Introduction to visualisation

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Contents

- Introduction: definition, motivation, outcomes
- Examples: mathematics, simulation data, experimental data, 3D scanning, illustration, heritage, cultural heritage
- Categories: volume visualisation, geometric representations, information, networks
- Techniques: colour maps, glyphs, dimension reduction, rendered vs realtime
- Hardware: resolution, stereoscopy, immersion
- Special topics: virtual environments, sonification, haptics, 3D printing, 360 video, gigapixel imaging, multispectral imaging, photogrammetry

Introduction

- Definition: "Visualisation is the process of applying computer graphics to data in order to provide insight into the underlying structures, relationships and processes.
- "Turning data into images and animations to assist researchers".
- The key is insight, may be insight to the researcher, their peers, the general public.

- Techniques that find application across a wide range of disciplines.
- Often employs novel capture methodologies, display technologies and user interfaces.
- Frequently requires high performance computing and advanced algorithms.

- Outcomes
  - Revealing something new within datasets.
  - Finding errors within datasets.
  - Communicating to peers (papers, conferences)
  - Communicating to the general public.

Examples: mathematics

- Equations are the Devil's Sentences. (Stephen Colbert)

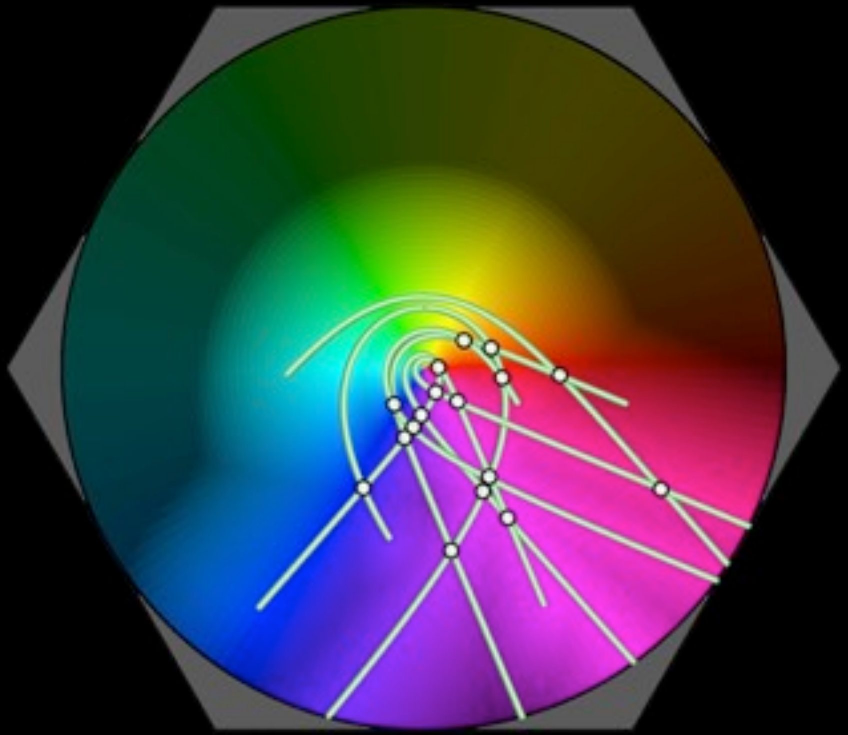
$$\varphi_p^{\mathbf{qr}'}(t) = f_p^{\mathbf{qr}'} \times Q_p\left(\mathbf{r}', t - \frac{|\mathbf{q} - \mathbf{r}'|}{\nu}\right)$$

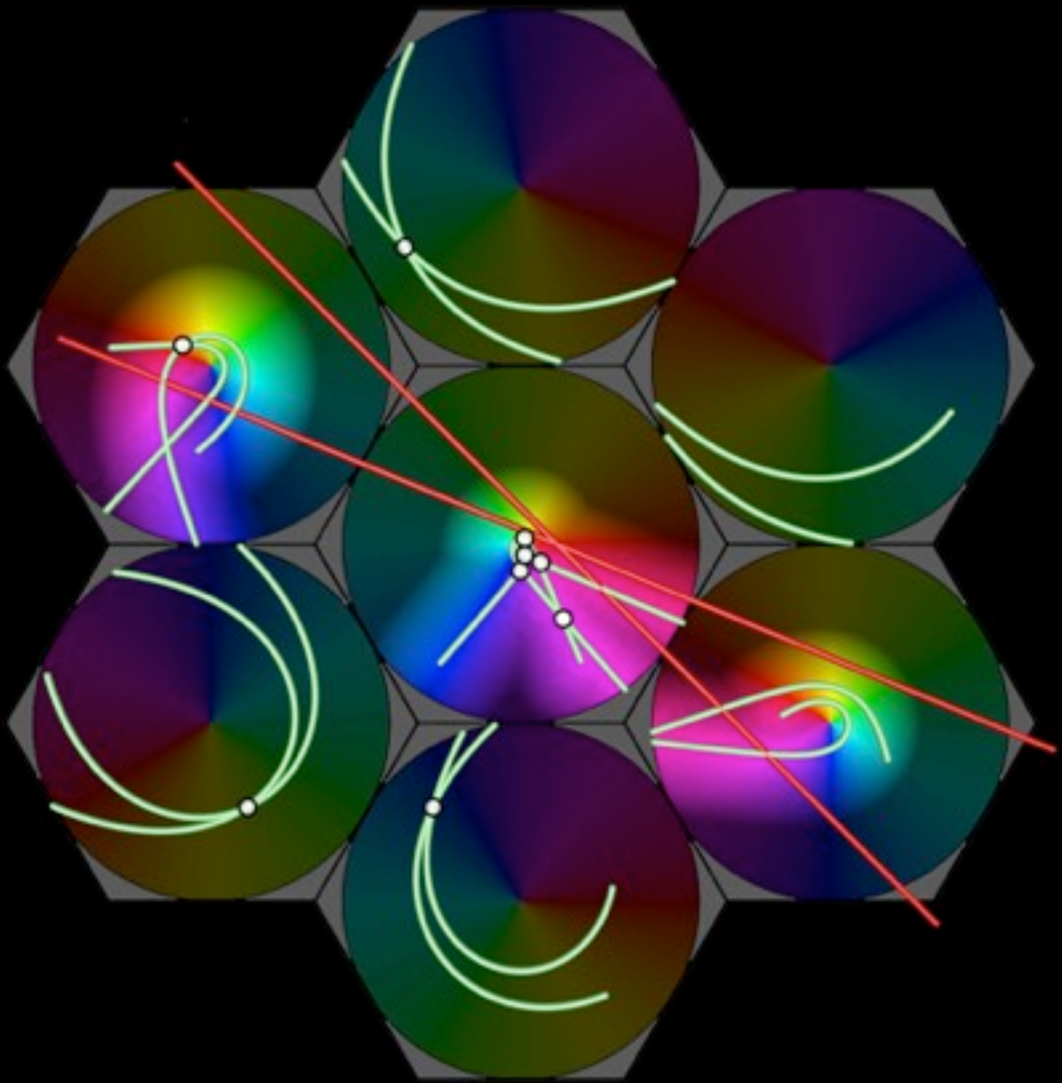
$$\psi_p^{\mathbf{qr}'}(t) = M_p^{\mathbf{qr}'} * \varphi_p^{\mathbf{qr}'}(t)$$

$$\Psi_p(\mathbf{q}, t) = \int_{\mathbf{r}'} \psi_p^{\mathbf{qr}'}(t) d\mathbf{r}'$$

$$V_p(\mathbf{q}, t) = \sum_{p=e \wedge p=i} G_p * \Psi_p(\mathbf{q}, t)$$

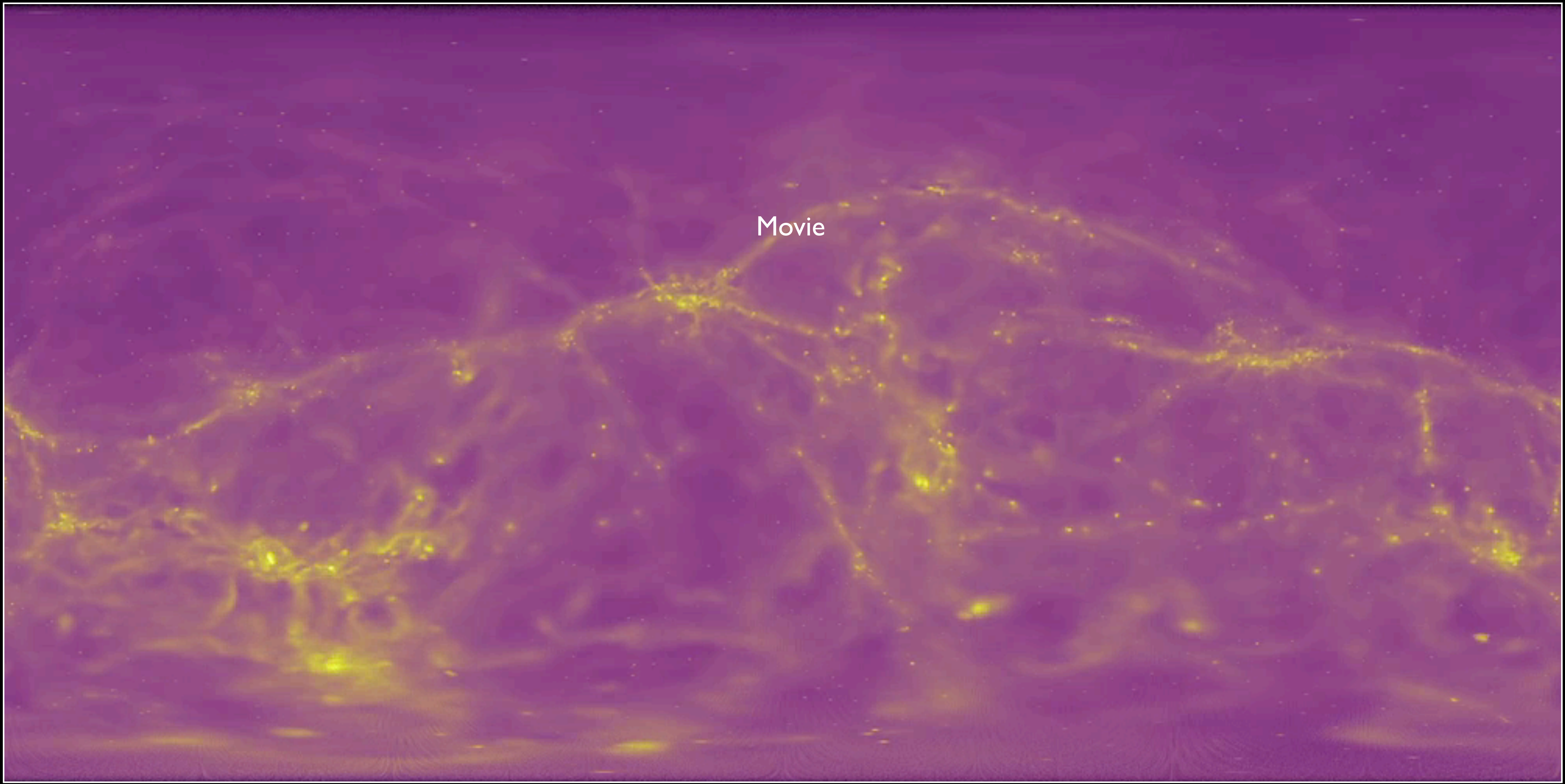
$$Q_p(\mathbf{q}, t) = f_\Sigma(V_p(\mathbf{q}, t)) + E_p(\mathbf{q}, t)$$





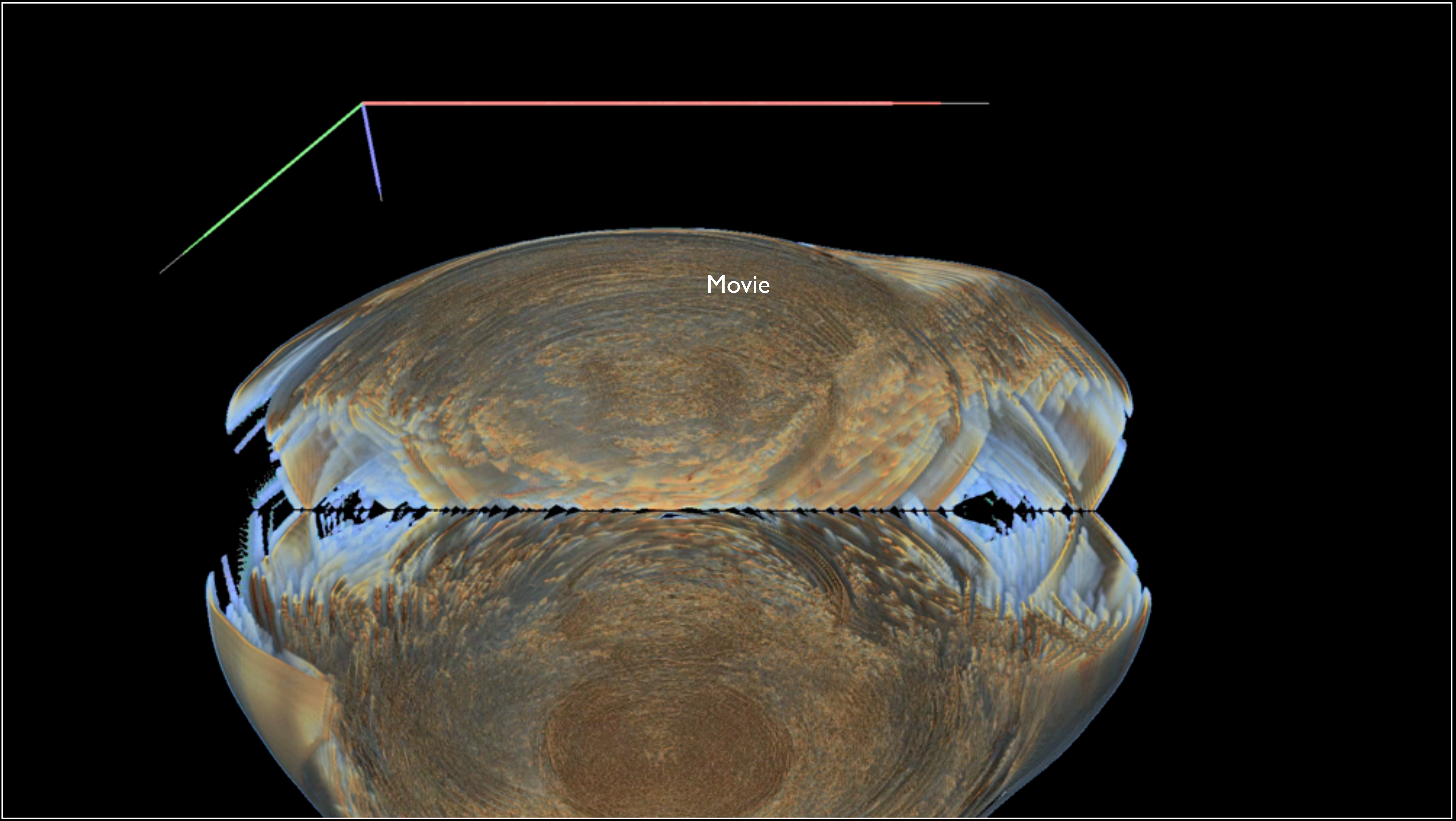
Examples: simulation

- Galaxy formation / evolution. (Allan Duffy, ICRAR)
- Example of visualisation also being performed on the supercomputers doing the simulations. 1/2TB per time step.



Examples: simulation

- Wave propagation in Geoscience simulations.
- 1TB dataset but visualisation is interactive on a high end workstation.



Examples: 3D scanning

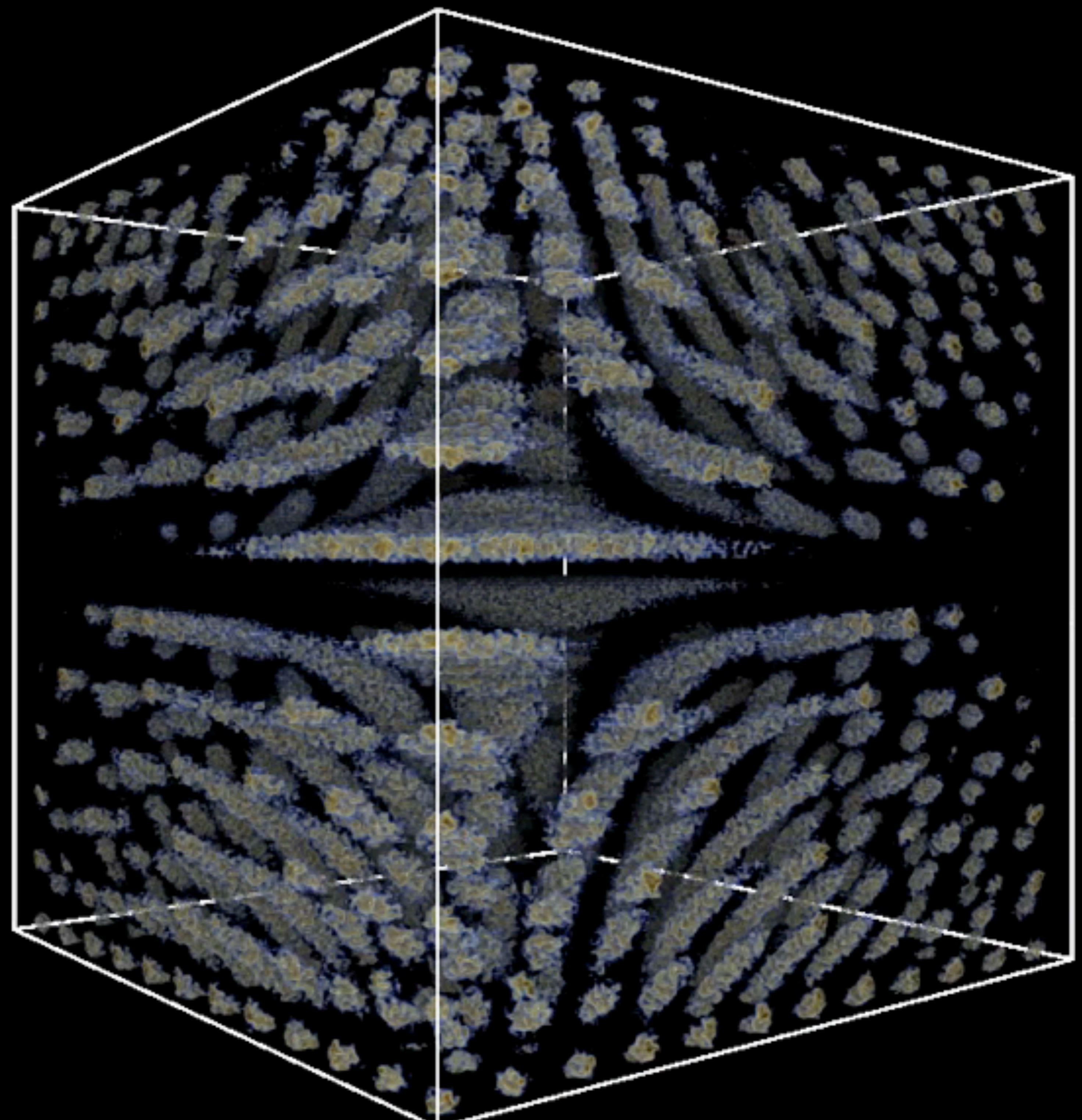
- Medical CT scan at Hobart hospital. (Pausiris mummy)
- The first time the interior of this Egyptian mummy was revealed, designed for forensic purposes but also as a public exhibition.

Movie

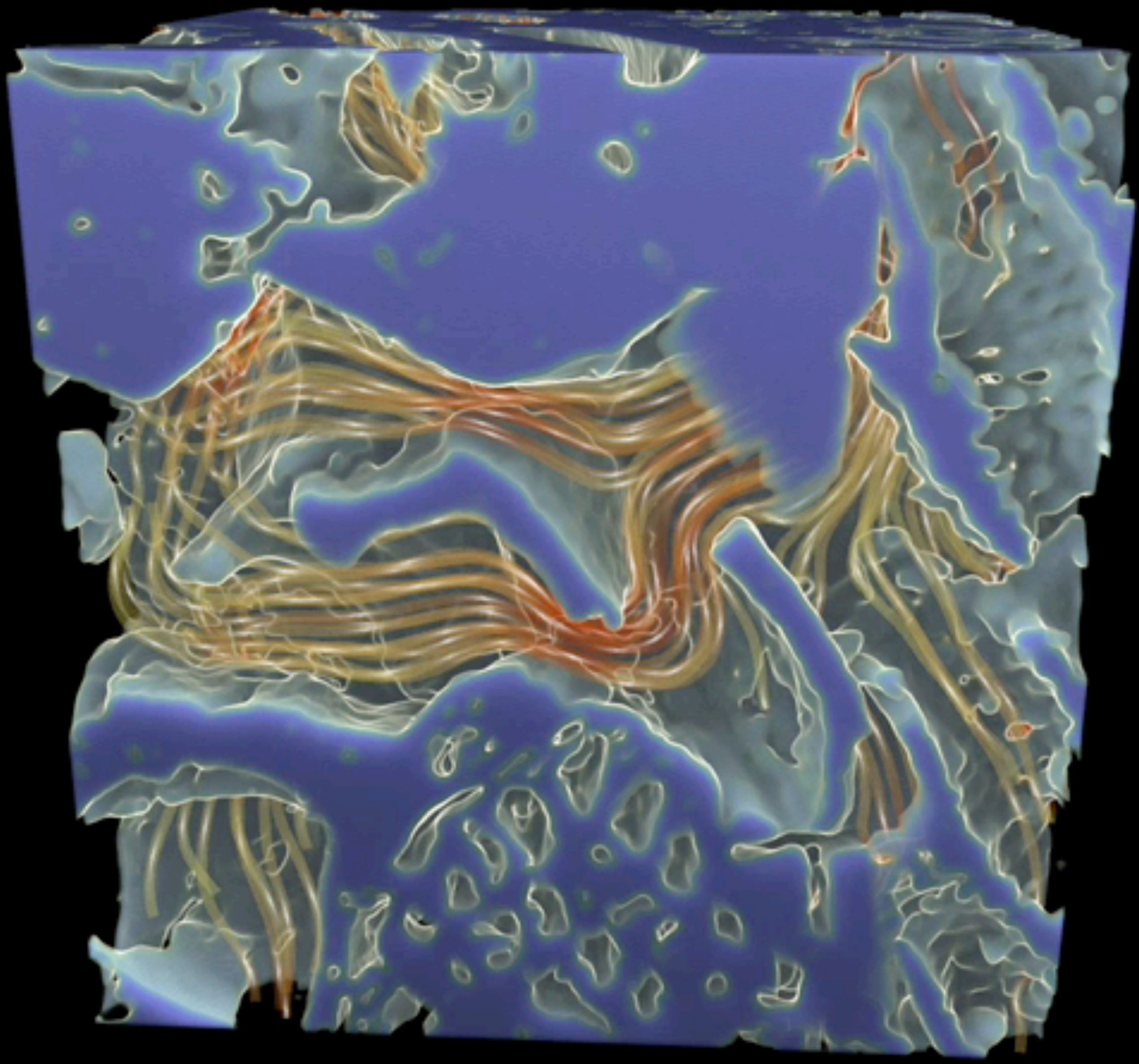
Examples: time varying volumes

- Standing waves in electromaterials.

Movie



Examples: flow visualisation



Movie

Examples: illustration

- Illustrative visualisation in medicine. (Drew Berry)
- Visualising a process without there necessarily being data involved.

Movie

Examples: heritage

- Visualising heritage objects.

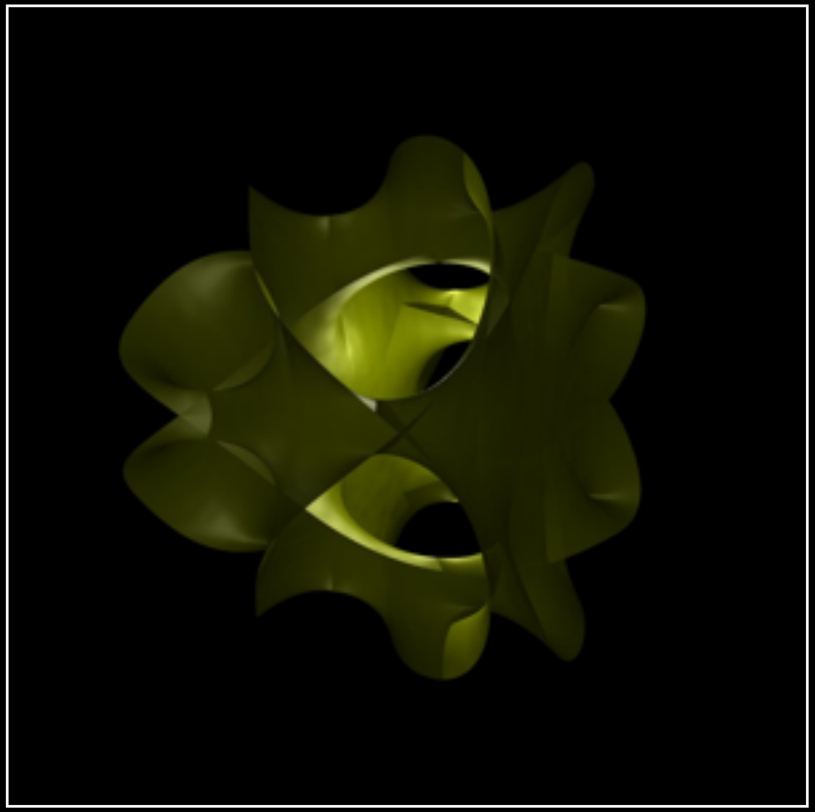
Movie

Examples: cultural heritage

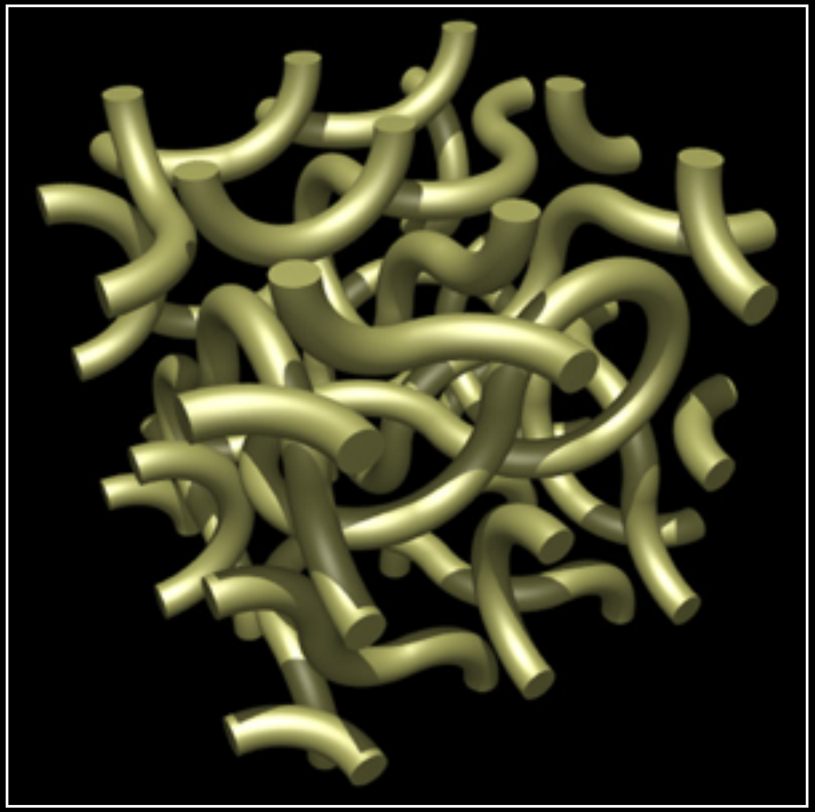
- Visualising other cultures, possibly from another time.
- Insight into what it may have been like to live in another culture or time.

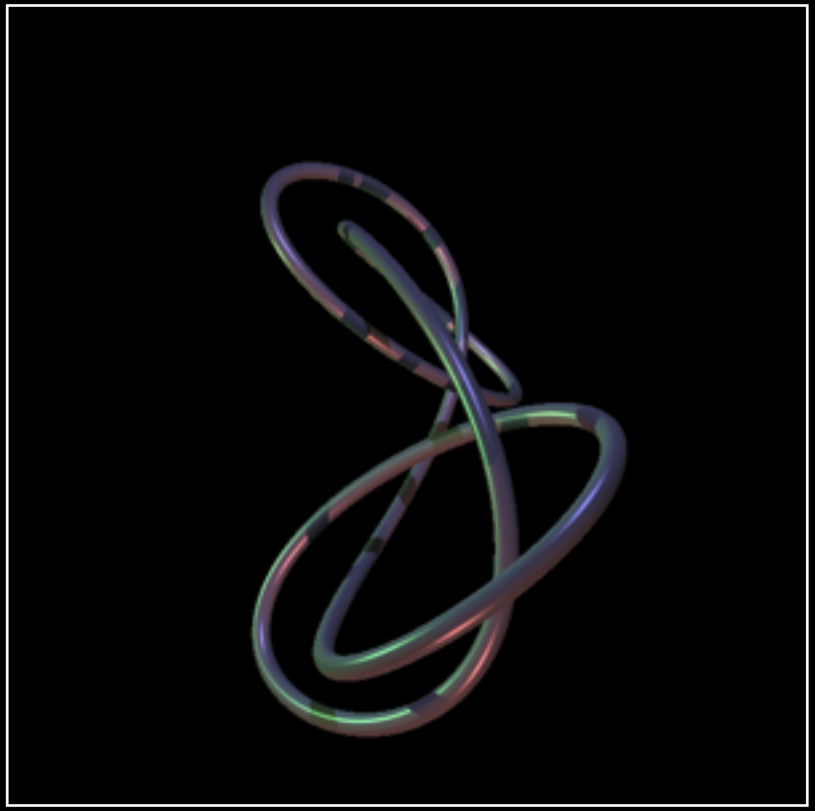
Example: geometry / topology

11 dimensional Calabi-Yau surface



3D Truchet tiles





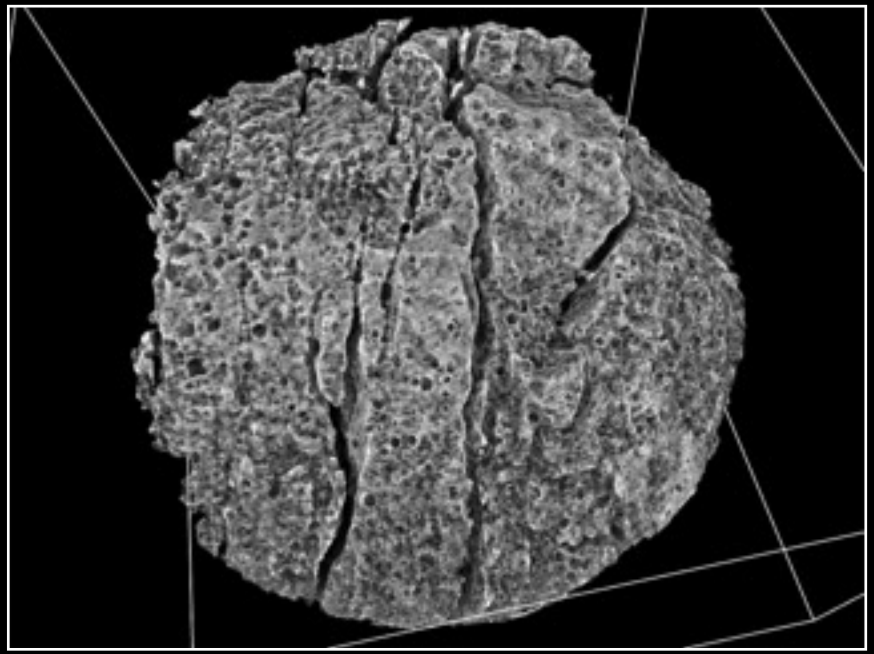
Knot theory

Borromean rings

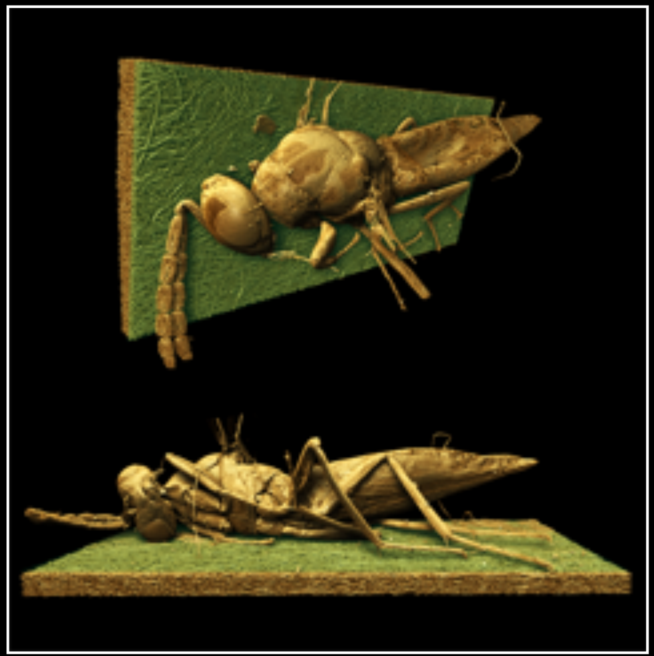
Categories: volume visualisation

- Very common form of data in the sciences.
- Traditionally one thinks about medical data, for example MRI.
- Other scanning and 3D imaging technologies include CT (MicroCT) and CAT scans.
- Volumetric data also arises from many numerical simulations.
  Quite common in astronomy and engineering (finite element calculations).
- In scanned volumetric datasets the quantity per voxel depends on the scanning technology.
  For example: MRI essentially gives water content, CT gives density.
- For volumetric datasets derived from simulation there can be multiple variables per voxel.

