HETDEX
The Hobby Eberly Telescope Dark Energy Experiment

Gary Hill (Chief Astronomer)
Phillip MacQueen (Chief Scientist)
McDonald Observatory

Karl Gebhardt, Eiichiro Komatsu
Department of Astronomy

University of Texas at Austin

- An introduction to McDonald Observatory and the HET
- HETDEX, the science and the experiment
• Introduction to McDonald Observatory
  – Mission is scientific education, research, and public outreach.
  – Started operation in 1939 with the 82" telescope, then the world's second largest.
  – Added the 107" telescope in 1968, at the time the world's third largest.
  – Added the HET in 1999, currently the world's third largest telescope.
  – McDonald operates with headquarters as part of the UT Austin astronomy program.
  – 70 staff members in west Texas (community impact: employer and service)
The 82-inch Struve telescope

- While now an historic telescope, it still shows scientific vitality in:
  - determining the age of our galaxy through the study of white dwarfs.
  - supporting a NASA space mission searching for exosolar planets.
The 107-inch Smith telescope

- Dedicated in 1968, then the world’s third largest telescope.
- Texas astronomers using it have made significant scientific contributions, including:
  - discovering water on Mars, now being studied by NASA rovers
  - experimentally verifying the theory of how stars generate their energy
  - playing a leading role in determining how successive generations of stars have made the elements
• The Media
• Radio
  – 2.2 million listeners a day for the 2-minute radio program Stardate and Universo played on 650 U.S. radio stations
• Internet
  – over 100,000 people a week access McDonald Observatory's websites for English and Spanish astronomical information
• Visitors program
  – 100,000 visitors each year to the McDonald Obs. Visitors Center
  – Visitors take guided tours of the research telescopes, hear talks, and view the sun and night sky through telescopes
Education

• K-12 education
  – McDonald conducts professional development workshops for about 700 K-12 teachers per year
  – The workshops provide required State Board of Education Certification (SBEC) continuing education credits for teachers
  – 1000 K-12 students visit McDonald each year for field experience
  – 1,700 students participated in field experience via videoconference
  – Educational activities are aligned with TEKS and TAKS.

• Undergraduate and graduate education
  – Astronomy uses many scientific and technical disciplines, and provides excellent research training
  – Our graduates go on to careers in research, education, and industry
The Hobby Eberly Telescope

- The HET, a 5-university partnership of 3 American and 2 German universities
- U.T. built and operates the HET, and has about a 60% share
The Hobby Eberly Telescope

- An innovative, high-technology telescope in order to be cost effective.
- Built for 20% of the cost of comparable telescopes.
- The HET is performing very competitively in key areas for which it was designed.
- Has now been copied and enhanced in South Africa as SALT, the Southern African Large Telescope (inaugurated on November 10th).
• Science highlights include:
  – exoplanets: discovering small planets, and determining planet properties
  – rapid response to Targets of Opportunity: exploding stars called Supernovae

• Astronomy is competitive - competition continues to invest heavily

• Texas has a significant strength because:
  – We have a relatively small astronomy community, and
  – we have a large fraction of the observing time on one of the World’s largest telescopes (HET)

• This is a competitive advantage for making the next big advances
  – these require huge amounts of observing time
The Quest for Dark Energy

- The Universe is made up of:
  - 4% Matter like us
  - 23% Dark Matter
  - 73% Dark Energy

- They are called “Dark” because:
  - We can’t see them directly
  - We have no firm idea what they are

- This is a very exciting time for Science
- In the next decade:
  - We can understand the constituents of the Universe
  - Texas can make the major contribution to understanding dark energy
So we have ended up with 125 questions, a fitting number for Science’s 125th anniversary. A note on what this special issue is not: It is not a survey of the big societal challenges that an help solve, nor is it a forecast of what science might achieve. Think of it instead as a survey of scientific ignorance, a broad swath of questions that scientists themselves are asking. As Tom puts it in his introductory essay, they are “opportunities to be exploited.”

