UC-HiPACC's International Summer School on AstroComputing presents: ISSAC 2013:

STAR & PLANET FORMATION

July 22 - August 9, 2013 | University of California, Santa Cruz

What is UC-HiPACC?

Assembling Galaxies of Resolved Anatomy (AGORA) High-resolution Galaxy Simulation Comparison Project -- and Comparison with Observations

Joel R. Primack, UCSC
(Director, UC-HiPACC)

The University of California
High-Performance AstroComputing Center
A consortium of nine UC campuses and three DOE laboratories

As computing and observational power continue to increase rapidly, the most difficult problems in astrophysics are now coming within reach of simulations based on solid physics, including the formation and evolution of stars, planets, and supermassive black holes, and their interactions with their galactic environments.

The purpose of HIPACC is to realize the full potential of the University of California's worldleading computational astrophysicists, including those at the affiliated national laboratories. HIPACC will do this by fostering their interaction with each other and with the rapidly increasing observational data, and by empowering them to utilize efficiently the new supercomputers with hundreds of thousands of processors both to understand astrophysical processes through simulation and to analyze the petabytes and soon exabytes of data that will flow from the new telescopes and supercomputers. This multidisciplinary effort links theoretical and observational astrophysicists, physicists, earth and planetary scientists, applied mathematicians, and computer scientists on all nine UC academic campuses and three national labs, and exploits California's leadership in computers and related fields.

HIPACC's outreach activities will include developing educational materials, publicity, and websites, and distribution of simulation outputs including visualizations that are beautiful as well as educational.

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High–Performance AstroComputing Center
A consortium of nine UC campuses and three DOE laboratories

UC-HiPACC Support: ~$350,000/yr from the University of California

UC-HiPACC Executive Committee

Director: Joel Primack (UCSC) <joel@ucsc.edu>
Coordinator from Northern California: Peter Nugent (LBNL)
Coordinator from Southern California: Michael Norman (UCSD)

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UC-HiPACC Staff

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Webmaster and Videographer: Eric Maciel <emaciel@ucsc.edu>

Funding Opportunities

Calls for proposals scheduled twice annually for Fall/Winter & Spring/Summer funding Cycles.

UC-HIPACC will support focused working groups of UC scientists from multiple campuses to pursue joint projects in computational astrophysics and related areas by providing funds for travel and lodging. At the heart of UC-HIPACC are working groups.

1. Small travel grants enable scientists, graduate students, and post-doctoral students to travel easily and spontaneously between Center nodes. UC-HIPACC will fund travel grant proposals submitted by faculty members, senior scientists, postdocs or graduate students up to $1000 on a first-come-first-served basis with a simple application describing the plan and purpose of the travel.

2. Grants ranging between $1000 - $5,000 to support larger working groups or participation in scientific meetings.

3. Mini Conference grants of up to $5,000 to support collaborations of multiple UC campuses and DOE labs.

4. Grants to faculty to support astrocomputing summer research projects by undergraduates.

5. Matching grants of up to $10,000 for astrocomputing equipment.

6. Innovative initiative proposals for other purposes that are consistent with the goals of UC-HIPACC. Such purposes could include meetings or workshops, software development, or education and outreach.

Annual Conferences in Northern and Southern California

HIPACC will sponsor two large meetings each year especially (but not exclusively) for scientists working on computational astrophysics and related topics at the UC campuses and labs. Unlike the more specialized meetings of working groups, we expect that these larger meetings will be broad, with the purpose of bringing theoretical astrophysicists together with computer science specialists, computer hardware experts, and observational astronomers. One meeting will be in northern California and the other in southern California to promote maximum participation. In addition to sharing new information, these meetings will highlight problems needing attention to advance the state-of-the-art and introduce participants to potential colleagues and begin collaborations.

Annual International AstroComputing Summer Schools

HIPACC will support an annual school aimed at graduate students and postdocs who are currently working in, or actively interested in doing research in, AstroComputing. Topics and locations of the annual school will rotate, and Caltech and Stanford are also welcome to participate.

The 2010 school was at UCSC, on the topic of Hydrodynamic Galaxy Simulations. Lectures were presented by experts on the leading codes (AMR codes ART, Enzo, and RAMSES, and SPH codes Arepo, GADGET, and Gasoline) and the Sunrise code for making realistic visualizations including stellar SED evolution and dust reprocessing. There were 60 students, including 20 from outside the USA. Lecture slides and videos, codes, inputs and outputs are on the UC-HIPACC website http://hipacc.ucsc.edu. Funding from NSF helped to support non-UC participant expenses.

The 2011 school was July 11-23 at UC Berkeley/LBNL/NERSC, on the topic of Computational Explosive Astrophysics: novae, SNe, GRB, and binary mergers. The scientific organizers were Daniel Kasen (LBNL/UCB) and Peter Nugent (LBNL). There was additional funding from DOE.

The 2012 school is at UC San Diego/SDSC, on AstroInformatics and Astrophysical Data Mining. The scientific director is Alex Szalay (Johns Hopkins) and the host is Michael Norman, director, SDSC. We have modest funding from DOE.

The 2013 school is at UCSC, on Star and Planet Formation, as you know, with no funds from NSF or DOE. The 2014 school will be at UC San Diego/SDSC, on nuclear astrophysics and supernovae.

Past UC-HiPACC Conferences & Workshops

- **June 14-16, 2012:** The Baryon Cycle, Beckman Center, Irvine, CA
- **August 8 - 12, 2011:** The 2011 Santa Cruz Galaxy Workshop, UC Santa Cruz
- **August 16 - 18, 2010:** The 2010 Santa Cruz Galaxy Workshop, UC Santa Cruz
- **December 16 & 17, 2010:** The Future of AstroComputing Conference, San Diego Supercomputer Center

- **June 24-27, 2012:** The Computational Astronomy Journalism Boot Camp
- **August 13-17, 2012:** The 2012 Santa Cruz Galaxy Workshop, UC Santa Cruz
- **August 17-20, 2012:** High-Resolution Galaxy Simulations Workshop

Upcoming UC-HiPACC Conferences & Workshops

- **August 12-15, 2013: The 2013 Santa Cruz Galaxy Workshop, UCSC**
- **August 16-19, 2013: AGORA Galaxy Simulation Workshop, UCSC**
- **February 12-14, 2014: Near-Field/Far-Field Cosmology, UC Irvine**

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The 2010 school was at UCSC, on the topic of Hydrodynamic Galaxy Simulations

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Announcing the 2011 UC-HIPACC International AstroComputing Summer School on Computational Explosive Astrophysics

Topics Include: supernovae, gamma-ray bursts, compact object mergers, energetic transients

Location: University of California, Berkeley/ Lawrence Berkeley National Lab/ National Energy Research Scientific Computing Center

Dates: July 18 – July 29, 2011

Organizers: Daniel Kasen & Peter Nugent (UCB/LBNL)

Description: The University of California High-Performance Astro-Computing Center (UC-HIPACC) is pleased to announce the continuation of its international summer school, to be held this year by UC Berkeley and LBNL from July 18-29, 2011. This year's summer school will focus on computational explosive astrophysics, including the modeling of core collapse and thermonuclear supernovae, gamma-ray bursts, neutron star mergers, and other energetic transients. Lectures will include instruction in the physics and numerical modeling of multi-dimensional hydrodynamics, general relativity, radiation transport, nuclear reaction networks, neutrino physics, and equations of state. Afternoon workshops will guide students in running and visualizing simulations on supercomputers using codes such as FLASH, CASTRO, GR1D and modules for nuclear burning and radiation transport. All students will be given accounts and computing time at NERSC and have access to the codes and test problems in order to gain hands on experience running simulations at a leading supercomputing facility.

http://hipacc.ucsc.edu/

UC-HiPACC 2012 International Summer School on AstroComputing students all got accounts on the new Gordon supercomputer at SDSC with 300 Tb of FLASH memory

Director: Alex Szaley, JHU
Host: Mike Norman, SDSC
HiPACC Director: Joel Primack

We will have ~37 students, 8 from UC, 19 from other US universities, and 10 from abroad.

UC-HiPACC & SDSC present:

AstroInformatics

The 2012 International Summer School on AstroComputing

July 9 - 20, 2012

San Diego Supercomputer Center
University of California, San Diego

http://hipacc.ucsc.edu/ISSAC2012.html

SDSC's Gordon Supercomputer. Photo: Alan Decker.

The data available to astronomers is growing exponentially. Large new instruments and new surveys are generating ever larger data sets, which are all publicly available. Supercomputer simulations are used by an increasingly wider community of astronomers. Many new observations are compared to and interpreted through the latest simulations. The Virtual Astronomical Observatory is creating a set of data-oriented services available to everyone. In this world, it is increasingly important to know how to deal with this data avalanche effectively, and perform the data analysis efficiently. The summer school will address this analysis challenge. The topics of the lectures will include how to bring observations and simulations to a common framework, how to query largedata-bases, how to do new types of on-line analyses and overall, how to deal with the large data challenge. The school will be hosted at the San Diego Supercomputer Center, whose data-intensive computing facilities, Including the new Gordon supercomputer with a third of a petabyte of flash storage, are among the best in the world. Special access to these resources will be provided by SDSC.

Director: Alex Szalay (Johns Hopkins University)

Speakers will include:

Main lecturers
Tamas Budavari (Johns Hopkins University)
Andy Connolly (University of Washington)
Darren Croton (Swinburne University)
Gerard Lemson (Max Planck Institute for Astrophysics)
Risa Wechsler (Stanford University)
Rick White (Space Telescope Science Institute)

Additional lecturers
Mike Norman (UCSD/SDSC)
Peter Nugent (LBNL / UC Berkeley)
Joel Primack (UCSC)
Alex Szalay (Johns Hopkins University)
Matt Turk (Columbia University)

Other Details

Housing: Students will be staying at Conference Housing near SDSC on the UCSD campus (approximately $50/night).
Registration for the summer school will be $300. Payment will be required at the time of acceptance.
Aid: UC-HiPACC will cover lodging and travel expenses for UC-affiliated students, and some financial assistance may be available for other students.

Apply by March 16, 2012. For more information and to apply: http://hipacc.ucsc.edu/ISSAC2012.html

UC-HiPACC 2013 International Summer School on Star and Planet Formation students all got accounts on UCSC's new Hyades astro-computer

Director: Mark Krumholz, UCS
HiPACC Director: Joel Primack

We have 48 students, more than half from abroad.

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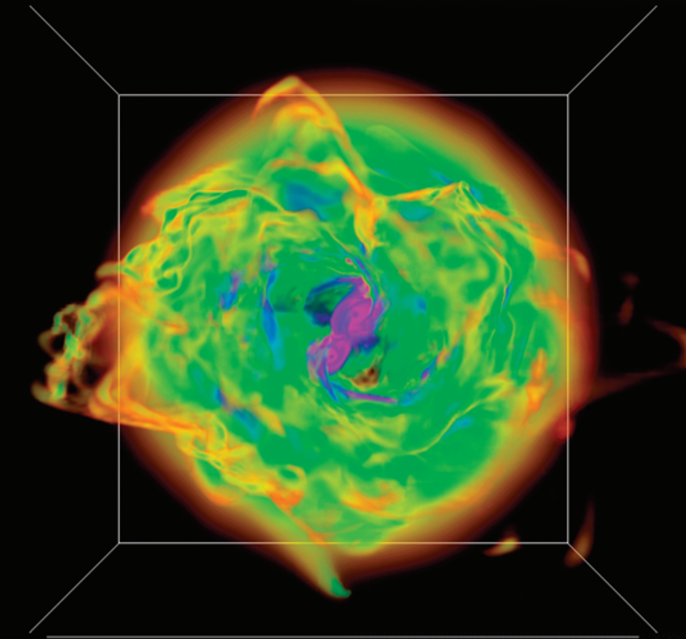
visit us on the web: **hipacc.ucsc.edu/ISSAC2013.html**

Description: Star and planet formation are central drivers in cosmic evolution: they control generation of radiation, synthesis of heavy elements, and development of potential sites for life. Because star and planet formation involve numerous physical processes operating over orders of magnitude in length and time scale, simulations have become essential to progress in the field. The objective of the 2013 UC-HiPACC AstroComputing Summer School is to train the next generation of researchers in the use of large-scale simulations in star and planet formation problems. The school will cover many of the major public codes in use today, including tutorials and hands-on experience running and analyzing simulations. Students will receive accounts on the new 3,000-core supercomputer Hyades on the UCSC campus for the duration of the school.



Volume rendering of the gas density in a simulation of the formation of a 70 Solar mass binary system. Krumholz

The school is directed by Prof. Mark Krumholz (UCSC), and is funded primarily by UC-HiPACC (Prof. Joel Primack, UCSC, Director). Additional funds are being sought from NSF for student support and from DOE for infrastructure support. Students will be housed on the UCSC campus (approximately $50/night). UC-HiPACC will cover lodging at UCSC for all accepted students and also travel for UC-affiliated students. Some financial assistance for travel may be available for other students.

Students must apply by filling in the online form at **http://hipacc.ucsc.edu/ISSAC2013_Application.php**

Applications are due March 16, 2013, although it may be possible to consider late applications. We aim to tell students who apply on time whether they are admitted by April 2, 2013. Upon acceptance, all students who plan to attend will pay a registration fee of $500. Weekday lunches, coffee breaks, the school banquet, and a special excursion will be provided for attendees.

Director: Mark Krumholz (UCSC)

Speakers and Topics will include:

Main lecturers
(5 lectures each and lead afternoon workshops):

Robi Banerjee (U. Hamburg, FLASH)
Paul Clark (U. Heidelberg, GADGET / SEREN)
Patrick Hennebelle (CEA/Saclay, RAMSES)
Stella Offner (Yale, RADMC / HYPERION / CASA)
Tom Quinn (U. Washington, GASOLINE / CHANGA)
Jim Stone (Princeton, ATHENA)

Additional Lecturers

Tom Abel (Stanford, first stars, ENZO)
Neal Evans (U. Texas Austin, observations of massive star formation)
Alyssa Goodman (Harvard, observations of low-mass star formation)
Phil Hopkins (Caltech, the IMF)
Meredith Hughes (Wesleyan, observations of protoplanetary disks)
Kaitlin Kratter (U. Colorado, binary formation)
Mark Krumholz (UC Santa Cruz, massive star formation)
Chris McKee (UC Berkeley, star formation rates)
Eve Ostriker (Princeton, the ISM/star formation connection)
Joel Primack (UC Santa Cruz, star formation and galaxy evolution)

APPLY BY MARCH 16, 2013. For updated information and to apply: http://hipacc.ucsc.edu/ISSAC2013.html

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Assembling Galaxies of Resolved Anatomy
AGORA High-Resolution Galaxy Simulation Comparison Project Steering Committee

Piero Madau & Joel R. Primack, UCSC, Co-Chairs
Tom Abel, Stanford
Nick Gnedin, Chicago/Fermilab
Lucio Mayer, University of Zurich
Romain Teyssier, Saclay & Zurich
James Wadsley, McMaster

Ji-hoon Kim, UCSC (Coordinator)

~90 astrophysicists using 9 codes have joined AGORA
Next meeting: after UCSC Galaxy Workshop Aug 16-19, 2013

www.AGORAsimulations.org

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High-Performance
AstroComputing Center
(UC-HiPACC)
Joel Primack, Director

University of California
Santa Cruz
Next Telescope Science
Institute (NEXSI)
Piero Madau, Director

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Key Earlier Galaxy Simulation Comparison

The Aquila comparison Project: The Effects of Feedback and Numerical Methods on Simulations of Galaxy Formation

C. Scannapieco,[1] M. Wadepuhl,[2] O.H. Parry,[3,4] J.F. Navarro,[5] A. Jenkins,[3] V. Springel,[6,7] R. Teyssier,[8,9] E. Carlson,[10] H.M.P. Couchman,[11] R.A. Crain,[12,13] C. Dalla Vecchia,[14] C.S. Frenk,[3] C. Kobayashi,[15,16] P. Monaco,[17,18] G. Murante,[17,19] T. Okamoto,[20] T. Quinn,[10] J. Schaye,[13] G. S. Stinson,[21] T. Theuns,[3,22] J. Wadsley,[11] S.D.M. White,[2] R. Woods[11]

2012 MNRAS 423, 1726

ABSTRACT

We compare the results of various cosmological gas-dynamical codes used to simulate the formation of a galaxy in the ΛCDM structure formation paradigm. **The various runs** (thirteen in total) differ in their numerical hydrodynamical treatment (SPH, moving-mesh and AMR) but **share the same initial conditions and adopt in each case their latest published model of gas cooling, star formation and feedback.** Despite the common halo assembly history, **we find large code-to-code variations in the stellar mass, size, morphology and gas content of the galaxy at z = 0, due mainly to the different implementations of star formation and feedback**. Compared with observation, **most codes tend to produce an overly massive galaxy, smaller and less gas-rich than typical spirals, with a massive bulge and a declining rotation curve**. A stellar disk is discernible in most simulations, although its prominence varies widely from code to code. There is a well-defined trend between the effects of feedback and the severity of the disagreement with observed spirals. In general, **models that are more effective at limiting the baryonic mass of the galaxy come closer to matching observed galaxy scaling laws, but often to the detriment of the disk component.** Although numerical convergence is not particularly good for any of the codes, our conclusions hold at two different numerical resolutions. Some differences can also be traced to the different numerical techniques; for example, more gas seems able to cool and become available for star formation in grid-based codes than in SPH. However, this effect is small compared to the variations induced by different feedback prescriptions. **We conclude that state-of-the-art simulations cannot yet uniquely predict the properties of the baryonic component of a galaxy, even when the assembly history of its host halo is fully specified. Developing feedback algorithms that can effectively regulate the mass of a galaxy without hindering the formation of high-angular momentum stellar disks remains a challenge.**

Aquila Comparison Project

Code	Reference	Type	UV background (z_{UV})	UV background (spectrum)	Cooling	Feedback
G3 (GADGET3)	[1]	SPH	6	[10]	primordial [13]	SN (thermal)
G3-BH	[1]	SPH	6	[10]	primordial [13]	SN (thermal), BH
G3-CR	[1]	SPH	6	[10]	primordial [13]	SN (thermal), BH, CR
G3-CS	[2]	SPH	6	[10]	metal-dependent [14]	SN (thermal)
G3-TO	[3]	SPH	9	[11]	element-by-element [15]	SN (thermal+kinetic)
G3-GIMIC	[4]	SPH	9	[11]	element-by-element [15]	SN (kinetic)
G3-MM	[5]	SPH	6	[10]	primordial [13]	SN (thermal)
G3-CK	[6]	SPH	6	[10]	metal-dependent [14]	SN (thermal)
GAS (GASOLINE)	[7]	SPH	10	[12]	metal-dependent [16]	SN (thermal)
R (RAMSES)	[8]	AMR	12	[10]	metal-dependent [14]	SN (thermal)
R-LSFE	[8]	AMR	12	[10]	metal-dependent [14]	SN (thermal)
R-AGN	[8]	AMR	12	[10]	metal-dependent [14]	SN (thermal), BH
AREPO	[9]	Moving Mesh	6	[10]	primordial [13]	SN (thermal)

All simulations share the same initial conditions a zoomed-in resimulation of the Aquarius Project halo “Aq-C”.

