A Glimpse at Strong Gravitational Lensing With The Next Generation of Radio Telescopes

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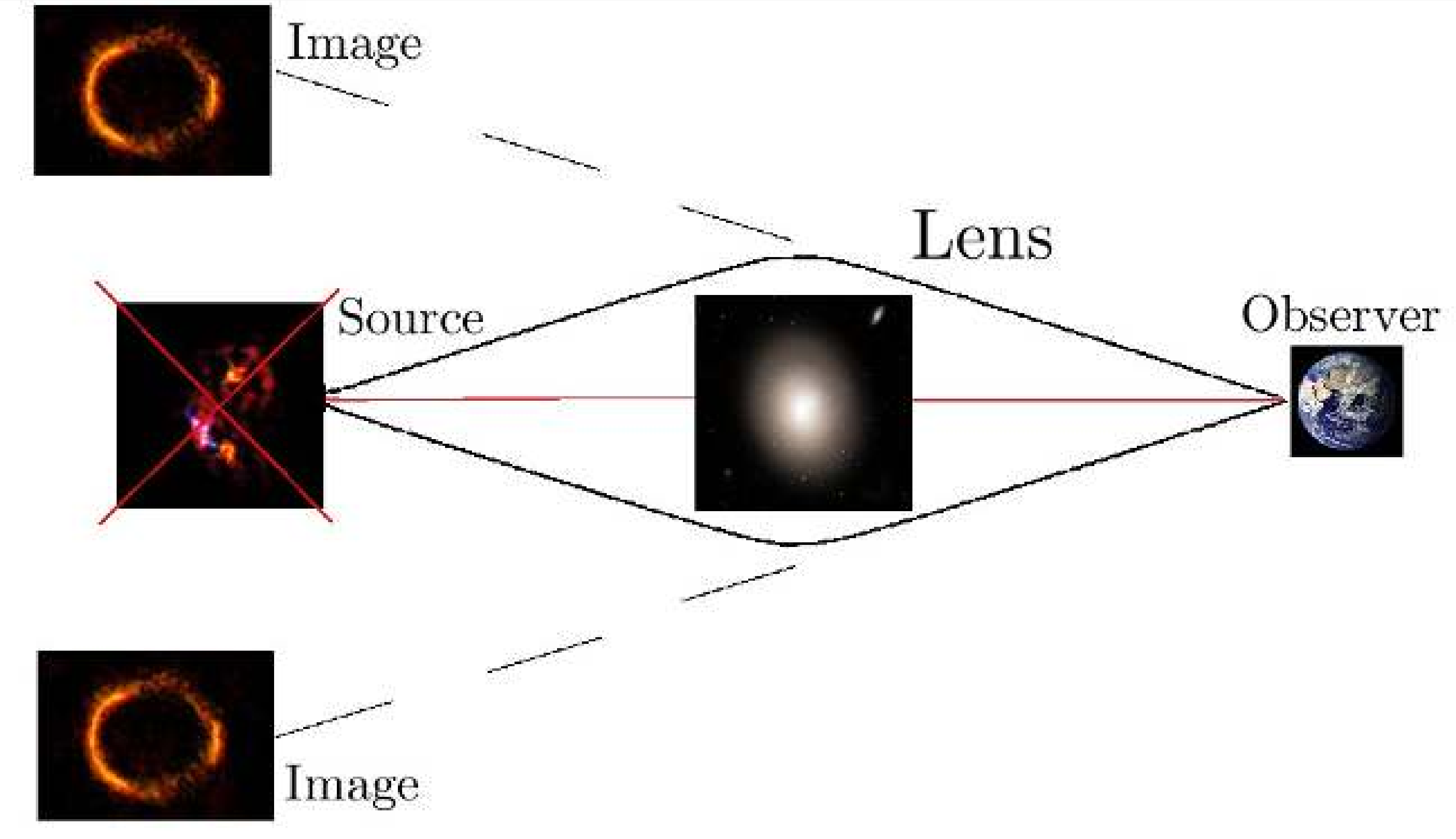
Overview

