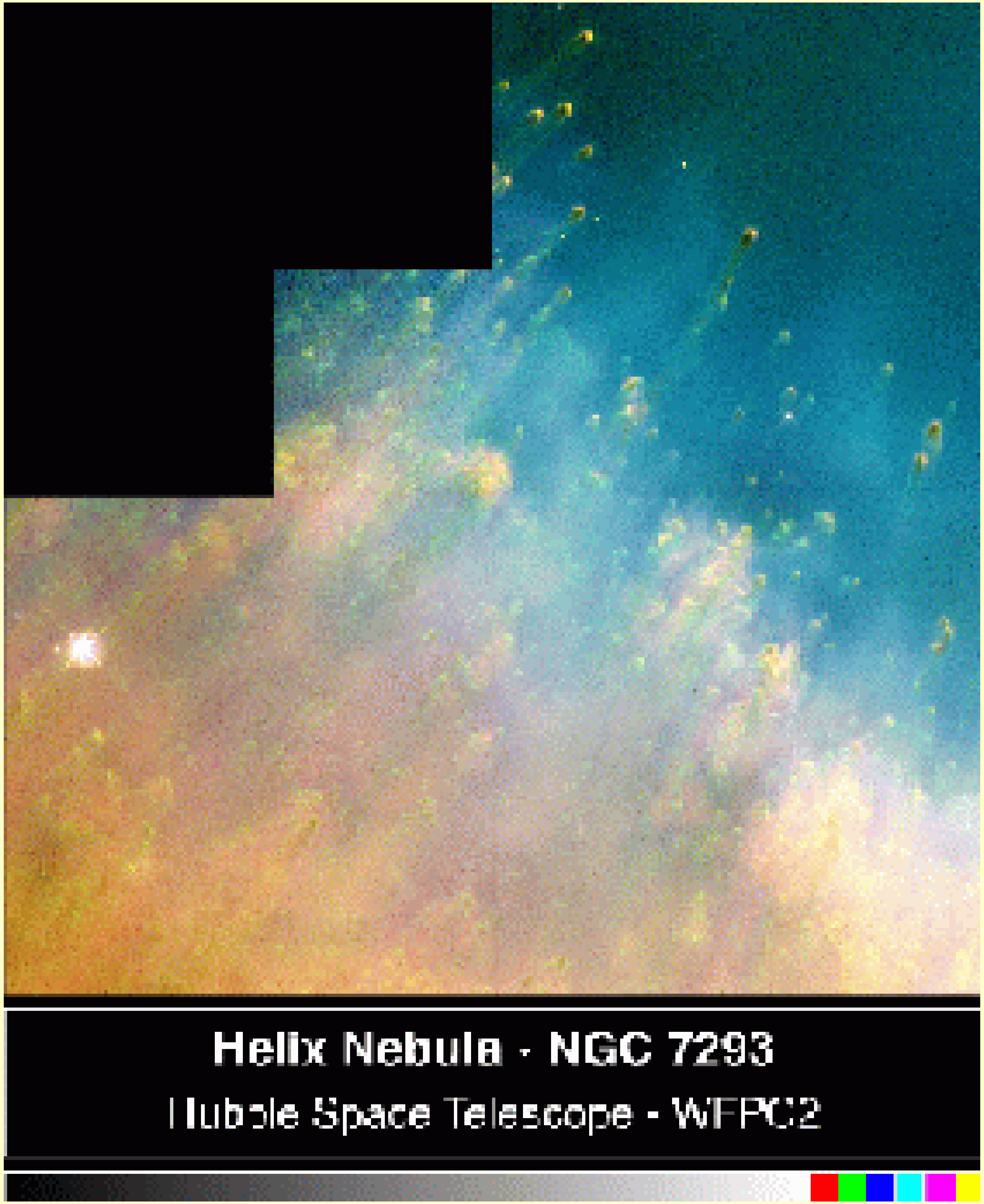
Numerical simulations in astrophysical research: Where do we stand?

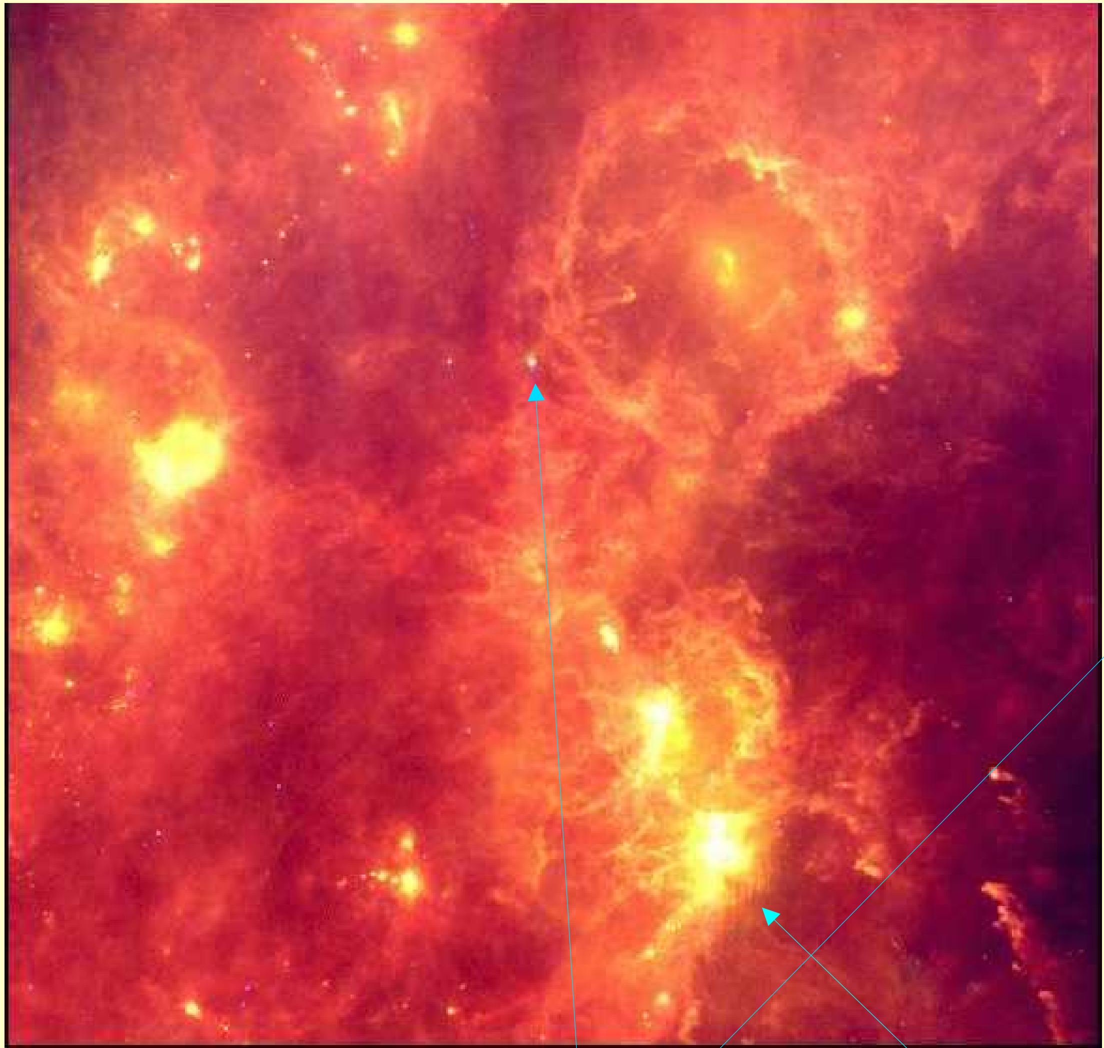
Why simulations are needed?

