

Lensing galaxies in the CFHT Legacy Survey

Rafael Küng¹, Prasenjit Saha¹,
Elisabeth Baeten², Jonathan Coles³, Claude Cornen²,
Christine Macmillan², Phil Marshall⁴, Anupreeta More⁵,
Surhud More⁵, Aprajita Verma⁶, Julianne K. Wilcox²

1) Physik-Institut, University of Zurich, Zurich, Switzerland
2) Zooniverse, c/o Astrophysics Department, University of Oxford, Oxford, UK
3) Exascale Research Computing Lab, Bruyeres-le-Châtel, France
4) Kavli Institute for Particle Astrophysics and Cosmology, Stanford University, Stanford, USA
5) Kavli Institute for the Physics and Mathematics of the Universe, University of Tokyo, Kashiwa-shi, Japan
6) Sub-department of Astrophysics, University of Oxford, Oxford, UK

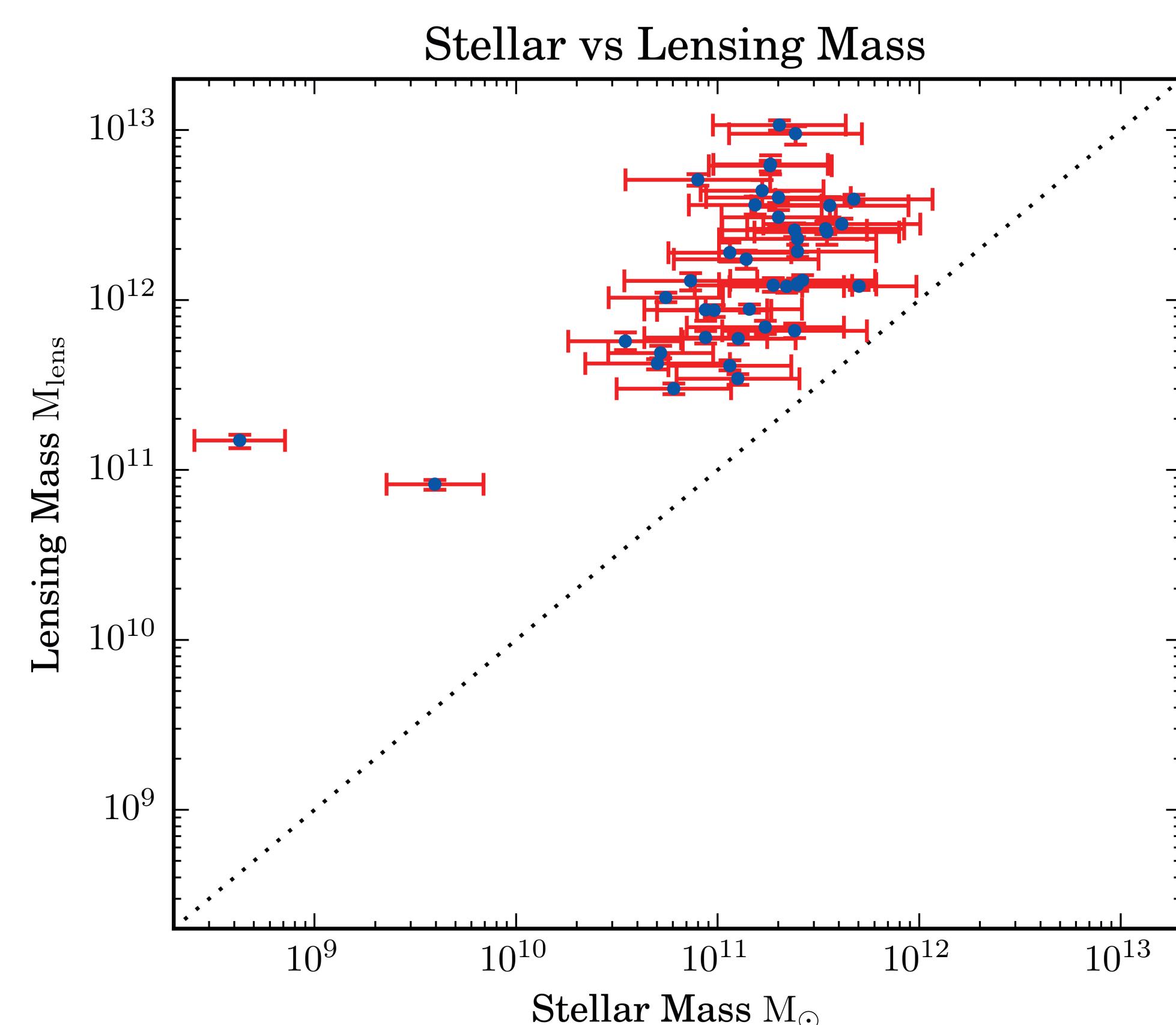
The Space Warps project enables citizen-science volunteers to search for gravitational-lens candidates by visual inspection of survey data. The first batch of discoveries consists of 59 new lens candidates from archival images of the CFHT Legacy Survey. In this work we present lens models of most of these candidates, produced collaboratively by experienced members of the volunteer community.