Strong Lensing



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Strong Lensing So Far

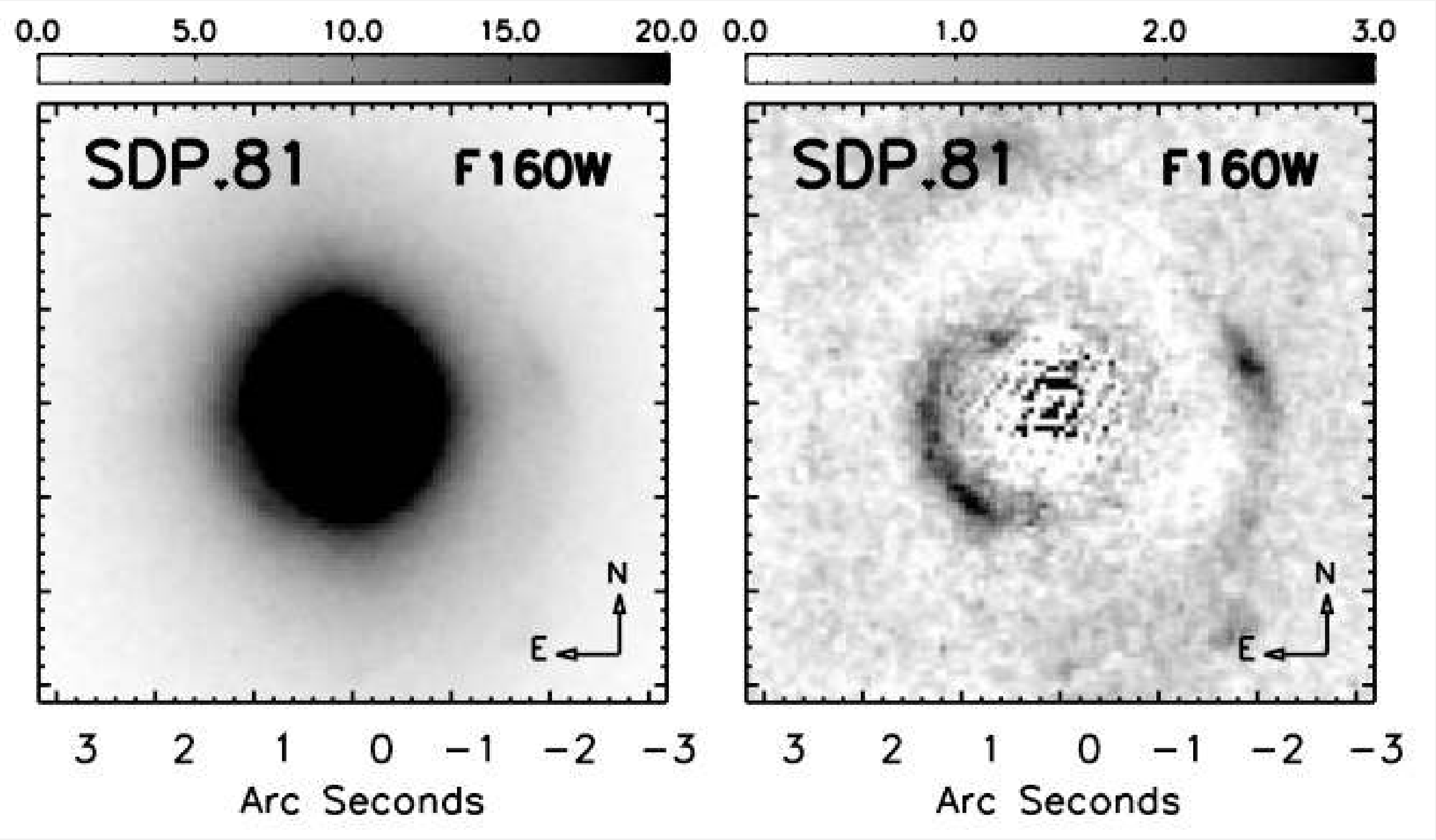
- **UV-Optical Wavelengths (λ = 3700Å – 5100Å)**

  - Currently ~200 lenses with SLACS / SL2S / BELLS

  - Projected 10000+ lenses with LSST / Euclid

  - Problem – Source / Lens blending

Source / Lens Blending



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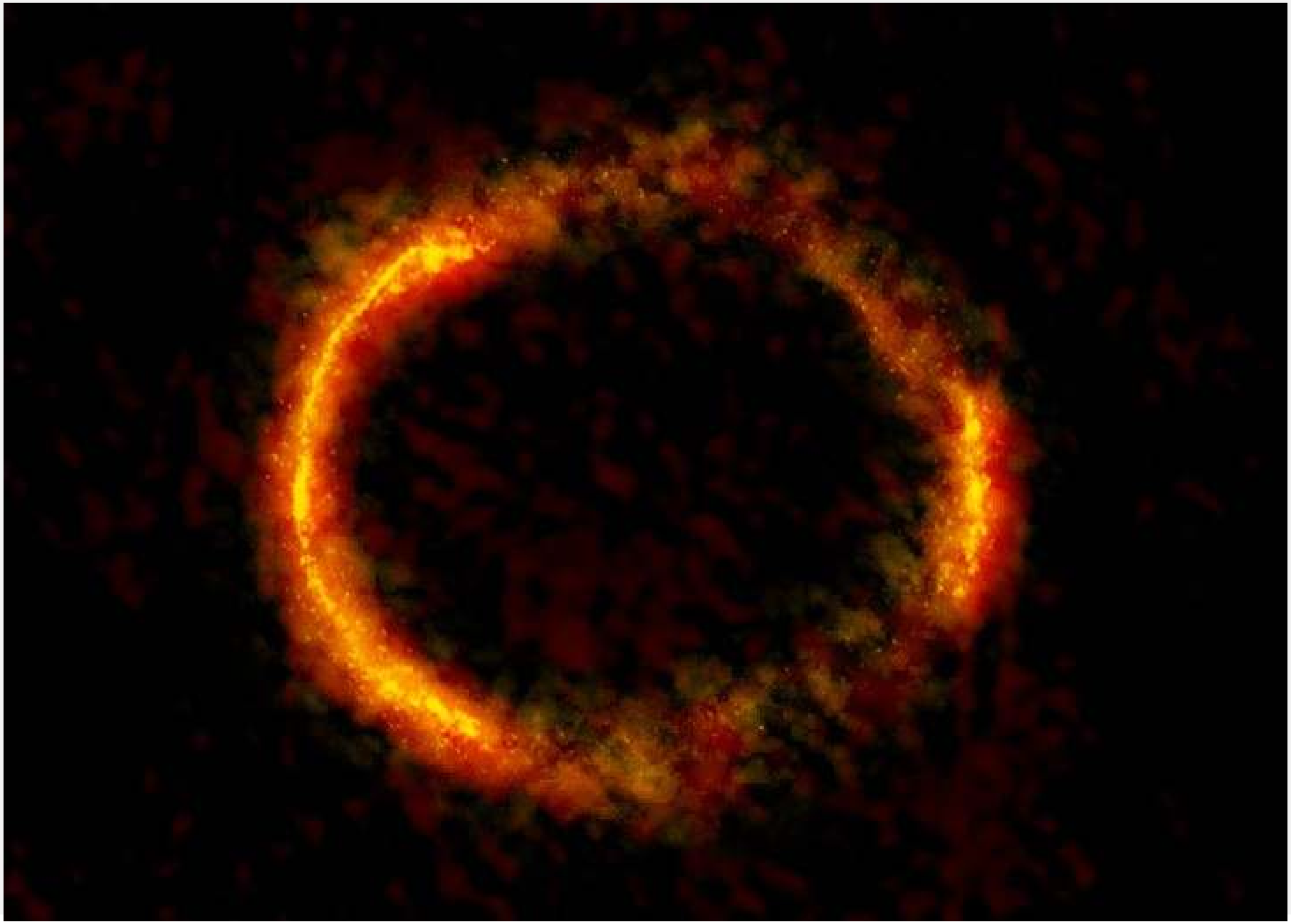

