Executive Summary of the Aspen Science Report

The Aspen Workshop is a science report articulating key questions in astronomy that can be addressed through new instrumentation at Gemini in the next 5-10 years. These key questions included:

- How do galaxies form?
- What is the nature of dark matter on galactic scales?
- What is the relationship between super-massive black holes and galaxies?
- What is dark energy?
- How did the cosmic "dark age" end?
- How common are extra-solar planets, including Earth-like planets?
- How do star and planetary systems form?
- How do stars process elements into the chemical building blocks of life?

In the Aspen Workshop report *Scientific Horizons at the Gemini Observatory: Exploring A Universe of Matter, Energy, and Life*, three different "Universes" are discussed as a means of naturally partitioning the questions listed above. This report is still in a draft form but will be broadly distributed in the near future. First, the "Universe of Matter" is discussed. Far more than just an ensemble of hydrogen, helium, and trace elements on the Periodic Table scattered through space, the nature of matter begs a deeper explanation. For instance, what led to the formation and evolution of the galaxies, which are some of the largest material structures in the Universe? We know that galaxies are surrounded by an unseen component, often referred to as dark matter, which dominates their dynamics and evolution, but what is the nature of dark matter? Through observations of the motions of stars within galaxies, we expect to gain a much better understanding of the interaction between matter and dark matter. Furthermore, some of the most bizarre structures known - black holes - are understood to have an important role in the evolution of galaxies, and perhaps even in their creation. Nonetheless, we lack a detailed understanding of how this interaction between massive black holes and galaxies works, how it relates to star formation processes, regeneration and enrichment of the elements, and ultimately, how all of this leads to planet formation and the seeds of life. Past observations have left us with a myriad of possible physical connections and correlations between these processes. What we lack is clear understanding of feedback mechanisms and how the "snapshots" that we have of distinct objects actually interact over time.

Next the "Universe of Energy" is discussed in the Aspen science report. Again, like matter, the bulk of the energy in the Universe exists in an unknown form, which was recently demonstrated by observations that the Universe is expanding through an unknown force that is counteracting the mutual gravitational attraction of the Universe's constituent galaxies. What is the nature of dark energy, does it change with time and what is its role in the formation and evolution of galaxies? Given that this energy is only manifest across cosmological distances, progress in this key area will undoubtedly be linked to astronomy, though links to high-energy physics abound. Also, what forms of energy dominated in the early universe, around the so-called period of "first light," when the first self-luminous structures erupted into existence and filled the early voids of the Universe with radiation? Also, what role did this first light process

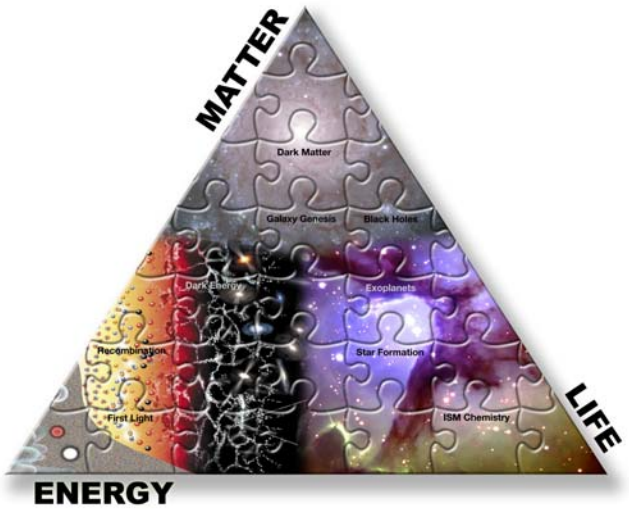

Figure 1 – Symbolically the investigations planned for the next-generation instruments at Gemini resemble a classic jigsaw puzzle, but on a grand scale. Research in modern astronomy will be pivotal in unraveling mysteries like dark matter, first light, and the origins of life. Arguably the most interesting pieces of this puzzle are the ones without labels – the pieces we have yet to discover.

have in triggering the eventual collapse of structures, including the galaxies that surround us now?

Finally, avenues for research on the "Universe of Life" were discussed in Aspen science report. In this area the proposed research is focused on the symbiotic relationship of stars, gas and dust in the Galaxy, various formation processes, and planets and debris disks surrounding young stars. Understanding supernovae mechanisms naturally feeds into a better understanding of "standard candles" upon which discoveries such as dark energy rely heavily. Furthermore, supernovae are the mechanisms by which enriched material is spread throughput space, only to collapse in time into more stars, disks, and planets. This life cycle of material processing, which is traceable back to the first stars in the early Universe, is an extraordinarily important research field since it substantially represents the mechanism through which normal matter evolves. Part of deriving a deeper understanding of this cycle includes understanding the planetary systems surrounding our own sun. We stand to capitalize on the growing census of planets in our solar neighborhood. Through advanced future observations using Gemini as a platform, it should be possible to directly image and begin to characterize extra-solar planets, rather than only detect them through indirect means.

The basic questions these new instruments are intended to answer can be conceptually grouped into three "Universes" that are inextricably tied together, yet with boundaries and interfaces that are at best only understood in a piecemeal fashion, similar to the early steps in solving a jigsaw puzzle. Only through detailed future observations will we collect enough pieces to understand the most important links, bridges and gaps in the puzzle, and ultimately recognize the picture that represents the actual Universe that we live within. Gemini, as one of the premier ground-based astronomical facilities in the world, will be an important tool in solving this puzzle by implementing the proposed science mission developed by our Community through the "Aspen Process" and by building the next generation instrumentation that will lead our collective research well into the next decade.