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SUNDIAL
H2020 Innovative Training Network

Universidad de La Laguna

# ULTRA-DEEP IMAGING DATA TREATMENT WITH LSST

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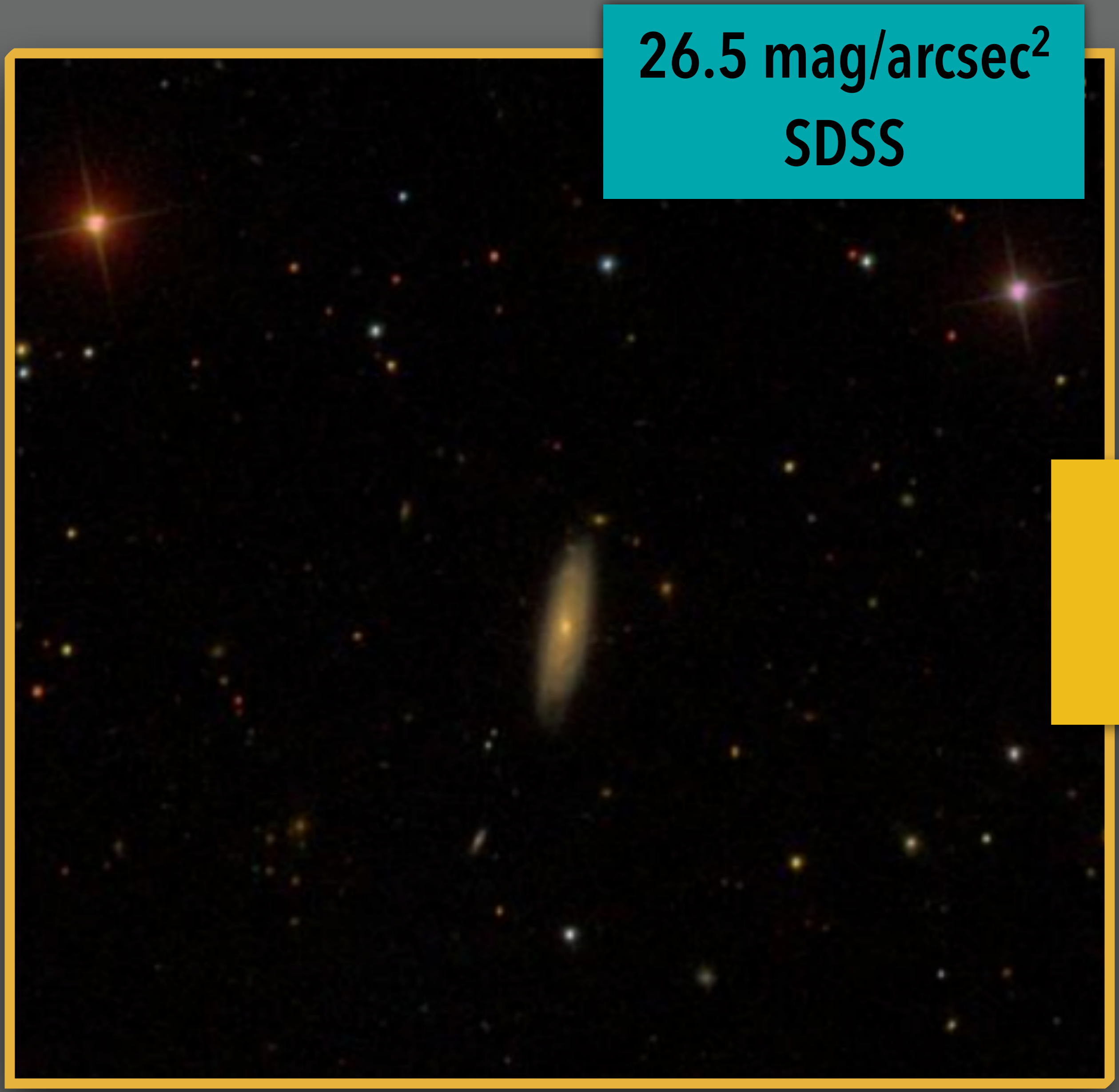
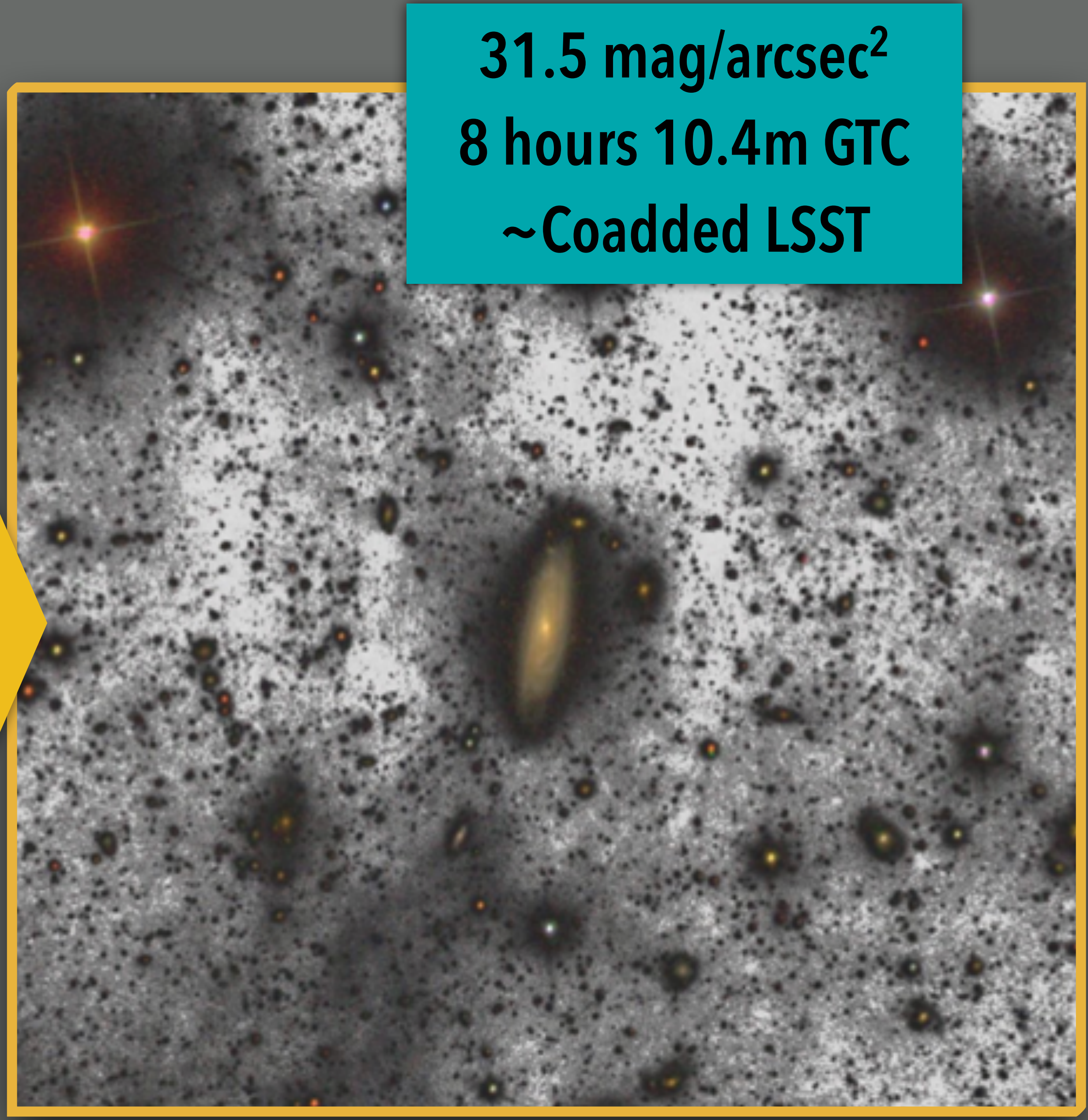
# WHY GO DEEPER?

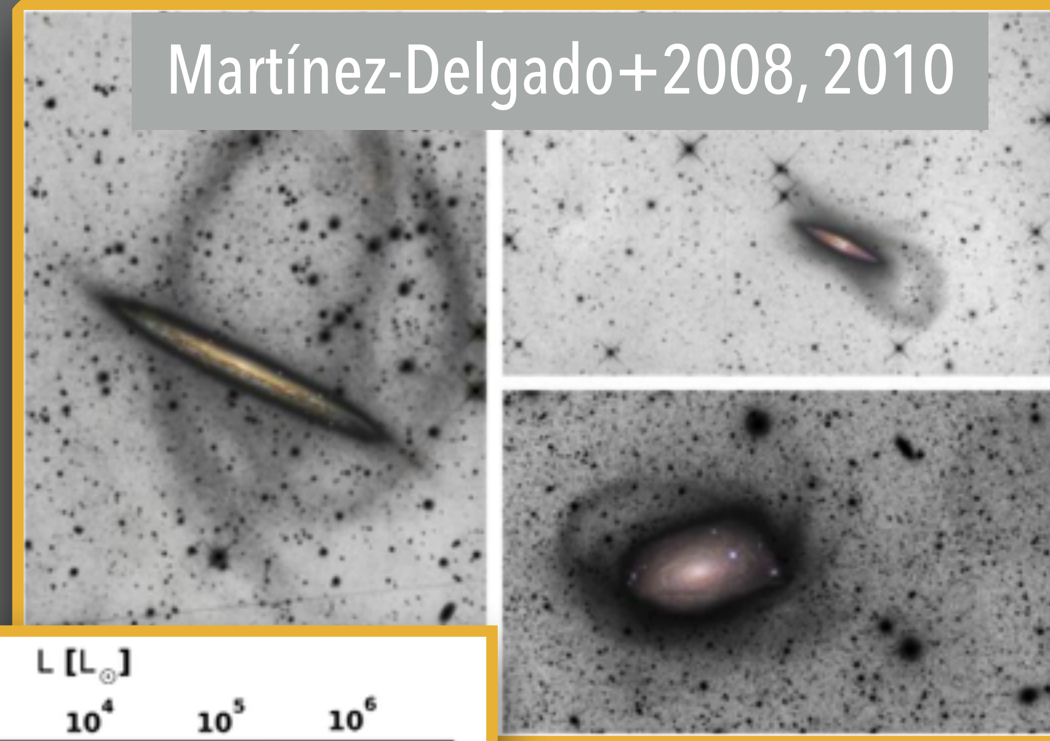



Trujillo & Fliri 2016

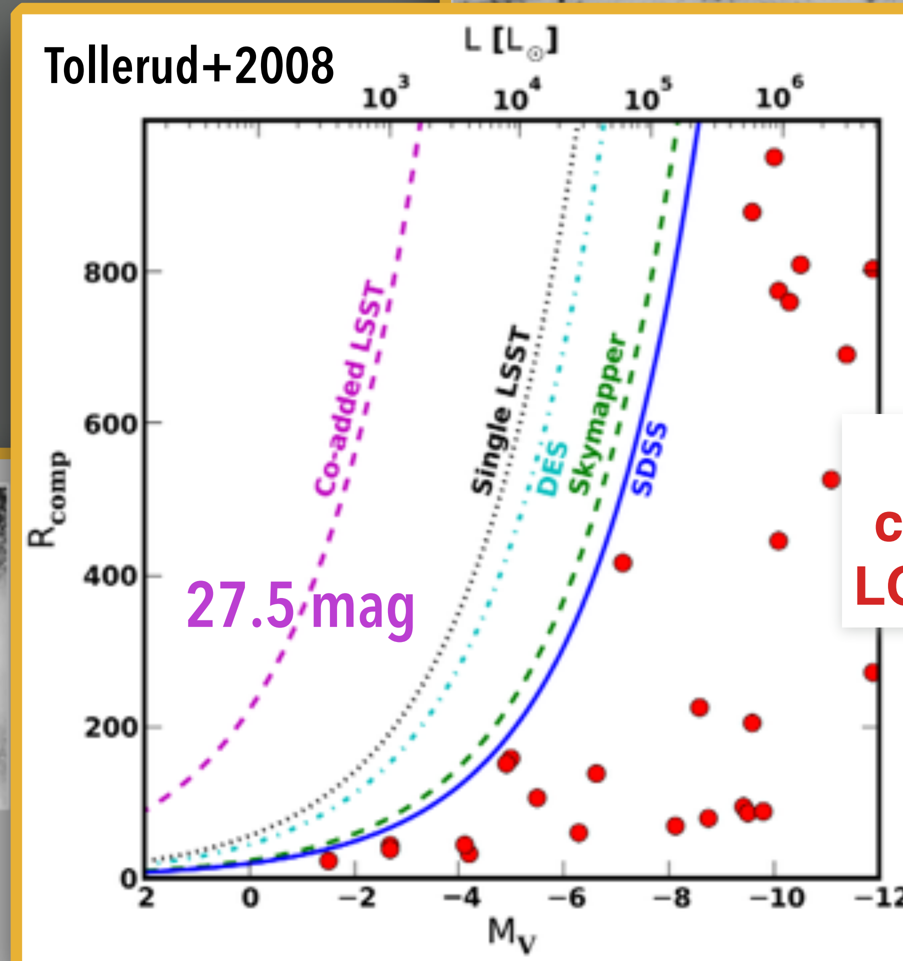
We are missing ~half of the science!