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- **Radio Wavelengths (λ = 0.7cm – 4m)**
  - 36 lenses in CLASS, more due with e-Merlin
  - Projected ~10000 'easy' lenses with LOFAR / SKA1-MID
  - In excess of *one hundred thousand* with SKA2

Talk Aims

- **Lets pretend the numerous technical challenges in finding, reducing, analyzing 100000 strong lenses don't exist and ask...**

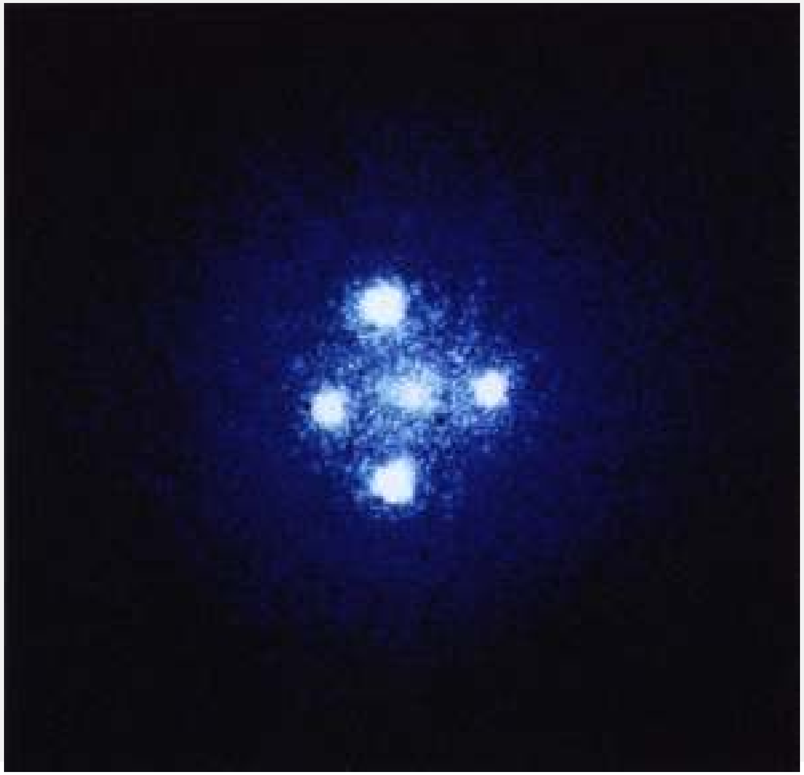
- **What can strong lensing offer the radio domain?**
- **What can the radio domain offer strong lensing?**
- **What can we do with *one hundred thousand* radio lenses?**

Theory / Method – Adaptive Semi-linear Inversion (SLI)

Strong Lensing – Extended Images

4 – 8 constraints

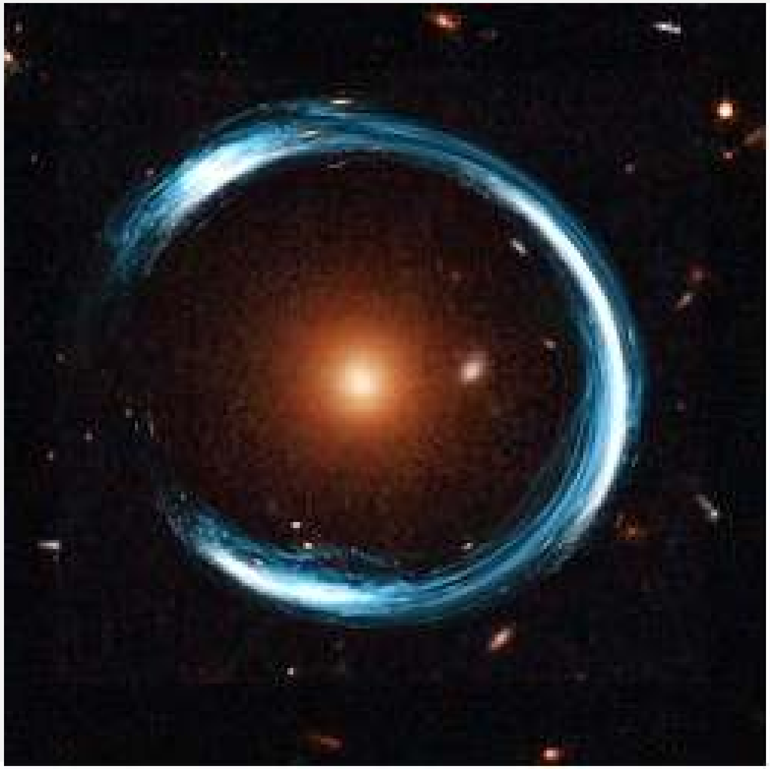
Lens Mass M_{Ein}



1000-2000+ constraints

Lens Mass, Density

Source Reconstruction



Adaptive SLI – Foreground Modeling

- **Assume profile for foreground light distribution (e.g. elliptical Sersic / bulge+disk)**

  - Subtract off image -> perform lensing analysis on residuals.