The observers are ahead!


Helix Nebula · NGC 7293
Hubble Space Telescope · WFPC2

Orion region

IRAS picture (12, 60, 100µ; 30°x24°)

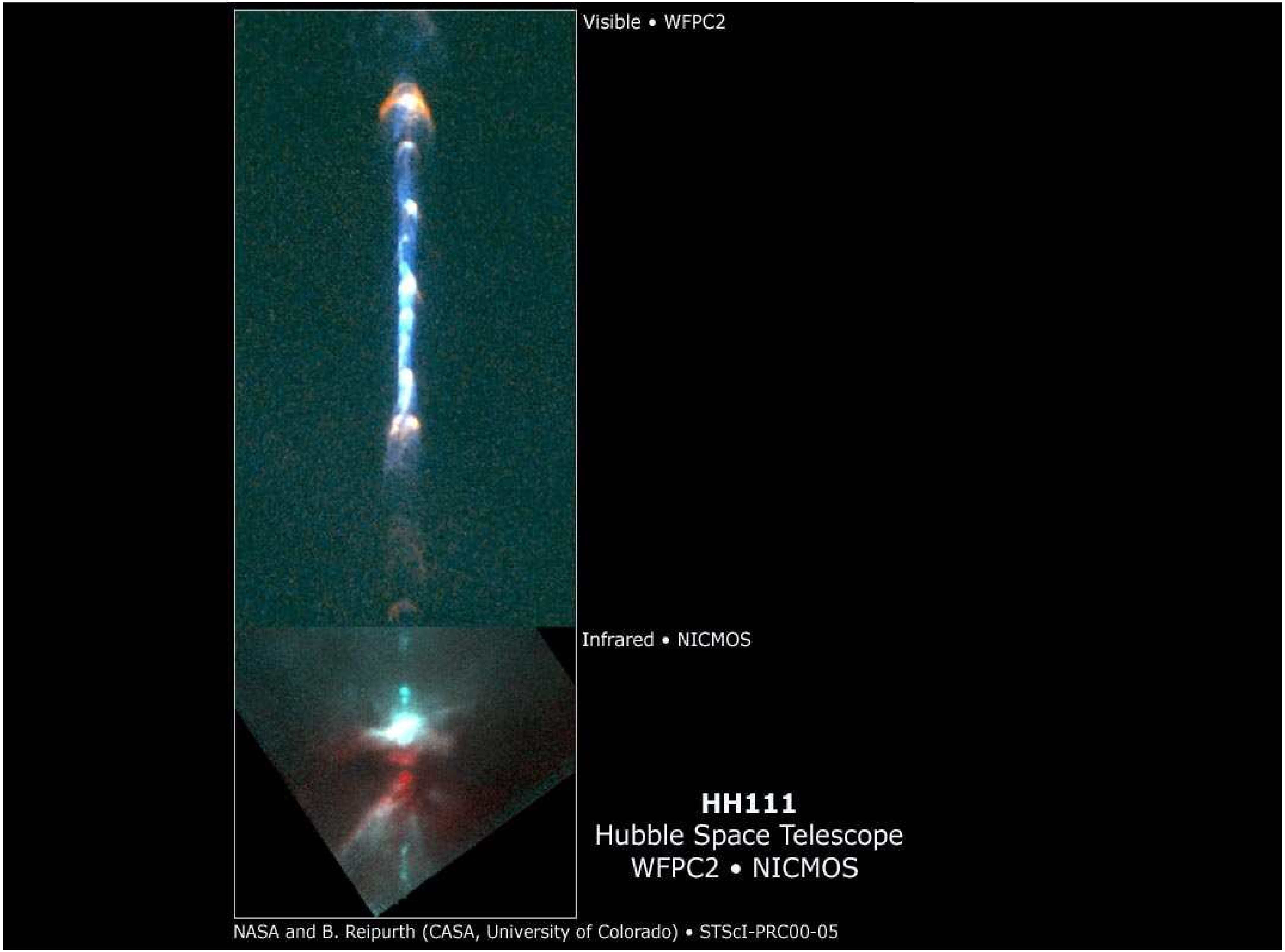


≈ 240 pc

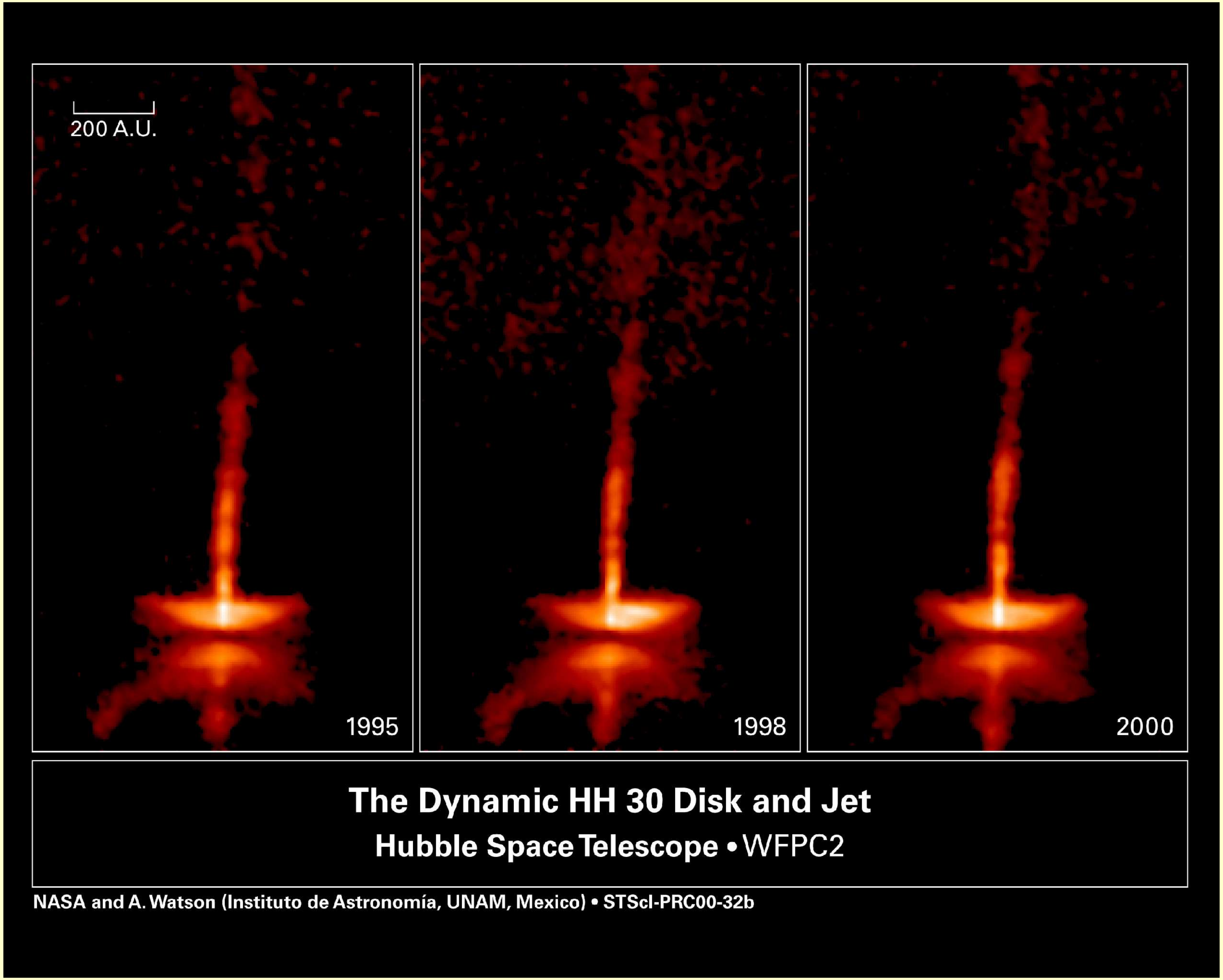
Visible (S.Kohle & T.Credner)