Medical research (MRI)

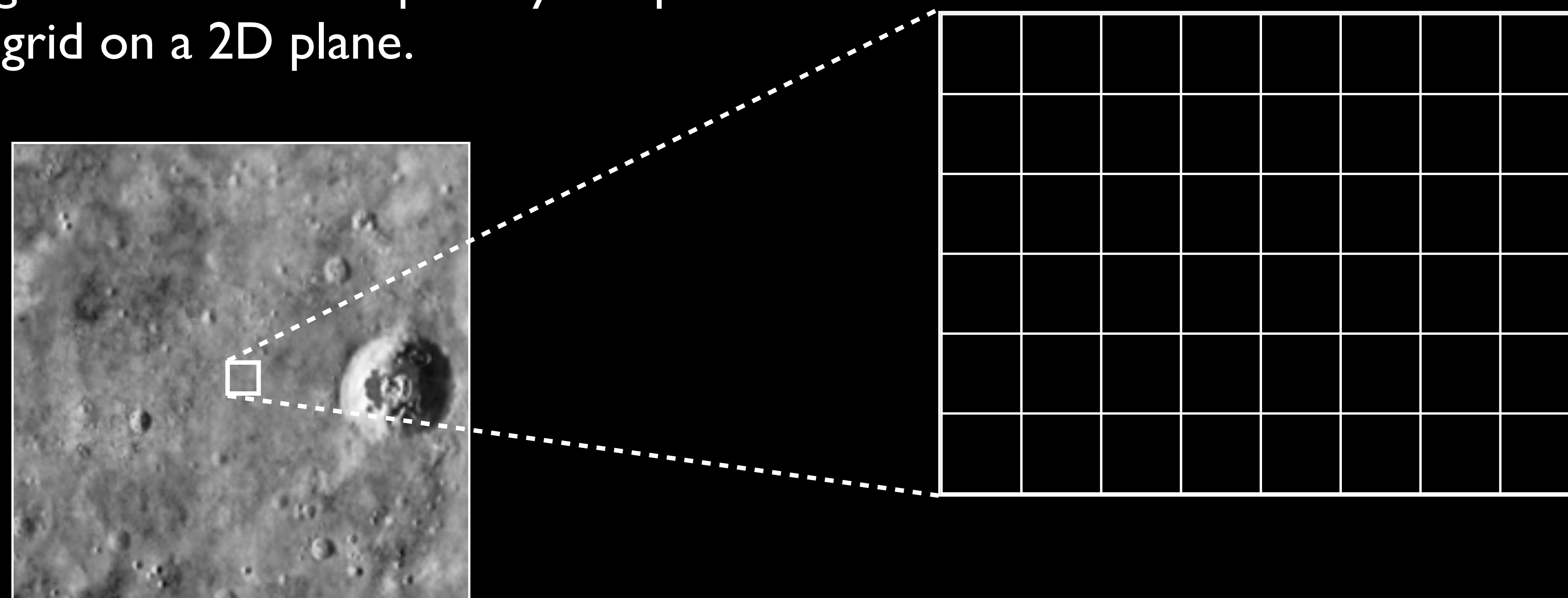


Geology (CT)

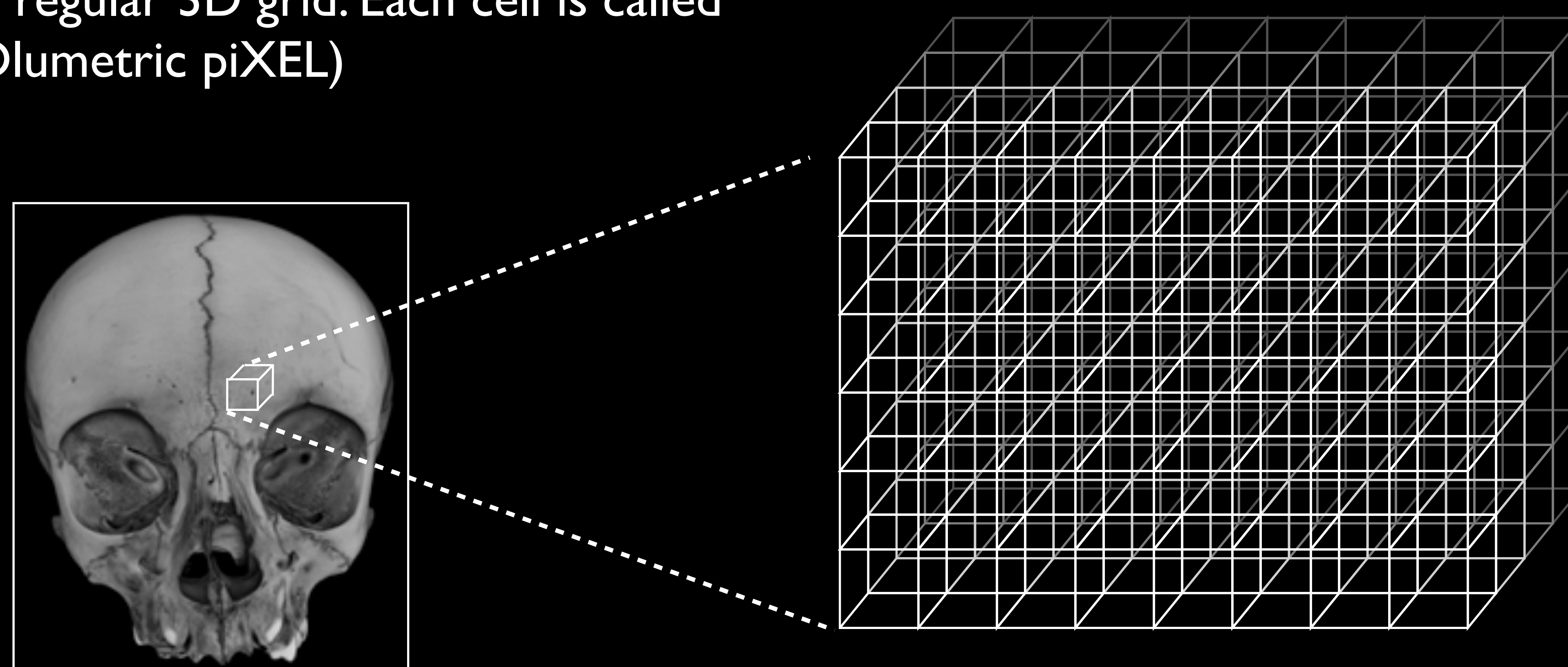


Entomology

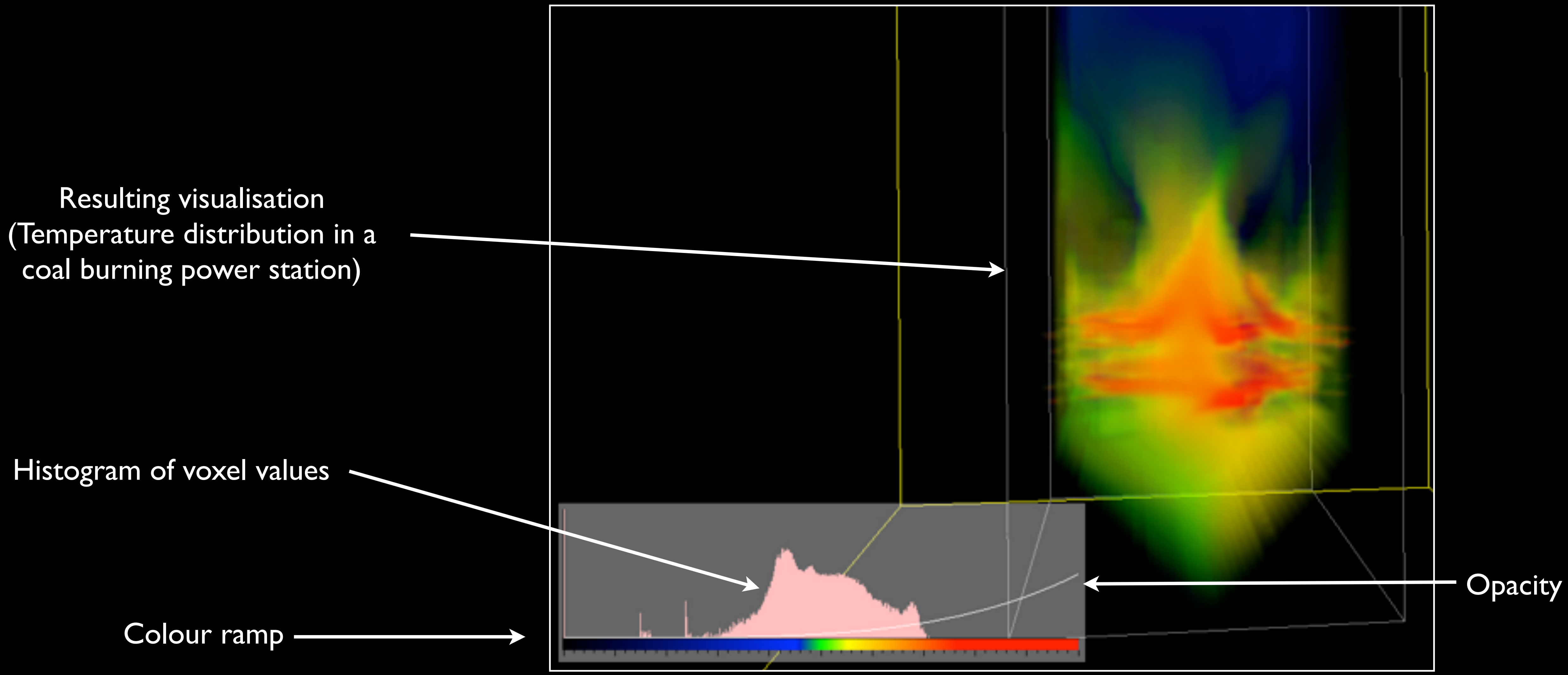
- A digital image contains some quantity sampled on a regular grid on a 2D plane.

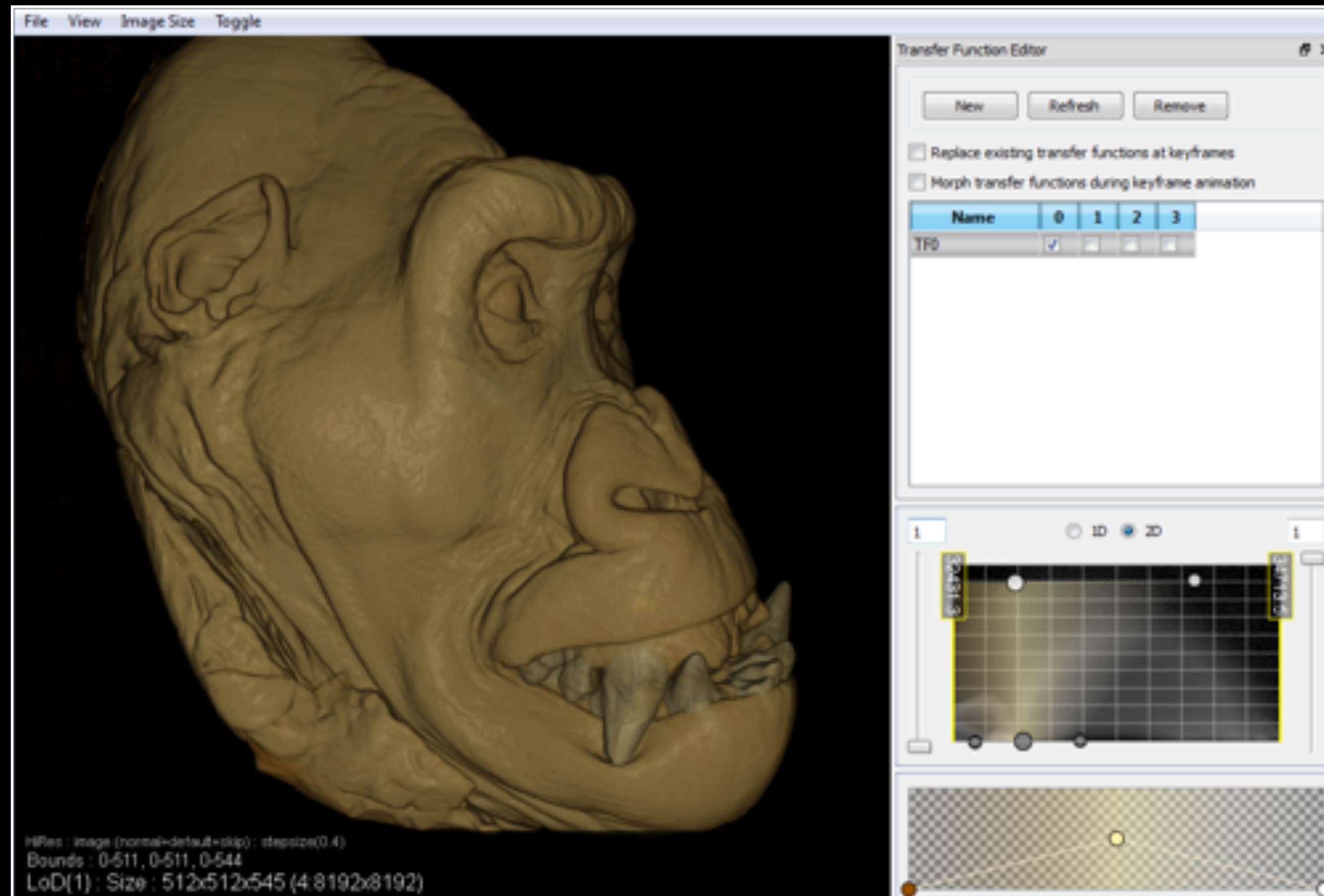


- In a volumetric dataset there is some quantity sampled on a regular 3D grid. Each cell is called a VOXEL (VOlumetric piXEL)



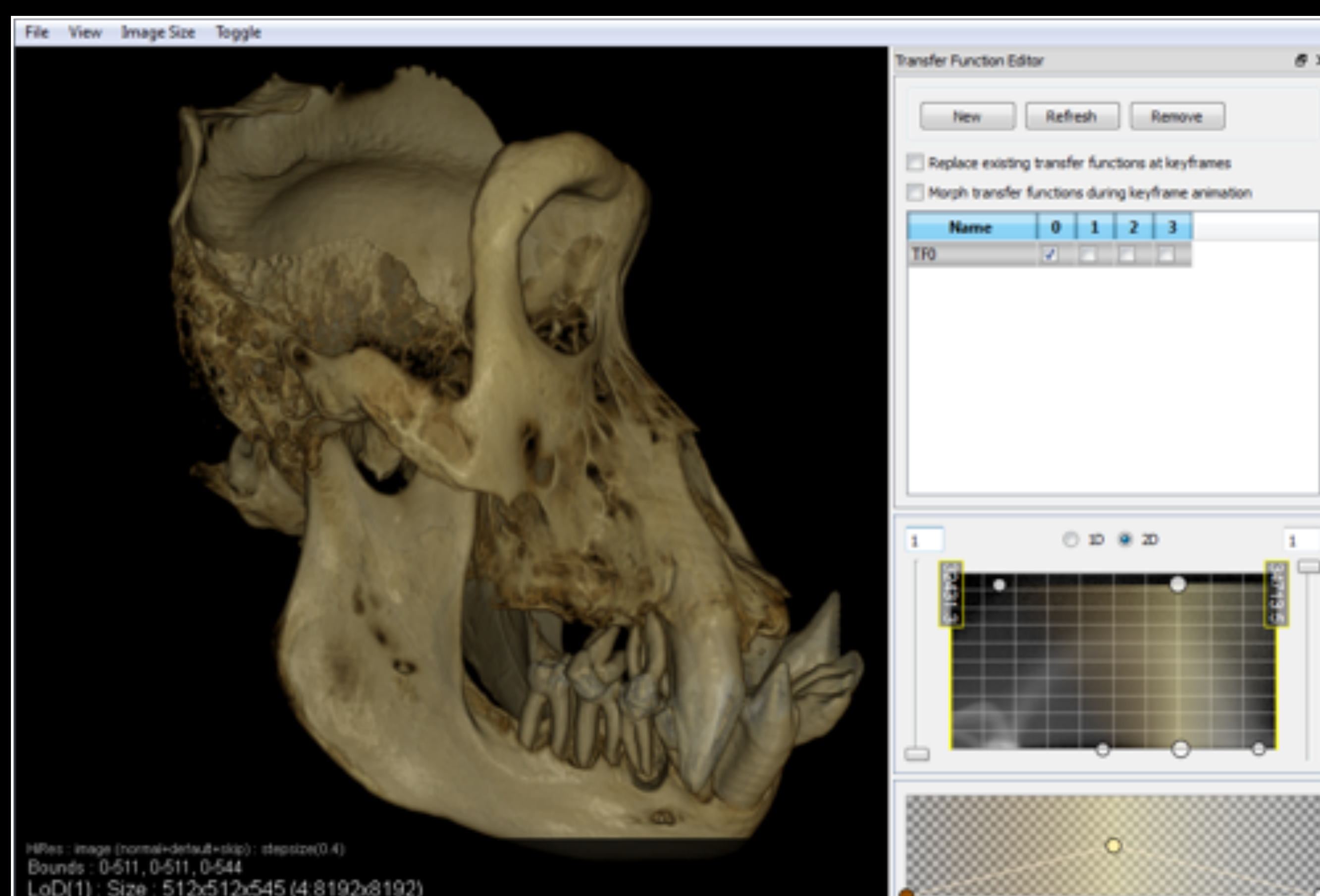
- Volumetric visualisation is the process of exploring and revealing the structure/interior of a volumetric dataset.
- The general approach involves a mapping between voxel values and colour/opacity.
- Realtime volume visualisation generally requires hardware assistance, notably graphics cards.
- Has always been a demanding area in visualisation, the data volumes researchers wish to visualise has always been ahead of the technology.
- Still the case with huge volumes from MicroCT scanners and Synchrotrons.





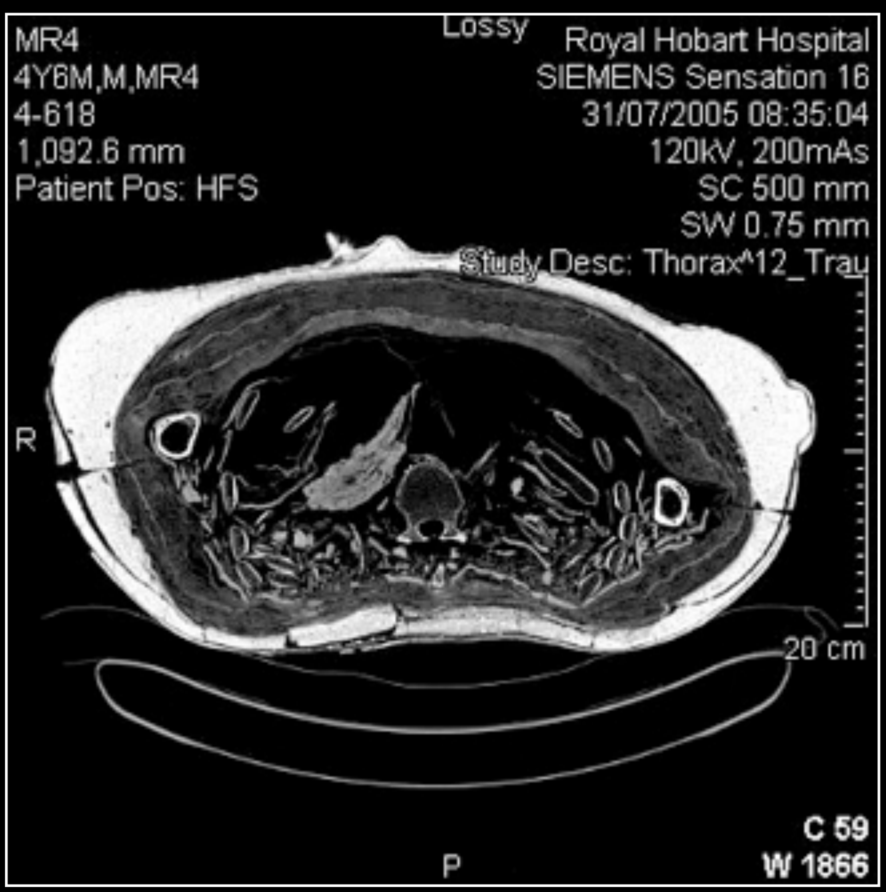
Density on horizontal axis

Same data but different transfer functions



Colour and opacity mapping

- Raw slice data is generally shown as a movie in just the axis of the slices.
- Colours are not real, that is a mapping choice by the person doing the visualisation.
- Can be chosen to enhance features, or based upon expected colour.
- There are volumes where the voxel values are RGB values, for example cryosection volumes.



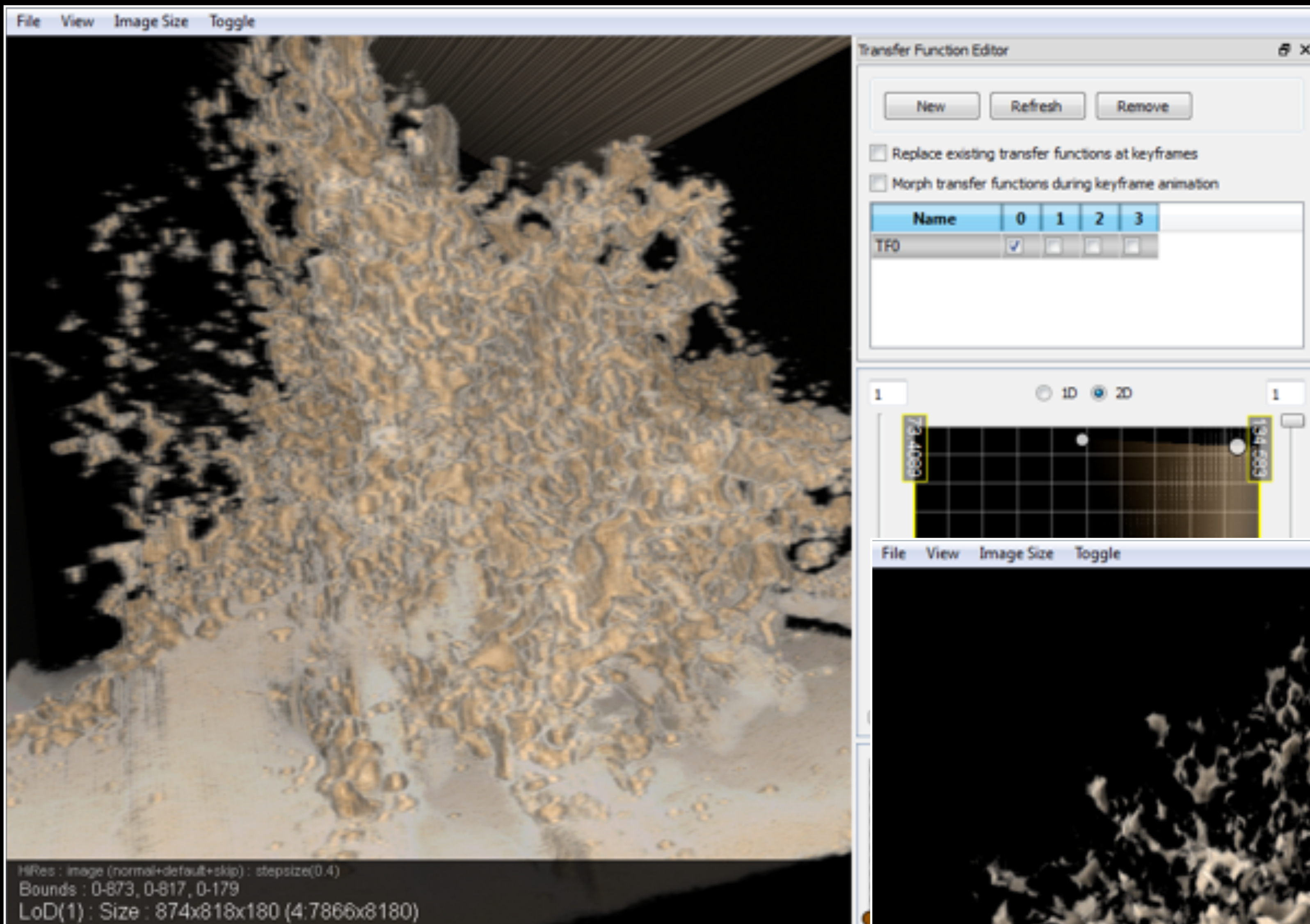
Slice data from the CT scanner

Volume visualisation

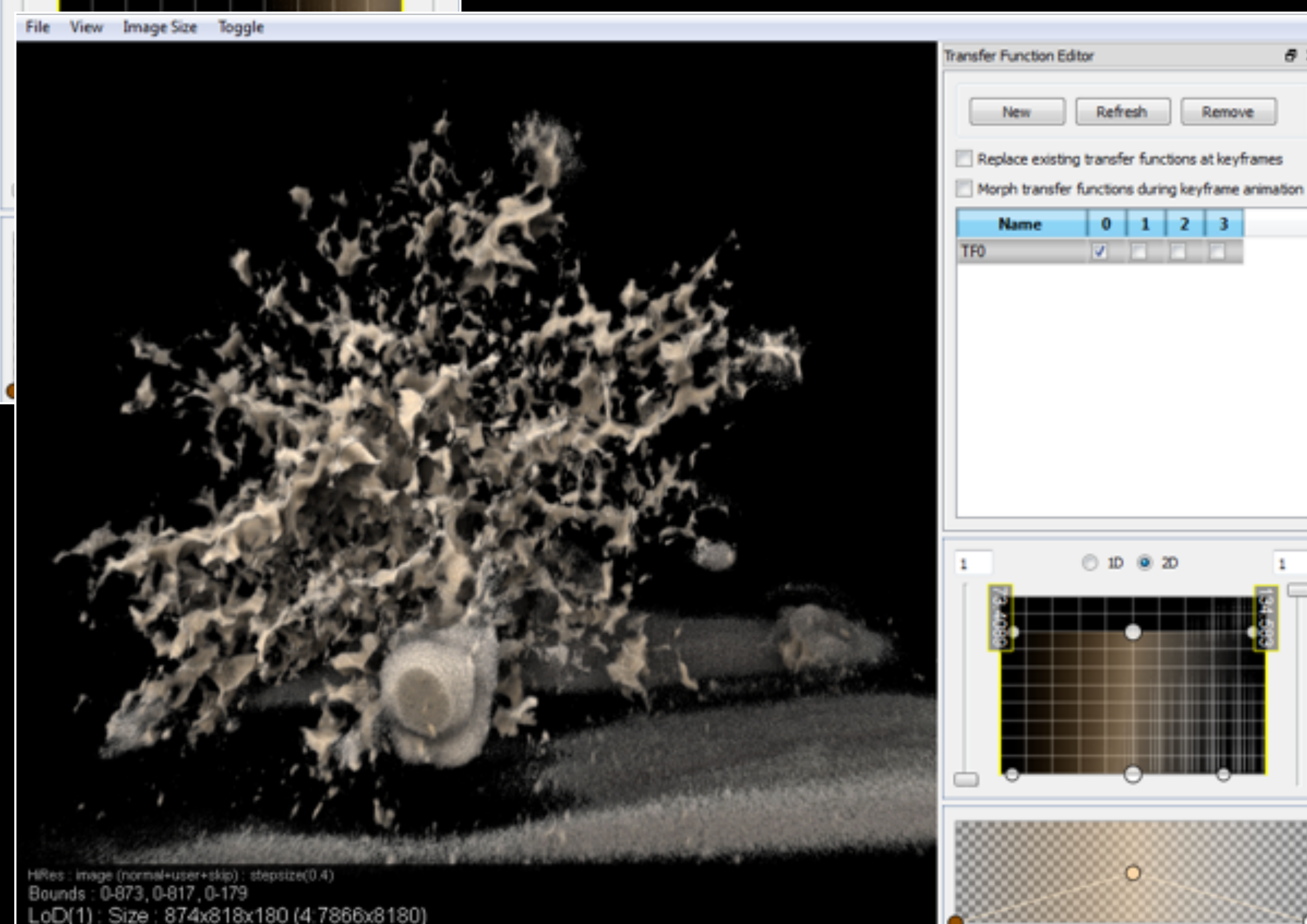
- RGB volume generally arise from slice and photograph techniques.
- For example, the visible human dataset)

Movie

- Microfossil



The structure is a 1.9 billion year old microfossil from the Gunflint chert of Canada. The image is a reconstruction of c. 180 slices through the microfossil. The slices were c. 15 x 15 microns in size and 75 nm thick. Slicing was achieved using a focused beam of gallium ions, and imaging of successive slices using a scanning electron beam of a Zeiss Auriga Crossbeam instrument at the Electron Microscopy Unit of UNSW.

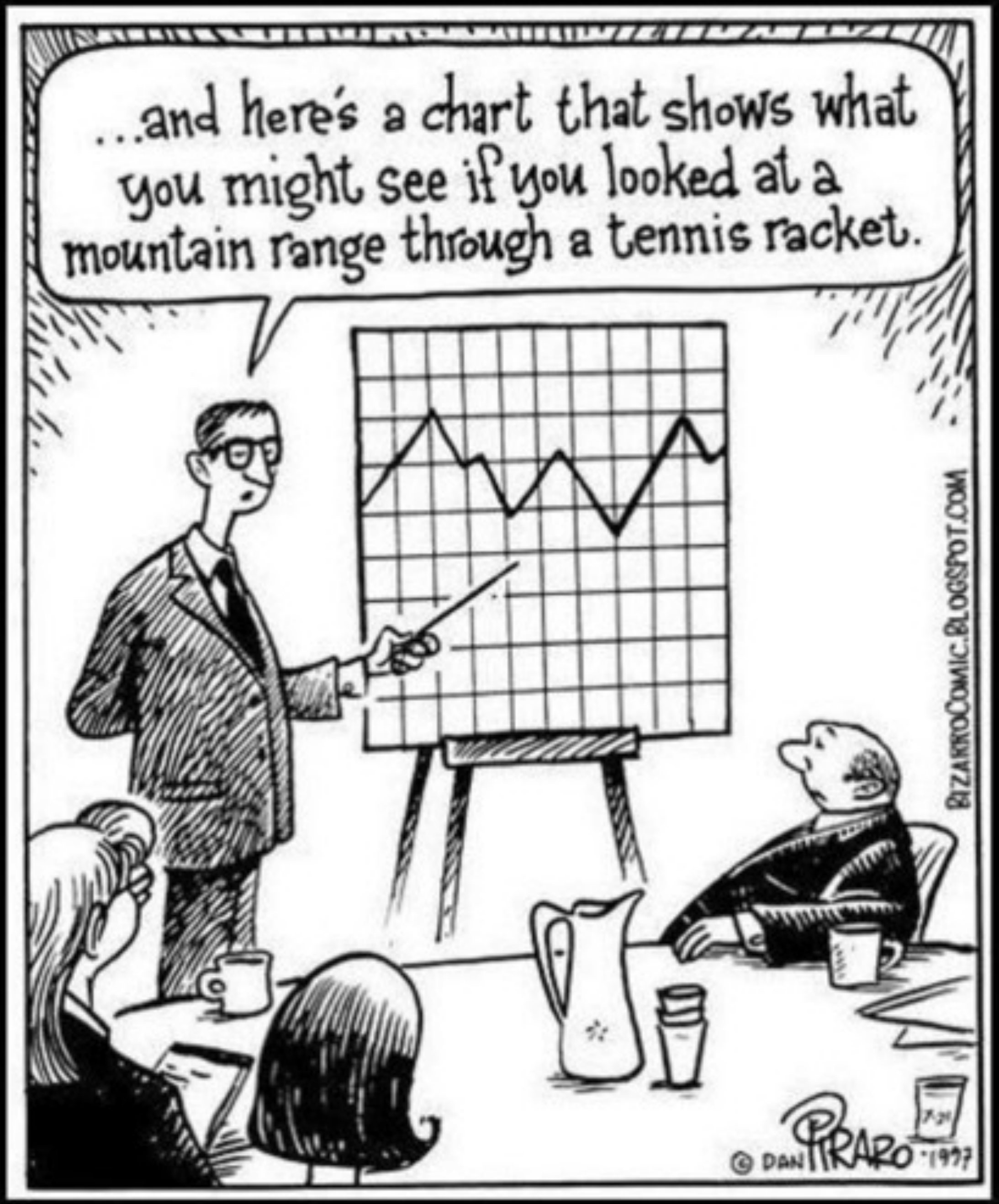


David Wacey (UWA), Charlie Kong (UNSW)

Movie

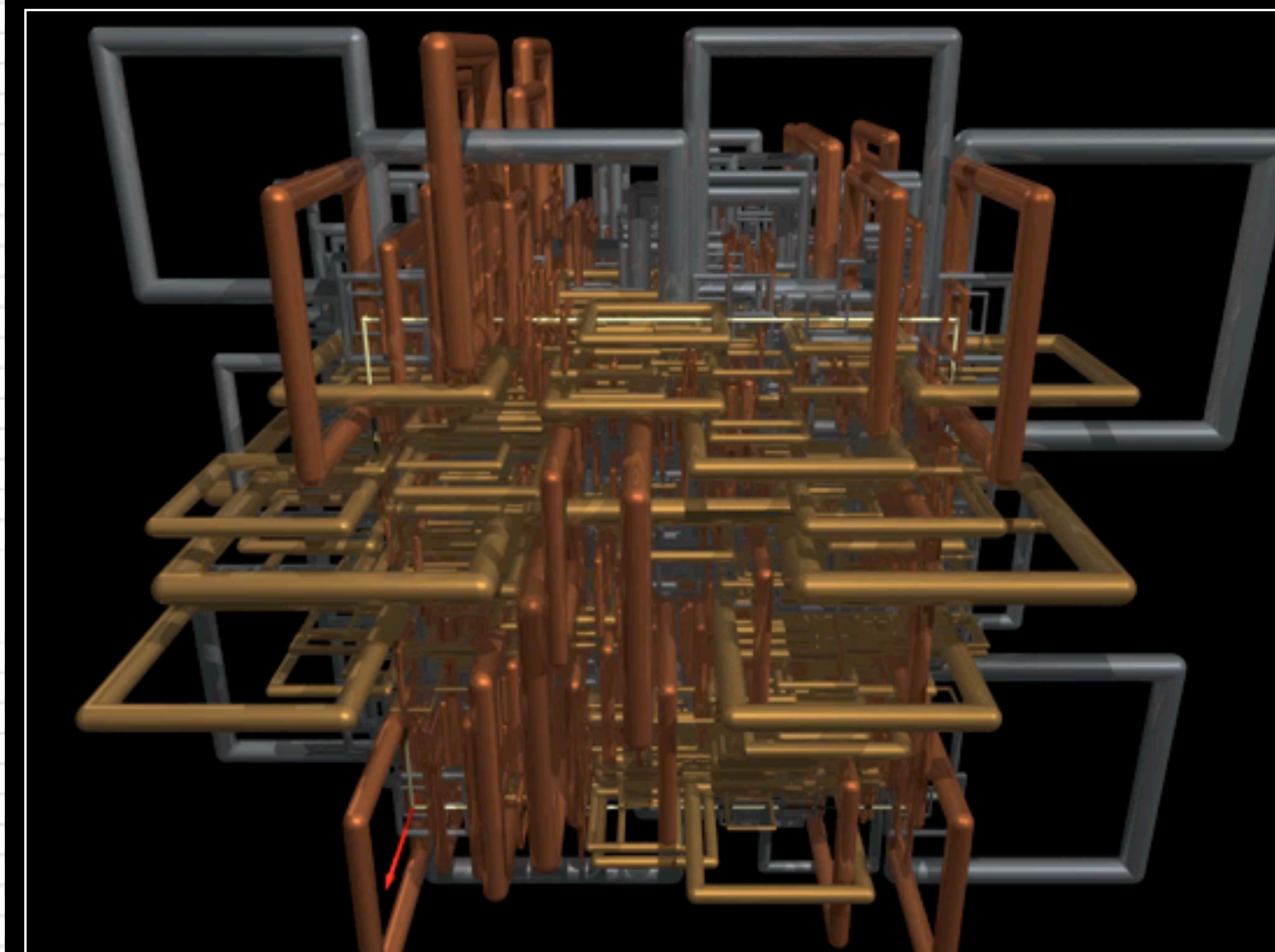
Categories: geometric representations

- Visualisation is often concerned about mapping data to geometry.
- The mapping is often obvious, other times not.