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- **Foreground modeling built fully into adaptive SLI simultaneous to lens analysis**

  - Degeneracies and errors between foreground and lens models fully sampled.

  - Necessary for accurate foreground light and mass model.

Adaptive SLI – Lens Mass Modeling

- **Typically assume an elliptical isothermal or power-law for the *total* mass distribution.**

  - Approximation breaks down at the small physical scales being measured.

  - Measurement of *total* density slope gives minimal information.

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- **Therefore now advocate density profile decomposition with Adaptive SLI.**

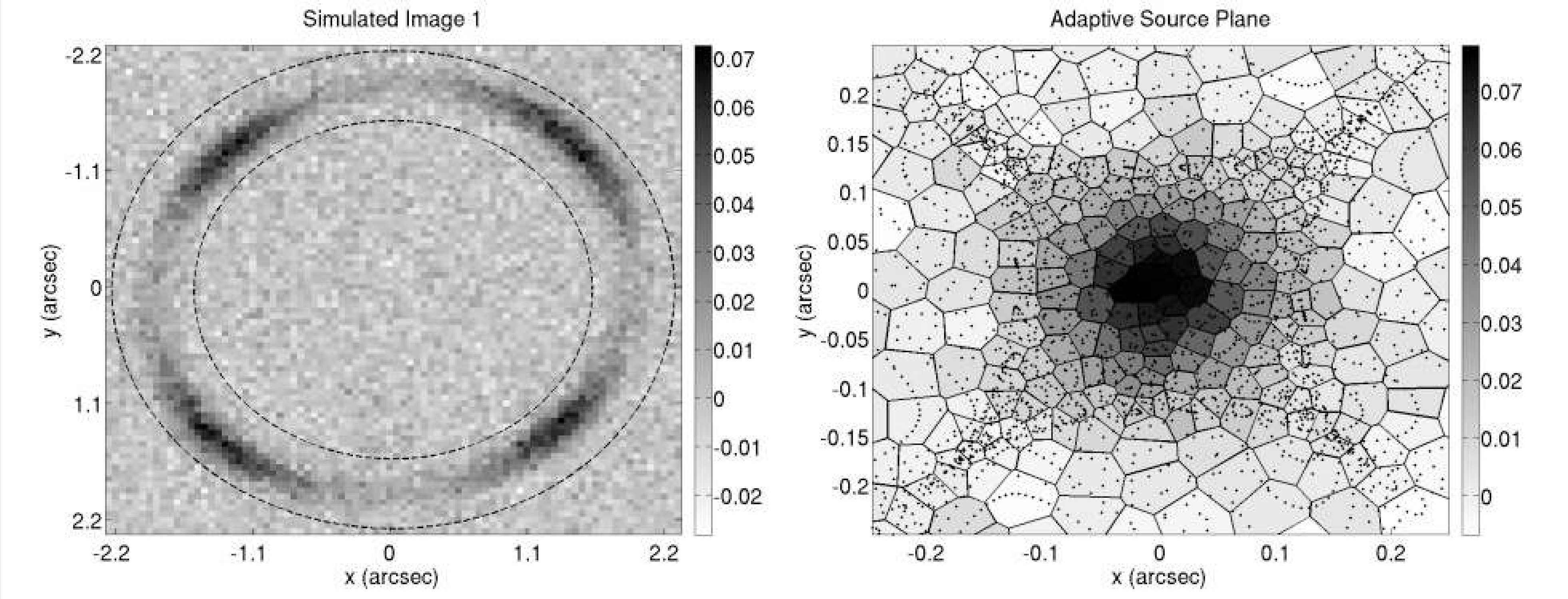
  - Multiply fitted light profile by M/L ratio.

  - Assume elliptical generalized NFW profile for dark matter halo.

  - More robust approximation.