# WHY GO DEEPER?

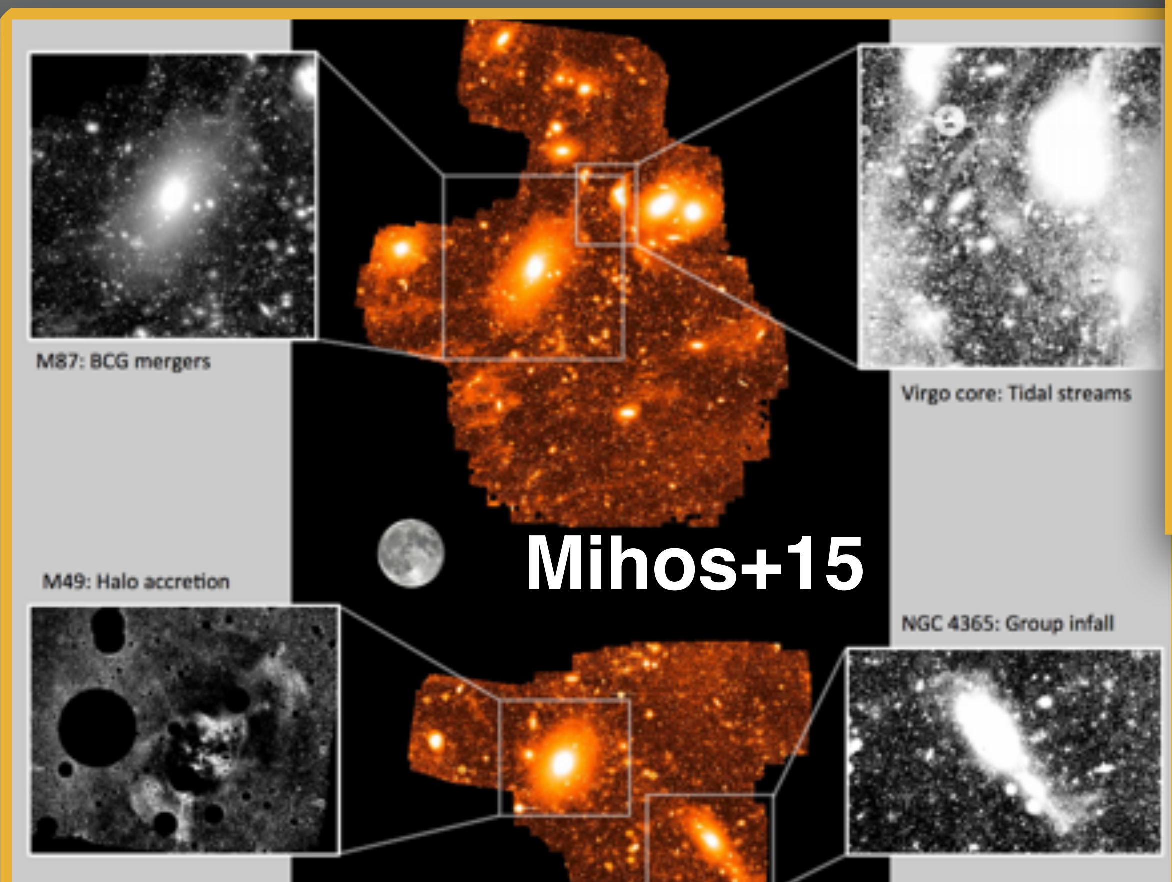



Tidal streams, Stellar haloes, ICL, Satellites, …

$\mu_r \gtrsim 28$ mag/arcsec$^2$

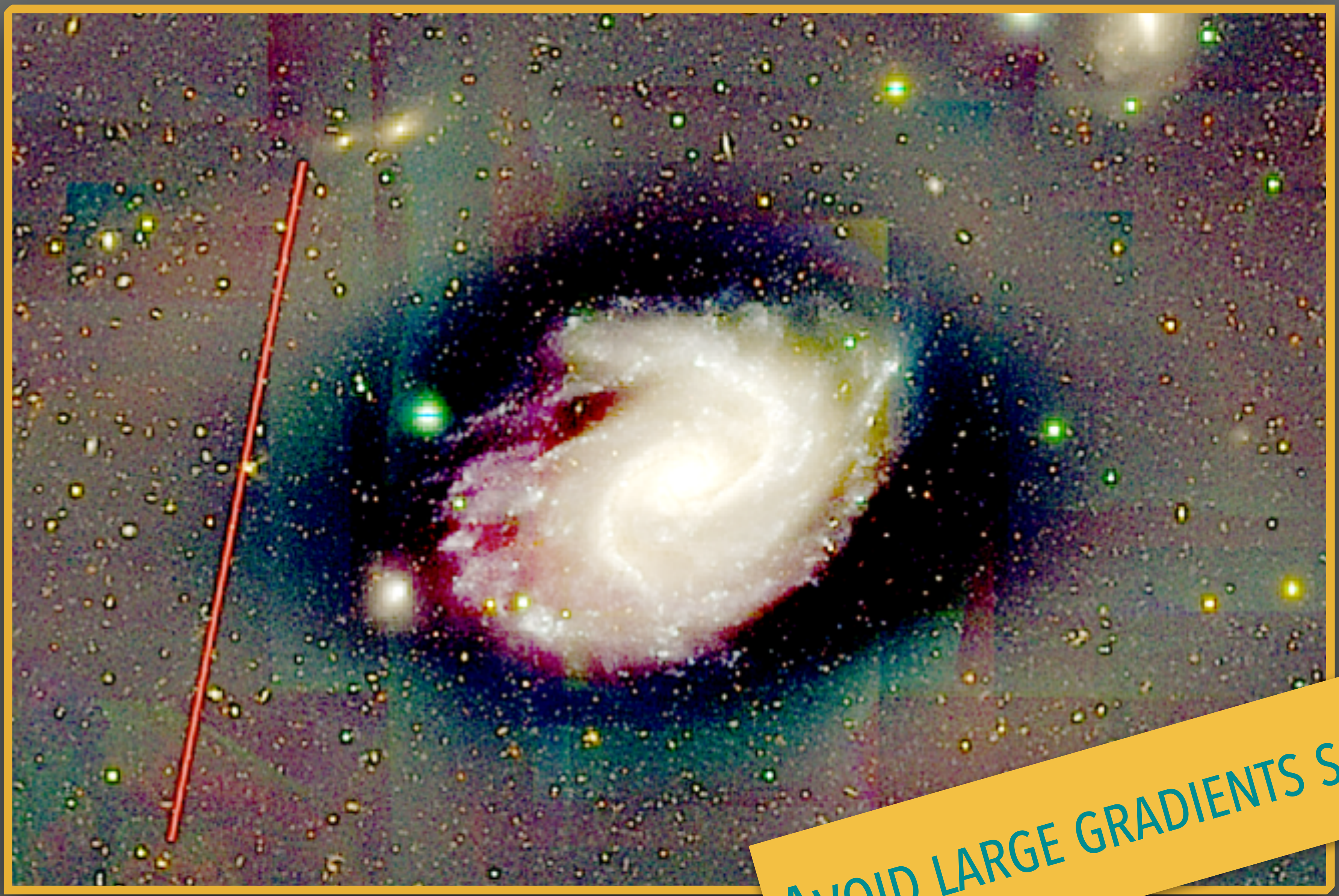



SDSS, classical & LG satellites




There is still many science to be done…

# But it's not that easy...



Oversubtraction
Hyper Suprime-Cam
Subaru Telescope

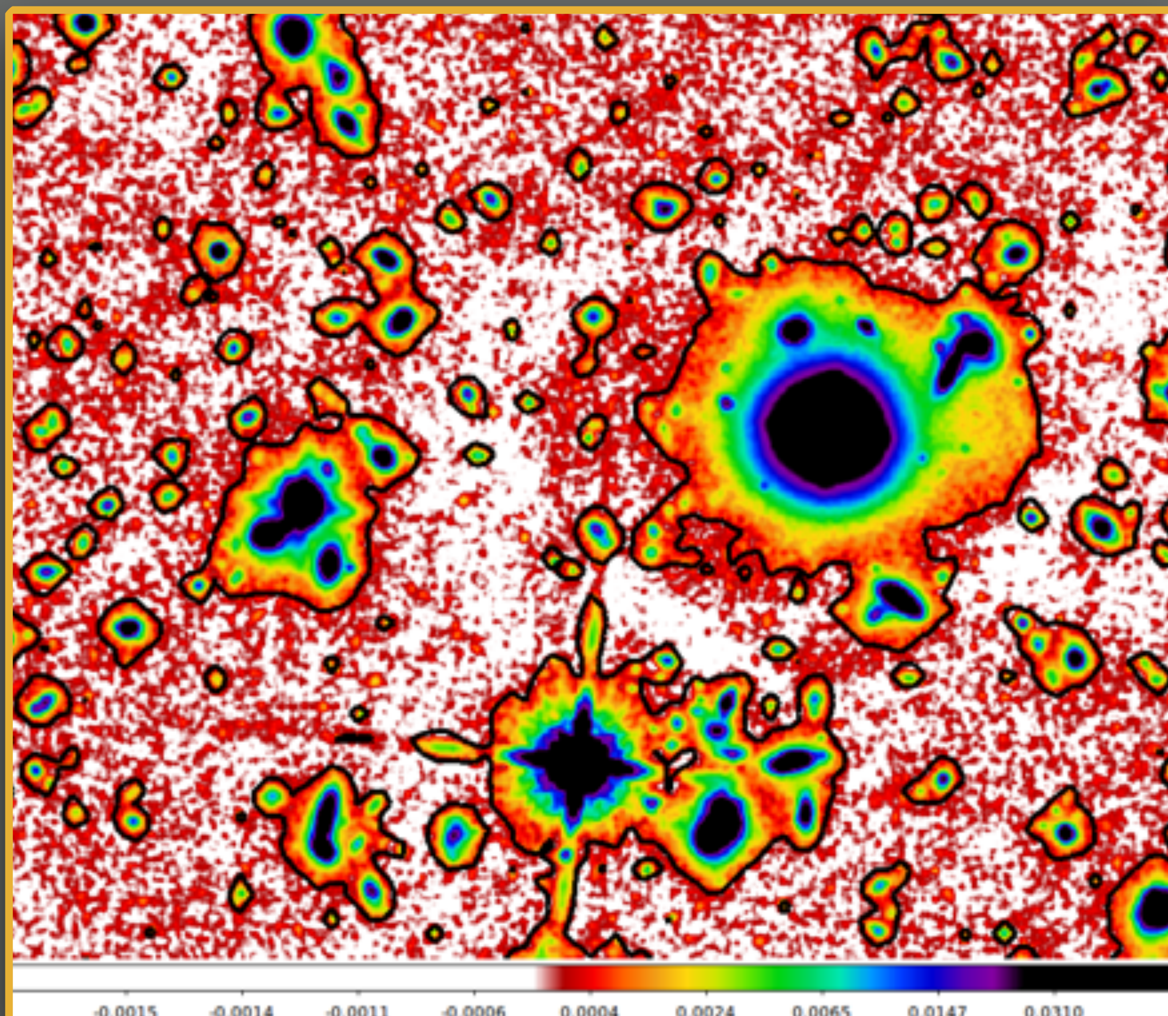
Aihara+2018

Avoid large gradients subtraction!!

