Easycritic:
Predicting strong lensing regions in the sky

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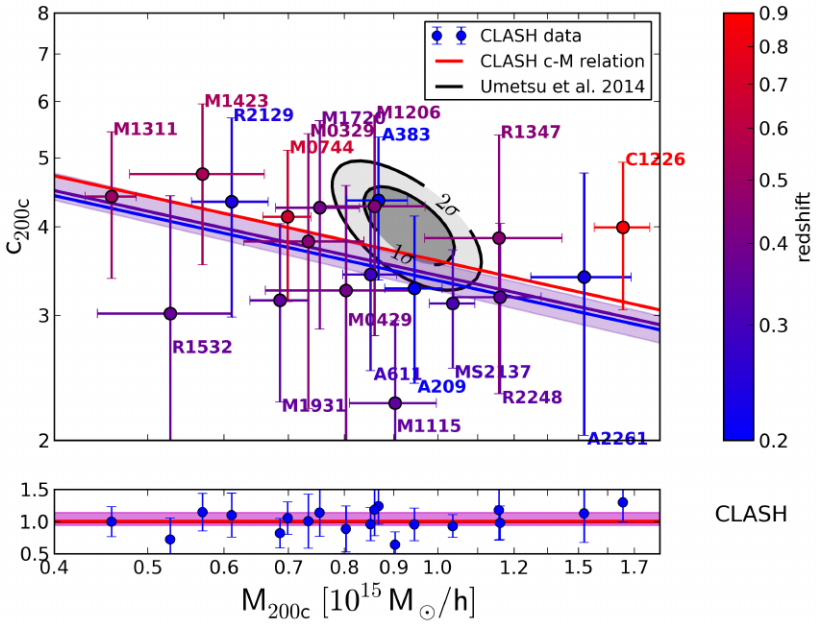
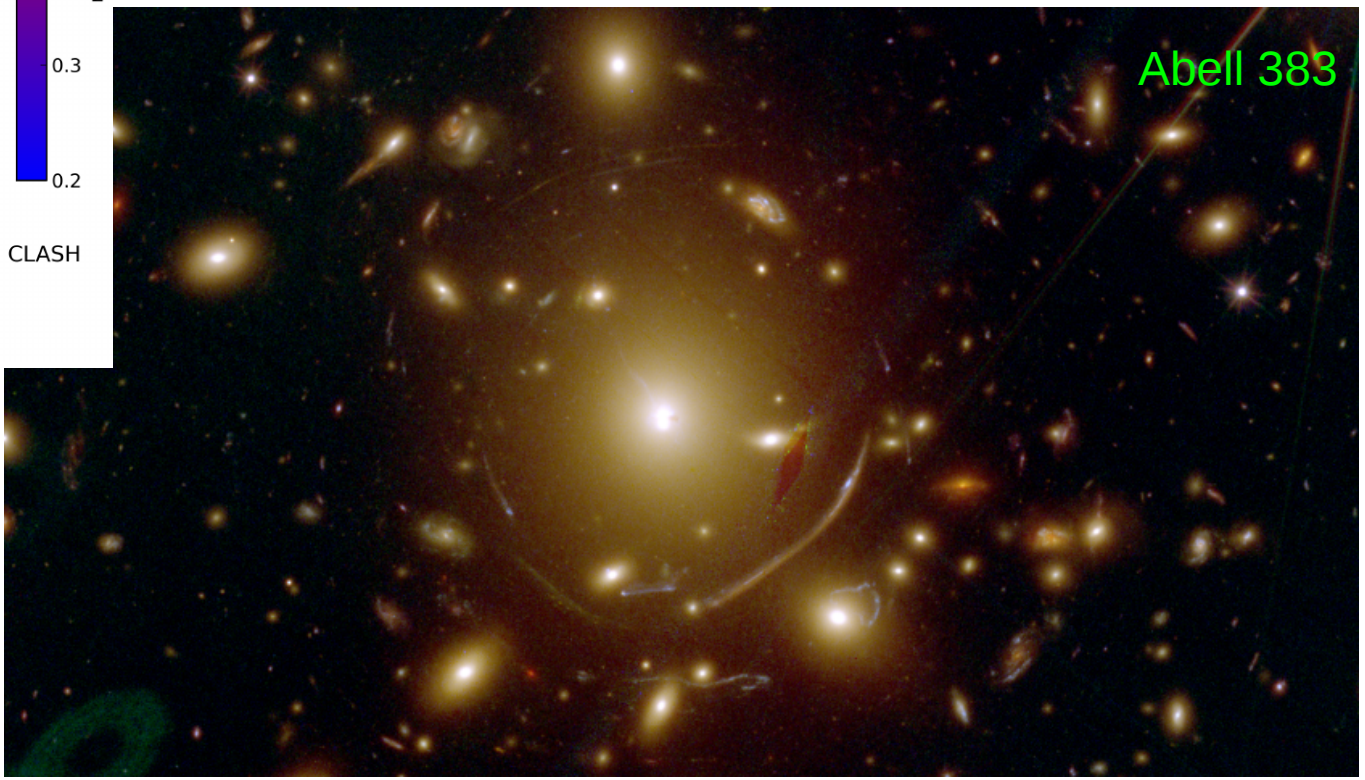
Galaxy clusters & gravitational lensing

Constraints on cosmological parameters: mass reconstructions



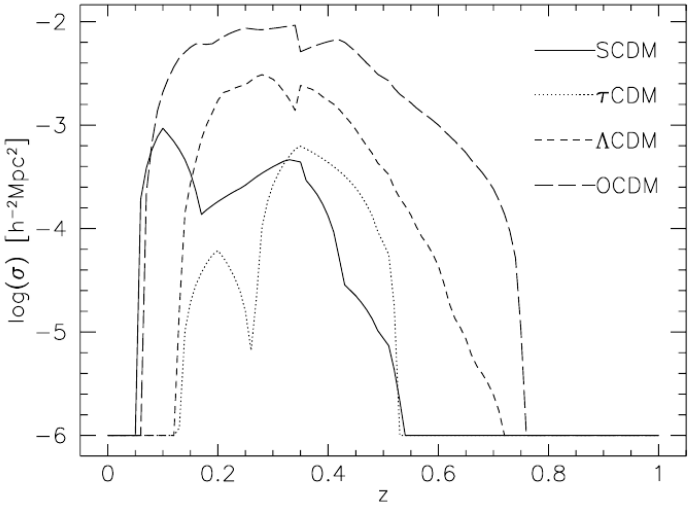
Merten et al. (2015)



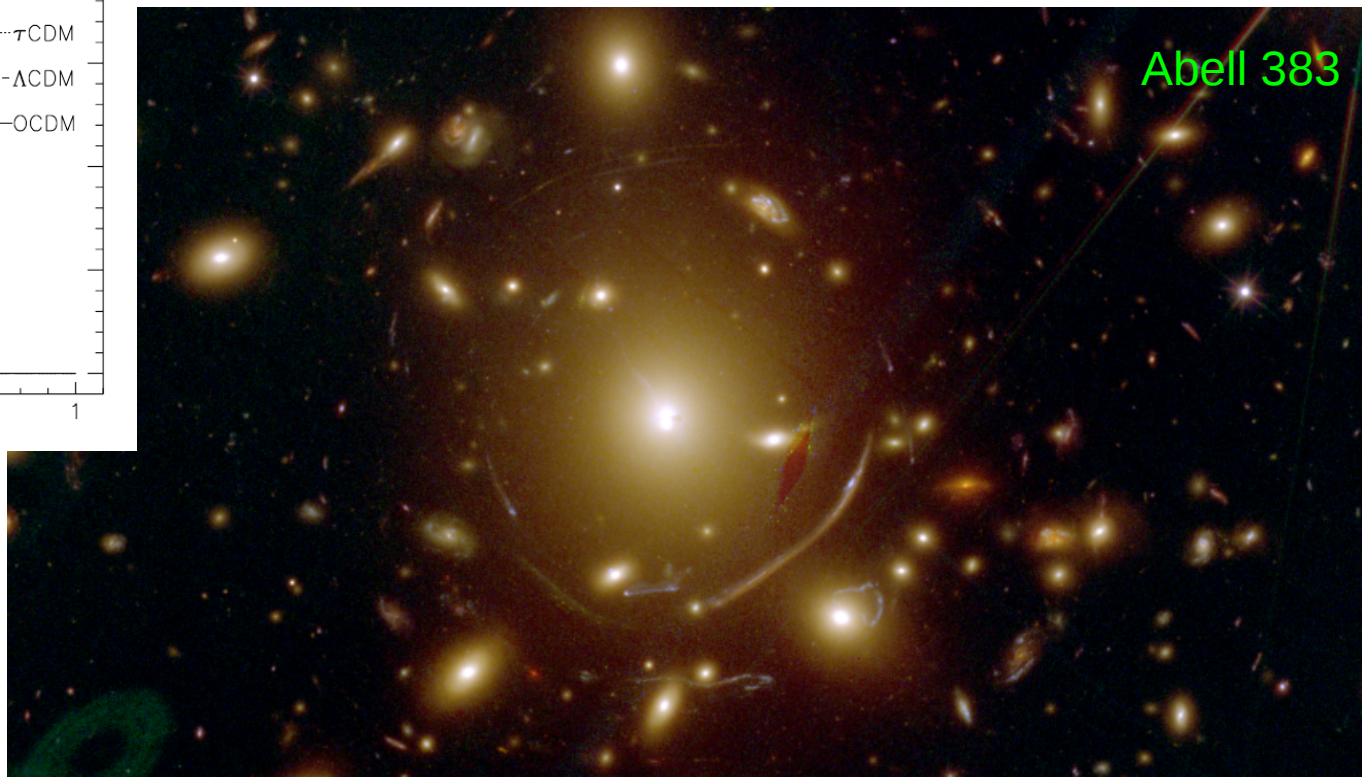
Galaxy clusters & gravitational lensing

Constraints on cosmological parameters: arc statistics

- The number of giant arcs on the sky is a complex observable that depends on the formation time and evolution of DM halos, as well as on intrinsic properties of the high-redshift galaxy population.



Bartelmann et al. (1998)



Goal

Searching for giant arcs

Searching for giant arcs in the sky

Visual inspection

Searching for giant arcs in the sky

Visual inspection

- Extremely time consuming
- Extremely astronomer consuming

Searching for giant arcs in the sky

Easycritic: Light-traces-mass

- Elliptical galaxies
- Initial mass model
- Critical curves
- Arcfinder
- Multy-colour filtering

Searching for giant arcs in the sky

Easycritic: Light-traces-mass

- We assign a fixed power-law profile to all elliptical galaxies.

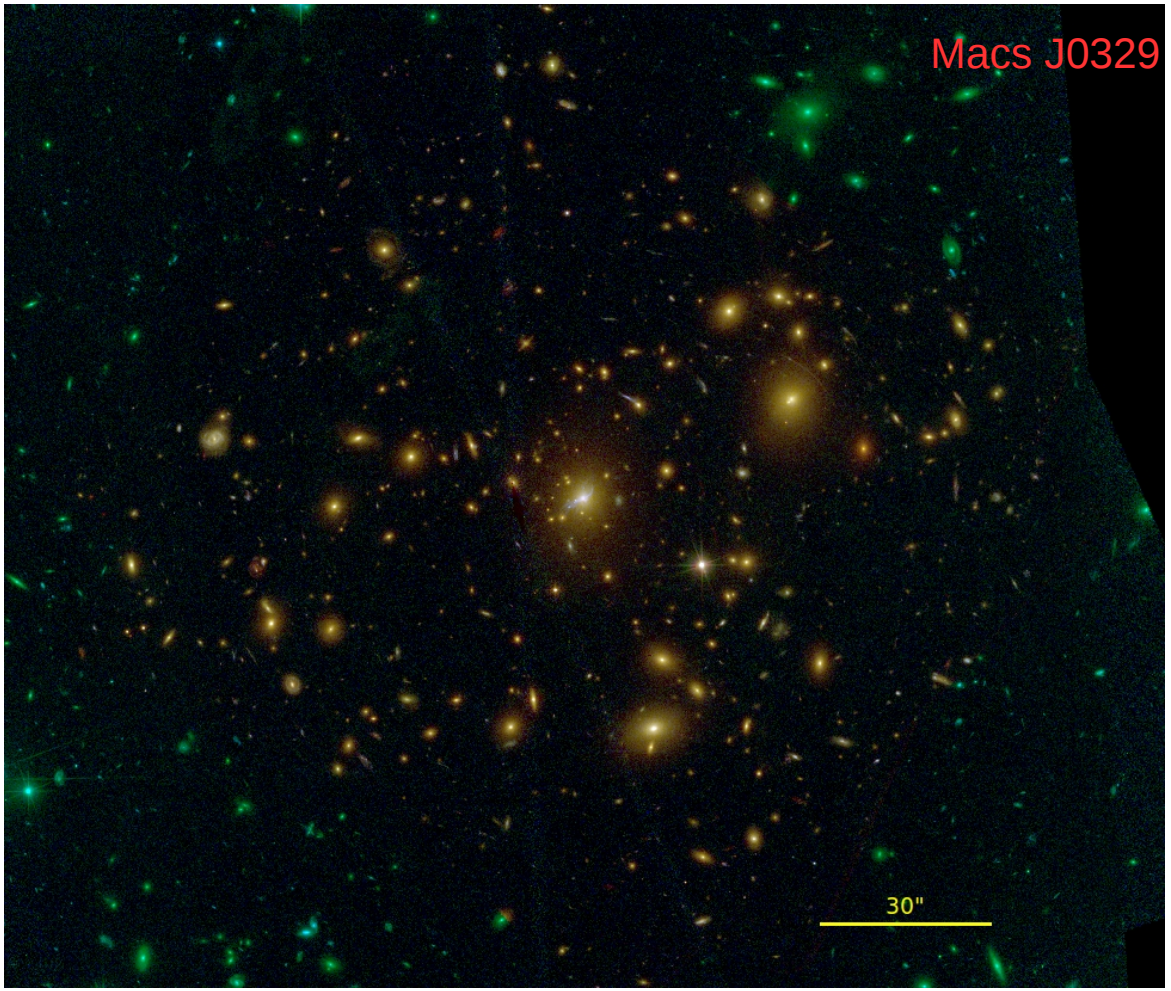
$$\Sigma(r) = K r^{-q}$$

$$M(<\theta) = \frac{2\pi K}{2-q}(d_l\theta)^{2-q}$$

$$\alpha(\theta) = \frac{4GM(<\theta)}{c^2\theta}\frac{d_{ls}}{d_s d_l}$$

- Unique M/L for all galaxies.