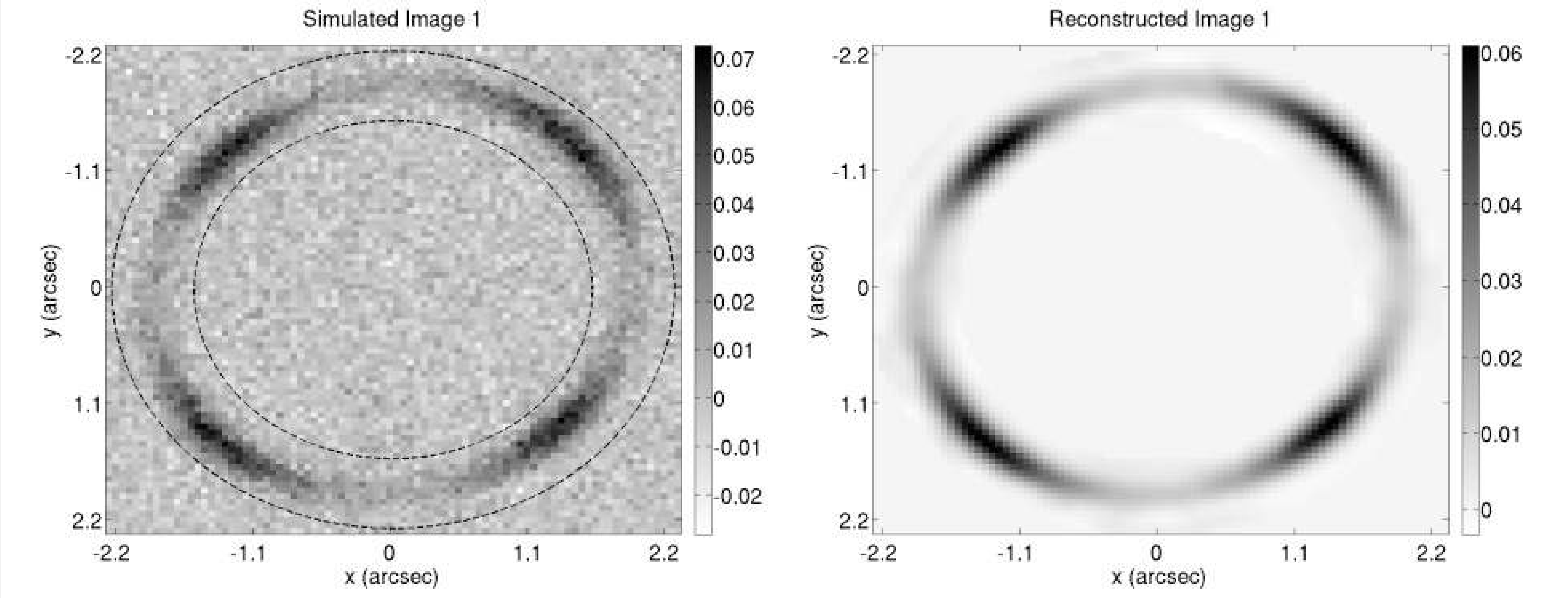
  - Gives numerous physically interesting measurements.

Adaptive SLI – Source Reconstruction



- **Adaptive SLI uses adaptive source grid reconstruct source.**

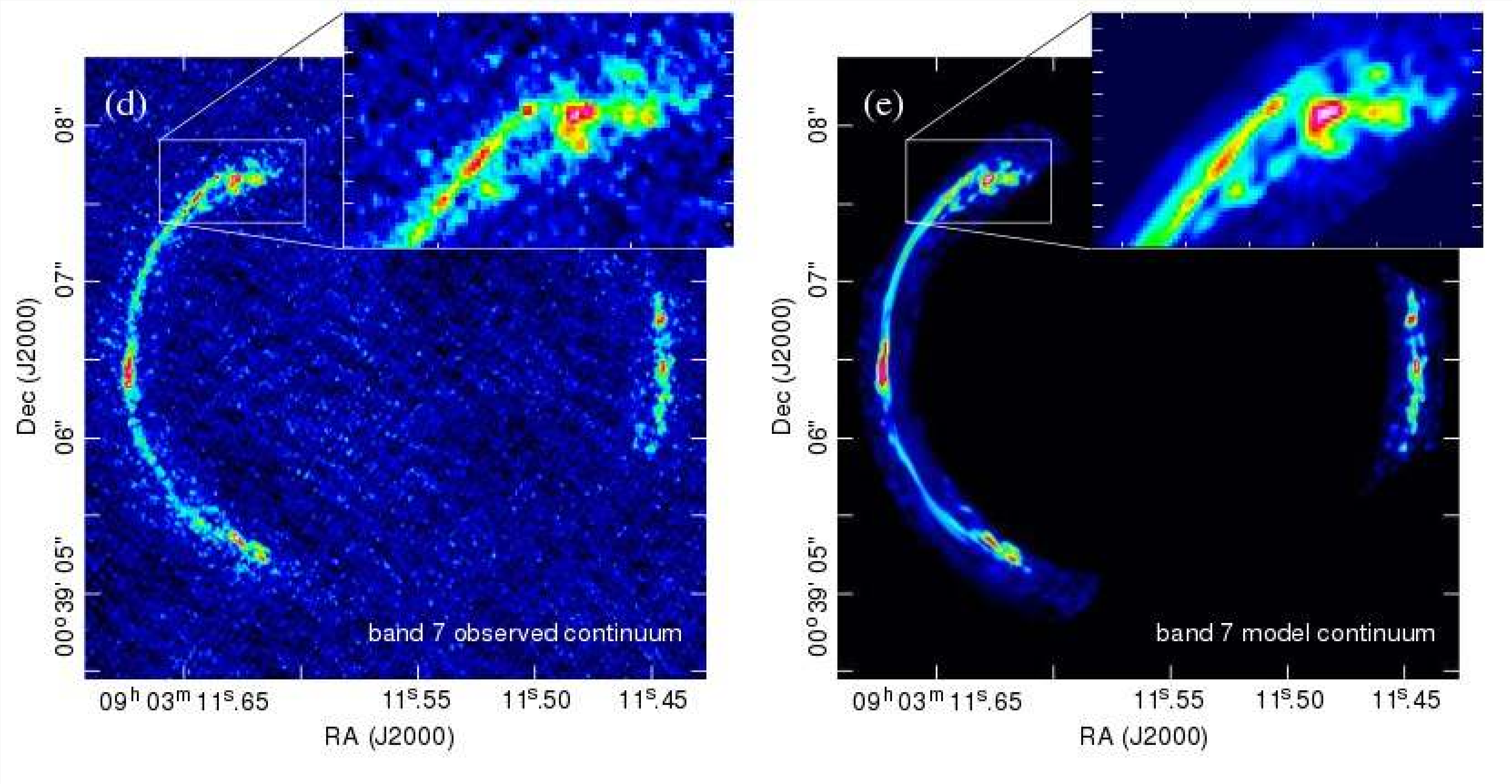
Adaptive SLI – Source Reconstruction



- **Reconstruct Image -> Compare with observed image.**
- **Residual based likelihood function -> Nonlinear search with MultiNest.**