Oversubtracted sky background

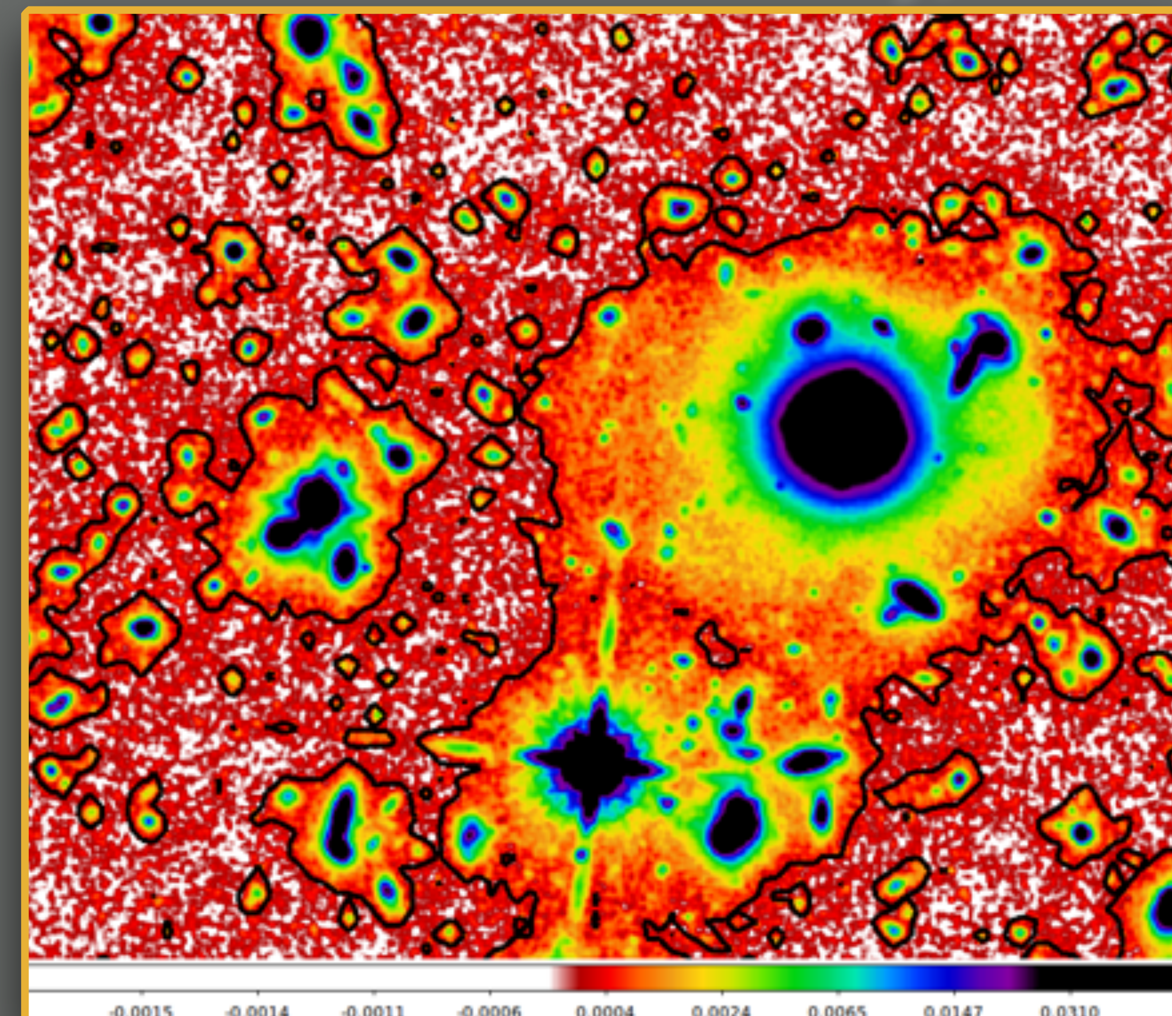
# But it's not that easy…

**XDF (oversubtracted sky)**




Illingworth+2013

**HUDF12 (less oversubtracted sky)**






**Oversubtracted sky background**

# How to perform a successful data reduction

**Bias & Overscan**

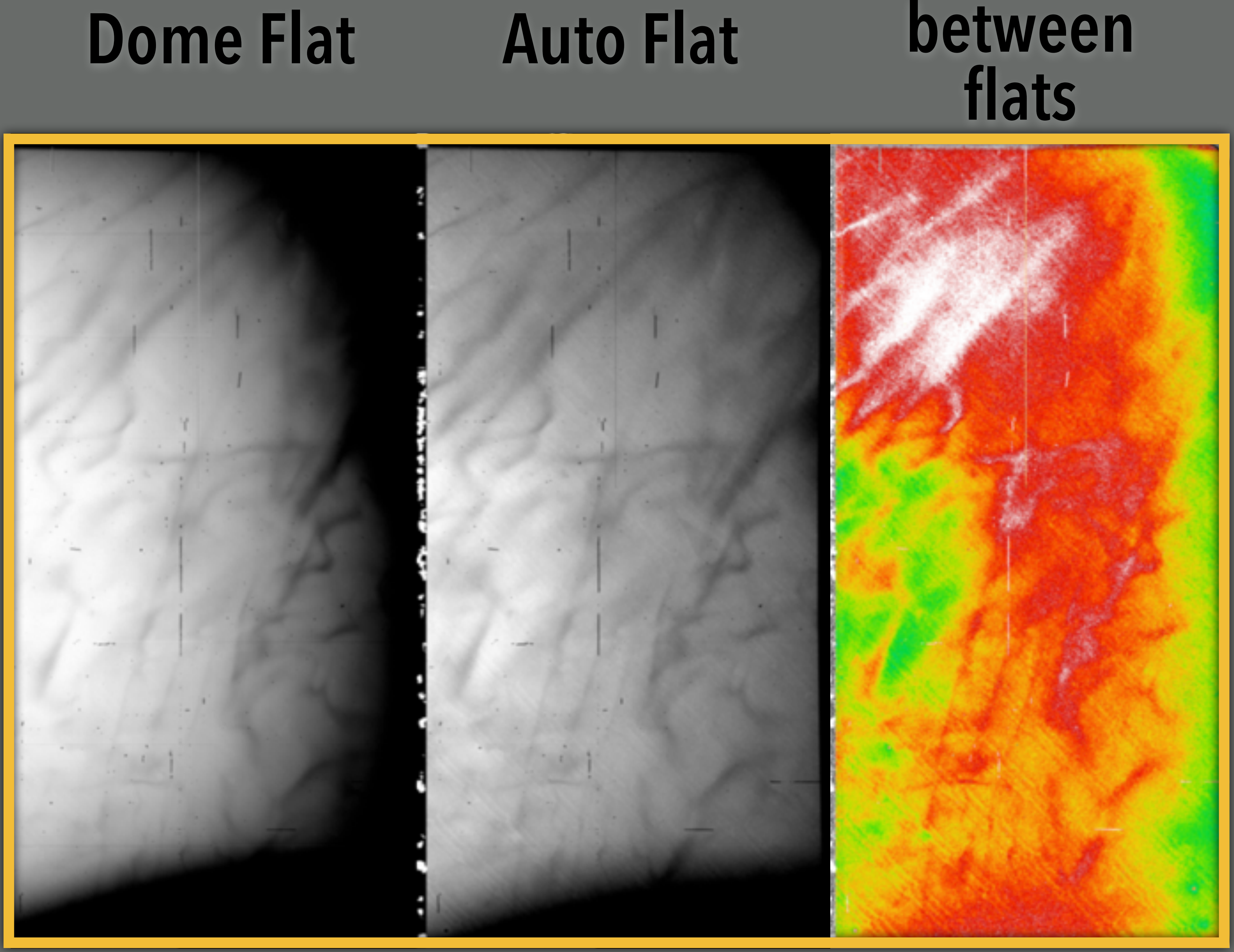
**Flat fielding**
* Vigneting
* Autoflat

**SKY SUBTRACTION**

**PSF characterization**

**It is like a standard reduction, but much more carefully**

# Flat Fielding: Auto Flat

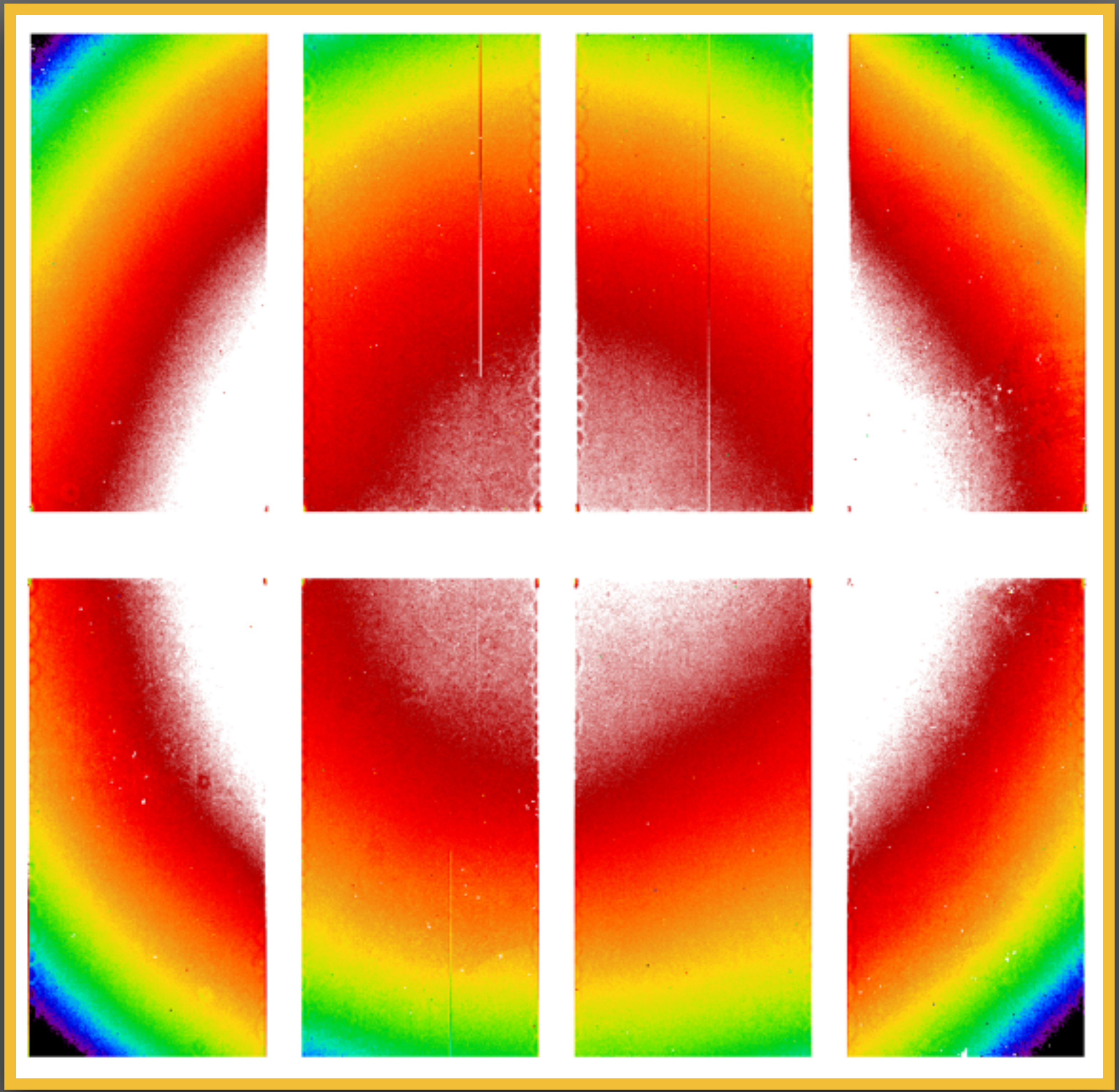



Differences up to 10%

PAUCAM@WHT, 4.2m
~1 deg$^2$, 18 CCDs
4 ch. each

Rotation: 0 deg

Infante+2018 (in prep)



