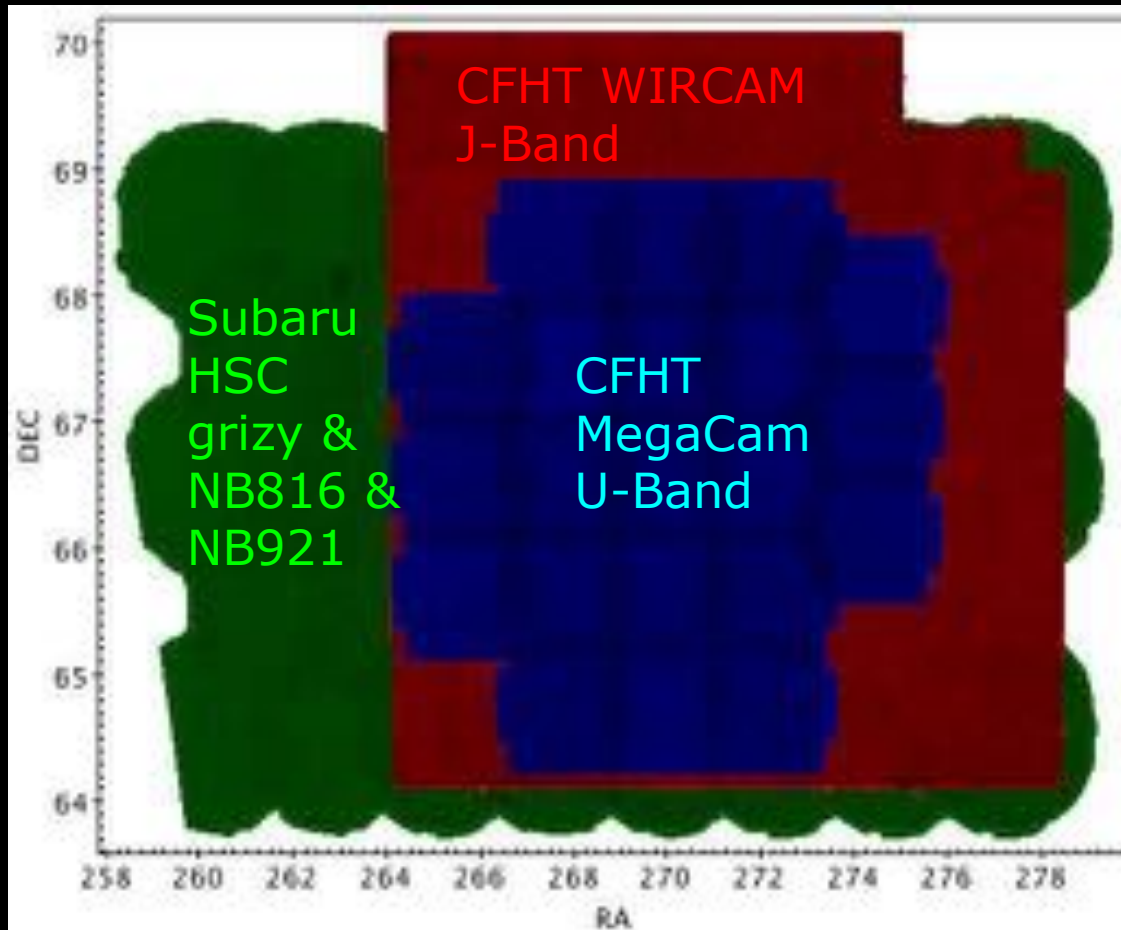
Table 1. HEROES specifications

Instrument (1)	Filter (2)	Redshift Range (3)	Exposure/pixel (mins) (4)	$5\sigma$ mag (5)
HSC SUBARU	g	...	10	26.5
	r	...	10	26.1
	i	...	15	25.7
	z	...	20	25.1
	y	...	20	24.4
	8140	5.67-5.75	10	24.1
	9210	6.53-6.62	20	24.0
WIRCAM CFHT	J	...	5	22.1
MEGAPRIME CFHT	U	...	20	25.5

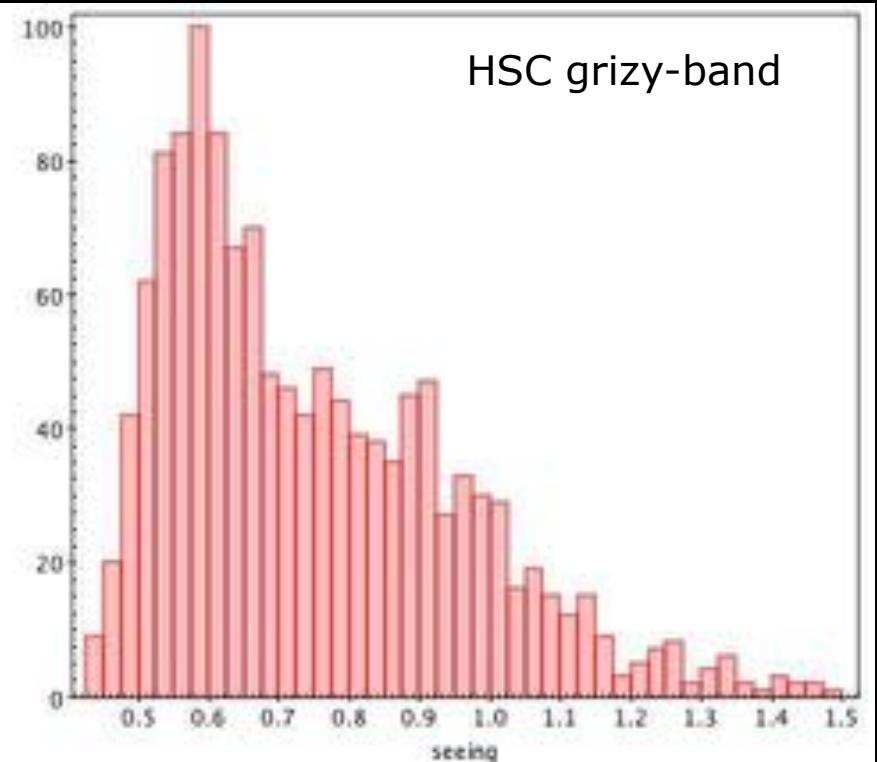
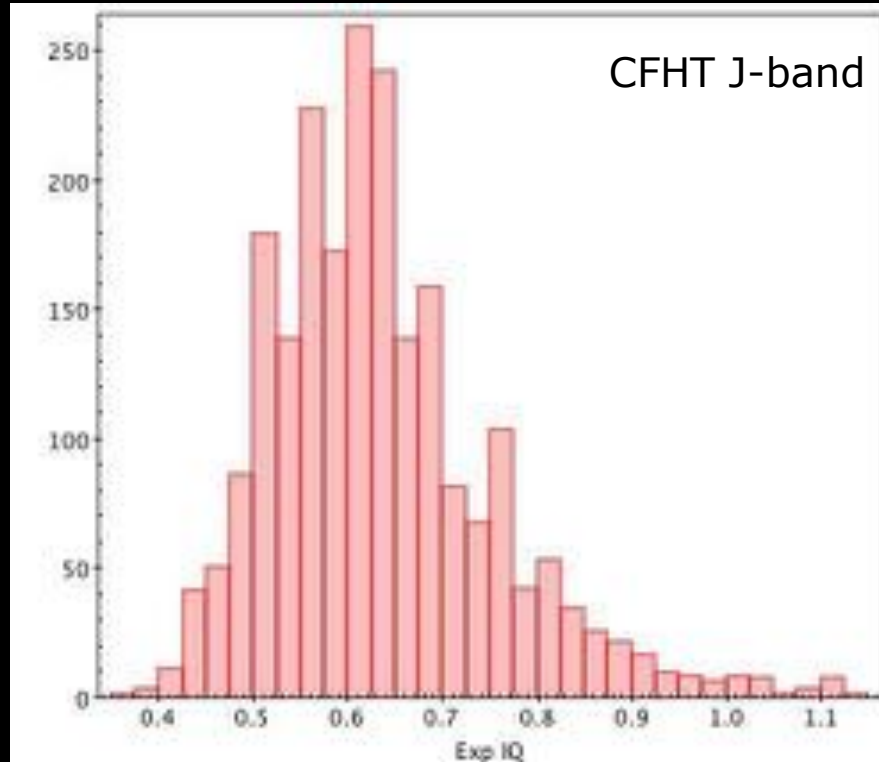
UH Large Program Status 2016-2018: First observations June/July 2016



