From Atoms to Galaxies: The Art of Scientific Imaging.

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Scientific Studies require data recording.

- Very difficult to do science with drawings as they are all very personal.
- Visual observations and drawings were all that was possible from Galileo until 1838 when Daguerre made a photo of the moon.
- However, photographic plates were (and still are) much less sensitive than the eye.
- But you had to use them........................
Photographic Plates

- Not very sensitive, but could cover very large areas.
- Glass plates greatly preferred as stable dimensionally. Film seldom used.
- Colour film almost never used (much less sensitive).

- At best 1-2% efficient (human eye can be up to 20% when fully dark adapted).
- Plates can integrate for hours (it is claimed), while human eye integrates from 5 msecs to 15 secs max.
- Plates can be very uniform: critical for sky limited images.
Efficient Electronic Detectors

- Eventually integrated circuit technology came to the rescue with the Charge-Coupled Detector (CCD).
- Relatively cheap to make, very efficient (up to 98%), all electronic, robust, matched well to telescope optics.
- Can be used for space missions.
- UK a key leader in the development of scientific CCDs.
Efficient Electronic Detectors

- Can be made into large mosaics to cover very wide fields.
- This is a large-scale survey instrument.
- This one has 1.4 billion pixels for $5 million.
- Widely used in phones, cameras, videos, etc.
Atmospheric Turbulence

- Causes images to be smeared out giving no more detail than a small (few inches diameter) telescope.

- May be corrected for bright stars.
Atmospheric Turbulence

• Can avoid by putting a telescope into space.
• The Hubble Space Telescope (HST) has been remarkably successful.
• Typically gives 5-8 times the ground-based detail.
• Also lets us work in wavelengths (colours) that do not penetrate the atmosphere.
More Detailed Images than Hubble can Give.

• More detail means a bigger telescope.
• Must be ground-based, but must deal with turbulence in the atmosphere.

• New technique developed in Cambridge called Lucky Imaging.
• Uses a high-speed photon-counting CCD camera, cooled to -120°C.
Lucky Imaging: The Einstein Cross

- HST/ACS (Left image), Lucky Image on NOT (Right image).

21 July 2010: The Art of Scientific Imaging
Large Telescope Lucky Imaging.

- Globular cluster M13 on the Palomar 5m.
- Seeing ~0.65 arcsec.
- Used PALMAO + our EMCCD Lucky Camera.
- With 30% selection, ~17% Strehl (I-band) ~40 mas resolution.
- Highest resolution image ever taken in the visible.
• The Lucky/AO images resolve <40 mas, ~ 3 times Hubble.
Aesthetics, Economy with the Truth, Fraud?

• None of the images I have shown is a true, honest representation of what was detected at the telescope.
• All have been calibrated, corrected and processed to look better.
• Real science not done on colour mock-ups but on single-band images.

• Dark background on HDF really very bright, but wouldn’t look so good.
Aesthetics, Economy with the Truth, Fraud?

- Colours are usually faked up to look good, and make you go “Wow!!!” and you do.

- All fair in love, war, image processing and certainly in art!
Aesthetics, Economy with the Truth, Fraud?

- Not only will we happily mess with the colours, we can also exaggerate or smooth over edges.
- Can also try to compensate for lack of resolution or atmospheric turbulence effects, so images come out looking much sharper than they are in reality.

- Can lead to highly misleading scientific interpretation.

- Many papers have divined great things from the over-interpretation of noise!
Imaging central to so many areas of Science:

- Scientific imaging techniques have helped us understand a great deal on the smallest imaginable scales.
- These images are of muscle cells stained with different colours of fluorescent dye to make them more visible.
- Otherwise very difficult to image: virtually transparent
Imaging central to so many areas of Science:

- We understand so much more about brain and other organ functions and disease from magnetic resonance imaging and X-ray imaging.
- These images do not exist in any real sense: they are entirely generated within the computer by tomographic scans.
"OK, Mrs. Dunn. We'll slide you in there, scan your brain, and see if we can find out why you've been having these spells of claustrophobia."
Neuronal Imaging

- On even smaller scales, we can look at shape and interconnection of individual nerve cells in the brain.
- A combination of fluorescently labelled optical imaging plus electron microscopy lets us get to see incredibly small imaging scales.
Neuronal imaging

- The best resolution is about 10,000 times better than theoretically possible in the visible so we can just see individual atoms.
Subatomic Imaging:

• Atomic nuclei are another factor of 100,000 smaller and impossible to image directly.
• We use particle accelerators such as the Large Hadron Collider to find out what is inside these nuclei.
Subatomic Imaging:

• Getting two atomic nuclei to collide is extremely difficult. To get them to interact requires incredible energies.
• This produces a shower of secondary particles that we detect to work out what was in the interacting nuclei.
• The most energetic particles ever detected have the energy of a golf ball struck by Tiger Woods.
• These had been detected after travelling across vast distances from active galactic nuclei.
14 December 2007: U3A, King's Lynn