Code	f_b (Ω_b/Ω_m)	m_{DM} [$10^6 M_\odot$]	m_{gas} [$10^6 M_\odot$]	Softening $\epsilon_g^{z=0}$ [kpc]	z_{fix}
G3 G3-BH G3-CR G3-CS G3-CK Arepo	0.16	2.2 (17)	0.4 (3.3)	0.7 (1.4)	0 (0)
G3-TO G3-GIMIC	0.18	2.1 (17)	0.5 (3.7)	0.5 (1)	3 (3)
G3-MM	0.16	2.2 (17)	0.4 (3.3)	0.7 (1.4)	2 (2)
GAS	0.18	2.1 (17)	0.5 (3.7)	0.46 (0.9)	8 (8)
R R-LSFE R-AGN	0.16	1.4 (11)	0.2 (1.8)	0.26 (0.5)	9 (9)

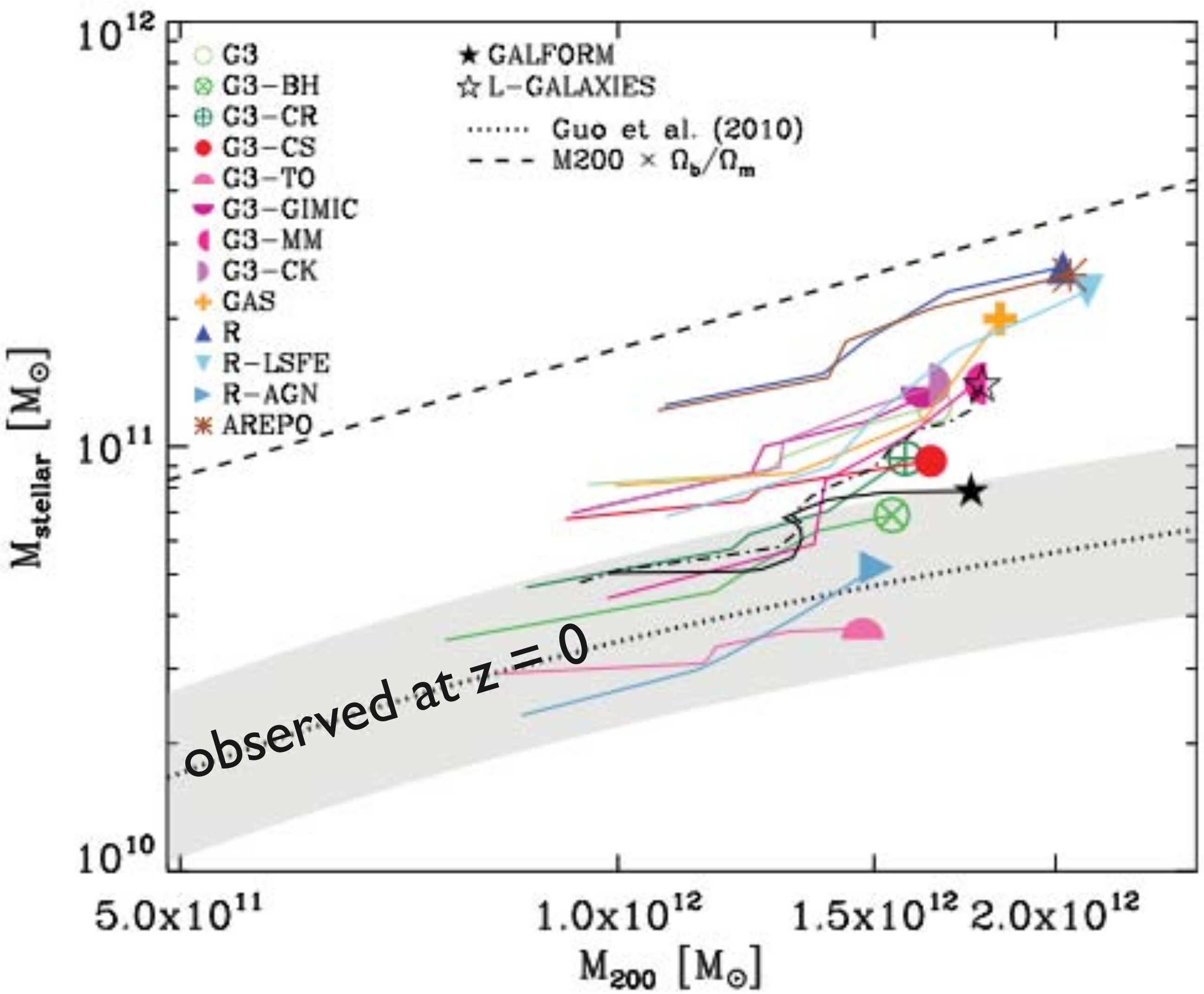
Most stars form in galactic disks, so realistic simulations should resolve disks. The scale height of the MWy disk is about 100 pc. It’s better yet to resolve GMCs, 10s of pc.

Softening is 500 pc or worse (fixed in comoving coordinates at $z = z_{fix}$).

Softening is 260 pc (fixed in comoving coordinates at $z_{fix} = 9$)

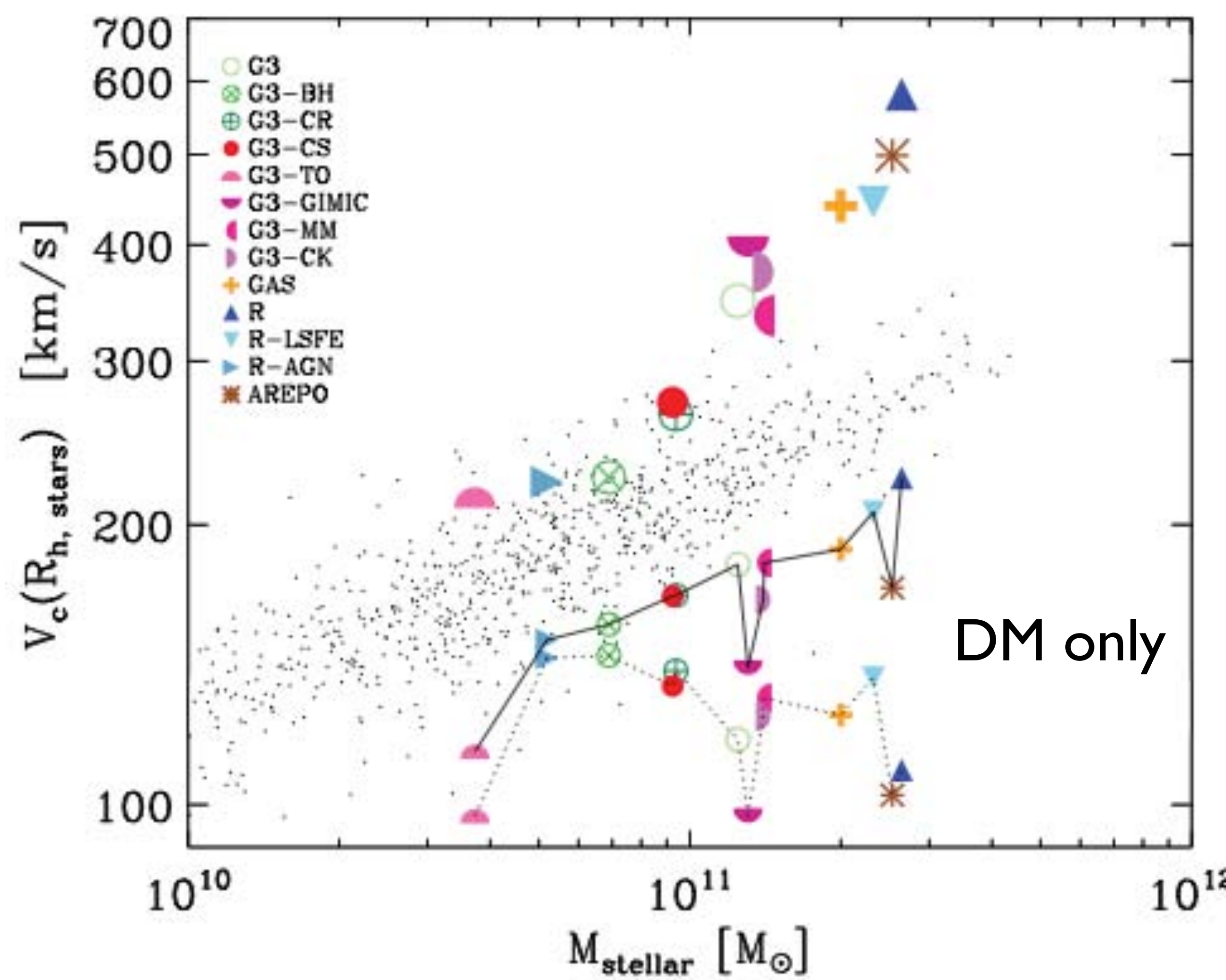
Aquila Comparison Project

$M_{stellar}$ vs M_{vir}



Curves track evolution *z* = 2 to 0.

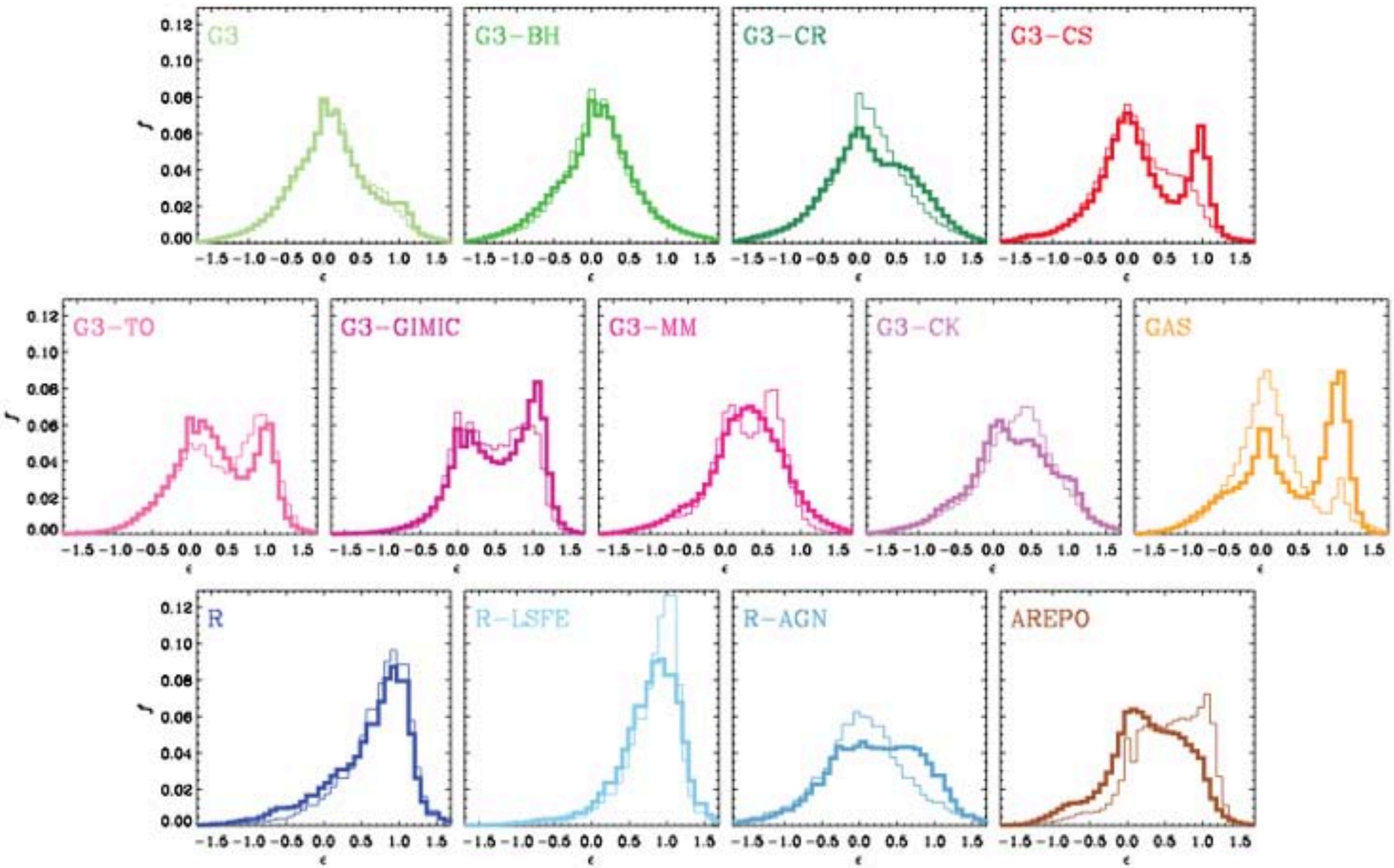
Tully-Fisher Relation

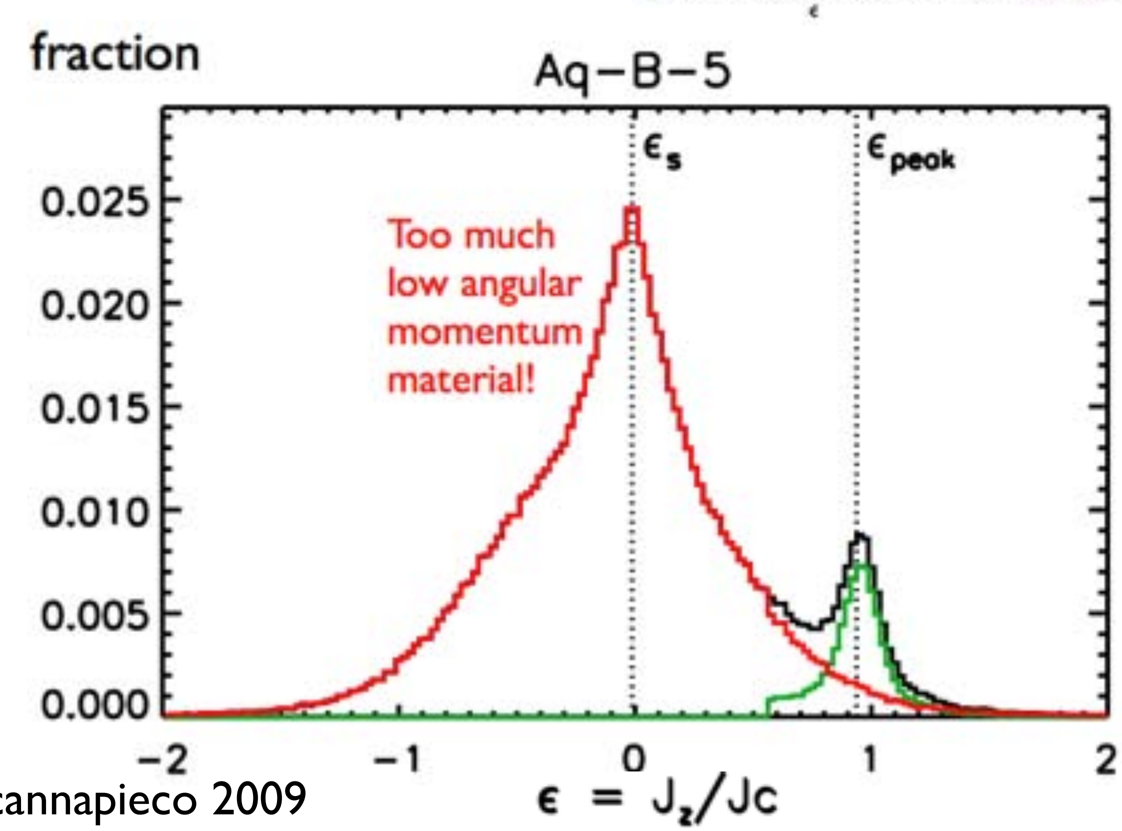


Circular velocity at stellar half-mass radius.