What Radio Offers Lensing (Lens Studies)

H-ATLAS J090311.6+003906



Lens Measurements

- **Errors quoted at 3σ Confidence**
- **Stellar M/L ratio – independent of stellar synthesis models.**

  - $\Gamma = 2.96 \pm 0.21\ h_{65}\ M_{O} / L_{BO}$
- **Roundness of Light / Dark Matter**

  - $q_{d} = 0.84 \pm 0.04$

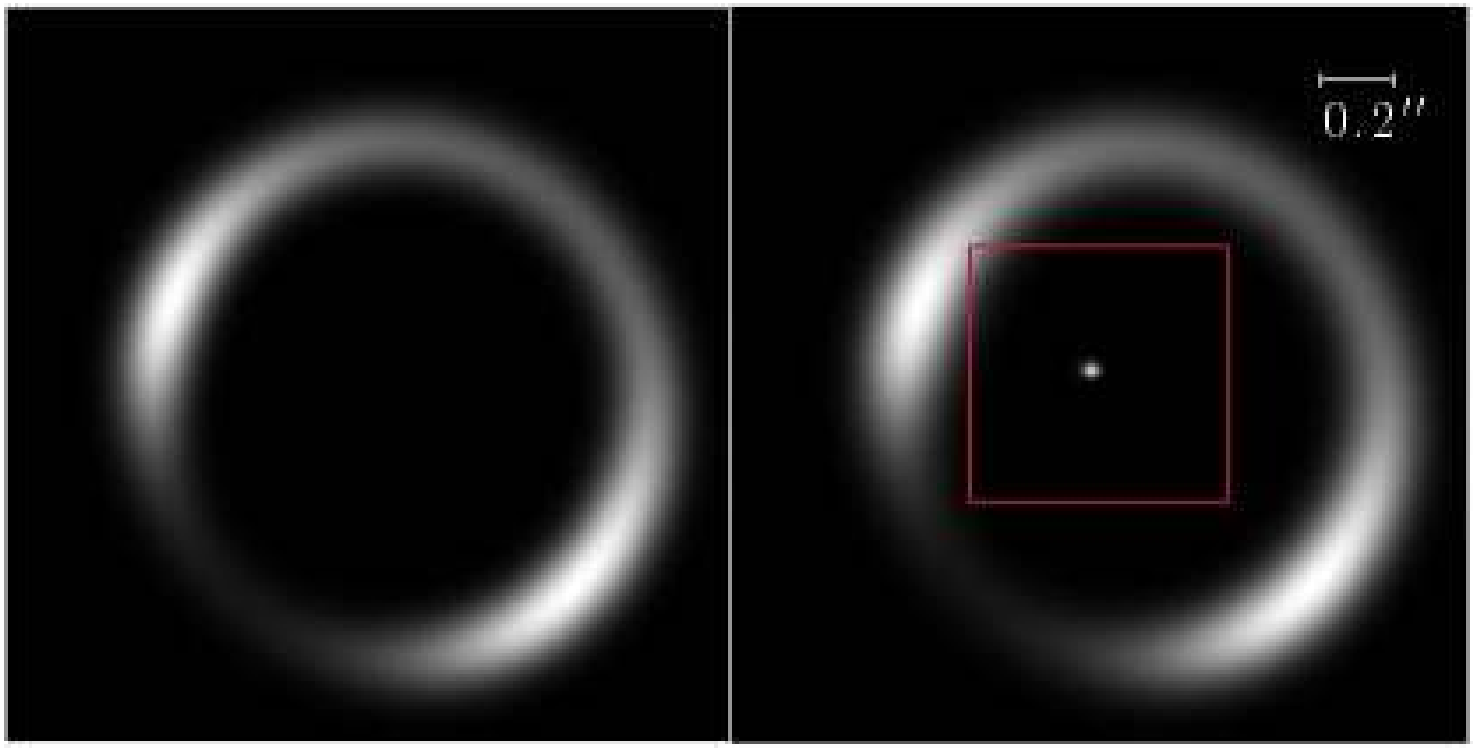
  - $q_{L} = 0.81 \pm 0.05$
- **Positional and Rotational Alignment of Light / Dark Matter**