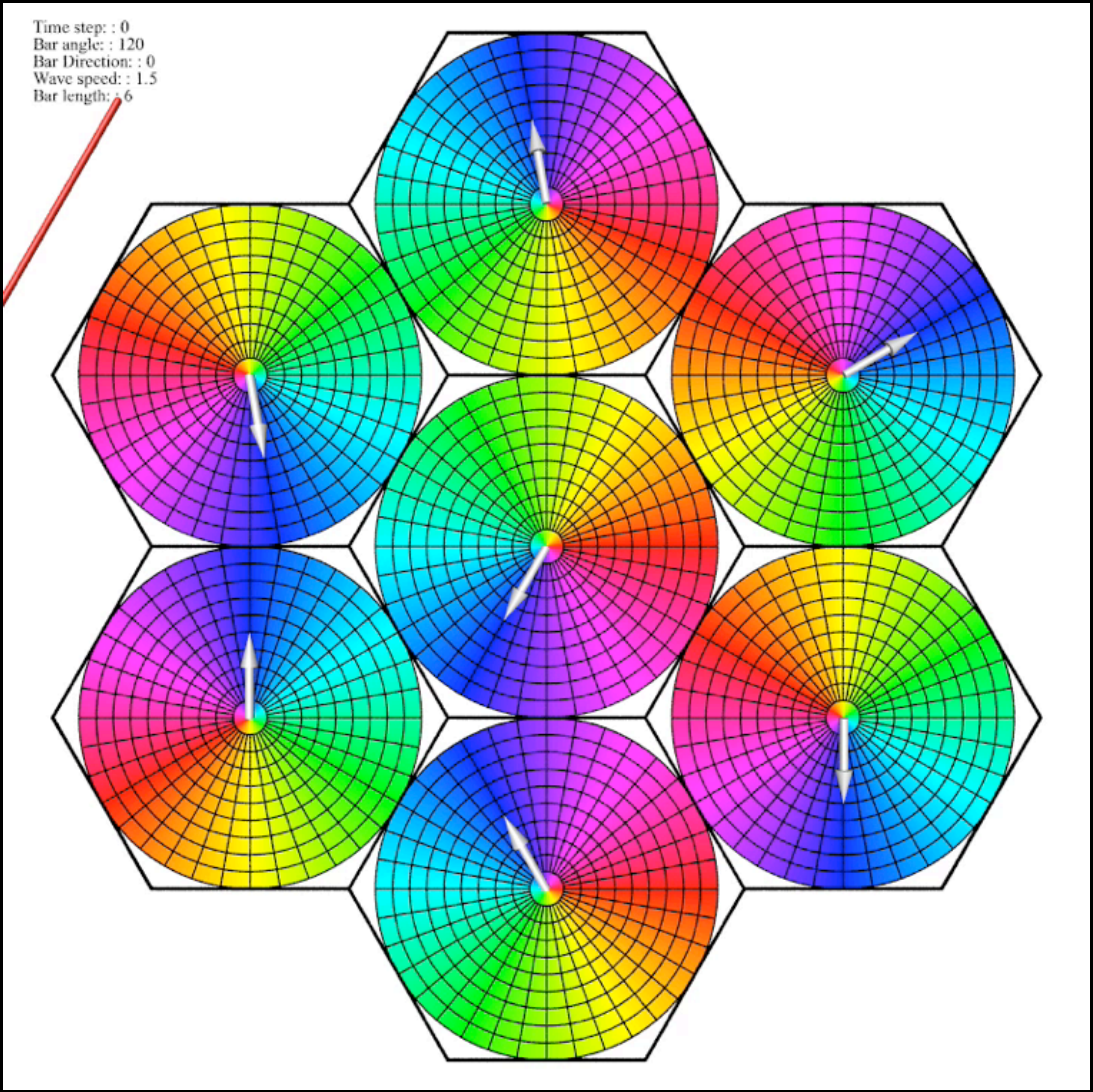
	A	B	C	D	E
1	X	Y	Z	R	Axis
2	3.094771	-2.206173	5.097041	2.910621	0
3	3.094771	7.793827	5.097041	2.910621	0
4	9.114162	2.697415	0.180805	2.828702	1
5	9.114162	12.697415	0.180805	2.828702	1
6	9.114162	2.697415	10.180805	2.828702	1
7	9.114162	12.697415	10.180805	2.828702	1
8	0.118114	2.967826	3.442576	2.754914	2
9	10.118114	2.967826	3.442576	2.754914	2
10	0.427236	-0.258223	6.412867	2.68795	0
11	10.427237	-0.258223	6.412867	2.68795	0
12	0.427236	9.741777	6.412867	2.68795	0
13	10.427237	9.741777	6.412867	2.68795	0
14	1.846255	6.221668	5.500492	2.626783	1
15	5.560567	3.806308	5.693708	2.570595	2
16	5.401607	4.61849	8.86958	2.51872	0
17	4.74108	3.939676	3.870554	2.470614	1
18	-0.058313	1.966198	2.037181	2.425826	2
19	9.941687	1.966198	2.037181	2.425826	2
20	-0.058313	1.966198	12.037182	2.425826	2
21	9.941687	1.966198	12.037182	2.425826	2
22	-0.916052	5.077406	7.016881	2.383977	0
23	9.083948	5.077406	7.016881	2.383977	0
24	8.261508	-2.266257	2.234689	2.344748	1
25	8.261508	7.733743	2.234689	2.344748	1
4978	0.036635	5.538867	6.293864	0.36667	1
4979	6.363881	5.627172	3.737942	0.366637	2
4980	2.976083	2.336567	9.22129	0.366604	0
4981	7.289498	2.35672	2.288495	0.366572	1
4982	8.17908	4.514182	6.687099	0.366539	2
4983	6.795975	5.465027	6.440717	0.366506	0
4984	2.330369	4.633094	9.5849	0.366474	1
4985	9.152864	2.912539	2.763119	0.366441	2
4986	4.295763	5.213909	0.333169	0.366408	0
4987	7.368822	4.872445	1.572595	0.366376	1
4988	2.326575	8.539257	9.341913	0.366343	2
4989	9.448618	3.542957	8.154446	0.366311	0
4990	1.356728	6.729697	4.519018	0.366278	1
4991	5.096654	3.247994	3.586767	0.366245	2
4992	-0.250326	5.085708	2.532254	0.366213	0
4993	9.749675	5.085708	2.532254	0.366213	0
4994	2.13282	4.316009	4.919343	0.36618	1

Movie



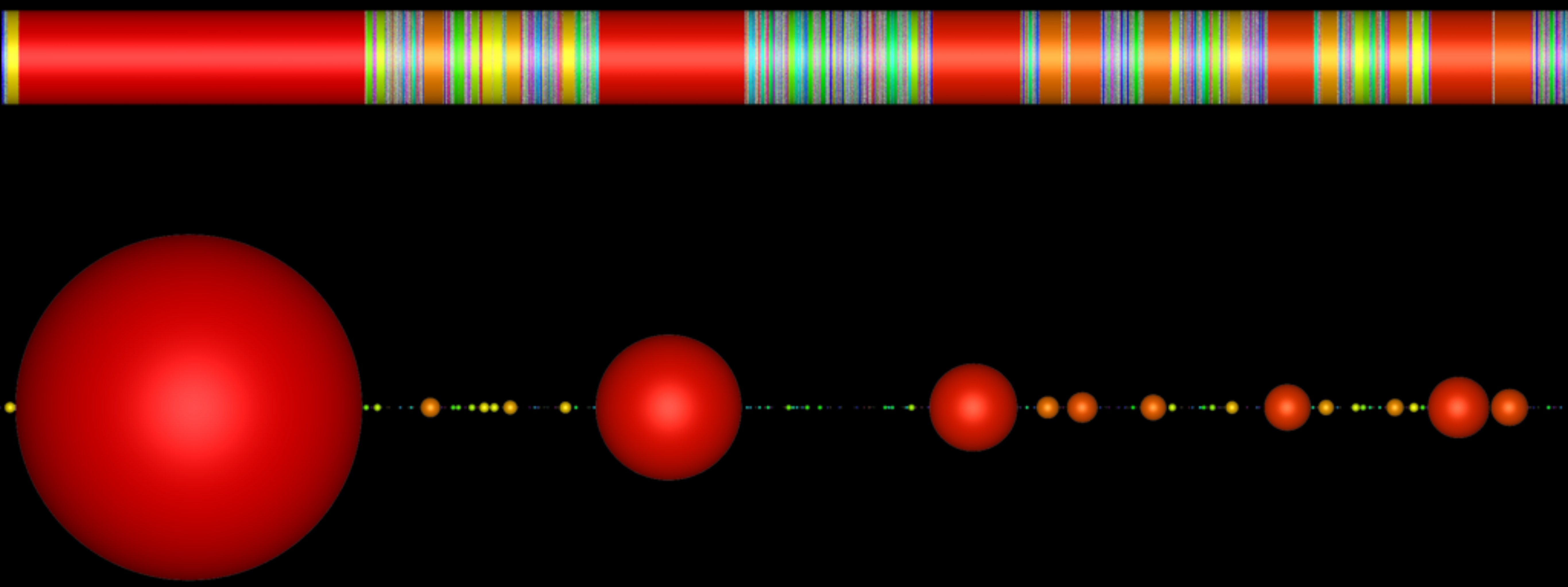
Movie

Movie


Time step: : 0
Bar angle: : 120
Bar Direction: : 0
Wave speed: : 1.5
Bar length: : 6

Categories: information

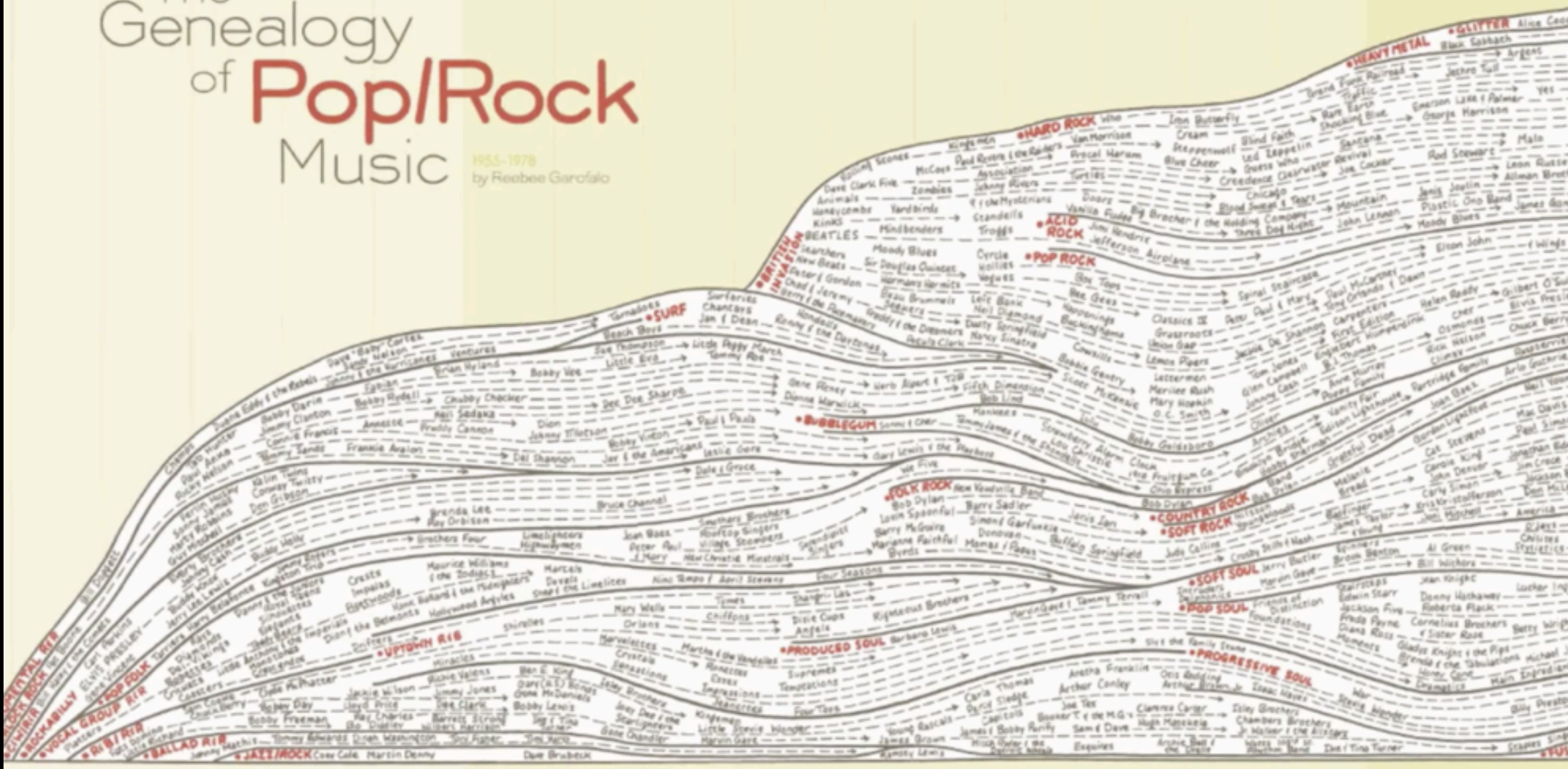
- A whole area of visualisation in itself.
- Often no direct / obvious mappings between data and visual representation.

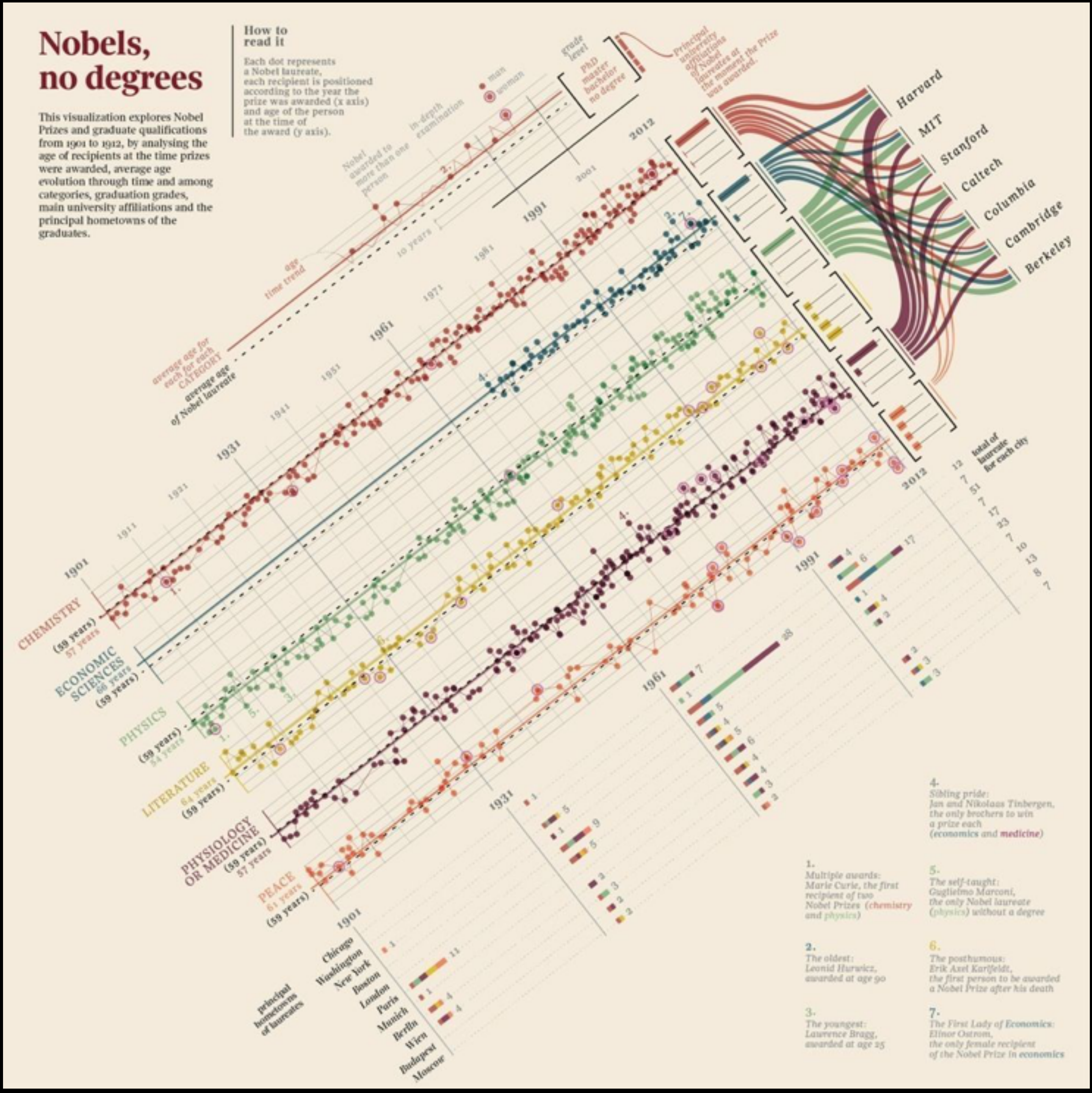


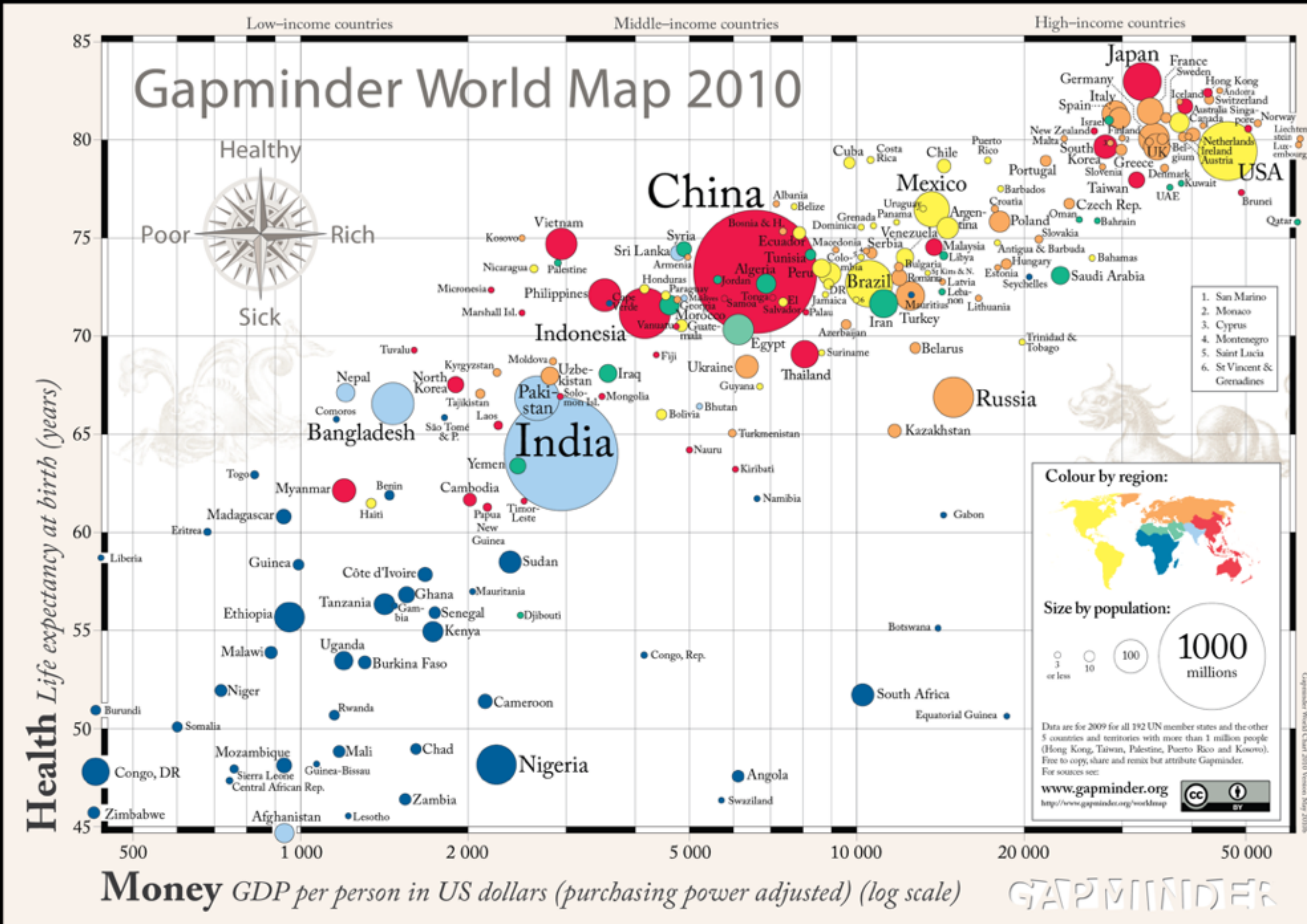
Time between earthquakes events

The Genealogy of Pop/Rock Music

1955–1978
by Reebee Garofalo

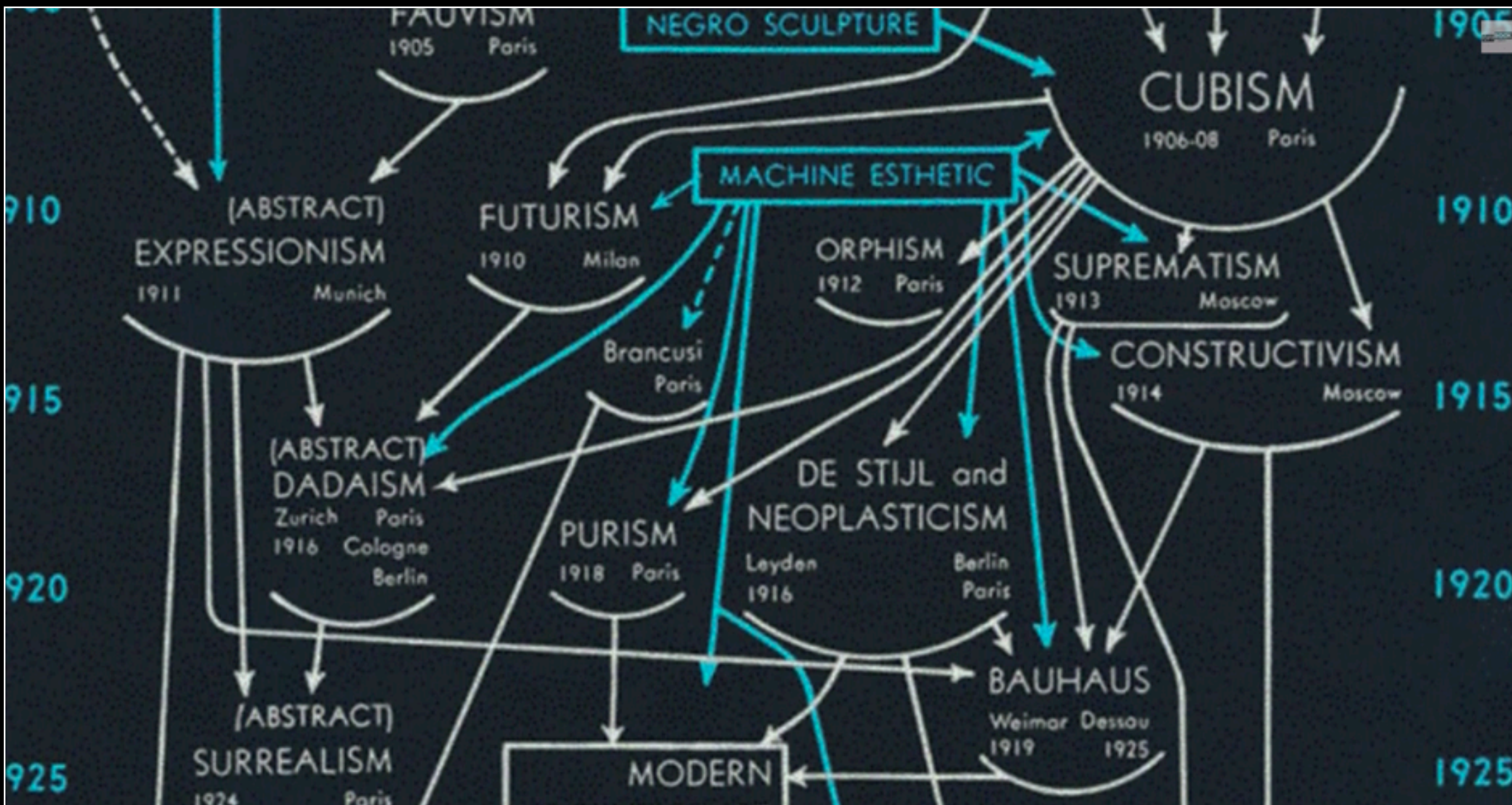



Nobels, no degrees
This visualization explores Nobel Prizes and graduate qualifications from 1901 to 1912, by analysing the age of recipients at the time prizes were awarded, average age evolution through time and among categories, graduation grades, main university affiliations and the principal hometowns of the graduates.
How to read it
Each dot represents a Nobel laureate, each recipient is positioned according to the year the prize was awarded (x axis) and age of the person at the time of the award (y axis).
man
woman
Nobel awarded to more than one person
in-depth examination
grade level
PhD
master
bachelor
no degree
Principal university affiliations of Nobel laureates at the moment the Prize was awarded.
age time trend
average age for each for each CATEGORY
average age of Nobel laureate
10 years
Harvard
MIT
Stanford
Caltech
Columbia
Cambridge
Berkeley
CHEMISTRY
(59 years)
57 years
ECONOMIC SCIENCES
66 years
(59 years)
PHYSICS
(59 years)
54 years
LITERATURE
64 years
(59 years)
PHYSIOLOGY OR MEDICINE
(59 years)
57 years
PEACE
61 years
(59 years)
1901
1911
1921
1931
1941
1951
1961
1971
1981
1991
2001
2012
total of laureate for each city
principal hometowns of laureates
Chicago
Washington
New York
Boston
London
Paris
Munich
Berlin
Wien
Budapest
Moscow
1.
Multiple awards:
Marie Curie, the first recipient of two Nobel Prizes (chemistry and physics)
2.
The oldest:
Leonid Hurwicz, awarded at age 90
3.
The youngest:
Laurence Bragg, awarded at age 25
4.
Sibling pride:
Jan and Nikolaas Tinbergen, the only brothers to win a prize each (economics and medicine)
5.
The self-taught:
Guglielmo Marconi, the only Nobel laureate (physics) without a degree
6.
The posthumous:
Erik Axel Karlfeldt, the first person to be awarded a Nobel Prize after his death
7.
The First Lady of Economics:
Elinor Ostrom, the only female recipient of the Nobel Prize in economics

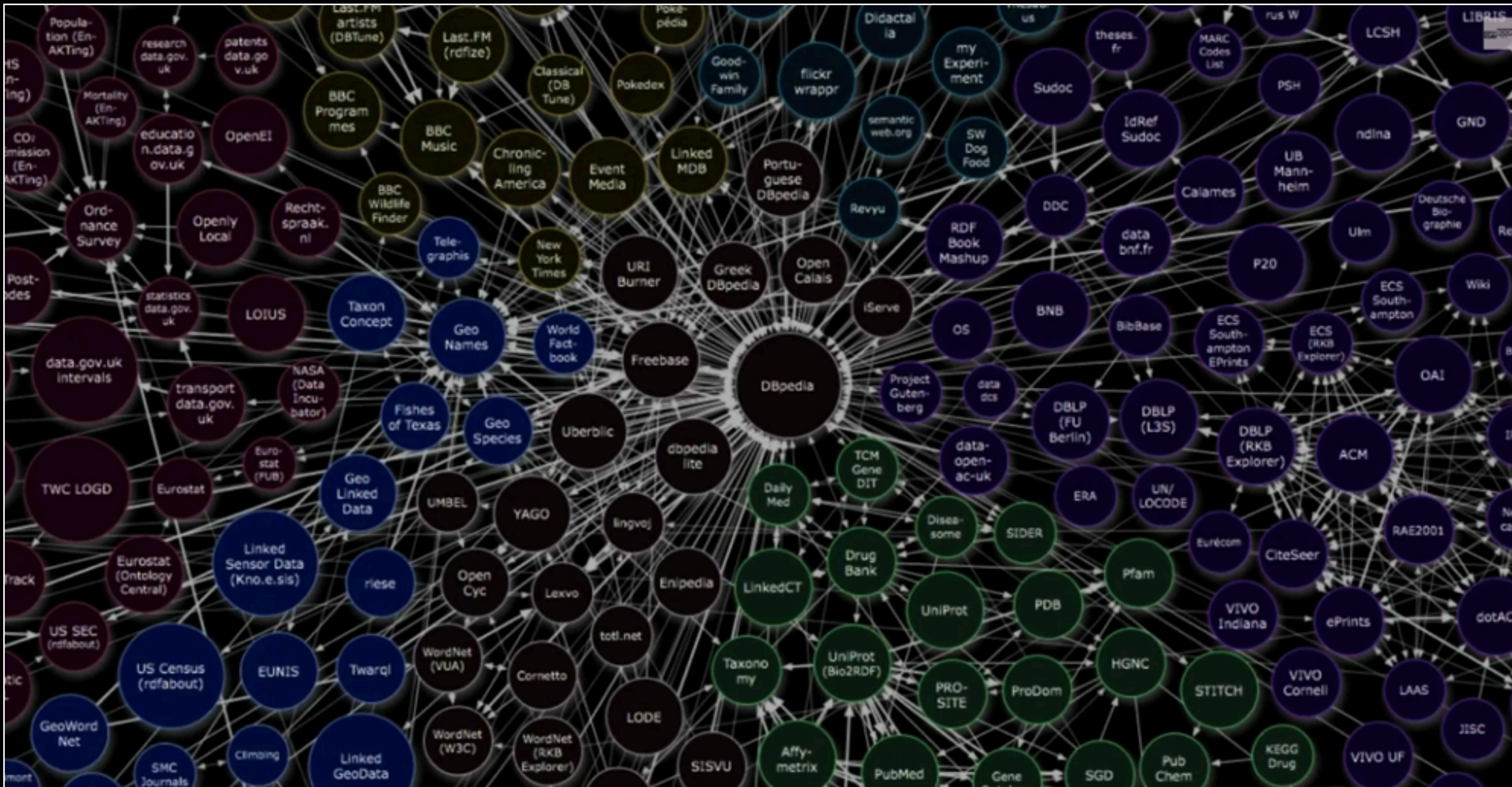

Gapminder World Map 2010
Low-income countries
Middle-income countries
High-income countries
Healthy
Sick
Poor
Rich
85
80
75
70
65
60
55
50
45
500
1 000
2 000
5 000
10 000
20 000
50 000
Health Life expectancy at birth (years)
Money GDP per person in US dollars (purchasing power adjusted) (log scale)
China
India
Indonesia
Pakistan
Bangladesh
Nigeria
Brazil
Russia
Japan
USA
Mexico
Vietnam
Philippines
Egypt
Iran
Turkey
Thailand
Ukraine
Kazakhstan
Belarus
Iraq
Uzbekistan
Nepal
North Korea
Myanmar
Cambodia
Yemen
Sudan
Ethiopia
Tanzania
Kenya
Uganda
Burkina Faso
Ghana
Senegal
Côte d'Ivoire
Guinea
Madagascar
Malawi
Niger
Cameroon
Mozambique
Mali
Chad
Congo, DR
Zimbabwe
Afghanistan
Zambia
Angola
South Africa
Botswana
Gabon
Namibia
Burundi
Somalia
Liberia
Eritrea
Togo
Benin
Haiti
Rwanda
Sierra Leone
Central African Rep.
Guinea-Bissau
Lesotho
Swaziland
Equatorial Guinea
Congo, Rep.
Mauritania
Djibouti
Gambia
Papua New Guinea
Timor-Leste
Laos
Tajikistan
Kyrgyzstan
Moldova
Mongolia
Solomon Isl.
São Tomé & P.
Comoros
Tuvalu
Marshall Isl.
Micronesia
Nicaragua
Kosovo
Palestine
Sri Lanka
Syria
Armenia
Honduras
Paraguay
Georgia
Morocco
Guatemala
Vanuatu
Fiji
Bolivia
Bhutan
Turkmenistan
Nauru
Kiribati
Guyana
Suriname
Azerbaijan
Algeria
Tunisia
Ecuador
Peru
Jordan
Tonga
Samoa
El Salvador
Palau
Jamaica
Colombia
DR
Macedonia
Serbia
Venezuela
Dominica
Grenada
Panama
Uruguay
Argentina
Bosnia & H.
Albania
Belize
Cuba
Costa Rica
Chile
Puerto Rico
Malaysia
Libya
Bulgaria
Romania
Latvia
Lebanon
Mauritius
Lithuania
Estonia
Seychelles
Hungary
Antigua & Barbuda
Slovakia
Poland
Croatia
Barbados
Portugal
Oman
Czech Rep.
Bahrain
Bahamas
Saudi Arabia
Trinidad & Tobago
Taiwan
Slovenia
Korea, South
Greece
Malta
New Zealand
Israel
Spain
Italy
Germany
France
Sweden
Finland
UK
Belgium
Denmark
Iceland
Hong Kong
Andorra
Switzerland
Australia
Canada
Singapore
Norway
Netherlands
Ireland
Austria
Liechtenstein
Luxembourg
Kuwait
UAE
Brunei
Qatar
1. San Marino
2. Monaco
3. Cyprus
4. Montenegro
5. Saint Lucia
6. St Vincent & Grenadines
Colour by region:
Size by population:
3 or less
10
100
1000 millions
Data are for 2009 for all 192 UN member states and the other 5 countries and territories with more than 1 million people (Hong Kong, Taiwan, Palestine, Puerto Rico and Kosovo).
Free to copy, share and remix but attribute Gapminder.
For sources see:
www.gapminder.org
http://www.gapminder.org/worldmap
Gapminder World Chart 2010 Version Map 2010b
GAPMINDER

Categories: networks

- Visualising networks is usually about arranging the nodes/connections so as to reveal informative structures.




FACEBOOK USERS WORLDWIDE


Popula-tion (En-AKTing)
research data.gov.uk
patents data.go v.uk
Last.FM artists (DBTune)
Last.FM (rdfize)
Poke-pédia
Didactal ia
my Experi-ment
theses.fr
MARC Codes List
LCSH
Mortality (En-AKTing)
education.data.gov.uk
OpenEI
BBC Program mes
BBC Music
Classical (DB Tune)
Pokedex
Good-win Family
flickr wrappr
Sudoc
PSH
GND
semantic web.org
SW Dog Food
IdRef Sudoc
ndlna
UB Mann-heim
Chronic-ling America
Event Media
Linked MDB
Portu-guese DBpedia
Revyu
DDC
Calames
Deutsche Bio-graphie
Ulm
Ord-nance Survey
Openly Local
Recht-spraak.nl
BBC Wildlife Finder
Tele-graphis
New York Times
URI Burner
Greek DBpedia
Open Calais
RDF Book Mashup
data bnf.fr
P20
Wiki
statistics data.gov.uk
LOIUS
Taxon Concept
Geo Names
World Fact-book
Freebase
iServe
BNB
OS
BibBase
ECS South-ampton EPrints
ECS South-ampton
ECS (RKB Explorer)
data.gov.uk intervals
transport data.gov.uk
NASA (Data Incu-bator)
Fishes of Texas
Geo Species
Uberblic
DBpedia
Project Guten-berg
data dcs
DBLP (FU Berlin)
DBLP (L3S)
DBLP (RKB Explorer)
OAI
ACM
Euro-stat (FUB)
dbpedia lite
TCM Gene DIT
data-open-ac-uk
TWC LOGD
Eurostat
Geo Linked Data
UMBEL
YAGO
lingvoj
Daily Med
Disea-some
SIDER
ERA
UN/LOCODE
RAE2001
Eurécom
CiteSeer
Linked Sensor Data (Kno.e.sis)
Eurostat (Ontology Central)
riese
Open Cyc
Lexvo
Enipedia
LinkedCT
Drug Bank
UniProt
PDB
Pfam
VIVO Indiana
ePrints
dotAC
US SEC (rdfabout)
US Census (rdfabout)
EUNIS
Twarql
WordNet (VUA)
Cornetto
totl.net
Taxono my
UniProt (Bio2RDF)
PRO-SITE
ProDom
HGNC
STITCH
VIVO Cornell
LAAS
JISC
GeoWord Net
SMC Journals
Climbing
Linked GeoData
WordNet (W3C)
WordNet (RKB Explorer)
LODE
SISVU
Affy-metrix
PubMed
Gene Ontology
SGD
Pub Chem
KEGG Drug
VIVO UF

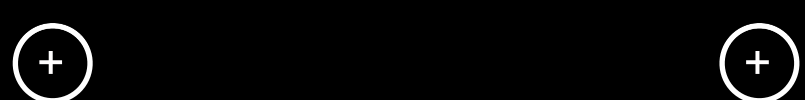
- One approach is to use a physical based system
  - Each node has a positive charge, so repel all other nodes.
  - Each connection between nodes is a spring that attracts connected nodes.

- Provides intuitively right characteristics.

- Run the physics simulations until (if) the structure stabilises.

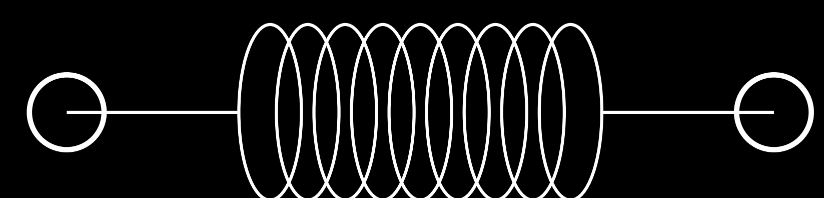
- No assurance to reach minimum energy state, may be local minima rather than global.

Same electrostatic charged nodes

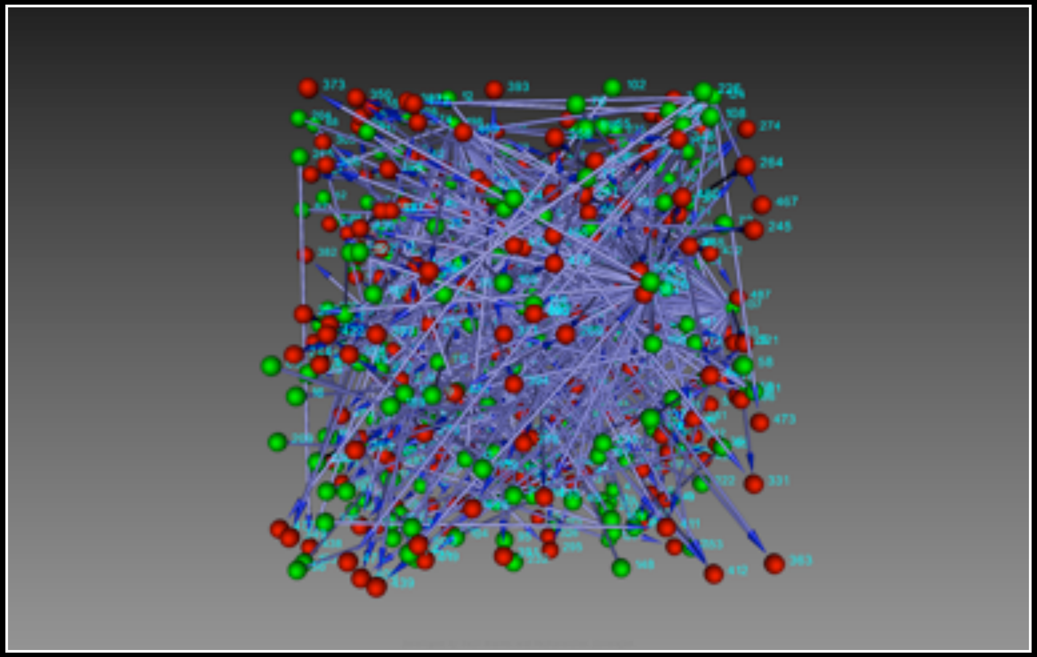


Repel each other with force inversely proportional to distance.