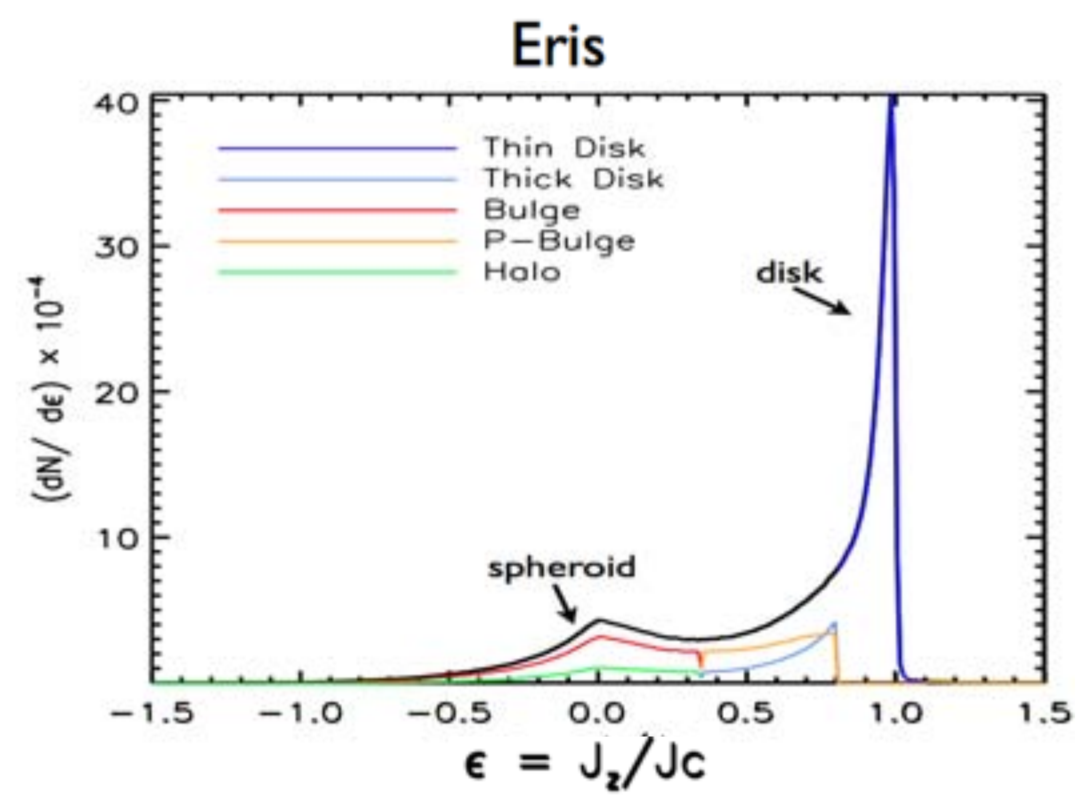
Aquila Comparison Project Stellar Circularities

$$\frac{j_z}{R\ V_{circ}(R)}$$





C. Scannapieco 2009



AGORA High-Resolution Simulation Comparison

AGORA Goals

(1) Inaugurate framework to compare high-resolution galaxy simulations (with resolution better than ~100 parsecs) across different high-resolution numerical platforms

(2) Establish cosmological and isolated disk initial conditions and shared astrophysics so each participating group can run a suite of simulations

(3) Maintain the collaboration online (telecon+webpage) between the in-person meetings

(4) Compare simulations with each other, with theory, and with observations

(5) Produce a set of simulation comparisons and scientific papers starting ~ 2014

AGORA Is Timely

We are launching this project at the time when several key technologies have just become available including

the **MUlti-Scale Initial Conditions generator (MUSIC)**,
the new **UV-background model CUBA,**
the new **Grackle hydro cooling code**,
several of the **simulation codes**, and
the **yt code for analyzing the outputs** from all the simulations in a parallel way.

This project will be state-of-the-art, and it will surely advance the entire field of galaxy simulations.

Project AGORA: High-resolution Galaxy Simulation Comparison

https://sites.google.com/site/santacruzcomparisonproject/

http://www.agorasimulations.org

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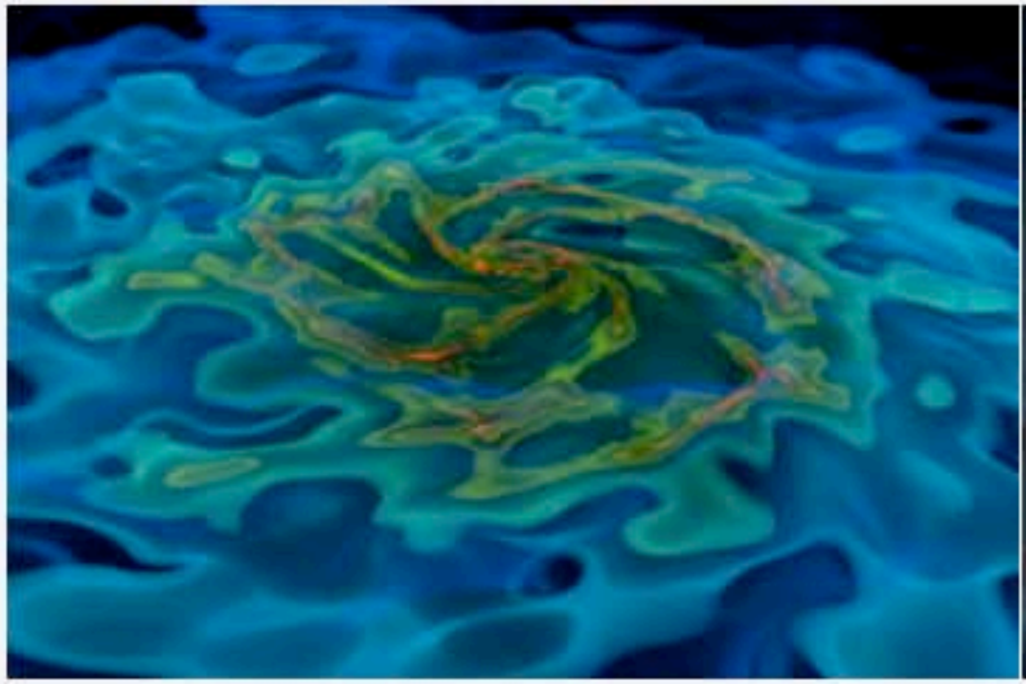

Welcome to Project AGORA: Assembling Galaxies Of Resolved Anatomy! We investigate galaxy formation with high-resolution numerical simulations and compare the results across different platforms and with observations. Learn what we plan to do by visiting Project Details. We welcome any group or persons who are interested in participating in the Project.

Project Announcements & News

Announcing 2nd AGORA Workshop (Aug. 16-19, 2013) We are pleased to announce that the 2nd Workshop of the AGORA Project will be held 16-19 August 2013 at the University of California, Santa Cruz. This workshop is ...

Posted May 21, 2013, 9:16 PM by Ji-hoon Kim

WGs I & IV Discussion Summary posted on the New Workspace Page for Rockstar+yt Thank you all very much for participating in the discussion on "Rockstar and YT in the AGORA Project". We had a very fruitful discussion on how to test the newest

AGORA High-Resolution Simulation Comparison

Initial Conditions for Simulations

MUSIC* galaxy masses at z~0: ~10^{10}, 10^{11}, 10^{12}, 10^{13} $M_\odot$

with both quiet and busy merging trees

isolation criteria agreed for Lagrangian regions

	Dwarf spheroidals	Dwarf-sized galaxies	MW-sized Galaxies	Ellipticals or Galaxy Groups
Halo virial mass at $z=0$	$\sim 10^{10}\,M_\odot$	$\sim 10^{11}\,M_\odot$	$\sim 10^{12}\,M_\odot$	$\sim 10^{13}\,M_\odot$
Maximum circular velocity	$\sim 30\,\mathrm{km\,s^{-1}}$	$\sim 90\,\mathrm{km\,s^{-1}}$	$\sim 160\,\mathrm{km\,s^{-1}}$	$\sim 250\,\mathrm{km\,s^{-1}}$
Selected merger histories	quiescent/violent at $z>0$	quiescent/violent at $z>0$	quiescent/violent at $z>0$	quiescent/violent at $z>2$

Isolated Spiral Galaxy at z~1: ~10^{12} $M_\odot$

	Dark matter halo	Stellar disk	Gas disk	Stellar bulge
Density profile	Navarro et al. (1997)	Exponential	Exponential	Hernquist (1990)
Physical properties	$v_{c,200}=150\,\mathrm{km\,s^{-1}}$, $M_{200}=1.074\times10^{12}\,M_\odot$, $r_{200}=205.4$ kpc, $c=10$, $\lambda=0.04$	$M_d=4.297\times10^{10}\,M_\odot$, $r_d=3.432$ kpc, $z_d=0.1\,r_d$	$f_{gas}=20\%$	bulge-to-disk mass ratio $B/D=0.1$
Number of particles	10^5 (low res.), 10^6 (medium), 10^7 (high)	10^5, 10^6, 10^7	10^5, 10^6, 10^7	1.25×10^4, 1.25×10^5, 1.25×10^6

* MUltiScale Initial Conditions Hahn & Abel (2011)

http://bitbucket.org/ohahn/music/

www.AGORAsimulations.org

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MUSIC galaxy masses at z~0: ~10^{10}, 10^{11}, 10^{12}, 10^{13} $M_{\odot}$

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Isolated Spiral Galaxy at z~1: ~10^{12} $M_{\odot}$

Astrophysics that all groups will include

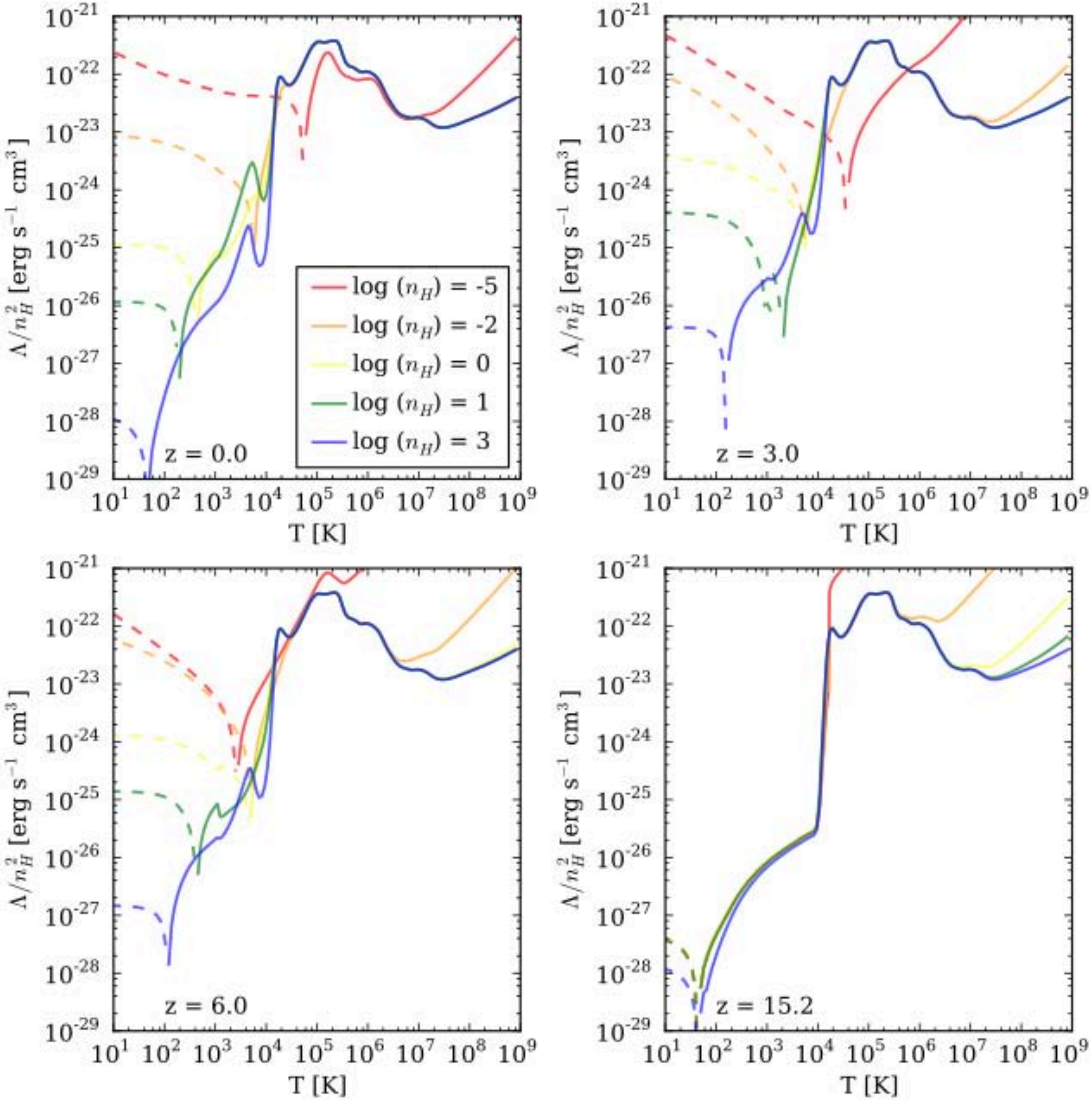
UV background (Haardt-Madau 2012)

cooling function (based on ENZO and Eris cooling)

www.AGORAsimulations.org

Gas cooling in the AGORA simulations

Equilibrium cooling rates normalized by n^2H calculated with the GRACKLE* cooling library for H number densities of 10^{-5} (red), 10^{-2} (orange), 1 (yellow), 10 (green), and 10^3 (blue) cm^{-3} at redshifts z = 0, 3, 6, and 15.2 (just before the UV background turns on) and solar metallicity gas. Solid lines denote net cooling and dashed lines denote net heating. The curves plotted are made with the non-equilibrium chemistry network of H, He, H_2, and HD with tabulated metal cooling assuming the presence of a UV metagalactic background from Haardt & Madau (2012).



* http://grackle.readthedocs.org

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Initial Conditions for Simulations

MUSIC galaxy masses at z~0: ~10^{10}, 10^{11}, 10^{12}, 10^{13} $M_\odot$

with both quiet and busy merging trees

isolation criteria agreed for Lagrangian regions

Isolated Spiral Galaxy at z~1, M ~ 10^{10}, 10^{11}, 10^{12} $M_\odot$

Astrophysics that all groups will include

UV background (Haardt-Madau 2012)

cooling function (based on ENZO and Eris cooling)

Tools to compare simulations based on *yt*, available for all codes used here (work in progress)

Images and SEDs for all timesteps from *yt* ➠ *Sunrise*

• **Data management:** Each participating codes will generate large quantities of unprocessed, intermediate data, in the form of "checkpoints" describing the state of the simulation at a given time. These outputs can be used both to restart the simulation and to conduct analysis. We plan to store 200 timesteps equally spaced in expansion parameter in addition to redshift snapshots at z = 6, 3, 2, 1, 0.5, 0.2, 0.0 at the very least. For many timesteps of simulations to be analyzed, central data repositories and post-processing compute time will be available at the San Diego Supercomputer Center at the University of California at San Diego, the new Hyades system at the University of California at Santa Cruz, and/or the Data-Scope system at the John Hopkins University. Additionally, we plan to reduce the barrier to entry for the simulation data by making a subset of derived data products available through a web interface.*

• **Public access:** One of the key objectives of the AGORA project is to help interpret the massive and rapidly increasing observational data on galaxy evolution being collected with increasing angular resolution at many different wavelengths by instruments on the ground and in space. We intend to make simulation results rapidly available to the entire community, placing computational outputs on data servers in formats that will enable easy comparisons with results from other simulations and with observations.

• **Multi-platform analysis:** the common analysis scripts can be applied to analyze outputs from grid codes and SPH codes. yt* will be used to access and analyze data from all of the simulation codes, enabling direct technology transfer between participants, ensuring reproducible scripts and results, and allowing for physically-motivated questions to be asked independent of the simulation platform.

*The first iteration of yt Data-Hub website is http://hub.yt-project.org/

www.AGORAsimulations.org

AGORA Task-Oriented Working Groups

	Working Group	Objectives and Tasks
T1	Common Astrophysics	UV background, metal-dependent cooling, IMF, metal yields
T2	ICs: Isolated	common initial conditions for isolated low-z disk galaxies
T3	ICs: Cosmological	common initial conditions for cosmological zoom-in simulations
T4	Common Analysis	support `yt` and other analysis tools, define quantitative and physically meaningful comparisons across simulations

AGORA Science Working Groups

	Working Group	Science Questions (includes, but not limited to)
S1	Isolated Galaxies and Subgrid Physics	tune the subgrid physics across platforms to produce similar results for similar astrophysical assumptions
S2	Dwarf Galaxies	simulate $\sim 10^{10} M_\odot$ halos, compare results across all platforms
S3	Dark Matter	radial profile, shape, substructure, core-cusp problem
S4	Satellite Galaxies	effects of environment, UV background, tidal disruption
S5	Galactic Characteristics	surface brightness, stellar properties, metallicity, images, SEDs
S6	Outflows	outflows, circumgalactic medium, metal absorption systems
S7	High-redshift Galaxies	cold flows, clumpiness, kinematics, Lyman-limit systems
S8	Interstellar Medium	galactic interstellar medium, thermodynamics
S9	Massive Black Holes	black hole growth and feedback in galactic context
S10	Lyα Absorption and Emission	prediction of Lyα maps for simulated galaxies and their environments including effects of radiative transfer

AGORA Task Oriented Working Groups

To successfully commence the project and ensure the consistent comparison across different codes, four task-oriented working groups are formed. Participants listed below are in an alphabetical order and will be regularly updated according to the most recent results of the sign-up.