$$M(<\theta) \propto \theta^{2-q} \rightarrow \alpha(\theta) = K_q F \theta^{1-q}$$



Searching for giant arcs in the sky

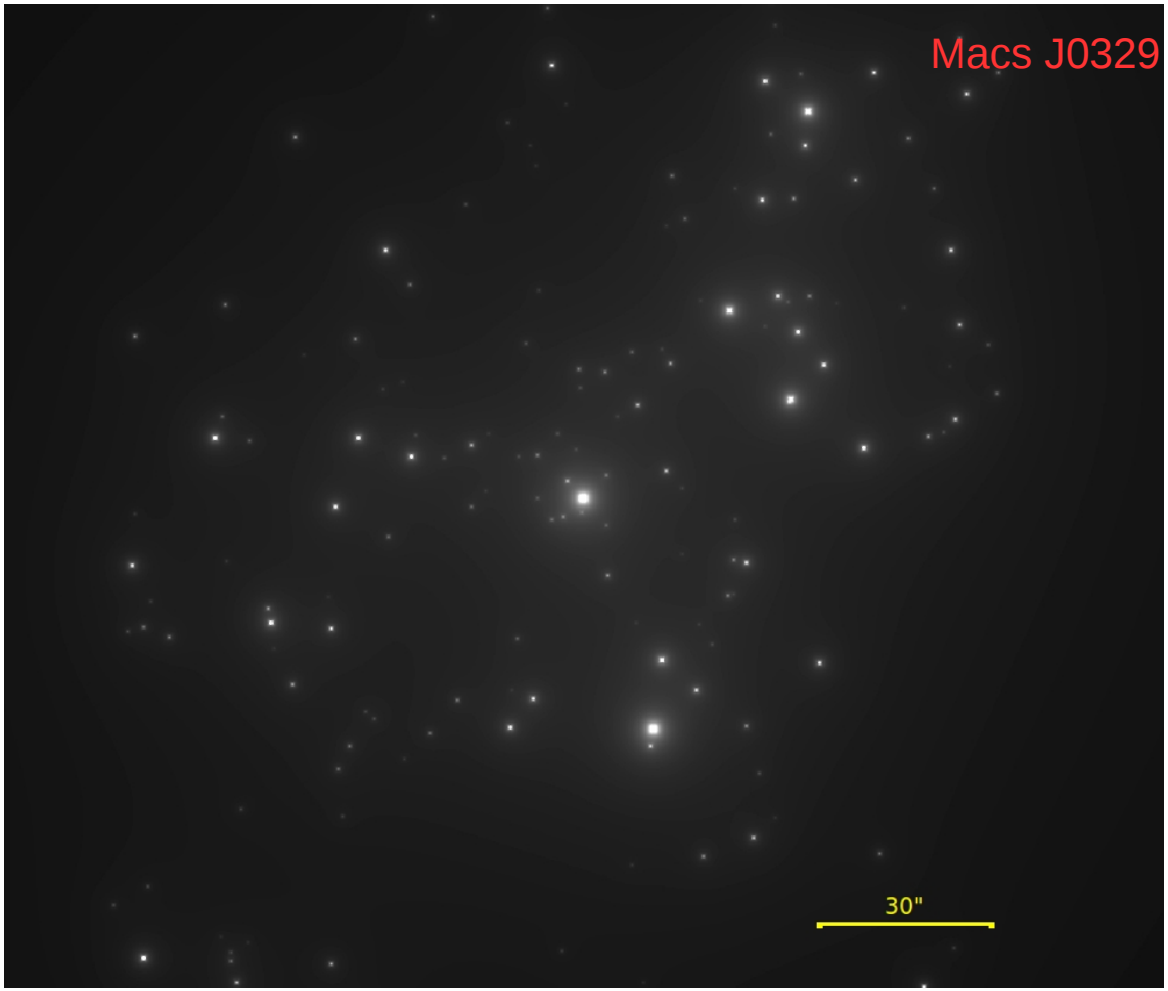
Easycritic: Light-traces-mass

- Total deflection field of the galaxy component

  → Linear combination of each galaxy contribution

$$\boldsymbol{\alpha}_{\rm gal}(\boldsymbol{\theta}) = K_q \sum_i F_i \, |\boldsymbol{\theta} - \boldsymbol{\theta}_i|^{1-q} \, \frac{\boldsymbol{\theta} - \boldsymbol{\theta}_i}{|\boldsymbol{\theta} - \boldsymbol{\theta}_i|}$$

- Convergence map → DM comp.



Searching for giant arcs in the sky

Easycritic: Light-traces-mass

- Smooth DM component

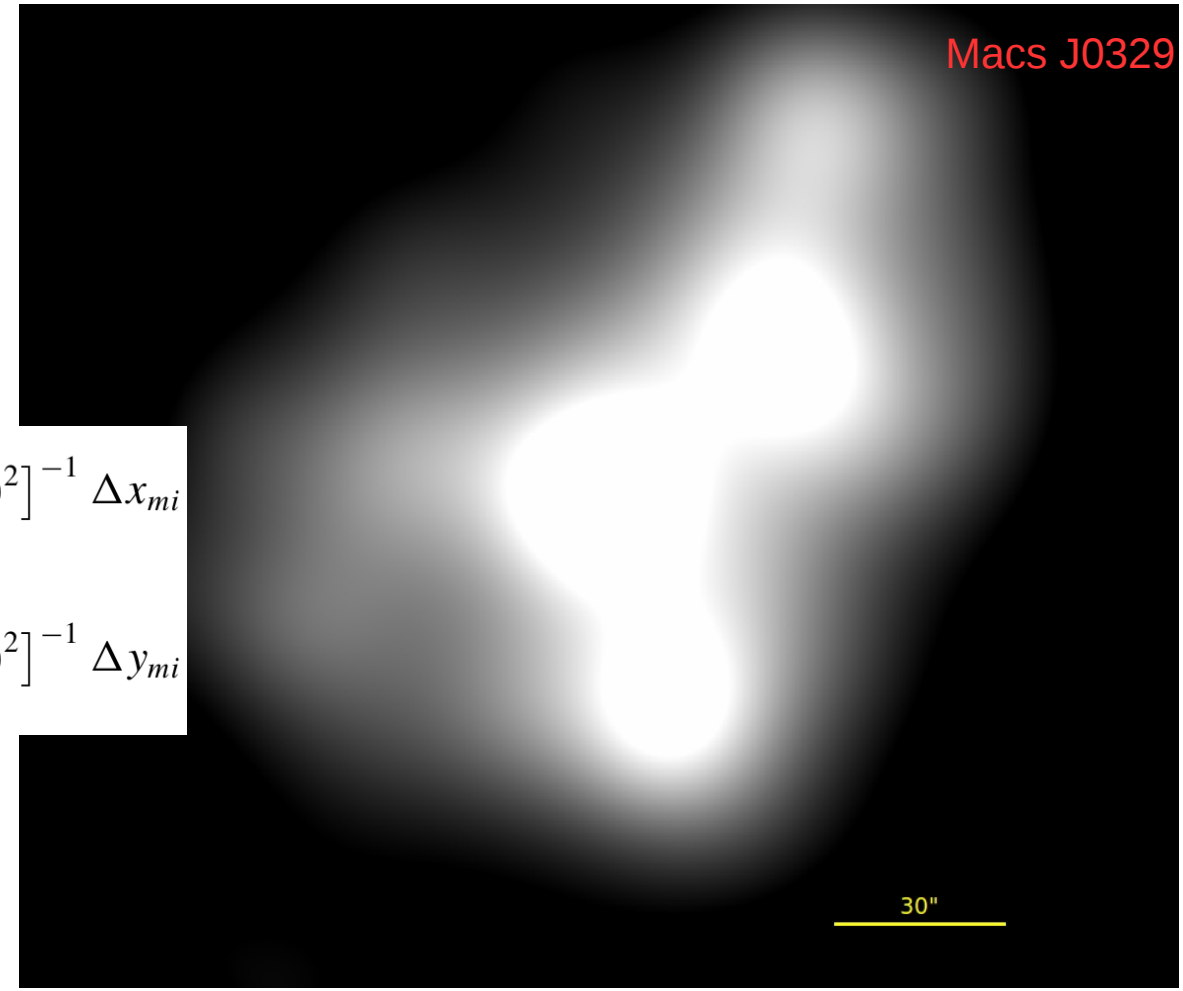
→ Gaussian convolution function

σ ~ 15"

- Total deflection field of the DM component is the linear combination of all pixel (Pi) contribution from the smooth map.

$$\alpha_{\mathrm{DM},x}(\boldsymbol{\theta}_m) = K_q \sum_i P_i \left[(\Delta x_{mi})^2 + (\Delta y_{mi})^2\right]^{-1} \Delta x_{mi}$$

$$\alpha_{\mathrm{DM},y}(\boldsymbol{\theta}_m) = K_q \sum_i P_i \left[(\Delta x_{mi})^2 + (\Delta y_{mi})^2\right]^{-1} \Delta y_{mi}$$

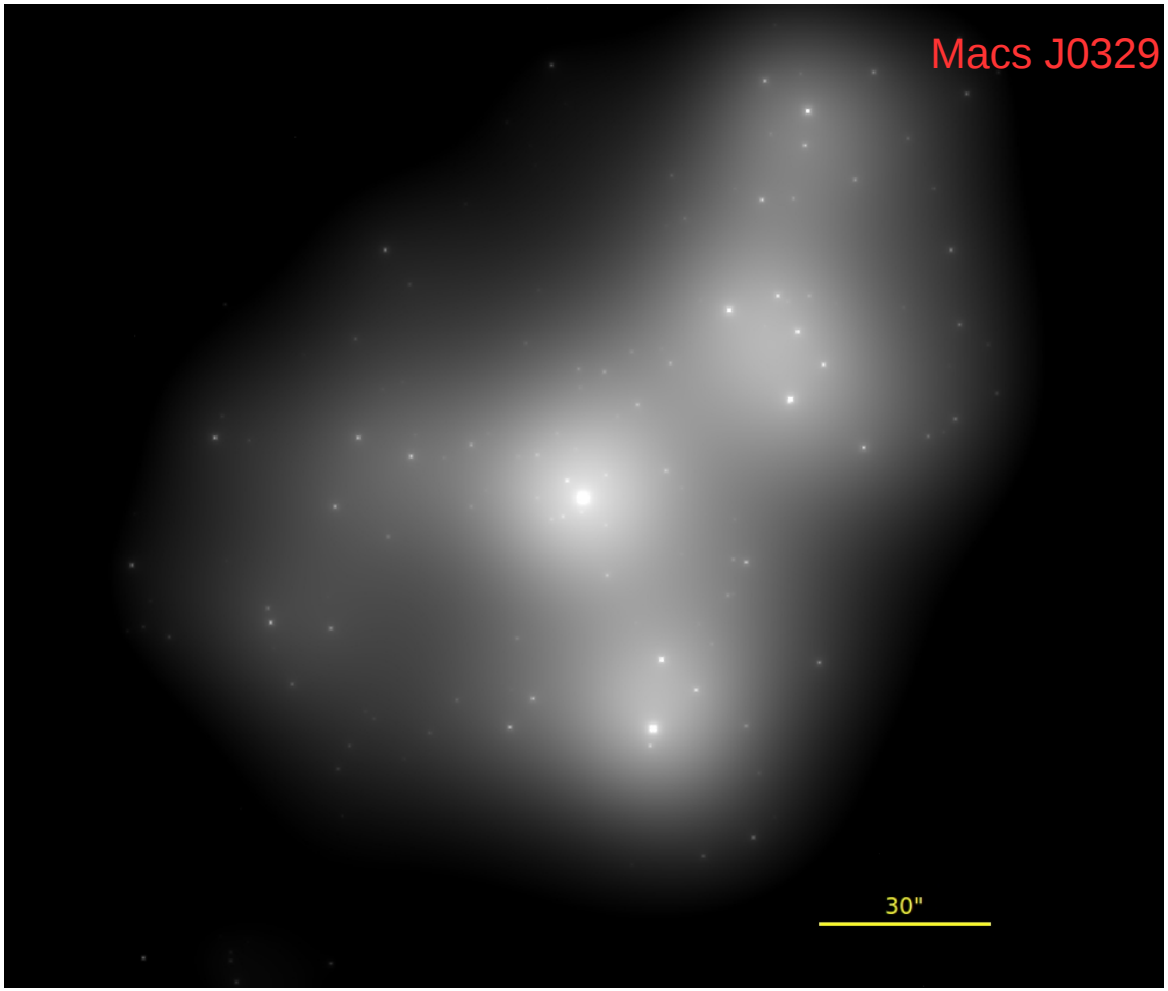


Searching for giant arcs in the sky

Easycritic: Light-traces-mass

- Total deflection field of the SL cluster

$$\boldsymbol{\alpha}_{\mathrm{T}}(\boldsymbol{\theta}) = K_{\mathrm{gal}}\boldsymbol{\alpha}_{\mathrm{gal}}(\boldsymbol{\theta}) + (1 - K_{\mathrm{gal}})\boldsymbol{\alpha}_{\mathrm{DM}}(\boldsymbol{\theta})$$