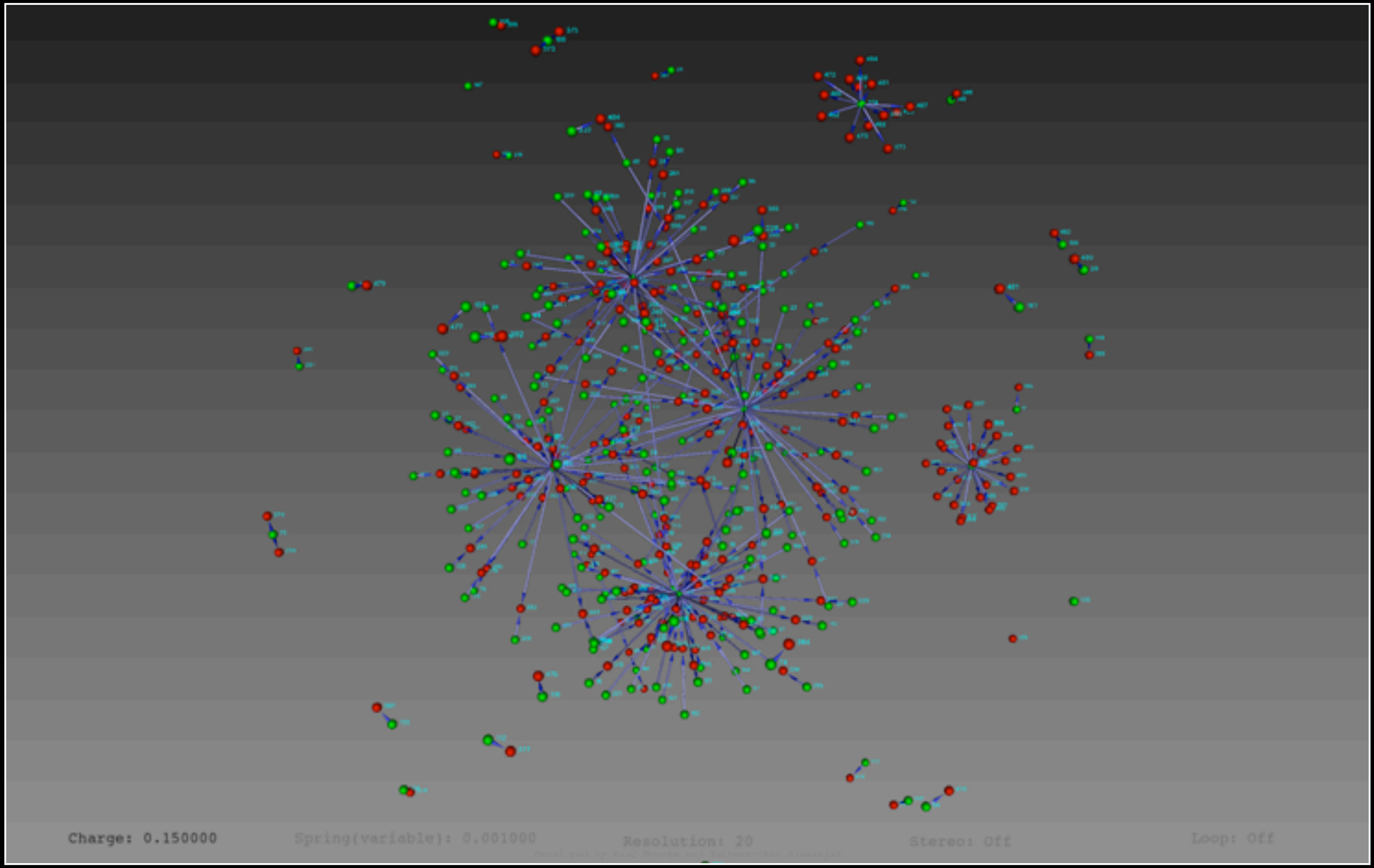
Spring to represent connections between nodes



Force given by Hooks law
Proportional to length - rest length
If length < rest length then nodes repel,
If length > rest length nodes are attracted



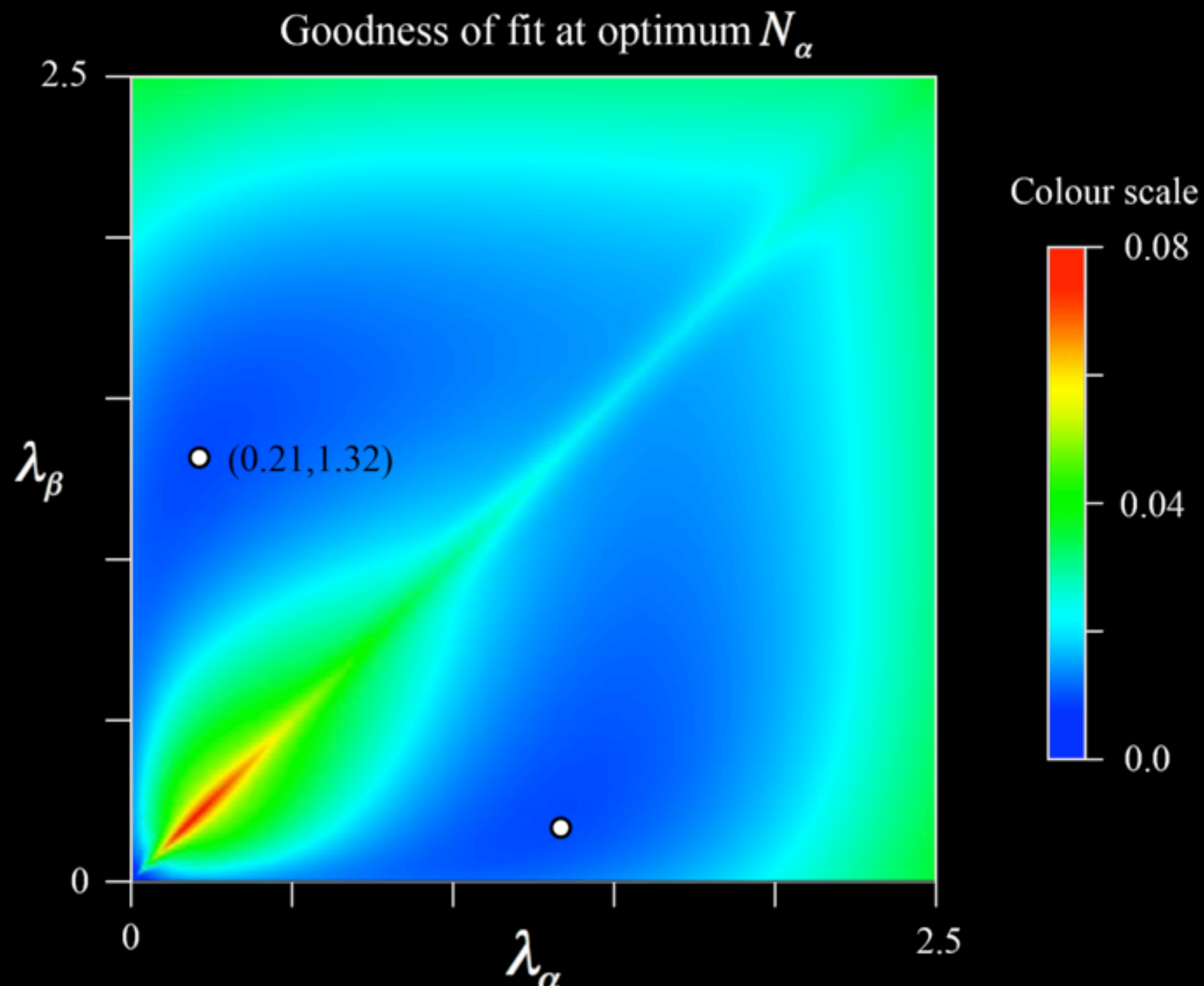
Initial random arrangement
No predefined structure



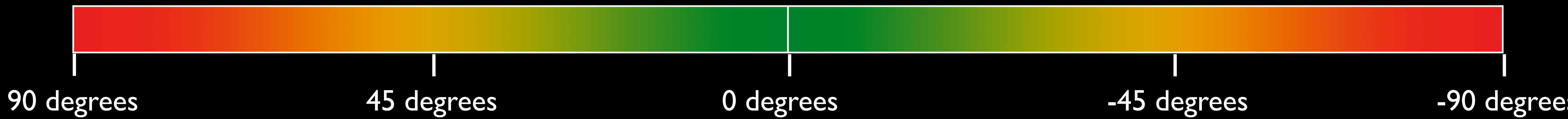
Structure and relationships evolve based upon the physics rules.

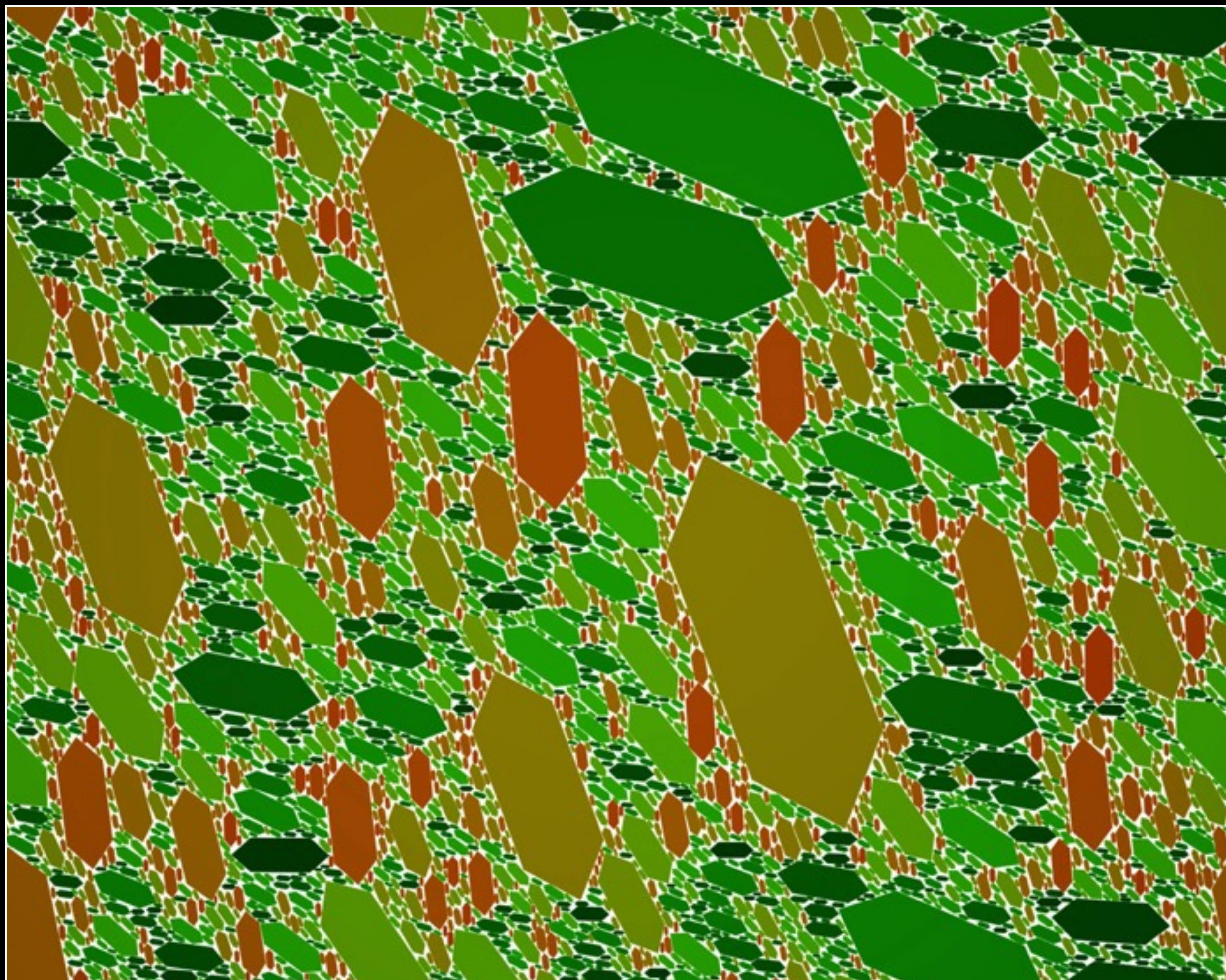
Techniques: colour maps

- Simplest method of mapping some quantity onto geometry.



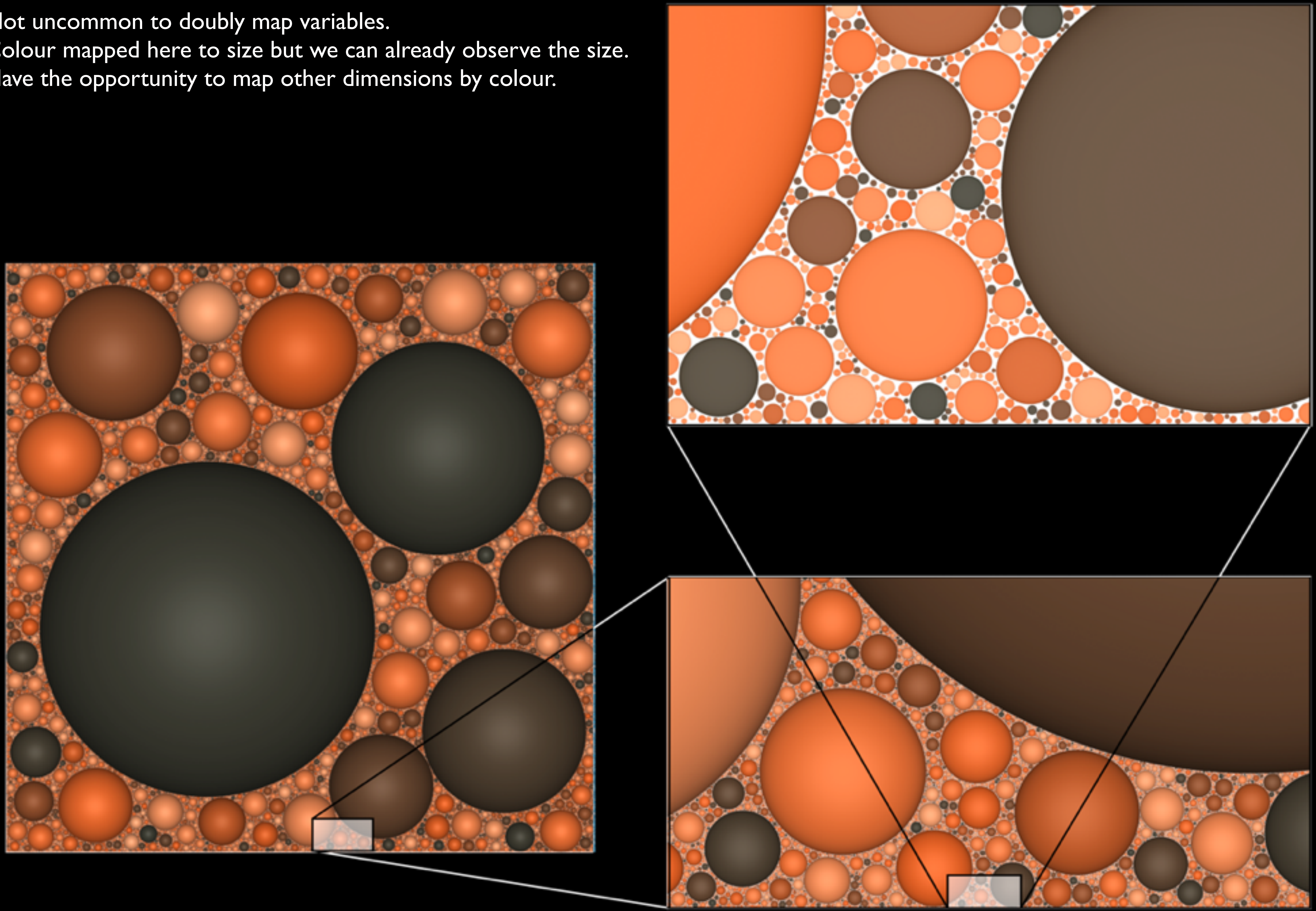
- When an angle is mapped to colour would typically use a circular colour map.



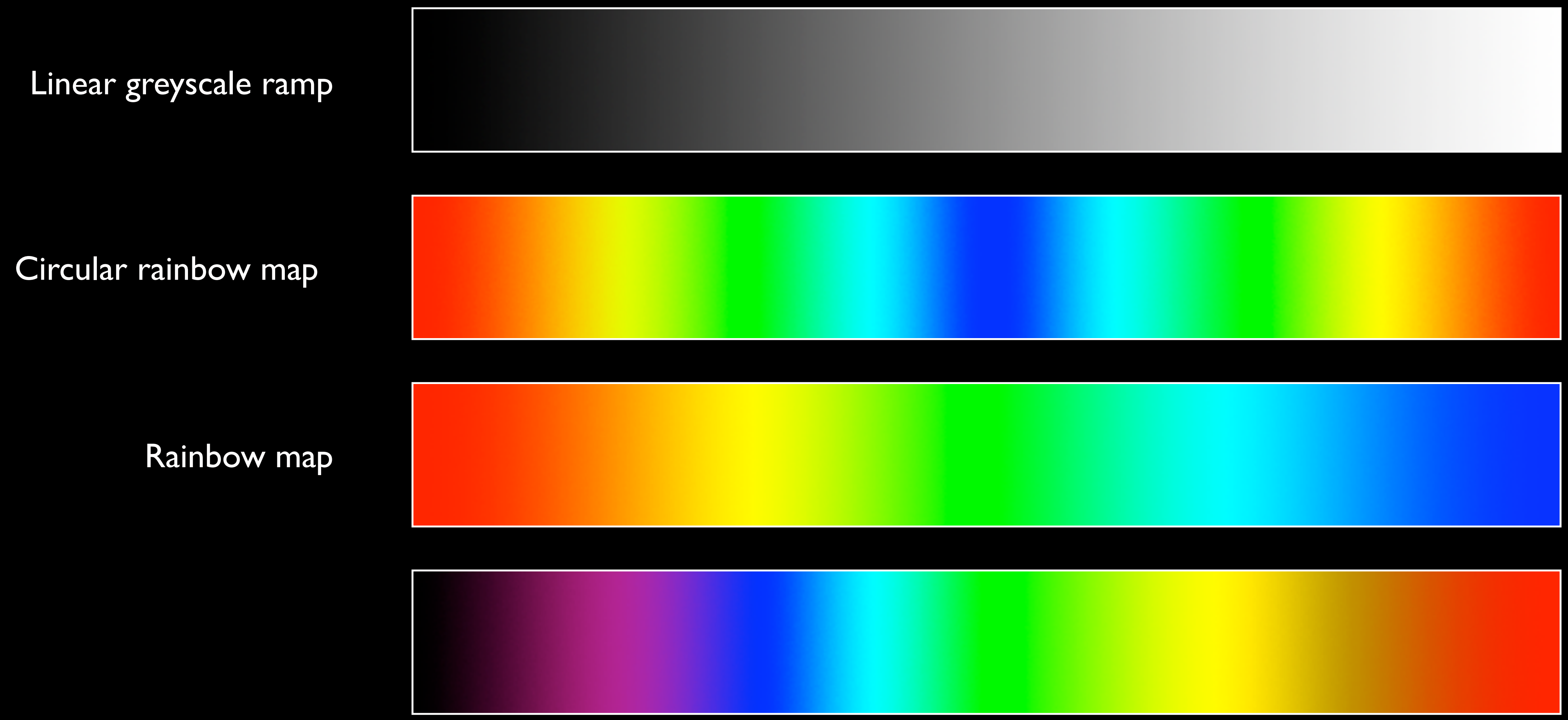


Simulated crystal alignment

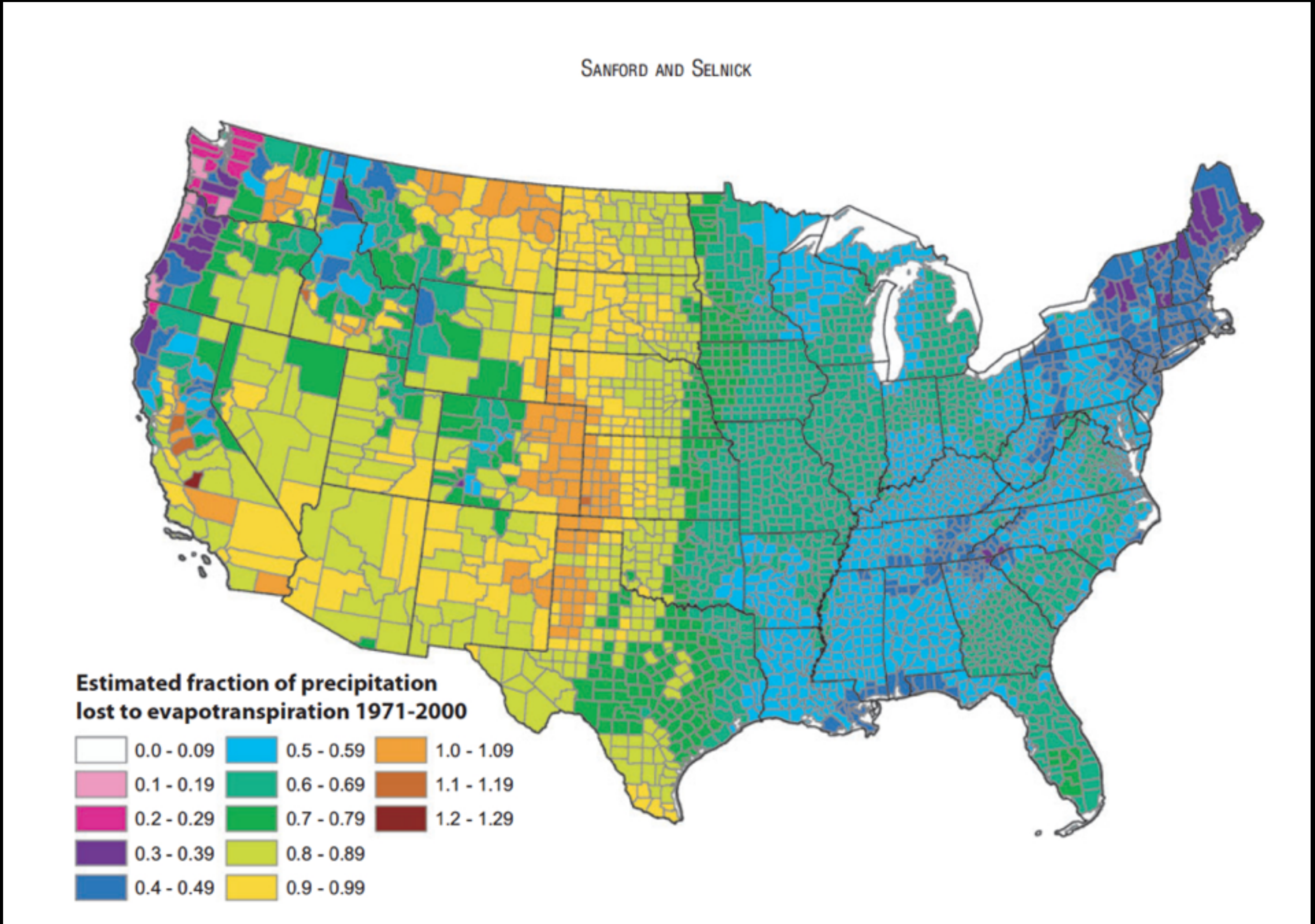
Not uncommon to doubly map variables.
Colour mapped here to size but we can already observe the size.
Have the opportunity to map other dimensions by colour.

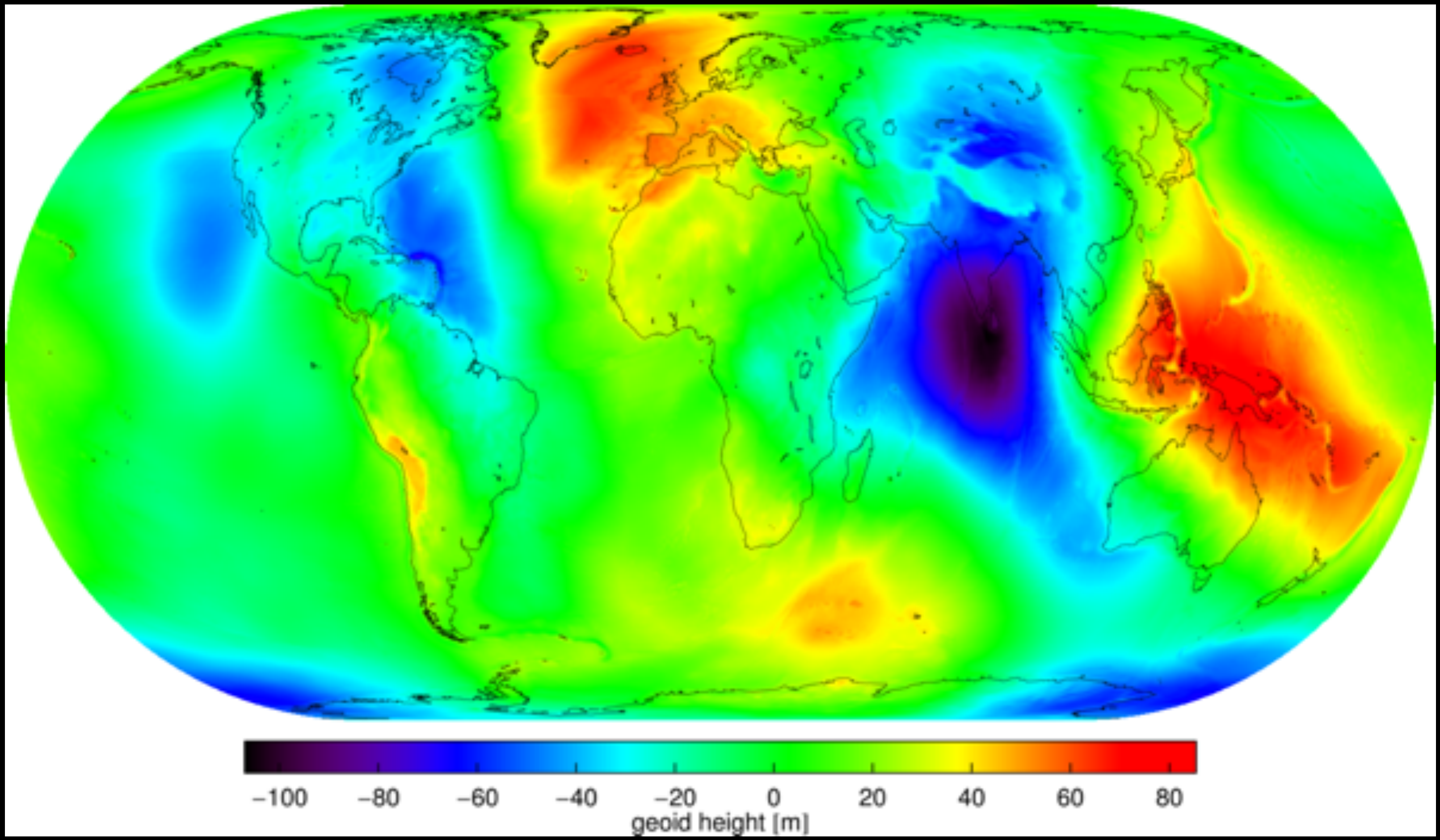


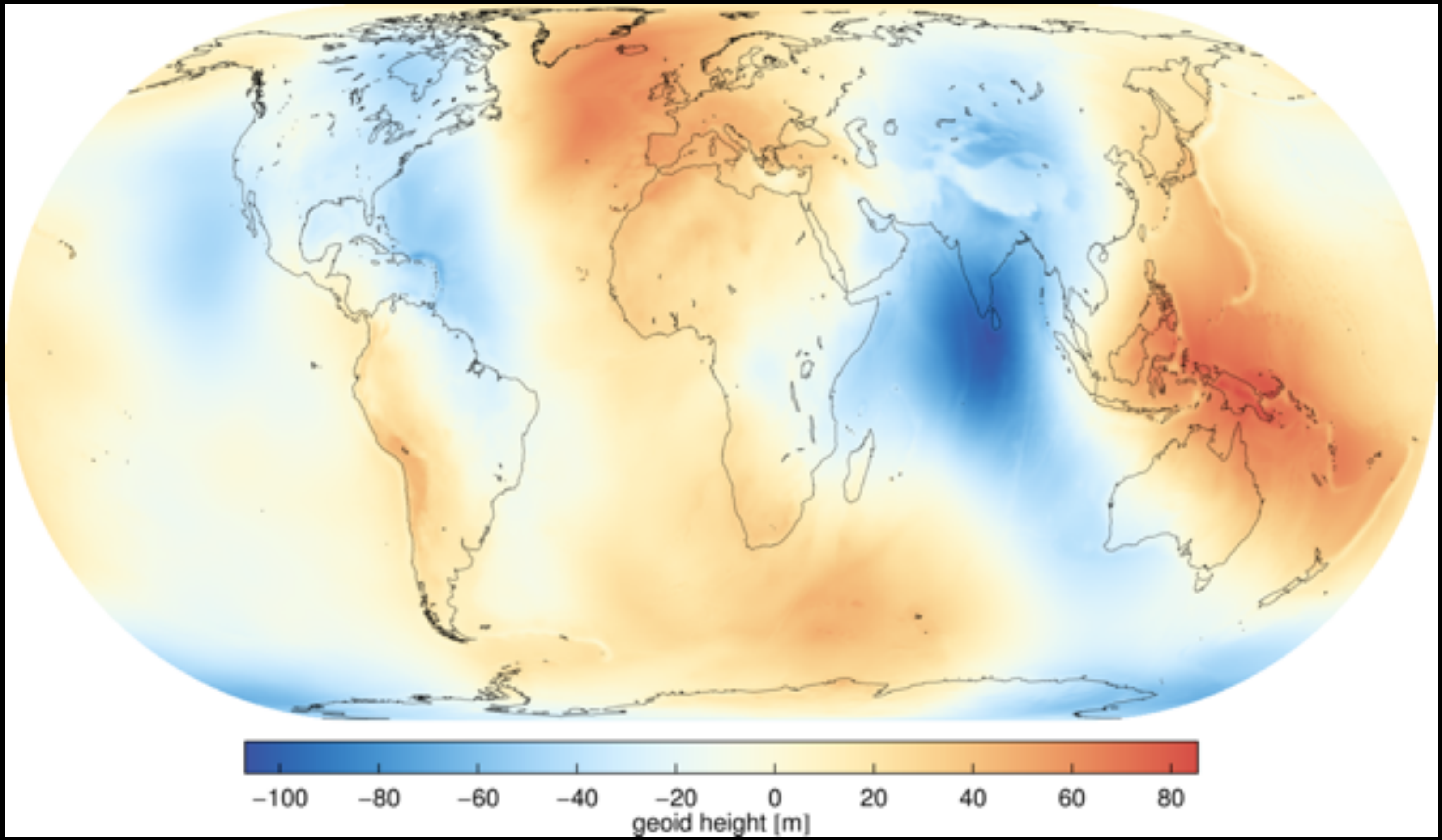
- Rainbow colour maps are dangerous.
- Introduce transitions where they don’t exist.
- “Everyone” knows they can be misleading but the technique is so engrained.



- Colour is hard, need a knowledge of the human visual system.

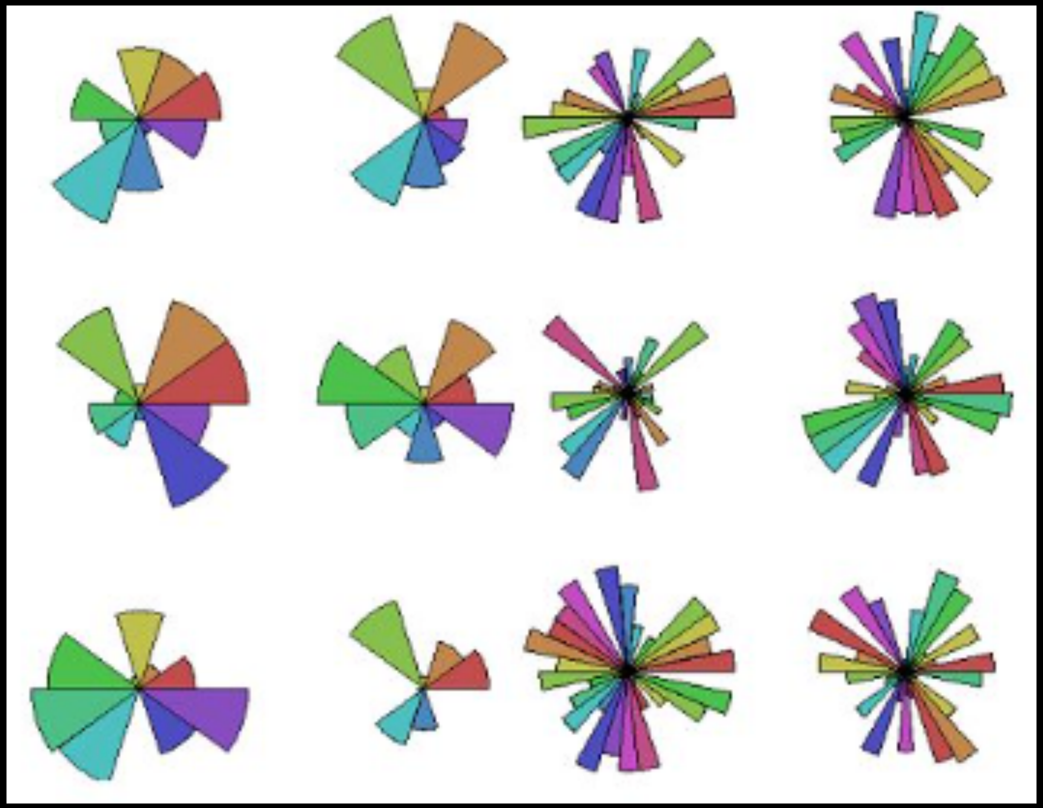


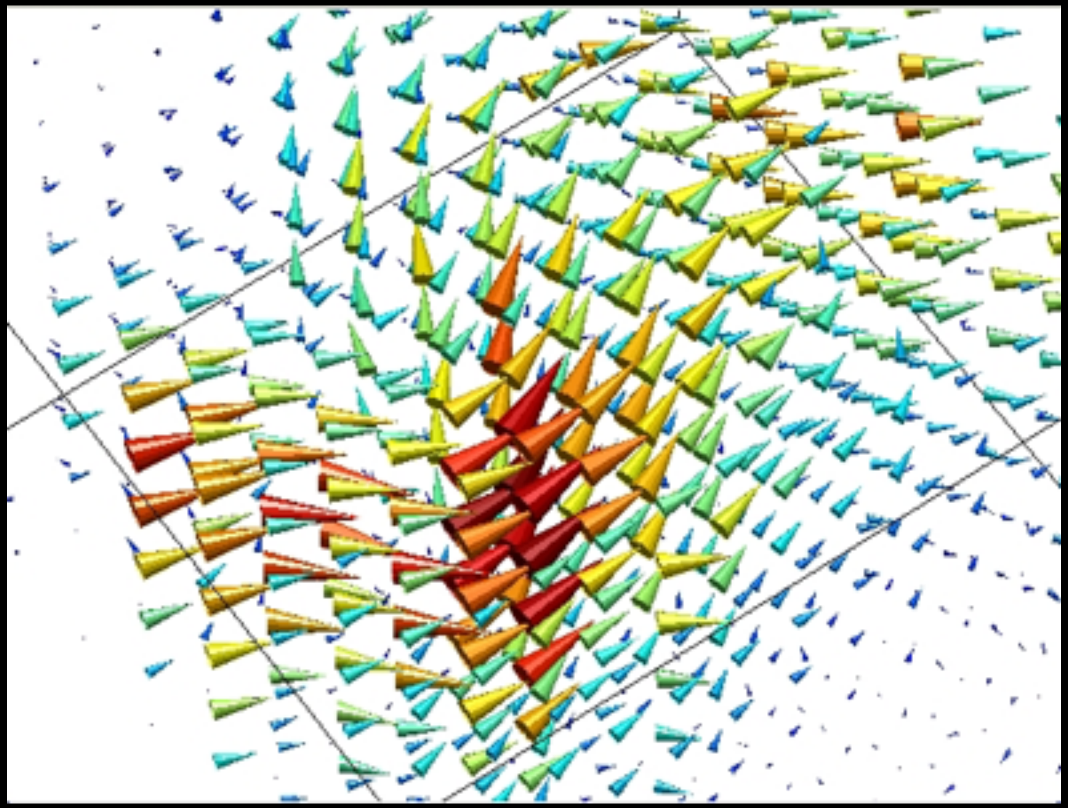

−100
−80
−60
−40
−20
0
20
40
60
80
geoid height [m]


−100
−80
−60
−40
−20
0
20
40
60
80
geoid height [m]

Techniques: Glyphs

- A large part of what occurs in visualisation is mapping variables to 2D and 3D geometry.
- Sometimes the mappings are obvious/intuitive, other times more freedom is possible.
- "Glyphs" is the term given to graphical elements whose characteristics reflect a number of variables. Direction, volume, strength ...