(1) Working Group I - Common Physics and Introduction to Project

- Task: Provide a common physics package for cosmological simulations, write a flagship paper introducing the comparison project and its rationale
- Leader: **Piero Madau**
- Participants: Tom Abel, Greg Bryan, Daniel Ceverino, Nick Gnedin, Oliver Hahn, Cameron Hummels, Ji-hoon Kim, Andrey Kravtsov, Mike Kuhlen, Piero Madau, Lucio Mayer, Daisuke Nagai, Ken Nagamine, Jose Onorbe, Brian O'Shea, Joel Primack, Tom Quinn, Brant Robertson, Sijing Shen, Britton Smith, Romain Teyssier, Matthew Turk, James Wadsley, [to be added]
- Description: We will provide a package of common physics for cosmological simulations. Participants to the Project will agree to a minimal set of common input parameters, from the initial stellar mass function to the metal yield, and to the ionizing ultraviolet background. Gas cooling tables as a function of density, temperature, metallicity, and UV background (or redshift) will be provided over the next six weeks or so to all Project participants for code implementation. We also aim to reach the first milestone of this project by publishing a flagship paper on a proposed comparison, common physics, and common analysis, in early 2013. [authored by Piero Madau]

...

(4) Working Group IV - Common Analysis

- Task: Develop a pipeline for common data analysis, write a research article introducing such analysis
- Leader: **Matthew Turk**
- Participants: Nathan Goldbaum, Cameron Hummels, Chris Moody, Daisuke Nagai, Jose Onorbe, Joel Primack, Britton Smith, Robert Thompson, Matthew Turk, [to be added]
- Description: This working group will focus on defining repeatable, quantitative and physically-meaningful comparisons of simulation results. Additionally, tools will be identified and developed to support making these comparisons. [authored by Matthew Turk]

AGORA Science Working Groups

In order to achieve the astrophysics-based comparison of high-resolution galaxy formation simulations, nine science-oriented working groups are formed. Each working group consists of individual volunteers from interested codes. Each group aims to perform original research based on its code comparison, and to produce a standalone journal article. The group leader is responsible for making every effort to initiate and maintain the collaboration within the working group, online and offline. Participants listed below are in an alphabetical order and will be regularly updated according to the most recent results of the sign-up.

(1) Working Group V – Isolated Galaxies and Subgrid Physics

– Science Question: Common vs. favorite physics in isolated galaxy formation simulations
– Leader: **Oscar Agertz** and **Romain Teyssier** (co-leadership)
– Participants: Oscar Agertz, Samantha Benincasa, Daniel Ceverino, Ben Keller, Nick Gnedin, Nathan Goldbaum, Javiera Guedes, Alexander Hobbs, Phil Hopkins, Amit Kashi, Ji-hoon Kim, Andrey Kravtsov, Sam Leitner, Nir Mandelker, Lucio Mayer, Ken Nagamine, Brian O'Shea, Joel Primack, Tom Quinn, Justin Read, Rok Roskar, Wolfram Schmidt, Sijing Shen, Robert Thompson, Dylan Tweed, James Wadsley, [to be added]

(2) Working Group VI – Dwarf Galaxies in Cosmological Simulations

– Science Question: Simulate and compare a 10^{10} M_{sun} galactic halo across *all* participating codes
– Leader: **Jose Onorbe**
– Participants: Kenza Arraki, Greg Bryan, Javiera Guedes, Jason Jaacks, Dusan Keres, Ji-hoon Kim, Mike Kuhlen, Ken Nagamine, Jose Onorbe, Brian O'Shea, Joel Primack, Justin Read, Emilio Romano-Diaz, Sijing Shen, Christine Simpson, Matteo Tomassetti, Sebastian Trujillo-Gomez, Dylan Tweed, John Wise, Adi Zolotov, [to be added]

(3) Working Group VII – Dark Matter

– Science Question: Dark matter profile, distribution, substructure, core-cusp problem, triaxiality, etc.
– Leader: **Mike Kuhlen**
– Participants: Javiera Guedes, Mike Boylan-Kolchin, Mike Kuhlen, Piero Madau, Annalisa Pillepich, Joel Prima
Justin Read, Miguel Rocha, [to be added]

(4) Working Group VIII – Satellite Galaxies

– Science Question: Environmental effects, UV background, tidal disruption, too-big-to-fail, etc.
– Leader: **Adi Zolotov**
– Participants: Javiera Guedes, Mike Boylan-Kolchin, Mike Kuhlen, Piero Madau, Lucio Mayer, Annalisa Pillepich, Joel Primack, Justin Read, Miguel Rocha, Christine Simpson, Adi Zolotov, [to be added]

(5) Working Group IX – Characteristics of Cosmological Galaxies

– Science Question: Surface brightness, disks, bulges, stellar properties, metallicity, images and SEDs generated by SUNRISE/yt, etc.
– Leader: **Javiera Guedes** and **Cameron Hummels** (co-leadership)
– Participants: Oscar Agertz, Daniel Ceverino, Maria Emilia De Rossi, Javiera Guedes, Cameron Hummels, Jason Jaacks, Dusan Keres, Andrey Kravtsov, Sam Leitner, Lucio Mayer, Daisuke Nagai, Ken Nagamine, Brian O'Shea, Joel Primack, Justin Read, Brant Robertson, Emilio Romano-Diaz, Rok Roskar, Sijing Shen, Britton Smith, Robert Thompson, Matteo Tomassetti, [to be added]

(6) Working Group X – Outflows

– Science Question: Galactic outflows, circum-galactic medium, metal absorption systems, the effect of AGN feedback, etc.
– Leader: **Sijing Shen**
– Participants: Greg Bryan, Daniel Ceverino, Colin DeGraf, Michele Fumagalli, Javiera Guedes, Alexander Hobbs, Phil Hopkins, Cameron Hummels, Amit Kashi, Dusan Keres, Sam Leitner, Piero Madau, Ken Nagamine, Justin Read, Wolfram Schmidt, Sijing Shen, Britton Smith, James Wadsley, [to be added]

(7) Working Group XI – High-redshift Galaxies

– Science Question: Cold flows, clumpiness, kinematics, Lyman-limit systems, etc.
– Leader: **Daniel Ceverino**
– Participants: Oscar Agertz, Daniel Ceverino, Maria Emilia De Rossi, Jan Engels, Michele Fumagalli, Nick Gnedin, Javiera Guedes, Jason Jaacks, Dusan Keres, Andrey Kravtsov, Mike Kuhlen, Sam Leitner, Piero Madau, Ken Nagamine, Brian O'Shea, Joel Primack, Brant Robertson, Emilio Romano-Diaz, Sijing Shen, Robert Thompson, Matteo Tomassetti, John Wise, [to be added]

(8) Working Group XII - Interstellar Medium

- Science Question: Interstellar medium, thermodynamics, etc.
- Leader: **Sam Leitner**
- Participants: Oscar Agertz, Daniel Ceverino, Charlotte Christensen, Nick Gnedin, Nathan Goldbaum, Cameron Hummels, Amit Kashi, Dusan Keres, Andrey Kravtsov, Sam Leitner, Piero Madau, Lucio Mayer, Ken Nagamine, Brian O'Shea, Brant Robertson, Emilio Romano-Diaz, Sijing Shen, Robert Thompson, Matteo Tomassetti, James Wadsley, [to be added]

(9) Working Group XIII - Black Hole Accretion and Feedback

- Science Question: Effect of black hole feeding and feedback on the evolution of galaxies (isolated and cosmological) across participating codes, etc.
- Leader: **Alexander Hobbs**
- Participants: Colin DeGraf, Alexander Hobbs, Phil Hopkins, Amit Kashi, Ben Keller, Lucio Mayer, Daisuke Nagai, Brian O'Shea, Justin Read, Romain Teyssier, [to be added]

(10) Tentative Working Group XIV - Lyman alpha absorption and emission

- Science Question: Lyman alpha absorption and emission predicted for simulated galaxies and their environments across participating codes including effects of radiative transfer, including associated metal lines, etc.
- Leader: Michele Fumagalli and Sebastiano Cantalupo (?)
- Participants: [to be added]

(11) Additional Working Groups - to be organized as needed

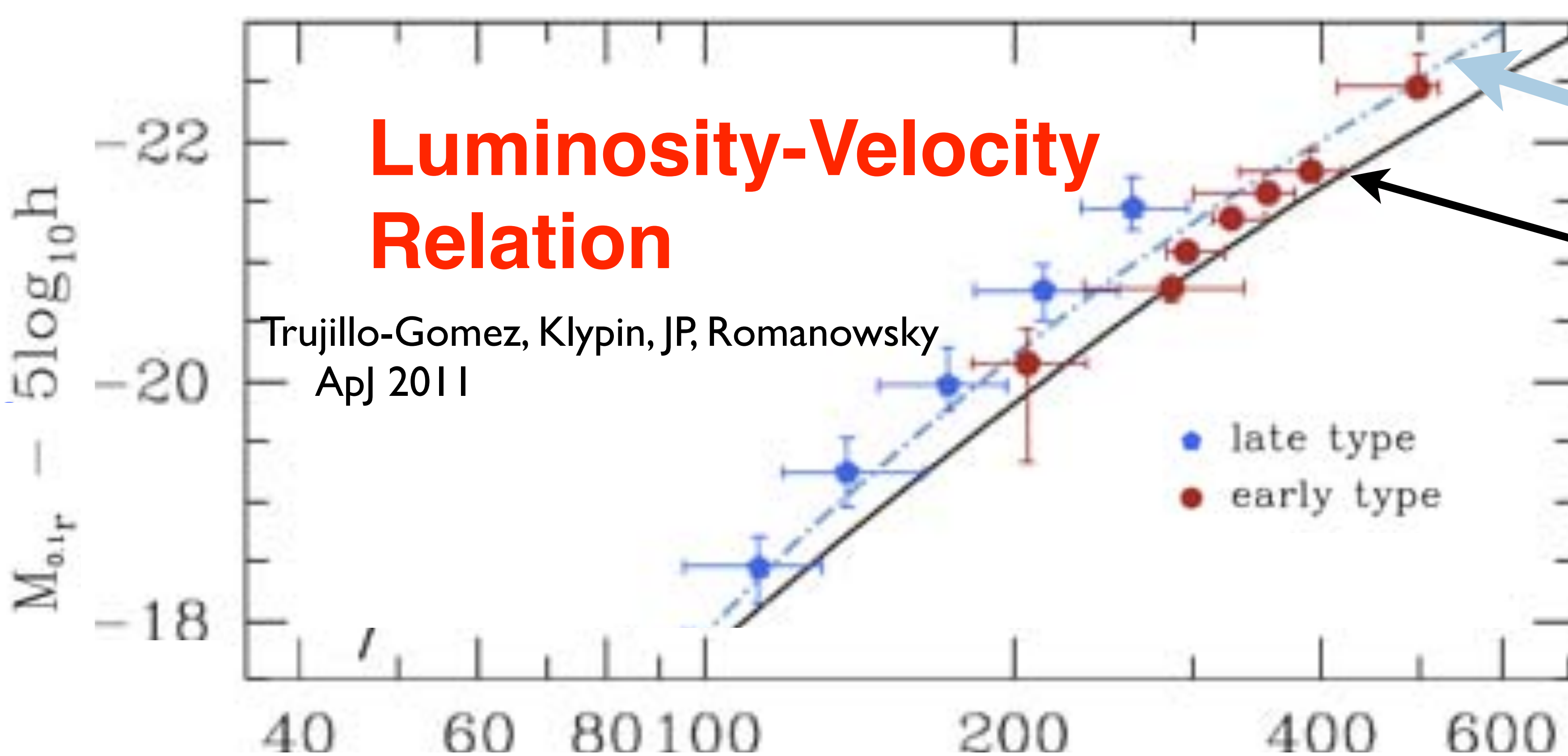
Online Collaboration

The leader of each working group is in charge of organizing the online collaboration via Google Sites, Skype, EVO-SeeVogh, etc. **One possible option is the newly-designed "Workspace" page on Google Sites.** In the new Workspace, each working group has its own page, and every registered collaboration member is granted a full access to read and write. This page may be used as a simplest option to share the data.

Examples of galaxy issues to be addressed by AGORA

- Feedback from SF and AGN - effects of different recipes, comparisons with observations such as SF efficiency, high-velocity outflows, clumps
- How to solve the too-high SF at high z in intermediate-mass galaxies?
- What quenches star formation in galaxies above a characteristic central density? Radio-mode FB? Cutoff of cold flows above M_{halo}~10^{12} $M_{\odot}$? Environmental effects (satellite quenching, halo quenching)?
- Angular momentum differences between DM and gas, especially after cooling and SF/FB are included?
- Producing as many bulgeless disk galaxies as observed?
- Effects of baryons on dwarf galaxies: core/cusp? TBTF problem?
- Why is Adiabatic Contraction important for EarlyTypeGs but not Spirals?

Maybe not even ETGs with bottom-heavy IMF



median Vcirc without AC

median Vcirc with AC

"AC" = Adiabatic Contraction of dark matter halos when baryons cool & condense to halo centers, following Blumenthal, Faber, Flores, & Primack 1986

Examples of galaxy issues to be addressed by AGORA

- Feedback from SF and AGN - effects of different recipes, comparisons with observations such as SF efficiency, high-velocity outflows, **clumps**

Observations show that about half of all star-forming galaxies at z = 1 - 2 are **clumpy**

Most stars form in galactic disks, but 2/3 to 3/4 of stars today are in spheroids. High-resolution ΛCDM simulations such as Bolshoi show that there are not nearly enough major mergers to produce the observed intermediate-mass spheroids. But semi-analytic models (SAMs) find that including violent disk instability (VDI) creating **clumps** that migrate to the galactic centers produces the observed abundance and properties of spheroids (Lauren Porter, Rachel Somerville, JP 2013).

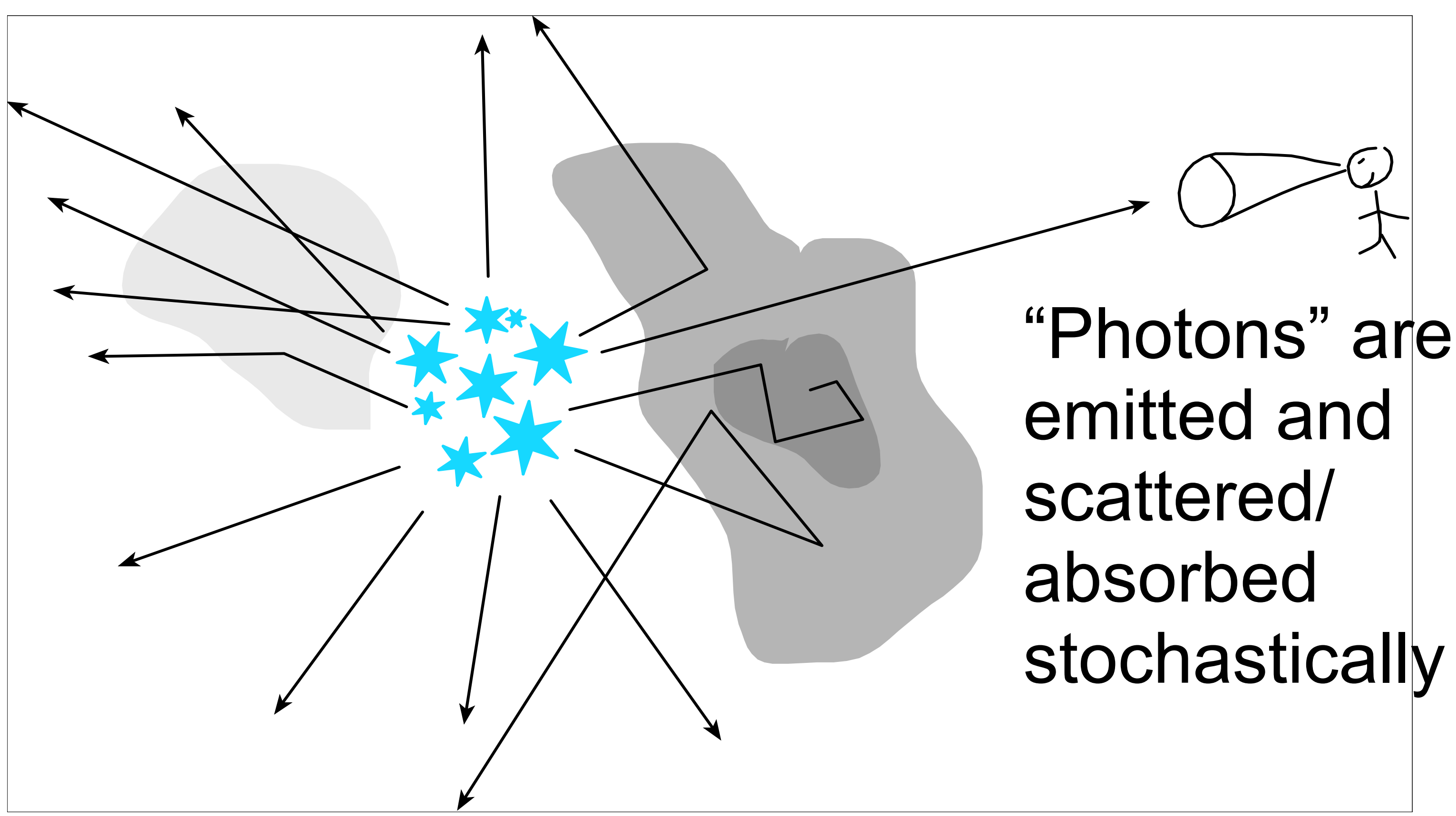
The next several slides show how we create realistic images using our *Sunrise* code and how we are comparising simulations and SAMs with CANDELS observations...

