Galaxy formation in SPHS

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SURREY

Background | Probing cosmology & galaxy formation







Gravity | Cold Dark Matter models

Doug Potter 2006

Potter 2006; Springel 2008; Stadel 2009

Gravity | Cold Dark Matter models



Springel 2008

Gravity | Cold Dark Matter models



 $N_{\rm hr} = 4,252,607,000$

Springel 2008

Gravity | The trouble with Warm Dark Matter



Wang & White 2007; and see Hahn et al. 2012; Melott & Shandarin 1989; Splinter et al. 1998



O Spurious halos







Hydrodynamics





Galilean invariant	Lagrangian Lagrangian vative
Couples to $O(N)$ grav	ity
Smoothed Particle	Hydrodynamics

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The "blob test"



A 1:10 density ratio gas sphere in a wind tunnel (Mach 2.7), initially in pressure eq.

Agertz et al. 2007

Fresh water

Dense salt water









Hydrodynamics | Improving SPH 'SPHS' [dissipation off]

 $P = A\rho^{\gamma}$

Read, Hayfield & Agertz 2010; Read & Hayfield 2012

Hydrodynamics | A 'non-radiative' galaxy cluster

Power, Read & Hobbs 2013

Hydrodynamics | A 'non-radiative' galaxy cluster

Power, Read & Hobbs 2013

Hydrodynamics | A 'non-radiative' galaxy cluster

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Power, Read & Hobbs 2013; Frenk et al. 1999

Hydrodynamics | A 'non-radiative' galaxy cluster

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Cooling | Forming stars & convergence

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Cooling | SPH versus SPHS

Cooling | Convergence

 $N_{\rm gas} = 1.5 \times 10^5$

Cooling | Convergence

 $N_{\rm gas} = 7.5 \times 10^5 (\times 5)$

Cooling | Convergence

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 $N_{\rm gas} = 3.75 \times 10^6 (\times 5)$

Conclusions

I. N-body discreteness errors produce spurious sub-structures. We introduce a novel form of adaptive force softening to solve this; potentially wide-ranging implications are under study.

- 2. 'classic' SPH has problems modelling fluid mixing between different phases. We present a solution - SPHS - that gives quite different results for galaxy formation simulations:
 - Non-radiative simulations ⇒ Entropy core;
 - With cooling ⇒ No more "cold blobs";
 - Gas discs have higher angular momentum; and
 - Cold streams form at the intersection of SNe bubbles, driving continuing star formation (positive feedback).
 - Cosmological simulations underway ...