The Origin of The Universe

Prof. Peter Quinn

The popularity of the topic of astronomy in this, the International Year of Astronomy 2009 (IYA2009), was upheld at the meeting of the Royal Society of Western Australia on 16th March when 94 people came the Kings Park Administration Building Theatre to hear Professor Peter Quinn's presentation on " The Origin of the Universe". After an Introduction by Dr Phil O'Brien, Professor Lister Staveley-Smith, Vice-President of the Western Australian Astronomical Society, opened The International Year of Astronomy on behalf of the Royal Society of Western Australia. He outlined the significance of IYA2009, what is happening in Astronomy in Western Australia and Australia during IYA2009, discussed the involvement of Western Australia in the Square Kilometer Array, and then introduced Professor Peter Quinn. Lister gave a synopsis of the many achievements of Peter Quinn including such highlights as co-discovering the Quinn-Goodman effect for angular momentum dependent galactic accretion and being awarded a NASA High Performance Computing and Communications Grand Challenge Award in 1992 for his work in computational astrophysics.

Professor Quinn commenced his presentation with a comment that as a society we are fortunate to be living in this current time when a glimpse of the beginnings of the Universe is possible (eventually, we will be unable to see the light from that distant event since the expansion of the Universe is moving our galaxy away from the point of origin). Peter then took the audience rapidly through the 400 year journey from Galileo's telescope to the Hubble Space Telescope. He then proceeded to eloquently and picturesquely documented human efforts to view the sky using various methods from the naked eye, to the development of optical telescopes, to current astronomical observatories employing the whole range of the electromagnetic spectrum including radio waves, infra-red microwaves, visible light, ultra-violet and gamma ray radiation, and finally to future plans for the latest and largest telescope ever constructed: the Square Kilometer Array.

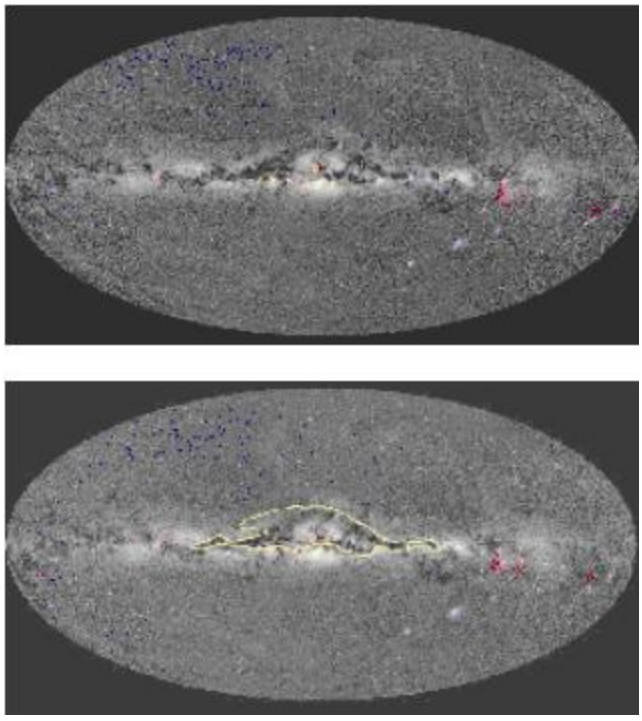
For human societies, the journey in Astronomy begins with the human eye which has a 5 mm diameter pupil allowing light in, however, if that diameter is increased 5 times by the use of a 25 mm diameter telescope, then 25 times more light can enter the eye. That is, telescopes make for bigger eyes, which Galileo discovered when he used a telescope to find new stars, see the mountains of the Moon and the moons of Jupiter. Since the mid 1500s to the year 2000, the "eyes on the sky" have increased from about 2 to almost 10,000,000

Today's telescopes are usually located in remote desert areas, e.g., the Atacama Desert, Chile, which has 365 clear nights a year and hence is the location of the La Silla Paranal Observatory where the largest optical telescope in the world, the Very Large Telescope (VLT) is located. The VLT has provided the first image of extrasolar planets (ESO 42/08), as well as tracking individual stars moving around the supermassive black hole at the centre of the Milky Way (ESO 46/08), and observing the afterglow of the furthest known Gamma-Ray Burst.