Over the next decade, the number of strong gravitational lenses may increase a hundred-fold. The lenses will demand modelling, and it is desirable to engage the most experienced volunteers of citizen science projects like SpaceWarps in this more expert task.

SpaghettiLens is a method to enable collaborative modeling of gravitational lenses and lens candidates. It's designed to be intuitive, yet powerful, so that it can be used by professionals and non-professional lensing enthusiasts as well.

Here we show some preliminary results from models of the newly discovered candidates. The figure on the right plots the lensing mass against the stellar mass of the candidate lens galaxies. The stellar mass fraction comes out to be of order 20 percent, with a decreasing trend for the most massive galaxies, as expected for early type galaxies. Outliers may be non-lenses, as the sample has not yet been spectroscopically confirmed.

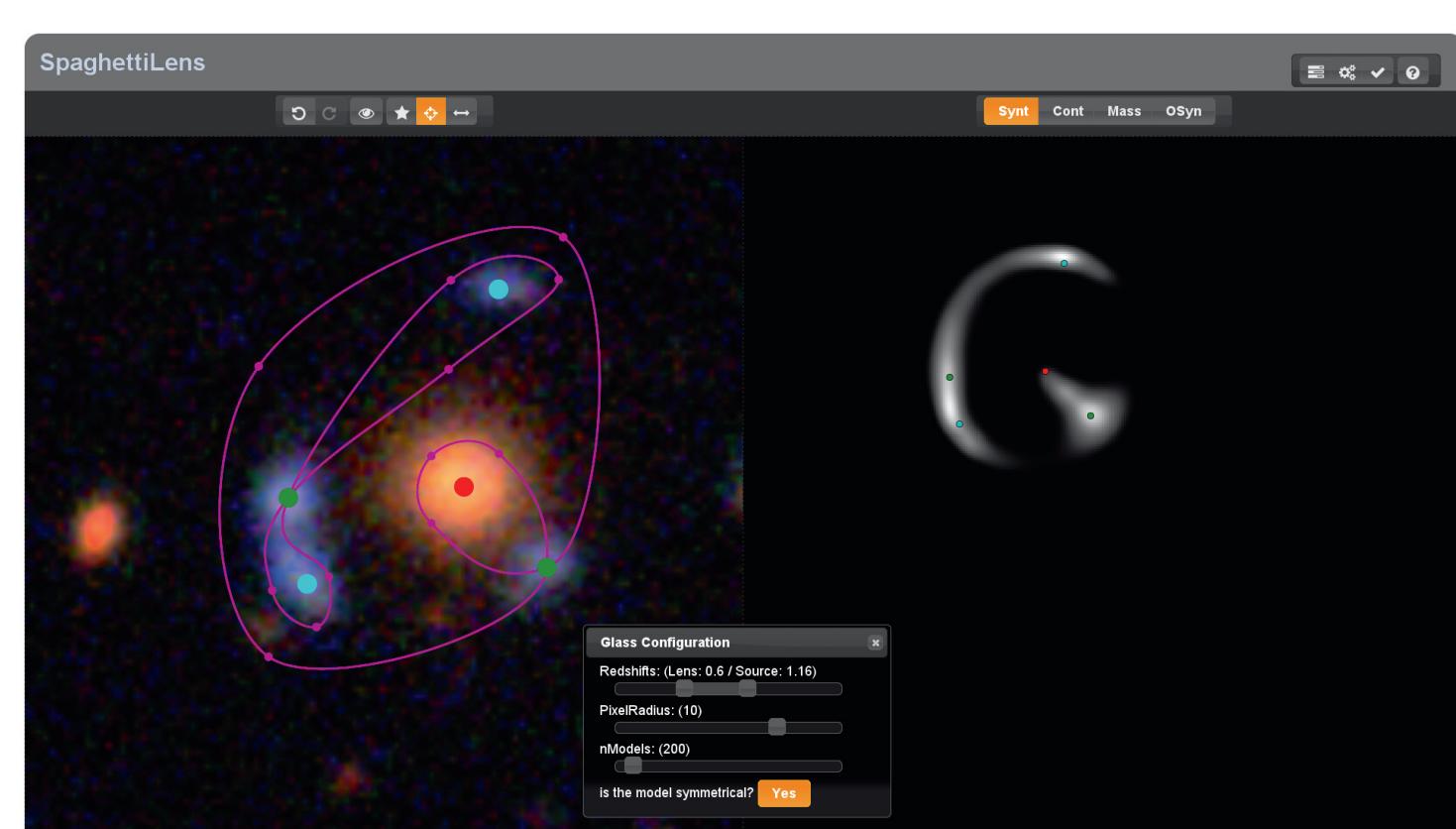
Space Warps and the CFHTLS lens candidates are introduced in Marshall et al (2015) and More et al (2015). Stellar population models are given by Ignacio Ferreras.