Betelgeuse

Orion nebula


Visible • WFPC2
Infrared • NICMOS
HH111
Hubble Space Telescope
WFPC2 • NICMOS
NASA and B. Reipurth (CASA, University of Colorado) • STScI-PRC00-05

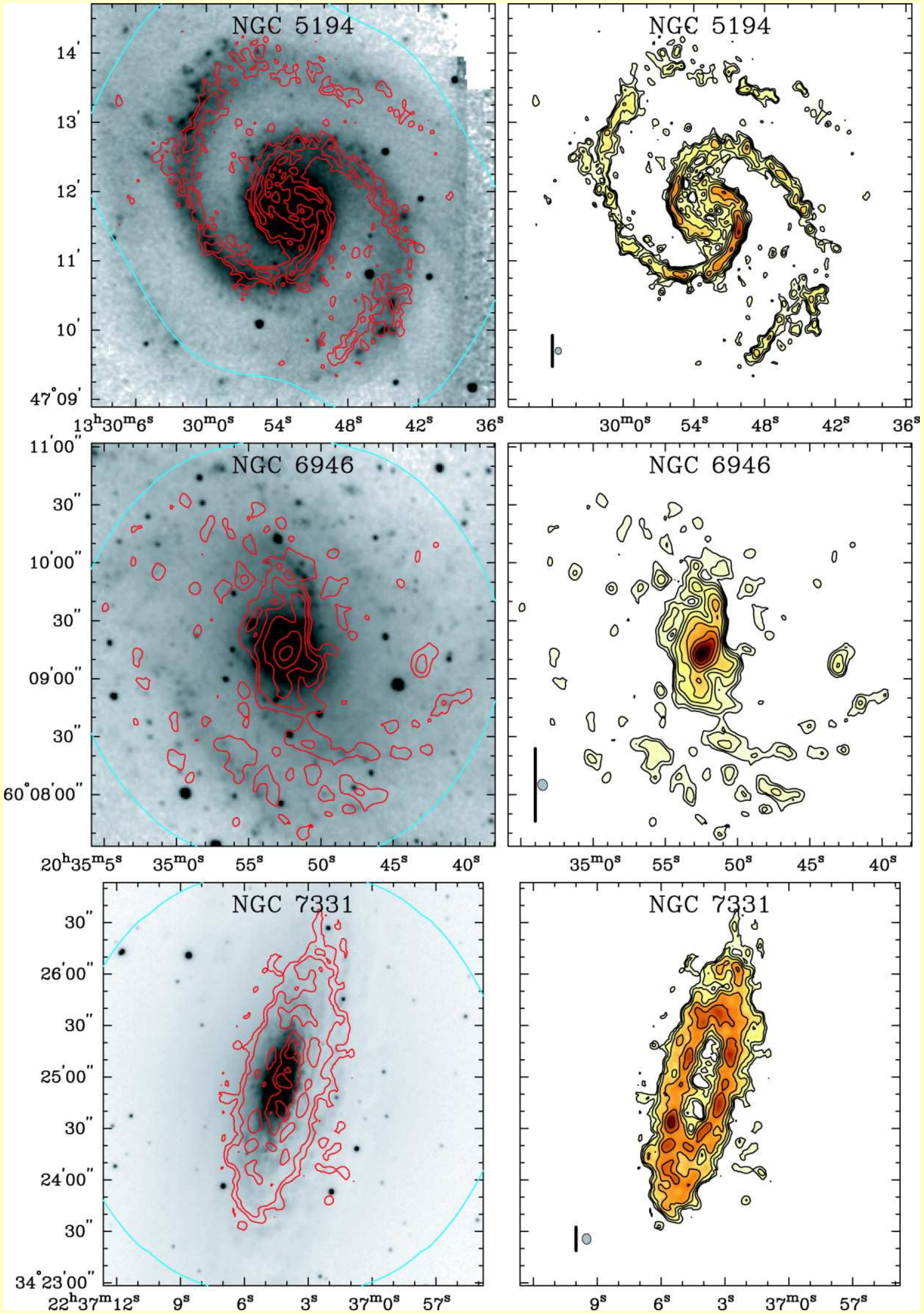
Star formation is accompanied by disks and jets