Sunrise Radiative Transfer Code

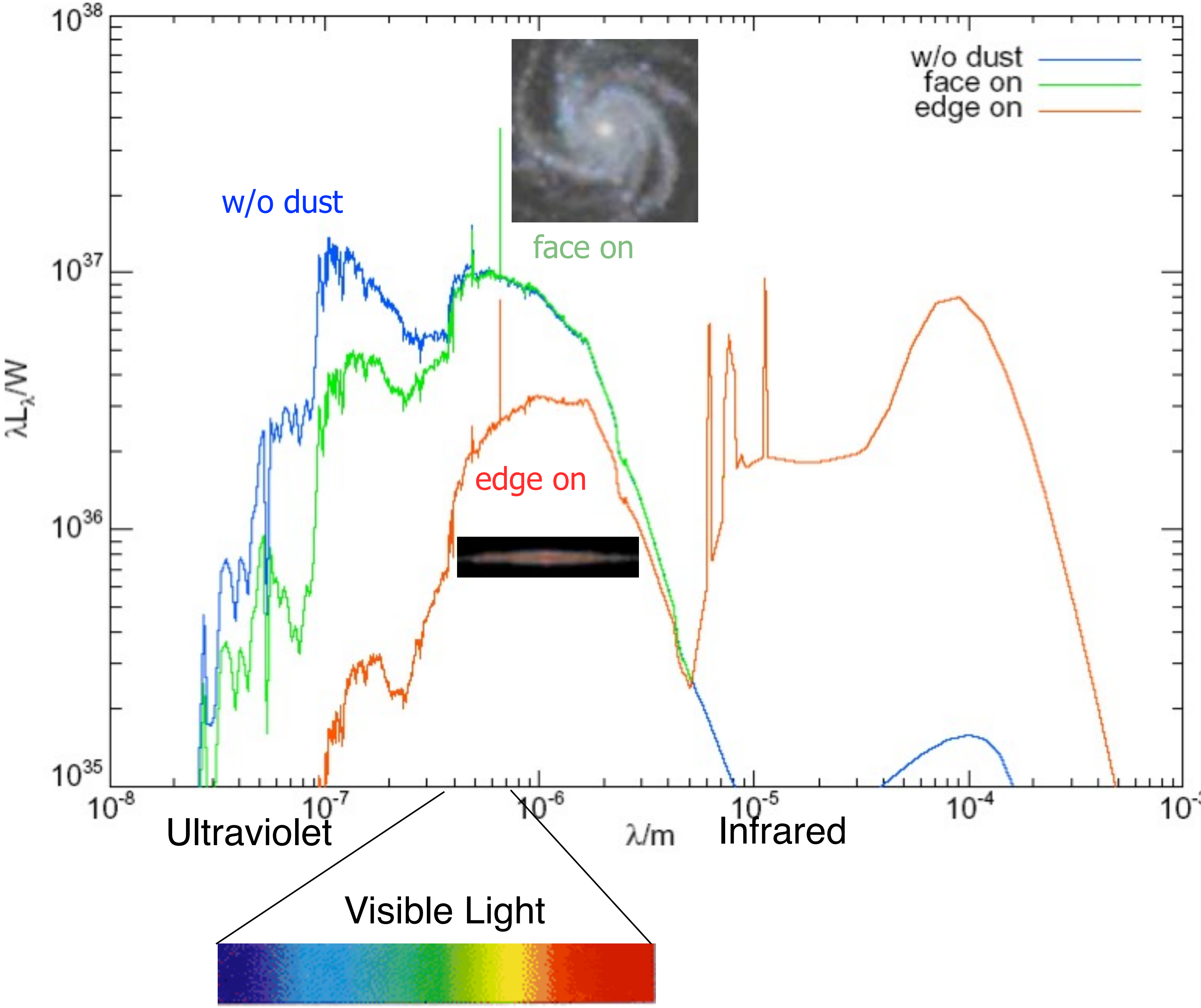
Patrik Jonsson
& Joel Primack

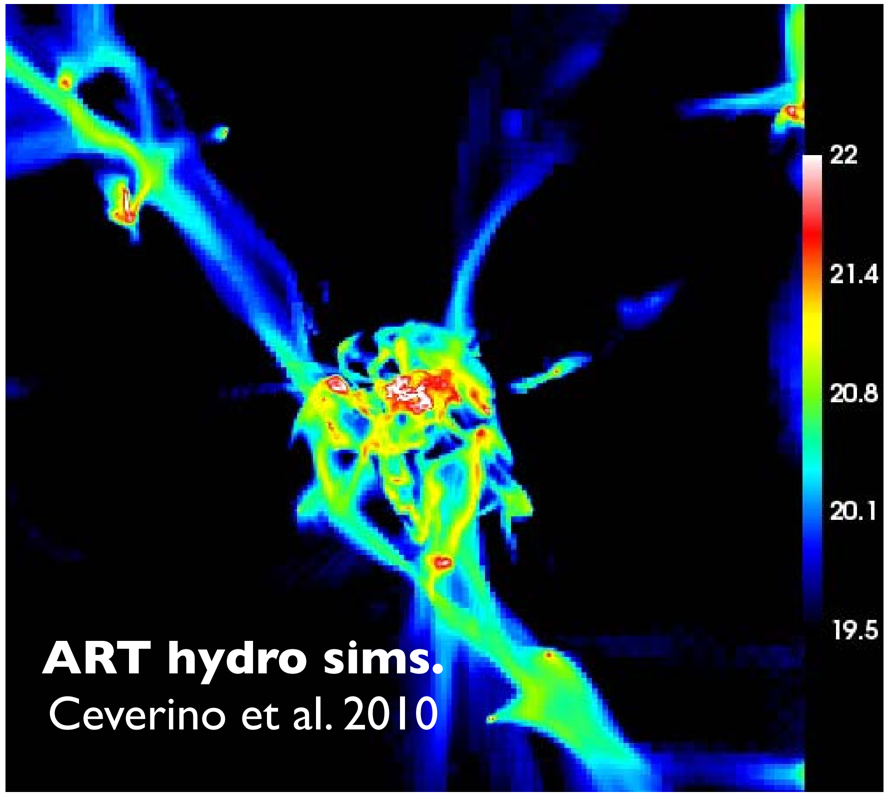
For every simulation snapshot:

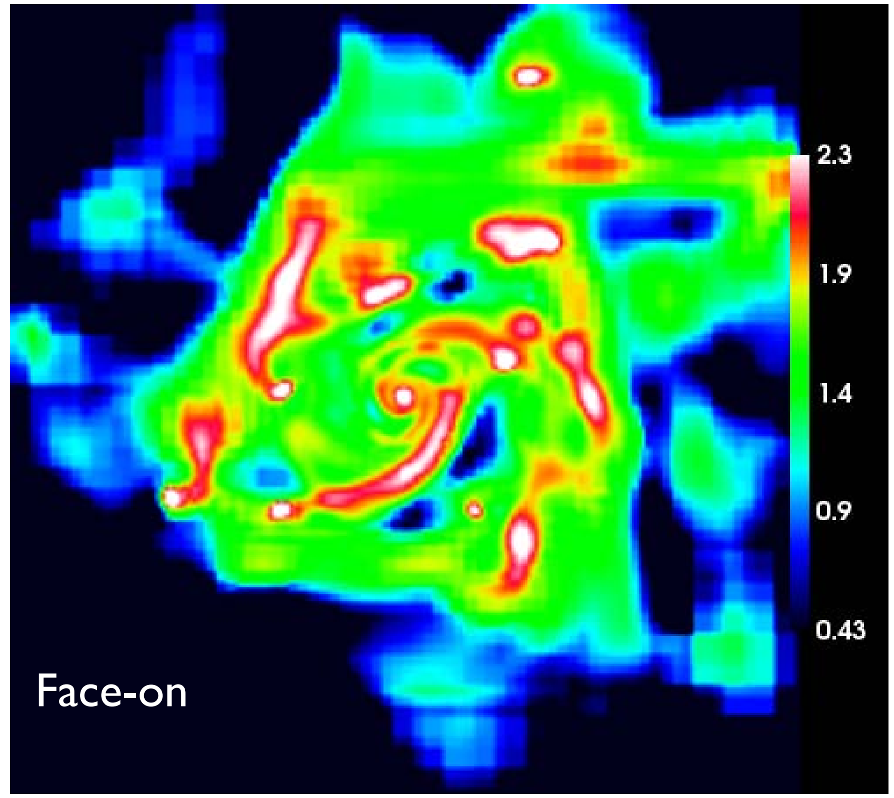
- Evolving stellar spectra calculation
- Adaptive grid construction
- Monte Carlo radiative transfer
- “Polychromatic” rays save 100x CPU time
- Graphic Processor Units give 10x speedup

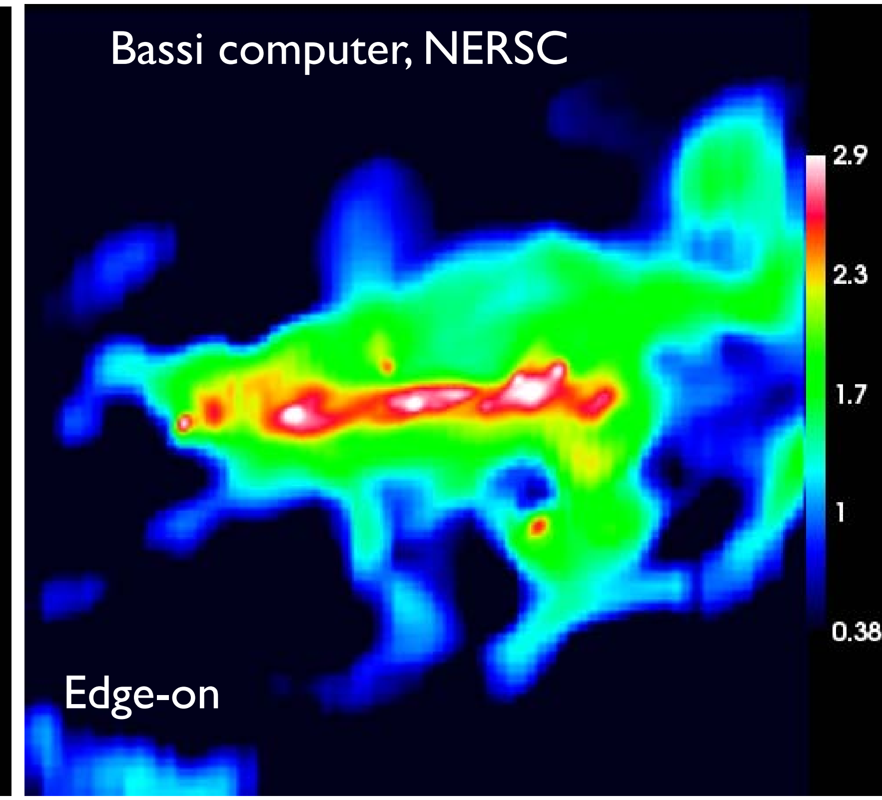


Spectral Energy Distribution

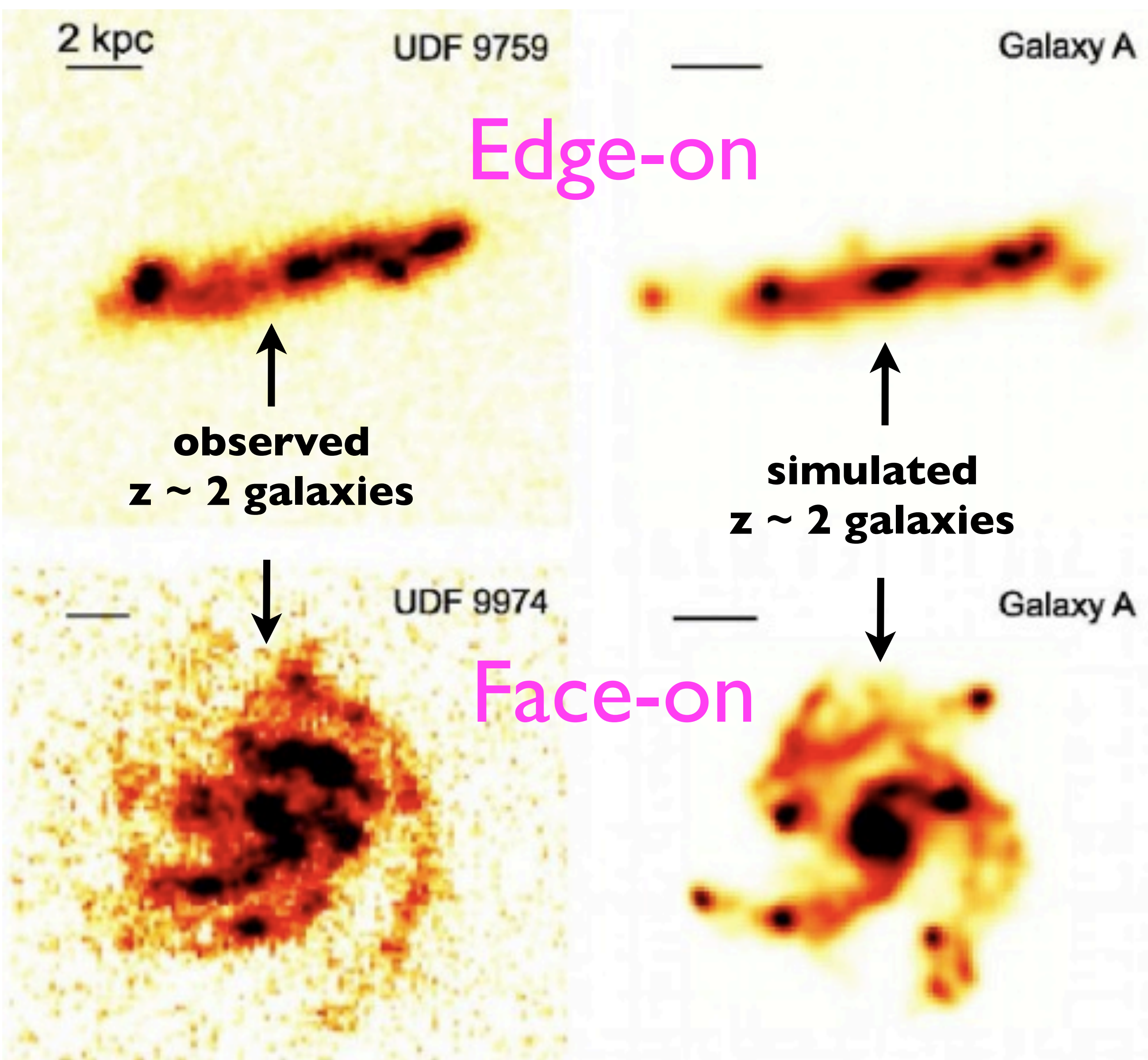




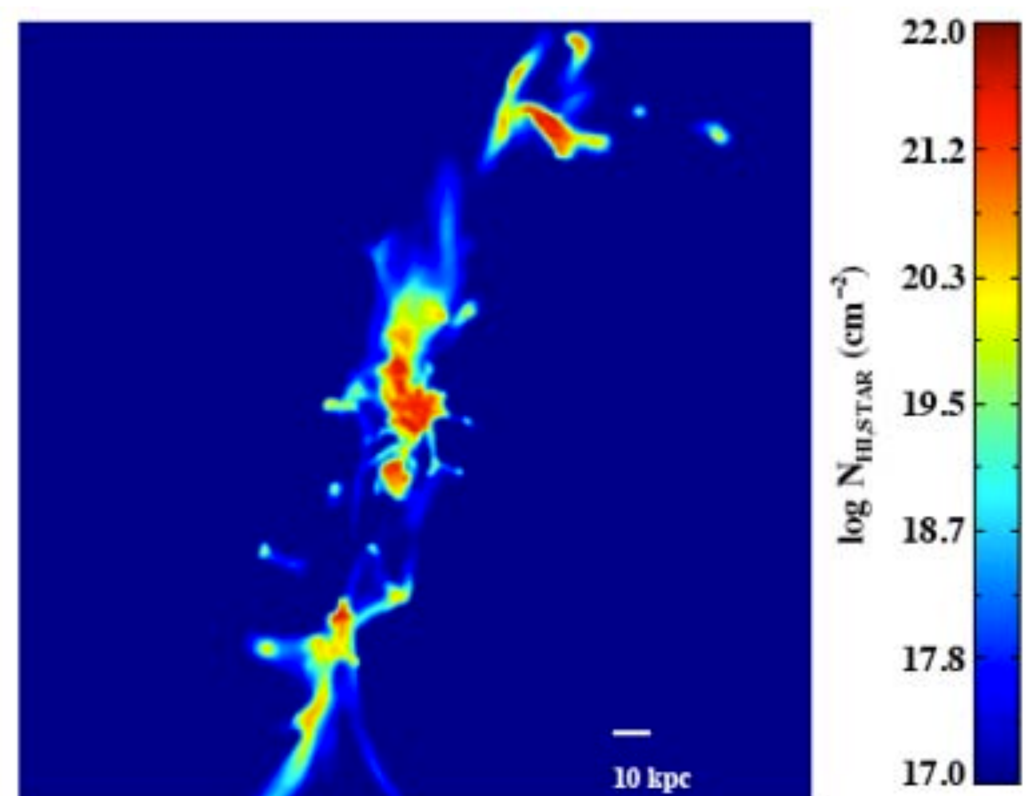




now running on NERSC Hopper-II
and NASA Ames Pleiades supercomputers

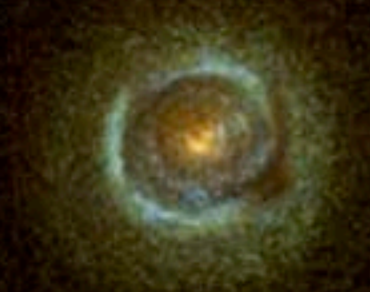


Ly alpha blobs from same simulation



Fumagalli, Prochaska, Kasen, Dekel, Ceverino, & Primack 2011

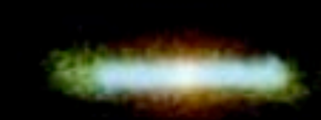
What’s the effect of including dust?