# Flat Fielding: Auto Flat

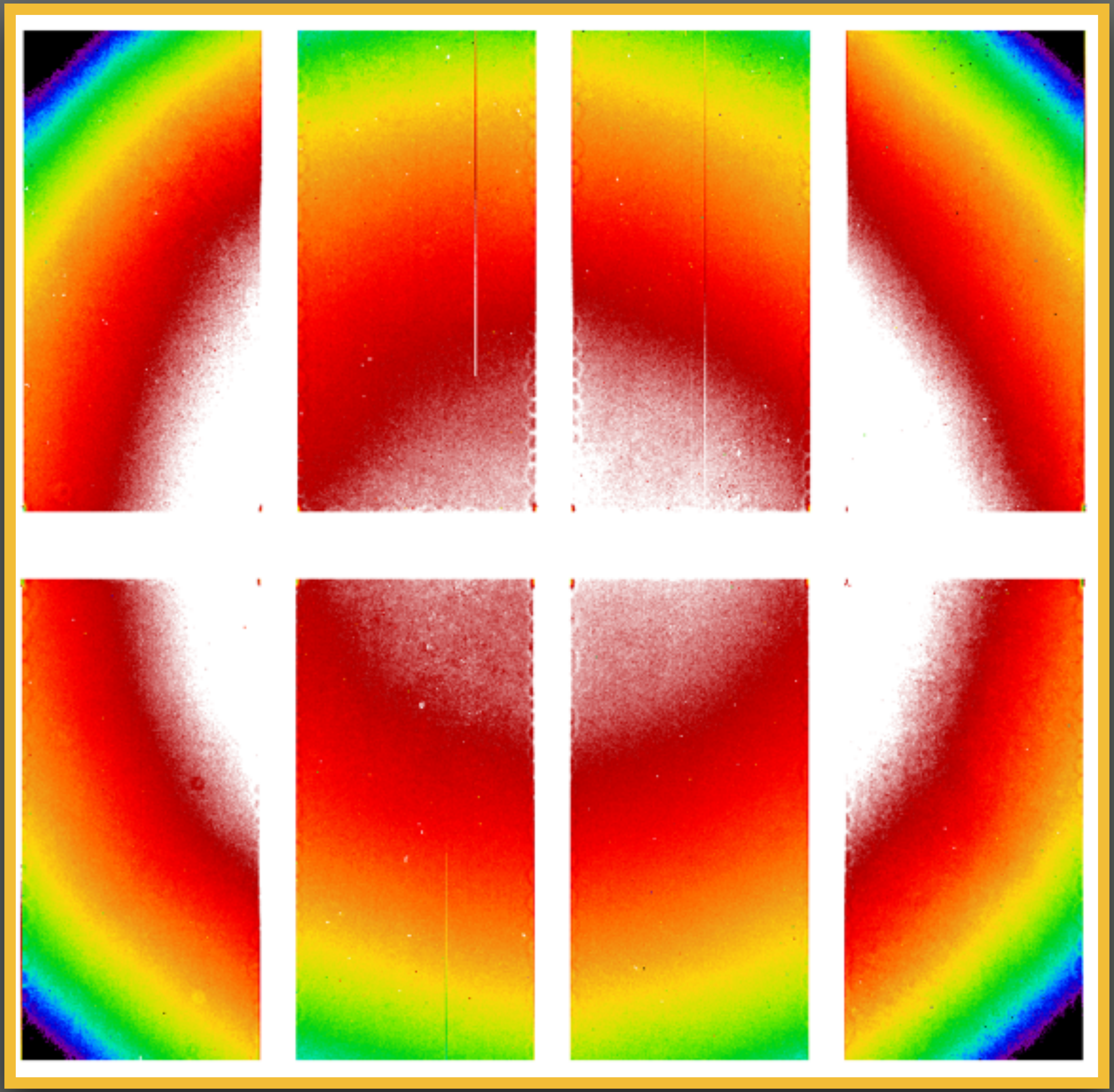
Take care with rotation

VIGNETTING EFFECTS!

PAUCAM@WHT, 4.2m
~1 deg$^2$, 18 CCDs
4 ch. each

Rotation: 120 deg

Infante+2018 (in prep)

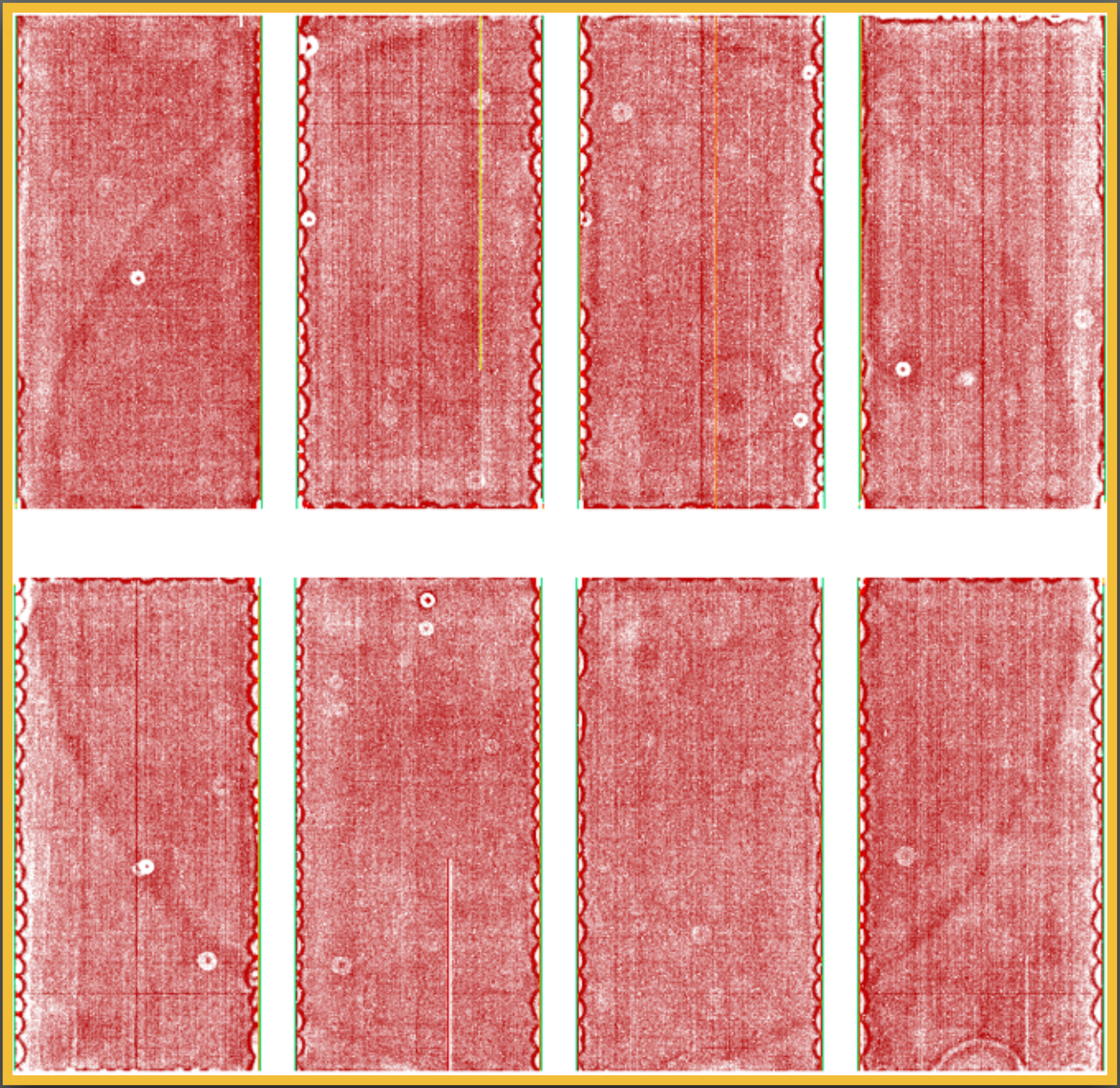


# Flat Fielding: Auto Flat

Take care with rotation

VIGNETTING EFFECTS!

# PAUCAM@WHT 4.2m, ~1 deg$^{2}$, 18 CCDs 4 ch. each



Infante+2018 (in prep)

# Flat Fielding: Auto Flat

**ACTUAL AUTO FLAT:**

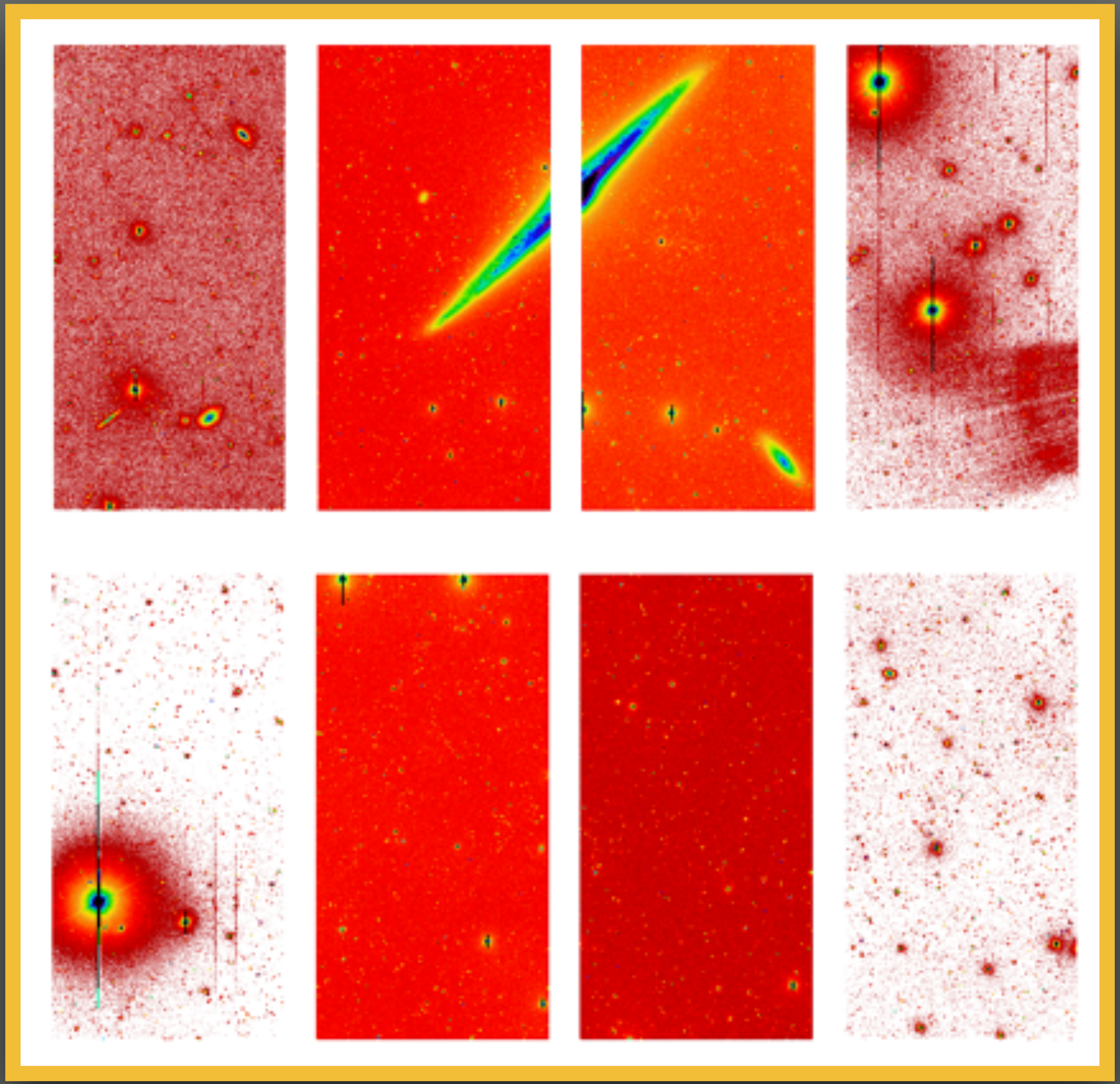
**pixel to pixel variations, CCD dust, electronic, …**

