Pioneering into the Extragalactic Frontier with the GMT

workshop summary
(some) key science drivers

- dwarf galaxies and dark matter profiles
- first stars and galaxies
- reionization (reionisation) = reionization
- growth of supermassive black holes
- galaxy assembly
- supernovae

- 18/20 key science goals of Astro-2010 decadal survey achieved by GMT.
- 4/5 discovery areas opened by GMT.
dwarf galaxies and dark matter
- talks by Josh Simon and Louie Strigari

- Missing satellites likely to remain a problem.

- Dwarf galaxies
  - Dwarf sizes 3-30'.
  - Require spectroscopy of >100 stars to confirm dwarfs. Require spec. of >5000 stars to measure shape of DM profiles.
  - GMT requirements: R~5000. R > 23 mag.
  - Chemical abundance studies possible with R>20,000 spectroscopy.

**Unique capability of GMT among GSMTs**.
dwarf galaxies and dark matter

- talks by Josh Simon and Louie Strigari

Velocity profiles of dwarfs agree with lambda-CDM predictions.

“Missing” moderate-mass-object problem? For every 1 Fornax dwarf, we should have ~10 “dark” Fornax satellites?

Where are the dwarfs with \( v = 30-50 \) km/s?

Do we have technology/surveys to identify “dark” satellites in Galactic halo?
first stars and galaxies

- talks by J. Bolton, K. Freese, A. Pawlik and E. Scannipieco, S. Finkelstein
- GMT offers spectroscopy of \( z > 7 \) galaxies in abundance (GMACS, NIRMOS, GMTIFS).
first stars and galaxies

- GMT offers spectroscopy of z > 7 galaxies in abundance (GMACS, NIRMOS, GMTIFS).

What are properties of z>7 galaxies?
How does IGM neutral fraction evolve at z > 6?
When did reionization occur and what sources are responsible?

- Normal or Exotic stellar populations?

- Kinematics/Star Formation in z > 7 galaxies? (GMTIFS)

- impact of galaxies on IGM.
  - Measure IGM absorption (3-10 Mpc) in region of influence of QSOs (3-10 Mpc: requires R>10,000).
  - Measure temperature of IGM. (G-Clef or GMTNIRS.)
first stars and galaxies

- Signatures of Pop III stars?
- He II 1640 emission.
- Measure temperature evolution of the IGM

Scannapieco et al. 2003
first stars and galaxies

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Bolton et al. (2010)
first stars and galaxies

- Nature of first stars and galaxies.

- Theoretical predictions for the properties and kinematics of first stars and galaxies (K. Freese and A. Pawlik).
first stars and galaxies

- Nature of reionization.

“current data at z>6.1 do not provide any constraining power. More spectra needed and higher resolution”.
evolution of supermassive blackholes

- talks by J. Greene and K. Gebhardt

- What is the evolution in M(BH)-sigma and M(BH)-L(R) relations?
  Strongly dependent on ability to select meaningful (mass-selected?) samples of galaxies at high redshifts (1 < z < 3).

- GMT has ability to satisfy the strong need to increase the number of local SMBHs with multiple, independent measurements of the BH mass (currently there are five). - J. Greene

- GMT has ability to measure the most constraints on the massive end of the M(BH)-sigma relation, including identifying (elusive) $10^{10}$ M$_{\text{sun}}$ BHs.
  Sets requirements
evolution of supermassive black holes

GMT can measure $>5 \times 10^9 \, M_{\text{sun}}$ black holes anywhere in the Universe. - K. Gebhardt

Sets requirements that observations achieve resolution where the mass of the SMBH equals the enclosed stellar mass.

Gemini requires several hours for $z=0.25$ work at 50 mas.

GMT requires about 8 hrs at 12 mas. at $z=0.5$.

At $z=1$, S/N is the issue, not resolution.
transient science

- talks by H.-W. Chen and J. C. Wheeler

- 50% of GRBs come from $z > 2$. Redshift distribution extends now to $z > 8$. $z > 8$ GRBs could be as bright as $K=10-15$ mag.

- LSST era $> 100,000$ SN yr$^{-1}$. (what will SN2020aaae be?).

- Transient science sets requirement for rapid target of opportunity observations and (possibly) rapid instrument swaps.

- GMT (GMACS/NIRMOS) $R\sim 2000, S/N\sim 10$ in 1 hr for 24th mag. SN Ia show intrinsically less dispersion in near-IR.

- Nature of evolution of SN Ia: single degenerate, double degenerate, or mix of progenitors?

- Nature of explosions, science driver for spectropolarimeter on GMT.
galaxy assembly

- talks by H.-W. Chen, K.-V. Tran, M. Im, D. Croton, S. Jogee, M. Kriek, E. Scannapieco, K. Glazebrook

Questions in the era of GMT:

What is UV escape fraction of distant galaxies?

What is the distribution of cold gas around galaxies? How is it accreted?

What is the role of environment? (Dependent on definition and environment?)

How do you form Massive, apparently compact galaxies at z~2-3?

What is nature of Massive galaxies at 1 < z < 3? Star-formation. Rotation vs pressure supported.

How do you transform Massive galaxies from z=2-3 to z=0?
UV escape fraction of galaxies

\[ \langle f_{\text{esc}} \rangle = \frac{1}{n} \sum_{i=1}^{n} \exp[-\sigma_{LL} N_i(\text{HI})] \]

- ~20% of GRB hosts show \( N(\text{HI}) < 10^{20} \text{ cm}^{-2} \)

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Chen et al. (2007)
Gnedin et al. (2008)

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IGM only
- \( \log N(\text{HI}) = 21.3 \), \( x_{\text{HI}} = 1 \)
- \( \log N(\text{HI}) = 21.6 \), \( x_{\text{HI}} = 1 \)

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GRB050904 @ \( z = 6.295 \)

Kawai et al. (2006)
distribution of cold gas

- Cold flows of gas touted as primary mechanism for gas accretion for high redshift galaxies.

- Observational evidence for such flows is still scant.

- What are observational signatures that we can test with GMT?

- Do measurements of the (evolution of the) Mass-metallicity relation provide constraints on gas accumulation?
role of environment

Does environment matter?
How do we test physics related to environment?
formation of massive, compact galaxies

z=2.2, r_e=0.8 kpc.  
Gemini/GNIRS=30 hr.  
GMT/NIRMOS in $10^4$ s.  
\( \sigma_V = 510 \text{ km/s.} \)
Most galaxies clumpy.

Ionized gas disp. of 30-120 km/s.

\( \frac{v}{\sigma} = 1-6 \) versus 10-20 in local disks, implies these are turbulent, thick disks.

Requires sub-kpc resolution. Sets observational requirement of \(<\sim 50 \text{ mas} \).
nature of galaxies at $1 < z < 3$

GMTIFSsim of UDF6462

Courtesy Rob Sharp. 9 (+3 sky) hour GMTIFS, 50 mas. ~ 500 pc.
Judging based on S/N, 25 mas resolution doable - Glazebrook criterion.

Wednesday, March 16, 2011
how do you transform galaxies from z=2 to 0

Courtesy S. Jogee
stellar kinematics at $1 < z < 3$

courtesy M. Kriek.
mJH (R~5000)
GMTIFS guide star available
R/K=16.1/14.1 @ 13.7"
50mas (& later 6mas for core)
100% on source
(source nodded in IFS field)
28x1800sec – 14hr on-source
Source Profile from Kriek et al. 2009
BC03 stellar population model
are these the correct extragalactic science drivers?

- dwarf galaxies and dark matter profiles
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extragalactic scientists in the pre-GMT era.

thank you