# Current status of HEROES



# Seeing Distributions

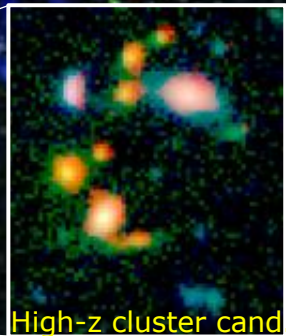


# HEROES – The Hawaii EROsita Ecliptic pole Survey

UH Large Collaborative Program: G. Hasinger  
(PI), A. Barger, E. Hu, M. Takamiya, R. Sunyaev,  
A. Cowie, R. Griffiths, L. Cowie & Conor  
McPartland

NGC6552

NGC6543 PN



High-z cluster cand

see: [www.ifa.hawaii.edu/HEROES](http://www.ifa.hawaii.edu/HEROES)



European Space Agency



# Keck Cosmic Web Imager (KCWI)

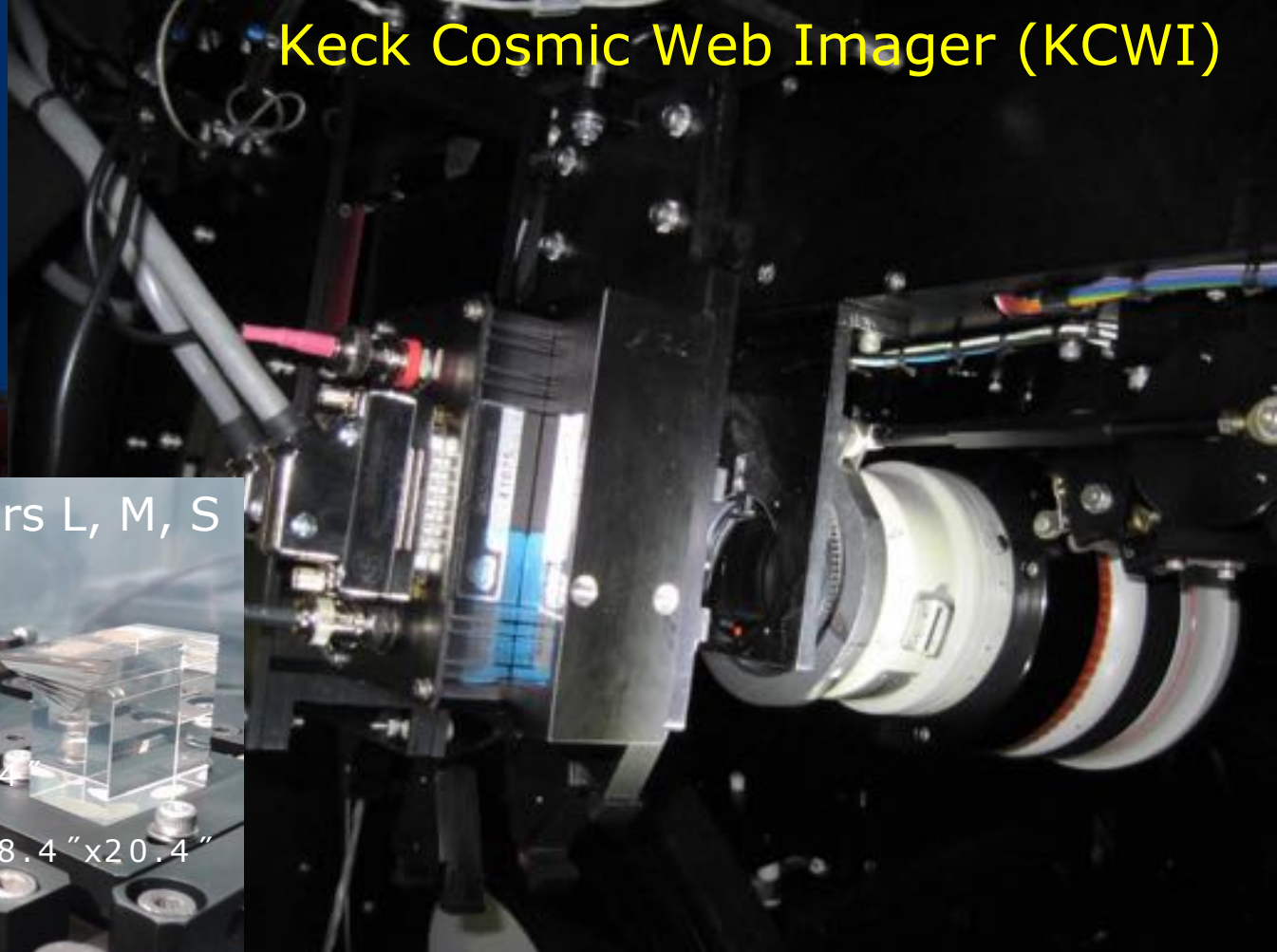


Image Slicers L, M, S

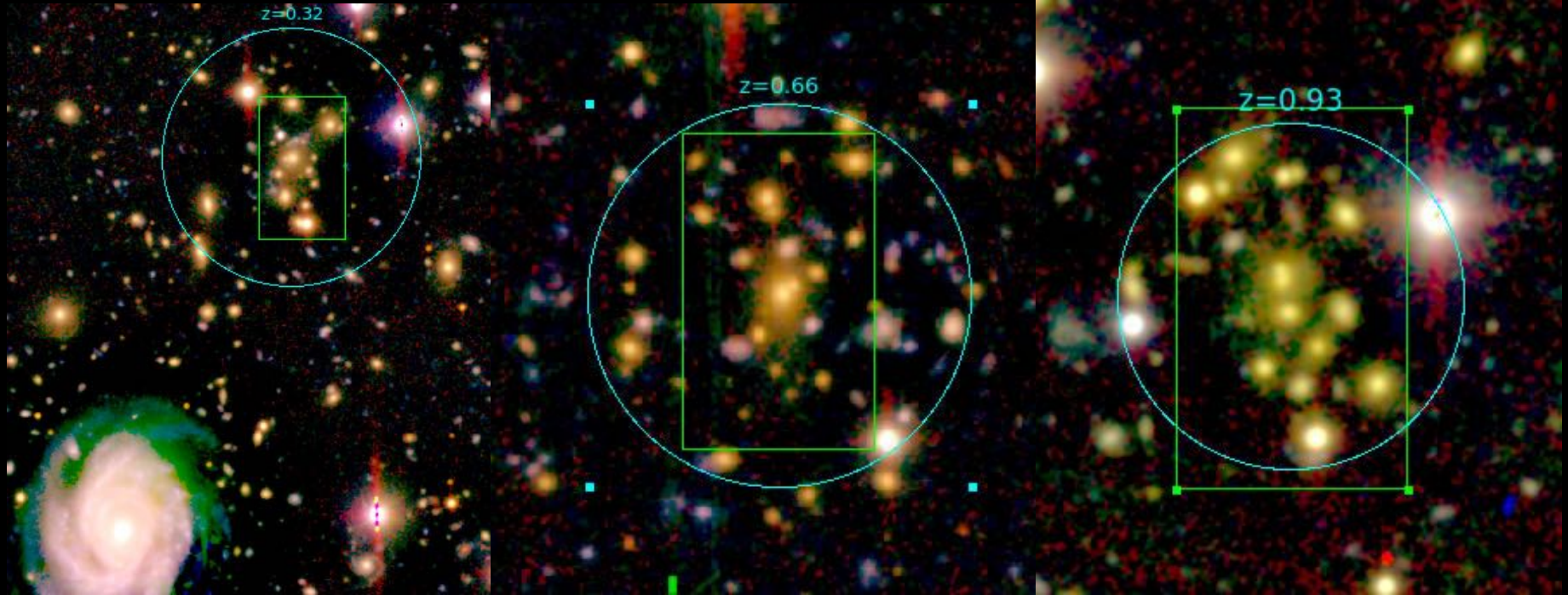
33" x 20.4"

16.5" x 20.4"

8.4" x 20.4"