VLT Facility, Northern Chile

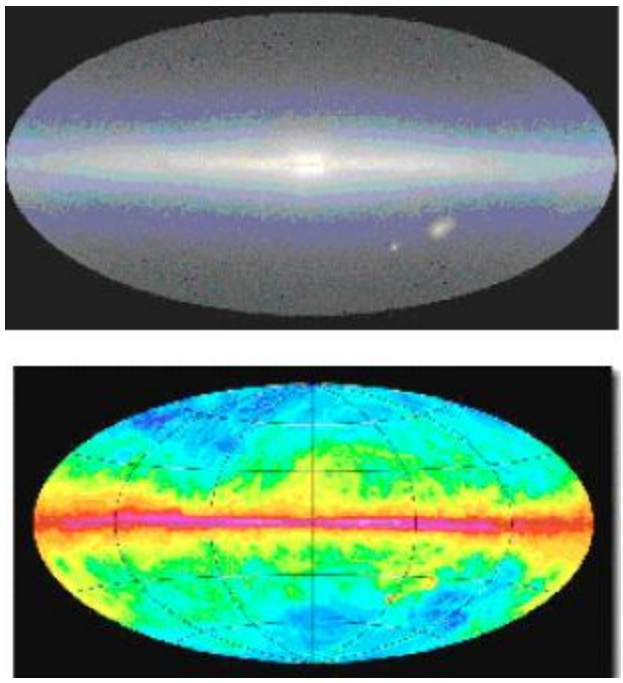
Also in the desert, the Atacama Large Millimeter/submillimeter Array (ALMA) at Altiplano de Chajnantor, a plateau at an altitude of 5000 metres, is being constructed to enable transformational research into the physics of the cold Universe, regions that are optically dark but shine brightly in the millimeter portion of the electromagnetic spectrum. Providing astronomers with a new window on celestial origins, ALMA will probe the first stars and galaxies, and directly image the formation of planets.

To explain the reason for the existence of the varying types of telescopes (radio, microwave, infra-red, optical, gamma-ray, etc.), Peter illustrated the different views available of a photograph of the Bavarian landscape in visible and infra-red radiation. The different types of telescopes provide different information on the observable Universe as shown by consecutive images of our own galaxy, the Milky Way where the “Big Emu” formation appears as a dark cloud in visible light but is not visible in an infra-red image that shows the centre of the galaxy, or in a microwave image which reveals different structures.



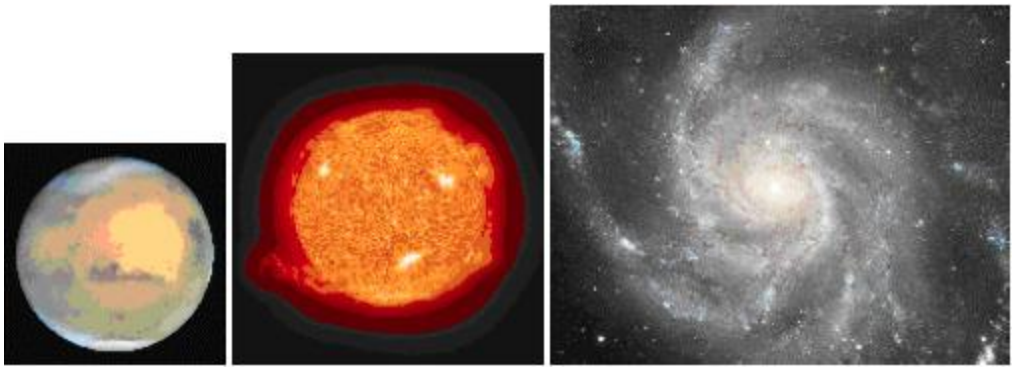
The Milky Way Galaxy, optical images (top), with the Big Emu (bottom)

Having explained the modus operandi for viewing the Universe, Peter then described what there was to see out there and all the other questions that astronomers ask about celestial objects such as: How Big? How Far? How Many? and How Old?