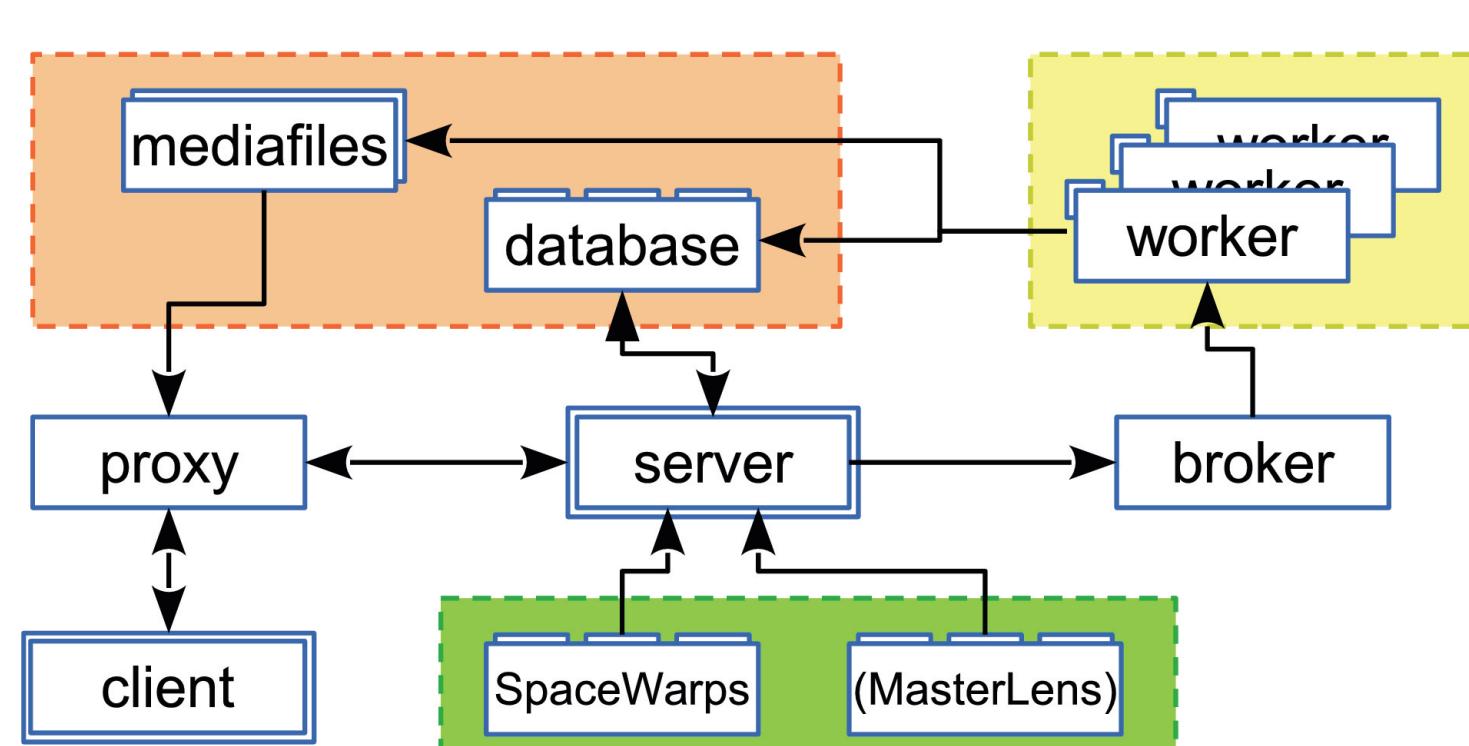
SpaghettiLens is a web based application for modelling strong gravitational lenses.
<http://labs.spacewarps.org/spaghetti>

It works as follows:

- The user sketches a so called spaghetti diagram, which on the one hand is a cartoon of the lensed images, and on the other hand encodes an initial guess for the mass distribution.
- The machine refines this initial guess into a free form mass map with uncertainties.
- The user examines various diagnostics and if satisfied, posts the model for discussion and possible improvement.



The user interface shows a side by side comparison of the image of the physical object with an overlay of the users input and a rendered synthetic image of the generated model. Other output like the mass distribution or arrival time surface can also be consulted.



On the server side, SpaghettiLens is built in a standard way. The server can possibly access several remote data sources to get images, that can then be loaded into the UI and modeled. The numerically intensive part of generating models and rendering them is distributed to dedicated worker nodes.