# 2017B KCWI Proposal



ASTR699 work from Erica Bufanda

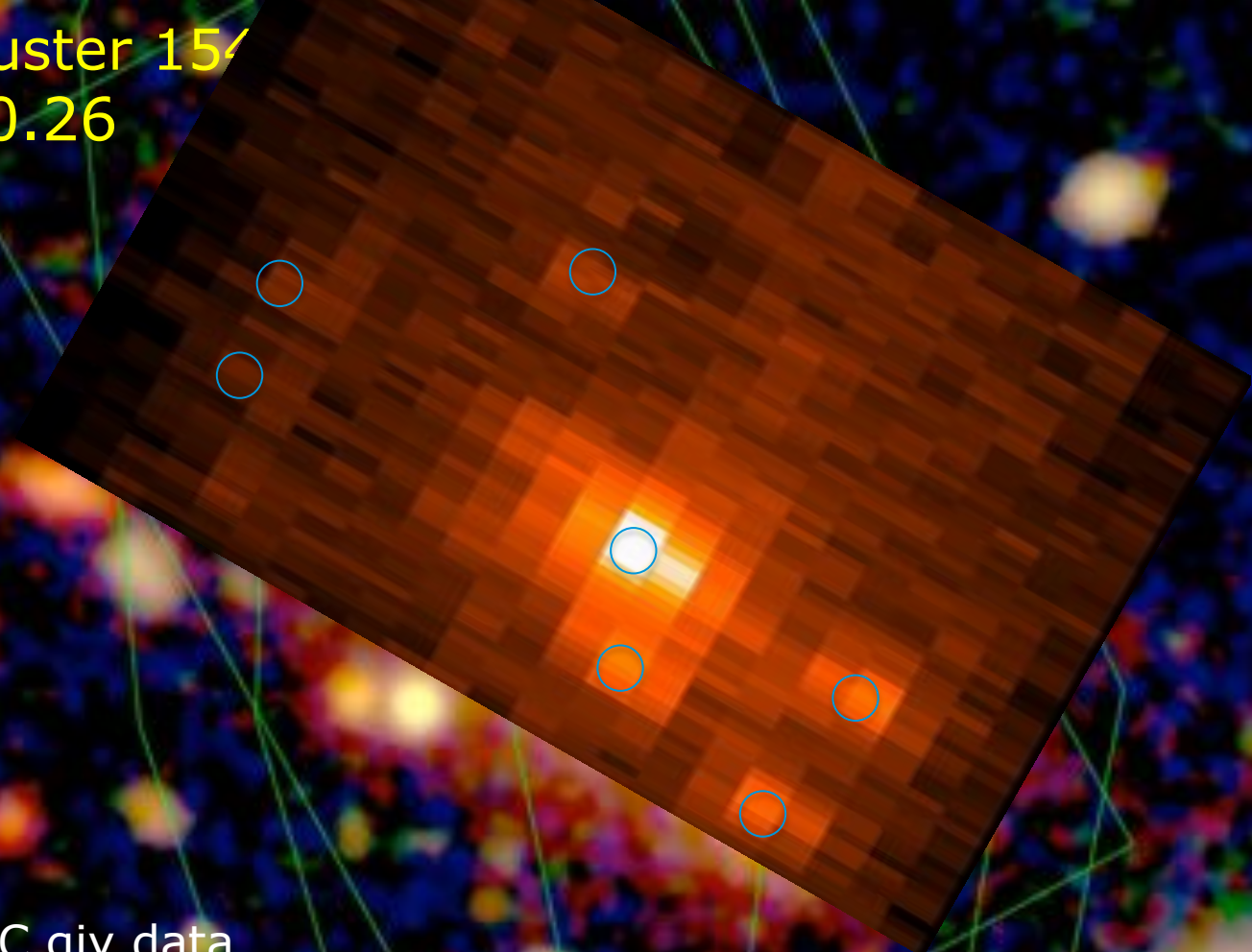


## ROSAT Coverage of the North- Ecliptic Pole

First joint analysis of  
ROSAT All-Sky survey  
and pointed raster scan  
data in the NEP Field



ROSAT Cluster 154  
Redshift 0.26

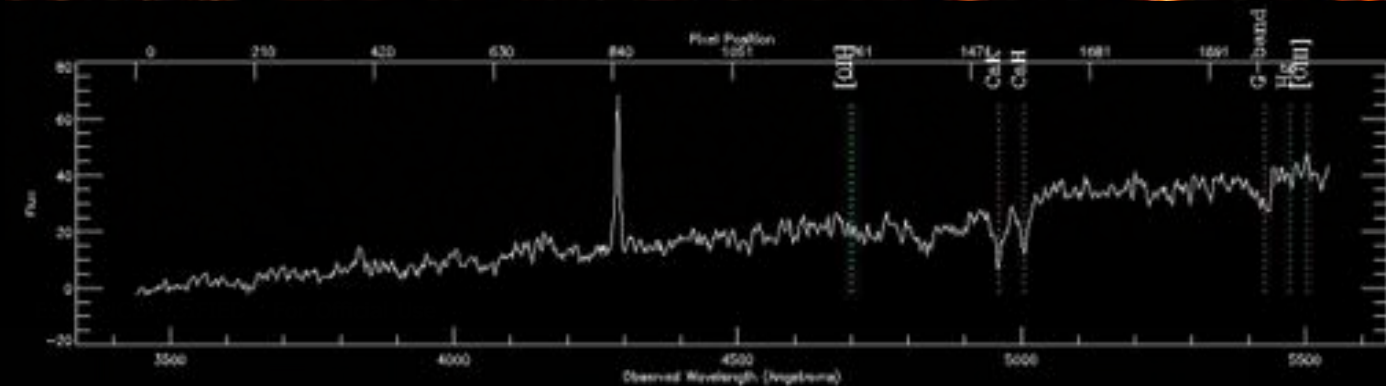


HEROES HSC giy data

## Sky-subtracted KCWI raw spectra from the Large slicer

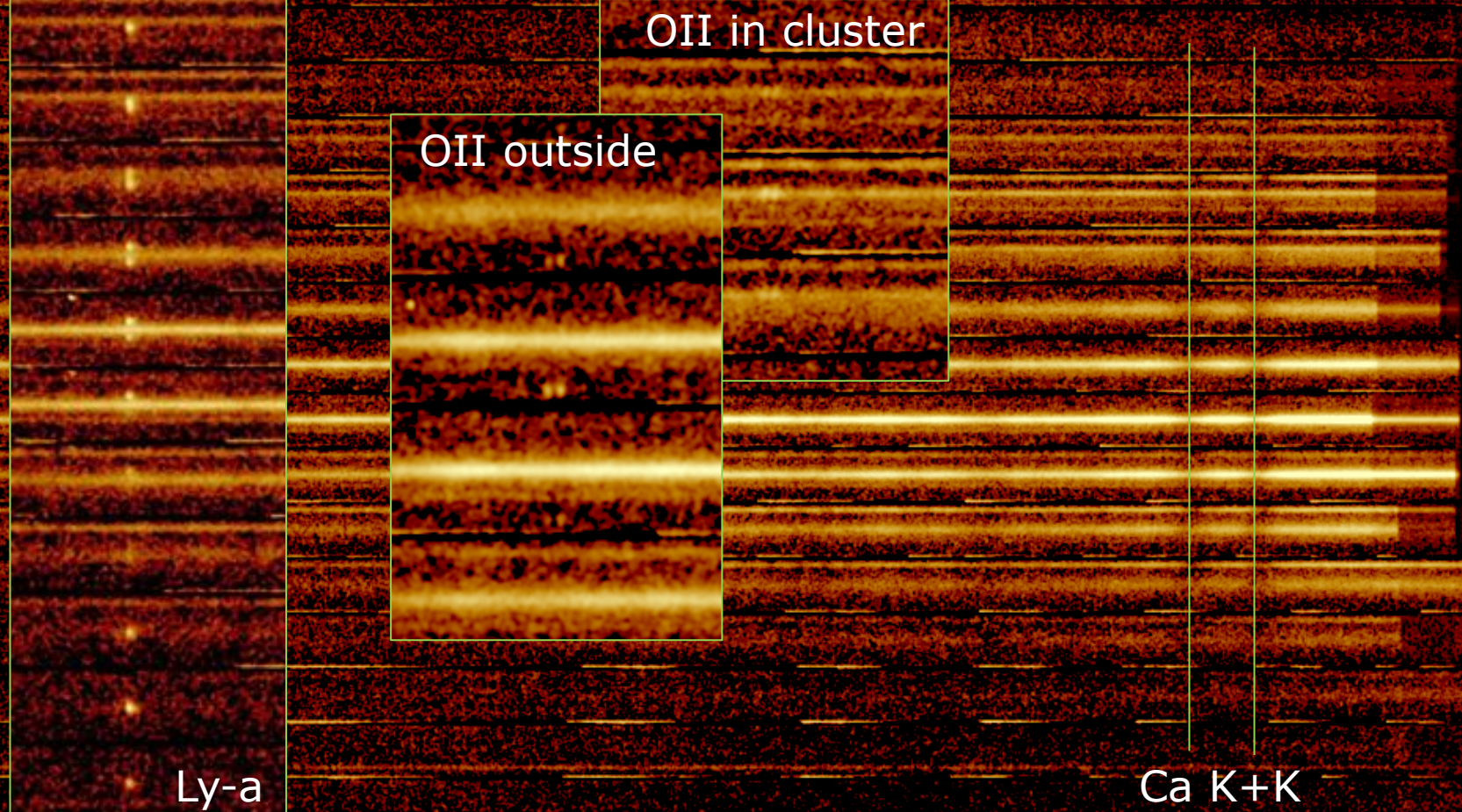
Emission line objects are close, but typically not in the bright continuum sources.