# The key point: Background subtraction

**PAUCAM@WHT**
**4.2m**
**~1 deg$^2$**
**18 CCDs**
**4 ch. each**

**NGC 4565**

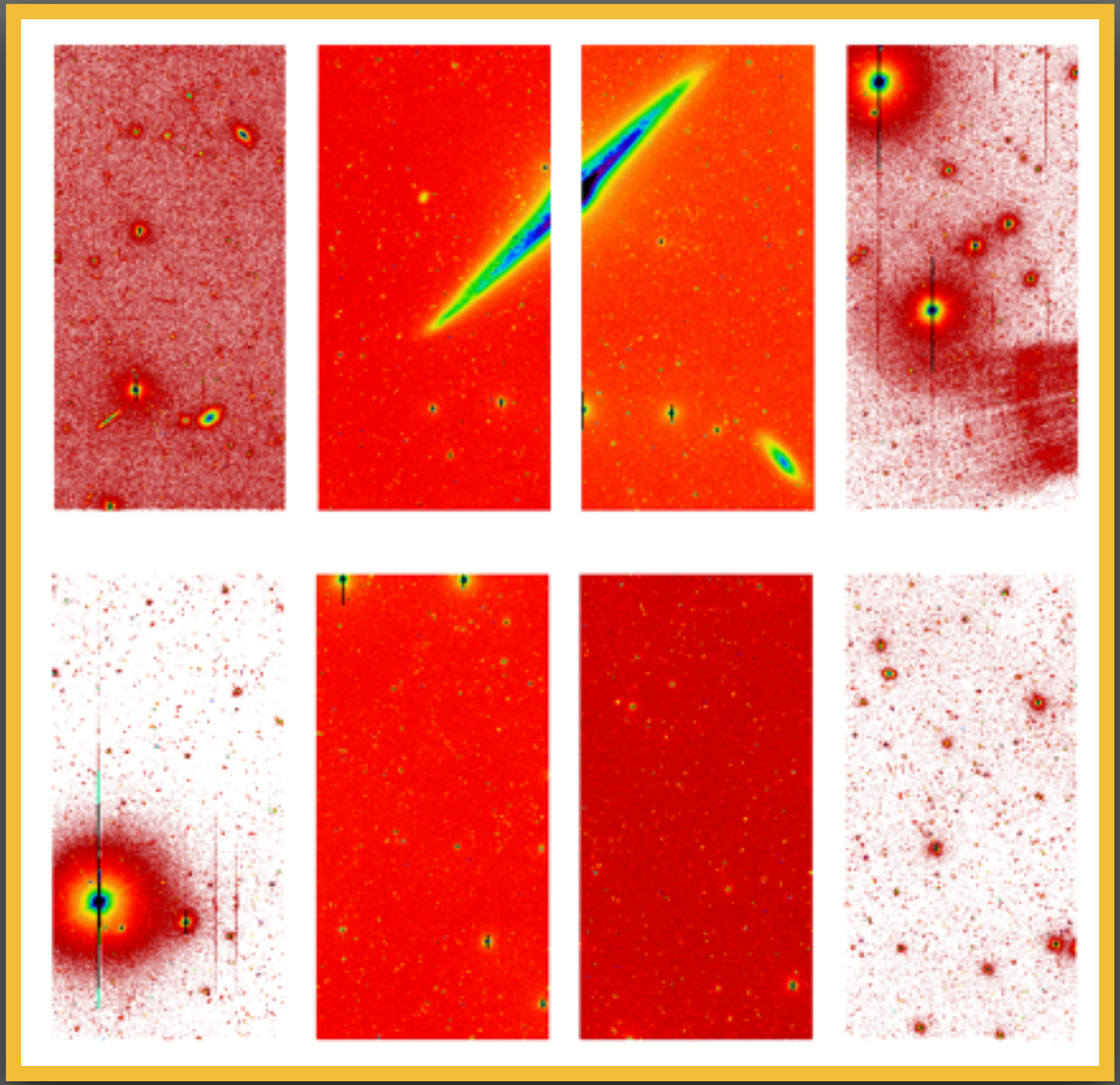
Infante+2018 (in prep)

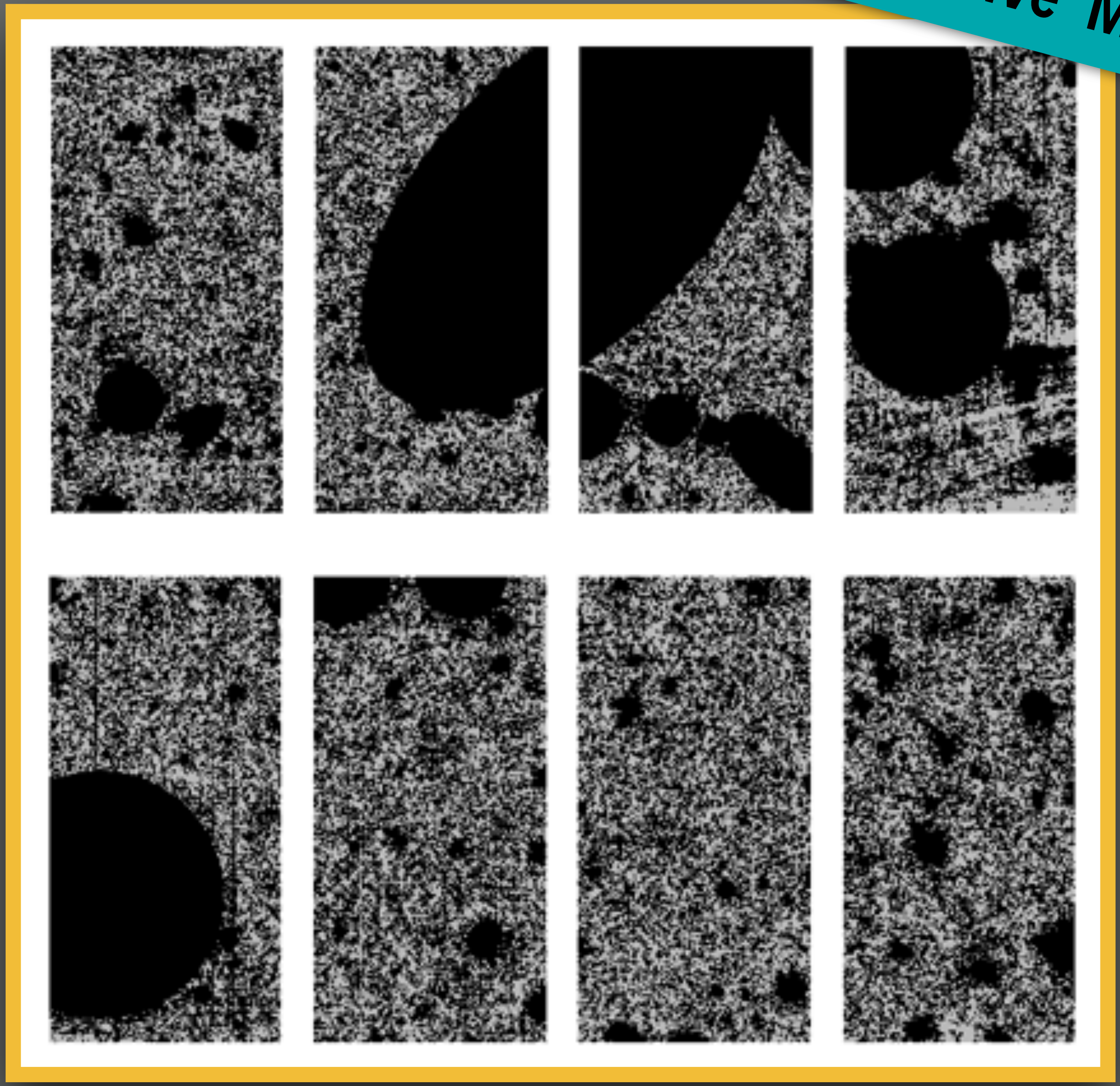


**Careful sky measurement and subtraction: flat sky**

# THE KEY POINT: BACKGROUND SUBTRACTION

Infante+2018 (in prep)



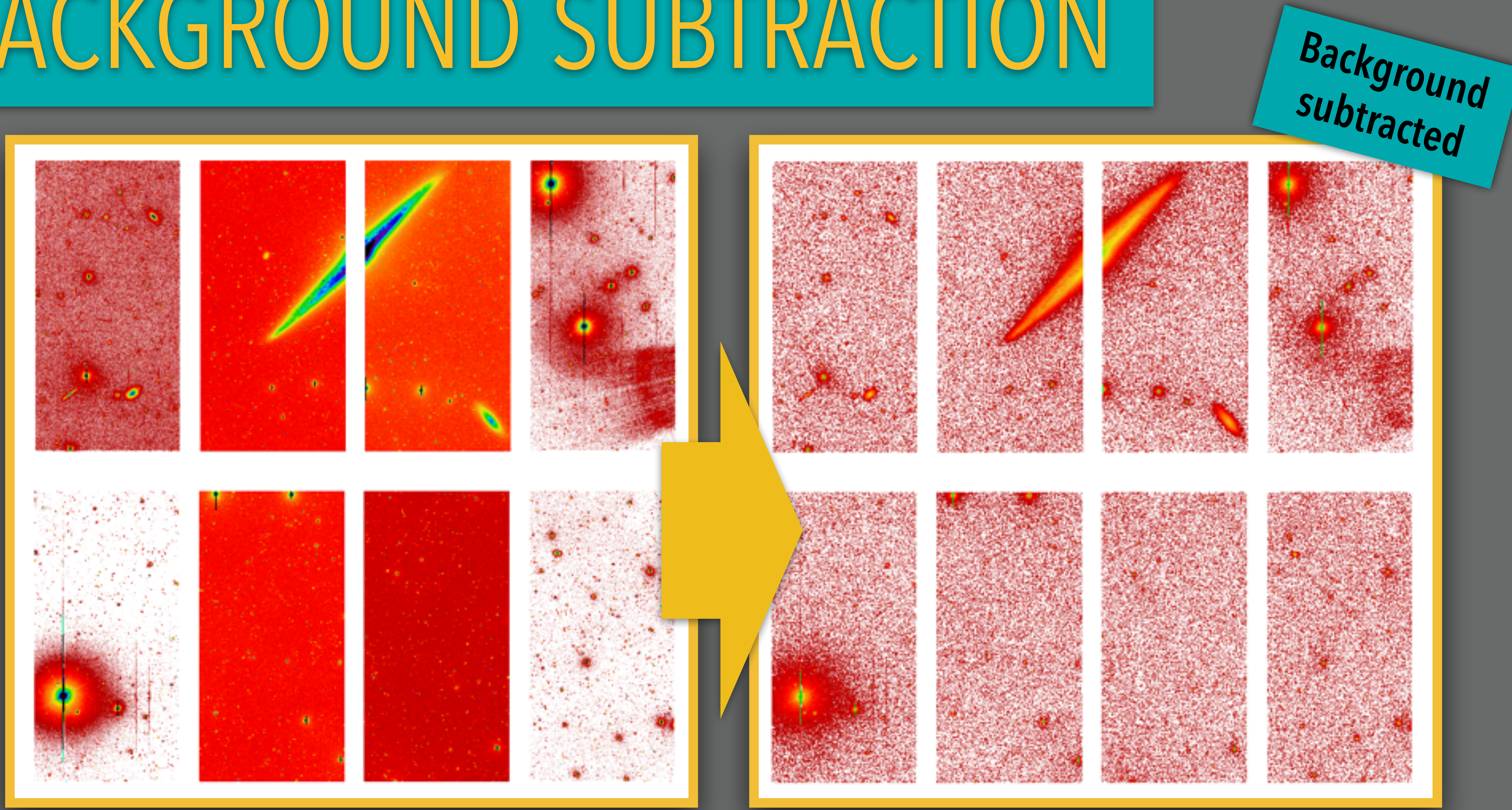


'Aggressive' Mask

**Careful sky measurement and subtraction: flat sky**

# THE KEY POINT: BACKGROUND SUBTRACTION

Infante+2018 (in prep)