Molecular gas in other galaxies

(BIMA SONG, Regan et al. 2002)

Shown is CO J=(1-0) emission,
- overlaid on near IR/visible (left)
- color coded (right)



Molecular gas often follows
- spiral arms of galaxies
- disk (Milky Way)

But:
- can extend beyond disk and/or spiral arms
- can be much more diffuse

Magnetfeld der Erde · Haarausfall · Aperiodische Ordnung

www.spektrum.de

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SCIENTIFIC AMERICAN
DEUTSCHE AUSGABE

Februar 02/2002
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ASTRONOMIE

Die ersten Sterne im Universum

SEUCHEN
Wie verbreitet sich der Milzbrand-Erreger?

ALTES ÄGYPTEN
Chirurgie im Reich der Pharaonen

INDIEN-PAKISTAN-KONFLIKT
Die nukleare Gefahr

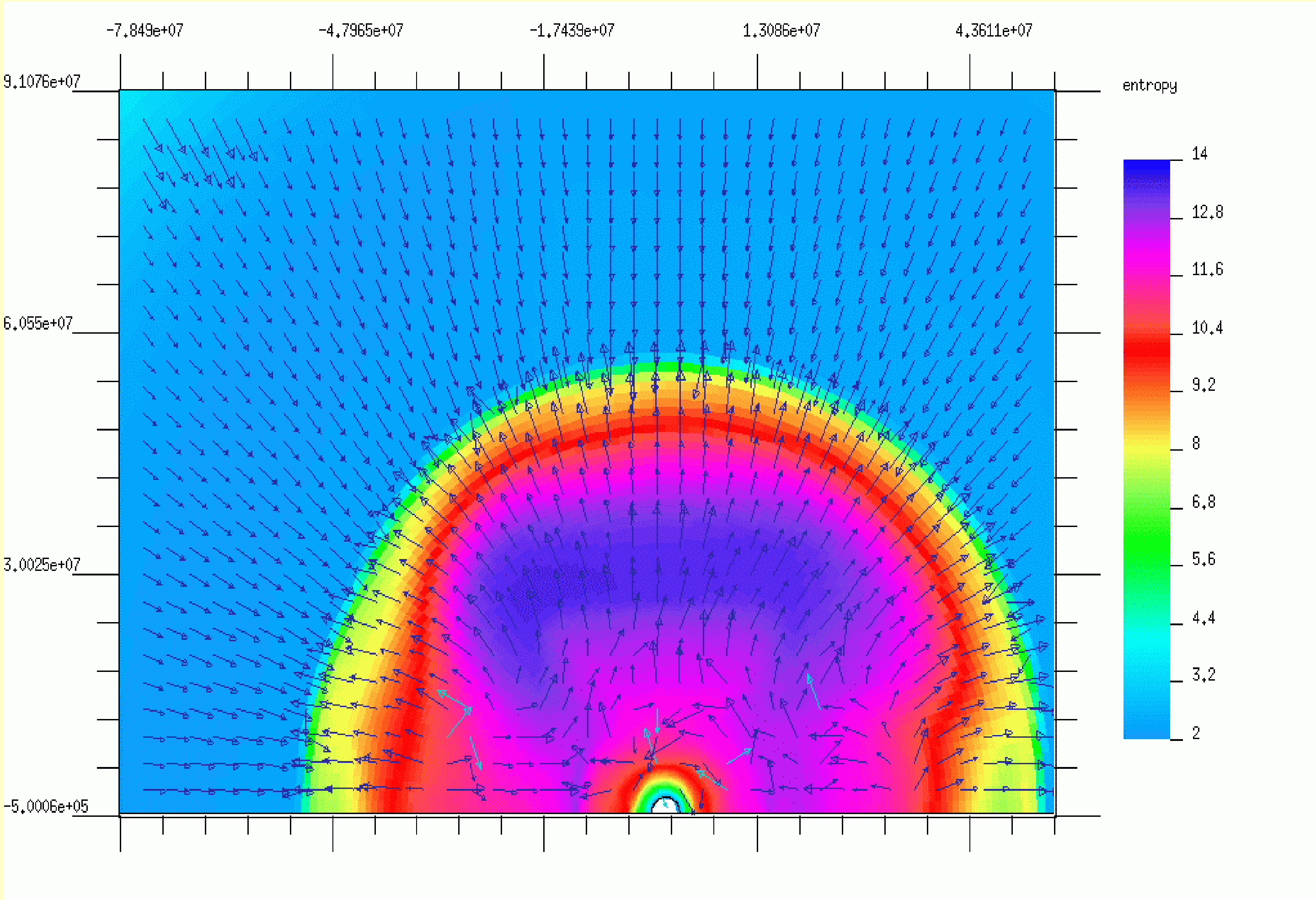
D6179E 13,50 Sfr / Österreich 6,90 € / Luxemburg 8,– €