with
dust

Dramatic effects on
-Appearance
-Half-mass radii (bigger with dust)
-Sersic index (lower with dust)

stars
only



cemoody.imgur.com

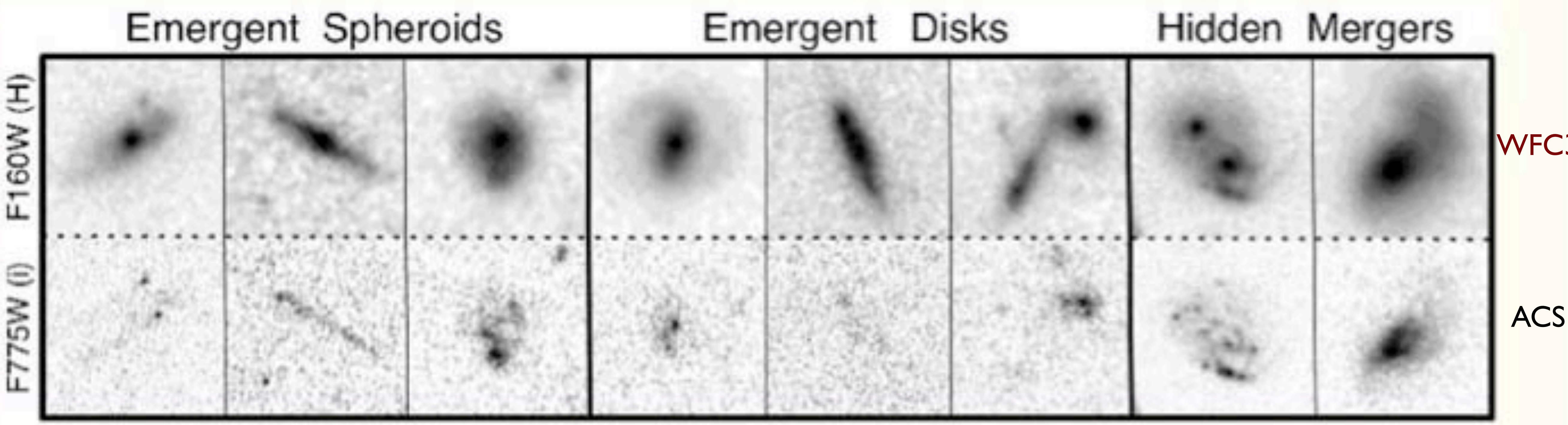
Ceverino+ VL6 Cosmological Zoom-in Simulation

Face-On | Edge-On

Chris Moody

The CANDELS Survey with new near-ir camera WFC3

GALAXIES ~10 BILLION YEARS AGO



CANDELS makes use of the near-infrared WFC3 camera (top row) and the visible-light ACS camera (bottom row). Using these two cameras, CANDELS will reveal new details of the distant Universe and test the reality of cosmic dark energy.

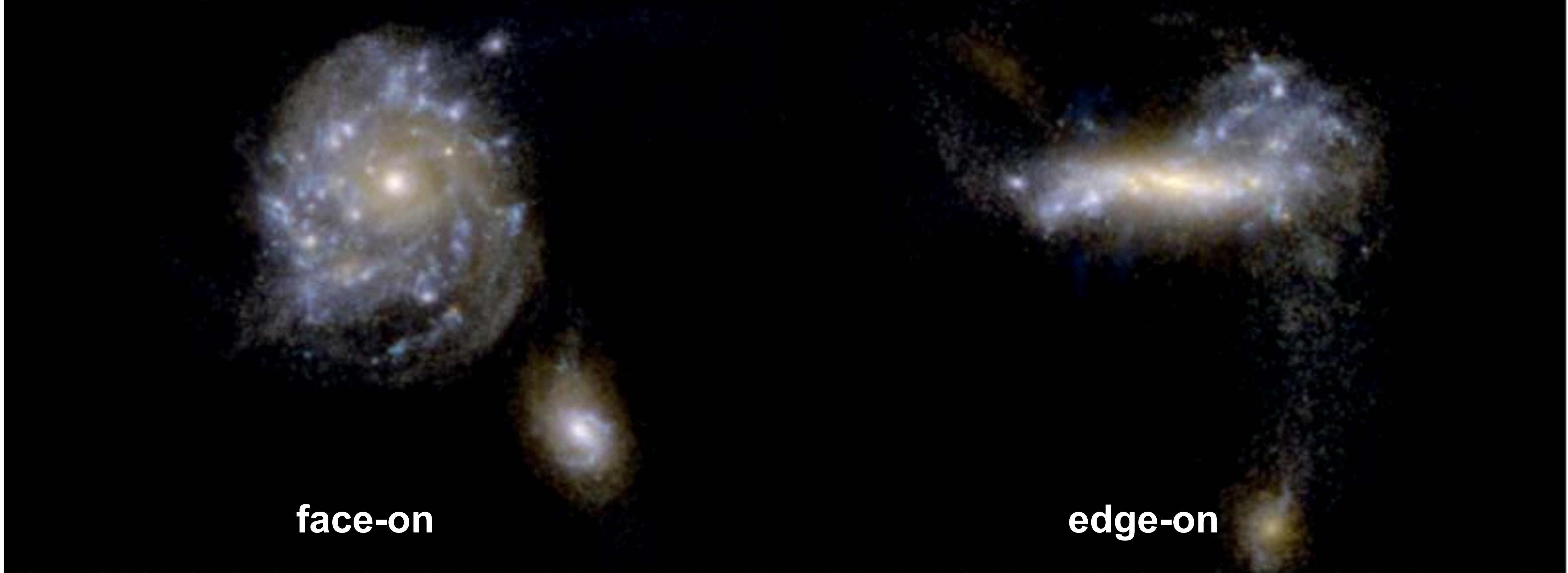
http://candels.ucolick.org

CANDELS is a powerful imaging survey of the distant Universe being carried out with two cameras on board the Hubble Space Telescope.

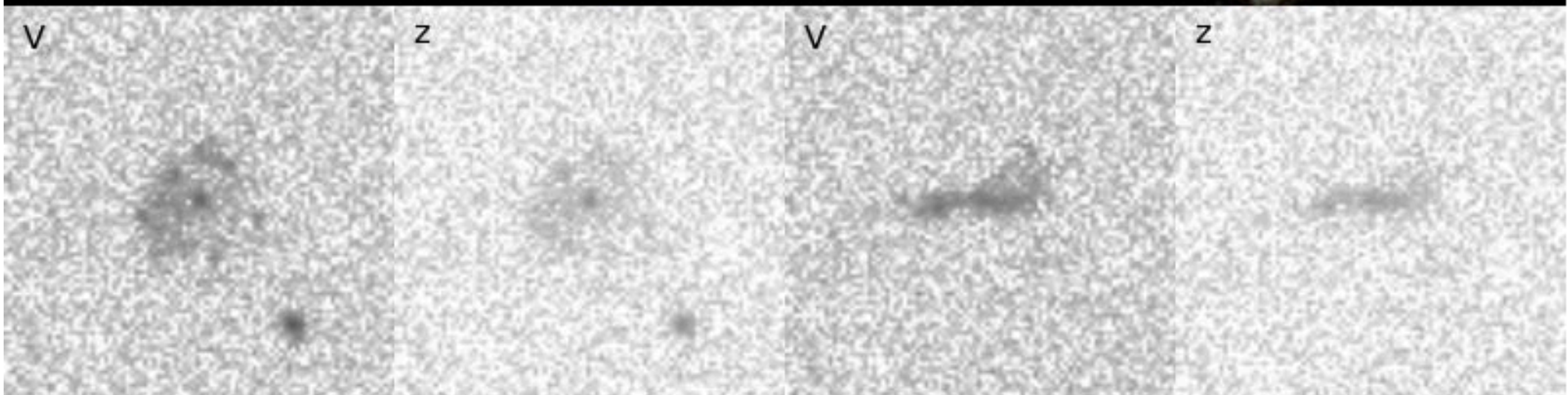
- CANDELS is the largest project in the history of Hubble, with 902 assigned orbits of observing time. This is the equivalent of four months of Hubble time if executed consecutively, but in practice CANDELS will take three years to complete (2010-2013).
- The core of CANDELS is the revolutionary near-infrared WFC3 camera, installed on Hubble in May 2009. WFC3 is sensitive to longer, redder wavelengths, which permits it to follow the stretching of lightwaves caused by the expanding Universe. This enables CANDELS to detect and measure objects much farther out in space and nearer to the Big Bang than before. CANDELS also uses the visible-light ACS camera, and together the two cameras give unprecedented panchromatic coverage of galaxies from optical wavelengths to the near-IR.

Simulated Galaxy 10 billion years ago

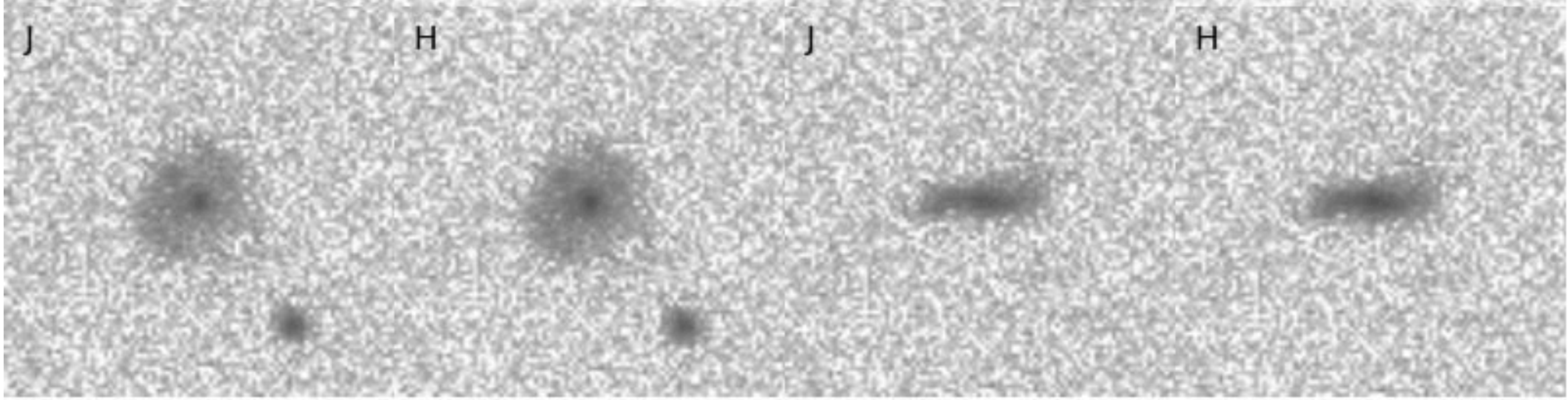
as it would appear nearby to our eyes



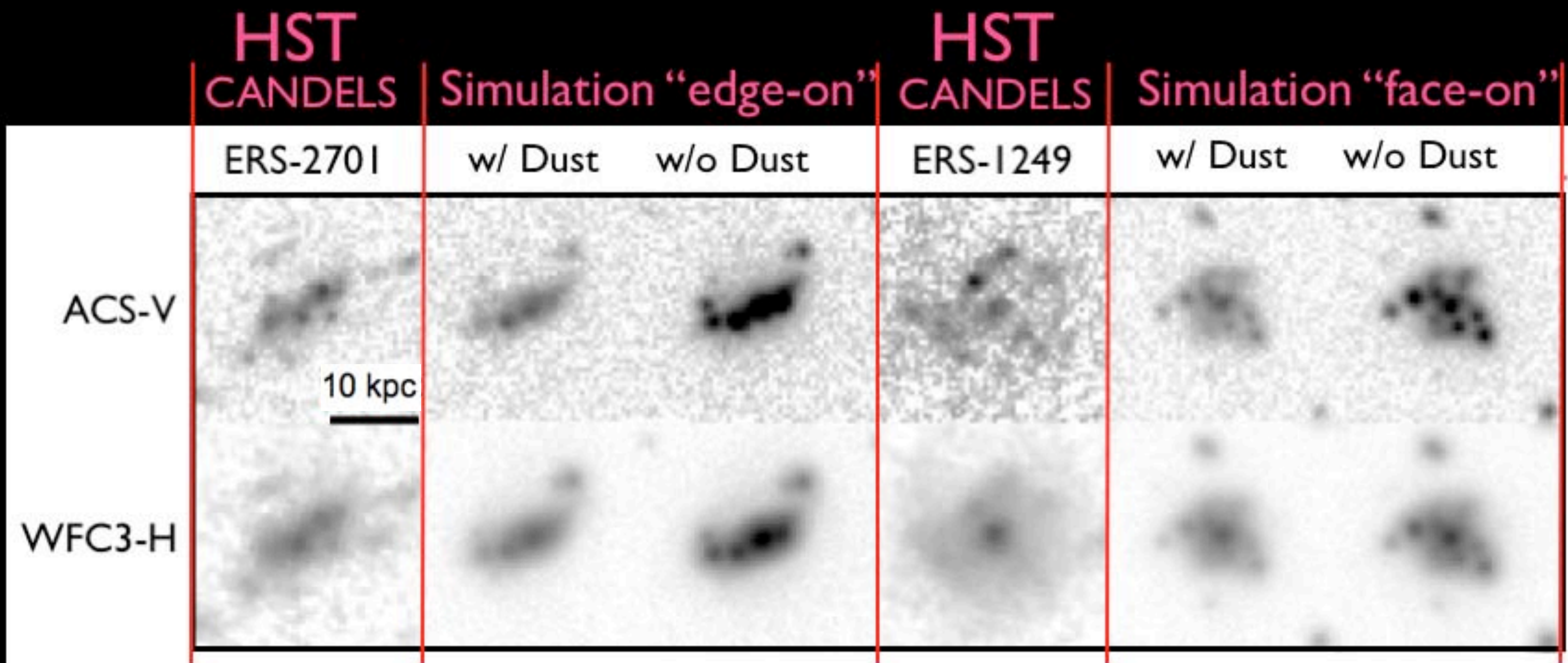
as it would appear to Hubble's ACS visual camera



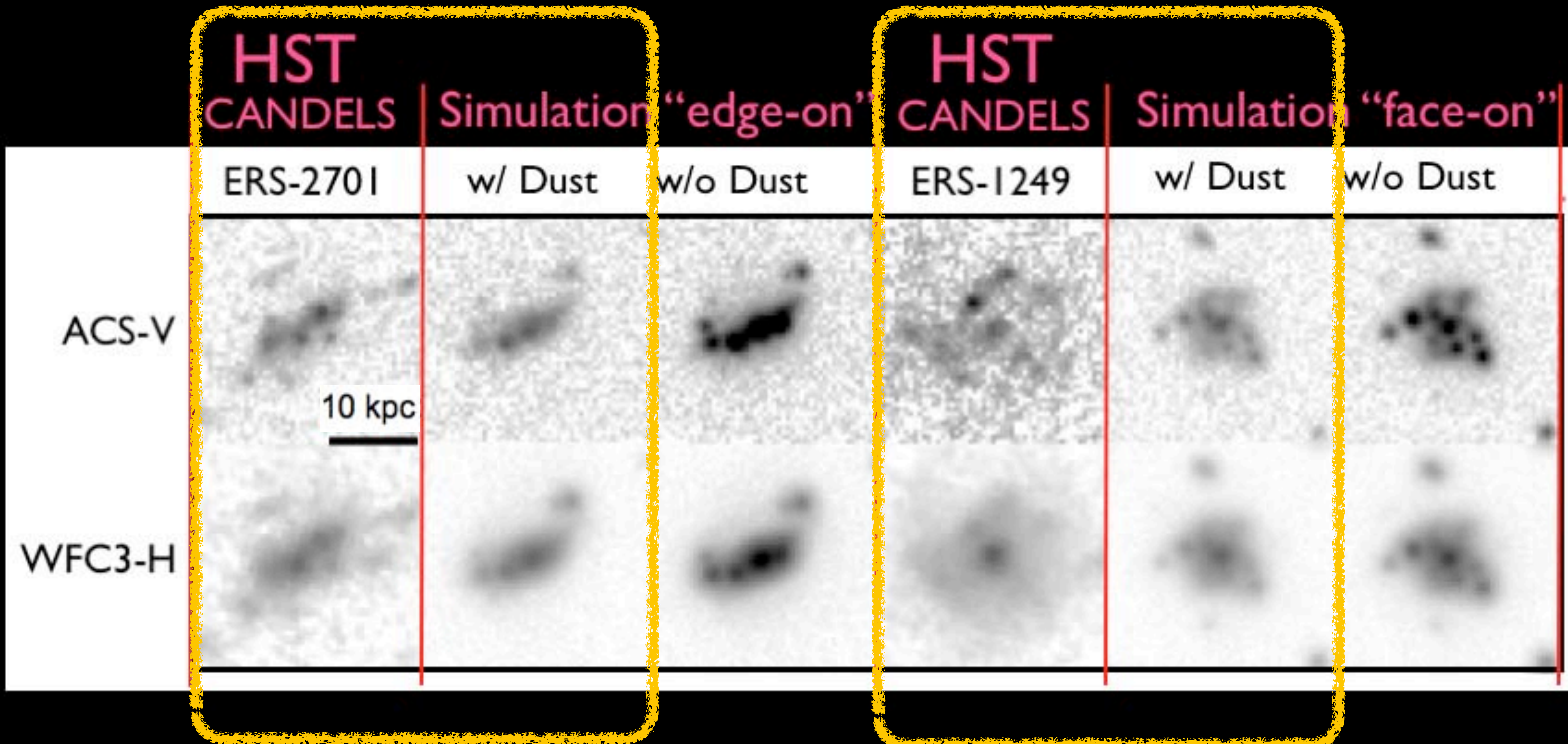
as it would appear to Hubble's new WFC3 infrared camera