Searching for giant arcs in the sky

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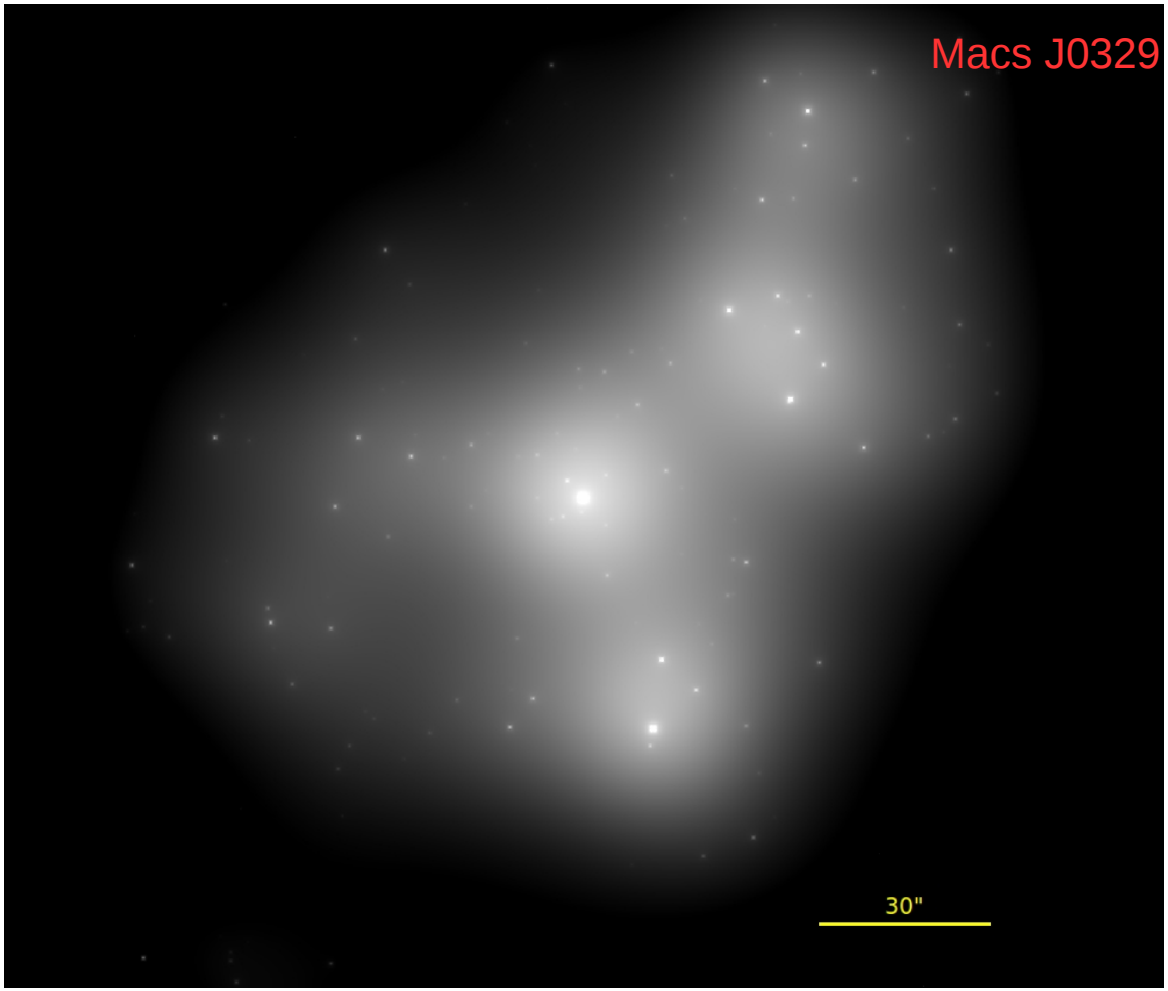
$$\boldsymbol{\alpha}_{\rm T}(\boldsymbol{\theta}) = K_{\rm gal}\boldsymbol{\alpha}_{\rm gal}(\boldsymbol{\theta}) + (1 - K_{\rm gal})\boldsymbol{\alpha}_{\rm DM}(\boldsymbol{\theta})$$

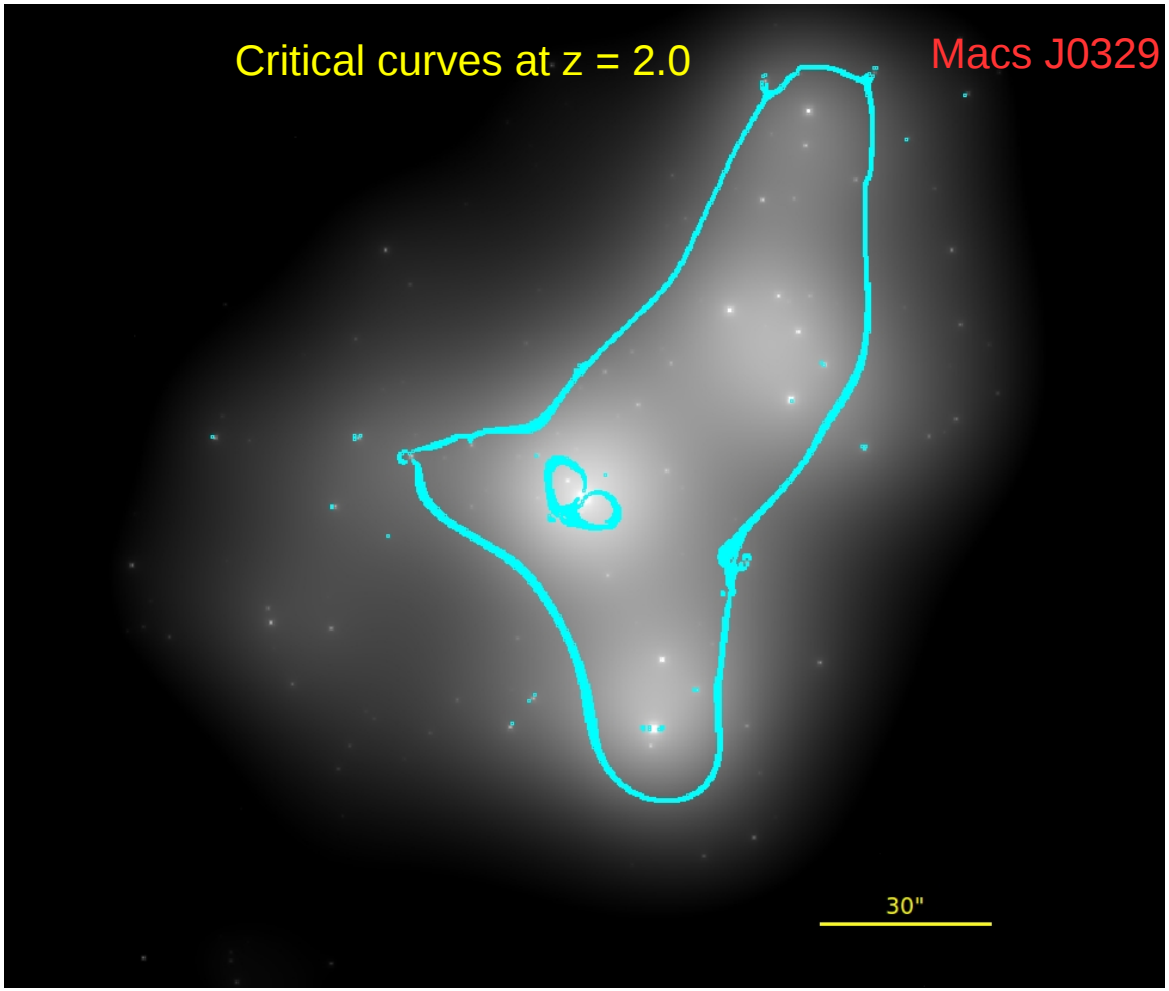
- Only 4 parameters:
  - q
  - K_q
  - σ
  - K_{gal}



Searching for giant arcs in the sky

Easycritic: Light-traces-mass

- Magnification map → critical points



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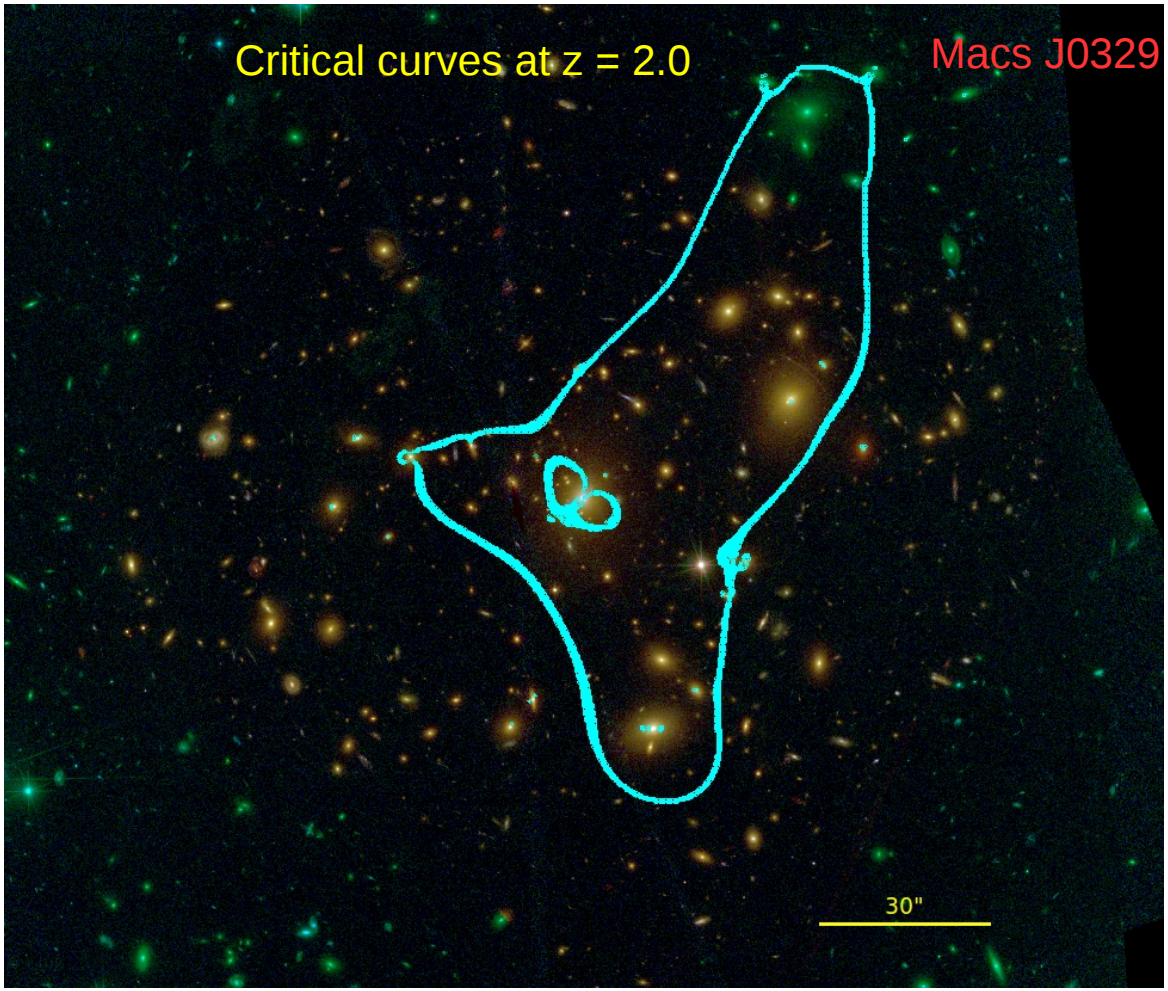
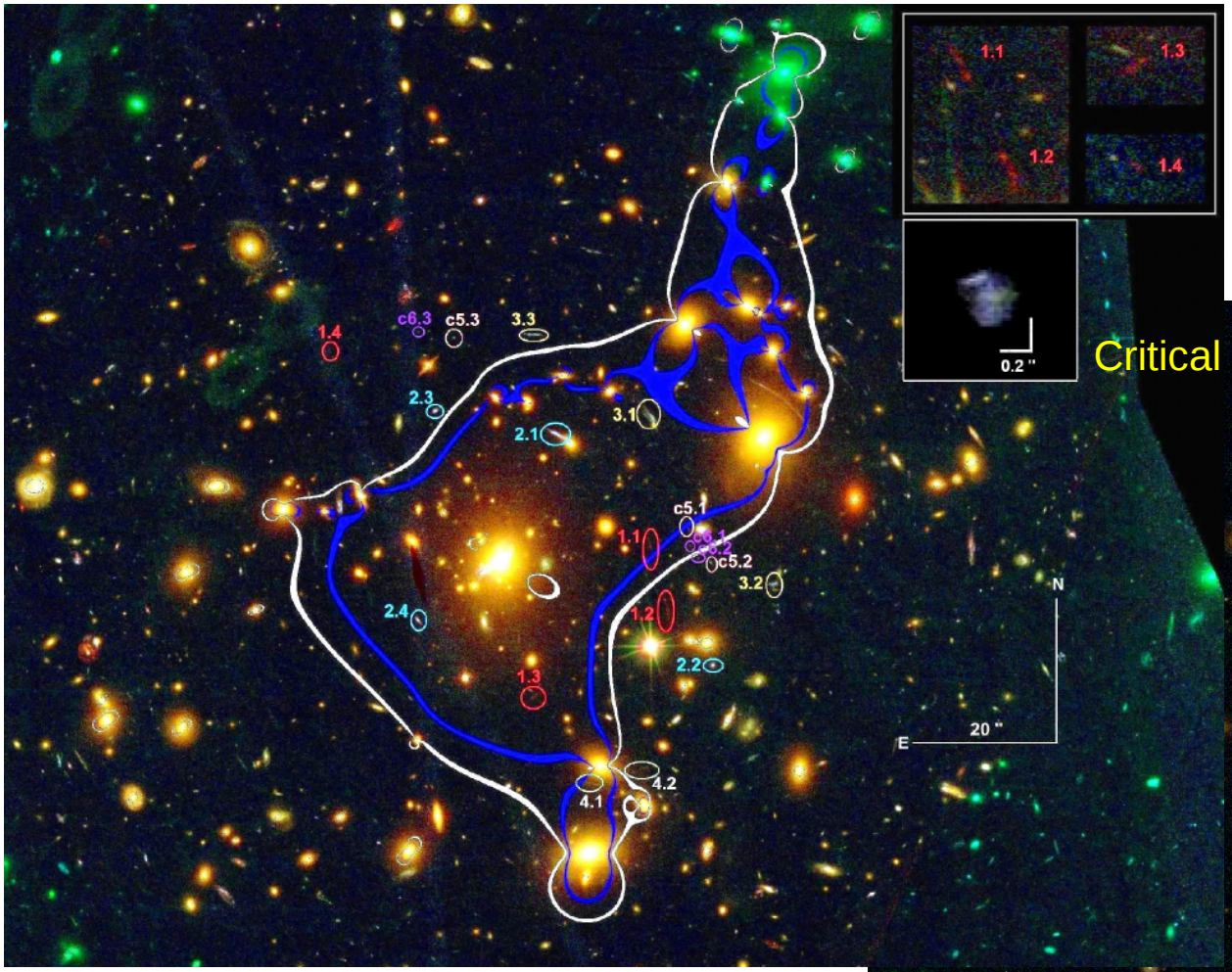
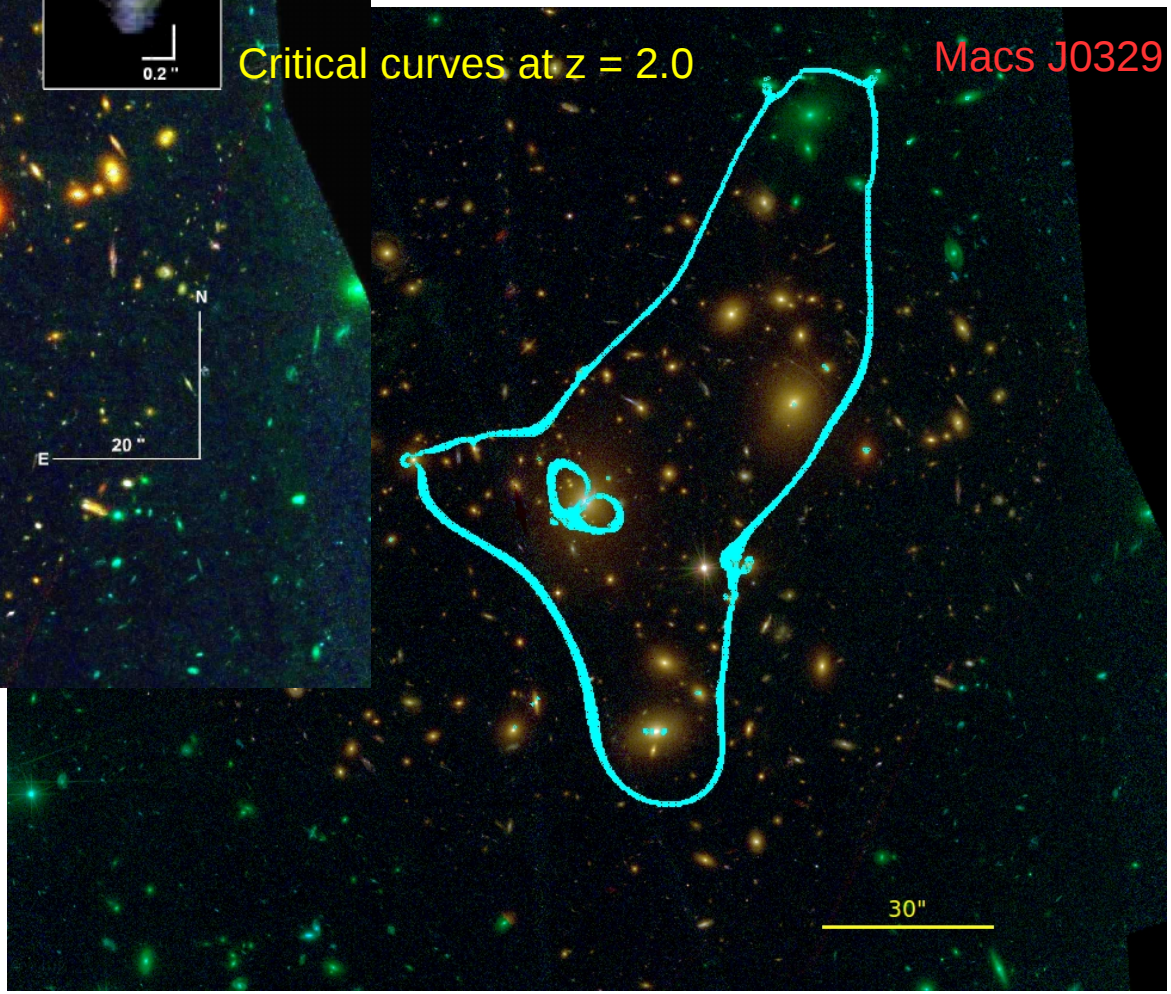