I selected 25 of the 125 questions to highlight based on several criteria: how fundamental they are, broad-ranging, and whether their solutions will impact other scientific disciplines. Some have immediate practical implications—the composition of the universe, for example. Others cause the answers will have enormous societal impact—whether an effective HIV vaccine is or how much the carbon dioxide we are putting into the atmosphere will warm our world. Some, such as the nature of energy, have come to prominence only recently, but others, such as the mechanism behind the spread of cancer, have been known for more than a century. We 25 highlighted questions in no special order, but we did group the 100 additional questions roughly by discipline. Other online publications are also devoted to these questions.
• Dark matter will probably be understood in the next decade by European physicists using the CERN collider in Switzerland
  – It could have been revealed by the Superconducting Supercollider in Waxahachie, Texas

• Dark Energy can only be studied using Universe as the laboratory
  – The only way to study dark energy is by measuring in detail its effect on how the universe has expanded with time
  – Understanding dark energy is something that Texas astronomers can do within 6 years
  – Requires a very large telescope, an innovative new instrument, and lots of telescope time
  – The measurement can be made before the competition even comes on the air
The Universe is Expanding

• In 1929 Edwin Hubble established that the Universe is expanding
  – It originated in the Big Bang

• Matter slows down expansion
• But the expansion of the universe is actually accelerating
  – Acceleration was detected using Supernovae
• The further away we look, the further back in time we see
  – astronomers can look back in time
• We can map out how the Universe expanded in detail
  – This will tell us what dark energy is
WMAP picture of the infant universe
HETDEX March 25, 2006

- Hobby Eberly Telescope Dark Energy Experiment
- Cartography through space and time
- Encoded in the distribution of galaxies is a standard length
- Measure this length through time
- HETDEX
  - will make the largest map of the Universe ever
  - will trace the expansion of the Universe with unprecedented precision
  - will unveil the nature of Dark Energy
  - will be Texas led, using Texas’ largest telescope
HETDEX will survey two huge areas on the sky to create the largest map yet of the distribution of galaxies.

The total area is equivalent to 1000 times the area of the moon.

HETDEX will measure the expansion history of the Universe with 1% precision, allowing us to measure the properties of Dark Energy for the first time.
• Dark Energy is a real prize, so we are not alone in this endeavor

<table>
<thead>
<tr>
<th>Project</th>
<th>Institutions</th>
<th>Start Date</th>
<th>DE evolution</th>
<th>Projected Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>HETDEX</td>
<td>UT Austin</td>
<td>2009</td>
<td>Yes</td>
<td>$33 million</td>
</tr>
<tr>
<td>SNAP</td>
<td>NASA/DoE</td>
<td>2018</td>
<td>Limited</td>
<td>$1 billion</td>
</tr>
<tr>
<td>JDEM</td>
<td>NASA/DoE</td>
<td>2020</td>
<td>Limited</td>
<td>$2 billion</td>
</tr>
<tr>
<td>WFMOS</td>
<td>Gemini/Subaru</td>
<td>2013</td>
<td>Yes</td>
<td>$70 million</td>
</tr>
<tr>
<td>SKA</td>
<td>EU/US</td>
<td>2015</td>
<td>Limited</td>
<td>$1 billion</td>
</tr>
<tr>
<td>DES</td>
<td>Fermilab</td>
<td>2010</td>
<td>No</td>
<td>$40 million</td>
</tr>
</tbody>
</table>

• HETDEX projection includes costs all the way to final papers

• None of these projects are yet funded

• National funding is on hold until the Dark Energy Task Force reports to NASA / DoE / NSF
  – Then the U.S. funding agencies will decide if they are going to support dark energy projects
  – Funding cannot come earlier than 2008

• We have the lead, and can maintain it if we have funding
• The cartography for HETDEX requires a huge amount of data to be taken

• In order to survey sky fast enough we will upgrade the HET
  – So it can look at more sky at once
  – So it can carry the new instrument

• The upgrade is partially funded by a grant through the Air Force
  – Thanks to US Representative Henry Bonilla

