Julian Merten

High cluster concentrations - A comparison using SUBARU and MareNostrum -

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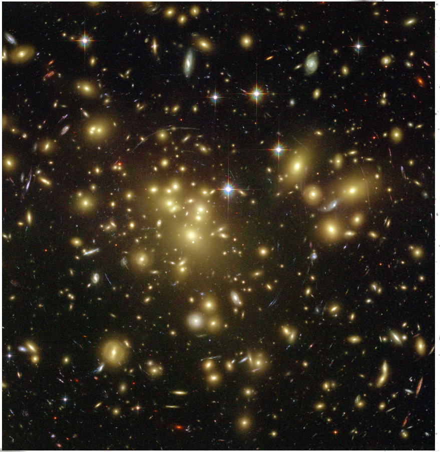
with: **M. Meneghetti, M. Bartelmann, T. Broadhurst, M. Oguri**

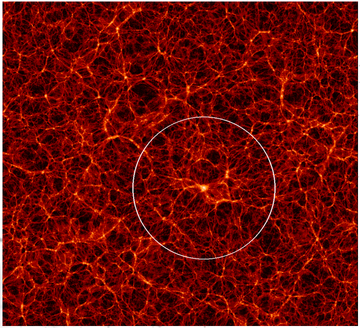
Strong lensing clusters

- Extremely powerful cosmological probes
  - Inner DM profile
  - Additional information to weak lensing
  - Arc statistics
- Several aspects can alter the lensing properties
  - Substructure, asymmetries and projection effects
  - cD galaxy properties
  - Gastrophysics
  - Dynamical state
- One has to be careful while interpreting individual results



The MareNostrum Universe (Gottlöber et al. 2006)

- Large cosmological hydro-simulation using `GADGET2`
- Gas is included, but only with adiabatic physics
- Box size: 500 h^{-1} Mpc
- DM: 1024^3 particles with a mass of $8.24 \times 10^9 M_\odot h^{-1}$
- Gas: 1024^3 particles with a mass of $1.45 \times 10^9 M_\odot h^{-1}$
- WMAP-1 cosmology:
  $\Omega_{\mathrm{m},0} = 0.3$
  $\Omega_{\lambda,0} = 0.7$
  $\Omega_{\mathrm{b},0} = 0.045$
  $\sigma_8 = 0.9$
  $n = 1$



Selecting clusters *(Meneghetti, Fedeli, Pace, Gottlöber, Yepes in prep.)*

- The MareNostrum Universe contains:
  - $\sim$ 957000 halos with $M > 5 \times 10^{11} h^{-1} M_{\odot}$
  - $\sim$ 4000 halos with $M > 5 \times 10^{14} h^{-1} M_{\odot}$
- Two classes of strong lenses:
  - Producing critical lines
  - Producing giant arcs with L/W > 7.5
- For these objects the lensing cross section σ is measured
  - 49366 critical lenses
  - 6375 clusters producing giant arcs
  - 11347 projections with $\sigma > 0$