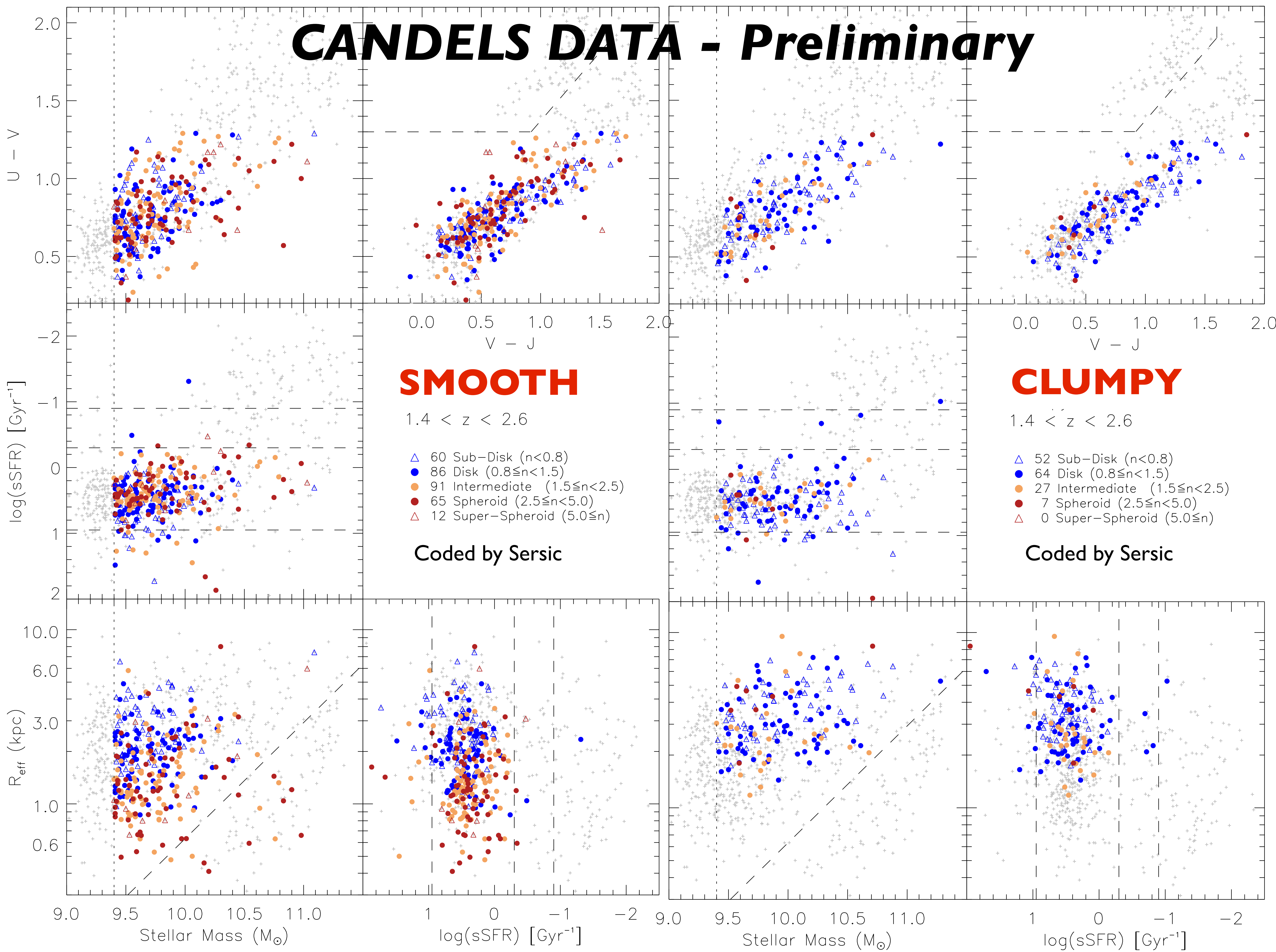
Our Simulations w/ Dust look a lot like galaxies from 10 billion years ago that we see with Hubble Space Telescope



Our Simulations w/ Dust look a lot like galaxies from 10 billion years ago that we see with Hubble Space Telescope