• After upgrading, the HET will see 200 times more sky at a time

• A very powerful instrument is required to capture all the available information

• It is called VIRUS
• The new instrument for HET is innovative but simple
  – Applies manufacturing methods to astronomy for the first time
  – Texas is leading the way in this innovation
• Design is a simple unit instrument to analyze light
  – Replicate the unit 145 times to cover a large area on the sky
  – Units are manufactured in quantity by industrial companies
• This approach saves time, cost, labor
  – Just as it did for Henry Ford
  – Very low risk
• Prototype under construction now
  – Will be used on the 2.7 m to verify the performance of VIRUS

Funded by a grant from the George & Cynthia Mitchell Foundation
VIRUS Mounted on the HET

HET is the world’s third largest telescope. It will be upgraded with a uniquely powerful new instrument called VIRUS.
$33 \text{ M total cost including } $4.2 \text{ M contingency}

- HET Wide Field Upgrade $9.7 \text{ M}
- VIRUS (145 copies + spares) $15.5 \text{ M}
- Data handling $2.7 \text{ M}
- Project and Science management $5.4 \text{ M}
$9.8 M funding in hand or committed
- NESSI $4.1 M
- NESSI expected FY07 $1.0 M
- Munich Observatory $2.3 M
- Astroph. Institute, Potsdam $1.0 M
- McDonald Observatory $0.9 M
- Mitchell Foundation $0.5 M

And we just received fantastic news
- Harold C. Simmons will provide a $5M challenge gift for HETDEX
- We hope to raise $5M in matching funds this year
- Then we will have 2/3 of required funds
- Funds the HET upgrade, builds the first 50 VIRUS units, and allows the project to officially start

This leaves $13 M needed to fully complete the project on the most competitive timescale
Summary

- Understanding Dark Energy is the most exciting scientific question of the next decade
  - result will be in all textbooks
- HETDEX can beat the international competition to this prize
  - Texas project
  - Texas' largest telescope
  - HETDEX can finish before the competition starts
  - No prize for second place
- The total cost of HETDEX is estimated at $33M
  - Cheaper than the competition
  - Technical approach is low risk
  - $15M in hand or committed

We thank Representative Henry Bonilla, Harold C. Simmons, and the Cynthia and George Mitchell Foundation for their generous support
What Is the Universe Made Of?

Every once in a while, cosmologists are dragged, kicking and screaming, into a universe much more unsettling than they had any reason to expect. In the 1500s and 1600s, Copernicus, Kepler, and Newton showed that Earth is just one of many planets orbiting one of many stars, destroying the comfortable Medieval notion of a closed and tiny cosmos. In the 1920s, Edwin Hubble showed that our universe is constantly expanding and evolving, a finding that eventually shattered the idea that the universe is unchanging and eternal. And in the past few decades, cosmologists have discovered that the ordinary matter that makes up stars and galaxies and people is less than 5% of everything there is. Grappling with the form of dark matter, made of an as-yet-discovered type of particle, must be sculpting these vast cosmic structures. They estimate that this exotic dark matter makes up about 25% of the stuff in the universe—five times as much as ordinary matter.

But even this mysterious entity pales by comparison to another mystery: dark energy. In the late 1990s, scientists examining distant supernovae discovered that the universe is expanding faster and faster, instead of slowing down as the laws of physics would imply. Is there some sort of antigravity force blowing the universe up?

All signs point to yes. Independent measurements of a variety of phenomena—cosmic background radiation, element abundances, galaxy clustering, gravitational lensing, gas cloud properties—all converge on a consistent, but bizarre, picture of the cosmos. Ordinary matter and exotic, unknown particles together make up only about 30% of the stuff in the universe; the rest is this mysterious anti-gravity force known as dark energy.

This means that figuring out what the universe is made of will require answers to three increasingly difficult sets of questions. What is ordinary dark matter made of, and where does it reside? Astrophysical observations, such as those that measure the bending of light by massive objects in space, are already yield-