Searching for giant arcs in the sky

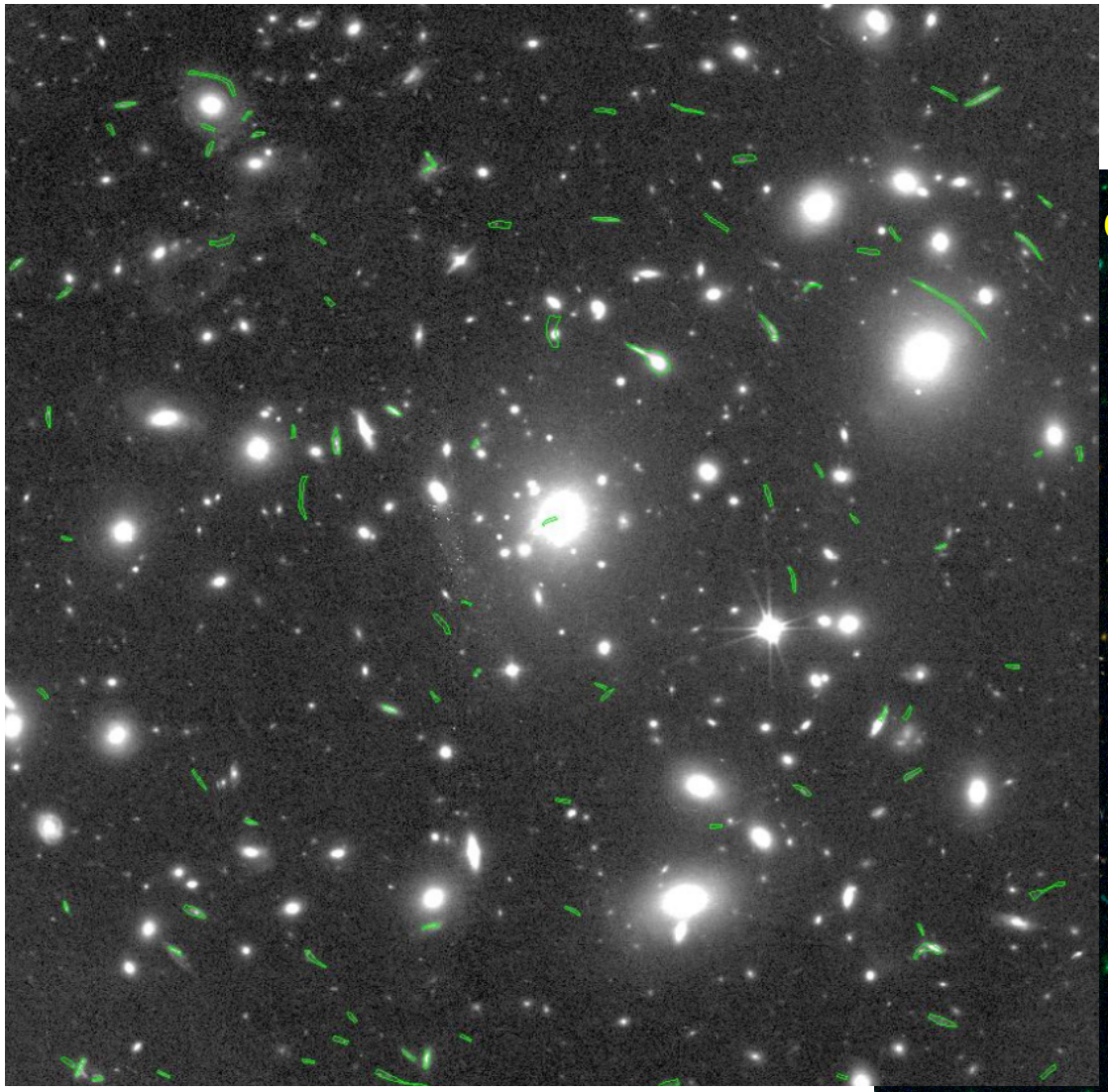


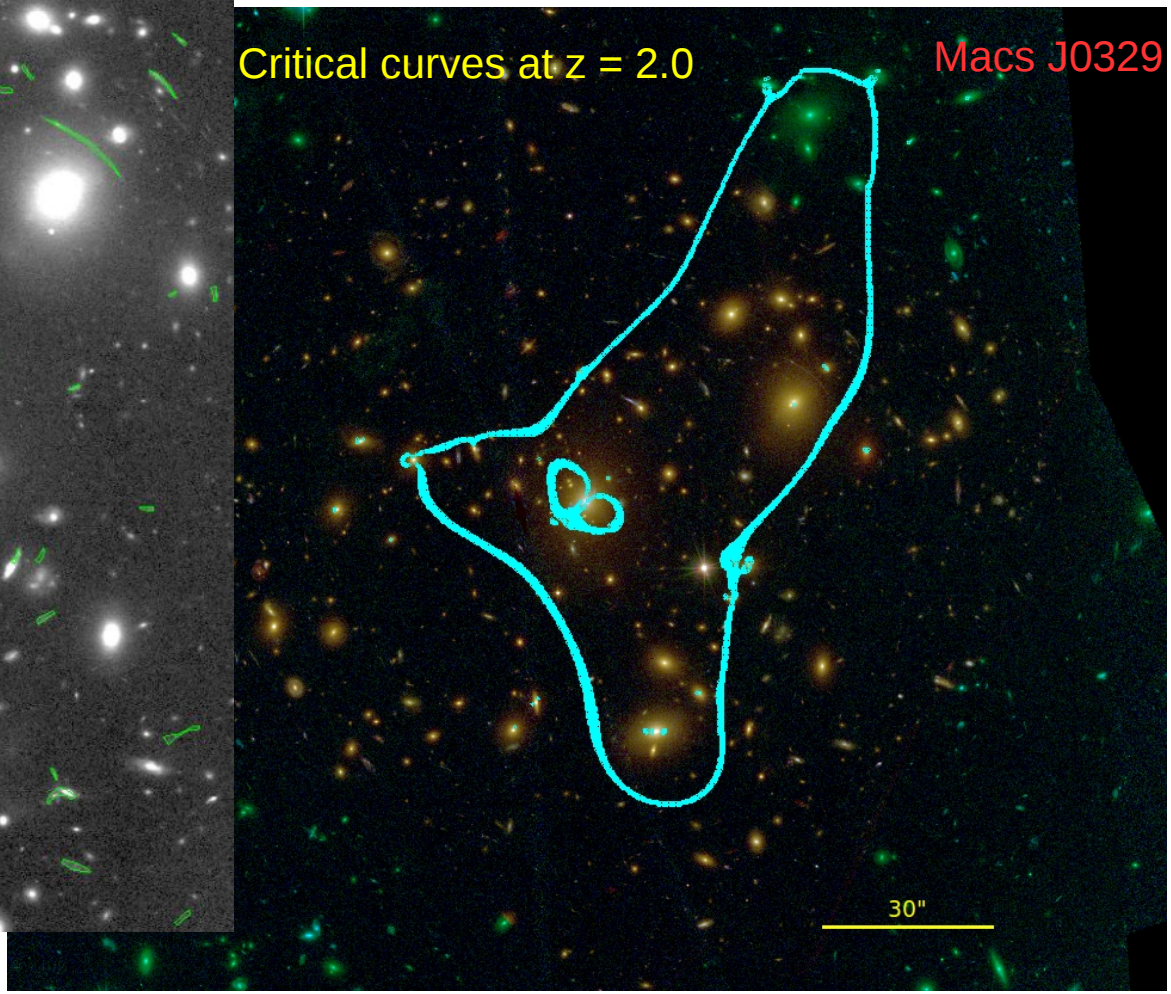


"Real" critical curves at z = 2.0 (blue) from Zitrin et al. (2012)

Searching for giant arcs in the sky

Easycritic + Arc-finder + multi-colour filtering

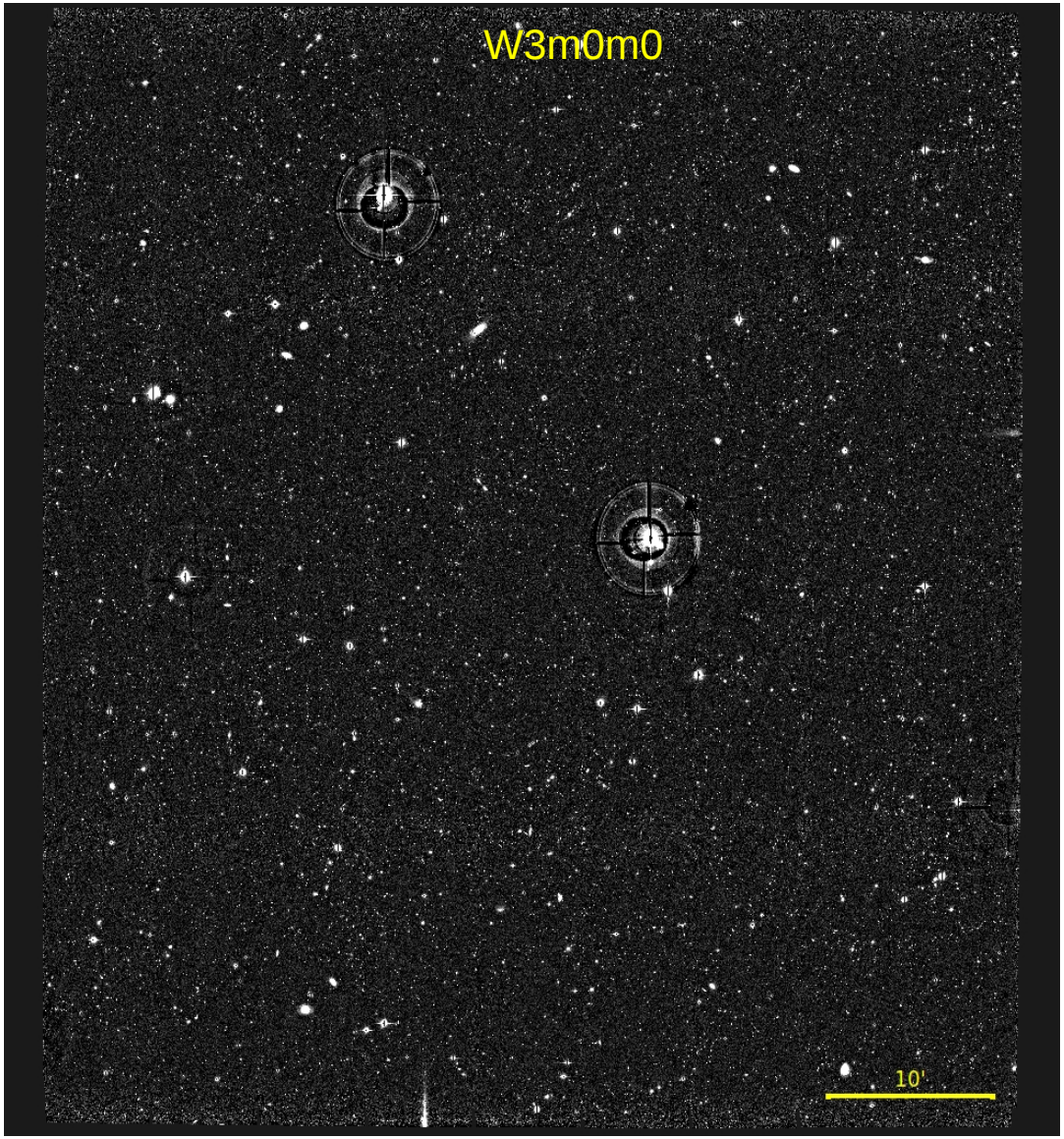




Searching for giant arcs in the sky

CFHT Lensing Survey: CFHTLenS

- ~ 154 sq degrees multi-colour optical survey in *ugriz* filter system
- High resolution imaging with 17 resolved galaxies per sq arcmin
- Deep multi-colour data with a median redshift of 0.75
- 5-σ limiting magnitudes → r' = 24.88
- Accurate photometry resulting in a photometric redshift scatter of 0.04x(1+z)