The Milky Way Galaxy, infra-red (top) and microwave radiation (bottom)

An example of the scale of objects that astronomers deal with was provided by a comparison of the radii of a planet, a star and a galaxy in kilometers and proportionally relative to the star. Similar comparisons were done with distance, mass and numbers of planets, stars and galaxies:



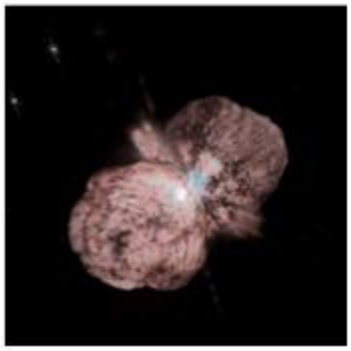
Planet Star Galaxy

At this stage, with the audience suitably awed by the enormity of the size and distances involved in the Universe, Peter went on to ask: Are We Alone? He explained the processes involved in the birth of new planets and described several indirect methods which astronomers have employed to detect planets, such as the eclipsing of light from the star presumably caused by the transit of a planet, and the radial velocity method where “wobbles” or permutations in a star’s orbit are presumably caused by a large mass such as that of a planet. This latter method is the reason that most planets discovered to date have Jupiter-like masses.

Next, Peter briefly discussed the Life and Death of Stars with the aid of spectacular pictures of nebulae and supernovae taken by the Hubble Telescope. There are many star-forming regions in dense molecular clouds such as the Orion Nebula or the Crab Nebula, which ironically are the remnants of the spectacular death of a massive star in a supernova explosion. The end for a star is heralded by the star losing mass, sometimes, if the star is massive enough, spectacularly in a super nova explosion. An example of a star in the throes of senescence is Eta Carinae ejecting vast clouds of material in polar jets.

