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(keynote) Graphics vs Physics : the light and dark sides of the Force

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Graphics vs Physics :

*the **graphics** side of the force*

What is the *Computer Graphics* domain ?



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Facets :

- **Shapes** (humans & animals & hairs, forests & landscape, clouds...)
- **Movement** (walk & crowds, skin & muscles, clothes, water & smoke, objects interactions...)
- **Visuals / “rendering”** (light transport simu + materials appearance)
+ sides : 3D manufacturing (3D printing) , image analysis (deep learning) , interface design (UI)...

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Users :

- **Industries** : movies (realistic or not), games, simulators (driving, medic...), impact studies (& architecture, museum), design (archi, cars...)
- **Users job** : interactive artist & engineer, → control, usable
boss & customer → purpose. often vague spec & valid
- + end user : public

List of requirements - mission statement

Amounts:

- 4 k² pixels * 500 k frames (+ stereo),
- ultra-complex scenes (quantitative, span, phenomena)
- time budget: 1-100 h/frame (movies)
1/60" real-time (games) + stereo [ratio: 10⁷ !]
- memory budget: GPU, RAM, disk/cloud (+ transfer rate)

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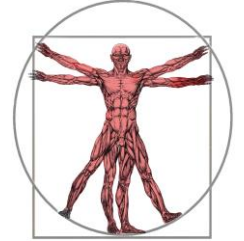
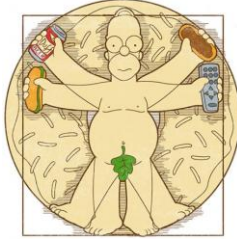
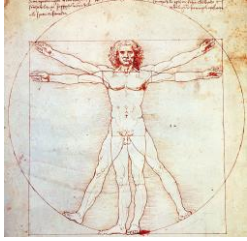
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Constraints:

- Design user :
 - almost any mixed input data (+large)
 - controllable (params (+intuitive), initial configuration, reliable preview, ... result)
 - action (show something, make something happen)
- End user :
 - space/time continuity (no artifacts - Human visual system)
 - games: reactive to unknown action
 - long time span
- A good one: world seen from camera , for humans

Diversity of approaches: eg, walking character

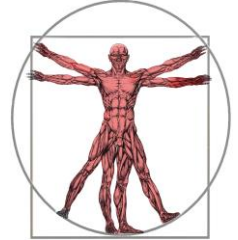
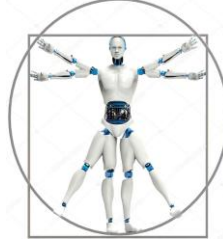
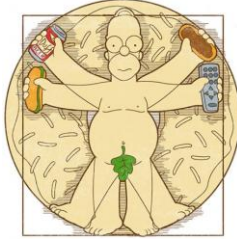
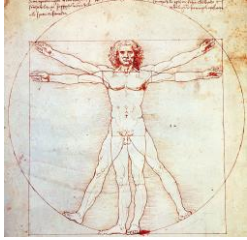
since diversity of purpose & target: cartoon / realistic / not-existing



- Disney-style motion design: puppet / creative / artist intuition / choreography
- Performance capture: (+ correct / retarget)
- Math/Phys: kinematics, inverse kinematics, solve balance, motion planning, inverse dynamics, [inverse problems]
- Bio/Physics: biomeca (muscles,skeleton :simu), anticipation, nerve activation pattern.
- Simu/Phys: liquids, smoke, flesh, cloth, hairs...

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→ toolbox: multitude of scienceS, physicS, mathS models.

E.g., just for ocean:

Fourier, waves, N.S., Bernoulli, Eulerian / Lagrangian (SPH)...

(+ capillary waves, spray, foam, lighting...)

Diversity of approaches: eg, walking character

→ multitude of scienceS, physicS, mathS models.

Reminder:

- complex, controlable, param not always available, or not the right ones
- target = motion + shape + material & light simu

→ CG domain =

- integrative of many Sciences (and more: arts, techs),
- for “integrative experiments” (e.g. sceneries)
- on which little control (customer. less and less negotiation).

→ required: usability, interoperability, compatibility,
scalability (computable, storable).