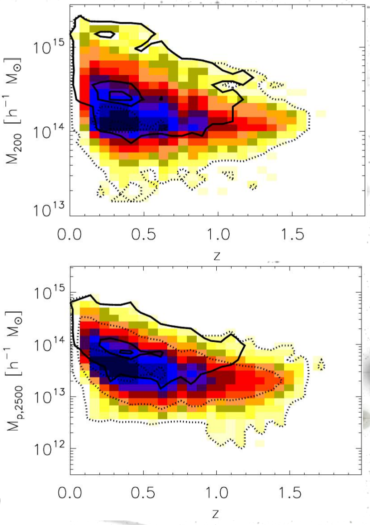
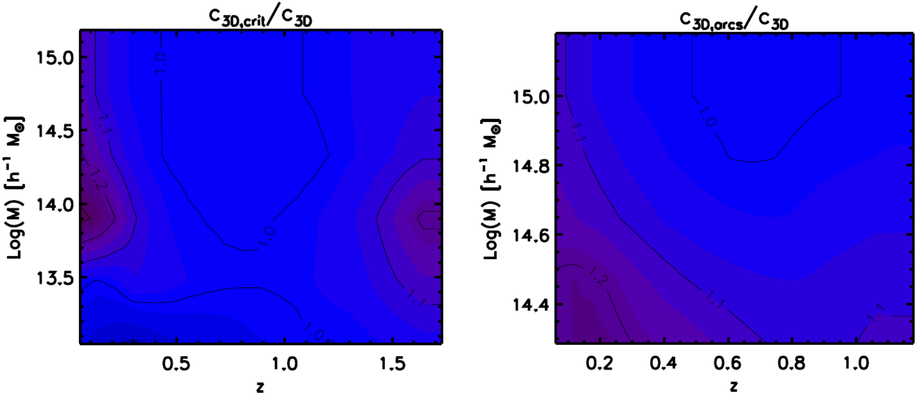
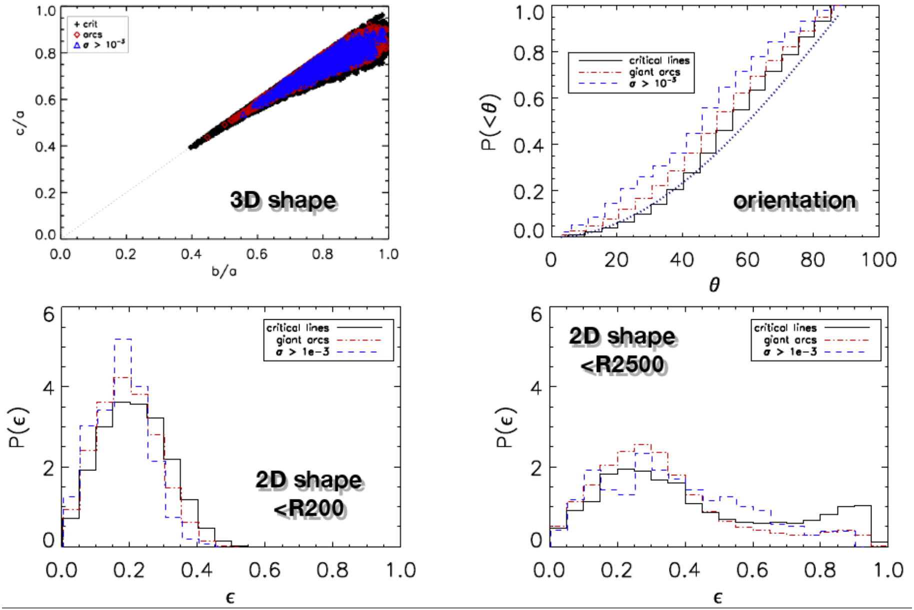


Figure: inner: 50%, outer: 90%

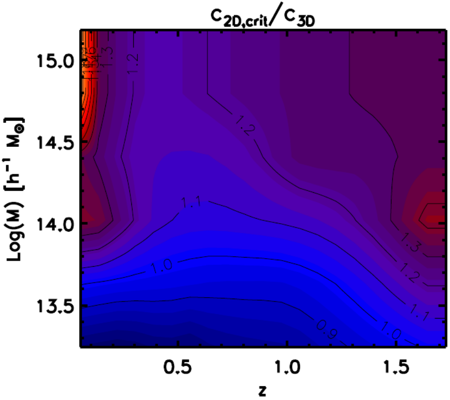
Concentrations

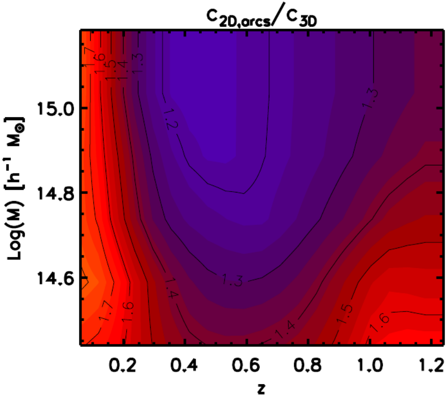


Orientation and triaxiality



Concentrations revisited





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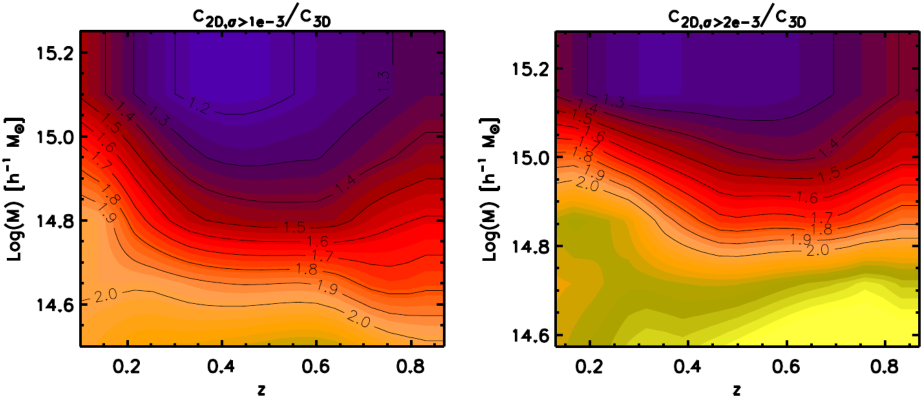

