Galaxy realtime quality rendering

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Fabrice NEYRET
ANR/veRTIGE (RSA-Cosmos, Obs.Meudon, INRIA)

facts:

- *~3. 10^{11} stars*
- *bulb*
- *disc of old stars (field stars)*
- ***arms:** density wave*
  - *young stars (different traj.)*
    clusters, ionizing, SN...
  - *fractal dust clouds ($1 \rightarrow 10^3$)*
    = nebula if lightened or ionized
- ***imager:** (Hubble)*
  48 filters (large to peak)

List of requirements: *(end: dec 2014)*

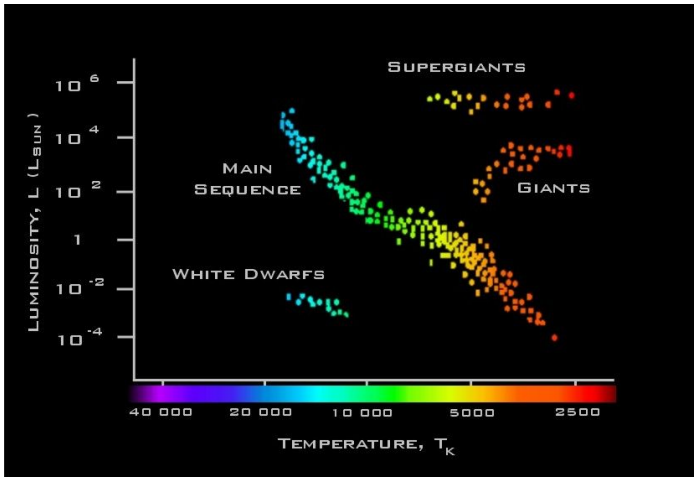
- *view from far*
- *view from inside*
- *continuous view from earth to nearby*
- *change imager filters*
- *animated galaxy (using GALMER SPH simulation)*
- *amplify from astronomy statistics + ref images*
- *quality rendering*
- *strong realtime on highres skydomes (planetarium)*

Some Challenges:

- *mass of data* *(won't fit memory & CPU)*
  - *astronomic objects*
  - *SPH simulation* *(> 3x 10 ^{6} partics. NB: Still running)*
- *all transparent* *(no star-star masking!)*
- *sub-scales count* *(appearance filtering)*
- *all spectral* *(sources, extinction, scatter, ionization, filter)*
- *non-linearities everywhere*
- *ranges of intensities + scales*
- *fusion of data* *(amplified SPH + star catalog)*
- *continuum to discreet*
- *interpolations*
- *knowledge from different fields, to revisit, non-complete*

Tools:

- *GigaVoxels* (**+** *for mass of data, LOD, transp, GPU)*
- *astro tables :*
  - *HR diagram: distrib P(L,T,Z,a)*
  - *iso-Padoue: distrib L,T,r(Z,a),*
  - *IMF, ICMF: distrib m stars resp/ clusters*



- *empirical eqn :*
  - *extinc(λ) , spectra (stars, scattering, ionization)*
  - *distrib Z,a,m(xyz) for star field layer*
- *SPH particles: (~30-40 blended)*
  - *3 layers : old stars field, gaz + young stars, black matter*
  - *M_{gaz}, M_{stars}, distrib(age,Z)*

Addressing some challenges

- *Spectral aspects*
- *non-linearities* *(extinct(λ,L) per se...)*
- *interpolations*
- *Transparency vs optimizations*
- *Filtering & LOD* *(pixel = star + dust mixture)*

1: Spectral aspects

- *a priori knowledge*

  ⚠ *lin vs log vs log-log ;* λ *vs* $\frac{1}{\lambda}$ *vs* f *; MKSA vs "column/Vsun"*

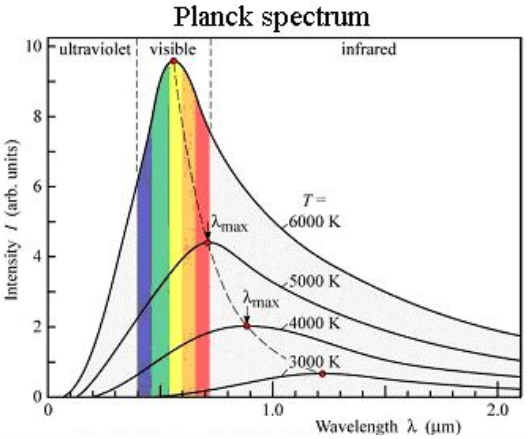
- *filters known at run time*

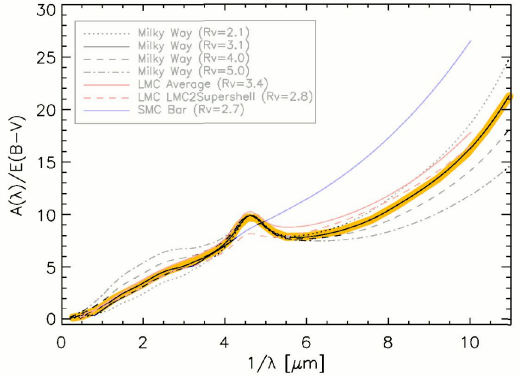
  → *in filter window; proj on func base*