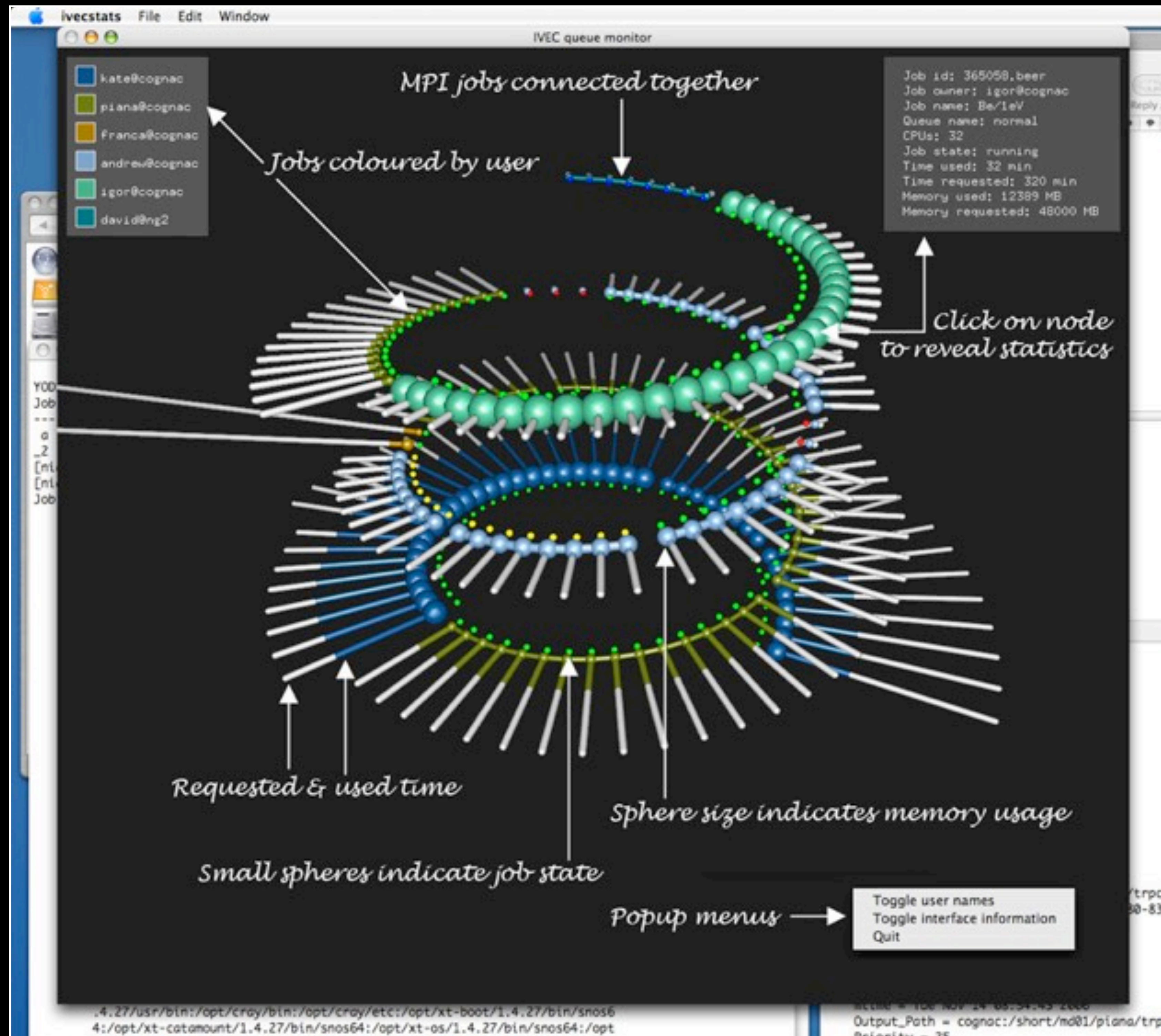


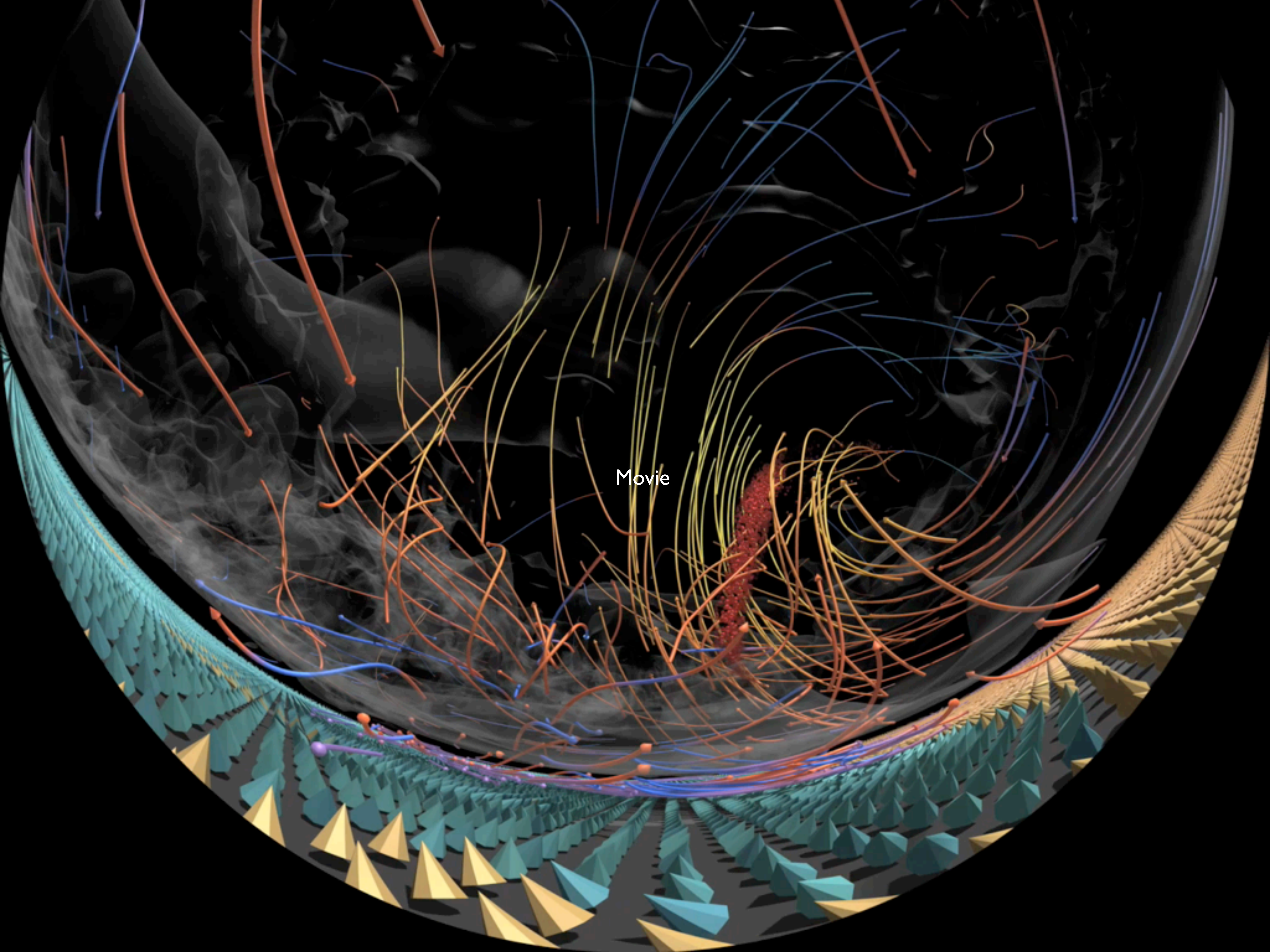


- Ideally the structure/form of the glyph has some intuitive meaning.

- Common to map a quantity scalar onto the size of the glyph, obvious examples ...
  - Map direction onto arrows.
  - The strength of the direction (eg: velocity) onto length of arrow.
  - Scalars also mapped onto colour.

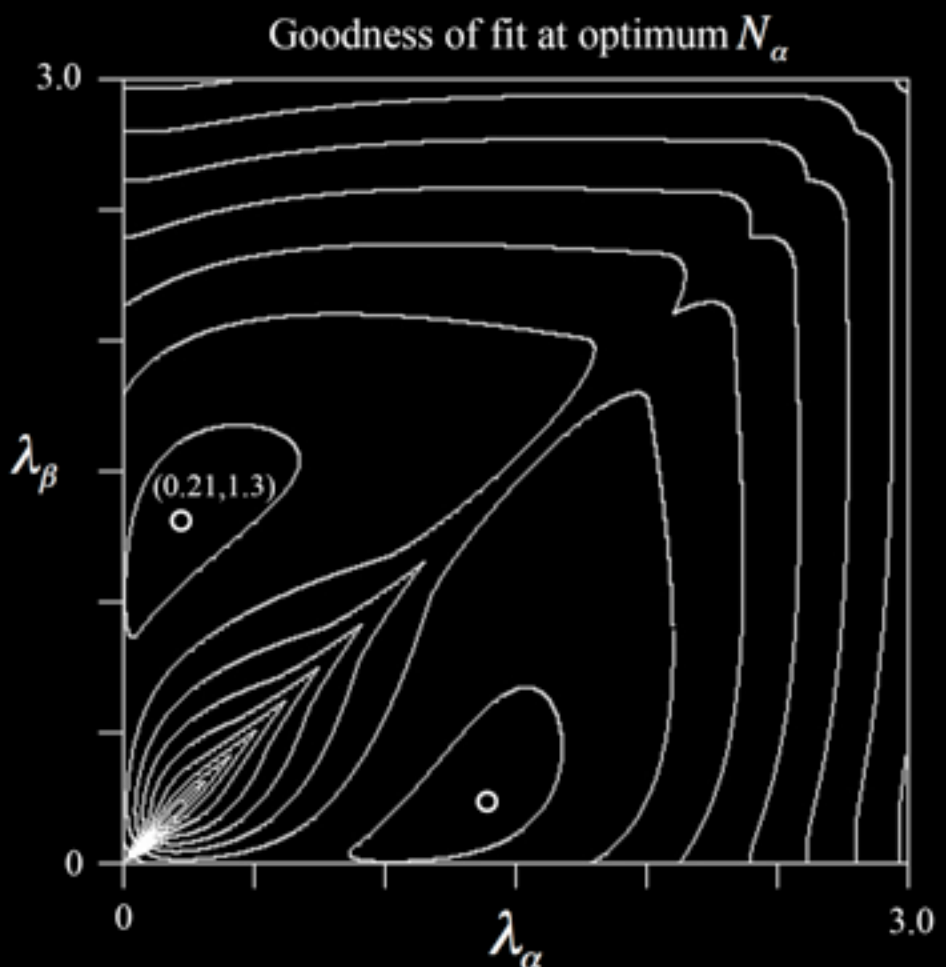
  ... and so on.



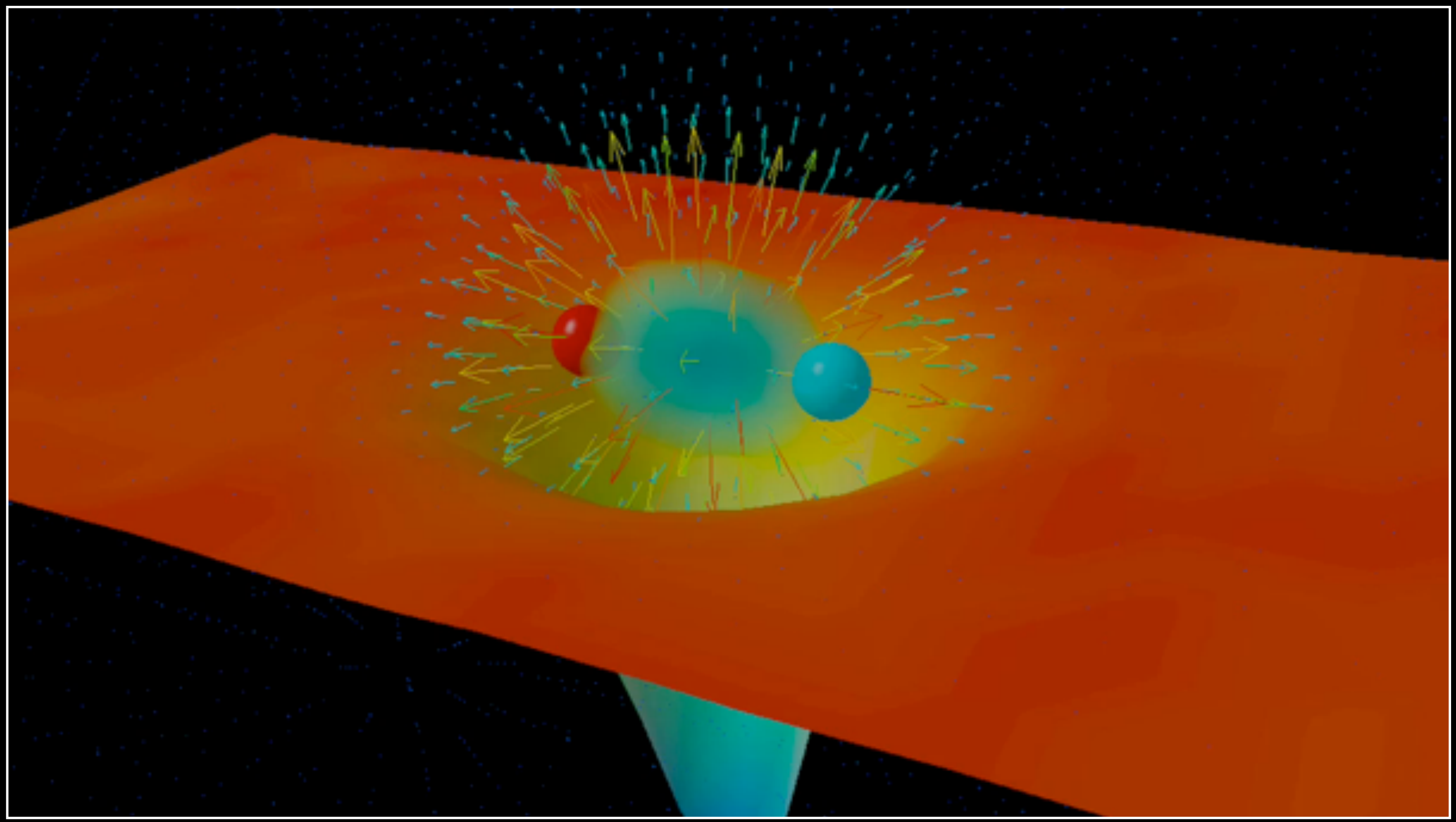

Movie

Techniques: Dimension reduction

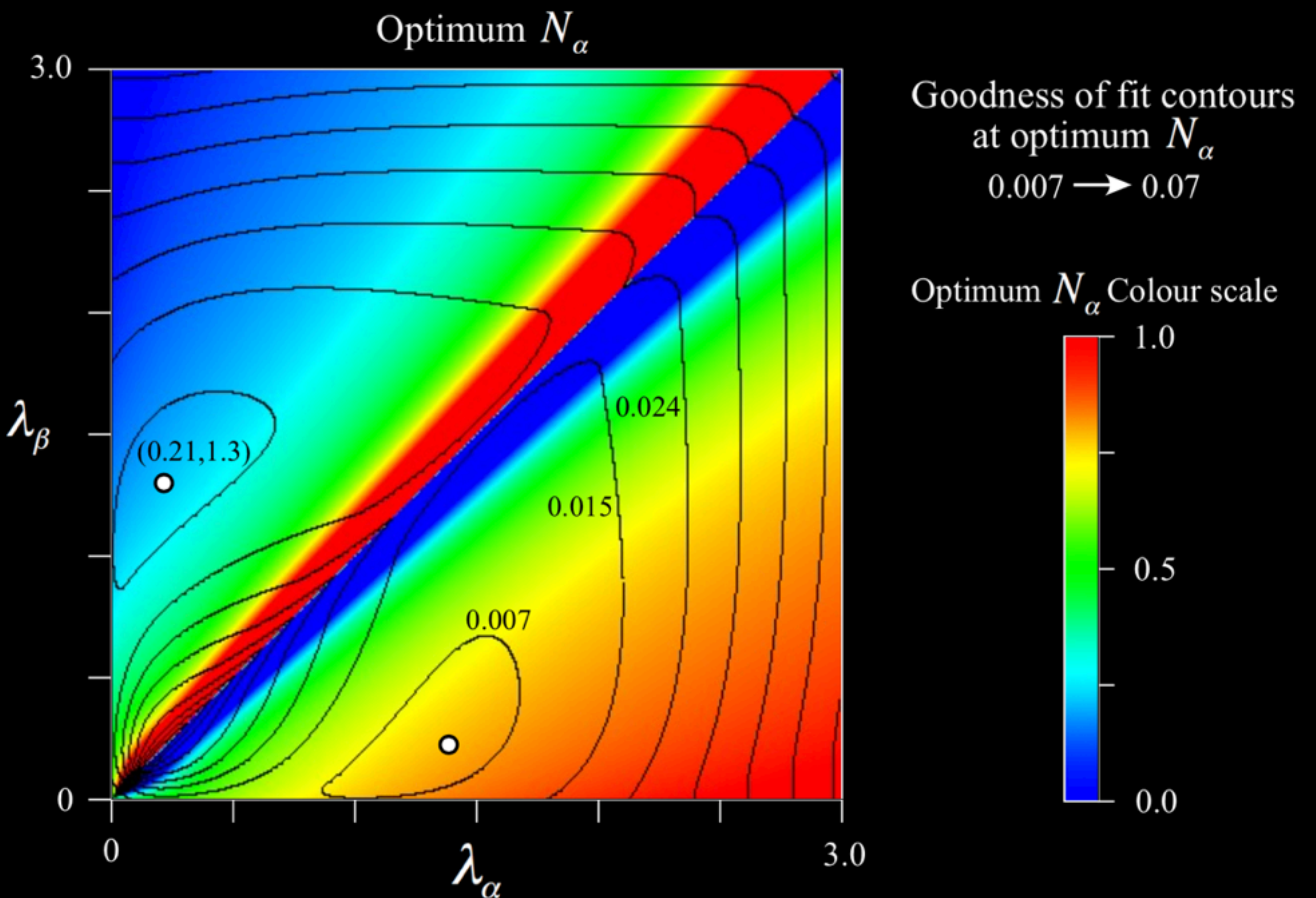
- Distinguish between topological dimension and embedded dimension.
- For example air pressure data is a surface (2D) embedded in 3D space.
- Familiar with the idea of reducing the dimension of data.
  Contour lines allow the height of a surface to be represented on a plane.
  Colour can also be used to represent height: continuous contours.
- Isosurfaces reduce a volume (4D) to be represented in 3D.



Movie

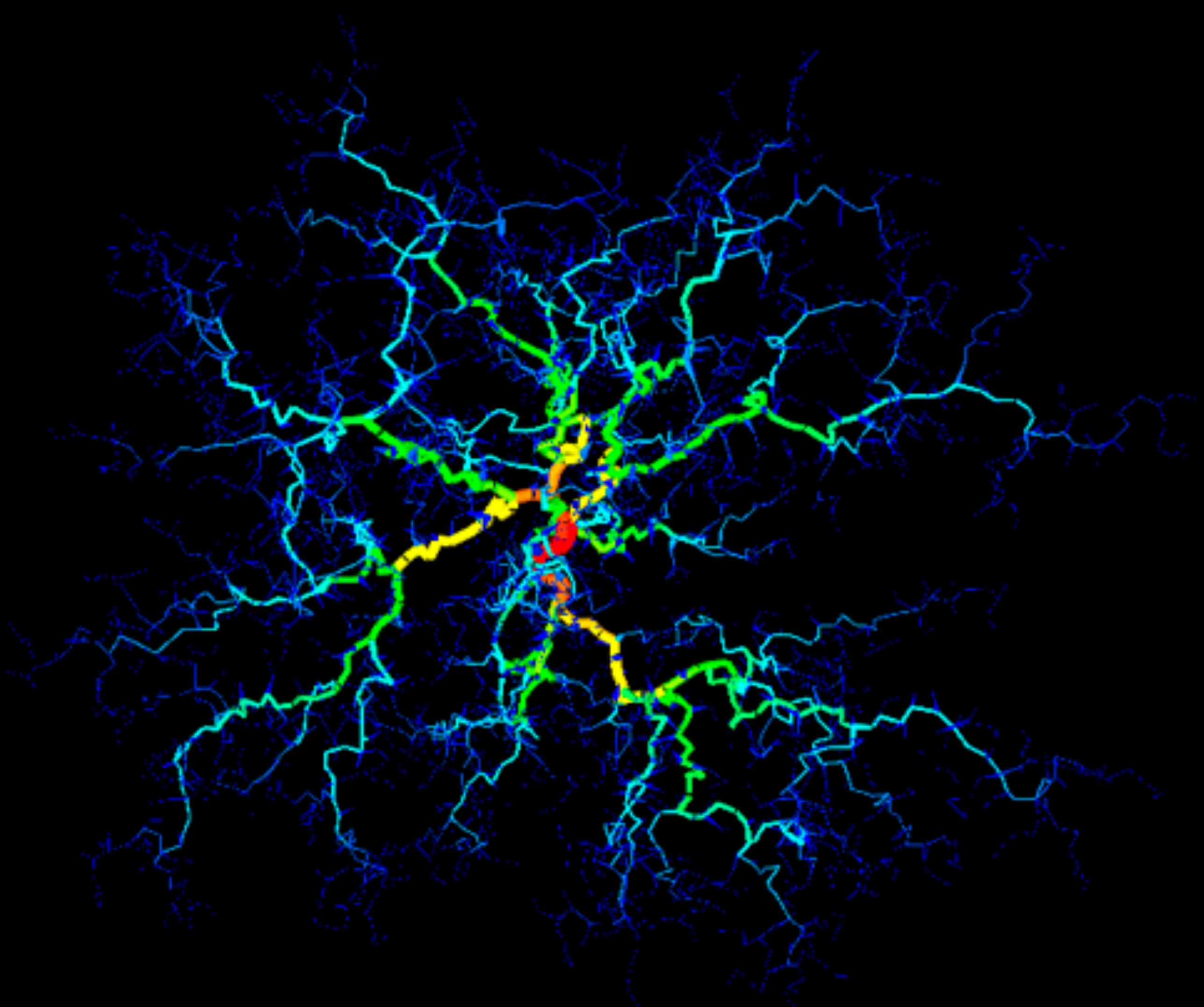


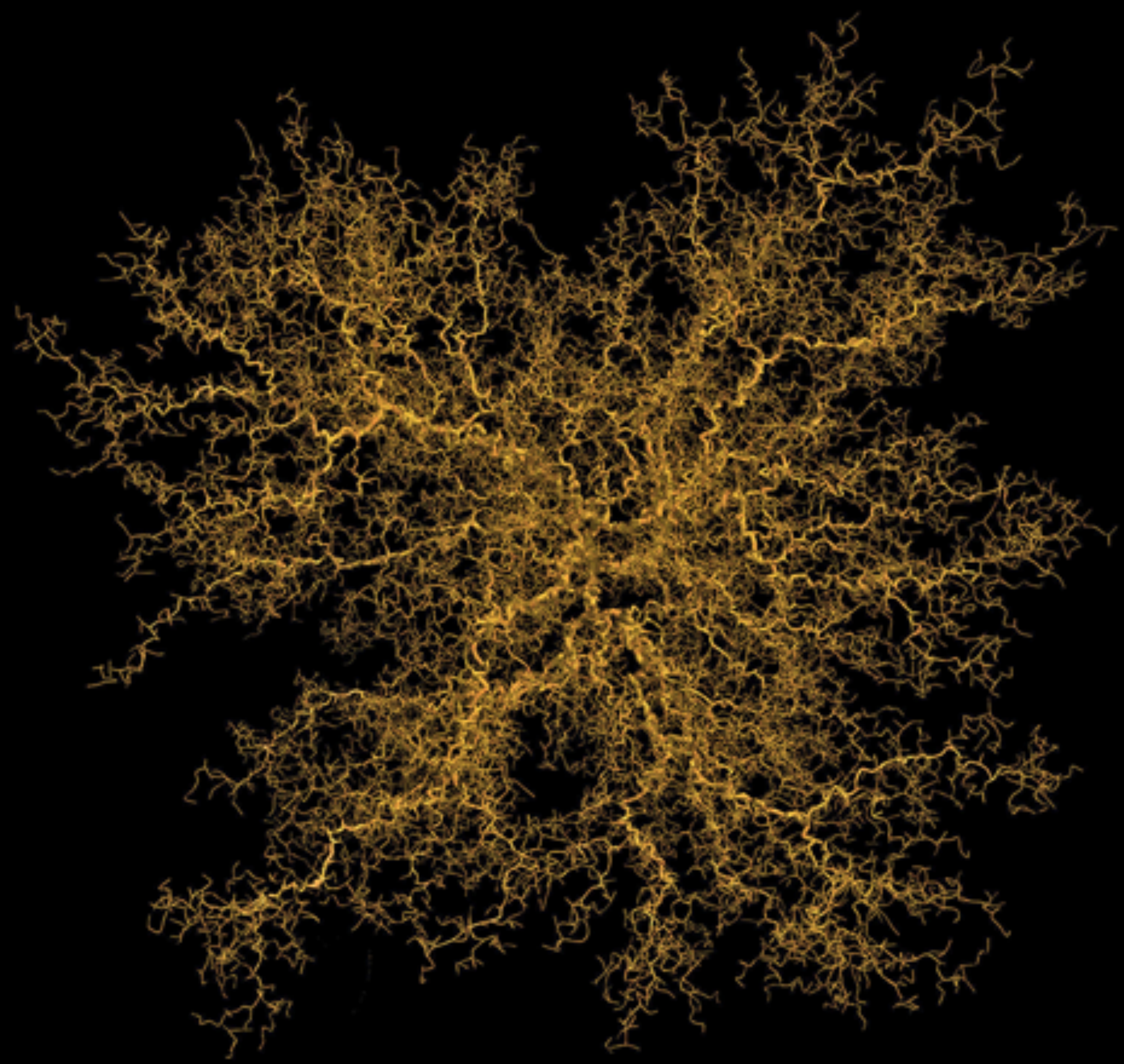
- Dimension reduction provides for increased variable representation.



Techniques: rendered vs realtime

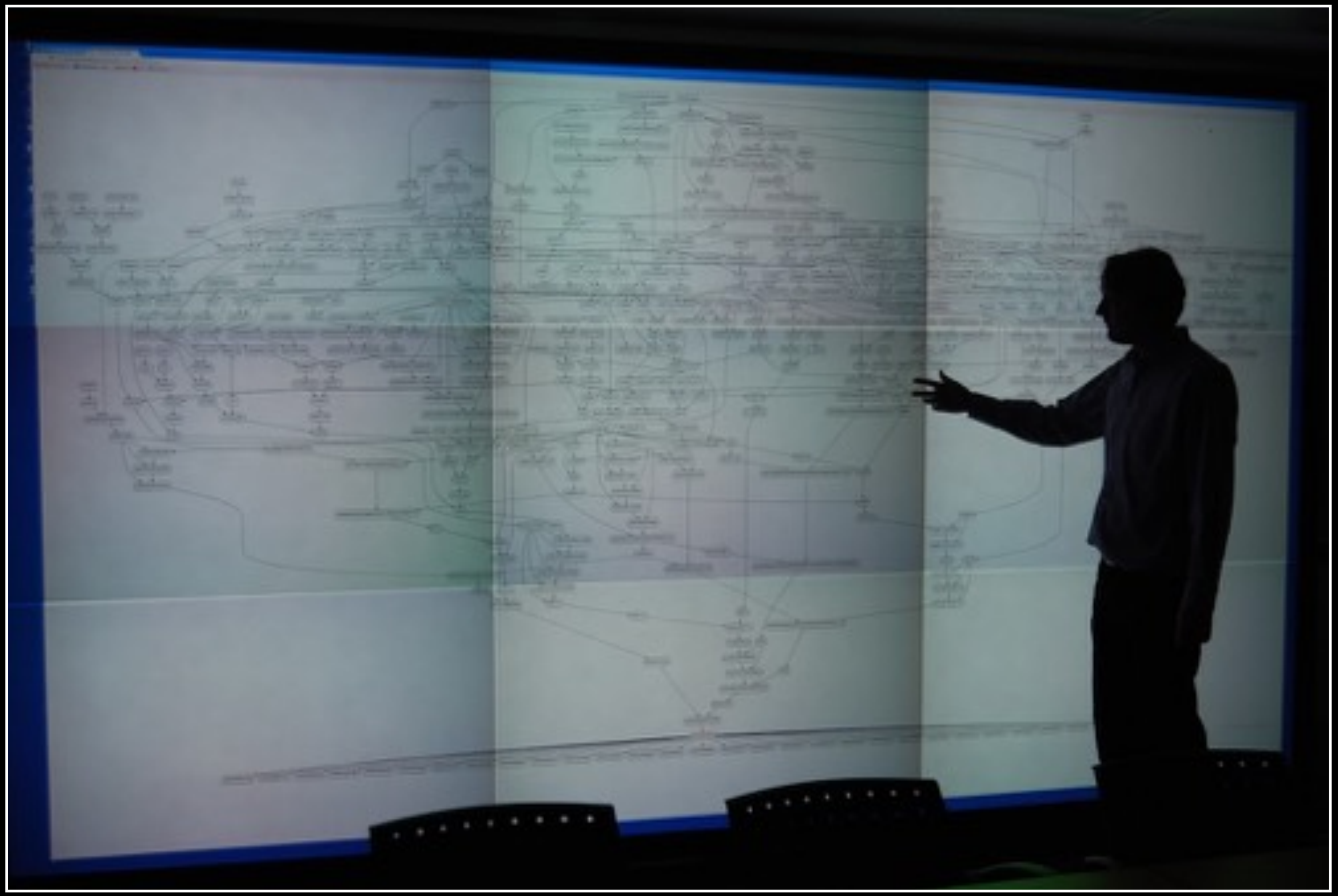
- Normally a matter of quality, visual impact.
- Less limited by rendering techniques or model size.



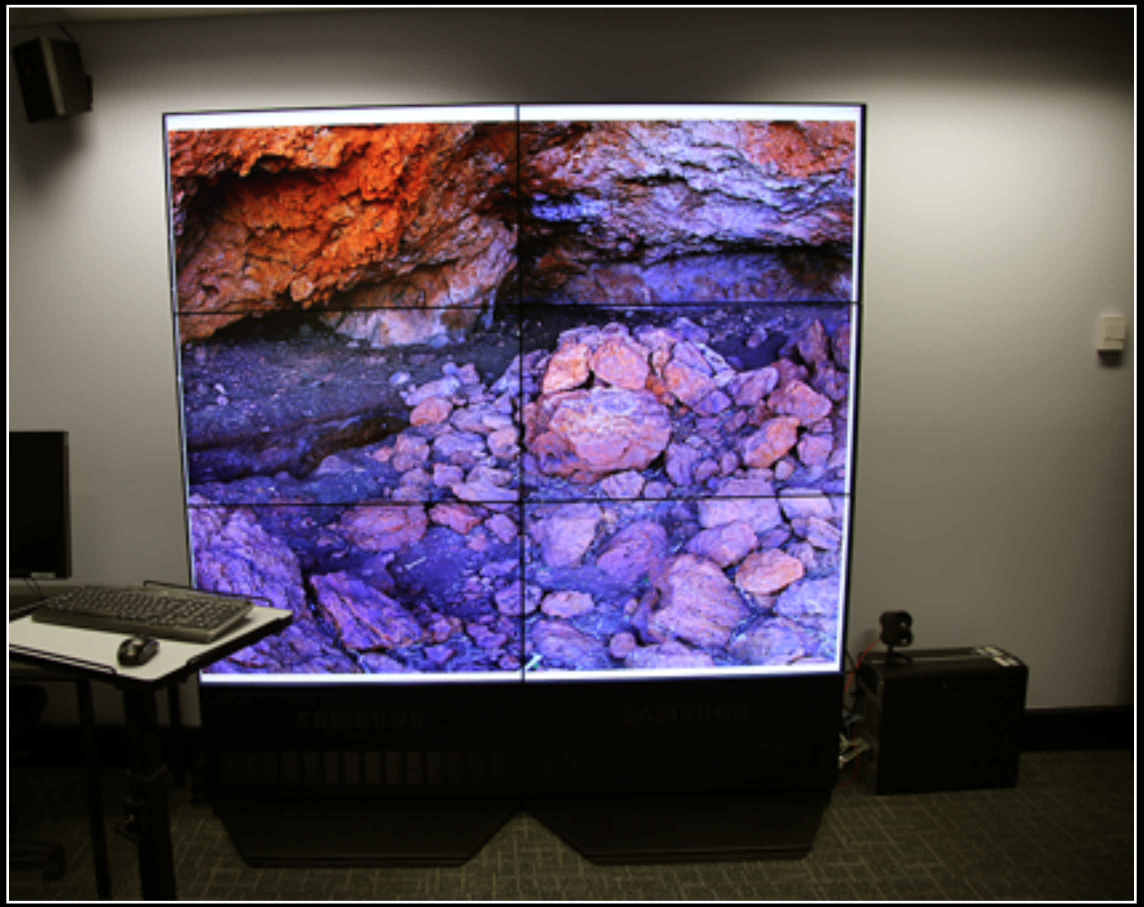


Hardware: resolution

- Often don't have enough pixels.
- HD resolution has about 2 million pixels, what happens if we have more then 2 million objects to represent?
- Constant zooming in and zooming out and one is trading off context for detail.



Murdoch University



UWA

- A number of displays managed by iVEC
- Pawsey building: 4K x 2K stereoscopic enabled.
- ARRC building and UWA: 6K x 3K stereoscopic enabled.
- UWA: 4K x 3K.
- ECU: 6K x 2K.