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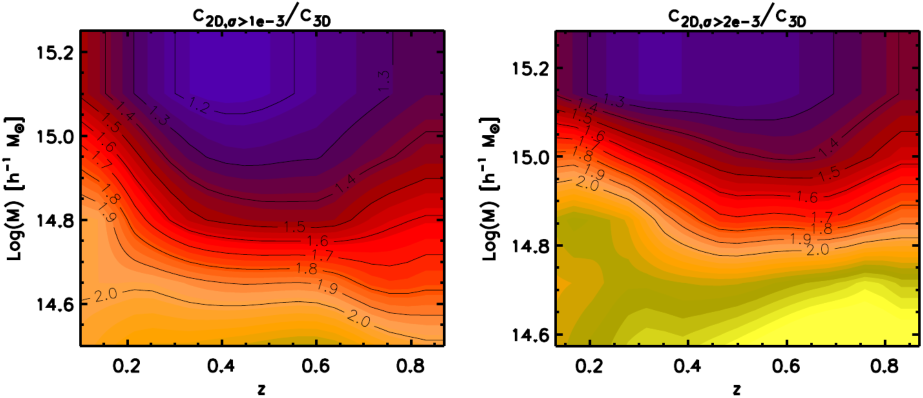


The analysis in Meneghetti et al. in prep. exceeds the scope of this talk. Also X-Ray luminosities and the dynamical state of the strong-lensing sample are discussed.

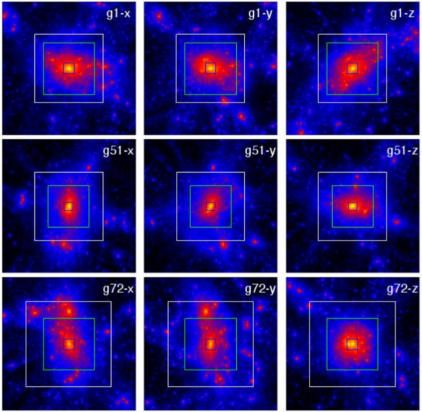
Focusing on reality: Reconstruction tools (JM et al. 2009)

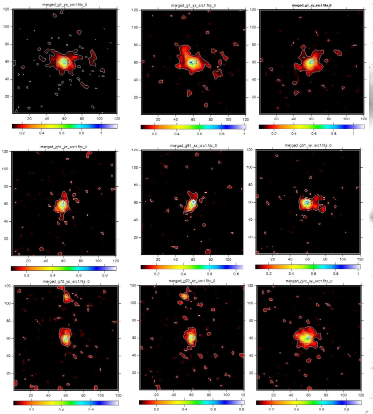
SaWLens in a nutshell

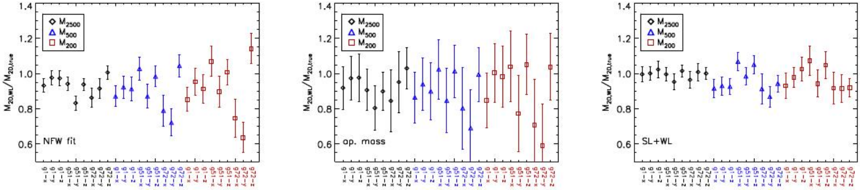
- Fully nonparametric joint reconstruction method
- Can make use of:
  - Ellipticity
  - Flexion
  - Multiple-image system
  - Critical-curve estimators
- Fully applicable to wide fields (tested with the COSMOS catalogues)
- MPI implemented
- Extensively tested

For pure strong lensing analysis we usually use `Lenstool` (Kneib et al. 1993, Jullo et al. 2007).