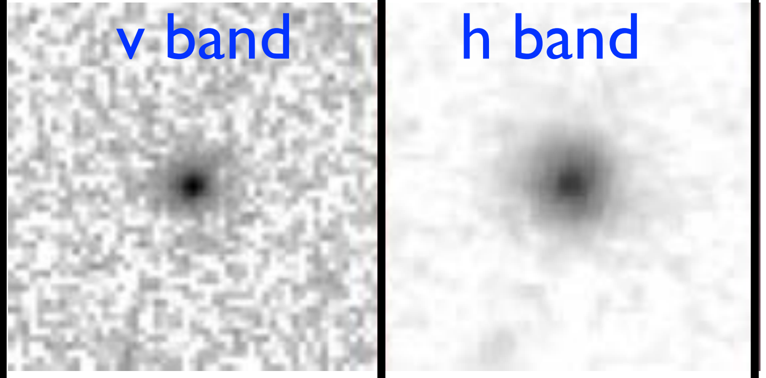


We are now systematically comparing simulated and observed galaxy images

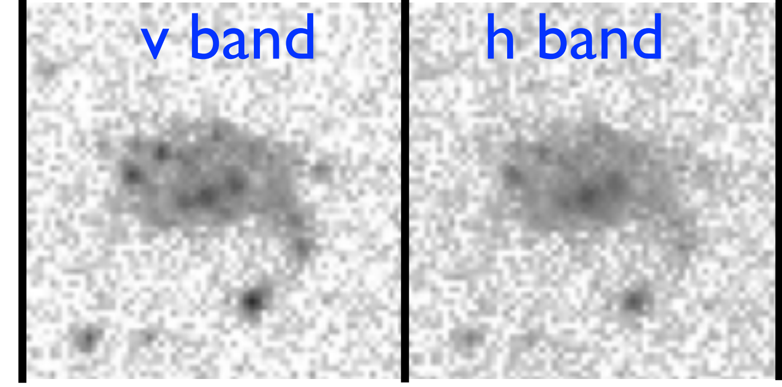


Tuesday, July 23, 13

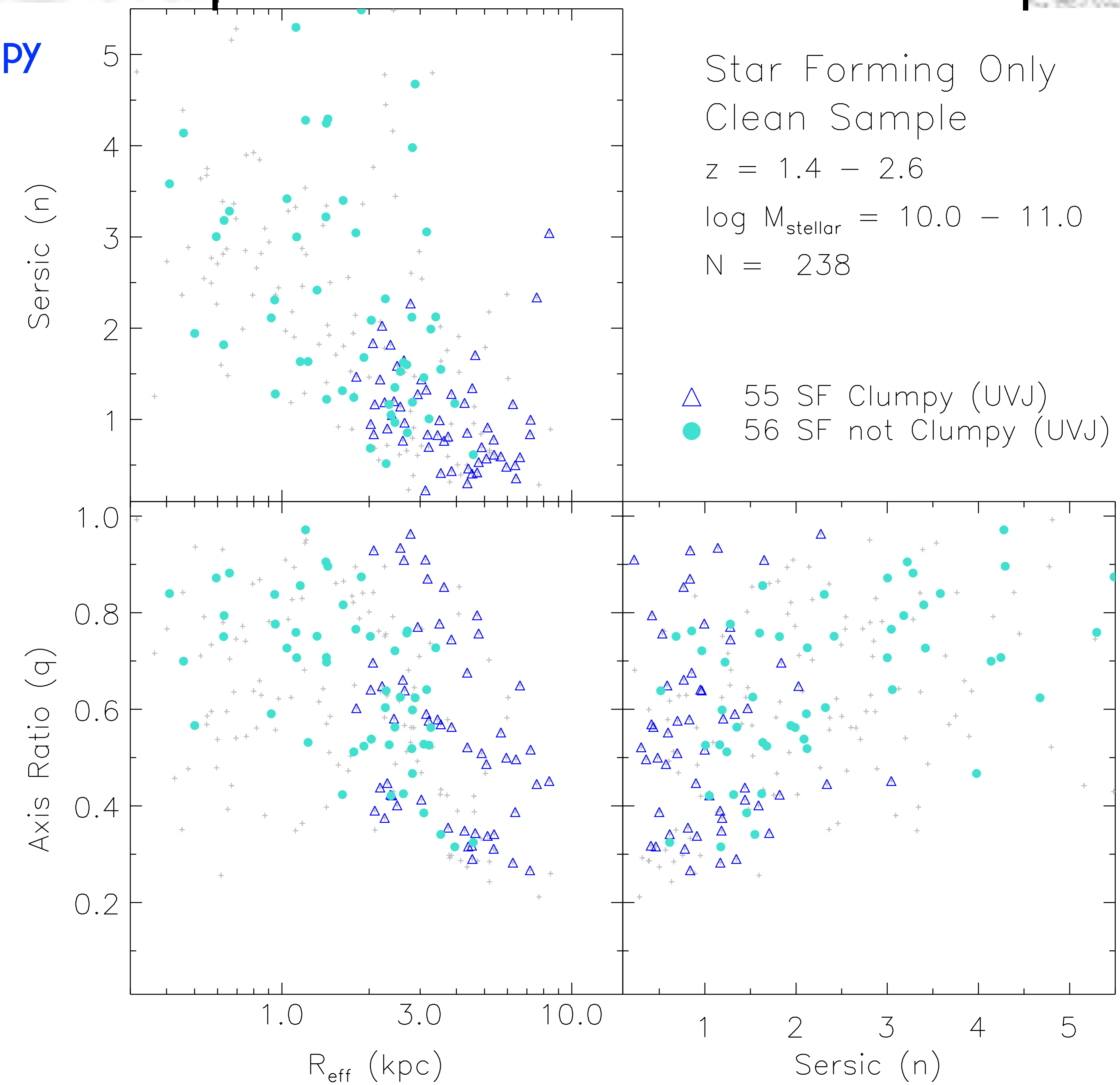
CANDELS DATA
Preliminary



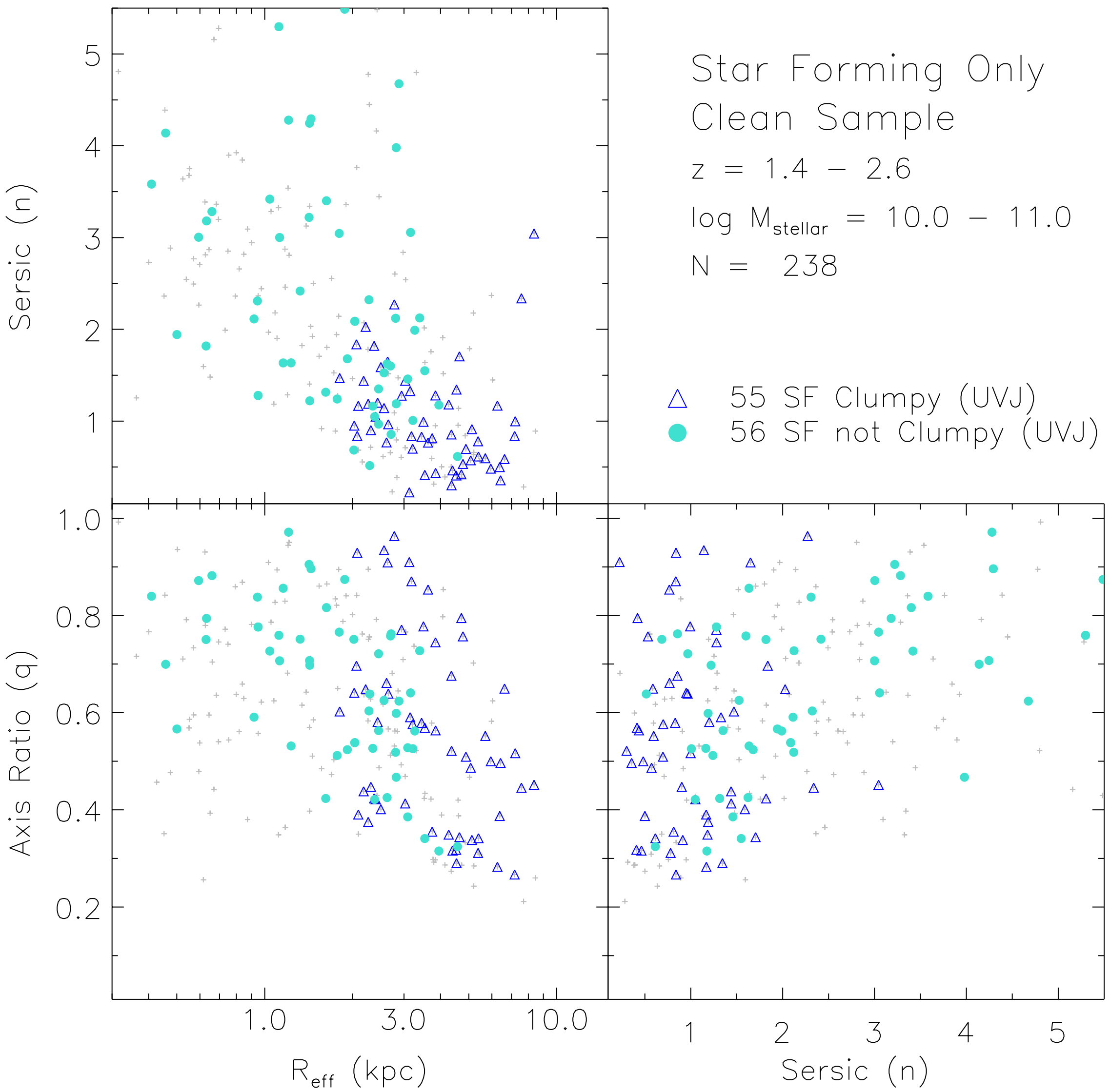
Not Clumpy

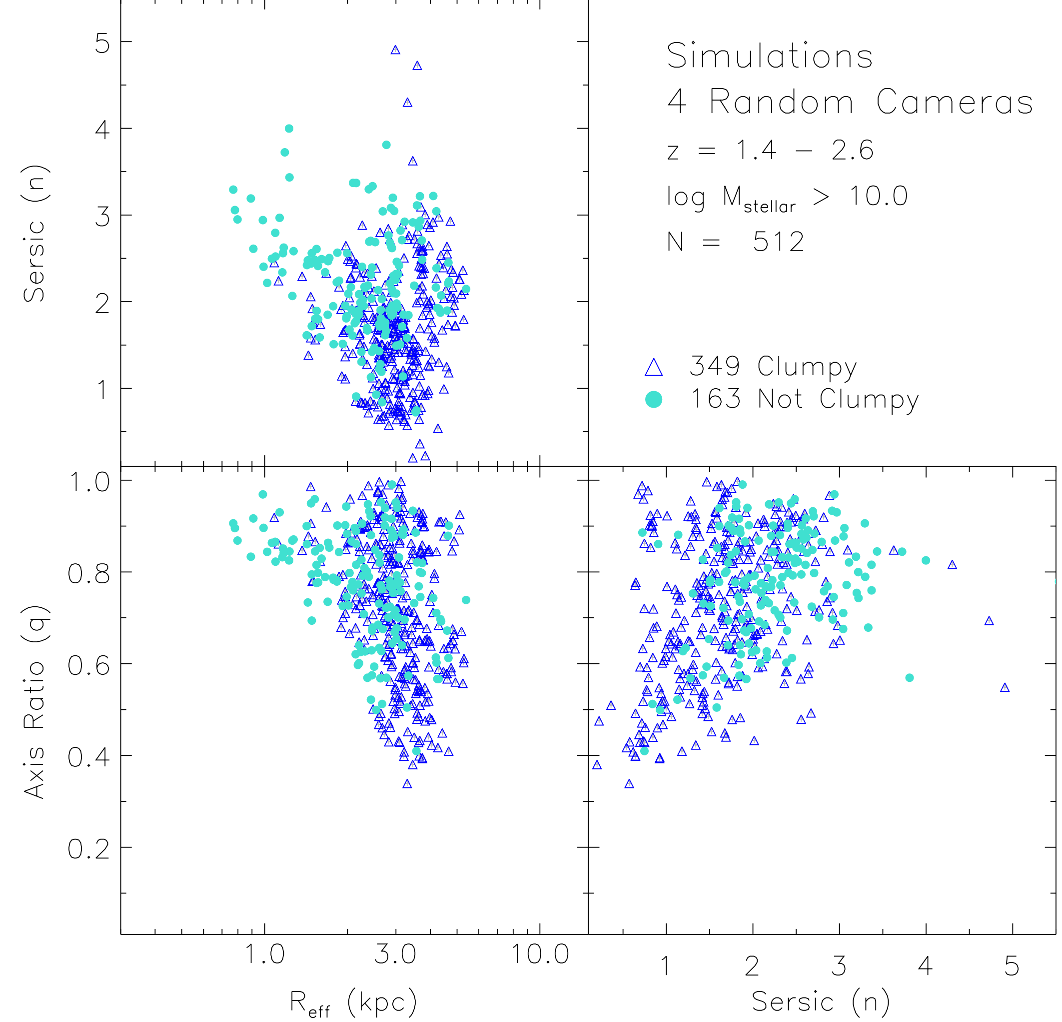


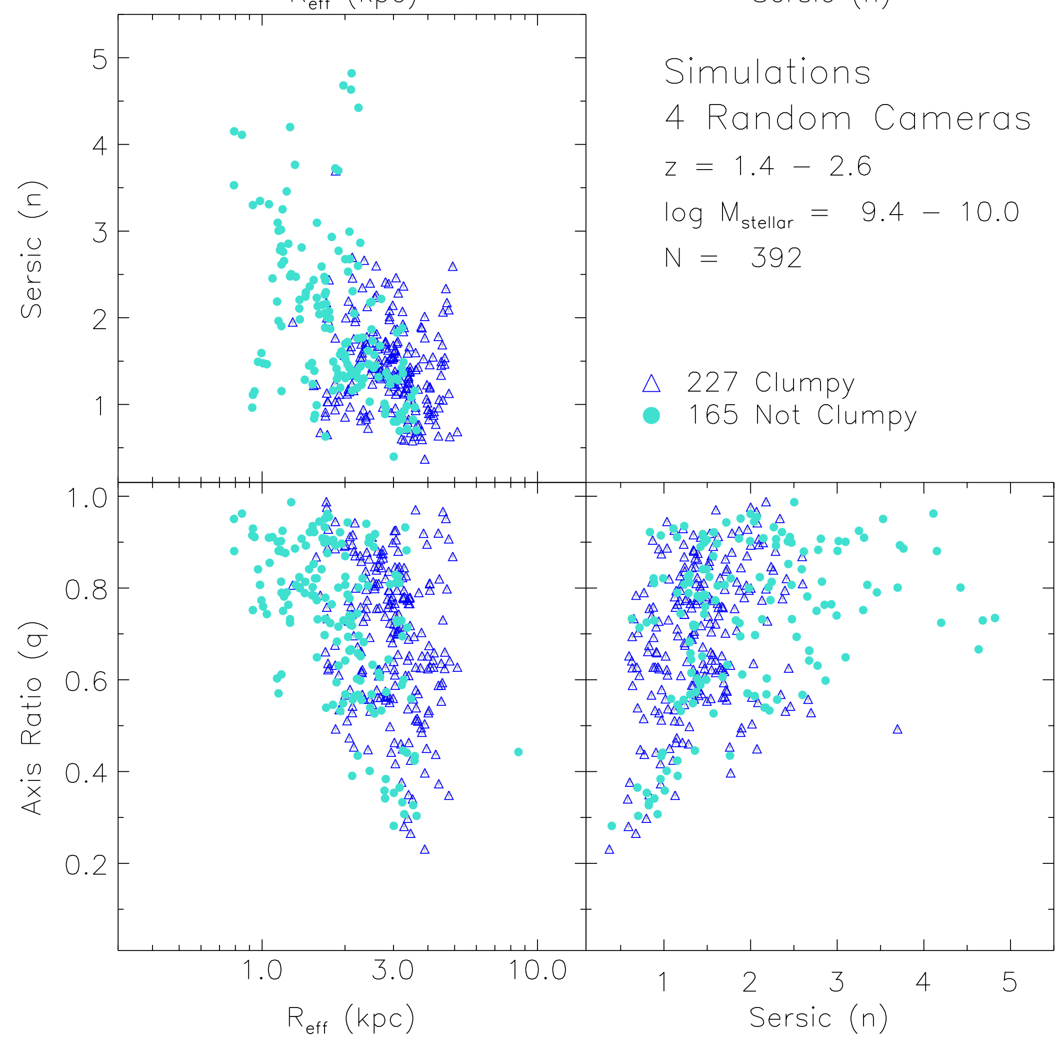
Clumpy



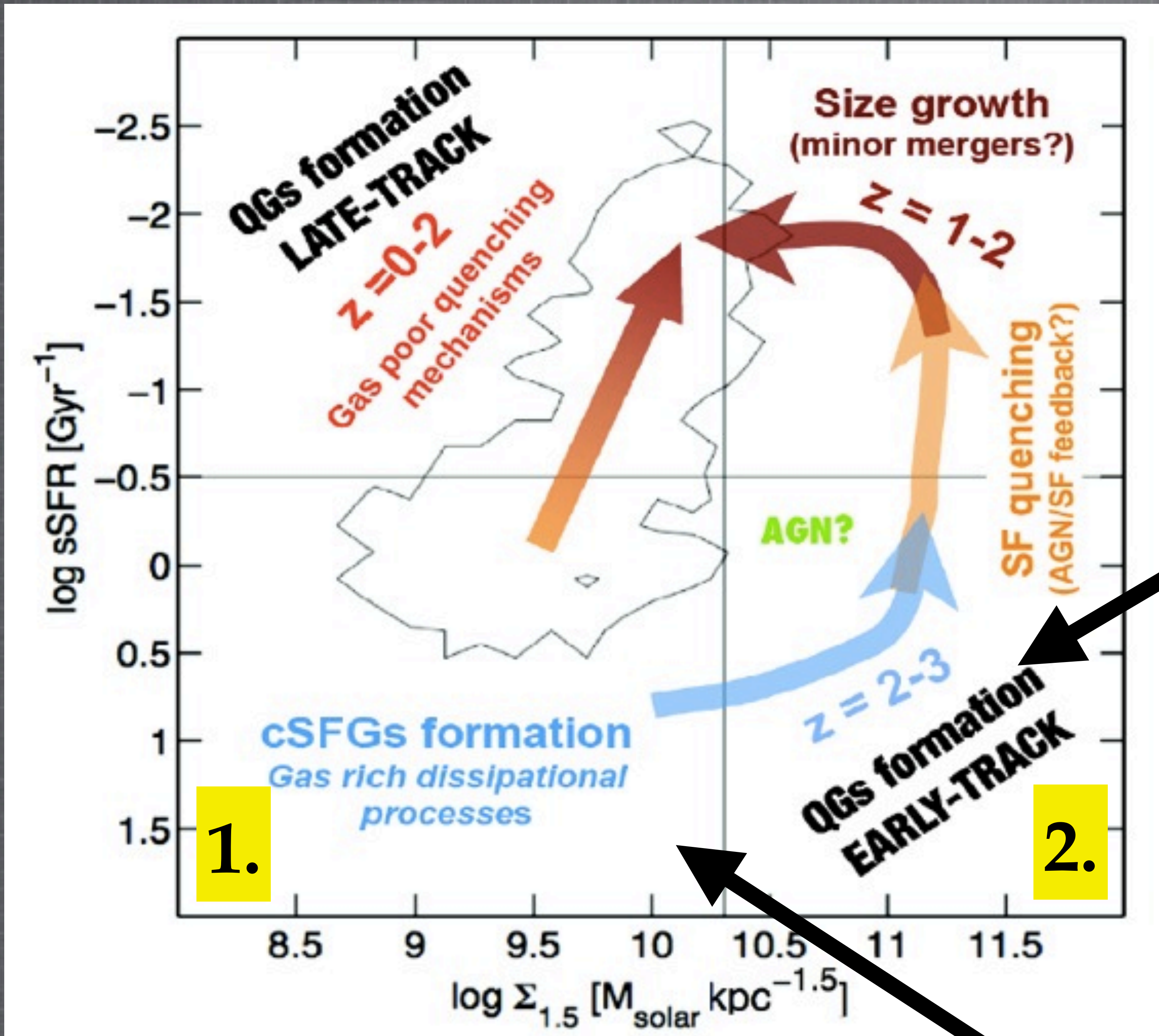
CANDELS DATA Preliminary







Compared with Daniel Ceverino's simulations without RP
by Mark Mozena, Chris Moody, Priya Kollipara, & JP →



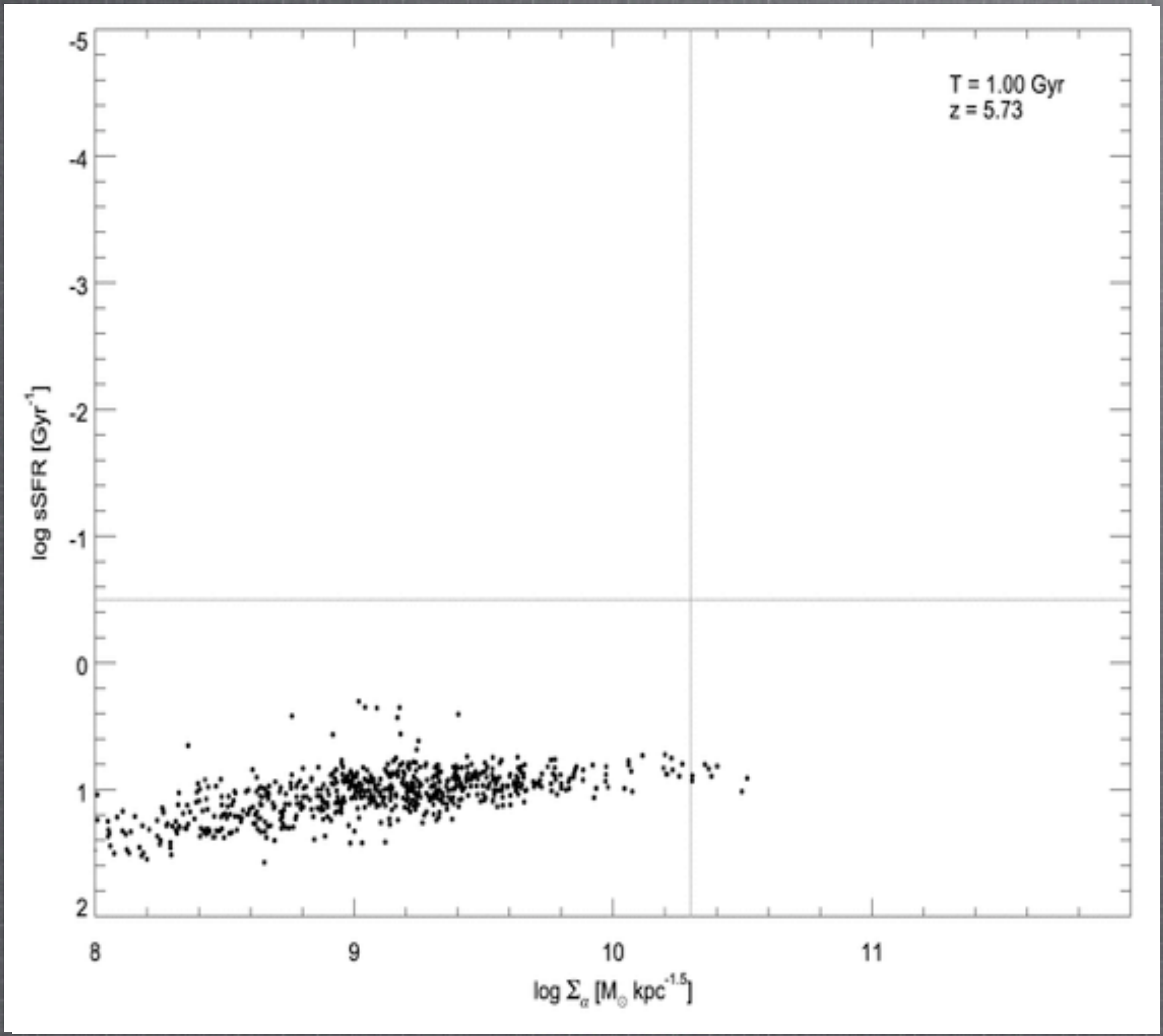
Compact SFGs properties 2.

- 80% dusty (IR-) star-formation.
- high-sersic, undisturbed app.
- 40% AGN det. fraction.
- 300 Myr -1 Gyr quenching times.
- AGN/SF feedback (outflows?)

Compact SFGs formation 1.

- SAMs - DI (60%) % wet mergers
- SAMs - Preferentially in already compact gal.
- ART-hydro - VDI time-scale 300 - 500 Myrs.

Guillermo Barro



Semi-Analytic Model: Lauren Porter, JP, & Rachel Somerville

Reproduces the CANDELS observations

Will simulations agree with the observations?

AGORA "Flagship Paper" to be submitted to ApJS

ASSEMBLING GALAXIES OF RESOLVED ANATOMY (*AGORA*): A HIGH-RESOLUTION GALAXY SIMULATIONS COMPARISON PROJECT

FOR THE *AGORA* COLLABORATION: TOM ABEL[1], OSCAR AGERTZ[2], GREG L. BRYAN[3], DANIEL CEVERINO[4], CHARLOTTE CHRISTENSEN[5], CHARLIE CONROY[6], AVISHAI DEKEL[7], NICKOLAY Y. GNEDIN[2,8], NATHAN J. GOLDBAUM[6], JAVIERA GUEDES[9], OLIVER HAHN[9], ALEXANDER HOBBS[9], PHILIP F. HOPKINS[10,11], CAMERON B. HUMMELS[5], FRANCESCA IANNUZZI[12], DUŠAN KEREŠ[13], JI-HOON KIM[6], ANATOLY KLYPIN[14], MARK R. KRUMHOLZ[6], MICHAEL KUHLEN[10], SAMUEL N. LEITNER[15], PIERO MADAU[6], LUCIO MAYER[16], CHRISTOPHER E. MOODY[6], KENTARO NAGAMINE[17], MICHAEL L. NORMAN[13], JOSE OÑORBE[18], BRIAN W. O'SHEA[19], ANNALISA PILLEPICH[6], JOEL R. PRIMACK[20], JUSTIN I. READ[9], BRANT E. ROBERTSON[5], DOUGLAS H. RUDD[2], SIJING SHEN[6], BRITTON D. SMITH[19], ALEXANDER S. SZALAY[21], ROMAIN TEYSSIER[16], ROBERT THOMPSON[17], KEITA TODOROKI[17], MATTHEW J. TURK[3], JAMES W. WADSLEY[22], JOHN H. WISE[23], AND ADI ZOLOTOV[7,24]

Draft version June 19, 2013

ABSTRACT

This paper introduces the *AGORA* project, a detailed comprehensive numerical study of well-resolved galaxies within the ΛCDM cosmology. Cosmological hydrodynamic simulations with force resolutions of ~ 100 physical pc or better will be run with a variety of code platforms to follow the hierarchical growth, star formation history, morphological transformation, and the cycle of baryons in and out of 8 galaxies with masses $M_{\rm vir} \simeq 10^{10}$, 10^{11}, 10^{12}, and 10^{13} $M_\odot$ at $z = 0$ and two different ("violent" and "quiescent") halo assembly histories. The numerical techniques and implementations used in this project include the smooth particle hydrodynamics codes GADGET and GASOLINE, and the adaptive mesh refinement codes ART, ENZO, and RAMSES. The codes will share the common initial conditions and common astrophysics packages including photoionizing UV background, metal-dependent radiative cooling, metal and energy yields, and stellar initial mass function. These are described in detail in the present paper. Their subgrid star formation and feedback prescriptions will be tuned to provide a realistic interstellar and circumgalactic medium using a non-cosmological disk galaxy simulation. Cosmological runs will be systematically compared with each other using a common analysis toolkit (`yt`), and validated against a variety of observations to verify that the solutions are robust – i.e., that the astrophysical assumptions are responsible for any success, rather than artifacts of particular implementations. The goals of the *AGORA* project are, broadly speaking, to raise the realism and predictive power of galaxy simulations and the understanding of the feedback processes that regulate galaxy "metabolism". The initial conditions for the *AGORA* galaxies as well as simulation outputs at different redshifts will be made publicly available to the community. The results from a proof-of-concept test simulation of the formation of a $\sim 1.7 \times 10^{11}$ $M_\odot$ halo by 9 different versions of the participating numerical codes are also presented.

AGORA High-Resolution Galaxy Simulation Comparison Project: Calendar

AGORA Kickoff Meeting: August 17-18-19, 2012, at UCSC

Summer 2013:

UC-HiPACC Summer School on Star and Planet Formation
July 22 - August 9, at UCSC, directed by Mark Krumholz
(more info http://hipacc.ucsc.edu/ISSAC2013.html)

Santa Cruz Galaxy Workshop - August 12-16
(Students at the HiPACC summer school are welcome)

AGORA Workshop August 16-17-18-19 at UCSC