Some selected examples

of 'advanced' simulations

of complex astrophysical objects

supernova, full neutrino- hydrodynamics

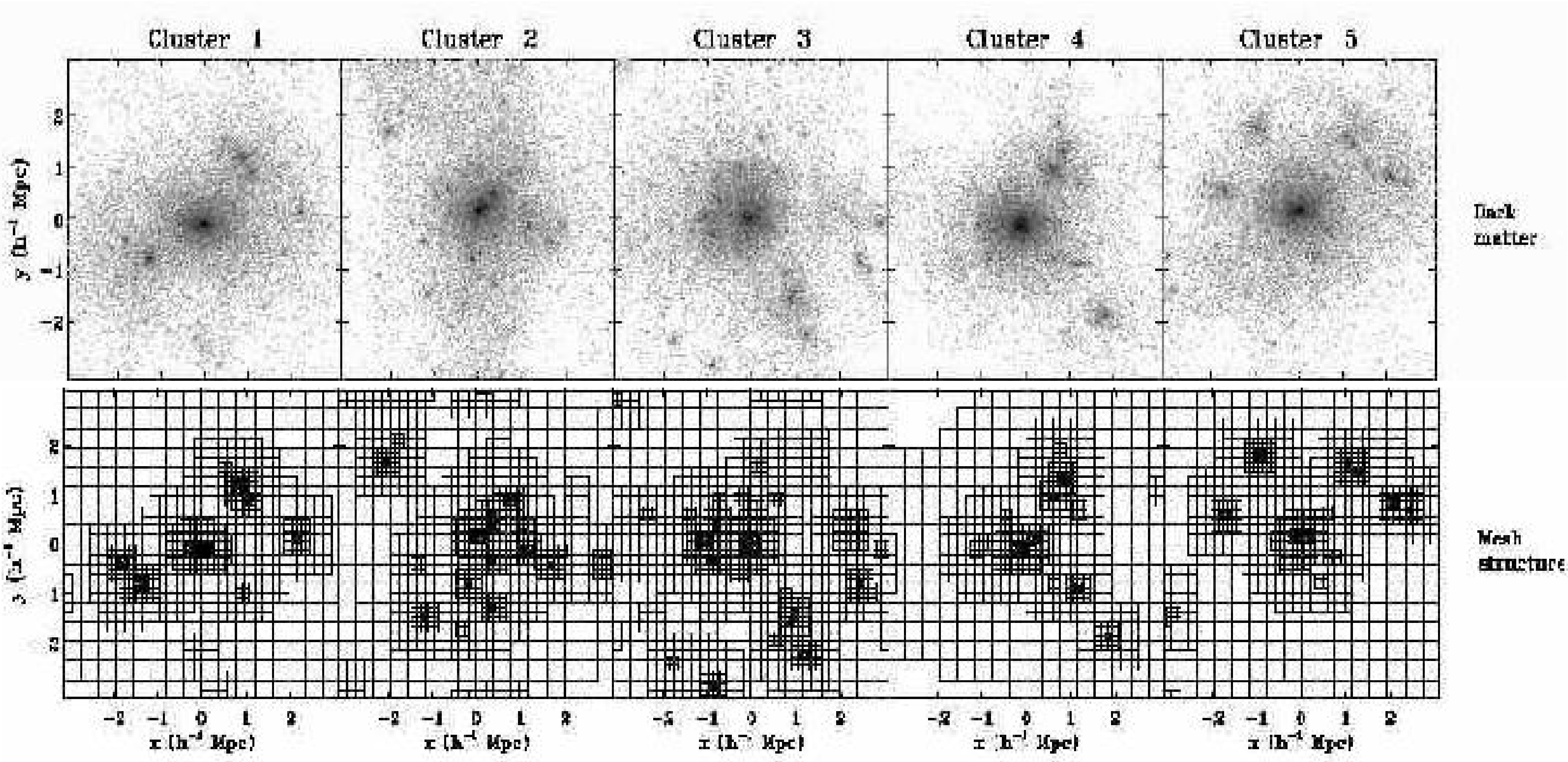


general- relativistic MHD

time- dependent solution of the relativistic Boltzmann equation for the neutrinos