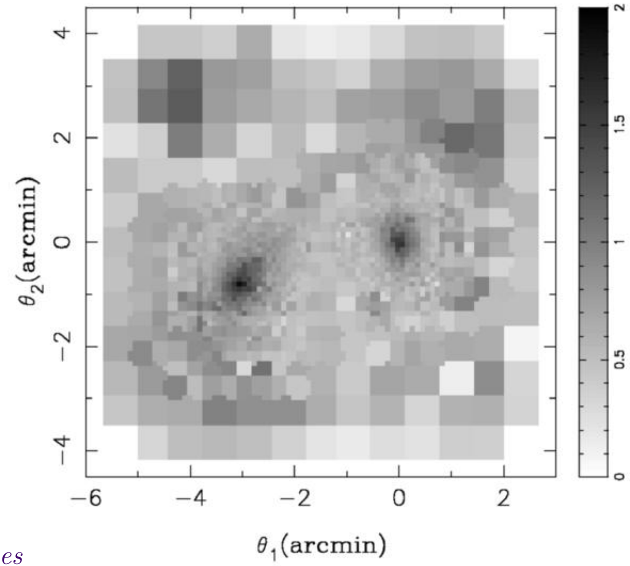
SaWLens performance (*Meneghetti, Rasia, JM et al. 2009*)







Next generation codes: AMR *(Bradač et al. 2009, JM et al. 2009, JM et al. in prep.)*



Next generation codes: GPU/CUDA (JM et al. in prep.)

- Problem: CPU time.
- In our case:

$$F_{lk} = a_i b_j C_{ij} D_{il} E_{jk}$$
$$G_l = a_i b_j C_{ij} E_{il}$$
$$l, k, i, j \sim \mathcal{O}(\text{grid\_dim}^2)$$

- *A lot* of simple arithmetic operations with no need for double precision.
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- CUDA interface (C-based)
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- Gains a lot of momentum in the astrophysics community, suggestions welcome!

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Expected performance *(on the back of an envelope)*

- Right now: 3hrs for a highly resolved reconstruction on a 24 core, InfiniBand, Linux cluster.
- $\sim$ 60 GFLOPS on a state-of-the-art quadcore CPU $\Rightarrow$ 360 GFLOPS on the cluster.
- Because of process communication $\Rightarrow$ effectively $\sim$ 300 GFLOPS.
- 933/300 $\sim$ 3 $\Rightarrow$ 1hr runtime on a desktop machine.
- But, GPU+MPI possible $\Rightarrow$ minute scale already in range if you need it.

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Possible targets (JM et al. in prep)

- SUBARU sample Broadhurst et al. 2008
- SUBARU sample Oguri et al. 2008
- SUBARU cluster CL0024+1654 Umetsu et al. 2009
- LBT cluster A611 Donnarumma et al. in prep.

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Cluster	z	Filters	Einstein Radius (arcsec)	$\langle D_{ds}/D_s \rangle$	$\frac{d \log N(<m)}{dm}$	M_{vir} $(10^{15}\ M_\odot\ h_{70}^{-1})$	c_{vir}	χ^2/dof
A1689	0.183	$V_J i'$	52 (z_s = 3.05)	0.704	0.150	$1.59^{+0.24}_{-0.22}$	$15.69^{+3.96}_{-2.88}$	4.94/9
A1703	0.258	$g' r' i'$	33 (z_s = 2.8)	0.722	0.062	$1.30^{+0.24}_{-0.20}$	$9.92^{+2.39}_{-1.63}$	2.69/5
A370	0.375	$B R_C z'$	43 (z_s = 1.5)	0.606	0.088	$2.93^{+0.36}_{-0.32}$	$7.75^{+1.12}_{-0.92}$	5.54/8
RX J1347−11	0.451	$V_J R_C z'$	35 (z_s = 1.8)	0.553	0.066	$1.47^{+0.26}_{-0.23}$	$10.42^{+3.25}_{-2.13}$	6.25/7