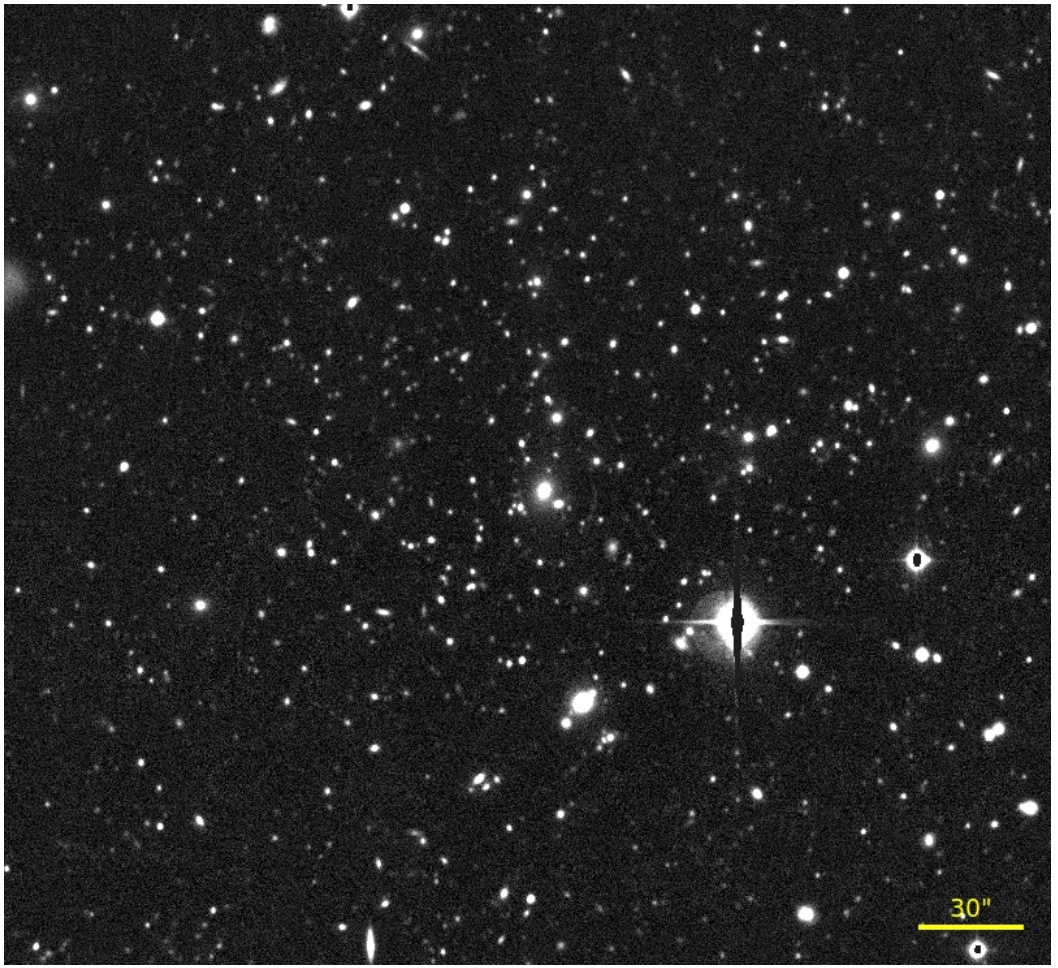
Searching for giant arcs in the sky

Easycritic → CFHTLenS

- All elliptical galaxies from
  - → $0.1 < z_{phot} < 1.0$
- Redshift slices
  - → $\Delta z = 2 \times 0.04 \times (1+z)$

Phot. z error

- Step function → DM comp
- Weight the deflection fields of each redshift slice by
  - → $D(z_{slice}, z_{source})/D(z_{source})$
  - → $z_{source} = 2.0$



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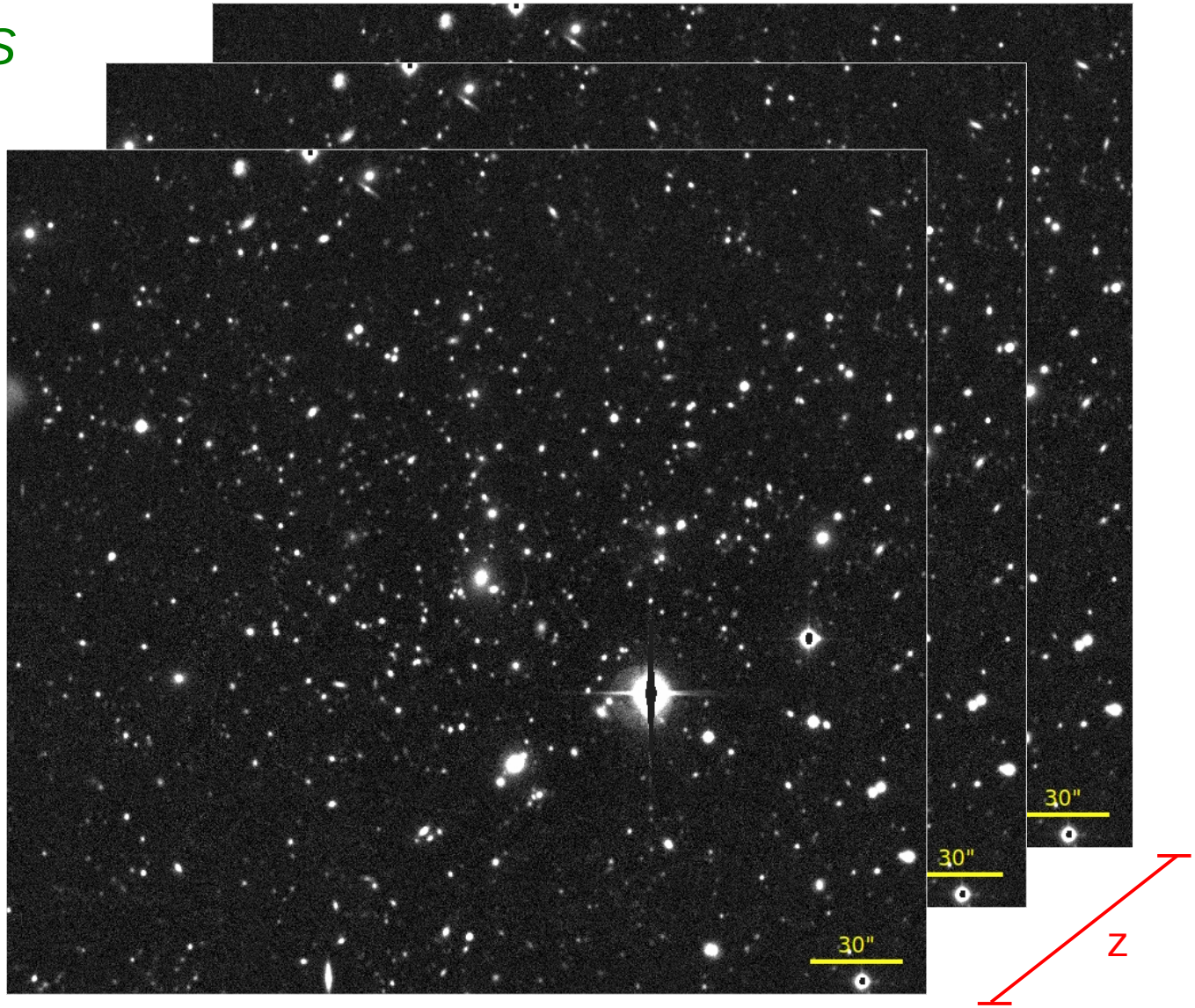
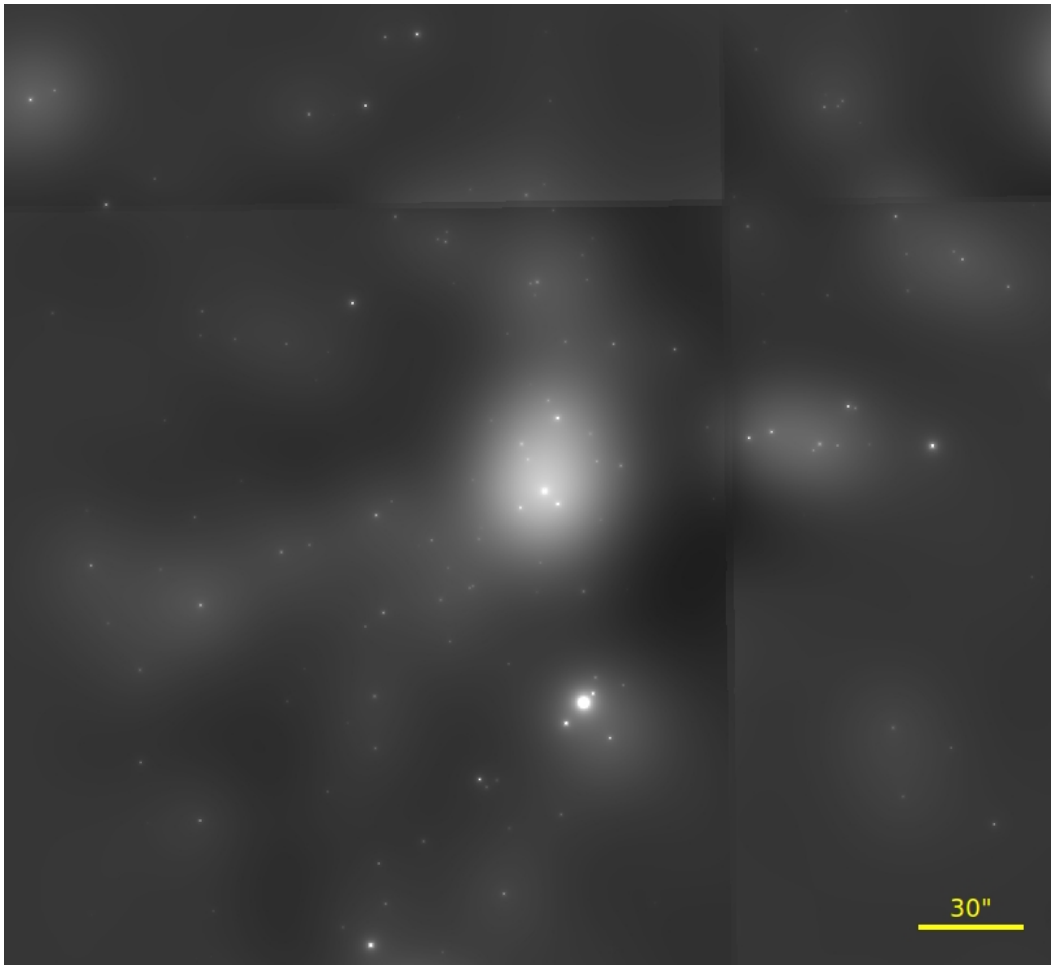


Searching for giant arcs in the sky

Easycritic → CFHTLenS

- Total reconstructed convergence map for all redshift slices at z_{source} = 2.0

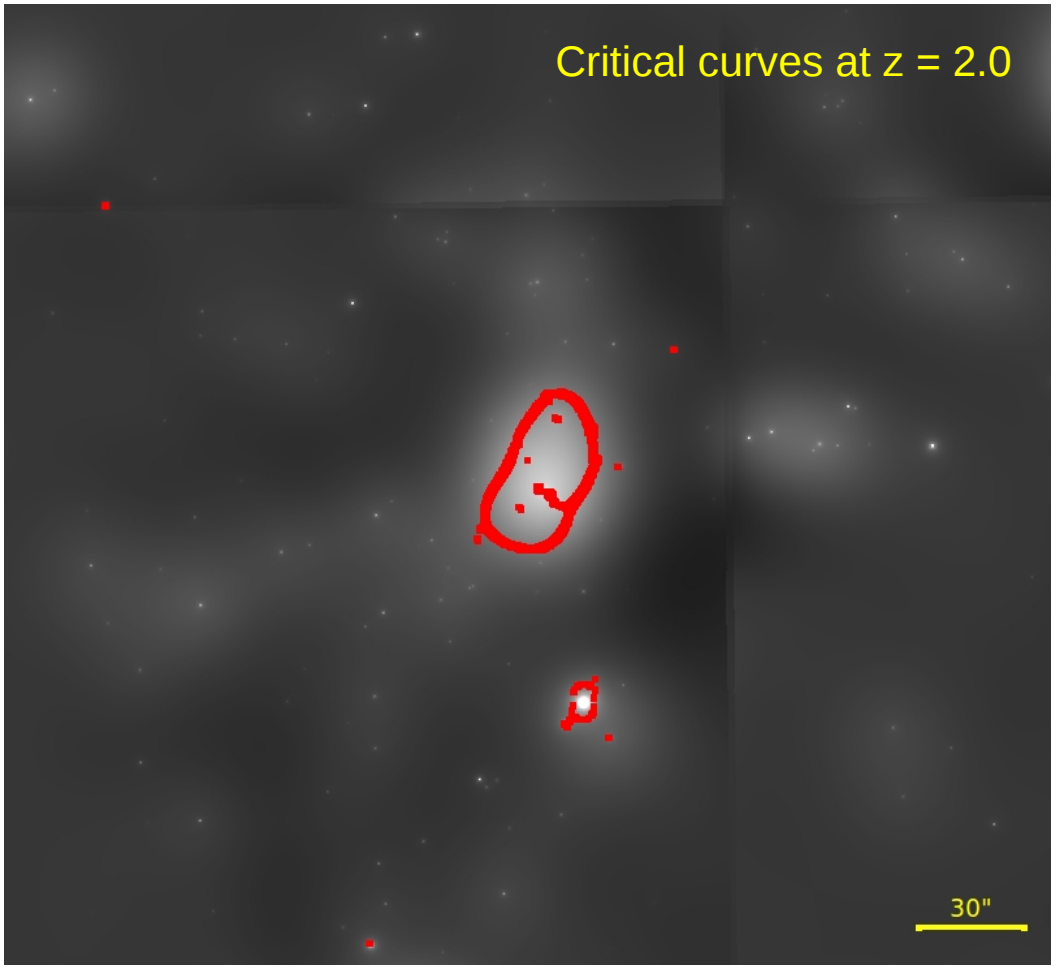


Searching for giant arcs in the sky

Easycritic → CFHTLenS

- Total reconstructed convergence map for all redshift slices at z_{source} = 2.0