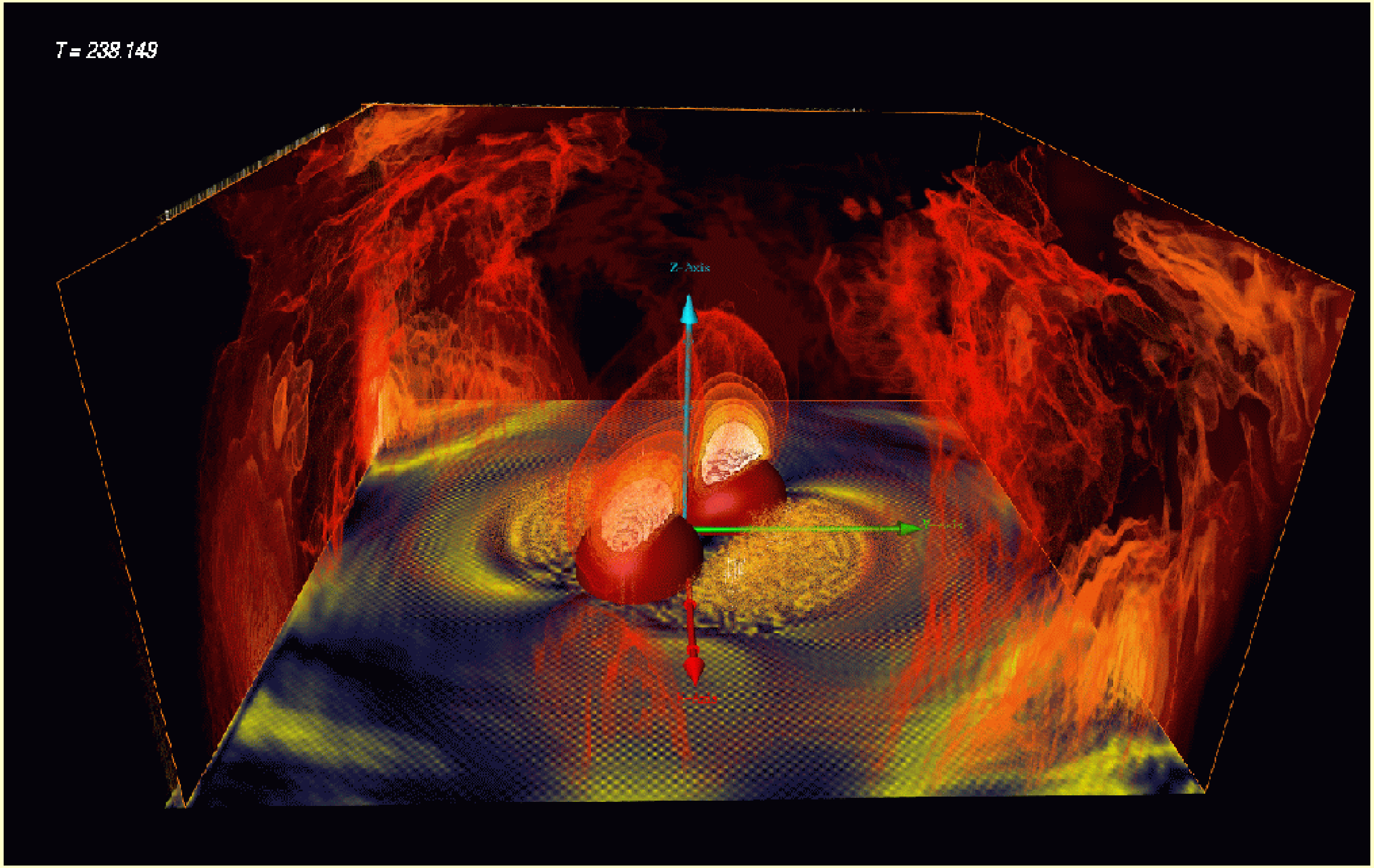
time- dependent solution of the neutrino and nuclei rate- equations