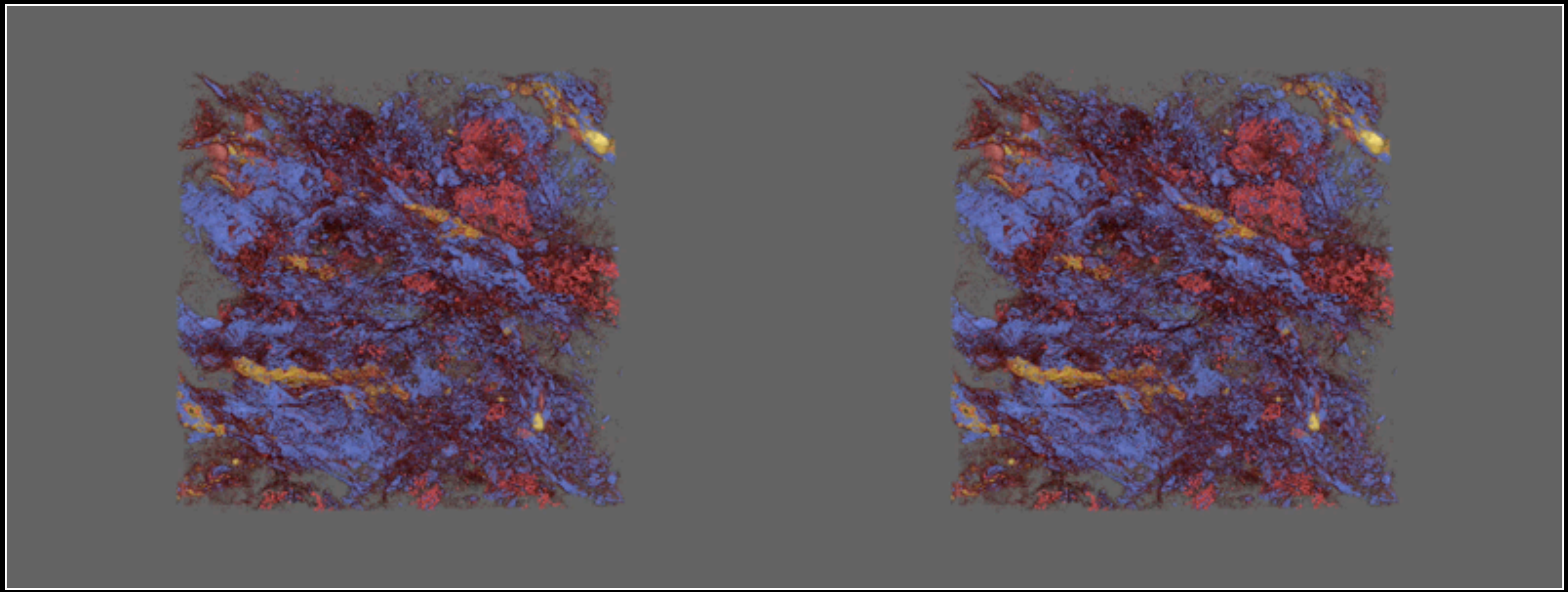
UWA

Pawsey building

Hardware: stereoscopy

- We perceive depth largely through stereopsis, having two eyes that get slightly different views of the world around us.
- Easy to imagine that for geometrically complicated relationships that depth perception could be valuable.
- Can obviously simulate those two views by computer rendering.
- The trick then is how to present them independently to each eye.
- Lots of options
  - anaglyph (red-blue) does so by encoding each eyes image by colour and the viewer wears matching colour glasses.
  - polaroid systems encode the left and right eye images by polarisation state of light.
  - active glasses encode the two images in time.
  - autostereoscopic = no glasses required
- In ALL cases there is only one thing going on ... a separate image needs to be presented to each eye. All the technology options are just a means to achieve that.

Computer generated



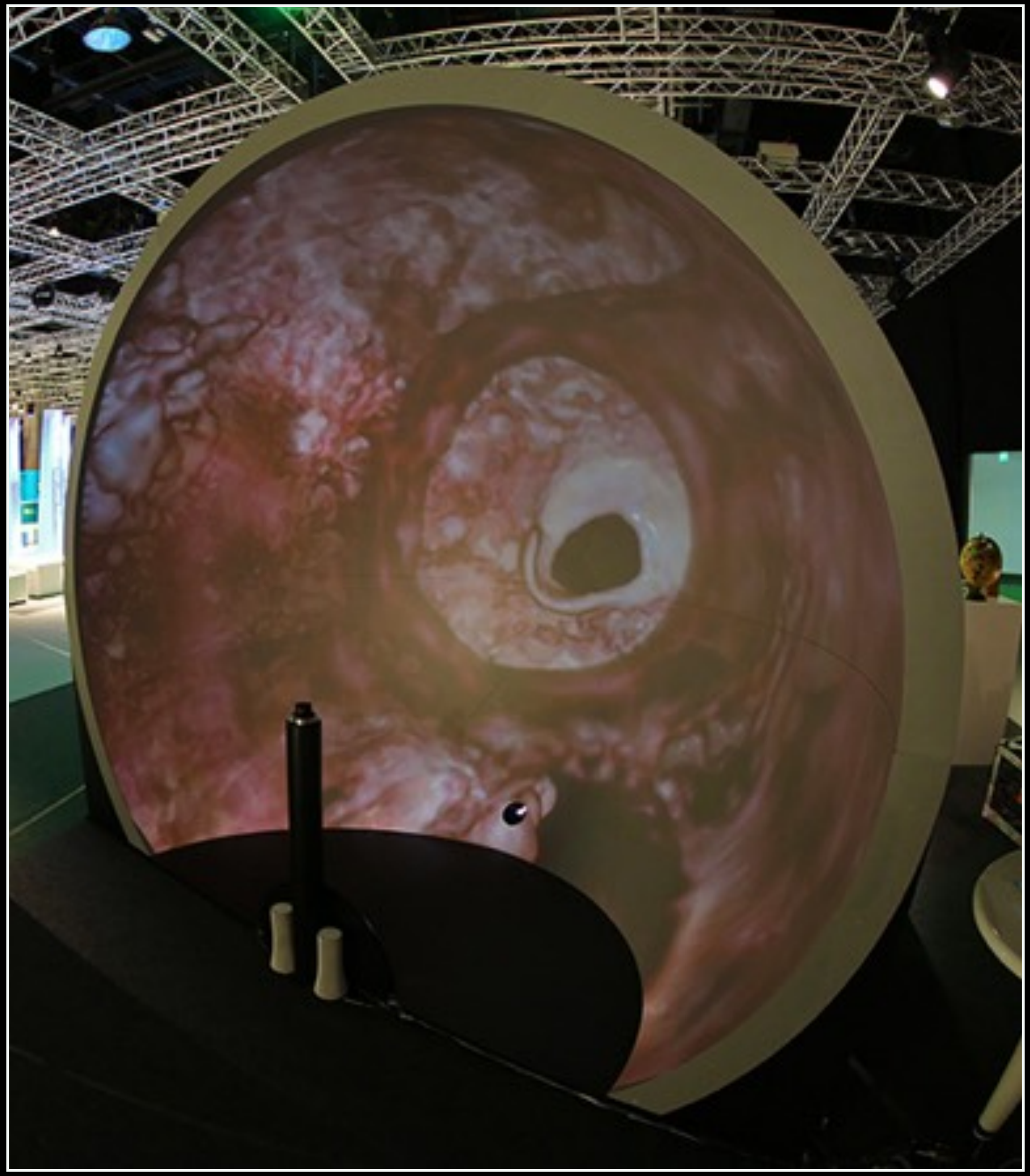
Left eye

Right eye

Filmed

Hardware: immersion

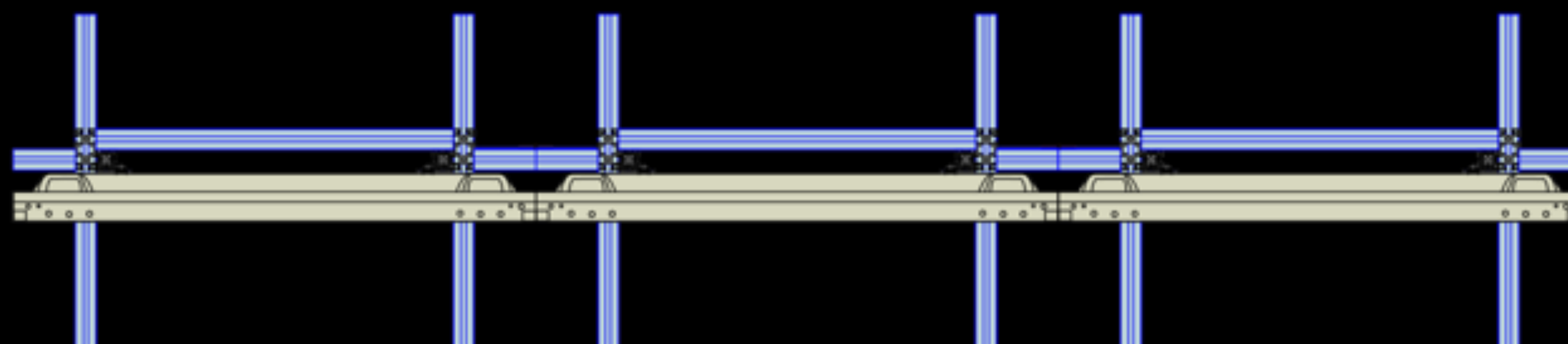
- Immersion: the sense of "being there".
- Main contributor is engagement of our peripheral vision.
- Human visual system has a almost 180 degree horizontal field of view and about 100 degree vertical field of view.
- Use perhaps 30 degrees when using a standard flat panel display.
- iDome is one way to engage the entire visual field of view.
- Value for data visualisation is when you are inside the data, the data becomes a virtual world.

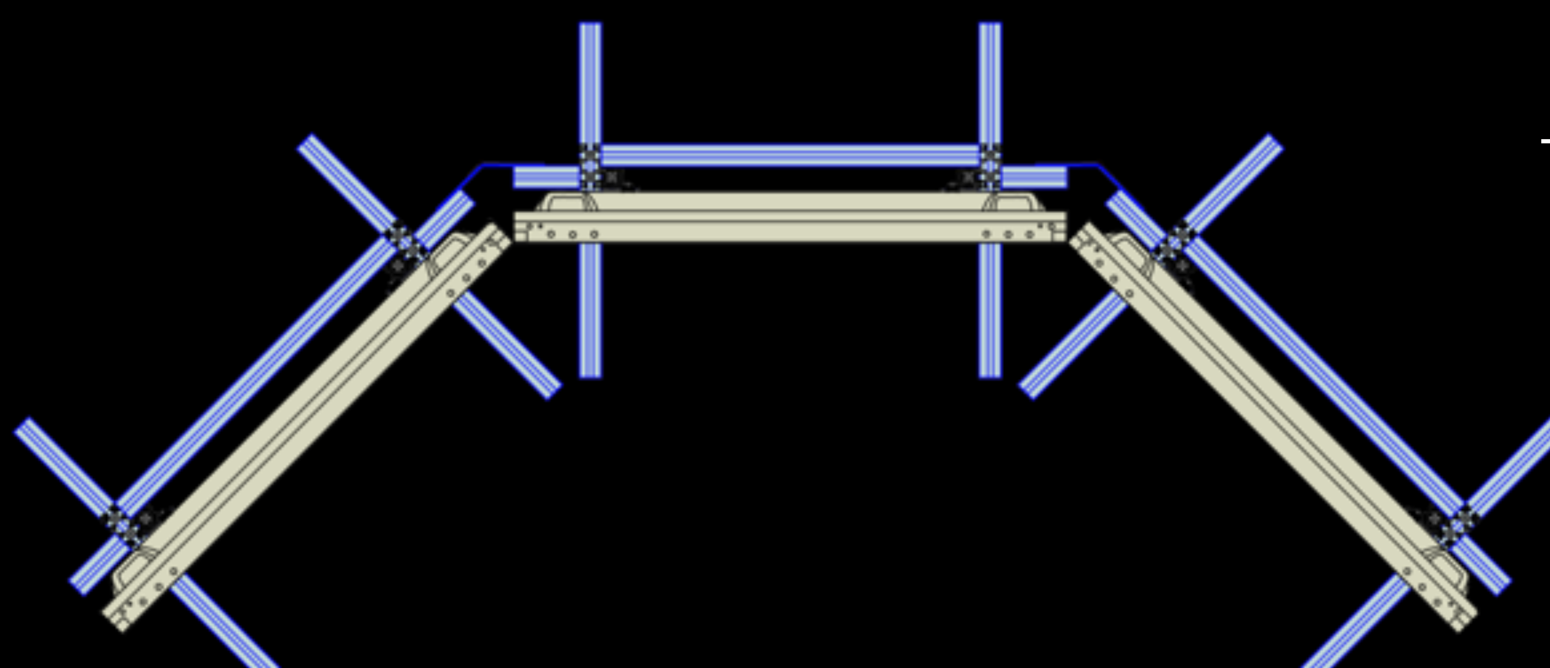


- Head mounted displays are another approach, but rarely engage more than about 100 degrees horizontally.
- Military / simulator HMDs can but they use multiple panels at a high price point.

Movie

- Tiled panels can engage a reasonable horizontal field of view if one can stand close enough.
- Helps if they are curved inwards.
- About to install the following at ECU.





Top view of 3x2 panel array

Special topics: virtual environments

- Common to experience visualisations within virtual environments.
- In the context of commodity infrastructure referred to as "serious gaming".

Movie

Rio Tinto ship loader


Fit for Life
Orbit

Special topics: sonification

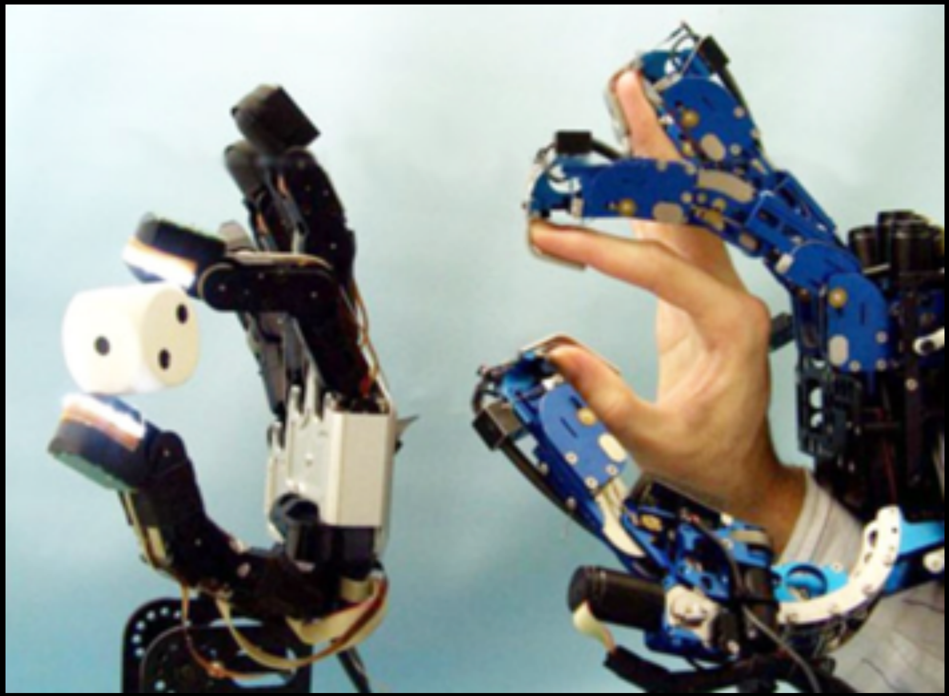
- Sonification is visualisation based upon audio, using our sense of hearing.
- Classic example are Geiger counter, hospital machine that goes "ping".
- Often a difficult mapping between data and audio/music.
- Two most common approaches are to map some variable to the waveforms (eg: amplitude or frequency modulation) or to map to instruments (eg: midi).
- More common to use audio to compliment visuals.

Direct frequency modulation

Midi instrument, equal tempered scale

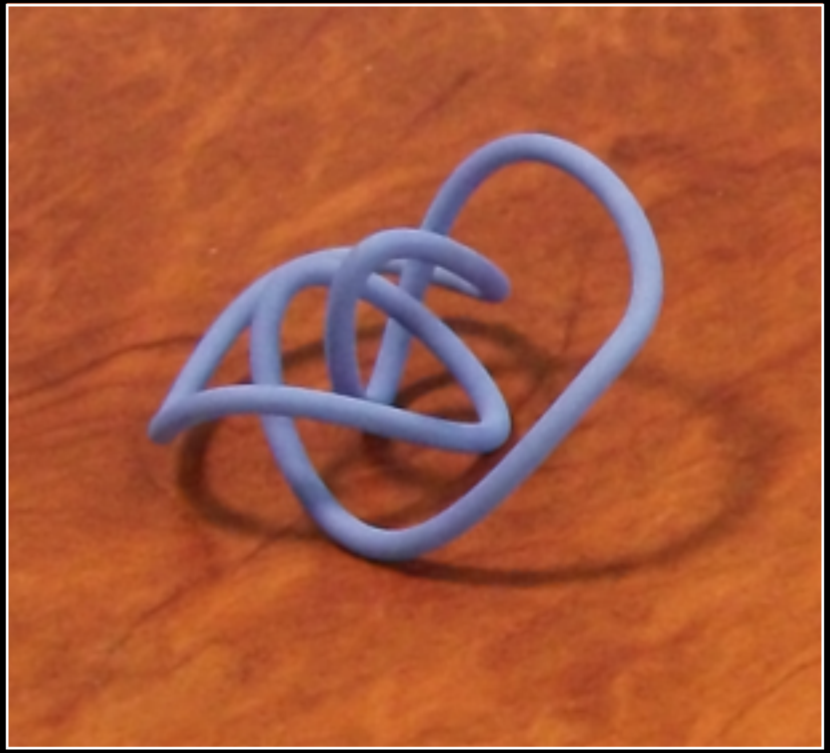
Special topics: haptics

- Haptics and force feedback uses the sense of touch to “feel” data or processes.
- Often just pitched as interface devices but can also allow one to “feel the data”.
- Commodity example is joystick vibration in car driving games.
- Used extensively in remote surgery - eg: force feedback scalpel.
- Range of devices/techniques: data gloves, mechanical arms, vibration, temperature ...



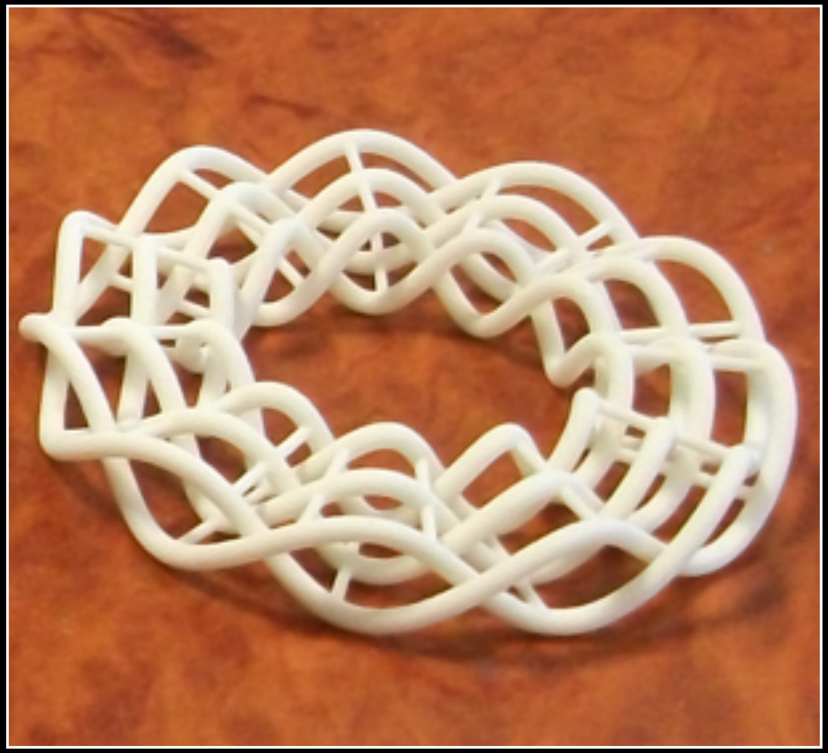
Special topics: 3D printing

- Tactile visualisation uses the sense of touch, used here in the context of touching physical models.
- Claim: Insight into the geometry / structure of an object can be assisted if we studying it in the same way as we explore objects in real life.
- 3D printing generally refers to additive processes where successive layers are laid down to form the model.
- Distinct from computer controlled milling or lathes (and others) where material is removed.
- People tend to imagine it is a recent technology, my first 3D prints were done in 1992.

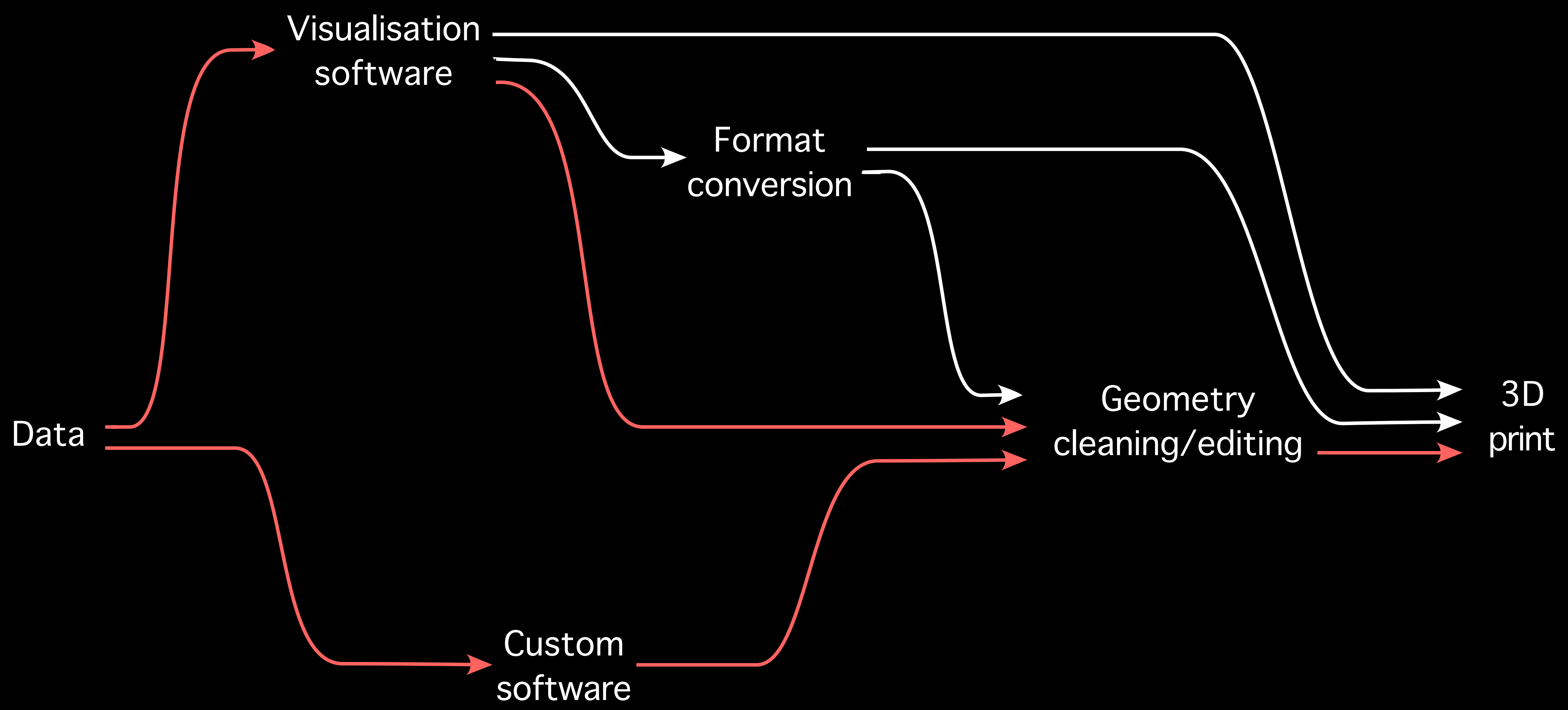


Visualisation in knot theory

Printing in metal



Visualisation in neuroscience



Red shows the most common workflows in my experience.

- Wide range of technologies
  - FDM: Fused deposition modelling
  - EBF: Electron beam freeform fabrication
  - DMLS: Direct metal laser sintering
  - EBM: Electron Beam melting
  - SLM: Selective laser melting
  - SHS: Selective heat sintering
  - SLS: Selective laser sintering
  - PP: Plaster-based 3D printing
  - LOM: Laminated object manufacturing
  - SLA: Stereolithography
  - DLP: Digital light processing

- The key questions for data visualisation are the limitations of a particular technology
  - Ability to create convoluted / concave structures
  - Colour reproduction
  - The finest structures / details that can be represented

- Lots of low cost solution now on the market but they can be limiting.

- Two most useful machines are:
  - ZCorp colour printers
  - ObJet from StrataSys

- ZCorp solved overhanging problem by using powder rather than liquid. Injet printer, prints coloured glue instead of ink onto a rising bed of powder rather than paper.
  - First good colour printer
  - Sandstone like material
  - Finest structures limited

- ObJet lays down one of N materials, photopolymer layers are cured by UV light. One layer may be a water soluble material for creating support layers.
  - Monochrome (until recently)
  - High structural strength plastic
  - Range of materials

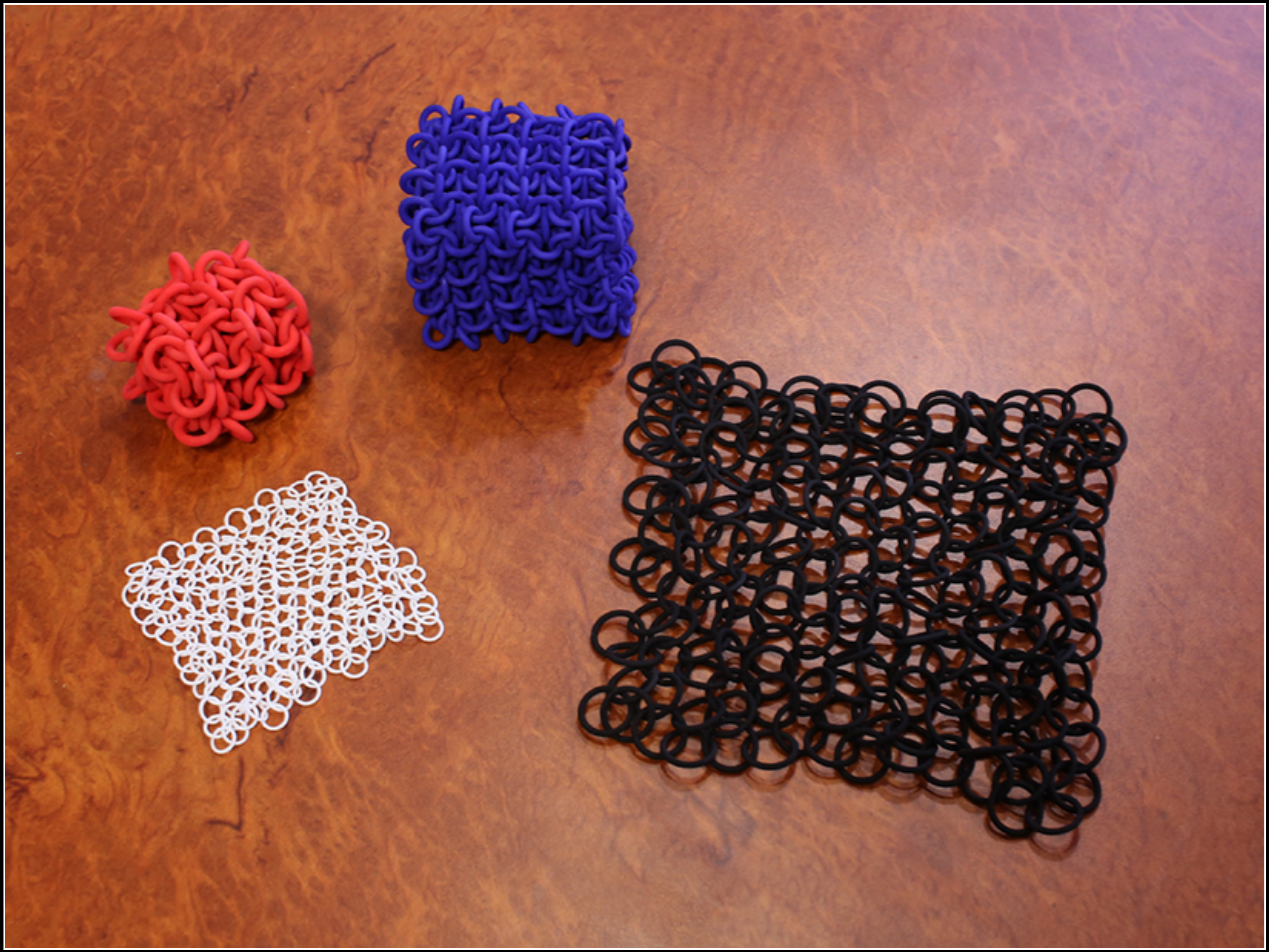
- Examples in geoscience

Fossils (Geology)

- Examples in chemistry

Series of peptides (Chemistry UWA)

- Examples in mathematics

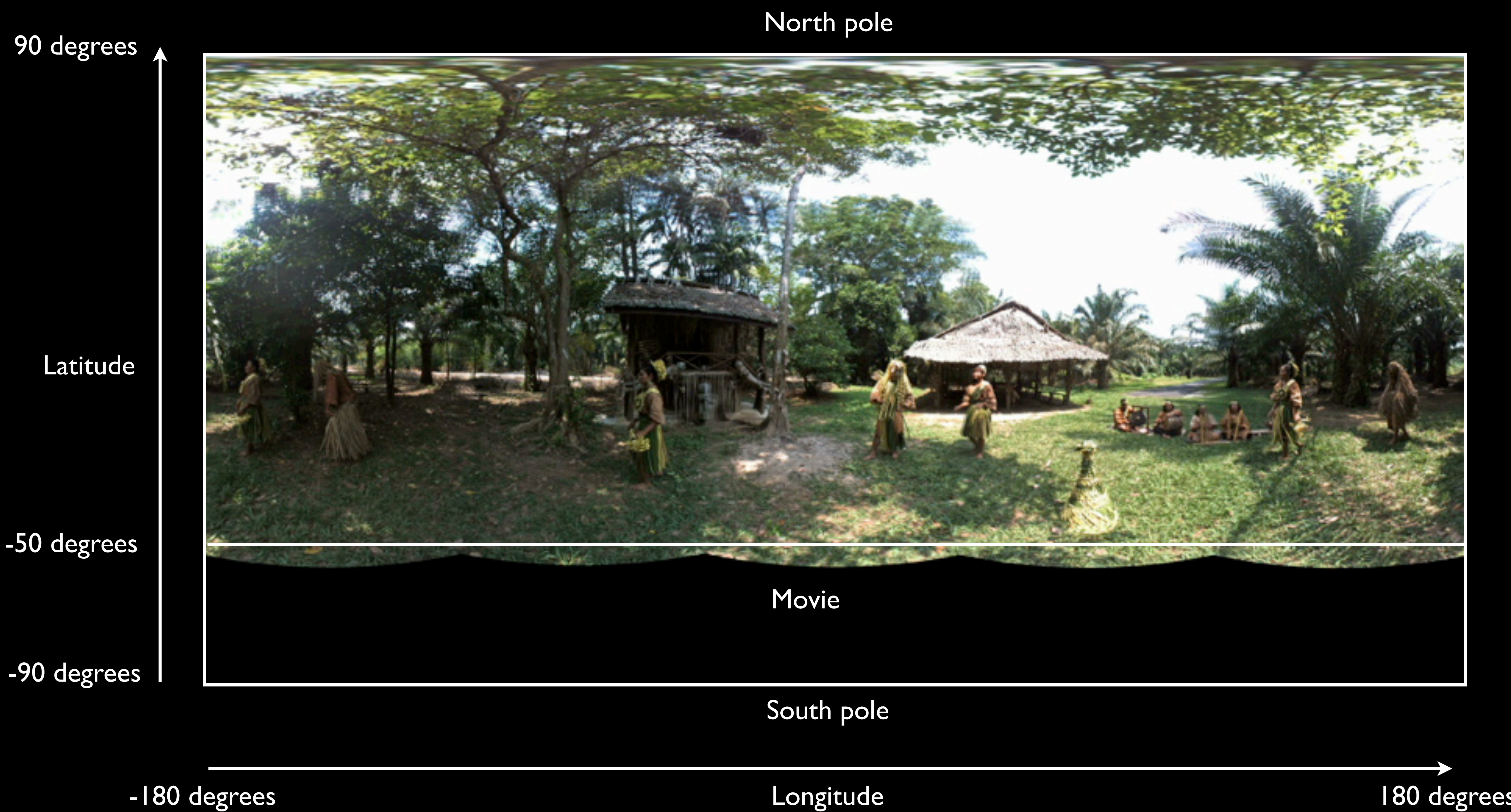


2D and 3D chainmail

Special topics: 360 video

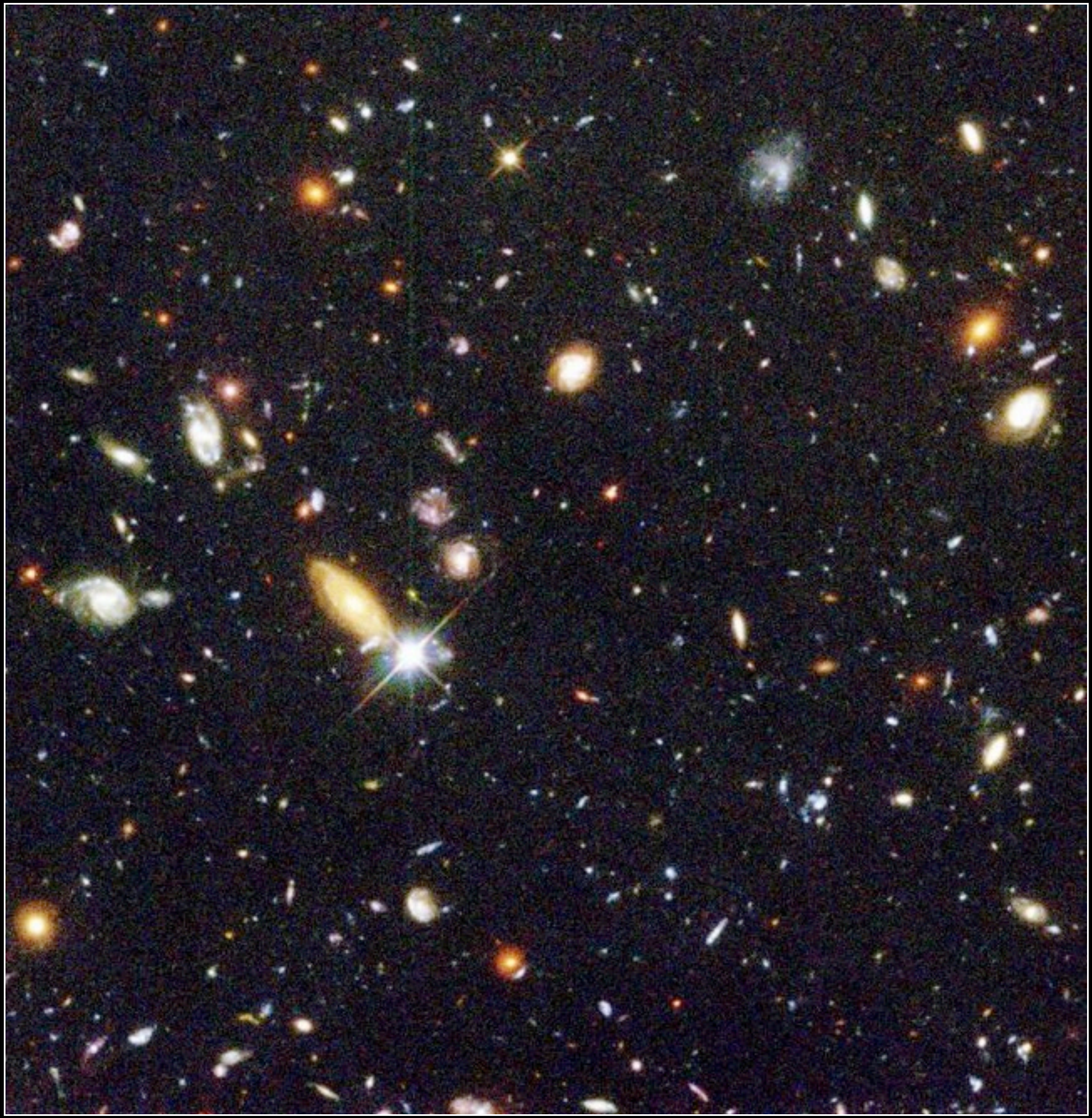
- Largely for projects in cultural heritage.
- Example: Mah Meri, West Malaysia remote tribe.
- Have a healing ceremony involving masks and dance ritual.
- Ceremony occurs around the patient, goal is to capture that perspective, the view from "being there

- Spherical panorama, projection onto a sphere unwrapped to form a flat plane.
- 360 video camera captures everything except the lower 40 degrees.



Special topics: gigapixel imaging

- Aim is to capture the context as well as the detail in a single image.
- Result in richer research assets than separate distant and closeup images.
- In the context of remote locations access may be problematic/expensive, goal is to capture as high a value recording as possible.
- For destructive processes one only gets one chance, again, record at as high a resolution possible to maximise future research outcomes.
- One cannot buy a camera with an arbitrarily high resolution sensor, the solution is to tile multiple images together.



