The Millennium Simulation

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The Main Paper

Simulating the joint evolution of quasars, galaxies and their large-scale distribution

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4097 v2 6 Apr 2005

Simulation Specs

- Simulated 10 billion particles of mass
- Traces the evolution of dark matter from the CMB (z=1080) to z=0
- Side of cube = 500 Mpc/h
- Took one month of non-stop computation
  - Output of 25 TBytes

The IBM pSeries 690

- Run at Max Planck Society in Garching, Germany
- Used the IBM pSeries 690 System
- Supercomputers can cost several million $$
- 822 Processors reaching a peak of 2.198 TFLOPS (trillion floating point operations per second)
- Went offline last June :(

Calculating the CF

- Calculations are using the Power 575 p6 computer at Max Planck
- Ranked 181 greenest supercomputer in the world (www.Green500.org)
- Averages 75 MFLOPS / watt (OPs / J)
- MS took 2.7 TJoules of energy!
  - 750,000 kilowatt hours
  - Equal to 675 tons of TNT exploding

Calculating the CF

- Cooling estimated as ten home air conditioning units, each using 3,500 watts
- For a month of non-stop use:
  - 25,200 kilowatt hours

Calculating the CF

- MS produced 400 tons of CO2
- Rough estimate of air condition adds another 15 tons of CO2
- Equal to 8% of the CF of flights out of Heathrow / year
- (Calculated from Heathrow averages):
  - 500,000 flights/year,
  - 0.25 ton of CO2 per hour of flight,
  - average flight time 4 hr

Upgrading the computer

- Max Planck also has a Blue Gene/p Solution supercomputer
- Ranked 7th greenest supercomputer in the world

- Simulation takes longer but calculates 5 times the # of calculations per watt
- Only produces 80 tons of CO2
- More efficient water-cooling air conditions only produce 4 additional tons of CO2

Green500 Rank	MFLOPS/W	Site*	Computer*	Total Power (kW)	TOP500 Rank*
1	488.14	IBM Germany	BladeCenter QS22 Cluster, PowerXCell 8i 3.2 Ghz, Infiniband	22.76	324
1	488.14	Fraunhofer ITWM	BladeCenter QS22 Cluster, PowerXCell 8i 3.2 Ghz, Infiniband	18.97	464
3	437.43	DOE/NNSA/LANL	BladeCenter QS22/LS21 Cluster, PowerXCell 8i 3.2 Ghz / Opteron DC 1.8 GHz , Voltaire Infiniband	2345.50	1
4	371.75	Argonne National Laboratory	Blue Gene/P Solution	31.50	304
4	371.75	Dublin Institute for Advanced Studies/ICHEC	Blue Gene/P Solution	31.50	305
4	371.75	Science and Technology Facilities Council - Daresbury Laboratory	Blue Gene/P Solution	31.50	306
7	371.67	RZG/Max-Planck-Gesellschaft MPI/IPP	Blue Gene/P Solution	94.50	52
7	371.67	Stony Brook/BNL, New York Center for Computational Sciences	Blue Gene/P Solution	63.00	75
7	371.67	ASTRON/University Groningen	Blue Gene/P Solution	94.50	51
7	371.67	IBM - Rochester	Blue Gene/P Solution	126.00	37
7	371.67	DOE/Oak Ridge National Laboratory	Blue Gene/P Solution	63.00	74
12	368.89	EDF R&D	Blue Gene/P Solution	252.00	13
13	357.38	Argonne National Laboratory	Blue Gene/P Solution	1260.00	3
14	357.14	IDRIS	Blue Gene/P Solution	315.00	9
14	357.14	Forschungszentrum Juelich (FZJ)	Blue Gene/P Solution	504.00	6

Summary

- MS is worth it
- Cited in over 500 papers since 2005
  - 0.83 tons of CO2 / paper
- Evidence that supercomputer developers are looking to go greener