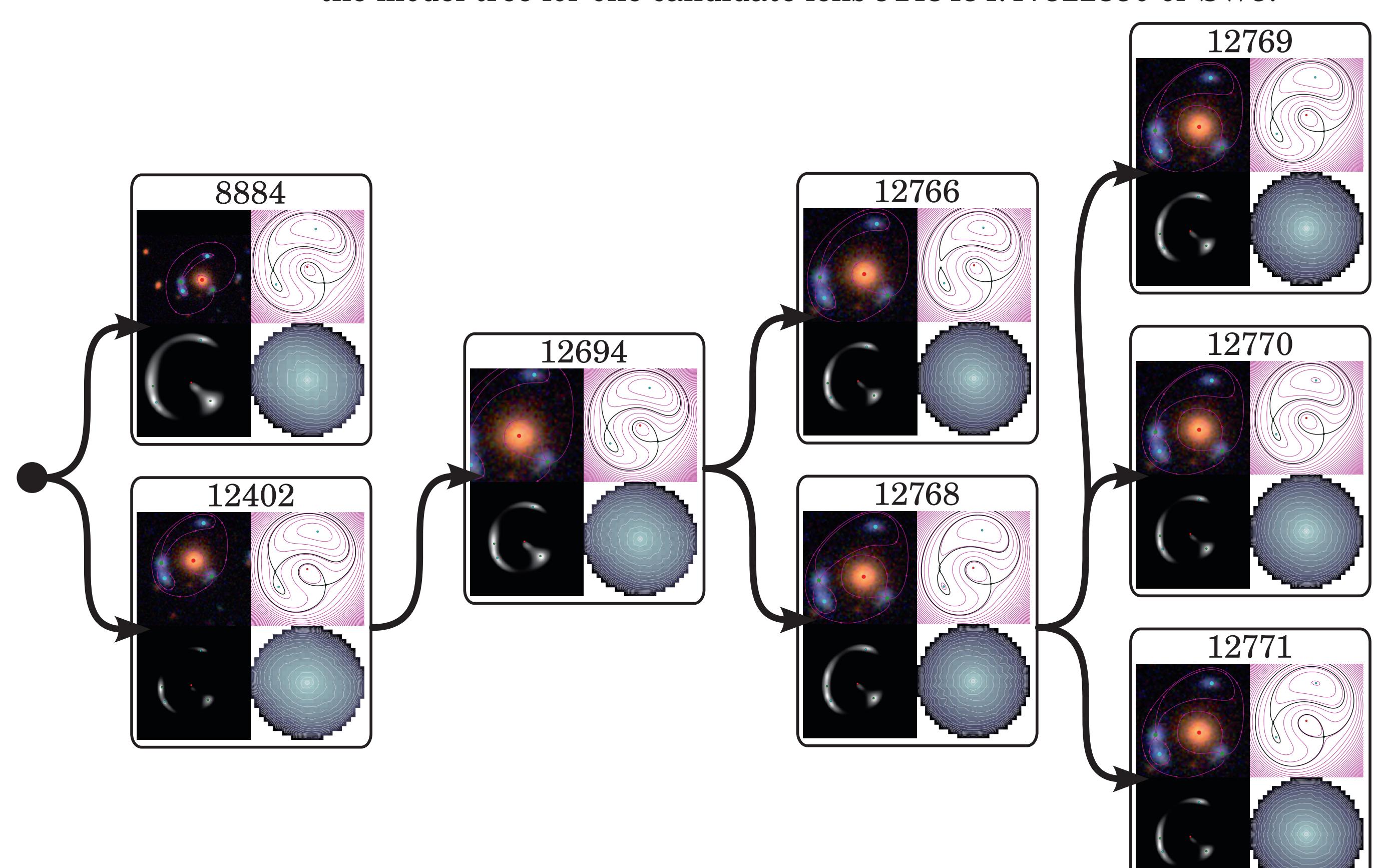


For more on SpaghettiLens, see Küng et al (2015).



Collaborative modelling is enabled through the modelling forum on
<http://talk.spacewarps.org>

Users can not only share and discuss models on the forum, they can revise existing models shared by others. This leads to tree of models, that can be debated upon and pruned again in discussion. Here is the model tree for one candidate lens J143454.4+522850 or SW5.



The discussion among the volunteers and with professionals helps strengthen the skills of all of the community.



For further details on collaborative modelling strategies see
<http://letters.zooniverse.org> on this topic.

References

- Küng et al.
Gravitational lens modelling in a citizen science context
03/2015, MNRAS, 447, 2170
- Marshall et al.
Space Warps: I. Crowd-sourcing the Discovery of Gravitational Lenses
04/2015, arXiv:1504.06148
- More et al.
Space Warps II. New Gravitational Lens Candidates from the CFHTLS Discovered through Citizen Science
04/2015, arXiv:1504.05587

Acknowledgment

We thank Ignacio Ferreras for providing the stellar-population models used to estimate the stellar mass.

A special thank to all the SpaceWarps volunteers who helped finding lenses and creating all the models.

This work was supported by the Candoc Forschungskredit by the University of Zurich.



University of
Zurich UZH