Diversity of researchers

Many domains/motivations:

(CG is more an encounter of domains than a domain)

- People/goals from industry(s), math(s), CS(s), phys, arts
- Some: care about integrativity, usability
- Some: generic toy models / “aquarium” situations
- (me:
 - “big old questions” relat. to all Humans can see for ages :-)
 - Understanding / testing sciences knowledge about natural phenomena. (transversal domain)
“If I can reproduce a convincing cloud, means we understand it enough”
 - 1st cursus in AppMaths (scientific computing)
 - From industry : CG = natural phenomena for humans
(transversal domain) (artist / boss-customer / viewer)

Science content is about...

equations & algorithms & representations

Science-to-engineering workflow:

- General physics → models & representations
- Given setup & question → select subset
- Mathematization → continuous eqn
- prep. computing: Discretization (→ scale closure ?)
- AppMaths: solvers
- implem: Computer Sciences

→ CG covers the “full stack”

How to modelize a problem / levels of modelization

- Scales & ranges ?

- Amounts ? vs time/mem budget

- repr. ● Which controls/params ? which constraints/hypothesis ?
where camera can't be ?

mod. phys.

- Is physics simulation necessary ? which level ? close or open domain ? BC ?

eqn.

discretiz.

appMaths

- Solver: eqn type/stability ? coupling ? subscales ?

algo

CS

- Integrable ? usable ? perf, / compatible // or GPU ?
Backup solutions. Conversions (for inputs / output data)

Practical issues: short projects / hard for students / publis vs useful
transfer knowledge to/from users

Science content is about...

equations & algorithms & representations
...and indeed, physical modelization.

- Eqn & concepts from physics:
 - Copy - paste
 - Adapt - simplify - analogy
 - Rework deeply - complete
 - + perceptions Sc. (→ new hypothesis: simplif + constraints)

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- Eqn & concepts from physics:
 - Copy - paste
 - Adapt - simplify - analogy
 - Rework deeply - complete
 - + perceptions Sc. (→ new hypothesis: simplif + constraints)
- Algo & representations:
 - Reminder: arbitrarily complex
→ have to be storable / computable / stable / interp. / control.
 - appMaths (solver), CS (comput. models: parallelism)
 - Perf: might be ignore for early sketch,
but soon important (even for movies, but ≠ qual crit)
(and to be able to work !)