They are not commensurate with the galaxy redshifts. Most likely Ly-alpha at  $z \sim 2.5-3$ .





# Flattened 2D Spectrum of KCWI Data Cube (M-slicer)



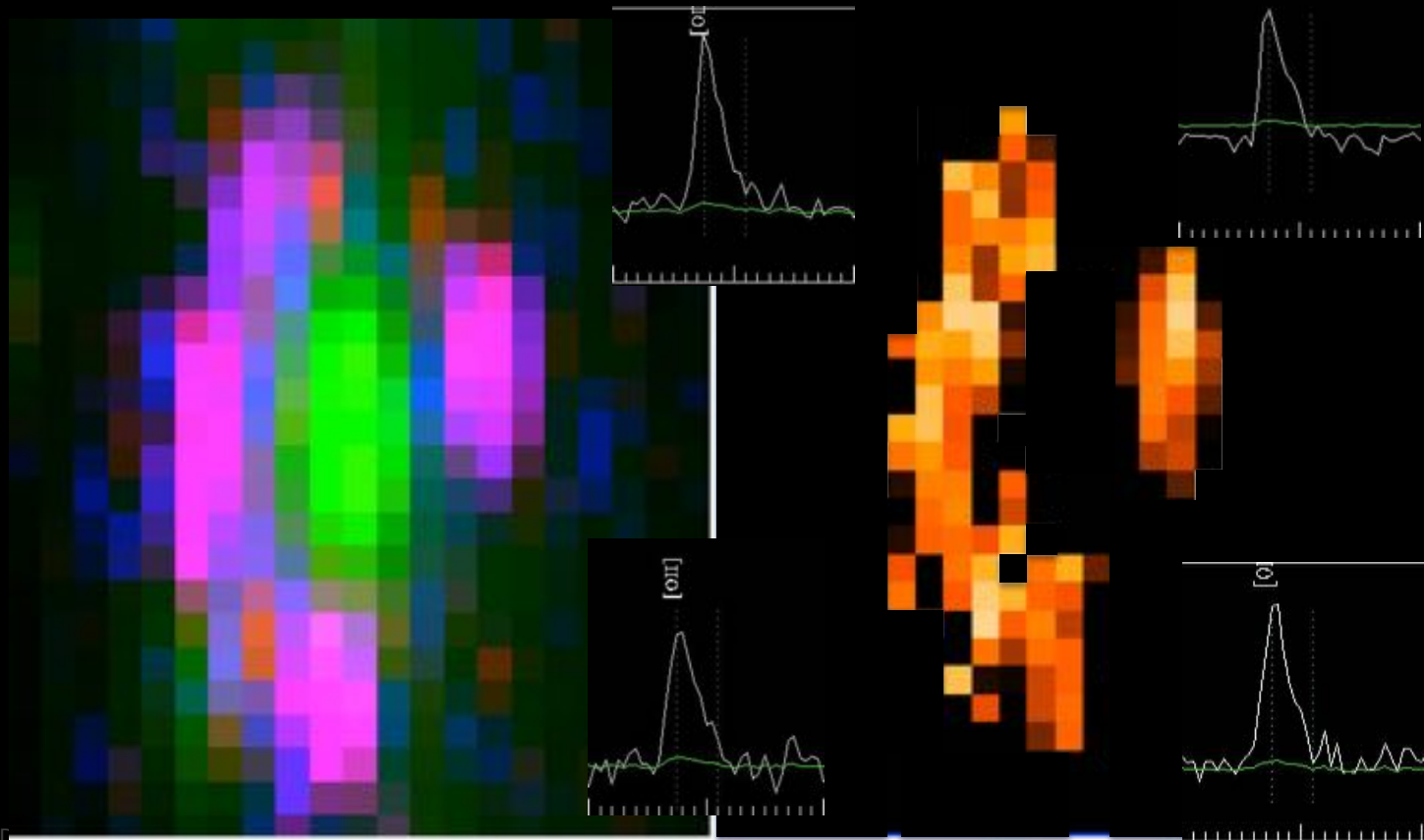


# ROSAT Cluster S1548 $z=0.26$

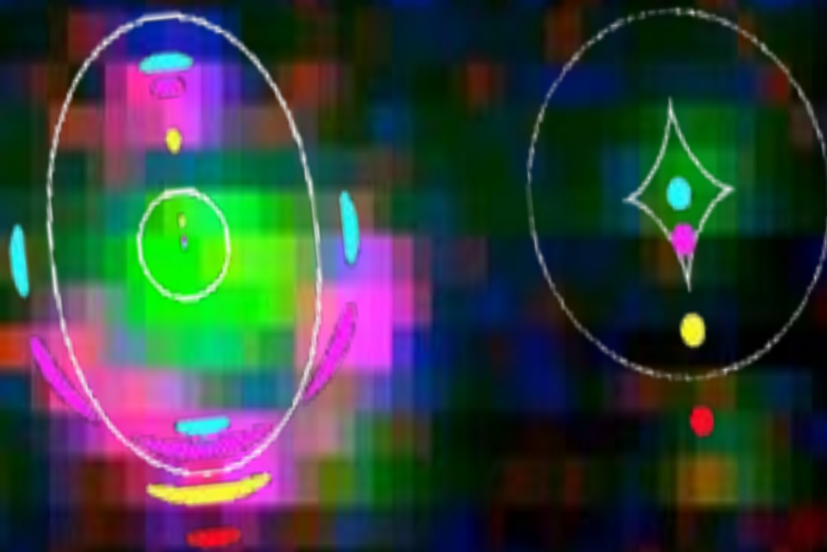
3 strongly lensed  
Ly- $\alpha$  emitters  
(1 Einstein cross)