Hubble deep field
340 image composite

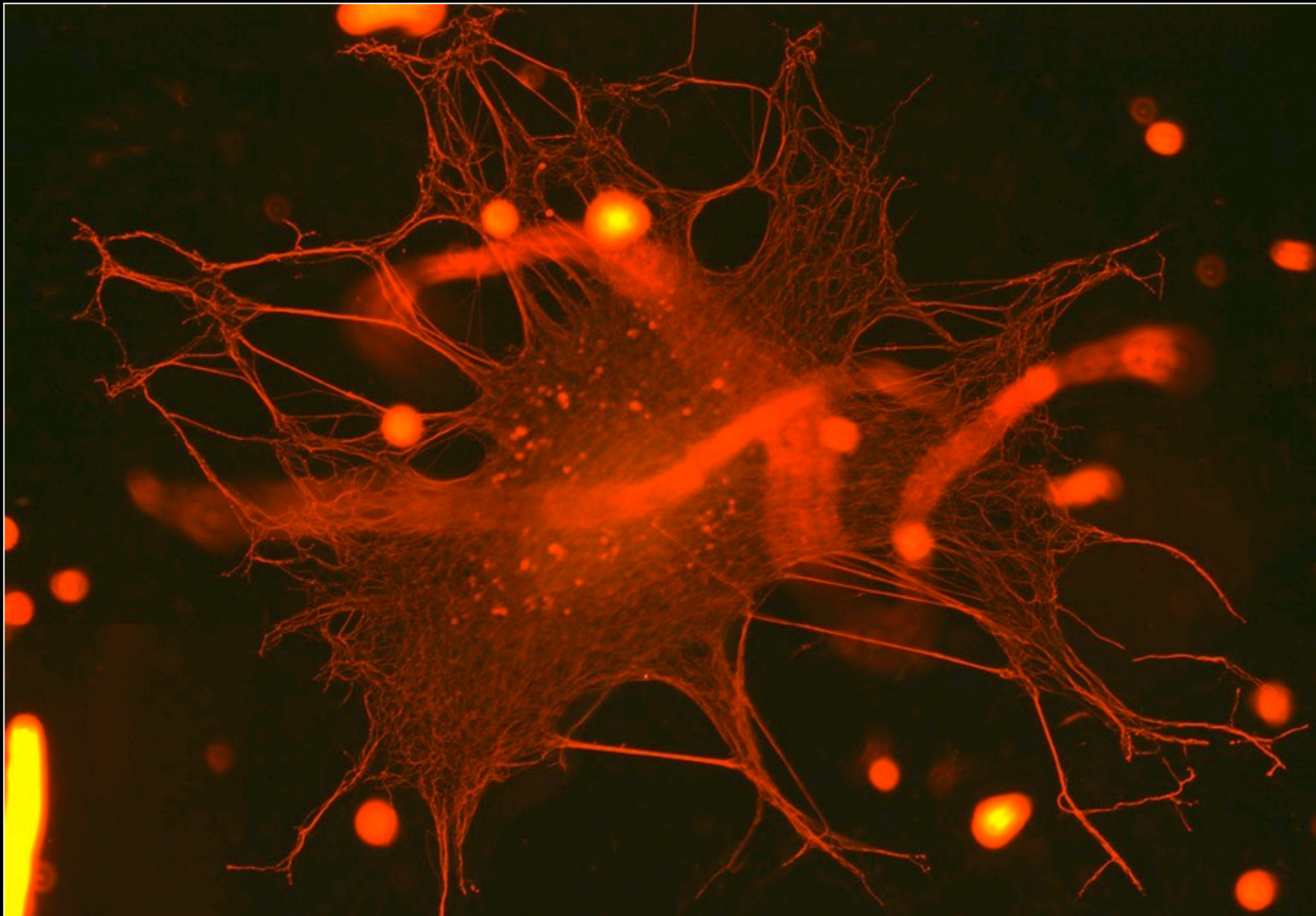


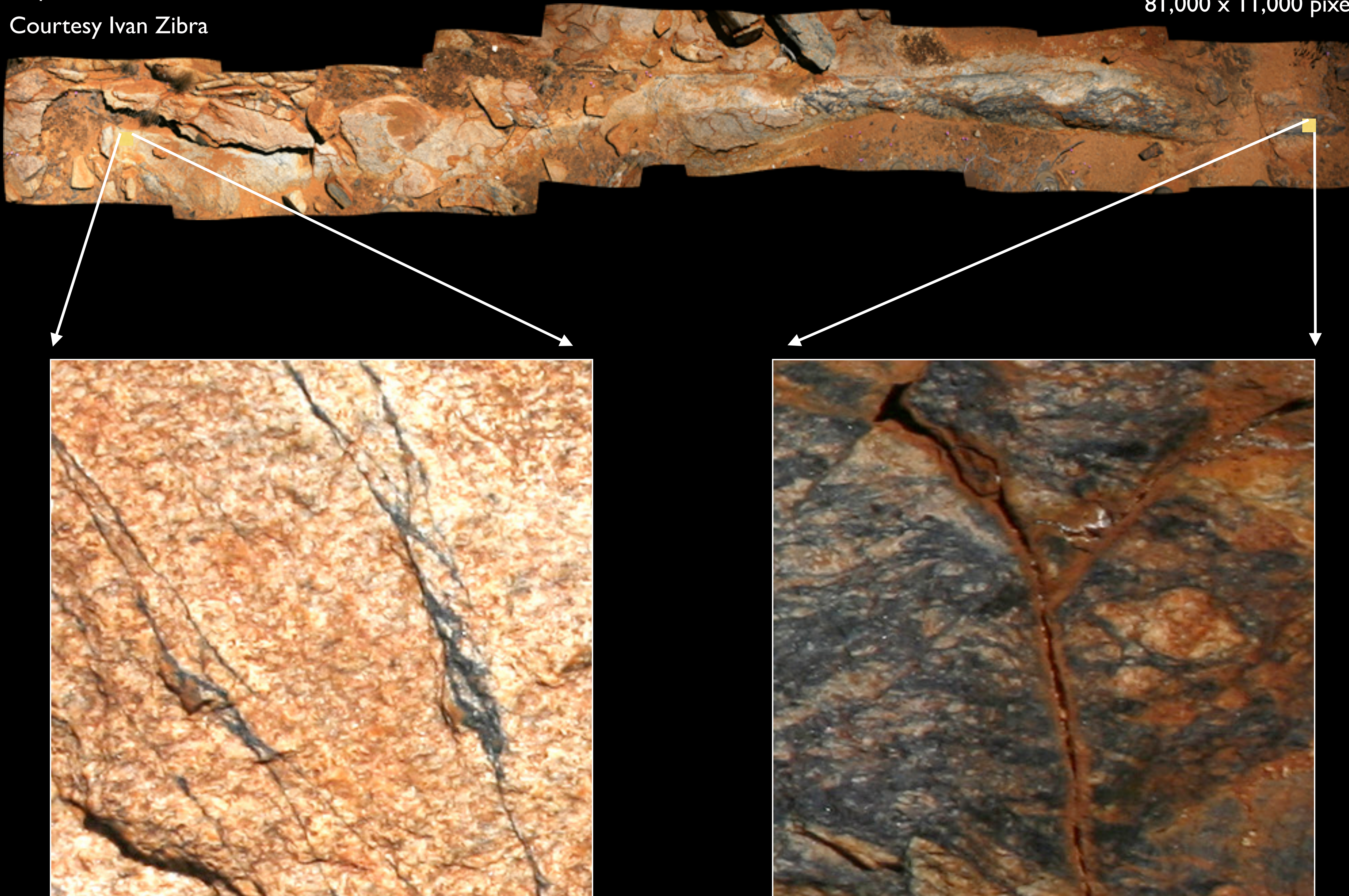
Image courtesy CMCA, UWA

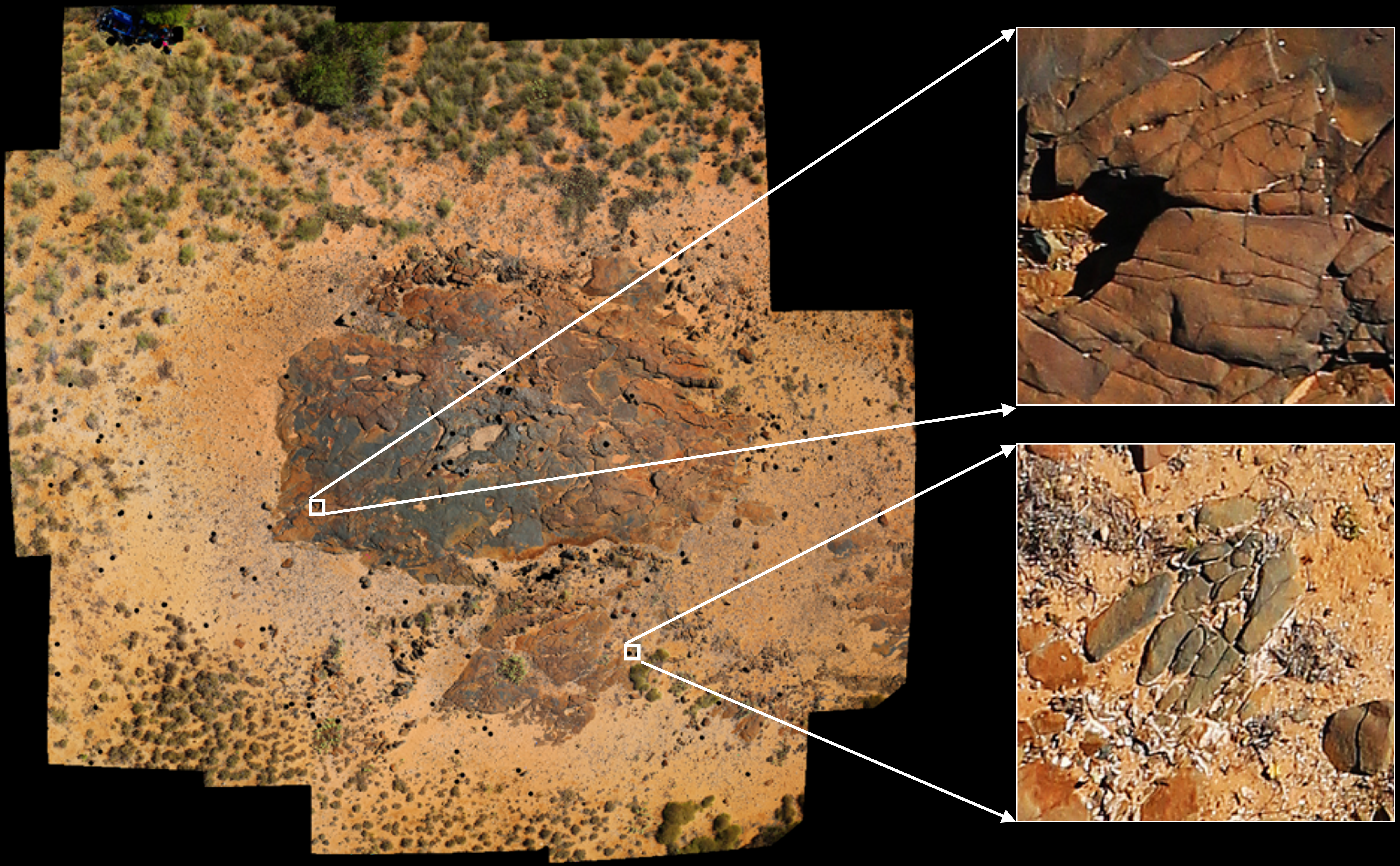
31,000 x 26,000 pixels

Department of Mines and Petrolium

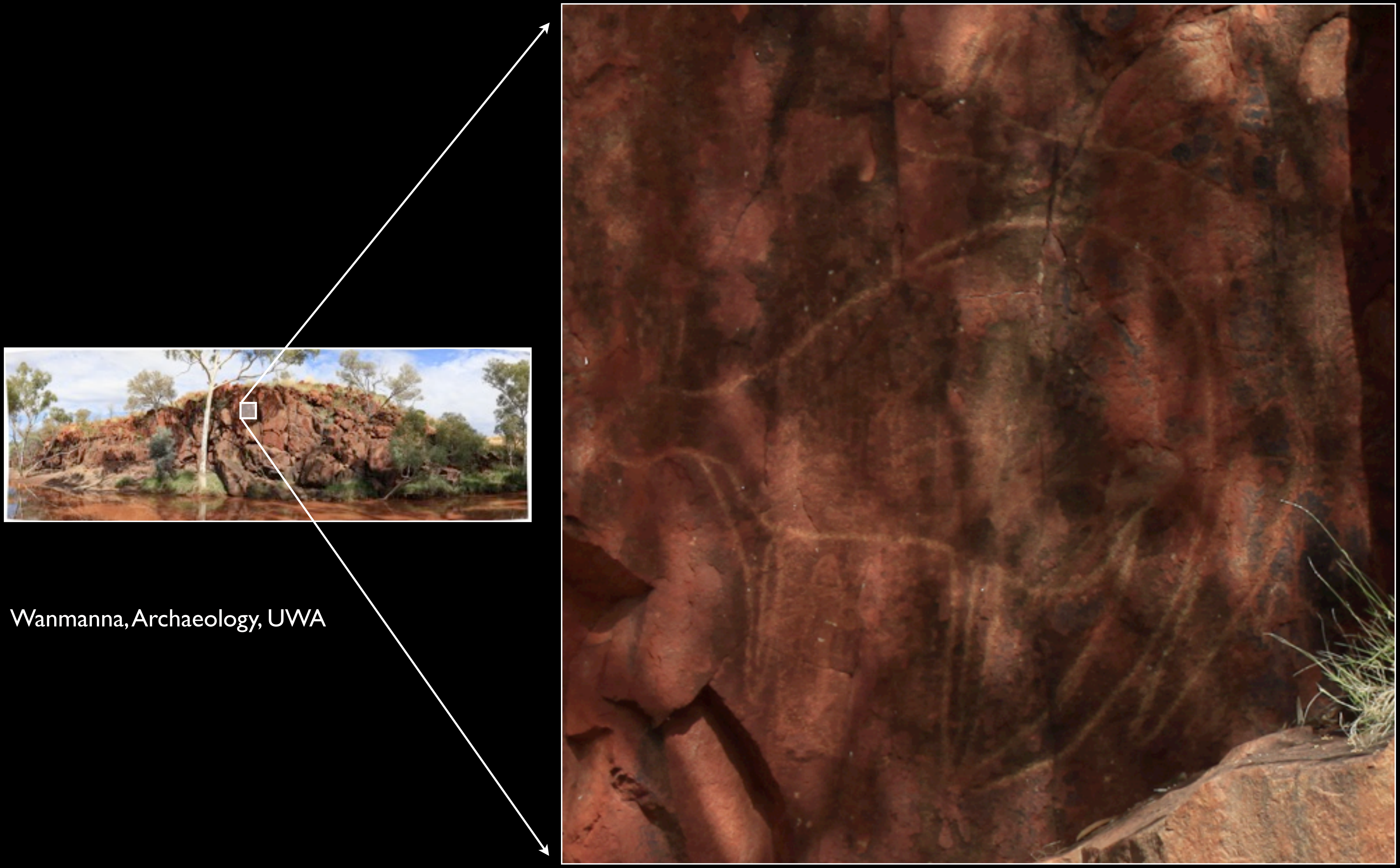
Courtesy Ivan Zibra

81,000 x 11,000 pixels





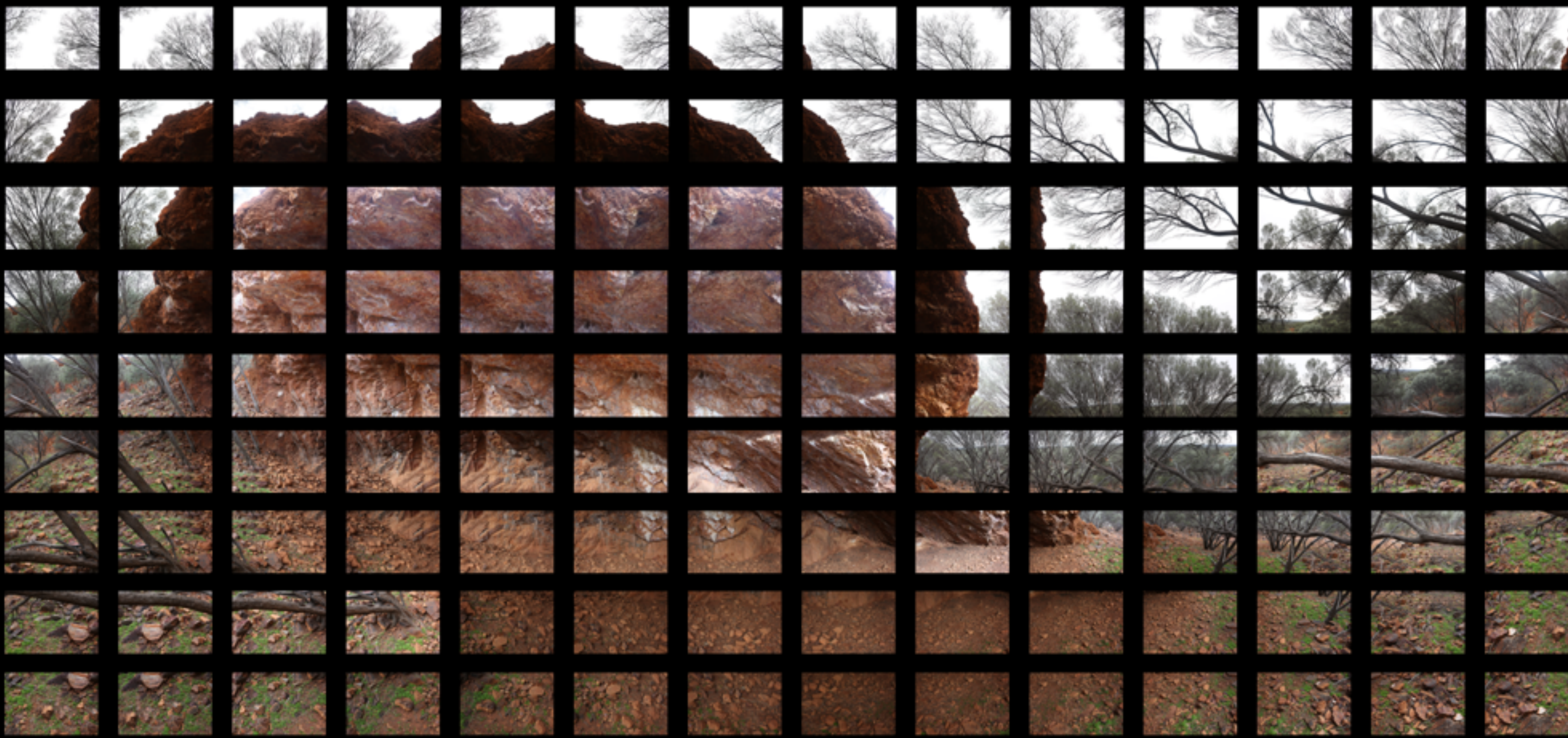
Centre for Rock Art Archaeology + Management, UWA

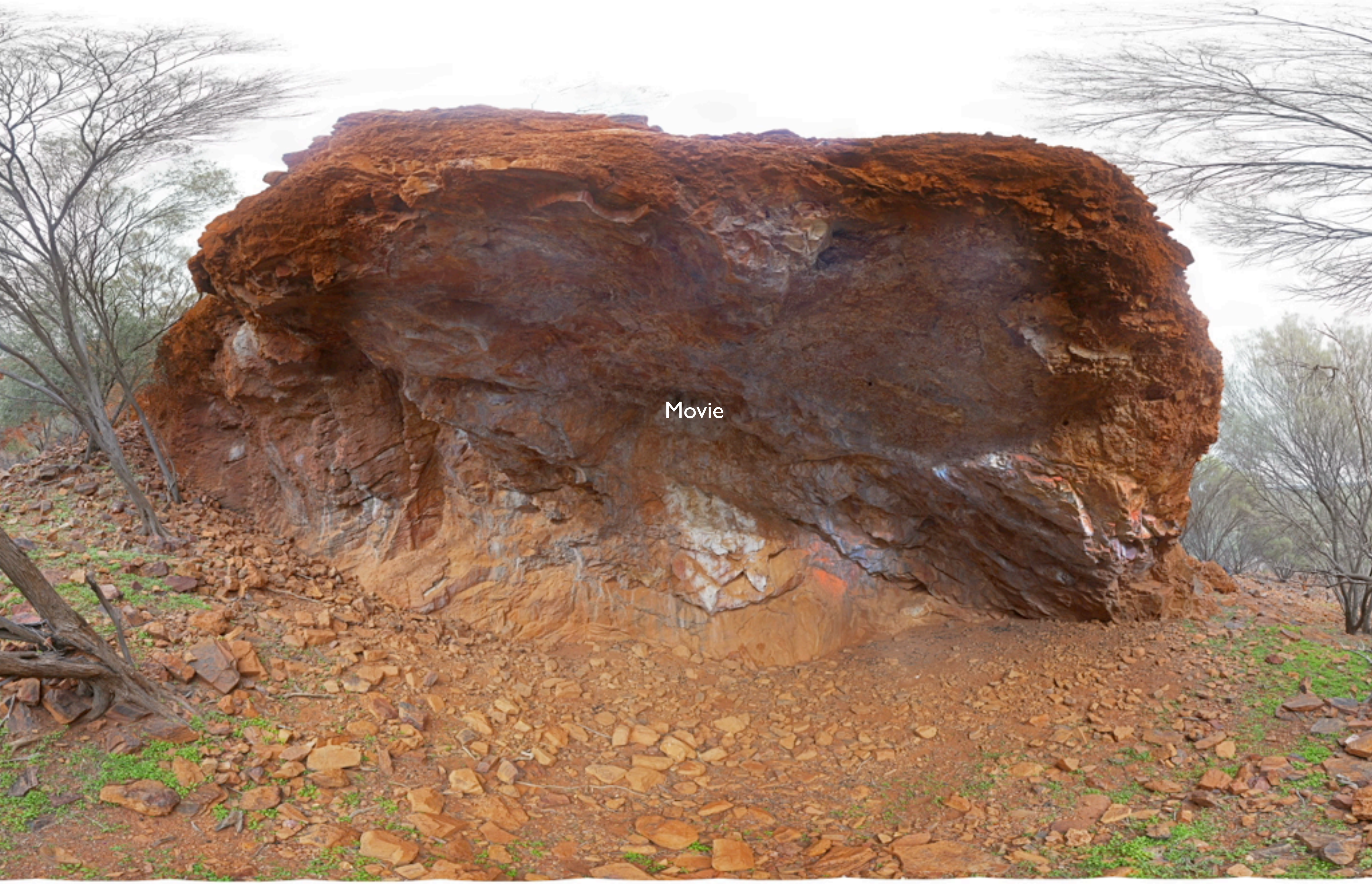


Wanmanna, Archaeology, UWA

40,000 by 20,000 pixels

Hurleys darkroom, Mawsons hut (Antarctica)
Courtesy Peter Morse



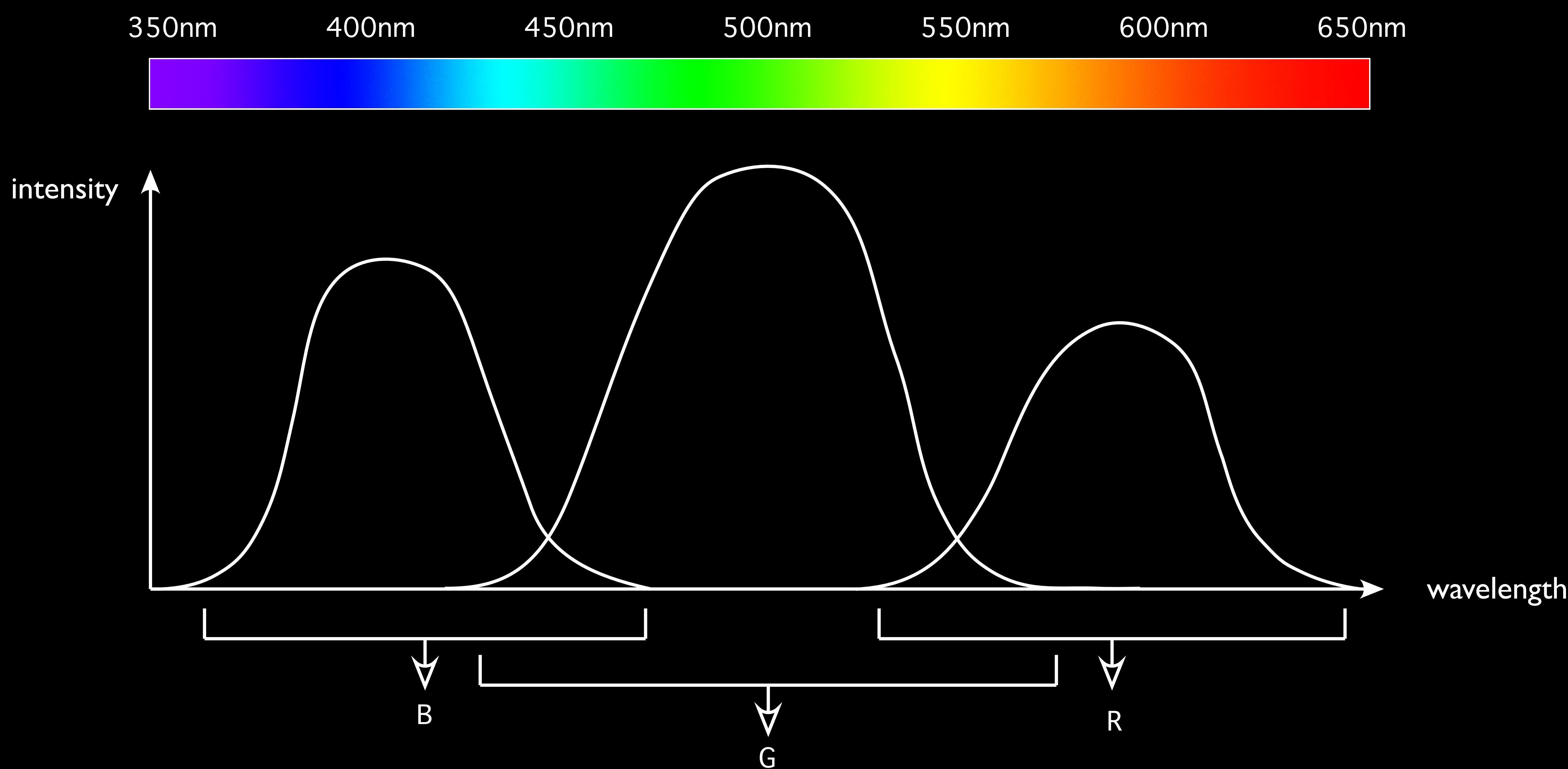

Movie

Special topics: multispectral imaging

Rock art is often very obvious and interesting

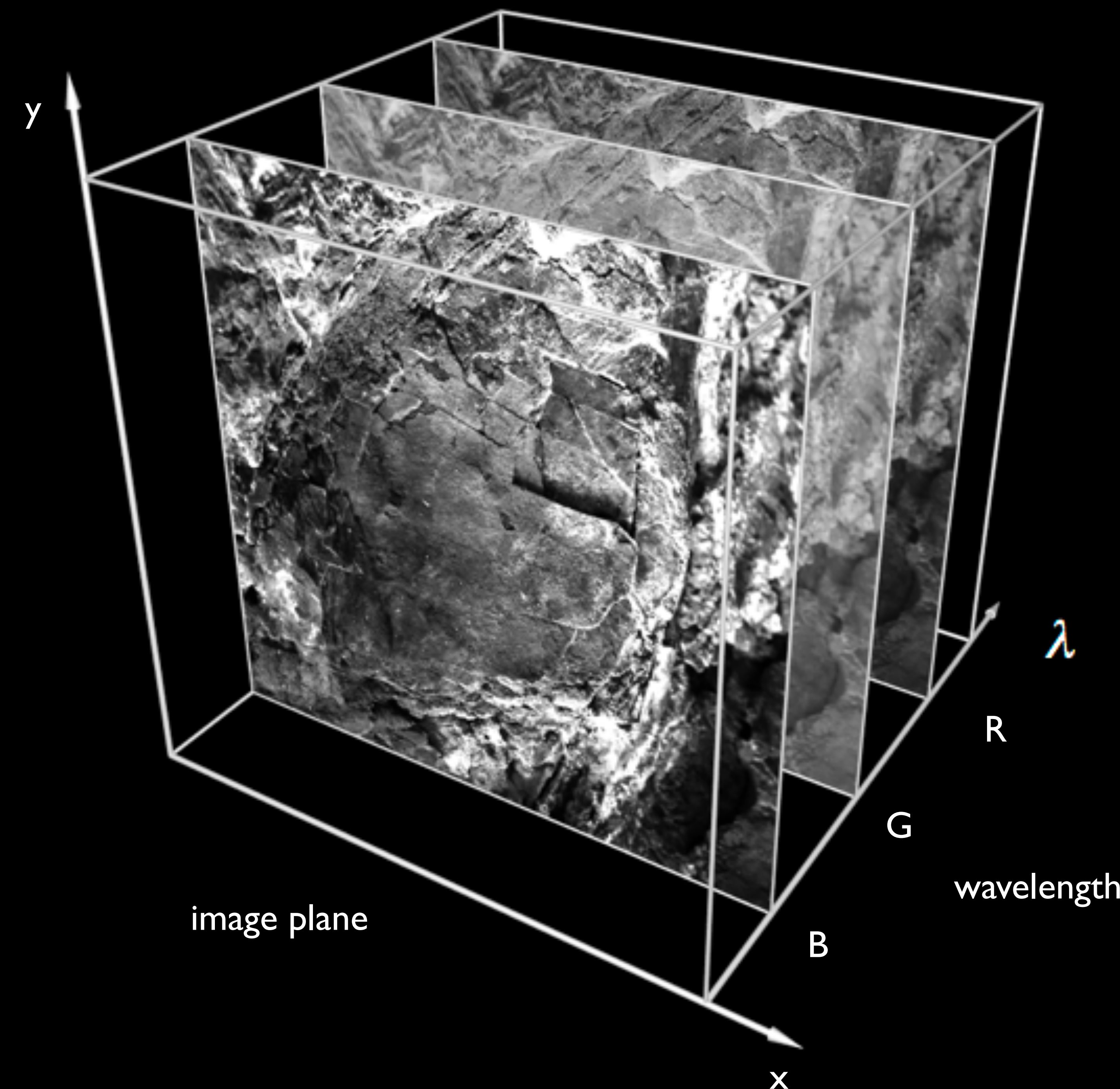
Other times less so

- A normal photograph is throwing away a huge amount of information.
- The energy across a range of wavelengths is being (weighted summed) into just 3 numbers, single R,G,B values.
- Can imagine materials that reflect strongly in different wavelengths but appear to be the same colour.

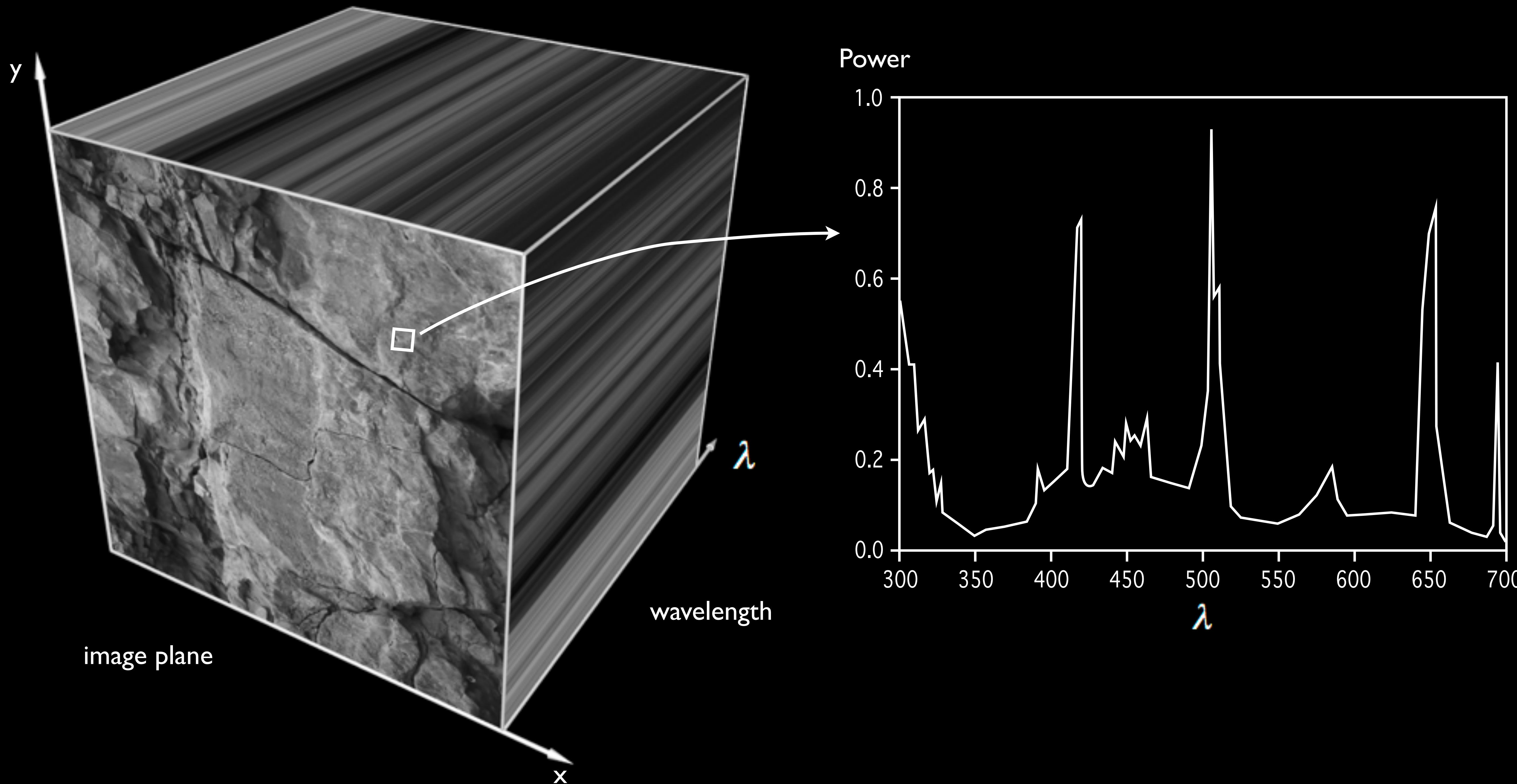


- Image cube (x,y, λ)

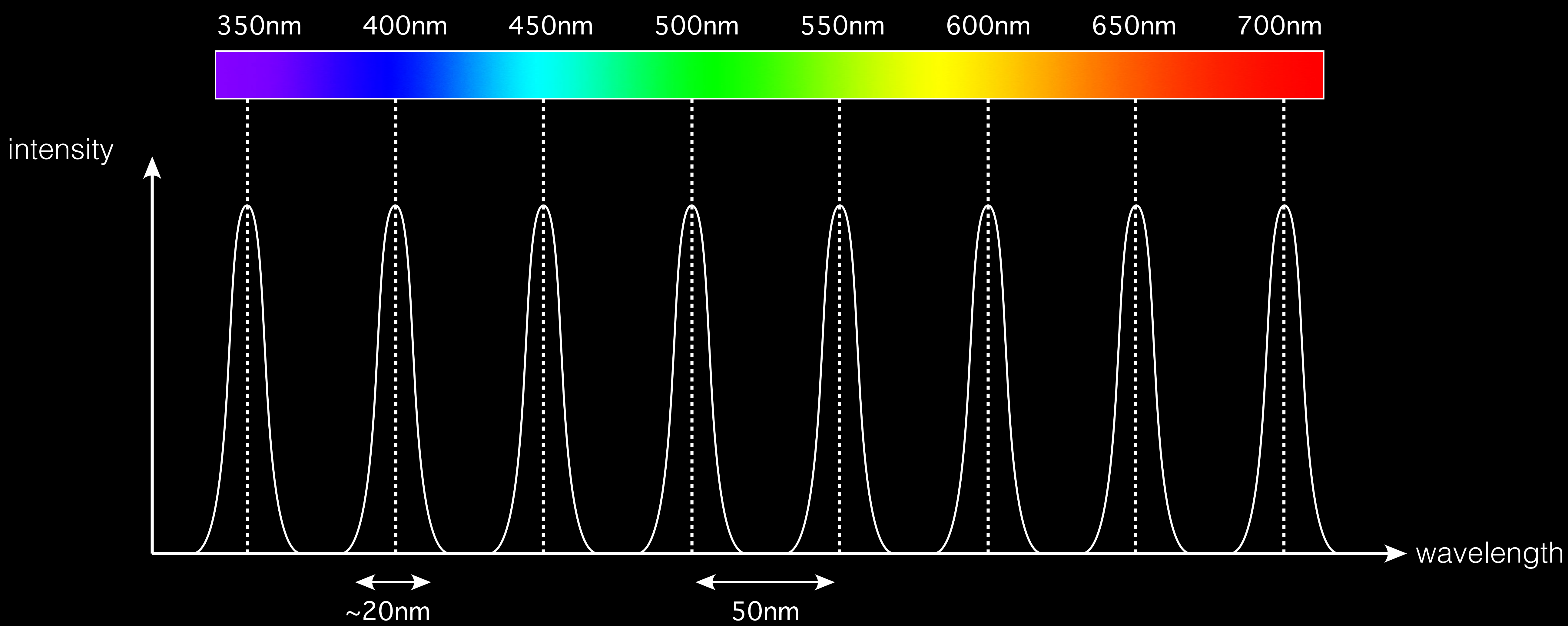
Hand print, West Angeles rock shelter.