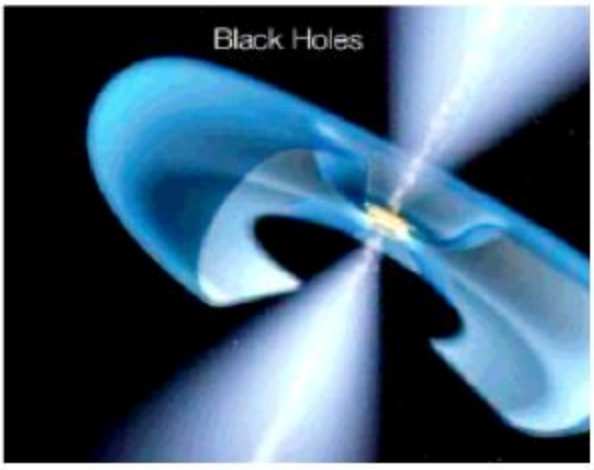
Orion Nebula

Crab Nebula

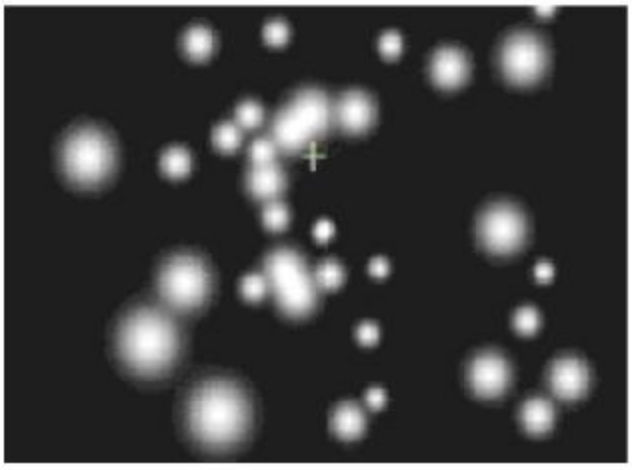


Eta Carinae

No discussion of astronomy would be complete without mention of Black Holes and Peter did not disappoint here, describing how the VLT in Chile (and smaller telescopes as well) have been employed to detect evidence of black holes. Animations of telescopic images showed the flashing of the bright radio source Sagittarius A, thought to be the rotating accretion disc of the massive black hole in the galactic centre and time-lapse photography of a star orbiting around an invisible black hole.



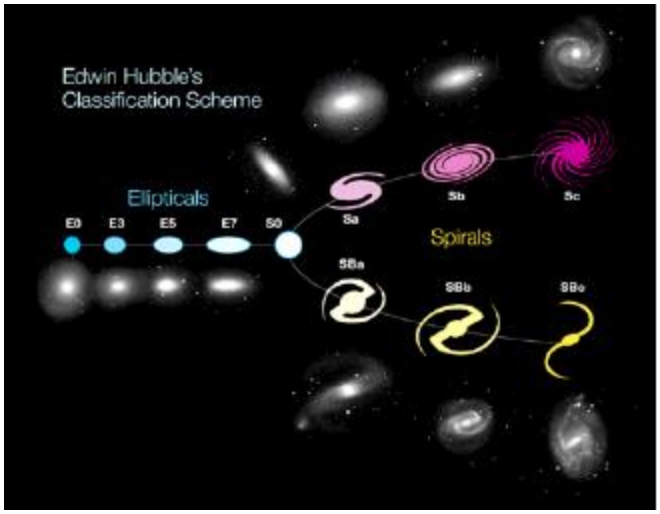
Artist's impression of a black hole.



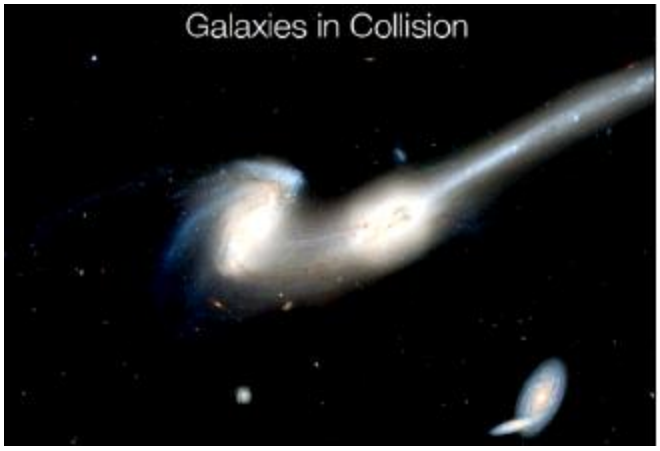
Stars orbiting invisible black hole (cross).

Leaving the confines of our own galaxy, Peter then drew the audience on a journey into the cosmos via Edwin Hubble who, 80 years ago, made two major discoveries using the largest telescope available: (1) the Andromeda Galaxy was not part of the Milky Way and in fact, there were different

types of Island Galaxies for which he devised a classification system, and (2) all of these galaxies were increasingly red-shifted the further away they were and so were moving away from the Milky Way in an expanding Universe (and therefore there had to be a point of origin which was the Big Bang). More recent observations from the telescope named in Hubble's honour have shown that the expansion of the Universe is not an even process as galaxies in close proximity display gravitationally caused distortion and some galaxies have collided.