2 OII emitters  
(one in cluster,  
one in front)

# KCWI Velocity Map



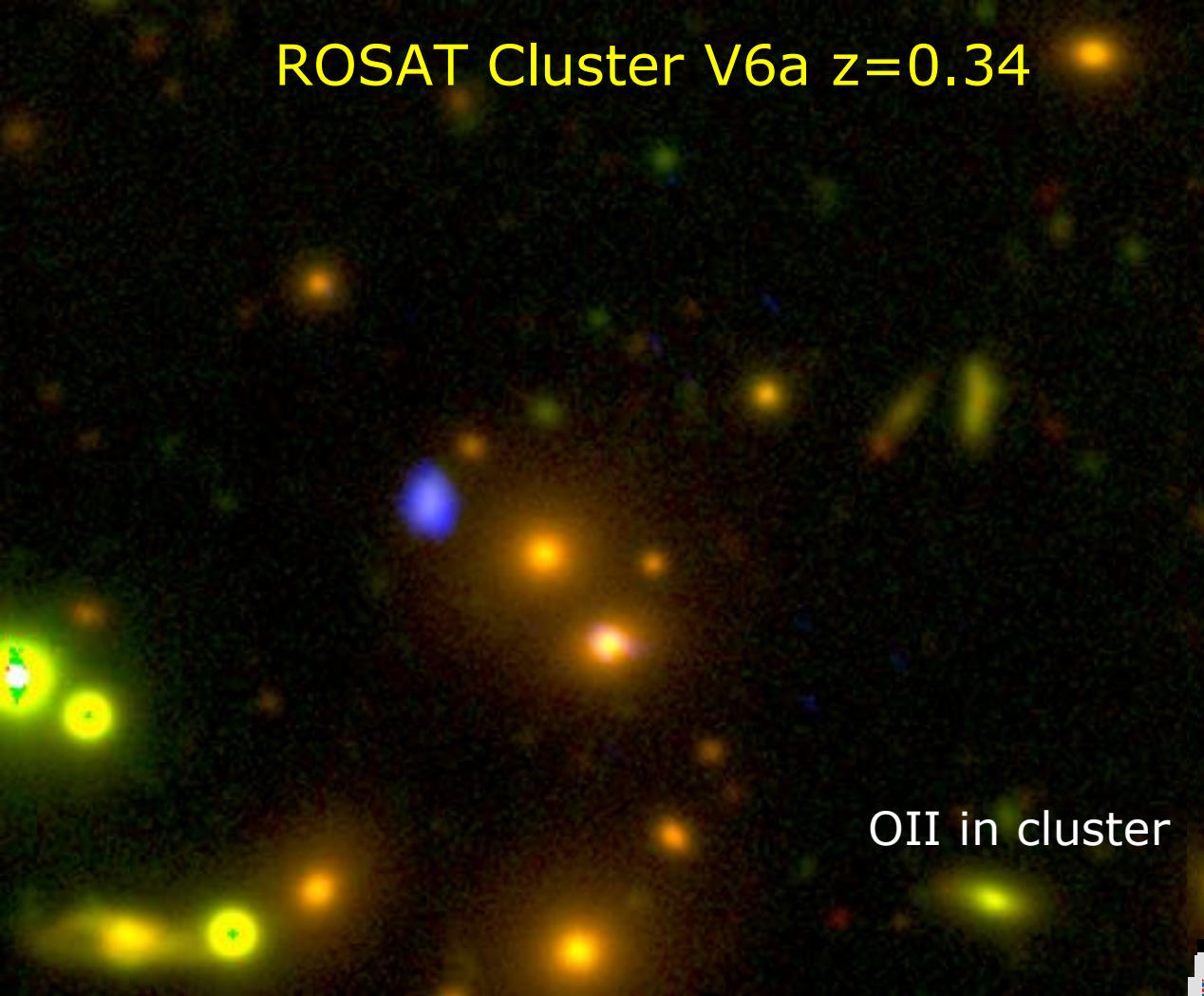
# Possible Lensing Configuration



In an elliptical Dark Matter potential there can be four magnified images plus one demagnified inside the critical lines. Images close to caustics are magnified most. Outside the caustics there is only one magnified image.