adaptive nbody and adaptive gasdynamics in cosmological context



R. Teyssier,Sacley, Ramses- code, 2001

General relativity and gravitational waves



Meudon group

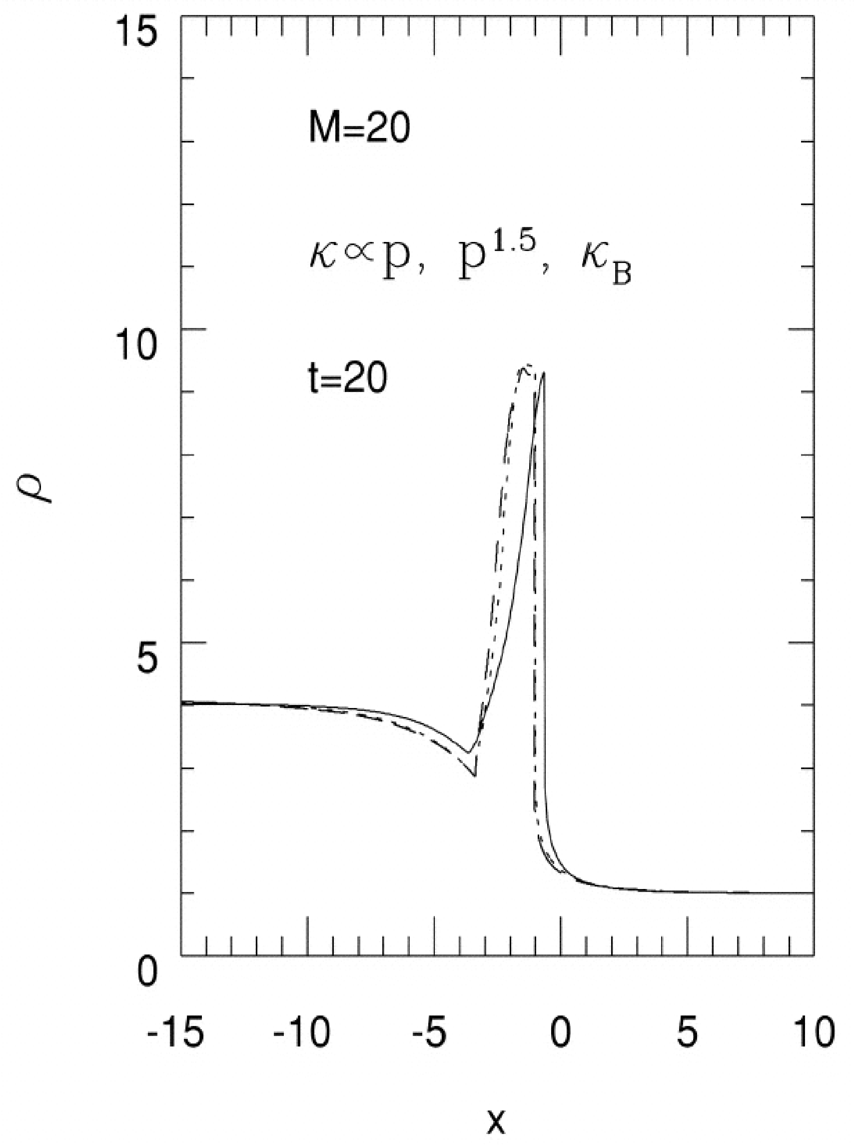
Some selected examples

of 'advanced' simulations

of basic physical processes

important in astrophysics

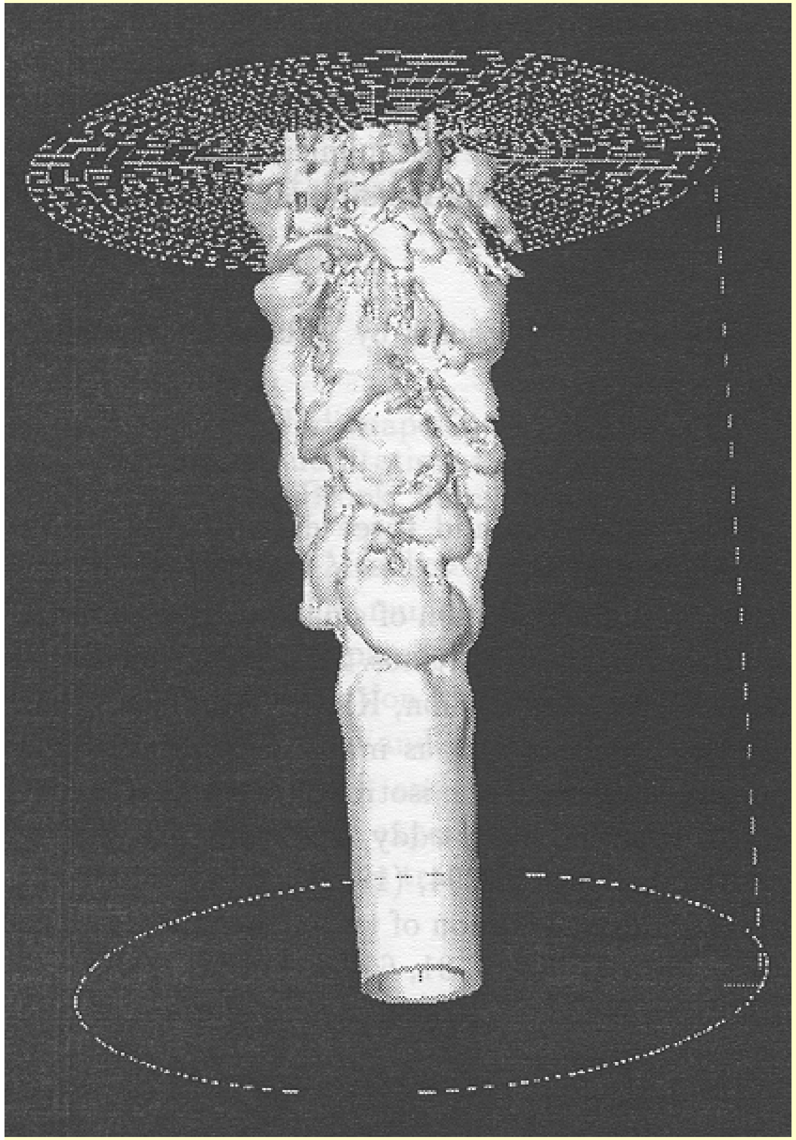
Couplage between particle solvers and hydro: shock diffusion acceleration of cosmic rays