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Cluster	z	Filters	Einstein Radius (arcsec)	$\langle D_{ds}/D_s \rangle$	$\frac{d\log N(<m)}{dm}$	M_{vir} ($10^{15}\ M_\odot\ h_{70}^{-1}$)	c_{vir}	χ^2/dof
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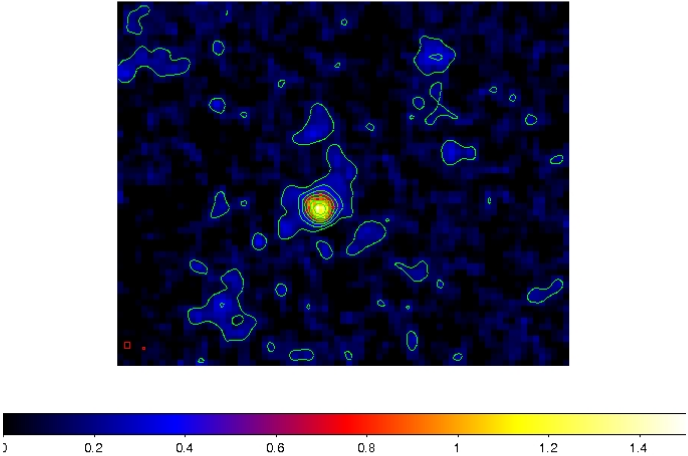
A1703	0.258	$g'r'i'$	33 (z_s = 2.8)	0.722	0.062	$1.30^{+0.24}_{-0.20}$	$9.92^{+2.39}_{-1.63}$	2.69/5
A370	0.375	$BR_C z'$	43 (z_s = 1.5)	0.606	0.088	$2.93^{+0.36}_{-0.32}$	$7.75^{+1.12}_{-0.92}$	5.54/8
RX J1347−11	0.451	$V_J R_C z'$	35 (z_s = 1.8)	0.553	0.066	$1.47^{+0.26}_{-0.23}$	$10.42^{+3.25}_{-2.13}$	6.25/7

- SUBARU sample Oguri et al. 2008

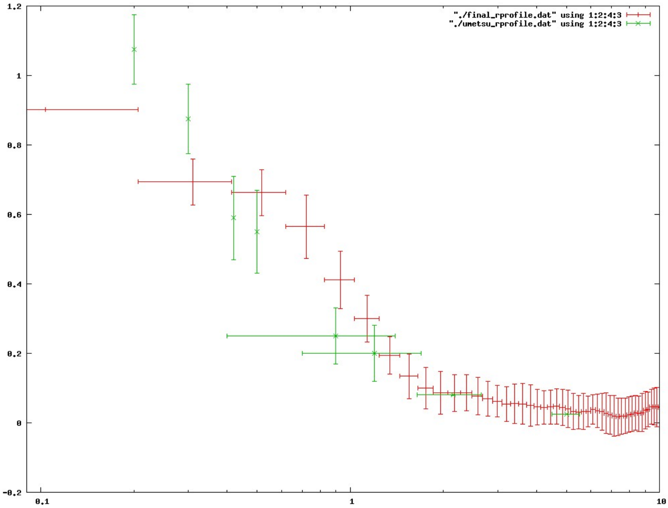
Name	Weak lensing			Strong and Weak lensing		
	$M_{vir}[10^{15}M_\odot]$	c_{vir}	χ^2/dof	$M_{vir}[10^{15}M_\odot]$	c_{vir}	χ^2/dof
A1703	$1.95^{+0.65}_{-0.50}$	$3.3^{+1.4}_{-1.1}$	2.7/5	$1.50^{+0.40}_{-0.35}$	$6.5^{+1.2}_{-0.7}$	7.9/7
SDSS1446	$0.83^{+0.29}_{-0.25}$	$9.1^{+11.4}_{-4.1}$	6.3/5	$0.83^{+0.30}_{-0.22}$	$8.3^{+3.9}_{-3.1}$	6.4/6
SDSS1531	$0.59^{+0.39}_{-0.26}$	$11.5^{+28.5}_{-7.4}$	8.0/5	$0.66^{+0.29}_{-0.24}$	$7.9^{+3.0}_{-1.5}$	8.1/6
SDSS2111	$0.92^{+0.41}_{-0.32}$	$14.1^{+25.9}_{-9.5}$	7.5/5	$0.92^{+0.41}_{-0.32}$	$14.1^{+25.9}_{-9.3}$	7.5/6

- SUBARU cluster CL0024+1654 Umetsu et al. 2009
- LBT cluster A611 Donnarumma et al. in prep.

CL0024+1654 (JM et al. in prep.)



CL0024+1654 (JM et al. in prep.)



Conclusions

1. Strong lensing clusters are important cosmological probes, but we have to understand better their properties.
2. The MareNostrum Universe delivers a large sample of strong lenses.
3. High cluster concentrations are not surprising for effective gravitational lenses.
4. Second generation nonparametric codes allow for a reliable comparison between observations and simulations.
5. GPU implementations will radically reduce the runtime of these methods.