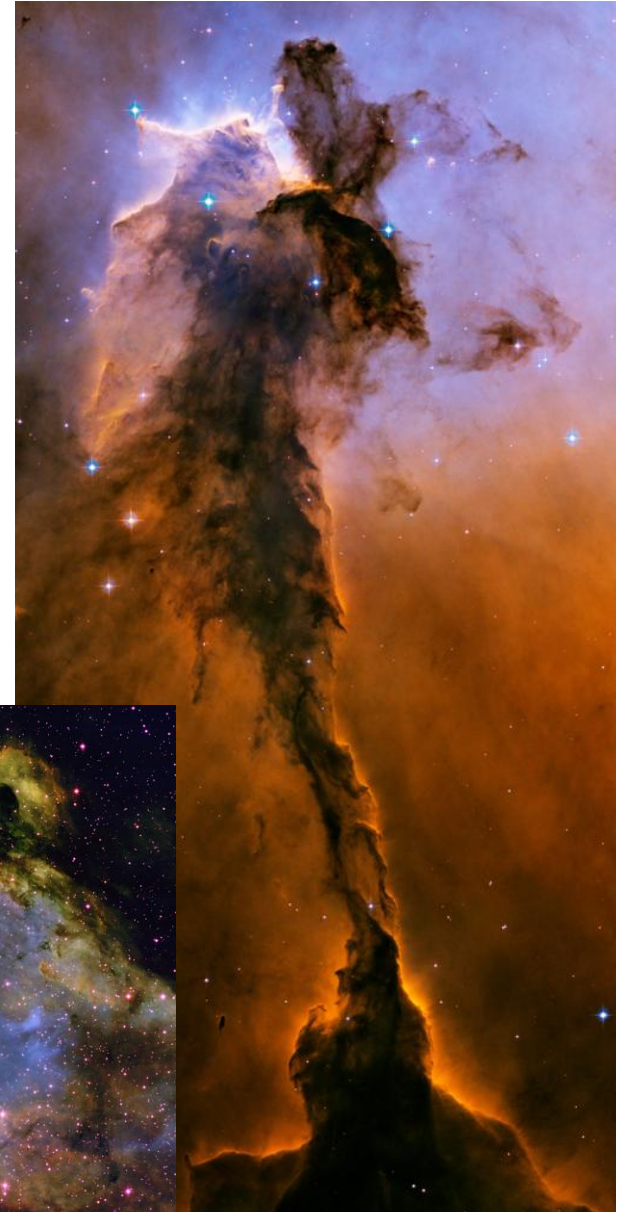
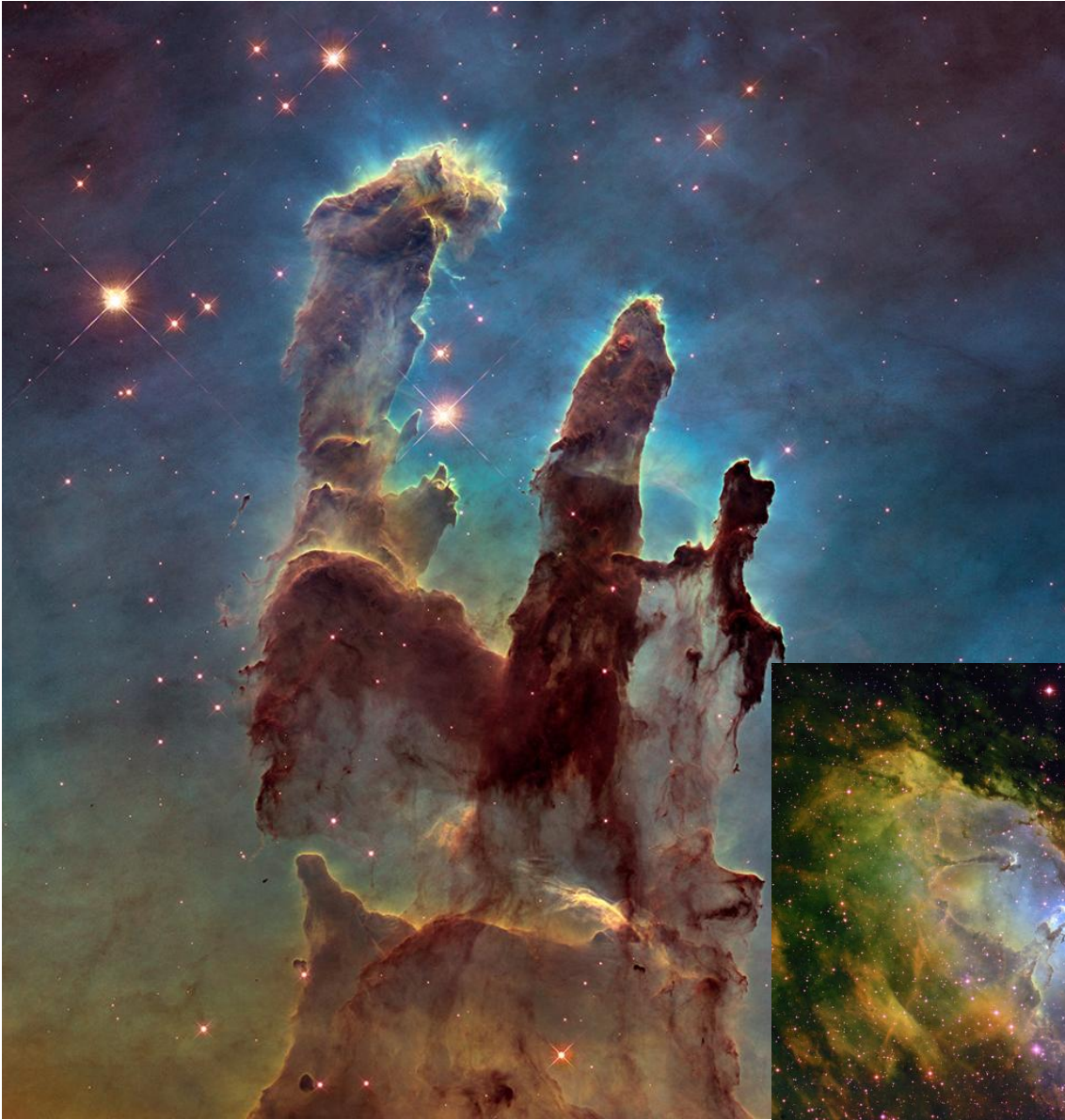
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