  - $\Delta r = 0.01 \pm 0.01$

  - $\Delta\Theta = 6.9 \pm 1.1$
- **gNFW Inner Dark Matter Slope**

  - $\gamma = 1.3 \pm 0.12$

Inner Core – Demagnified Image



Hezaveh et al. 2015

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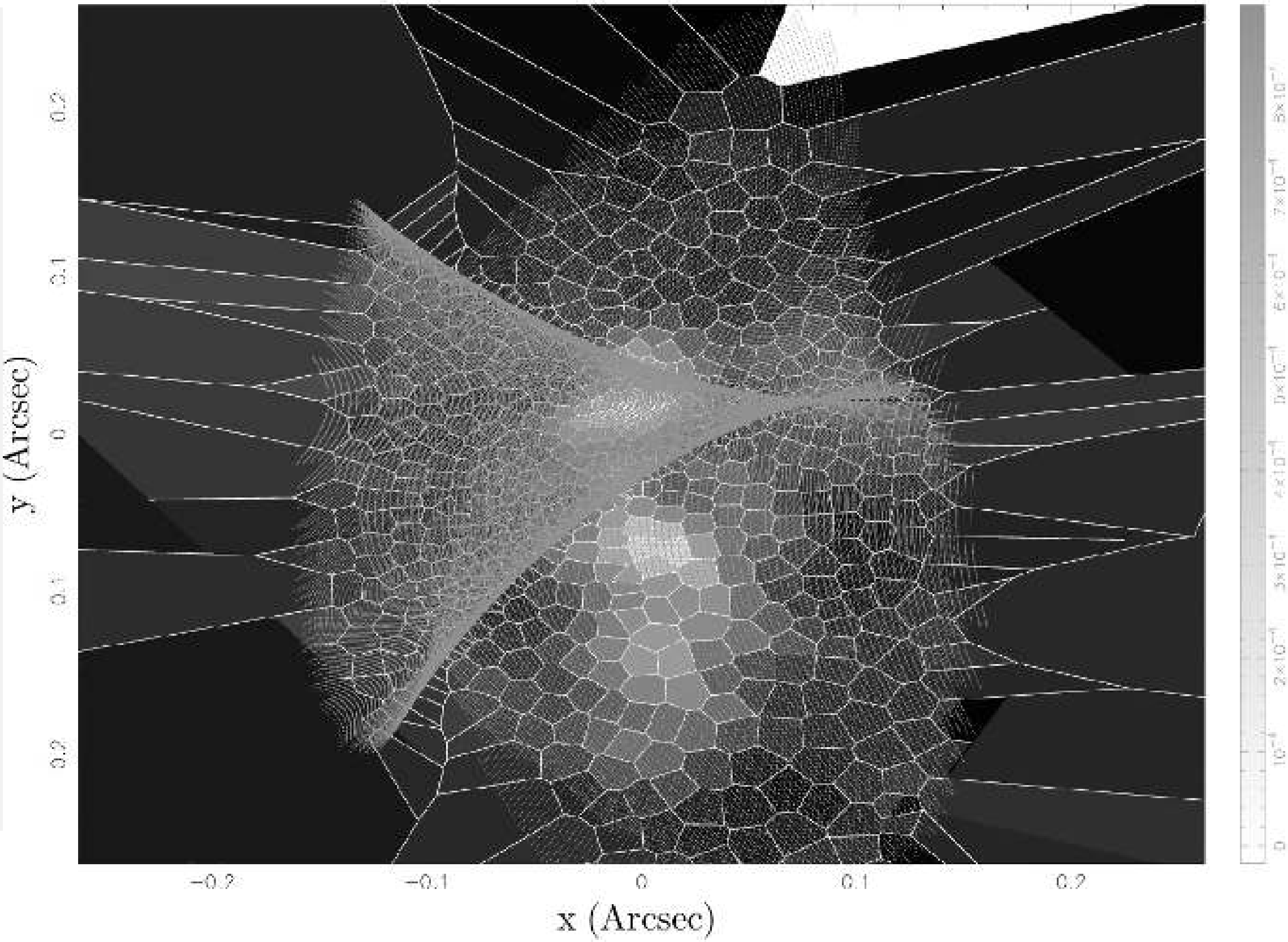
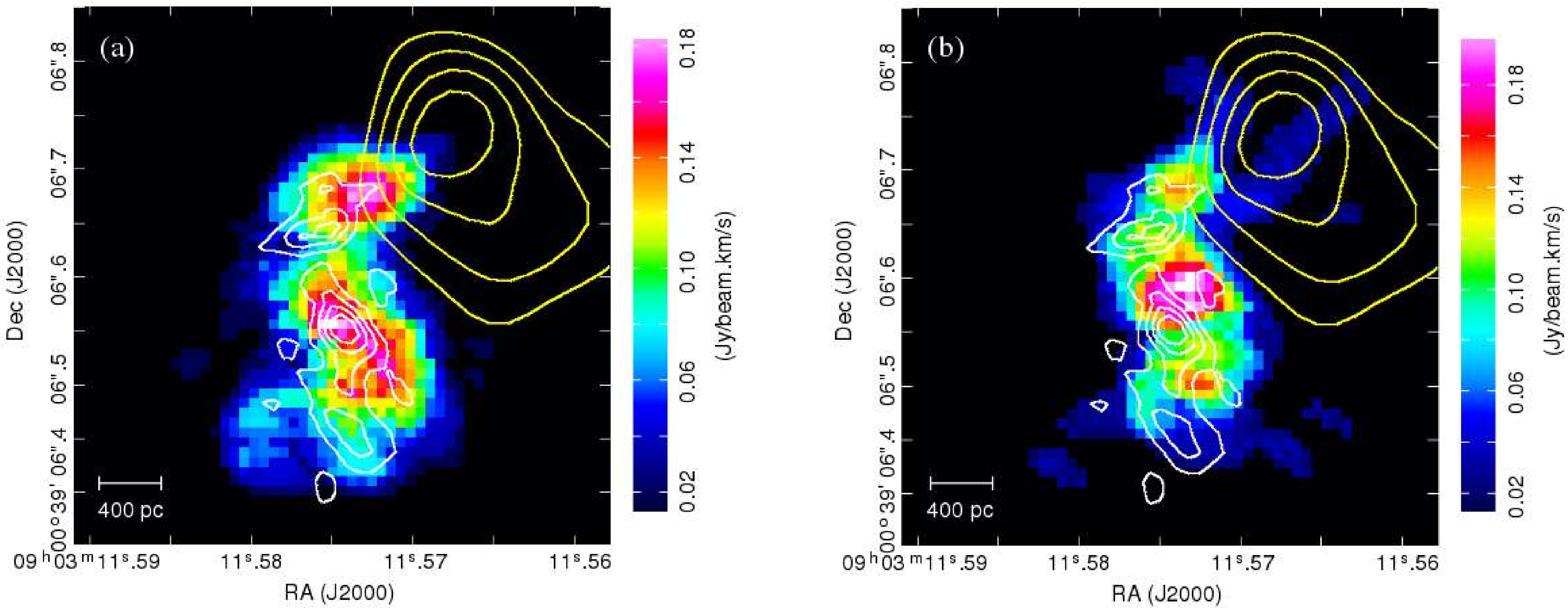
What Lensing Offers Radio (Source Studies)