# ROSAT Cluster V6a $z=0.34$



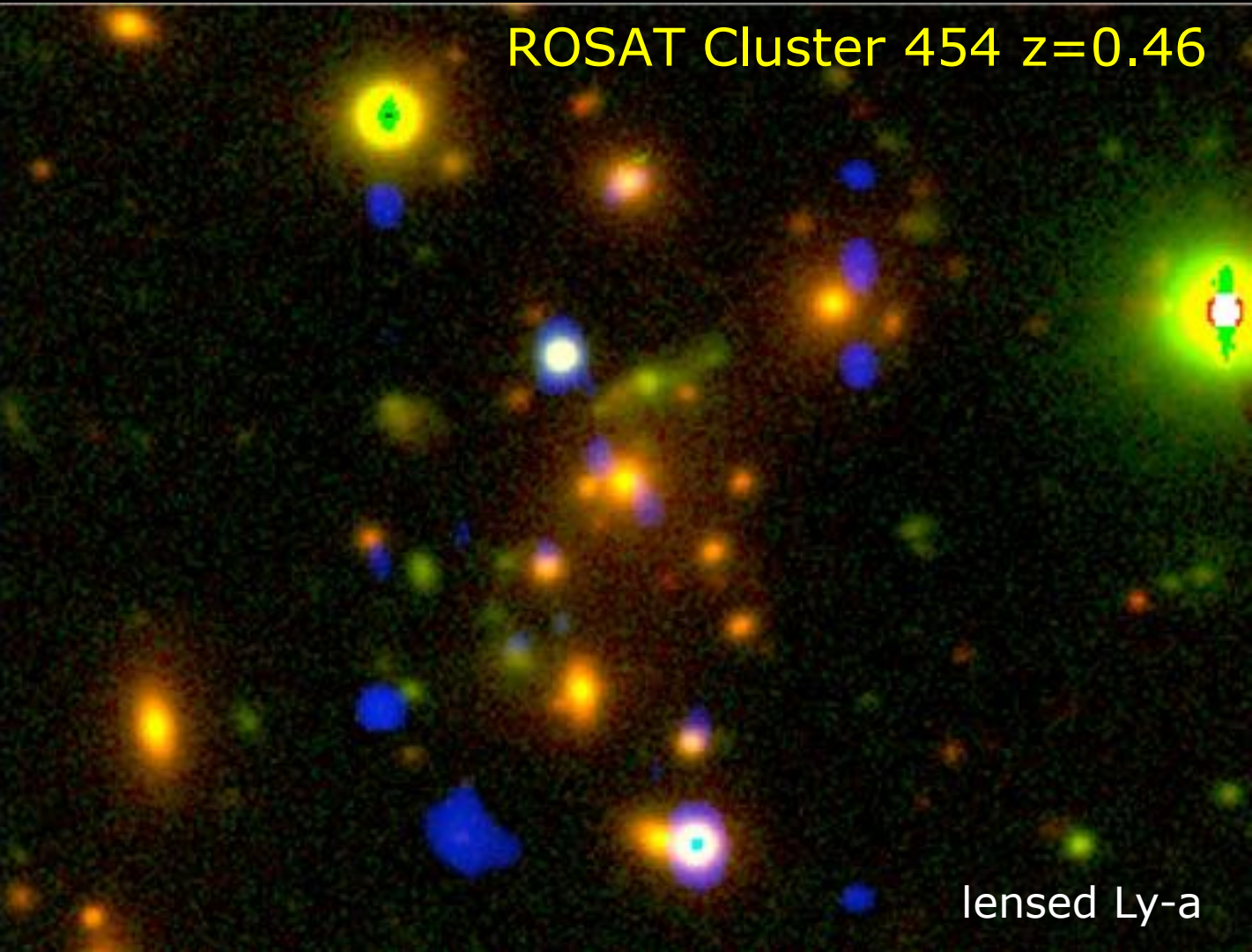
2 strongly lensed  
Ly- $\alpha$  emitters  
(1 triple lens)