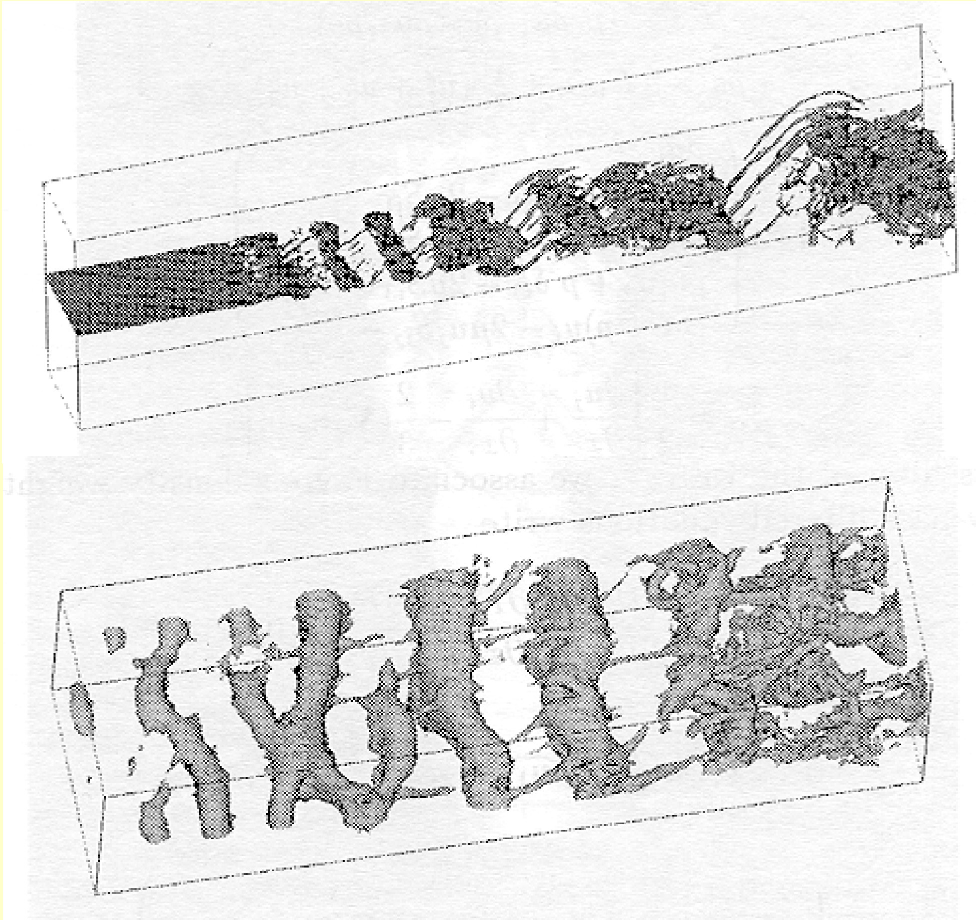


a combination of shock-tracking methods, adaptive meshes and particle solvers

H. Kang, T.W. Jones,
R.J. LeVeque, K.M. Shyue,
ApJ 2000

Turbulence modeling and the consideration of viscous fluxes



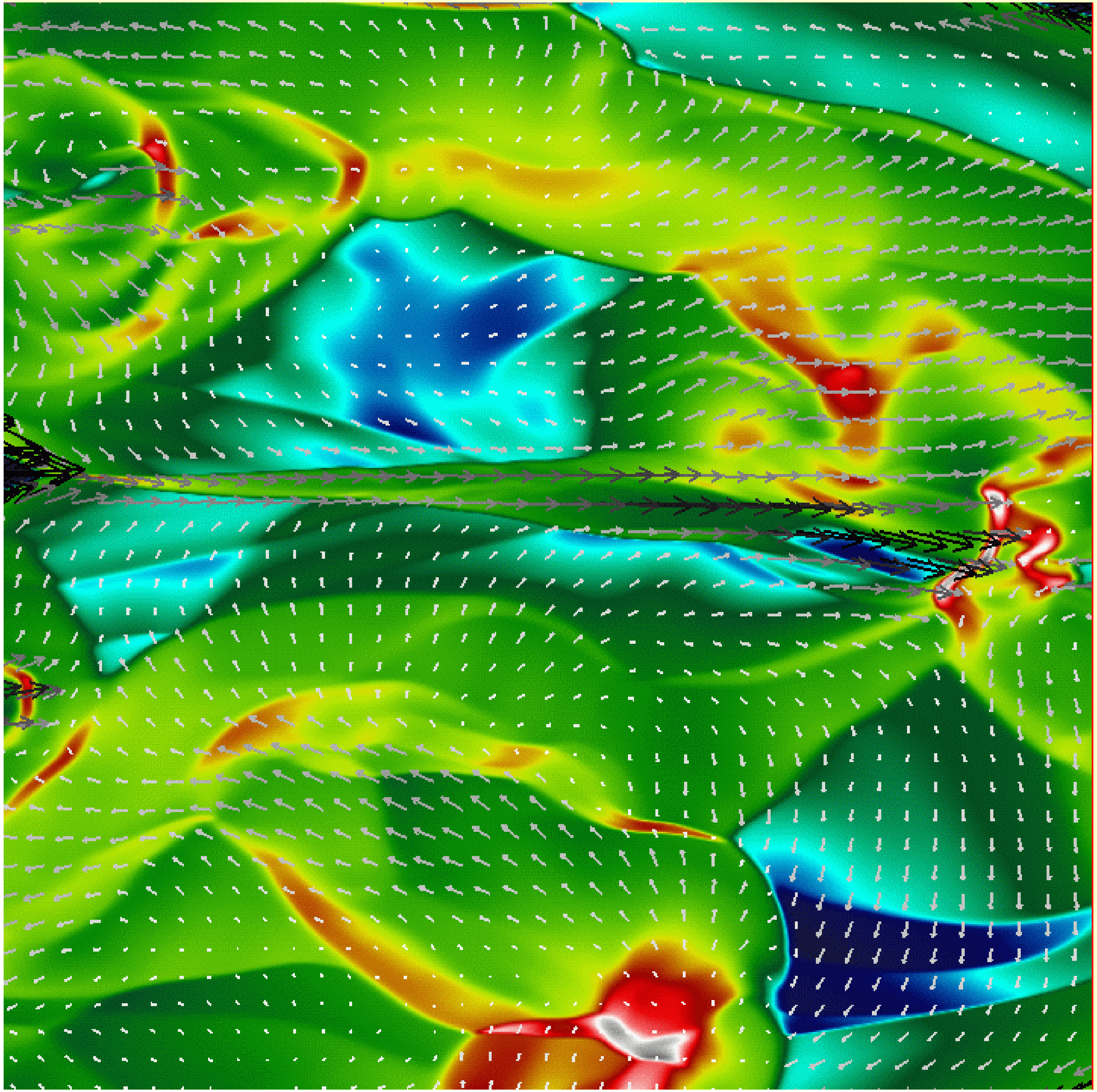


different disturbances

Mach 1 jet

Lesieur, turbulence modeling
'large eddy' simulations

compressible turbulence



Some selected examples

of 'advanced' hardware

The fastest 10 computer . . . the USA and others

Rank	Manufacturer	Computer	R_{max}(GFlops)	Installation Site	Country	Year	Installation Ty
1	NEC	Earth-Simulator	35860.00	Earth Simulator Center	Japan	2002	Research
2	IBM	ASCI White, SP Power3 375 MHz	7226.00	Lawrence Livermore National Laboratory	USA	2000	Research
3	Hewlett-Packard	AlphaServer SC ES45/1 GHz	4463.00	Pittsburgh Supercomputing Center	USA	2001	Academic
4	Hewlett-Packard	AlphaServer SC ES45/1 GHz	3980.00	Commissariat a l'Energie Atomique (CEA)	France	2001	Research
5	IBM	SP Power3 375 MHz 16 way	3052.00	NERSC/LBNL	USA	2001	Research
6	Hewlett-Packard	AlphaServer SC ES45/1 GHz	2916.00	Los Alamos National Laboratory	USA	2002	Research
7	Intel	ASCI Red	2379.00	Sandia National Laboratories	USA	1999	Research
8	IBM	pSeries 690 Turbo 1.3GHz	2310.00	Oak Ridge National Laboratory	USA	2002	Research
9	IBM	ASCI Blue-Pacific SST, IBM SP 604e	2144.00	Lawrence Livermore National Laboratory	USA	1999	Research
10	IBM	pSeries 690 Turbo 1.3GHz	2002.00	IBM/US Army Research Laboratory (ARL)	USA	2002	Vendor

7 times faster than any other European computer: CEA France

To note:

- Terraflops is nominally established, petaflops are envisaged

- All but 2 in the US
- While declared research, mostly military

- Mostly IBM / Power- series, with some HP / alpha

- All parallel
- Distributed memory to some degree

- Compilers have not made the same revolution
- Tools for developping codes (coding / debugging) are primitive
- Software has not made big progress

Some theses

We need a better understanding of the underlying physical processes

---> collaboration with theoreticians, observers, and experimentalists

We need a better validation of codes

---> collaboration with experimentalists, numerical
mathematicians and computer scientists

We need well equiped labs!

---> Need computers, supplementary devices
AND people to administer the hardware / software

We need good interdisciplinary teams

---> Astrophysicists, theoretical physicists, experimental physicists, numerical mathematicians, computer science people, system administration and staff

We have to educate such people !