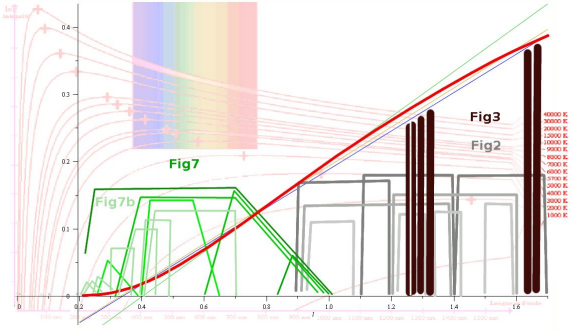
  - *peaks: separately, if needed*
  - *Filter weight:* P_0 *or* P_1
  - *Source:* ~ P_1 *to* P_3
  - *Extinction:* $e^{-\frac{cst}{\lambda}}$ *;* ~ P_1 *or* P_2

→ *F.S.E :* P_n *or* $P_n . e^{-f(\lambda)}$

- *store + render coefs (not spectra)*
- $\int_{\lambda}$ *easy*







2: Filtering & LOD

not 1 star, but:

- *star mixture in pixels/voxels*

$$\int_{xyz} \rho(xyz) \int_{m} \int_{p'} \int_{f \in filtre} W(f)\ \langle I.S_{BB} \rangle (f, LTr_{(m(p');\ a(z,p'),Z(xyz))})\ df\ dp'\, dP_{IMF}(m)\ d_{xyz}$$

in facts,

- *star* **+ *gaz extinct*** *mixture*
- " " **+ *emissions*** *mixture*
- " " " **+ *inhomogeneous gaz*** *(so long 'density')*
- " " " " **+ *gaz-star correlation***

→ *Master 2013/2014 subject :-)*

3: GigaVoxel framework

- *high-level: octree of particles*
  - *phys data*
  - *3 layers : gaz, clusters, stars (more compact + higher res)*
  - *produced from : Galmer' CPU particles + filters*
  - *resident*

- *low-level: octree of voxel bricks*
  - *for rendering*
  - *2 layers : "mixture color" + "cloud opacity"*
  - *produced from : GPU particles + eqn("2:filtering")*
  - *transcient*

Transparency vs optimizations

- *Occlusion by dust:*

  dark clouds are not iron walls

  stars intensity not in [0,255]

  so: never sure light won't peak through !

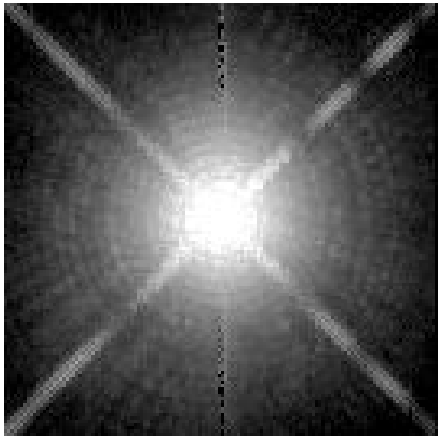
→ *estimate before draw/load voxels:*

- *min-max Lum :* *RenderDetails(loc) iif* $trsp_{cur} * L_{max}(loc) > \varepsilon$
- *min-max Extinct :* *RenderDetails(loc) iif* $trsp_{cur} * trsp_{\Delta}(loc) > \varepsilon$
- *stronger a priori knowledge ?*

- *Occlusion by stars:*

  stars << pixel... but large disk of saturated pixels→ let's use it !

  clamp($10^{10}.\delta_{star} * PSF_{captor} * CircleOfConfusion_{optic}$ *)*



Interpolation and non-linearities

find non-linear blending or reparameterize for X-lin vars

- *Blending(spectra),* Π *extinction(),*
- *Voxel = MIPmaping = interp*$_{4Dlinear}$*(vars)*
- *SPH reconstruction = barycentric lin interp*
- *LODs*
- *fetch in maps (HR, spectra,…):* *lin or log or x ?*