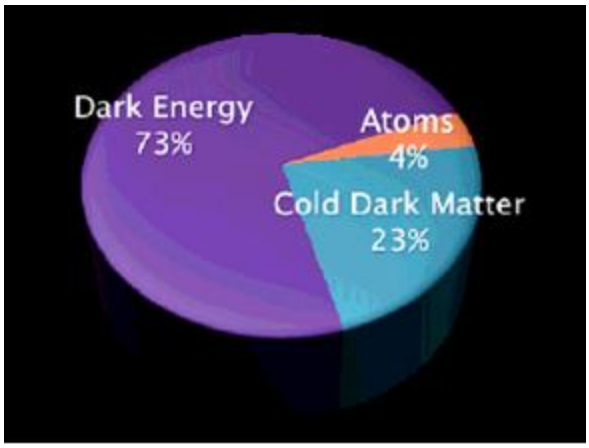


Hubble's Classification of galaxies



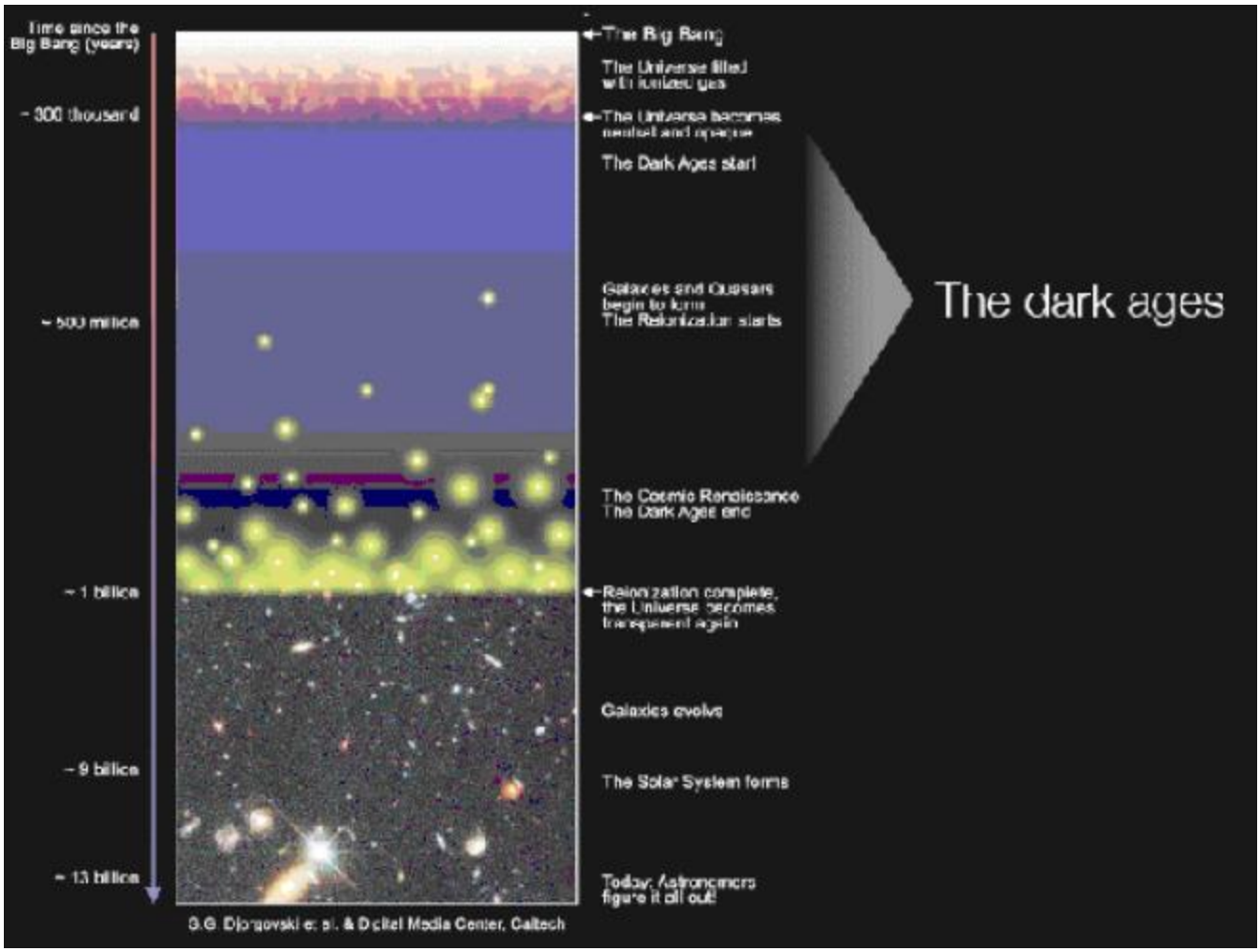
Galaxies in collision

Now definitively within a universal perspective of the cosmos, Peter proceeded to talk about the large-scale structure of the Universe where astronomical observations of the filamentary structure of the visible Universe have been replicated with computer simulations of the evolution of the cosmos according to the laws of physics. However, Peter sounded a warning note here, saying that we only see 4% of the Universe and illustrated the problem by showing a small green, fairly homogenous square (4 %) which when expanded to 100%, was revealed to be part of the complex and variably-hued portrait of the Mona Lisa. Relating that concept to the Universe, we