- Critical points derived from the magnification maps



Searching for giant arcs in the sky

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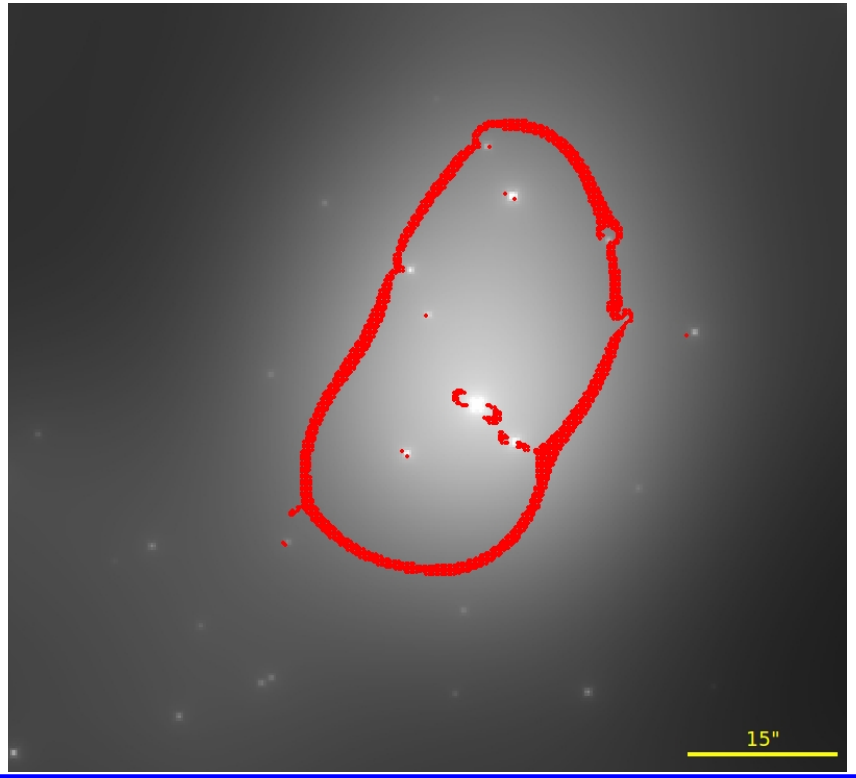

Searching for giant arcs in the sky

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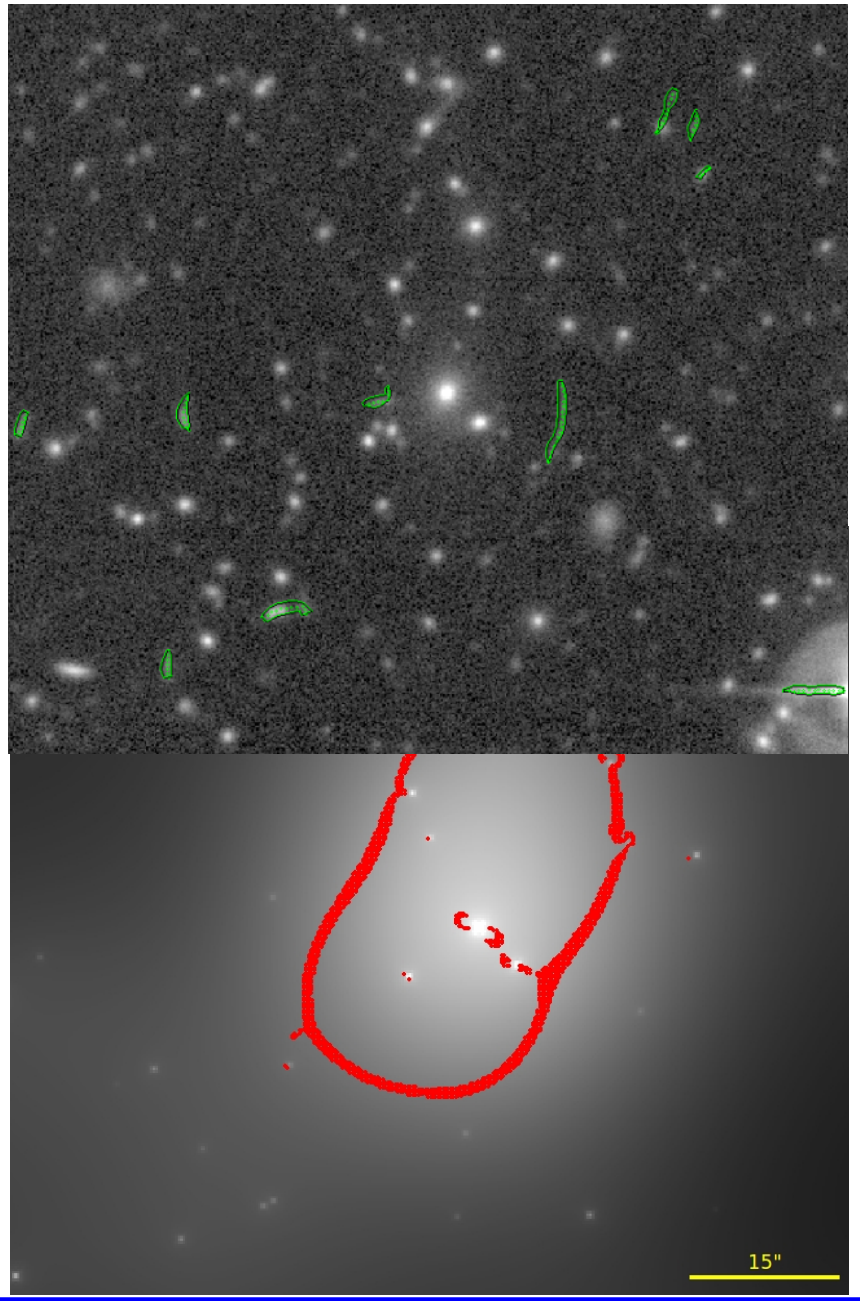

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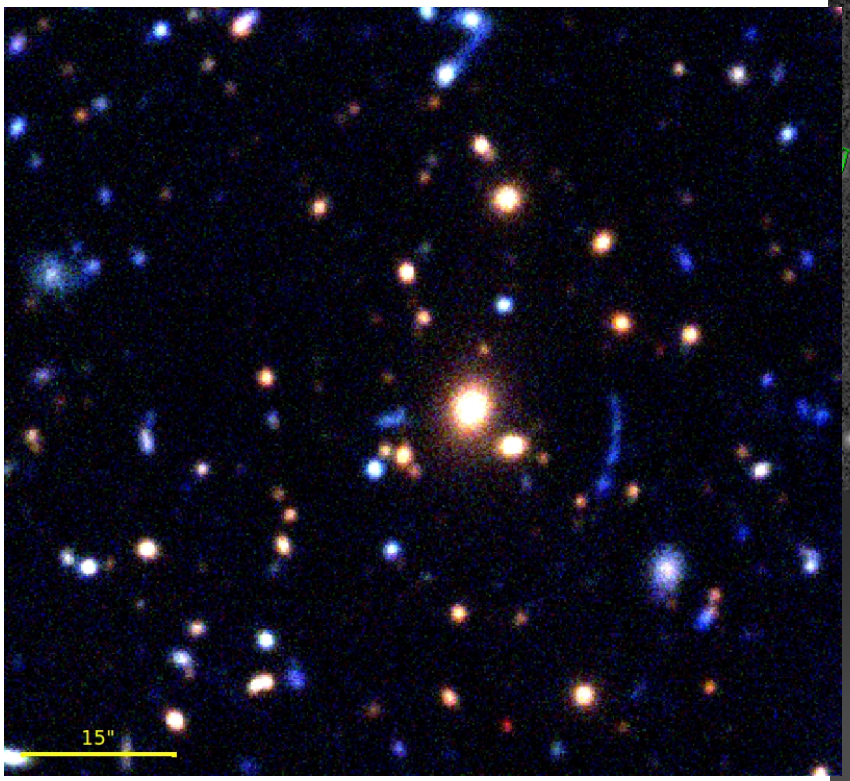

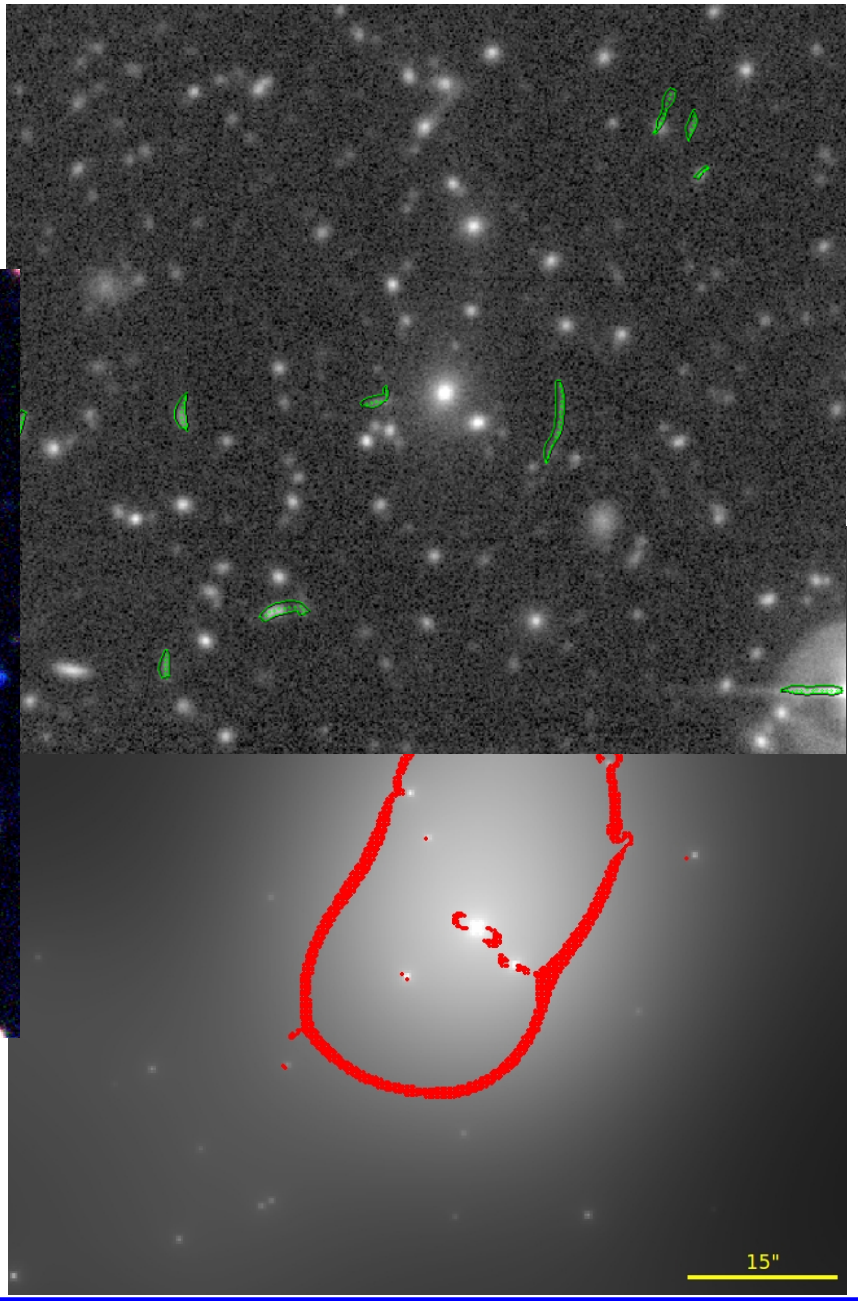

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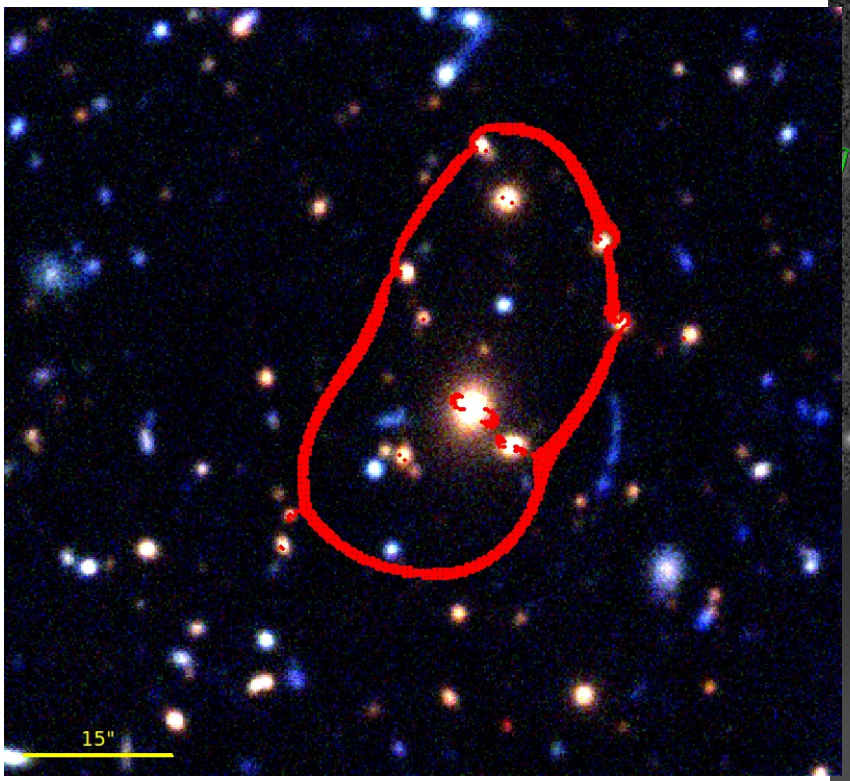
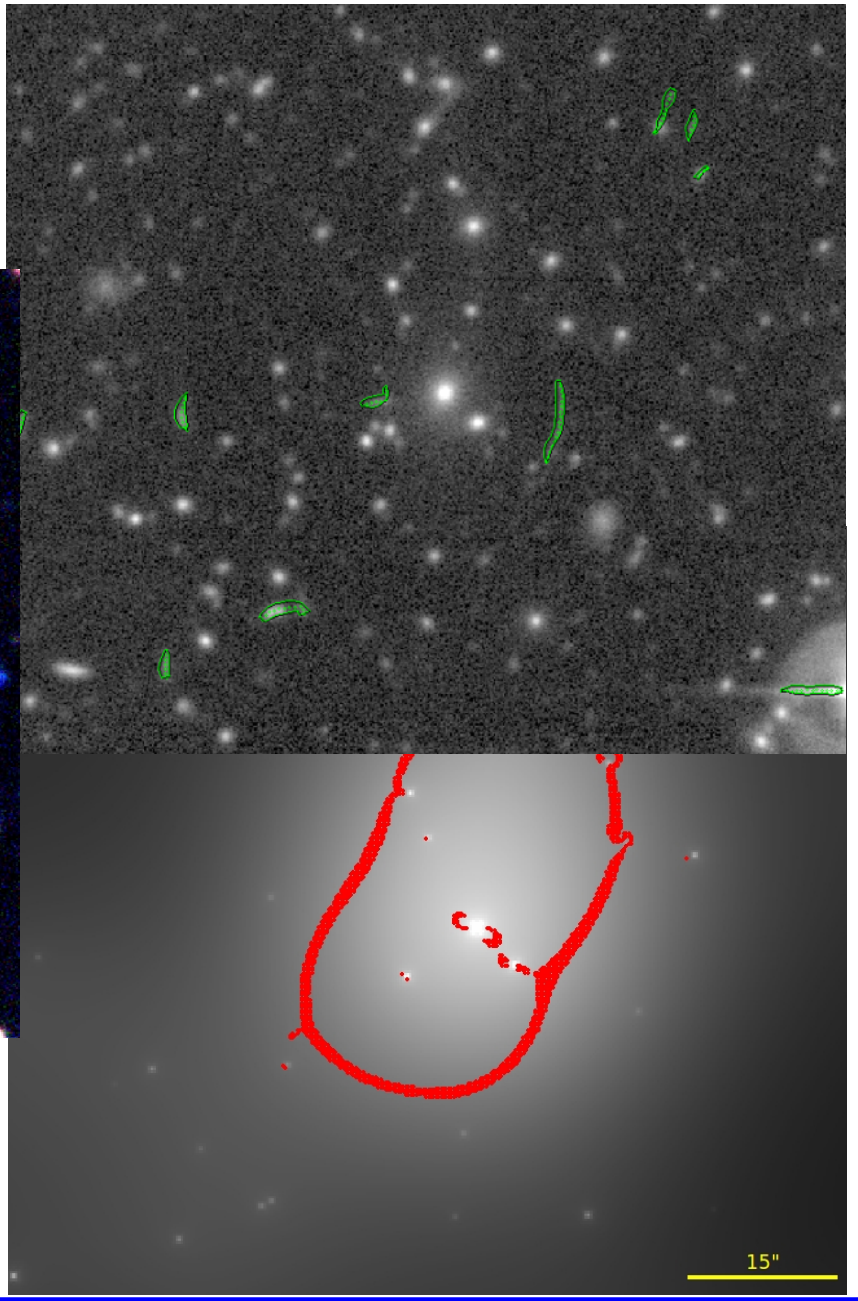