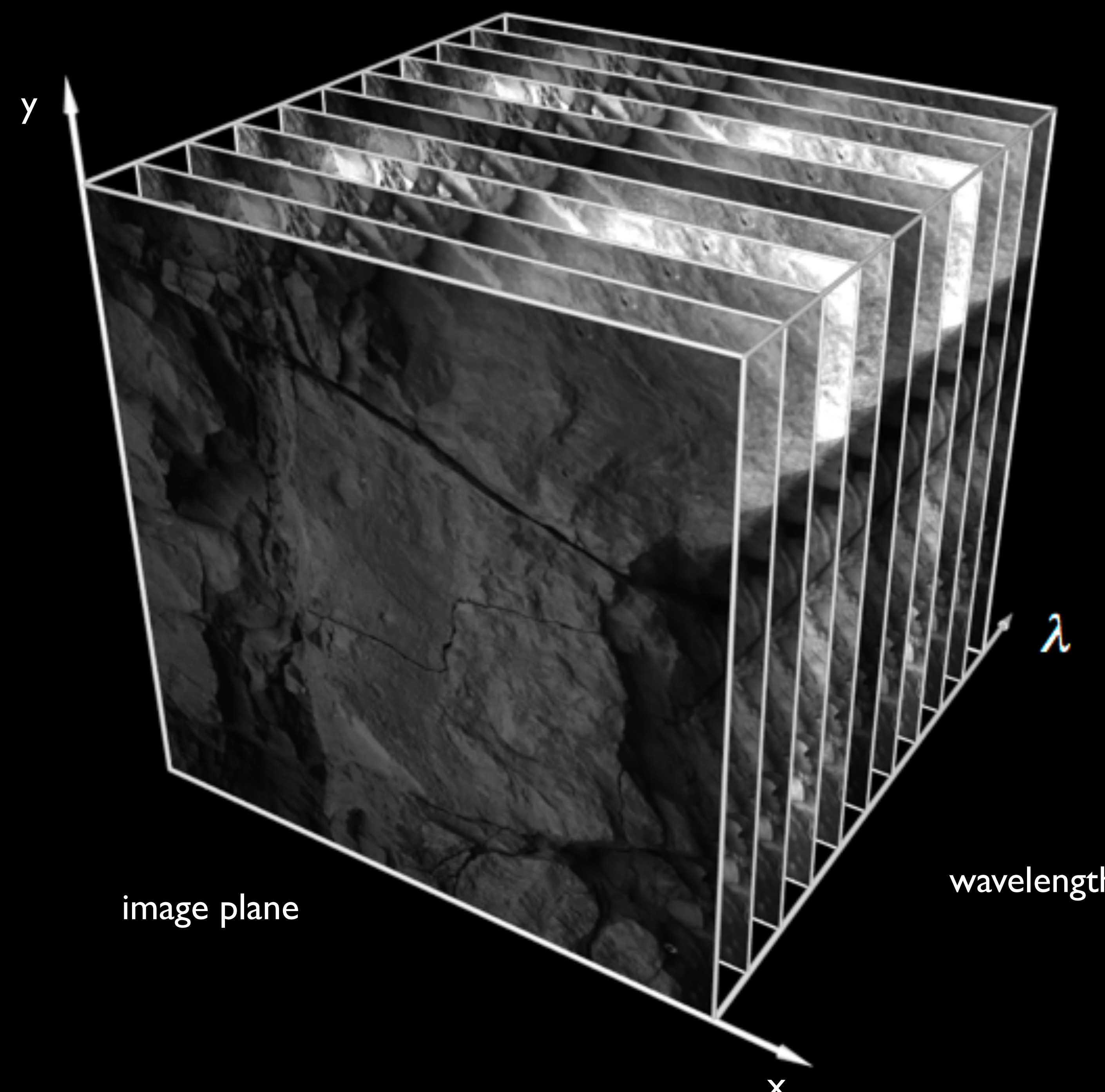
- Continuous image+wavelength cube



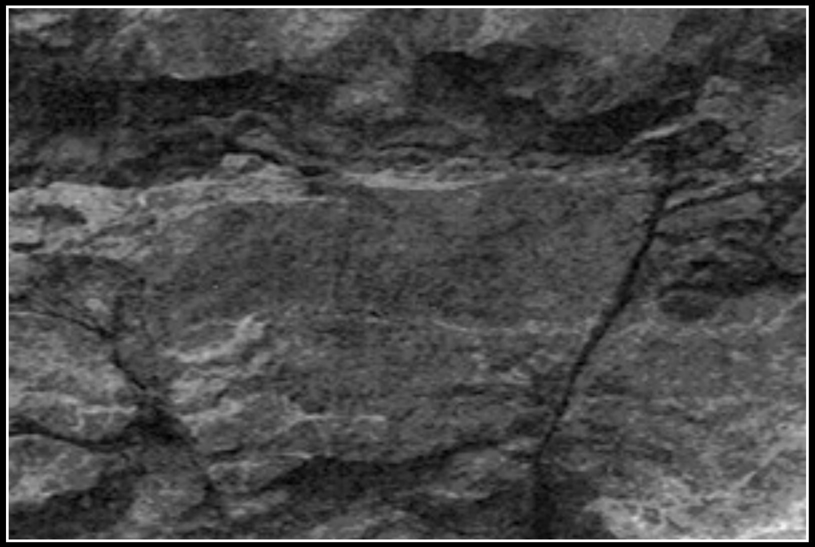
- Low cost alternative
- N filters across the visible spectrum
- Capture narrow wavelength ranges.
- For this initial experiment used 8 interference bandpass filters across the visible range. 350nm to 700nm.
- Filter banks 50nm apart and 20nm wide.



- 8 slices of the image cube



- Example



400nm

450nm

500nm

550nm

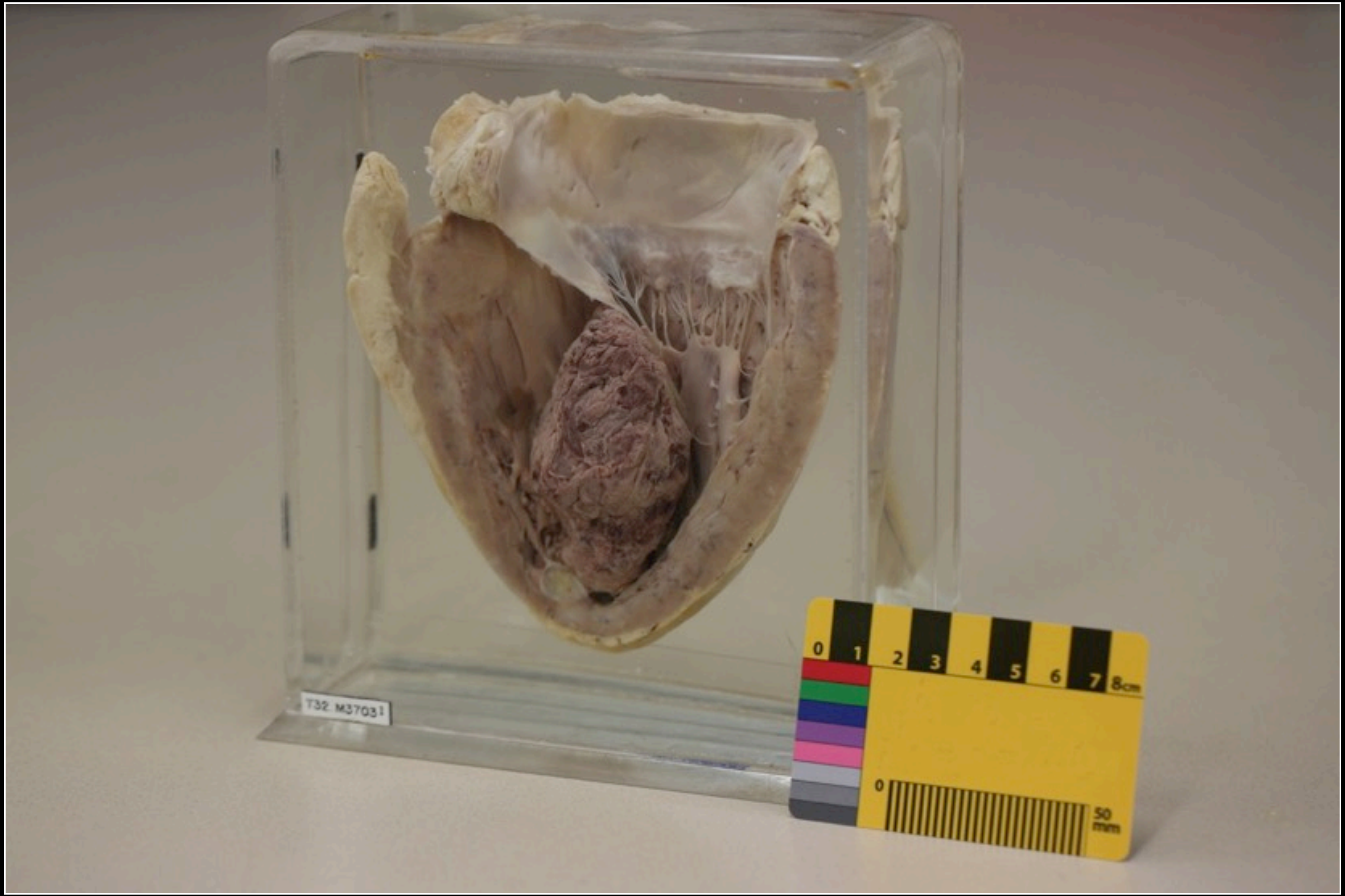
600nm

650nm

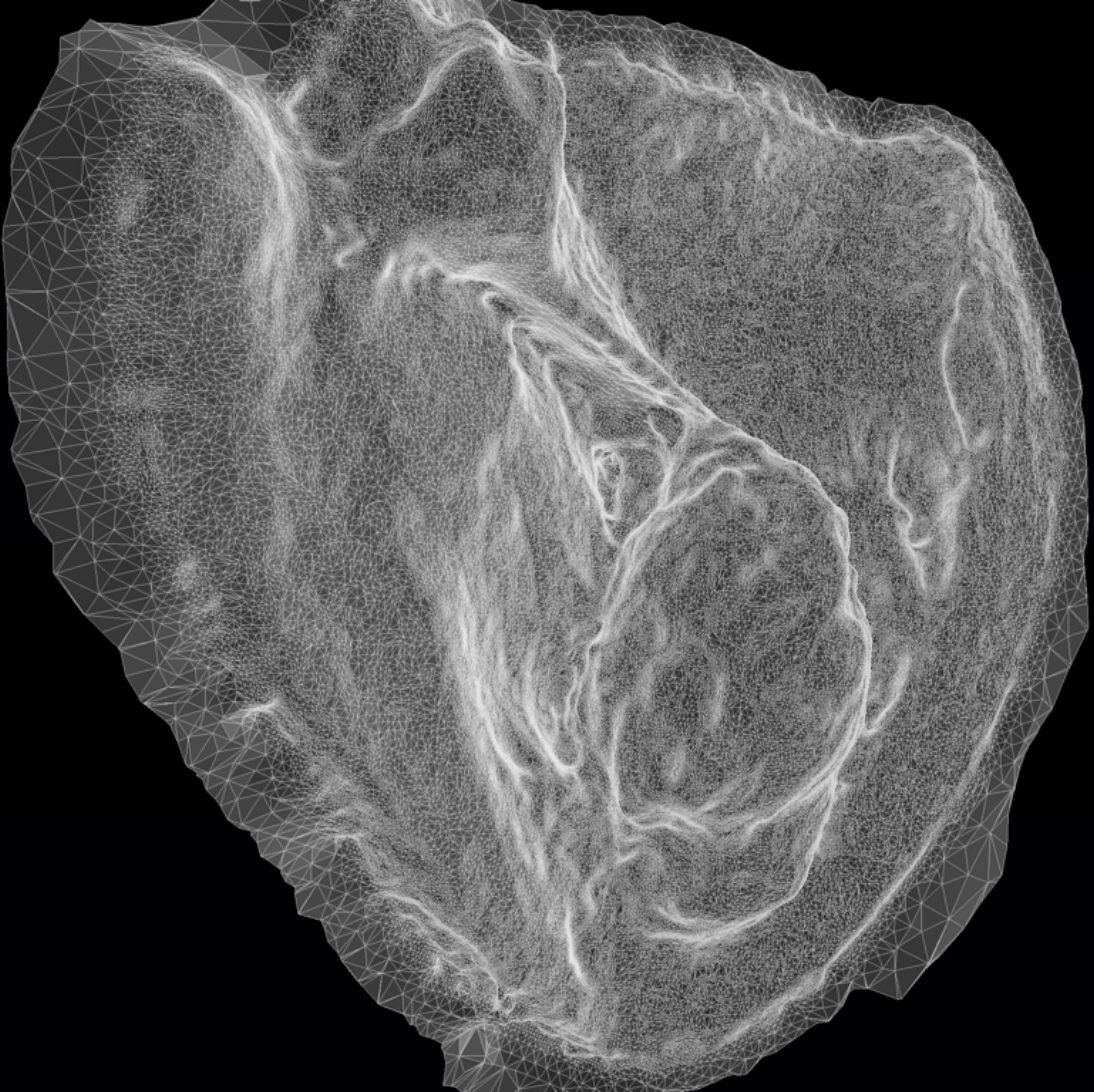
- Might imagine multiplying 500nm and 550nm and subtracting 650nm.
- Note that here we are interested in identification, much of multispectral imaging is more about quantitative analysis.

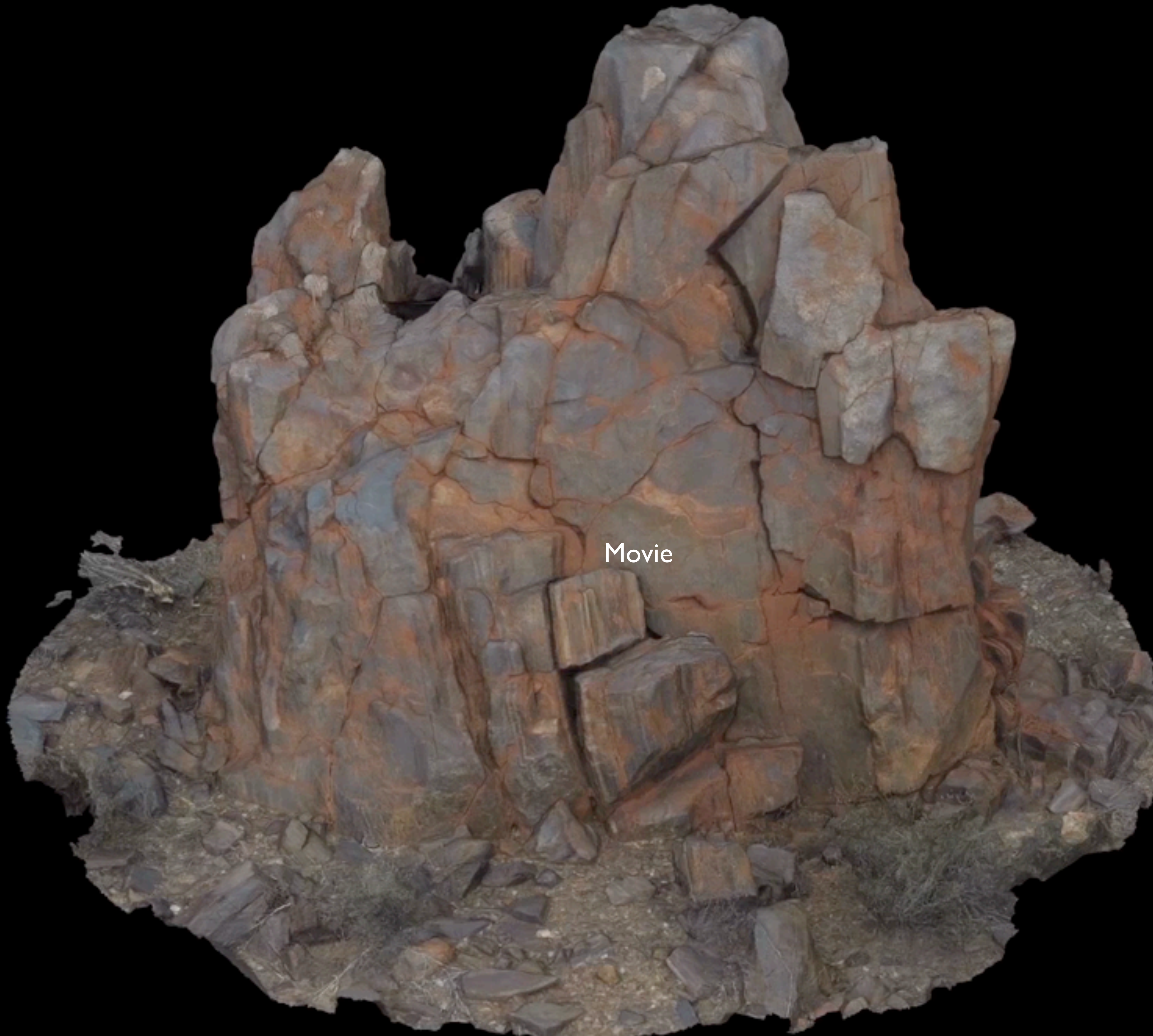
Special topics: Photogrammetry

- Process of deriving some 3D quantity solely from photographs.



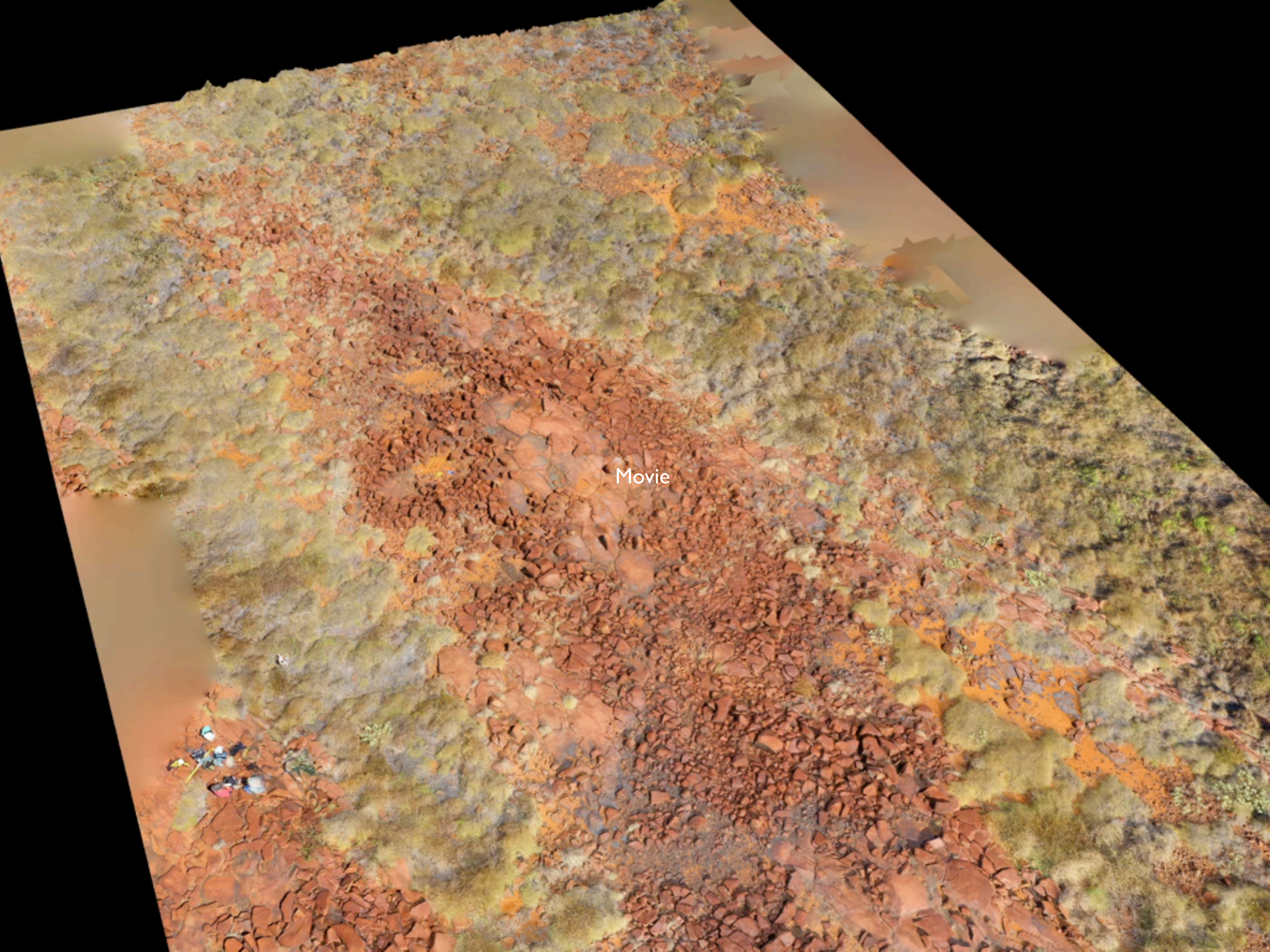

Movie



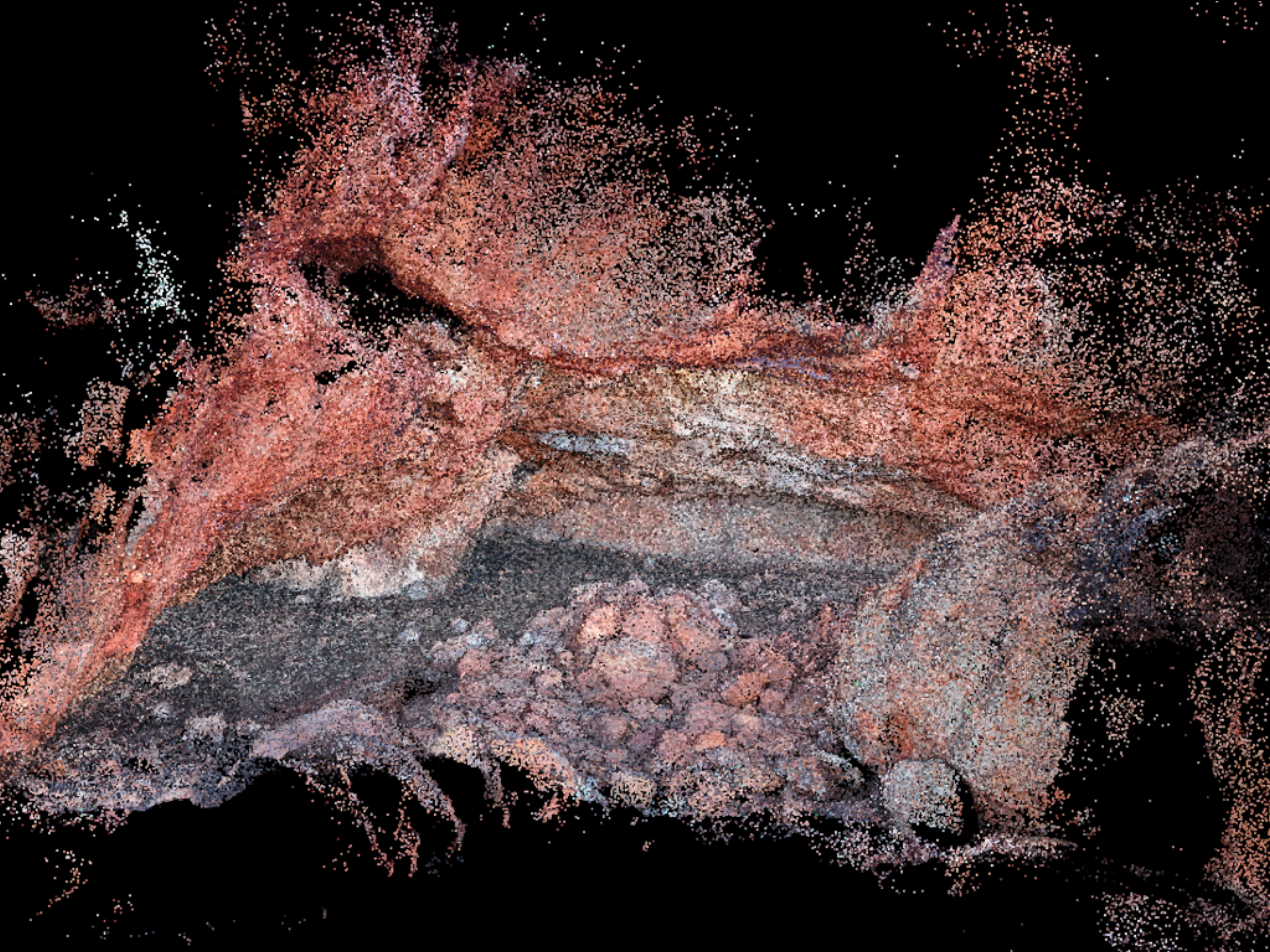


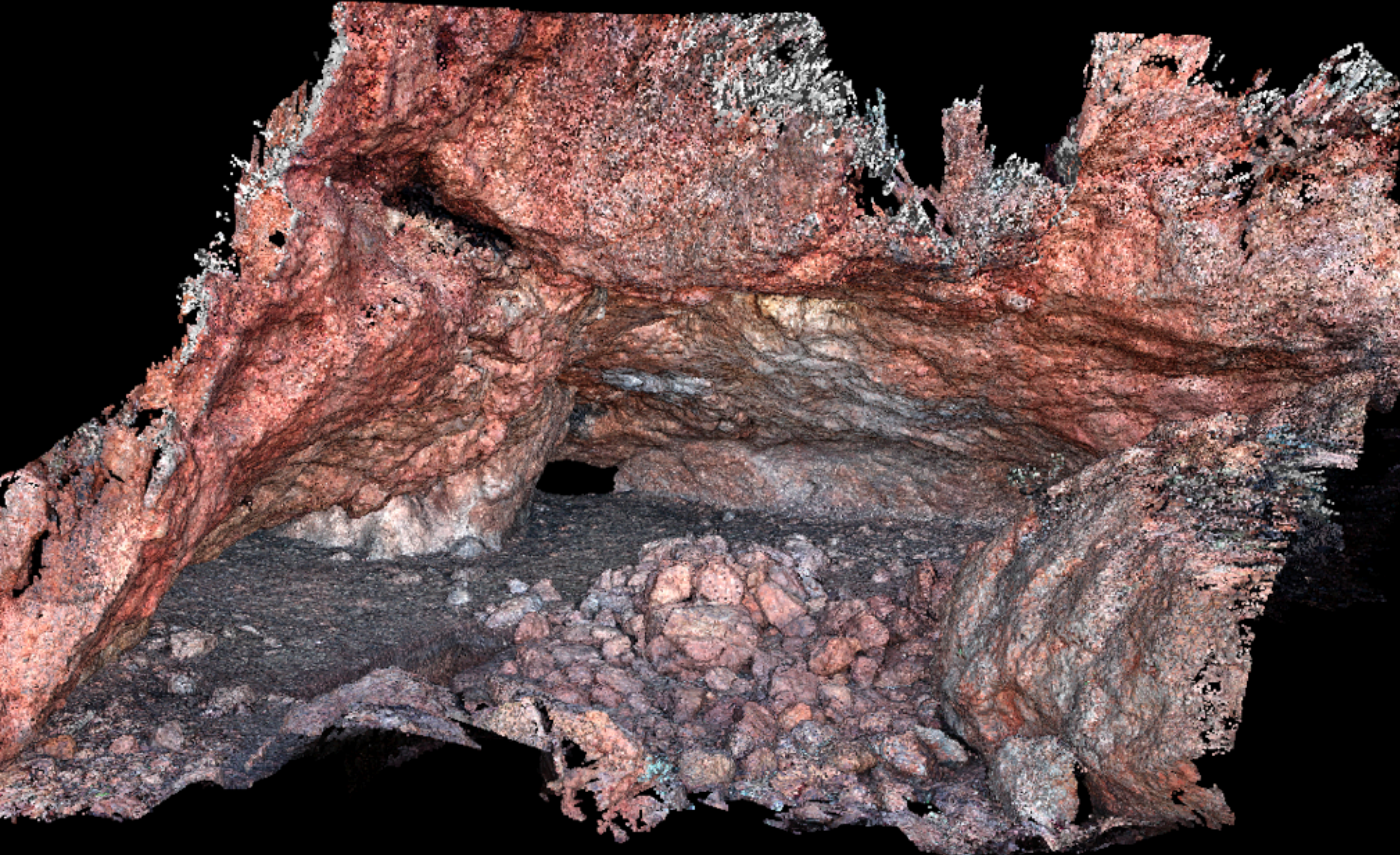
Department of Mines and Petroleum

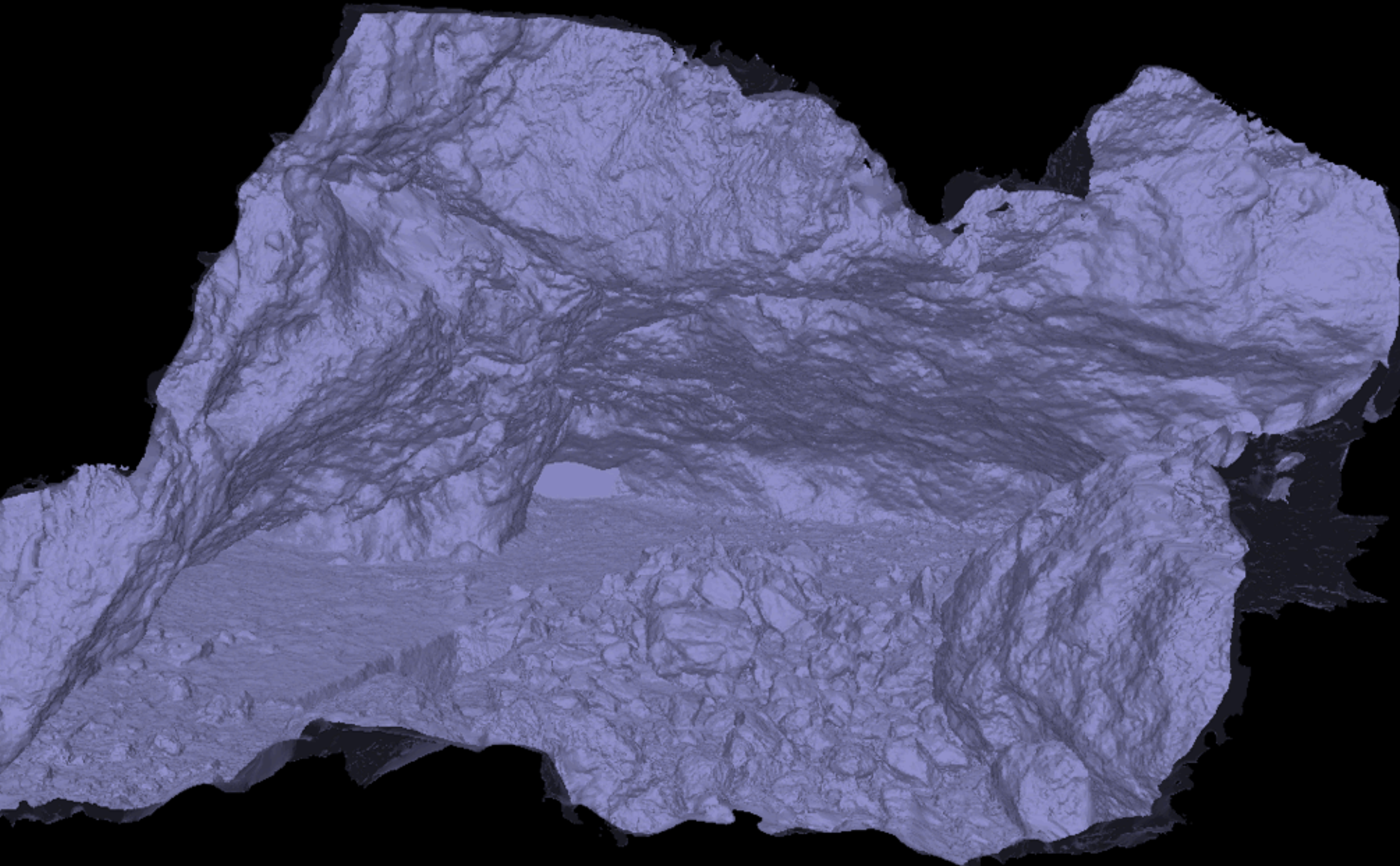

Movie

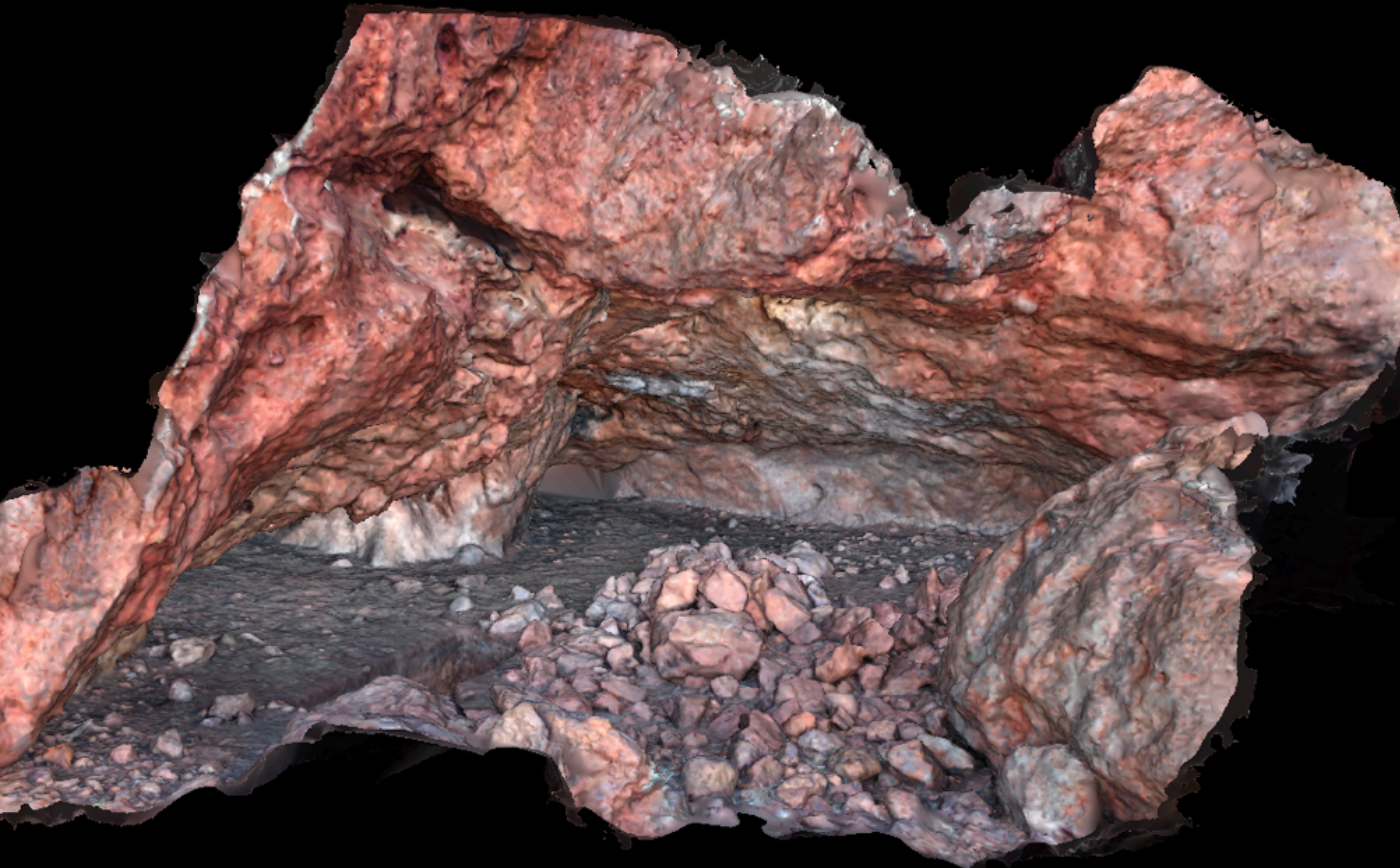

Movie

350 x 22MPixel photographs









Questions?