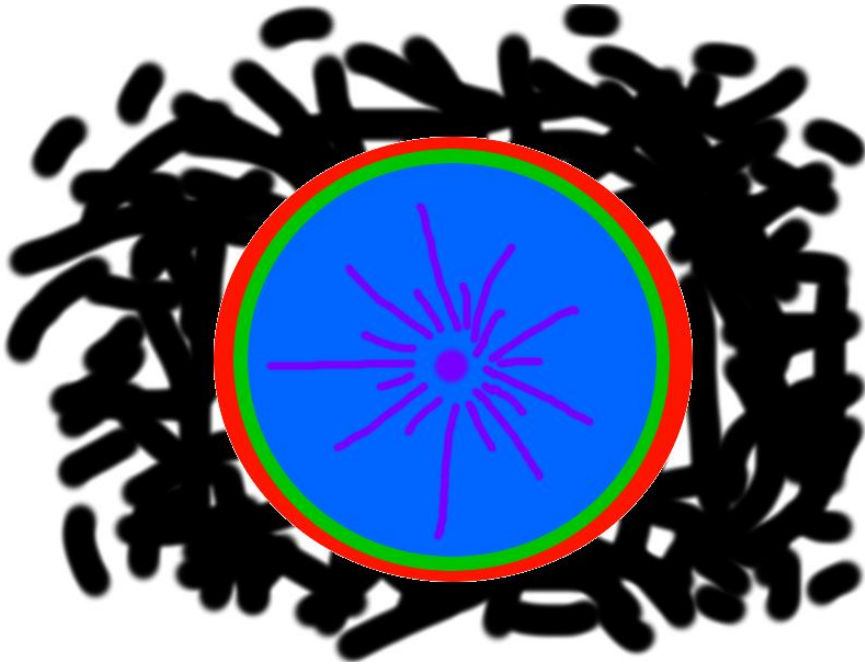
Cousin to physics & engineering. Can be a trap !
Sometime hard to communicate with physicists since:

- Shape/details are crucial
Every pixels & colors count (Seriously. wrong pixels forbidden)

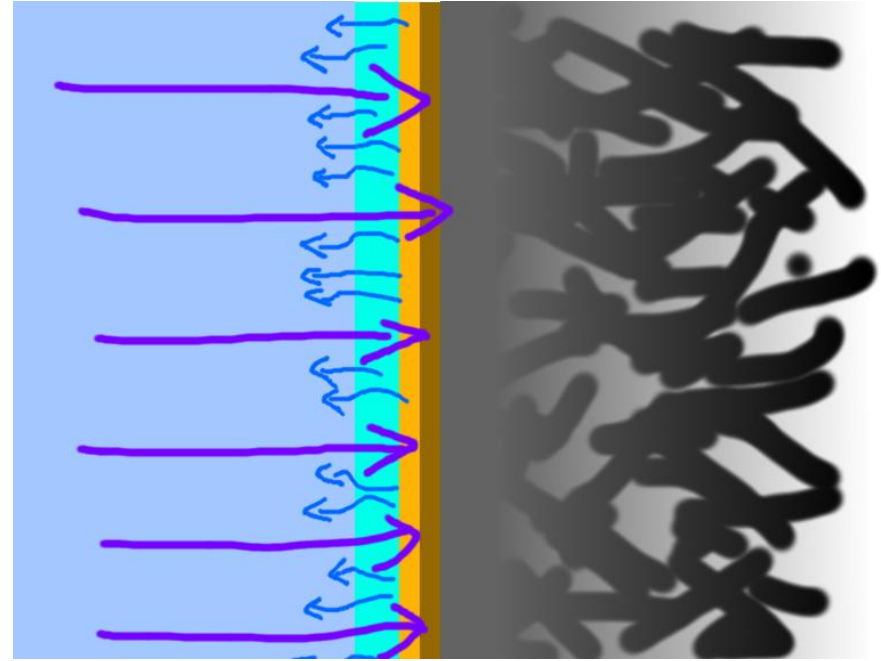
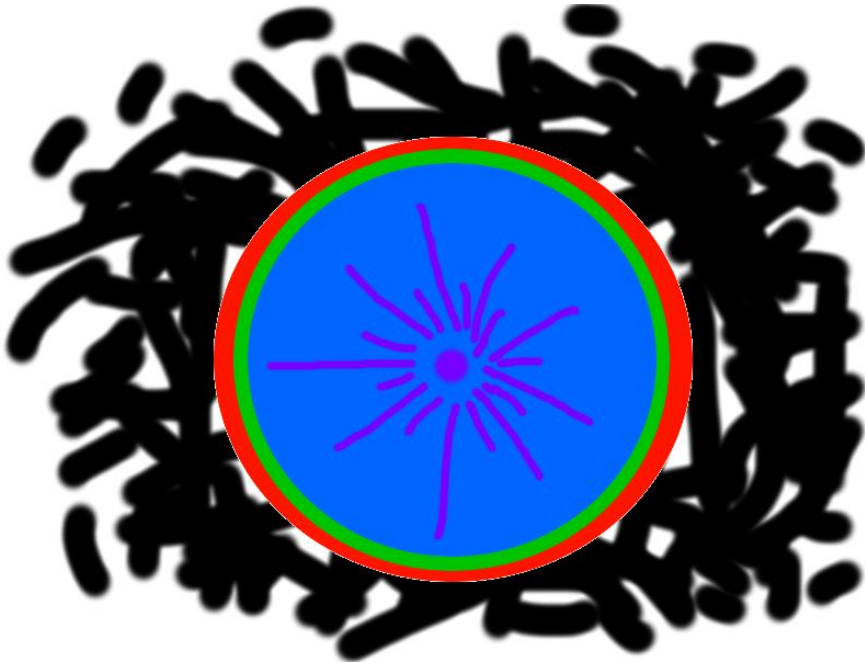
ex: Nebula simulation. “biblio” inquiry



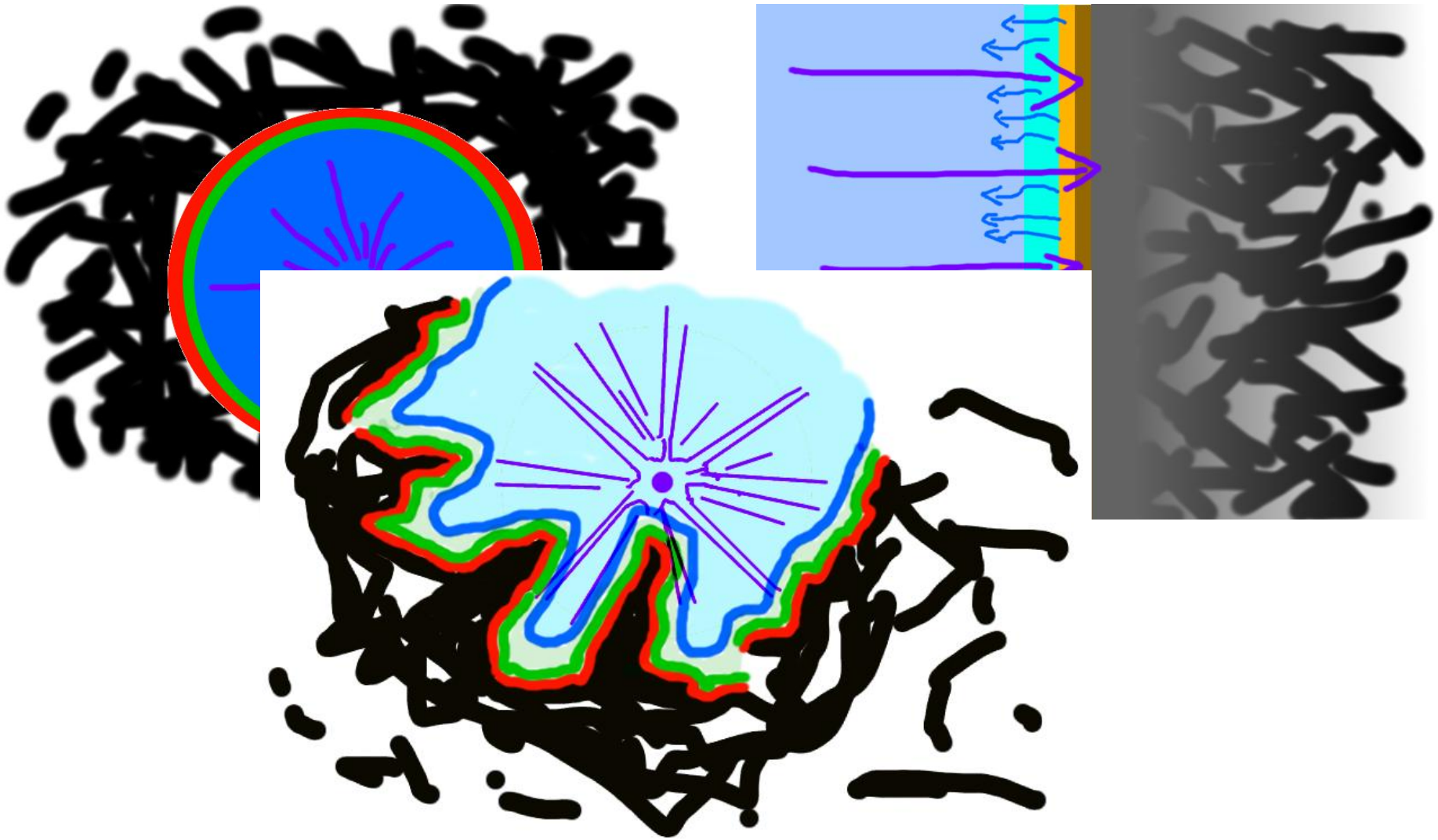
Asking the astrophysics expert 1:



Asking the astrophysics expert 2:



“reality” (ie, extrapolating better model) from biblio



Issue:

reality = ultra-heterogeneous
physics = nonLinear(density)

Same for clouds...

Reality:

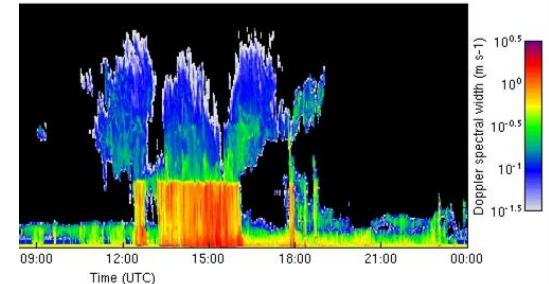


+ paragliders testimonies

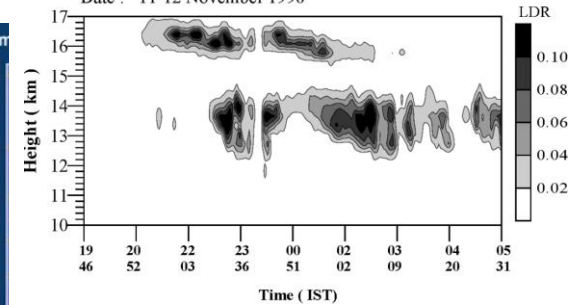
For physicists:



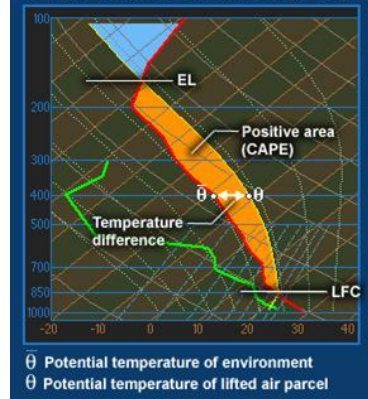
opposed experts opinion



Date : 11-12 November 1998



Depiction of CAPE on a Skew-T-logP Diagram



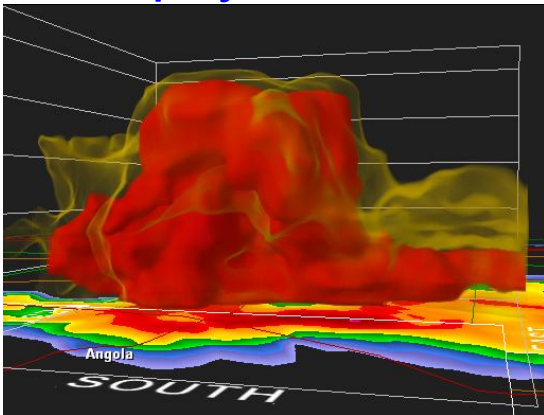
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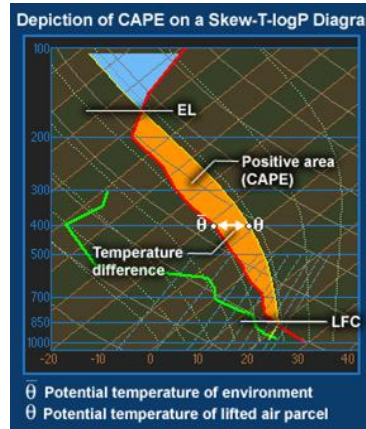
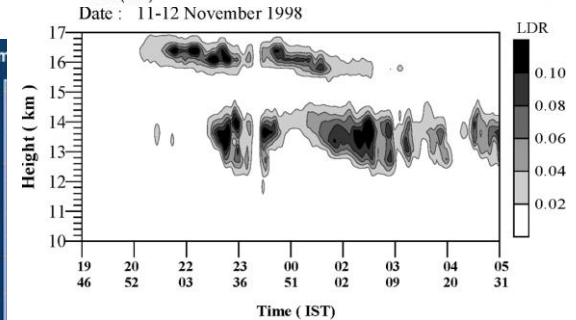
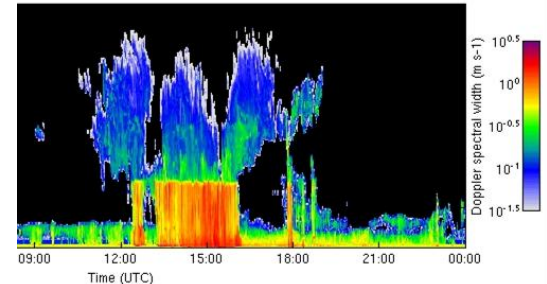
→ from physics simulation:



For physicists:



opposed experts opinion



Issues:

Details-induced thermodynamics

Sharp borders / inversion: Shannon-Nyquist

Same for water surface...

expert 1: “capillarity is always negligible”



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- Integrated scope. scalability / calculability

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 - Integrated scope. scalability / calculability
- + human issues:
- Language exactness
 - Not exact same sub-sub-field / configuration / focus
 - Wrong projection about who we are / different constraints
 - Projects scale / Publi: achievement required level

Claim: C.G. IS a physic science ! (or can be)

Reminder: What is science

scientificity (Popper) : Predict relation between observables
for given question + setup (range, scales)

Just: CG vs engineering vs physicists often rely to different question / use-case

High transversal culture in math/phys/CS (individually or collectively)
[+ some naïvetés]

→ Might help mediating between physicists or industry
Or even, help validating Sc models ?

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Issue: How validating models ?

- Ourselves and coworker :-p / reviewer
- Boss / customer / expert
- Pragmatic: no crash, no, artifact perf ok → what else ? :-) Well...
- Raw difference to ref. case
- “Atomic test case” / global behavior
- User studies

Some provocative questions :-D

Frustrations:

- Why are physicists pointless ? :-p
 - what about real complexity / scenes / materials - explain every pixels
 - general cases (3D, nearfield-connection, long time span)
 - knowledge where money is ? microelec / nano / fluids vs clouds / ocean / astro
- Why can't they understand what we want ? :-D
- Why do they have blind spots about perf / mem ?
availability of data / BC ?
- Why don't they know there own colleagues topic ? over-assume ?
Use different units/hypothesis ? and don't even tell explicitly ?

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- Where is the secret book of “physical principles” magic shortcuts ?
- Why Nature doesn't punish them for their invalid maths ? :-)

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Togetherness:

- Is simulation hopeless for real problems ? (real river boundary cond...)
- How to do real science (refut.→ Lakatos) on simulation (cosmology, climatology...)
Should we let physicists play with it (alone) ?
- Would s.o. be interested in us (CG) *mediating* integrated physics ?
- When will computers be 1000 times more powerful ? (comput / mem)