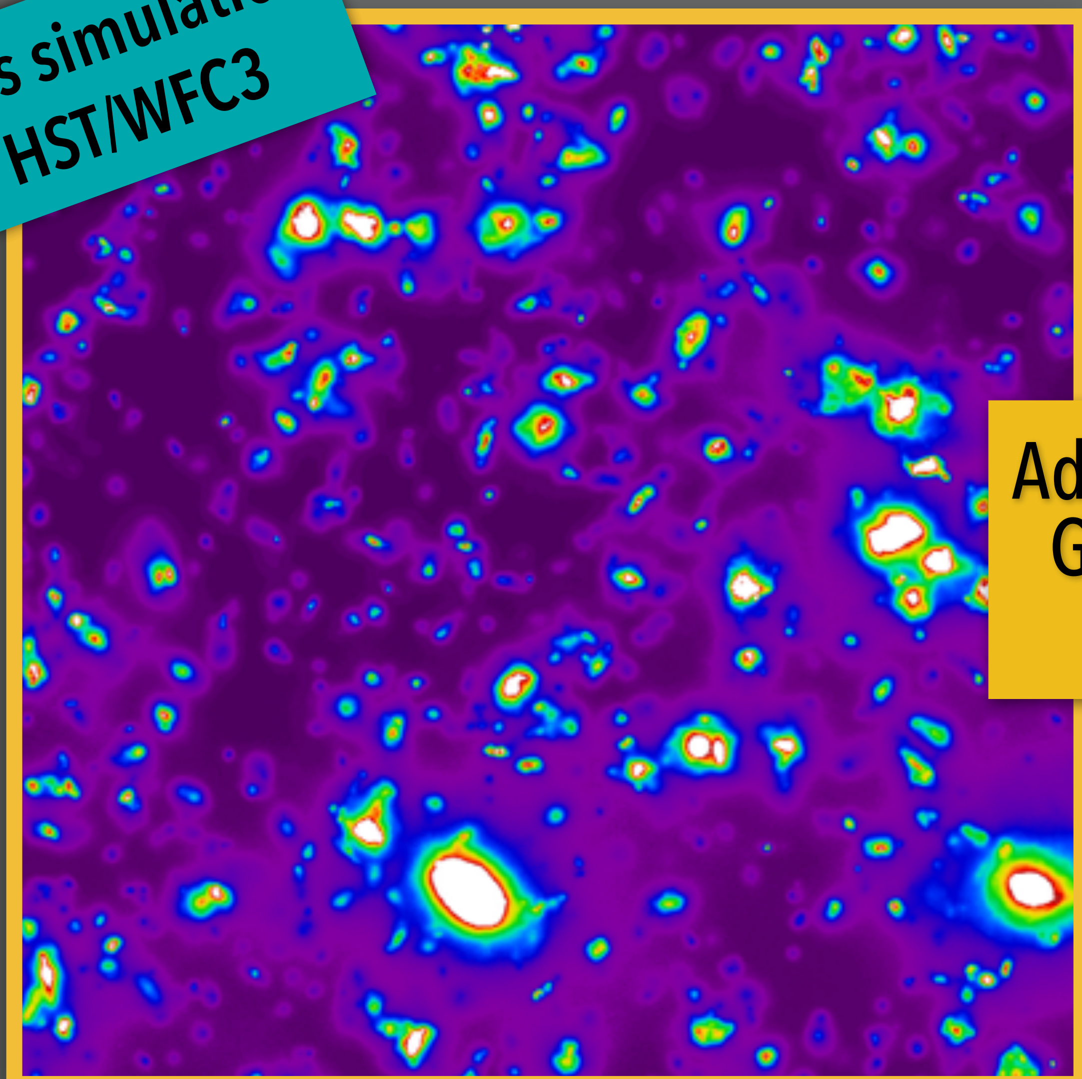



**Careful sky measurement and subtraction: flat sky**

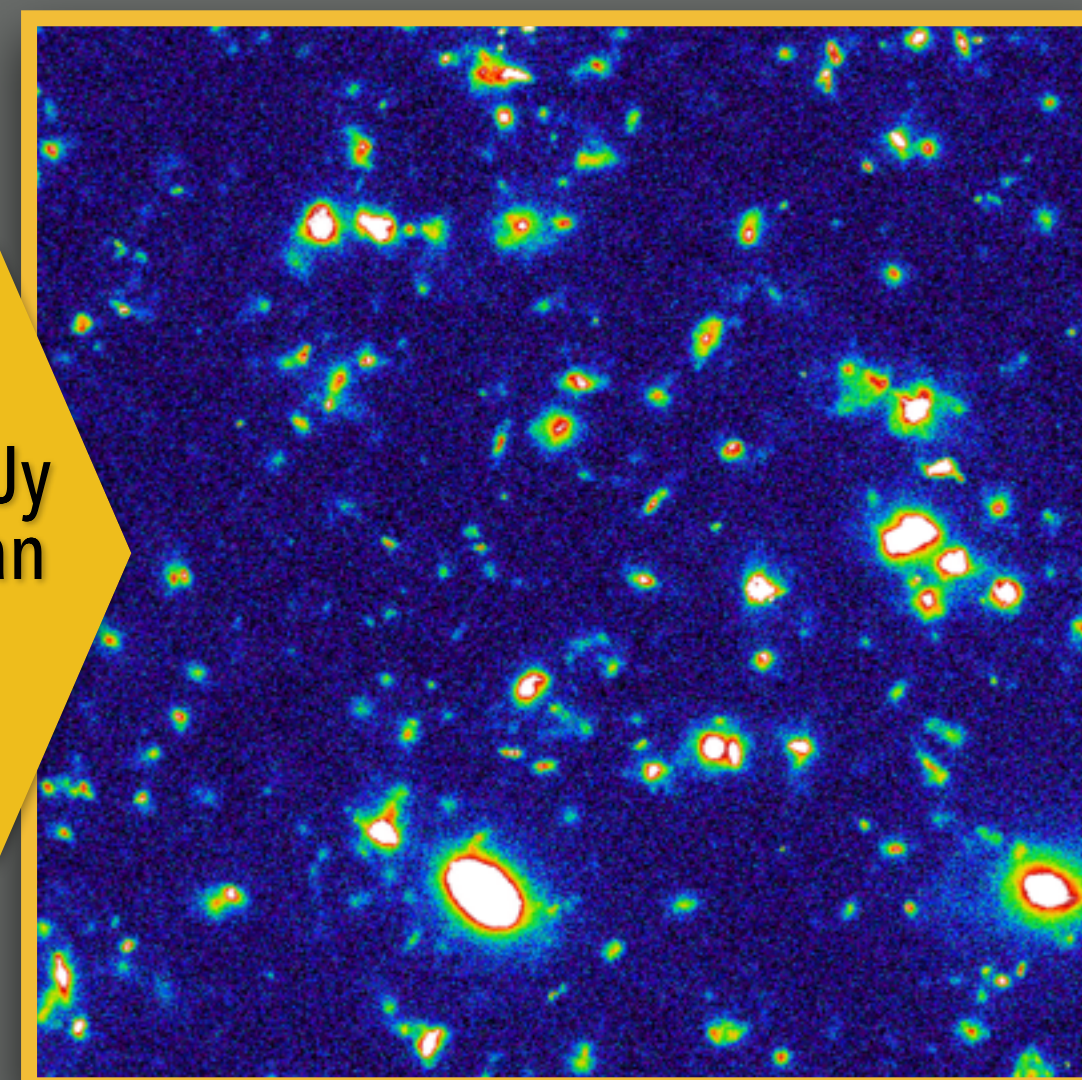
# THE KEY POINT: BACKGROUND SUBTRACTION

Borlaff+2018 (in prep)

Illustris simulation for HST/WFC3



Add 0.5 Jy Gaussian noise



**Careful sky measure and subtraction: gradient**

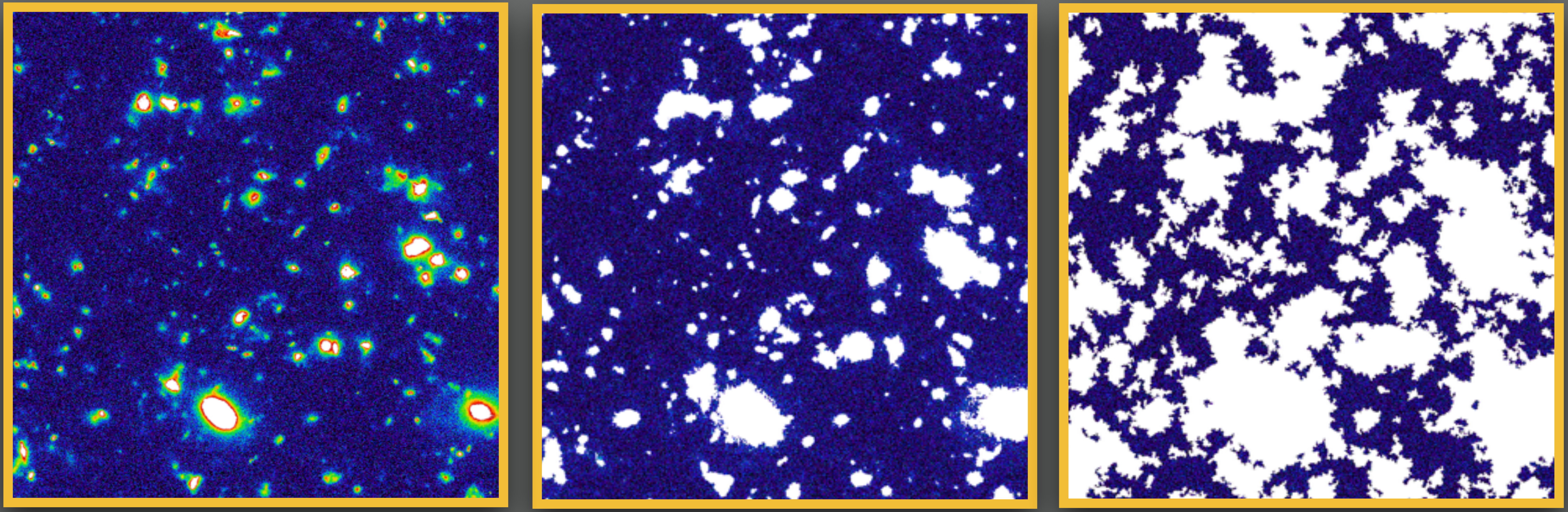
# THE KEY POINT: BACKGROUND SUBTRACTION

Borlaff+2018 (in prep)

Illustris simulation for HST/ WFC3 + 0.5 Jy Gauss. noise

1 sigma mask Sextractor (Bertin & Arnouts 1996)

Default NoiseChisel mask (Akhlaghi & Ichikawa 2015)

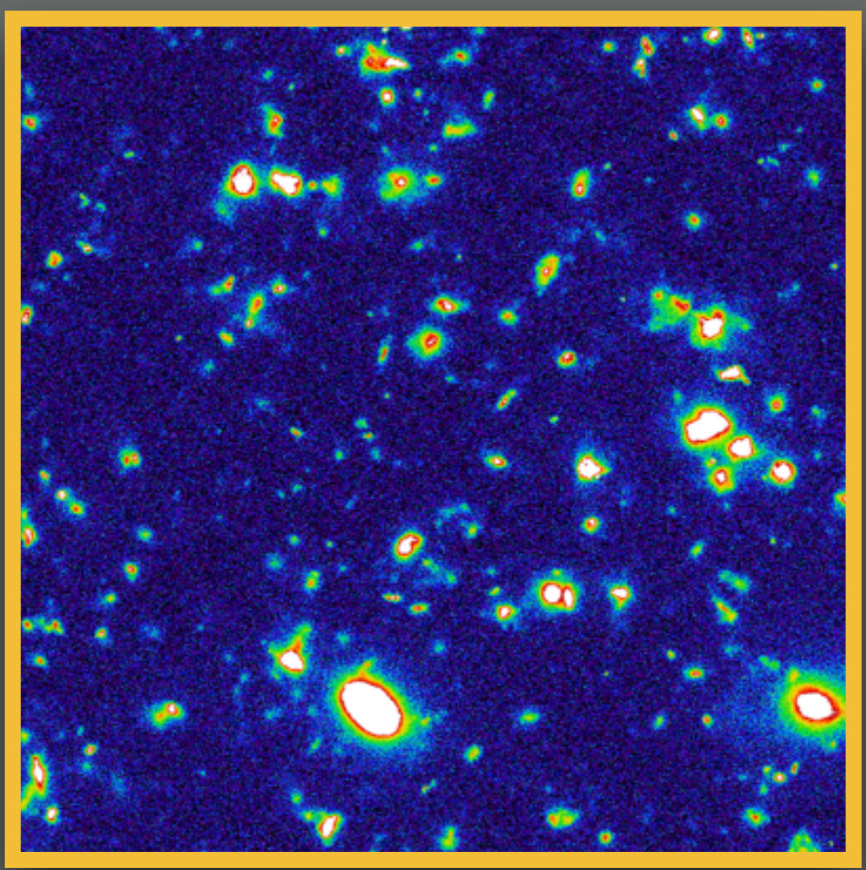


**Careful sky measure and subtraction: gradient**

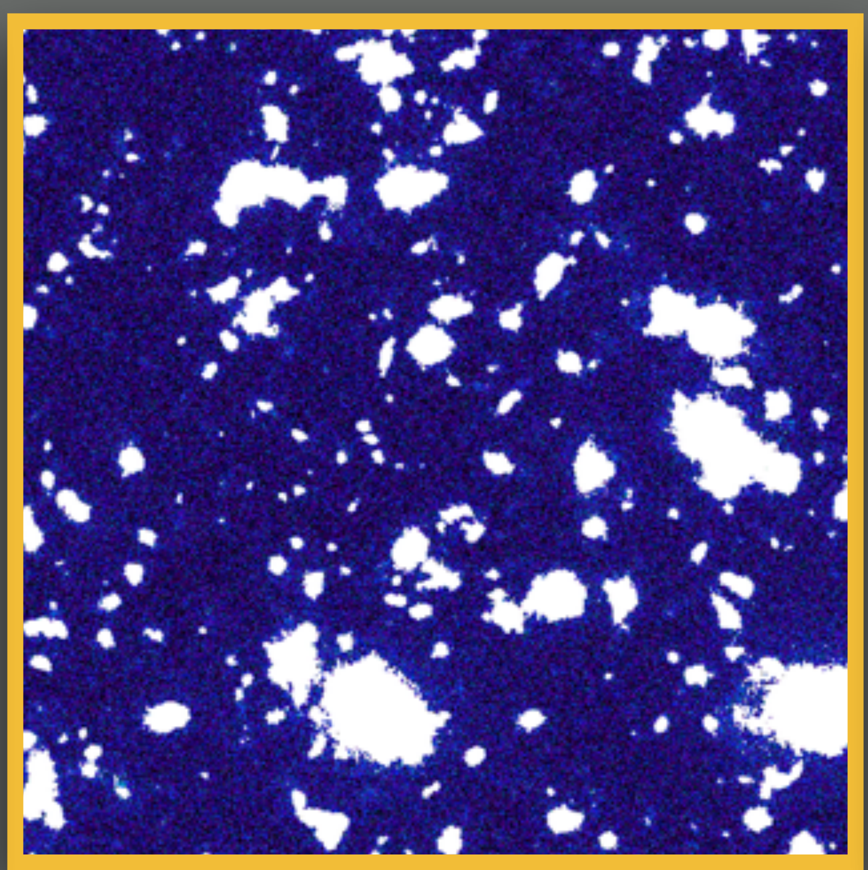
# THE KEY POINT: BACKGROUND SUBTRACTION

Borlaff+2018 (in prep)