1 OII emitter in cluster

1 broad [MgII] emitter  
in background QSO

OII in cluster

# ROSAT Cluster 454 $z=0.46$



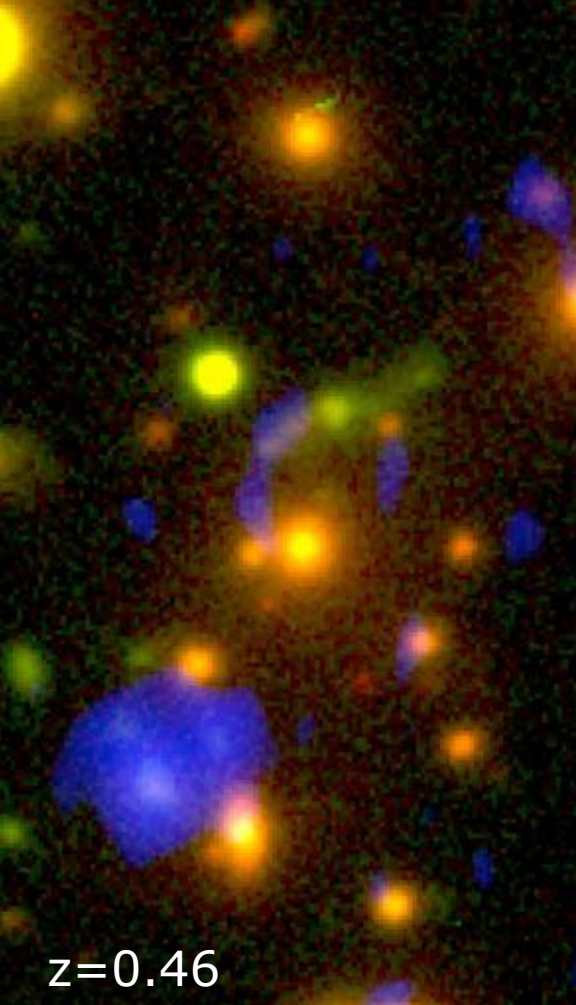
3 strongly lensed  
Ly-a emitters

3 OII emitters  
(two in cluster,  
including one  
stripped,  
one in front)

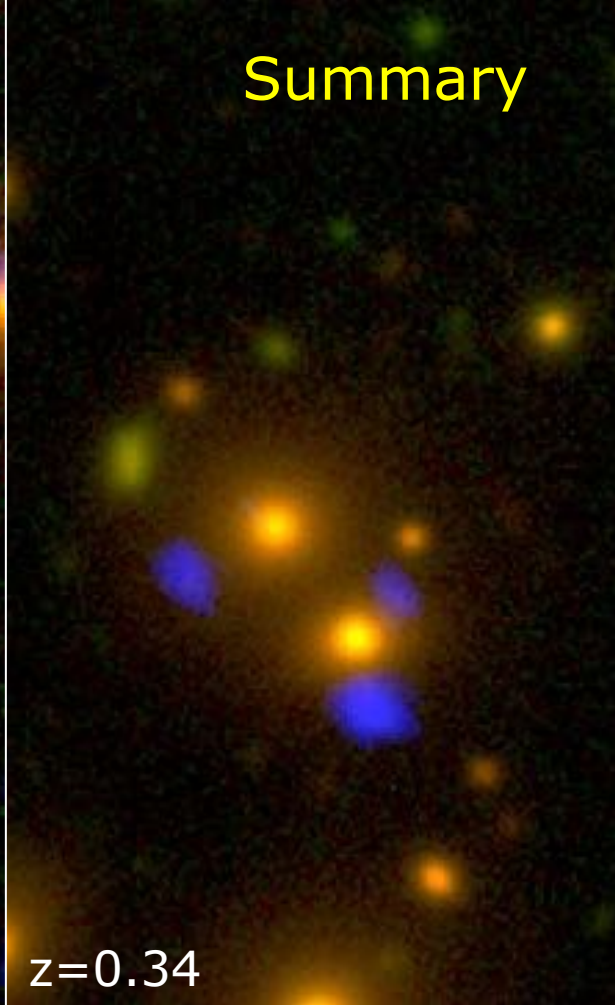
lensed Ly-a



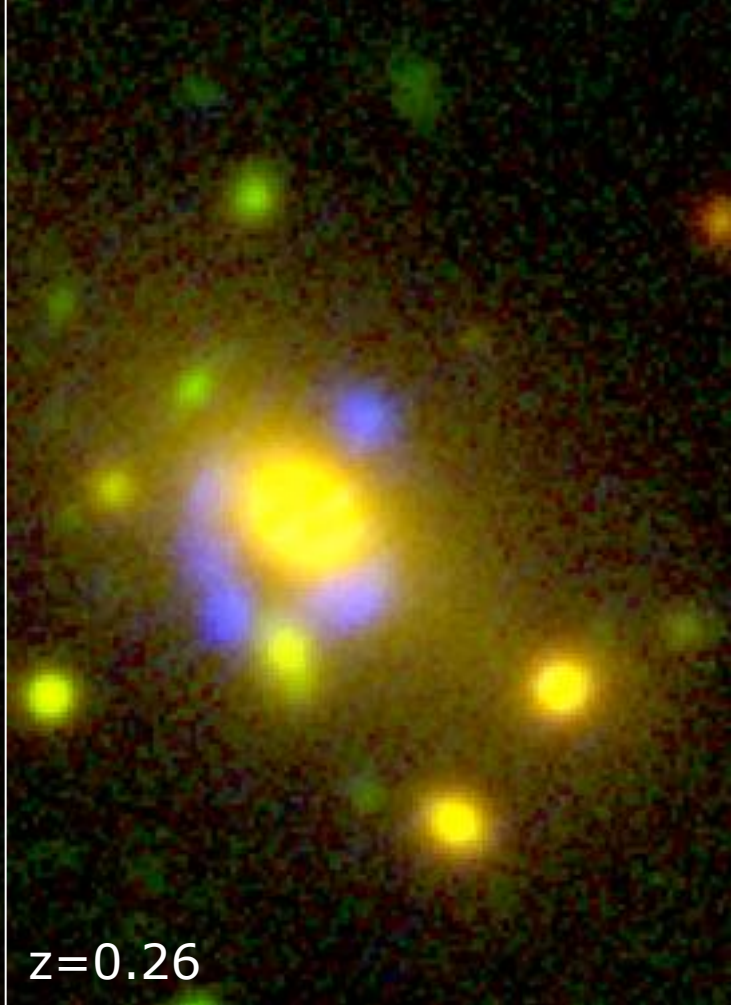
# Summary



$z=0.46$



$z=0.34$



$z=0.26$





# Summary and Conclusions

KCWI Integral-field spectroscopy of clusters of galaxies provides an unprecedented sensitive new probe for emission line galaxies.

Morphology of gas inside the cluster accessible through OII line spectroscopy.

Background Ly-a emitters become accessible through lensing amplification.

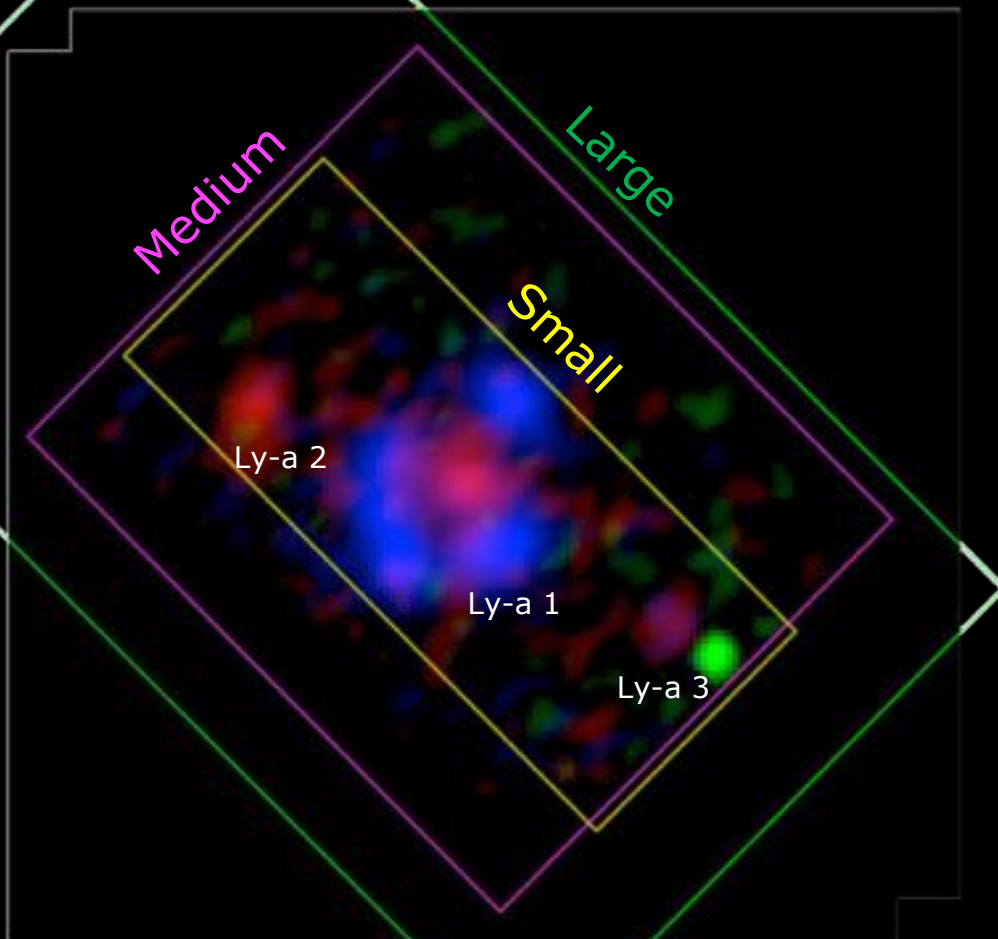
Practically every massive cluster seems to have one multiply lensed system and several single lensed.

Unique new way to identify Einstein crosses.

Statistics of strong lensed sources indicates a high surface density of these background emitters. Consistent with independent measurements with DEIMOS and MUSE.

Looking forward to 3 more nights of KCWI observations in July 2018

# Outlook



I will try to do Large and Medium image slicers for a total of  $\sim 10$  clusters, and Small for the most interesting ones.

Keck2, 10-12. July

A composite image of Earth from space. The Earth is shown in the lower-left and center, with a bright light source (the sun) on the right, creating a lens flare effect. The background is a dark blue space with a faint grid of lines and stars. The text "Thank you very much!" is overlaid in the upper right in a bold, yellow font.

**Thank you  
very much!**