then, integrals = MIPmapping

amplification and noise

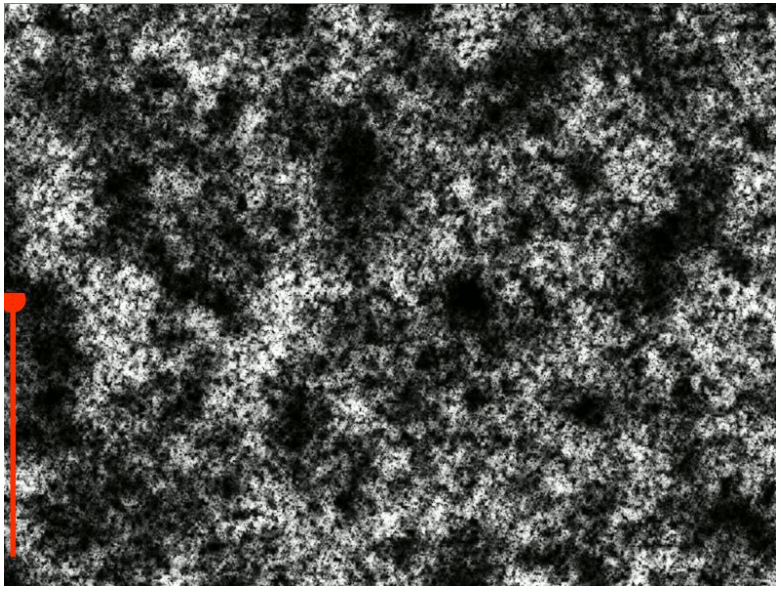
SPH simu: recons = smooth fields

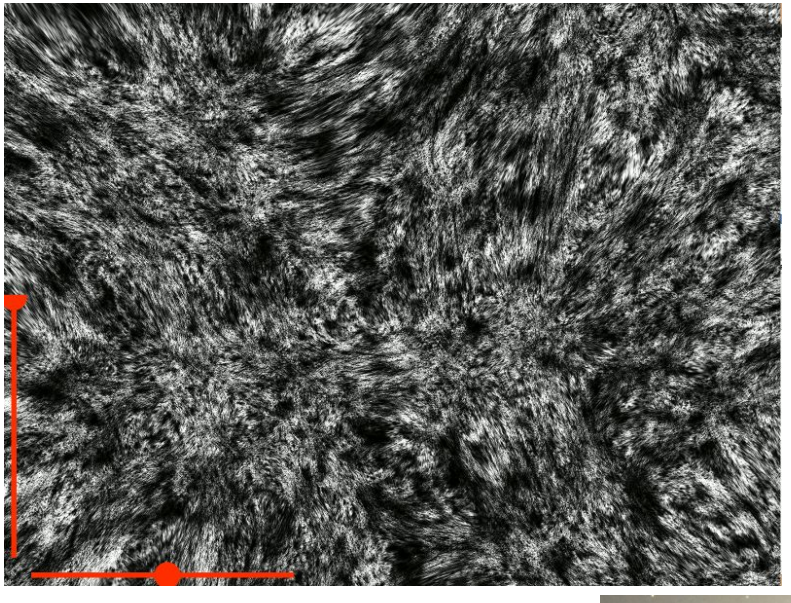
- *density continuum fluctuations*
- *continuum to discreet (clusters of clusters, clusters, stars)*
- *dust clouds*
  - *fractal, on large range of scales*
  - *features at all scales (cloud, arms, plumes...)*
  - *anisotropy*
  - *shaped by stars (shockwaves, ionization, SN)*