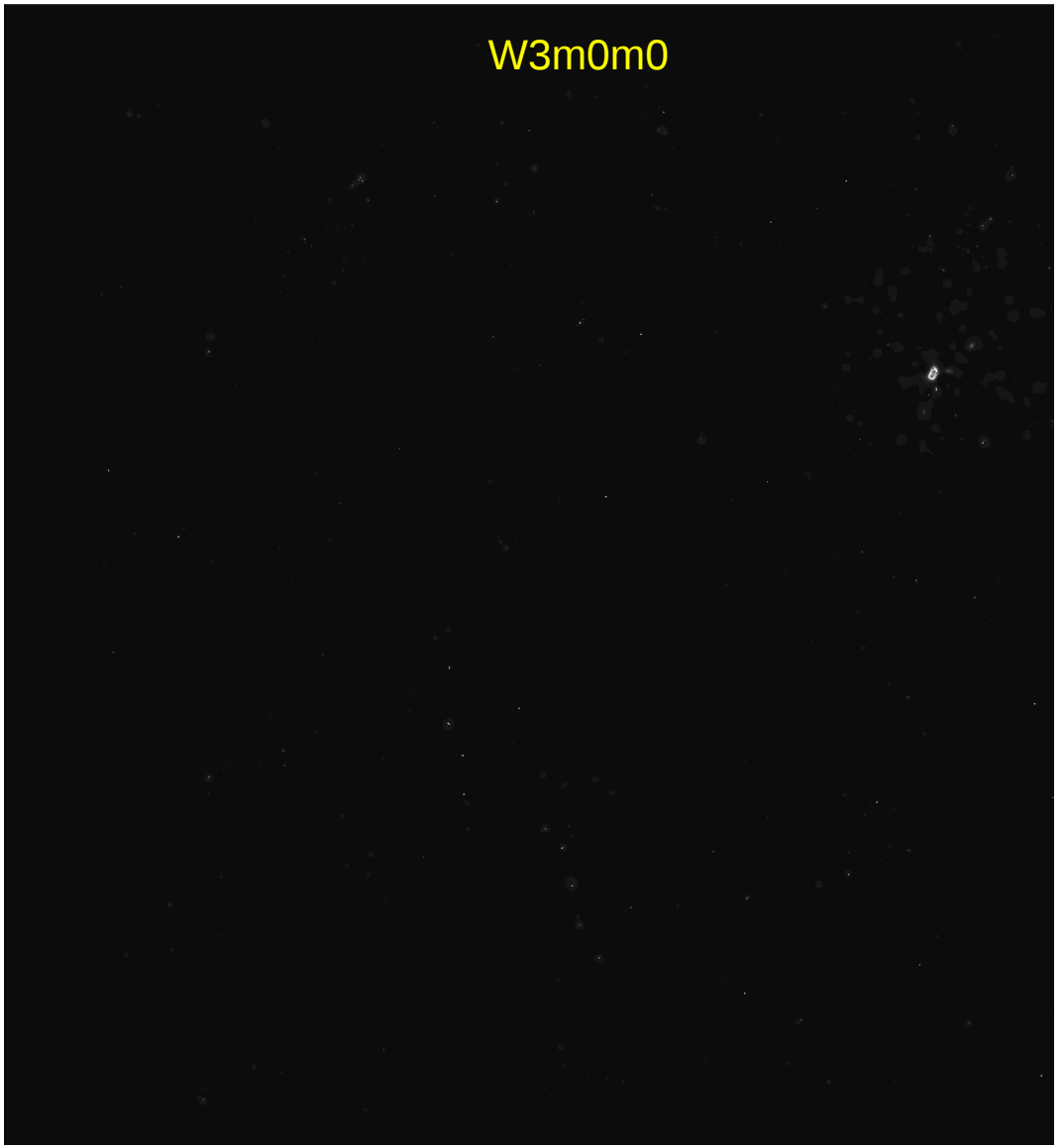
Searching for giant arcs in the sky

Easycritic → CFHTLenS

- 1 core computer ~ 3.5 days in 1 sq degree

  → 50 cores ~ 1.5 weeks all CFHTLenS

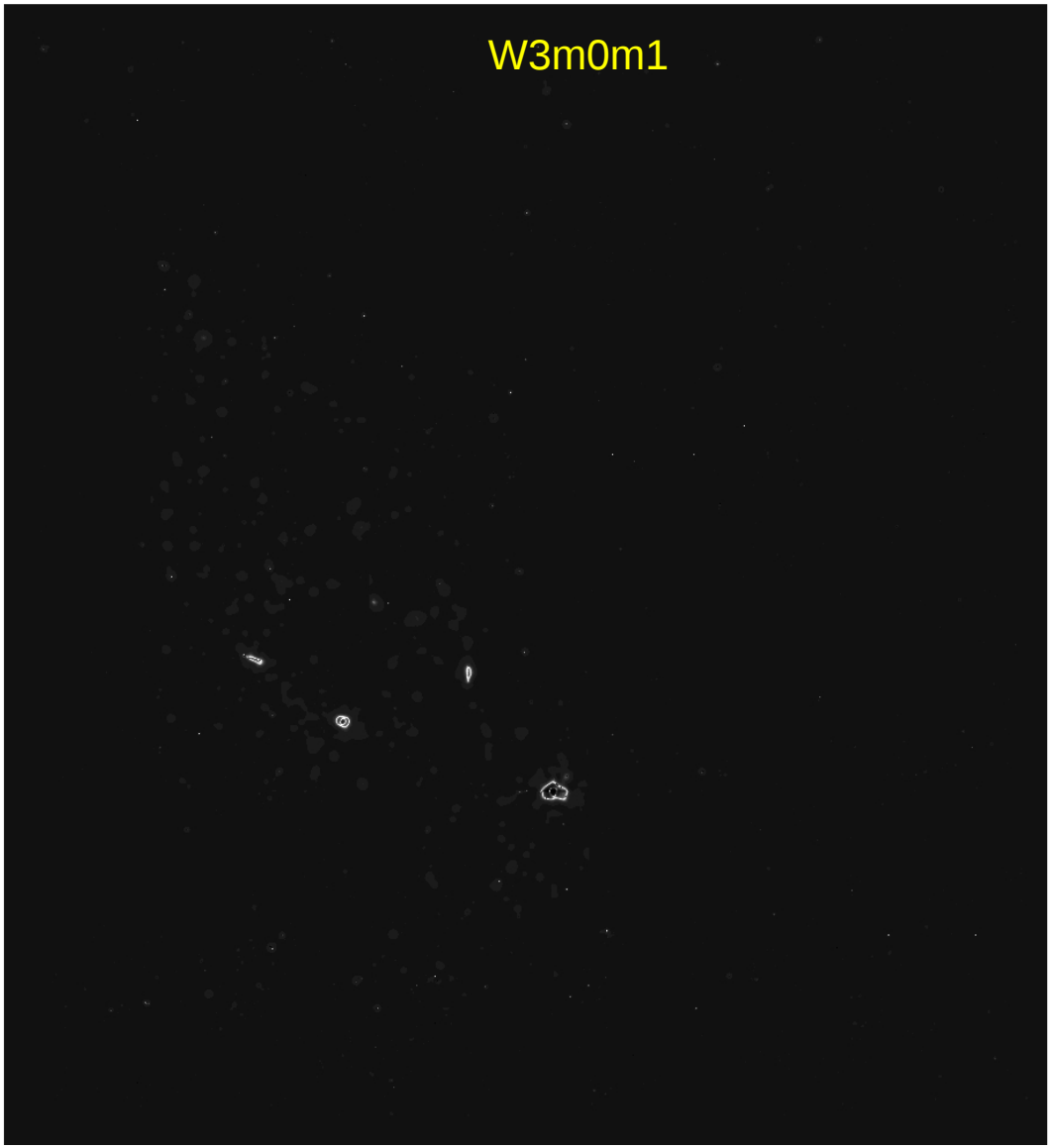
- No false positvies:
  - 1 SL region → 1 known SL cluster



Searching for giant arcs in the sky

Easycritic → CFHTLenS

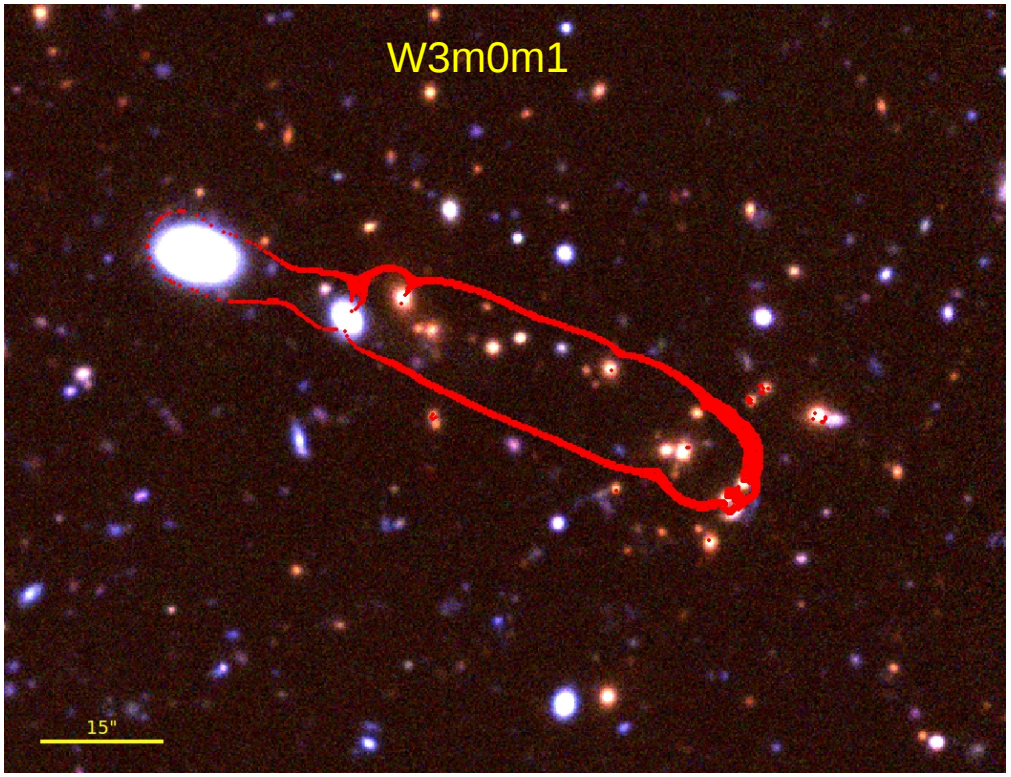
- No false positvies:
  - 2 SL regions → 2 known SL clusters
  - 2 candidates → 2 galaxy (groups) clusters