only see the 4% that consists of atoms, while 23% is cold, dark matter, predicted by Einstein and confirmed by telescopic images of its gravitational lensing effect on light from distant galaxies, and 73% is dark energy, a repulsive force proposed to explain astronomical observations that the expansion of the Universe is accelerating.



Proportions of matter, cold dark matter, and dark energy in the Universe

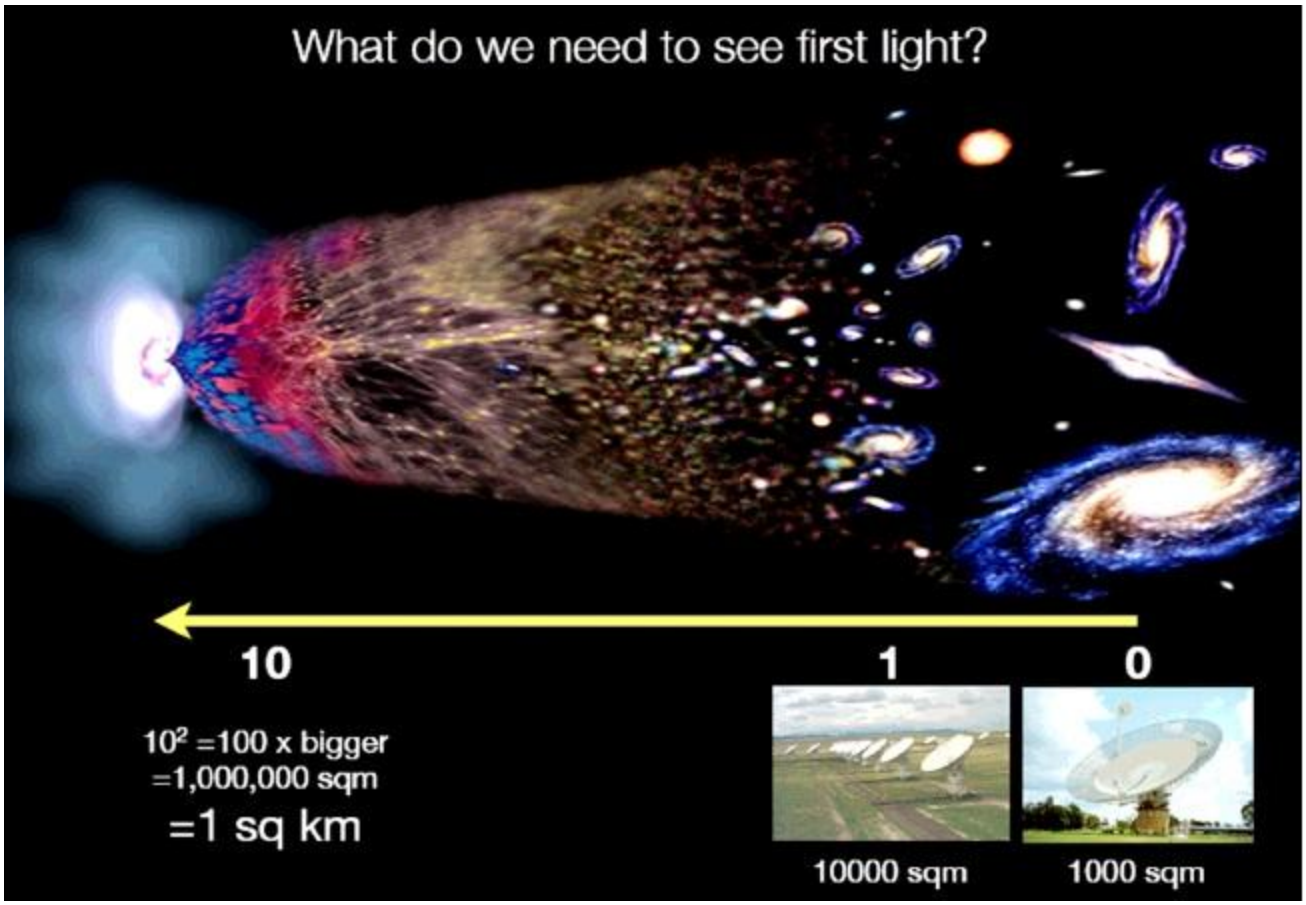
While astronomers have observed the current structure of the cosmos, they are also very interested in observing the origins of the Universe which Peter explained, could be achieved by employing telescopes as time machines, since light takes time to travel and the further away from Earth the object is, the older the image of the object is.