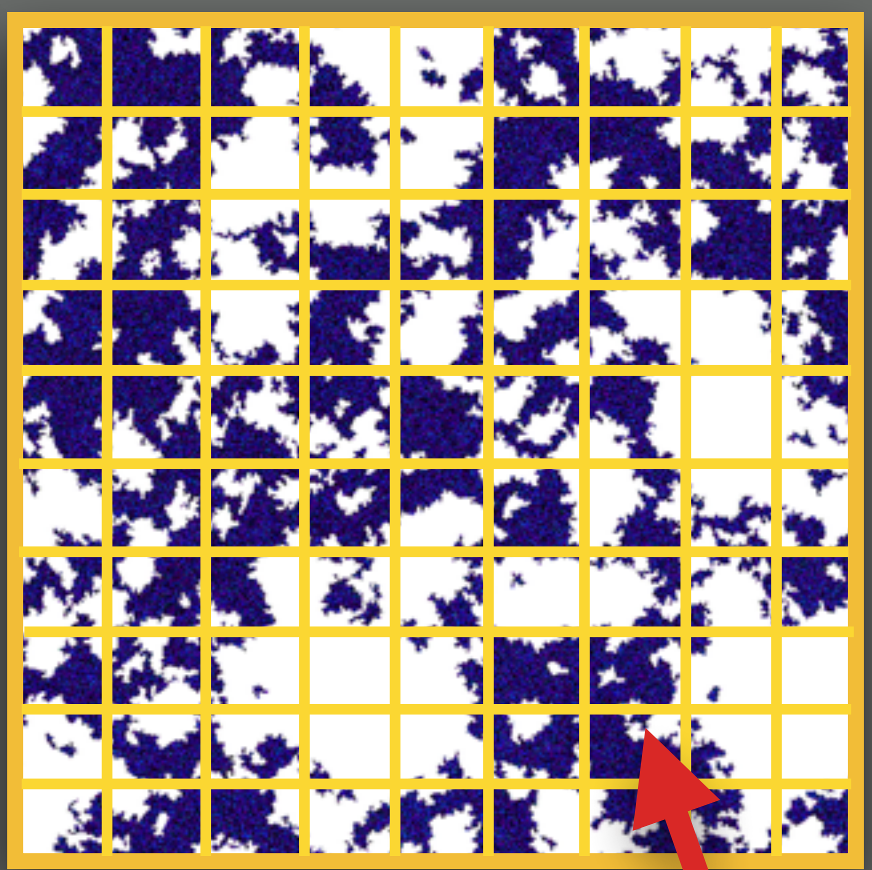
**Illustris simulation for HST/ WFC3 + 0.5 Jy Gauss. noise**