y (Arcsec)
x (Arcsec)
-0.2
-0.1
0
0.1
0.2

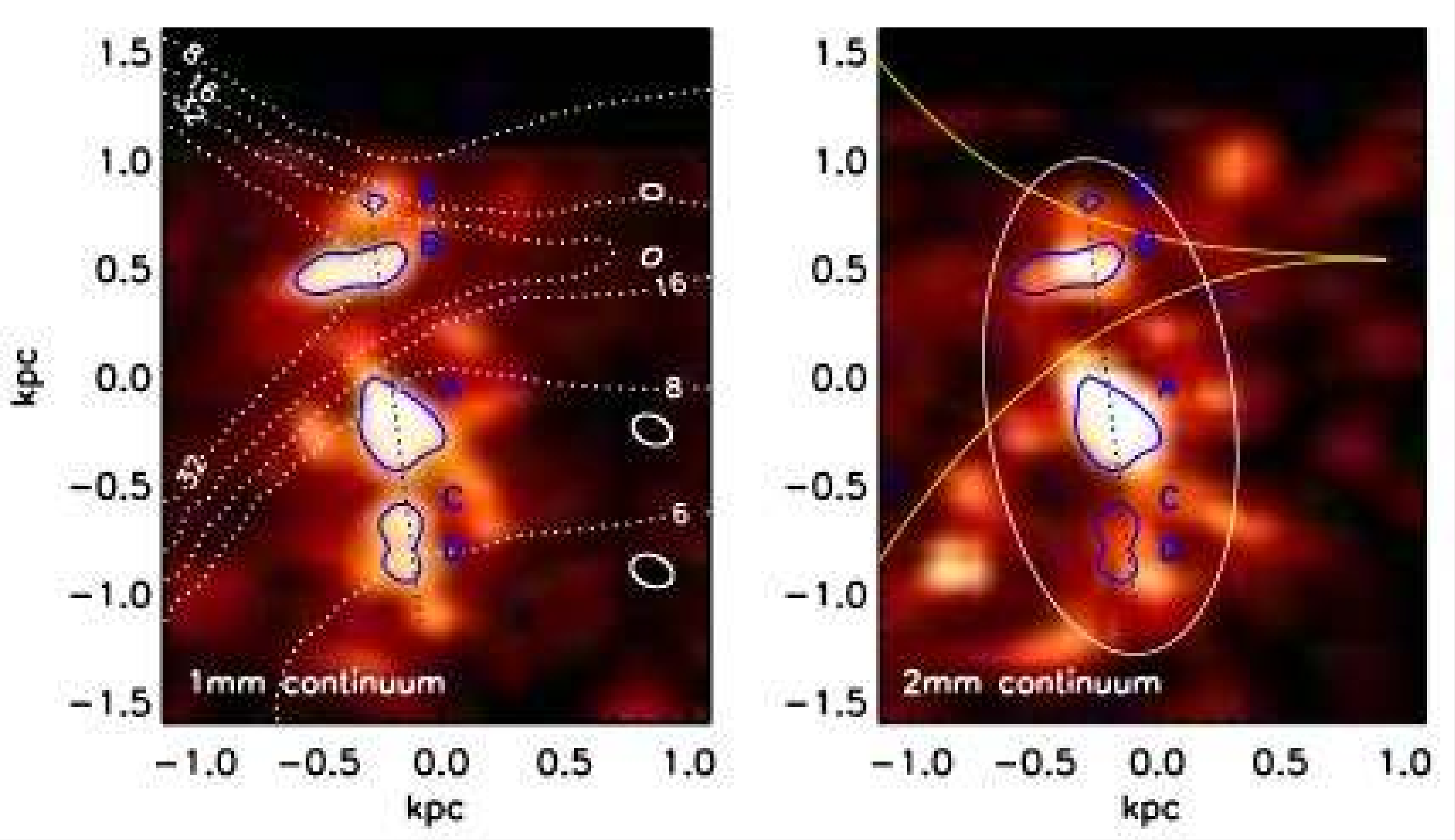
Emission Line Reconstruction

CO(5-4) **CO(8-7)**



Dye et al. 2015

Dynamical Modeling



Swinbank et al. 2015

Conclusions - One Hundred Thousand Lenses

Strong Lensing and Radio

- **Lens studies**

  - Decomposition of light / dark matter of a comprehensive sample of ETG's and LTG's.

  - Massive scope when combined with complementary observations (weak lensing, stellar dynamics, stellar population synthesis, X-ray, etc).

- **Source studies**

  - Unprecedented physical resolution of radio sources.

  - Roughly equal split of lensed AGN / starbursts.

  - Unlock the otherwise unobservable faintest radio population in the universe (if it exists!).