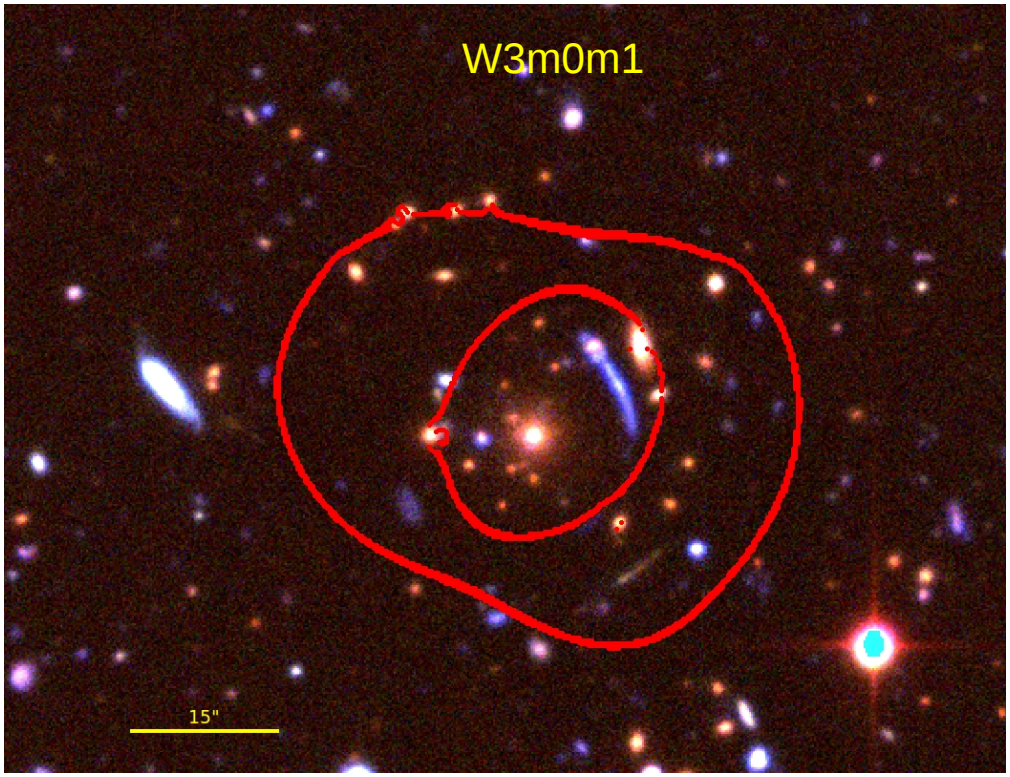


Searching for giant arcs in the sky

Easycritic → CFHTLenS

- Known SL galaxy clusters

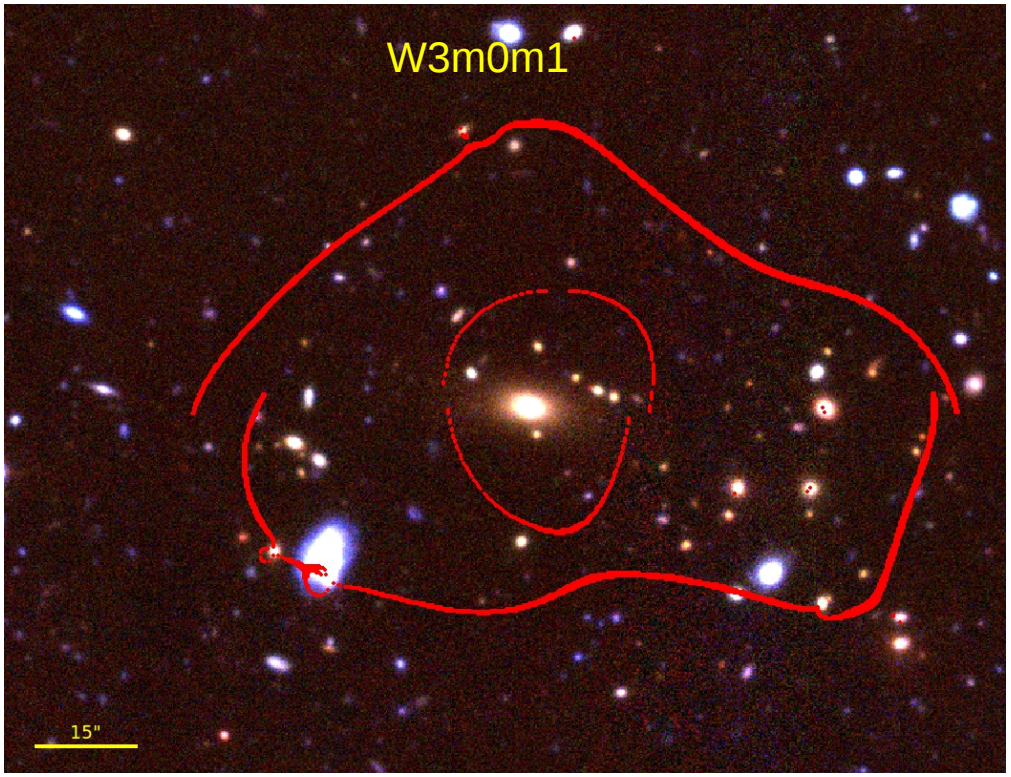


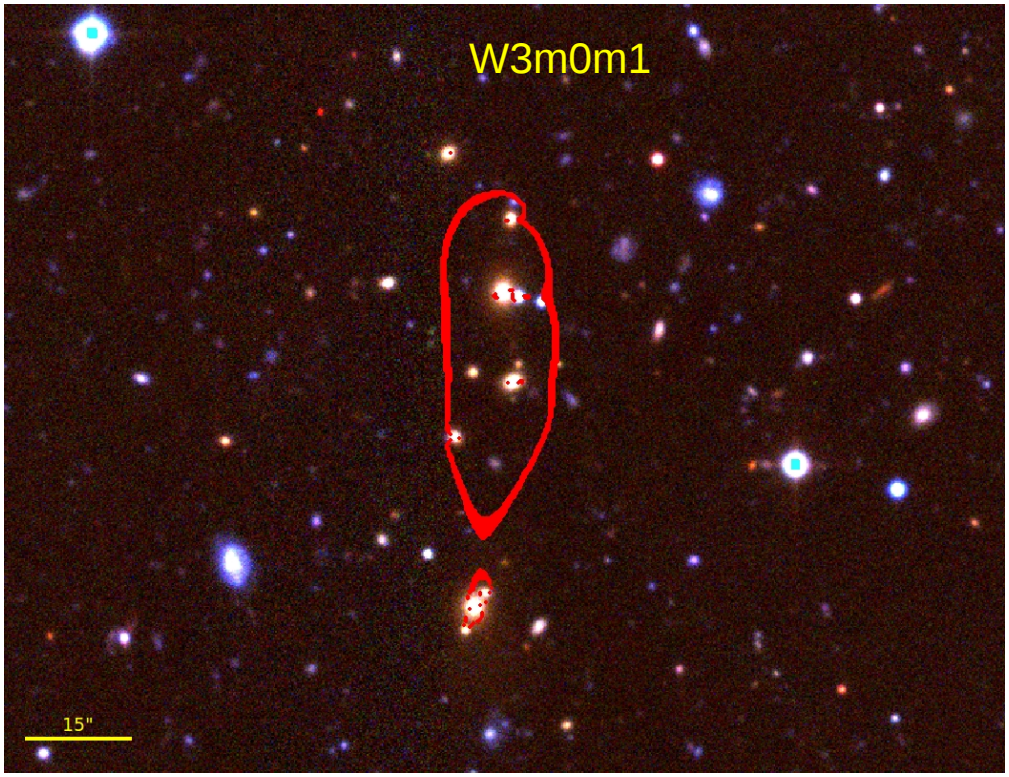


Searching for giant arcs in the sky

Easycritic → CFHTLenS

- Candidates for SL regions





Searching for giant arcs in the sky

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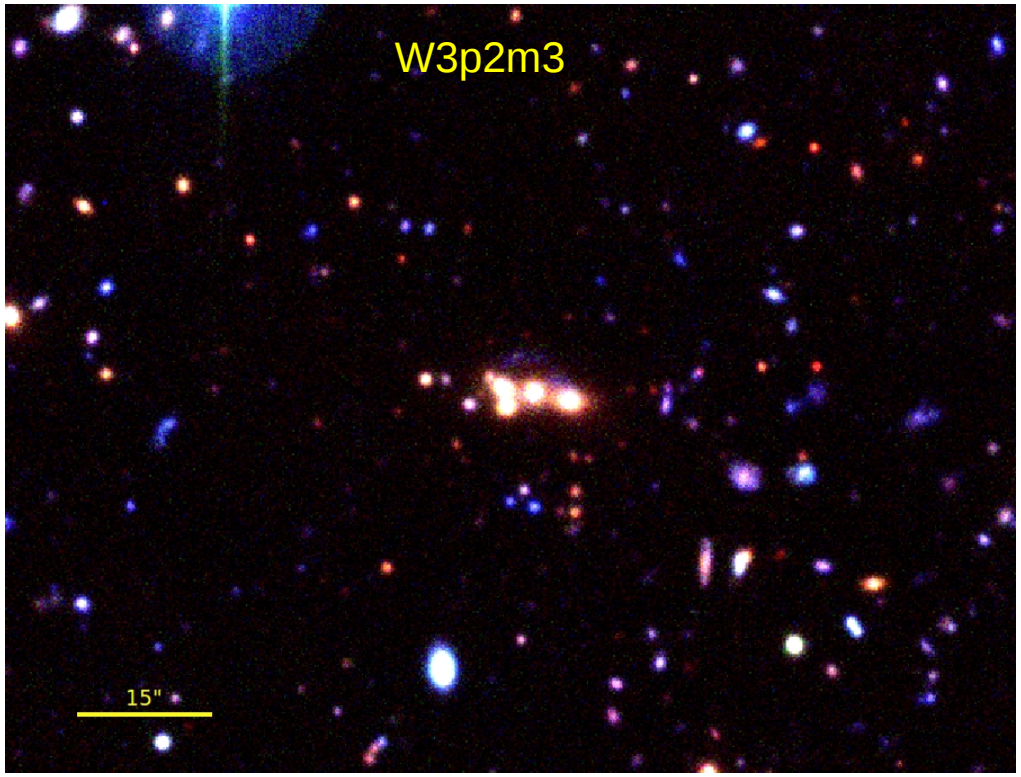

Searching for giant arcs in the sky

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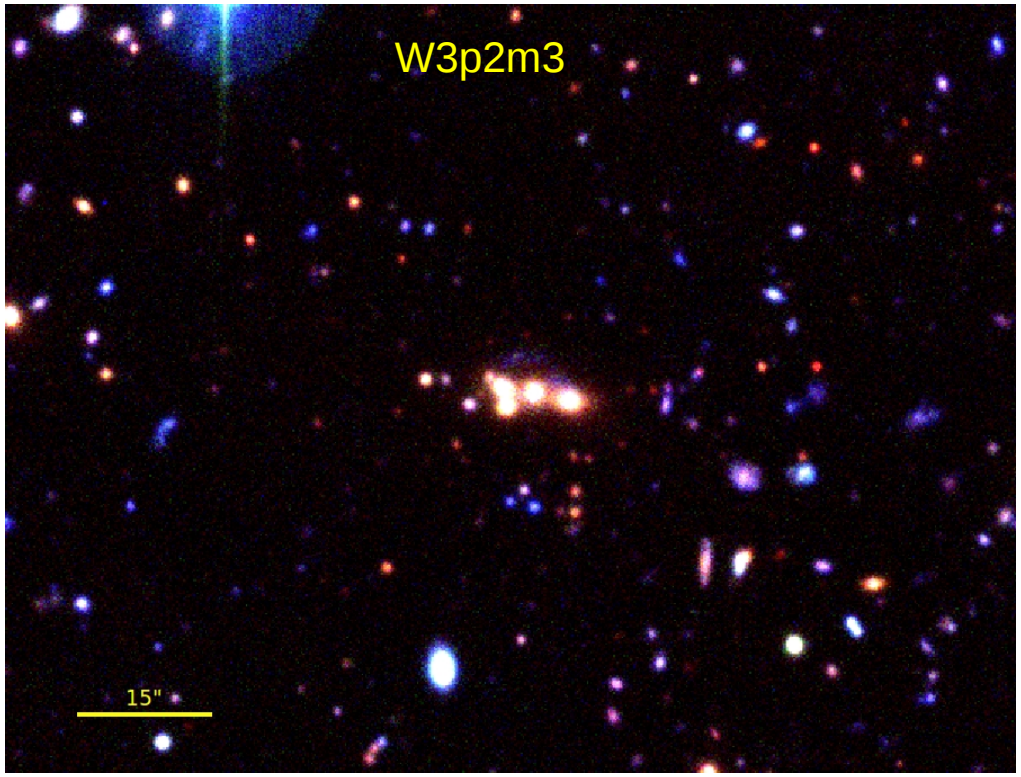

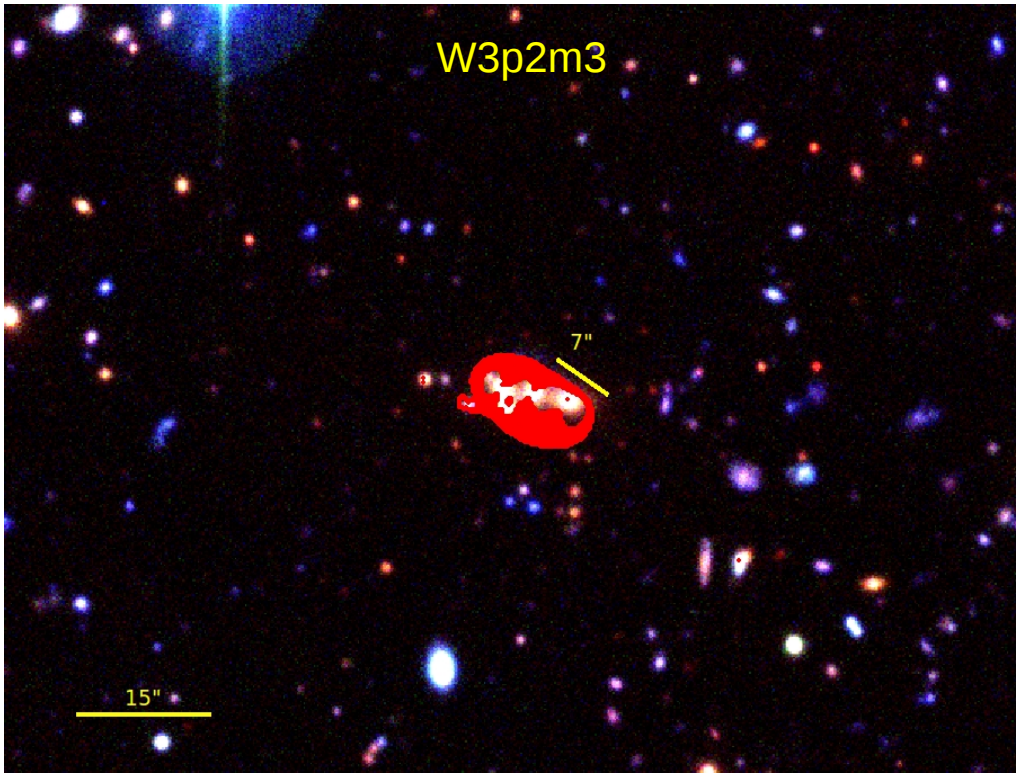

Searching for giant arcs in the sky

Summary and conclusions

- Using the light of all elliptical galaxies between $0.1 < z_{phot} < 1.0$, we construct a initial mass model that is able to predict the SL regions in the sky: *Easycritic*.

- *Easycritic* analyzes 1 square degree in ~ 3.5 days using one core. Parallelization will allow us to analyze the whole CFHTLenS in 1.5 weeks using only 50 cores.

- *Easycritic* have found all known SL galaxy clusters in the analyzed regions.

- Practically no false positives. Extra SL regions belong to galaxy groups or galaxy clusters.

- *Easycritic* is a very important step towards efficient automated searches of giant luminous arcs.