**1 sigma mask Sextractor (Bertin & Arnouts 1996)**

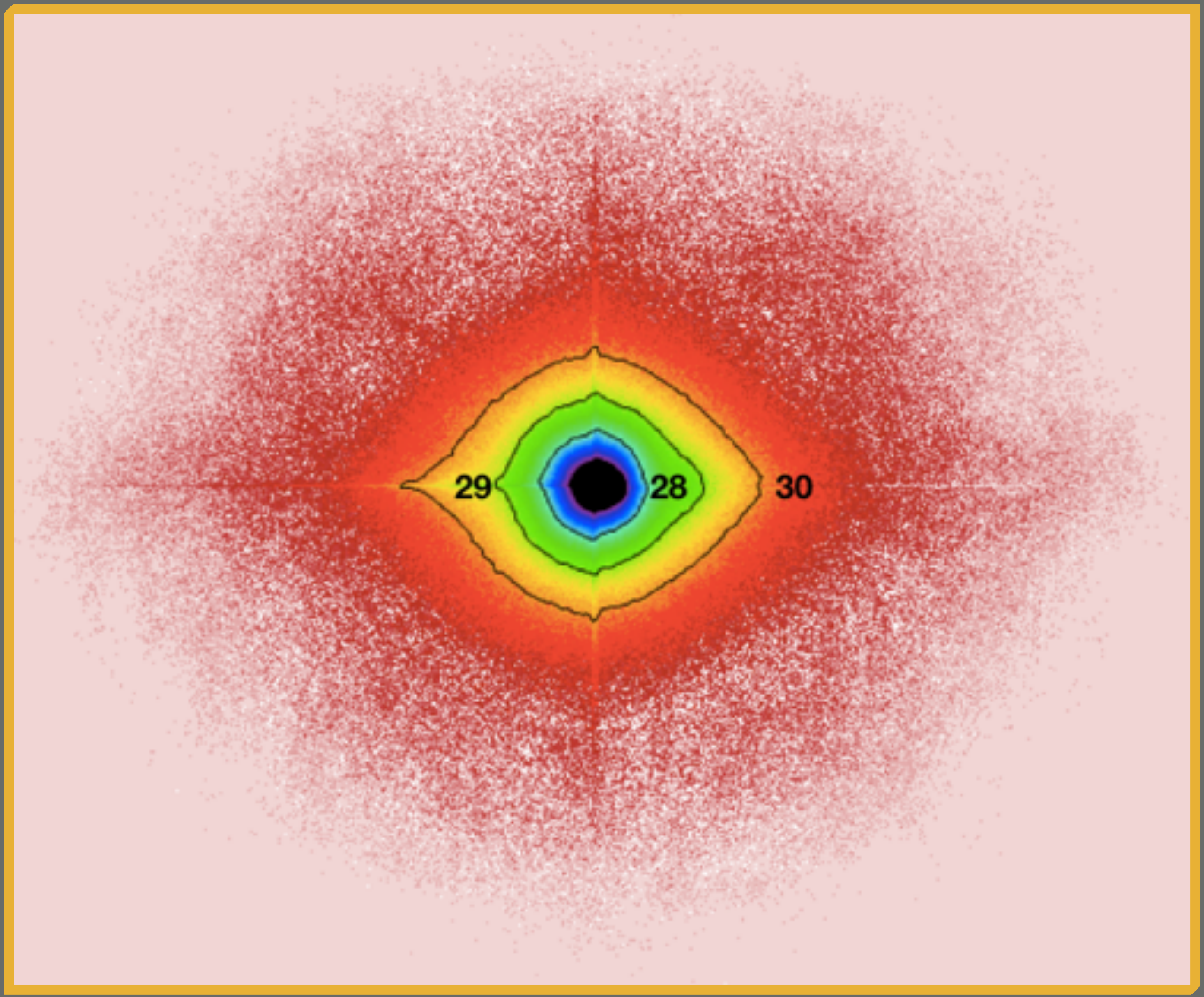


**Default NoiseChisel mask (Akhlaghi & Ichikawa 2015)**



**Careful sky measure and subtraction: gradient**

# PSF Treatment



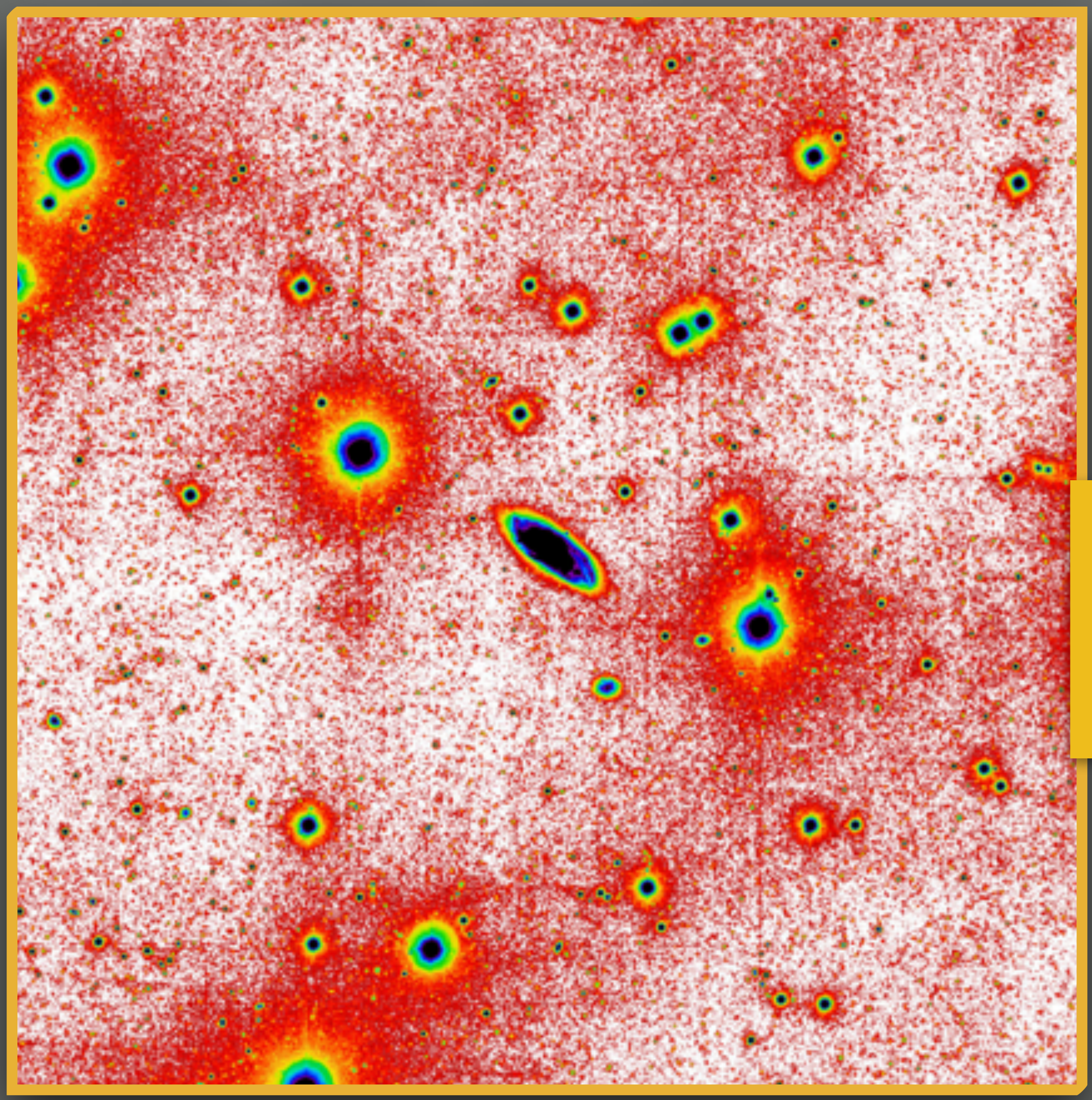

**PSF Stripe 82 *g*-band**
**$\sim 9 \times 9$ arcmin$^2$**
**scaled to flux $\sim 10^6$**

**Large PSFs and exquisite image treatment**

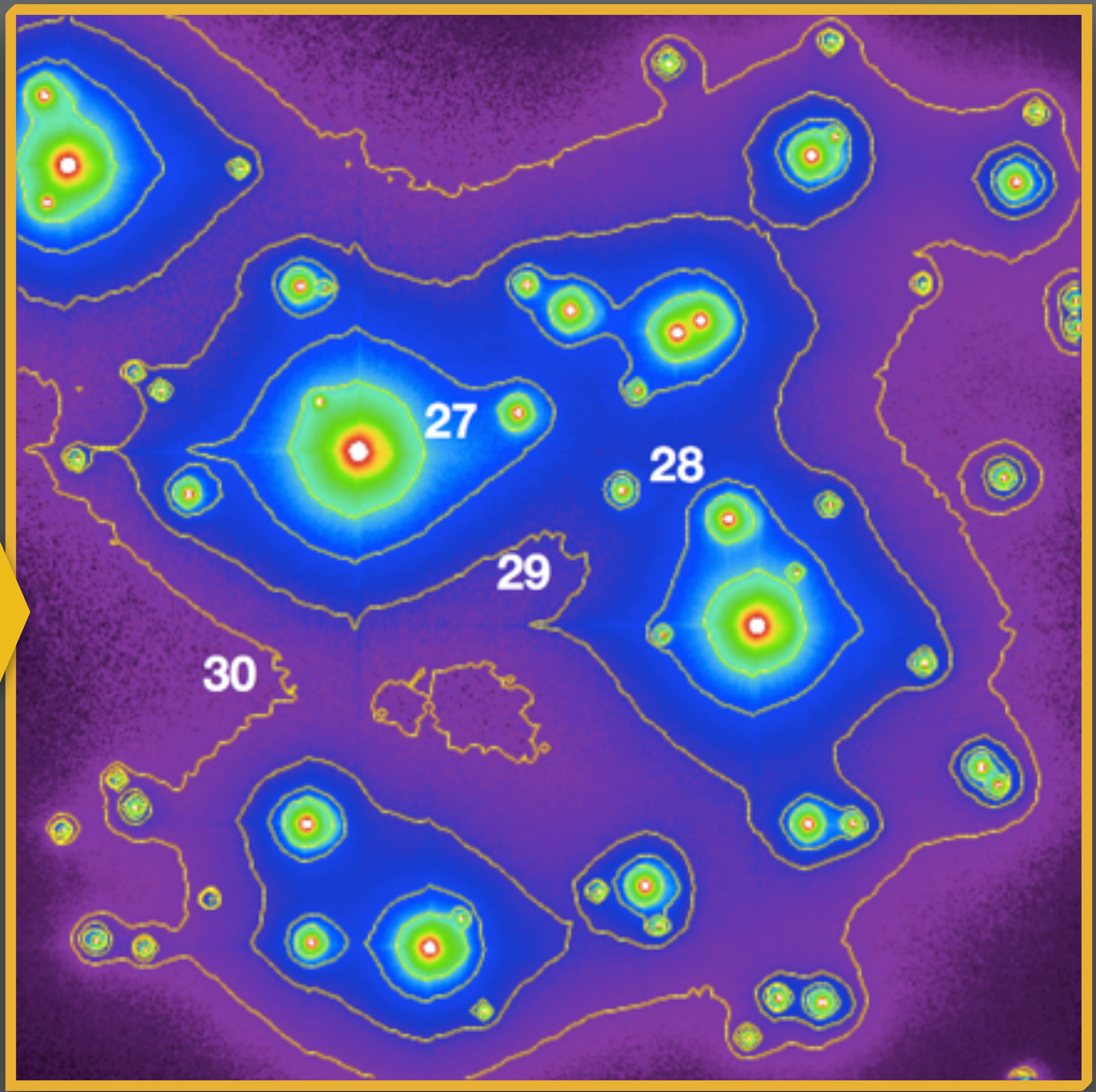
Chamba+2018 (in prep)

# PSF TREATMENT

29.2 mag/arcsec$^2$
IAC Stripe 82 g-band



Scattered light
model




Chamba+2018 (in prep)

**Large PSFs and exquisite image treatment**

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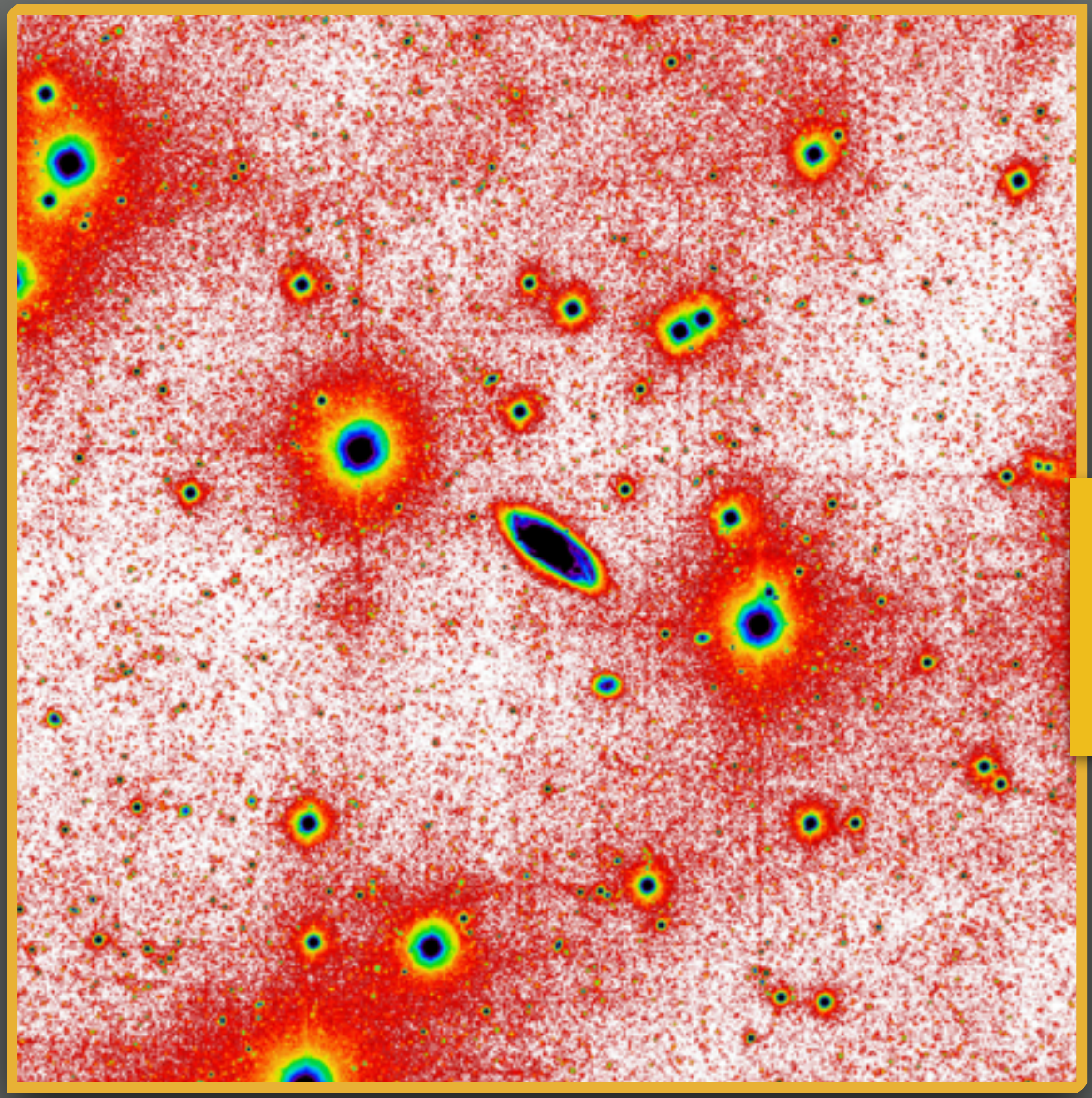
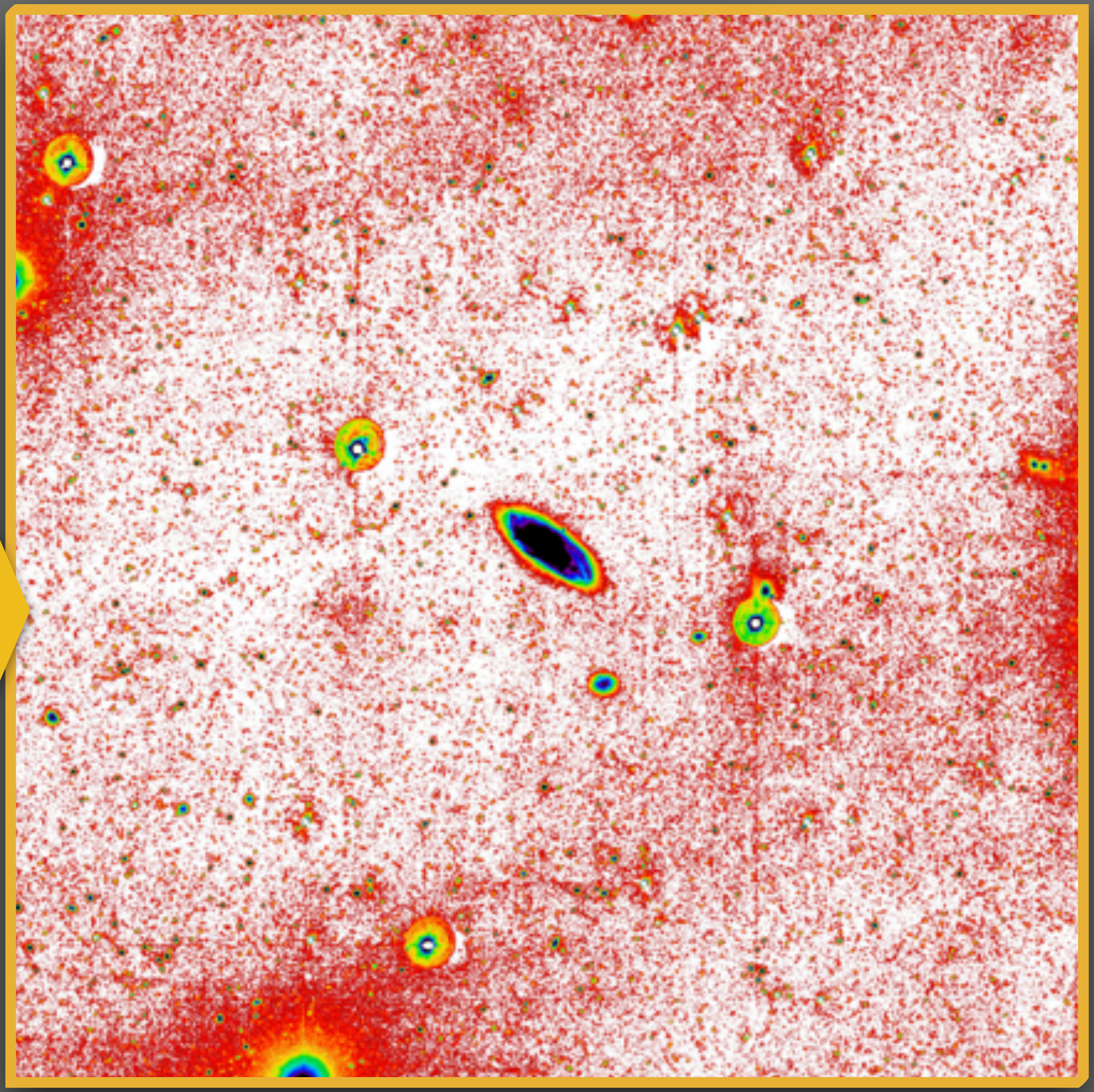
29.2 mag/arcsec$^2$
IAC Stripe 82 g-band



Scattered light subtracted



**Large PSFs and exquisite image treatment**

Chamba+2018 (in prep)

**PSFs** are time-variable (scales of mins), depend on atmosphere as well as optics, wavelength, on position on the sky, and on position in FoV

Need to explore how PSF changes for every science exposure over FoV and with time as well as establish the effect of PSF on shape measurement, in particular of the faintest sources

Not just for the 'standard' PSF core (seeing) but for WINGS out to 8-10 arcmin using the brightest stars combined with fainter ones

# LSST Commissioning

Construct very deep and large PSFs [R~30 arcmin] in all bands following a similar observational strategy than science data

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**Mini Survey 2** (200 deg$^2$ to r~28 mag/arcsec$^2$): point to a field with VERY LARGE STREAMS (i.e., M 83 or NGC 253) to check whether LSB features are recovered in the reduction process.

# THANK YOU!

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## TAKE HOME MESSAGE...

* LSST is an unprecedented opportunity to unveil the Low Surface Brightness structures over 20,000 $deg^2$ of sky

* Data Reduction is crucial to preserve LSB features

* The commissioning and Science Verification are the opportunity to evaluate the systematics and potential implications for key science drivers

**ARE WE GOING TO MISS IT?**

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