Evoloution of the Universe from the time of the Big Bang

In the current model of the historical development of the Universe, the Big Bang was followed by a period of time known as the "Dark Ages" where matter was homogenously distributed and there was only a background "hum". When matter began clumping under gravitational influence, 1 billion years after the "Big Bang", the Universe became transparent and the Epoch of "First Light" began, followed by the evolution of galaxies up to the present time, 13 billion years after the "Big Bang".

In the journey to see "First Light" astronomers have to consider the Doppler Effect and Red Shift where radio emissions from hydrogen gas with initial wavelength of 21 cm is increased to 210 cm in the oldest observed galaxies at the very edge of the known Universe and the frequency is likewise lowered from 142 MHz to 1420 MHz. What, then, do astronomers need to see the oldest galaxies, formed 10 billion years ago? Existing radio telescopes of 1000 square metre diameter can produce images of closer, younger galaxies, and existing 10,000 sqm radio telescopes detect images of the older galaxies at the edge of the known Universe, therefore a 1,000,000 sqm (1 square kilometre) radio telescope could detect the earliest star formation. The Square Kilometre Array (SKA) will be the largest radio telescope constructed to date and is a global project of 50 institutions in 19 countries. It will consist of 4,000 radio telescope dishes spread over an area of 3, 000 km and must be located in a flat, dry, geologically, economically and politically stable area free of radio interference but with access to technology and the scientific community.



Why do we need to see first light?

Need for a site free of radio interference

Two countries are being considered as sites for the SKA: Australia (the Murchison Observatory, 350 km northeast of Geraldton Western Australia) and South Africa. Australia is demonstrating its capability of hosting the SKA by commencing a SKA Pathfinder project in 2009, involving an array of 36 antennae each 12 m in diameter, to be completed in 2020.

The SKA Pathfinder Project

An International Centre for Radio Astronomy (ICRAR) has been established in Perth to demonstrate an ability to handle the enormous amount of data to be generated by the SKA. Globally one exobyte of data is produced annually - the SKA will produce one exobyte of data daily. Peter ended his presentation on a very positive note for the future of astronomy in Australia with the words: Australia- home to the first astronomers and the beginning of a new journey.

More information on the SKA Project can be found in the following link:

http://www.skatelescope.org/