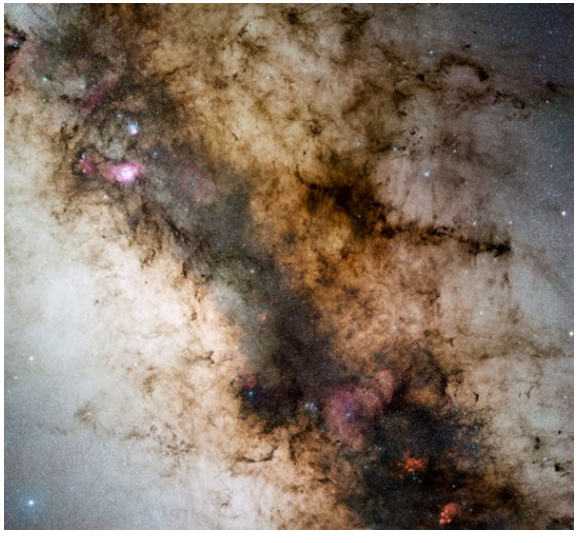
hierarchical autogravity collaps

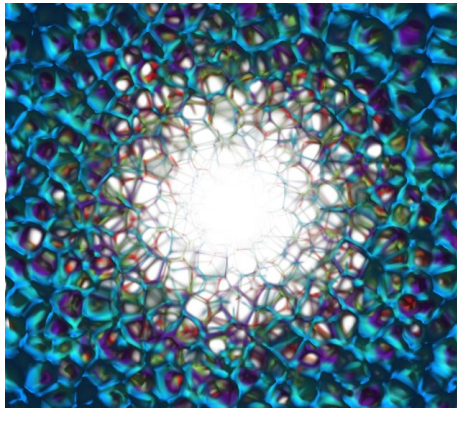
→ not fractal; multifractal

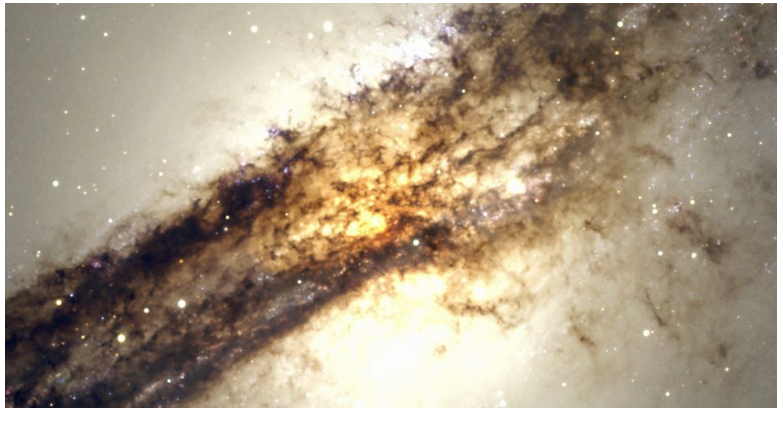
→ not Perlin-∑; Perlin-Π: $\Pi(1 + k.\, sBaseNoise(warp(2^i x)))$





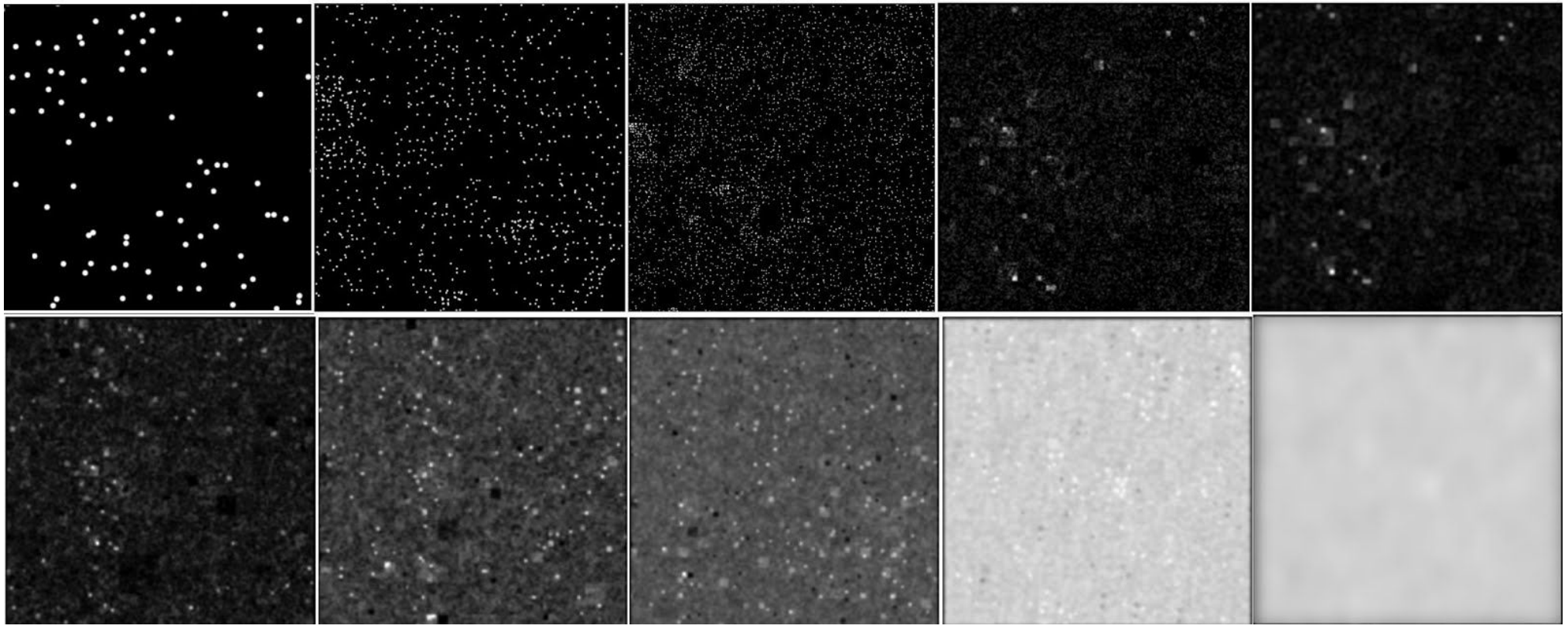






Eulerian Poisson noise:

recursive top-down intervals



to be continued !