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 ($1\rightarrow10^3$)
  = nebula if lightened or ionized
- imager: (Hubble)
  48 filters (large to peak)
List of requirements:  

- 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 parts. 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**:
  - $extinc(\lambda)$, 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
  - $M_{\text{gaz}}, M_{\text{stars}}, \text{distrib}(\text{age},Z)$
Addressing some challenges

- Spectral aspects
- non-linearities (\(\text{extinct}(\lambda,L) \text{ per se...}\))
- interpolations
- Transparency vs optimizations
- Filtering & LOD (\(\text{pixel} = \text{star} + \text{dust mixture}\))
1: Spectral aspects

- **a priori knowledge**
  - $\text{lin} \ vs \ \text{log} \ vs \ \text{log-log} ; \ \lambda \ vs \ \frac{1}{\lambda} \ vs \ f$; MKSA vs “column/Vsun”

- **filters known at run time**
  - $\rightarrow$ in filter window; proj on func base
    - peaks: separately, if needed
    - Filter weight: $P_0$ or $P_1$
    - Source: $\sim P_1$ to $P_3$
    - Extinction: $e^{-\frac{\text{cst}}{\lambda}}$; $\sim P_1$ or $P_2$

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

- **store + render coefs (not spectra)**

- $\int \text{easy} \ \lambda$
2: Filtering & LOD

not 1 star, but:

- star mixture in pixels/voxels
  \[ \int_{xyz} \rho(xyz) \int_m \int_{p'} \int_{f \in \text{filter}} W(f) \left\langle I(S_{BB}) (f, LTr_{(m'(p'); a(z,p'),Z(xyz))}) \right\rangle df \; dp' \; dP_{IMF} (m) \; d_{xyz} \]

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 \( \text{trsp}_{\text{cur}} \cdot L_{\max}(\text{loc}) > \varepsilon \)
  ● min-max Extinct : RenderDetails(loc) iif \( \text{trsp}_{\text{cur}} \cdot \text{trsp}_{\Delta}(\text{loc}) > \varepsilon \)
  ● stronger a priori knowledge?

● Occlusion by stars:

stars \ll\ pixel... but large disk of saturated pixels→ let’s use it!
clamp( \( 10^{10} \cdot \delta_{\text{star}} \cdot PSF_{\text{captor}} \cdot CircleOfConfusion_{\text{optic}} \) )
Interpolation and non-linearities

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

- Blending(spectra), $\Pi$ extinction()
- Voxel = MIPmapping = interp$^4$Dlinear(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 : Π(1 + k \cdot sBaseNoise(warp(z^i \cdot \mathbf{x})))
Eulerian Poisson noise:
recursive top-down intervals
to be continued!