Astrophysics Program in Tsinghua Center for Astrophysics

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General Introduction on THCA

- Founded in 2001
  - ~10 faculty & staff scientists, ~30 graduate students
- Main research areas
  - Space Astronomy
    - Hard X-ray Modulation Telescope satellite
    - Gamma-ray burst missions: SVOM satellite & POLAR experiment
  - High Energy Astrophysics
    - Compact objects: neutron stars & black holes, GRBs
  - Theoretical Astrophysics
    - MHD
    - Cosmology
    - General Relativity

Research activities in my group related to the research interests of the US delegates

- Microquasars: black hole binaries with relativistic jets
- Magnetars: neutron stars with surface magnetic fields exceeding the quantum limit (~10^{14} G)
- Gamma-ray bursts & Cosmology
- Sun-Black Hole-Gamma-ray burst connection
- SDSS AGNs
- WMAP, SDSS & NVSS correlation analysis & Cosmology

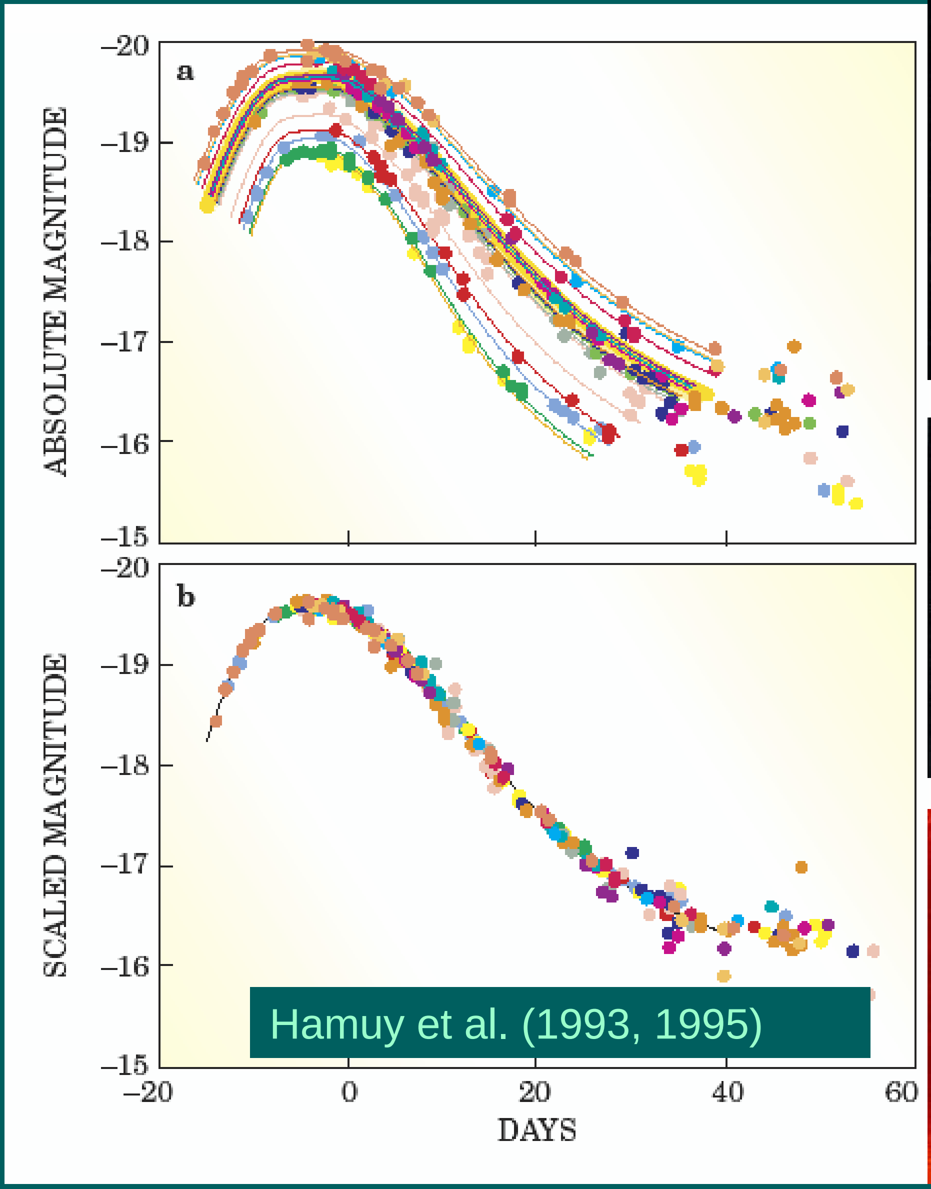
Compact objects

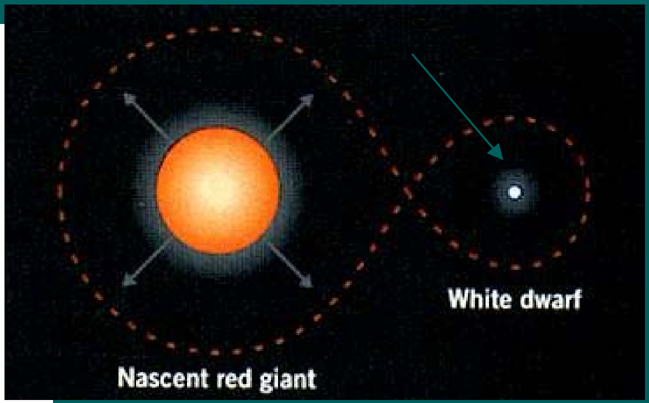
- Microquasars: black hole binaries with relativistic jets
  - Found that most microquasars are located in extremely low density or cavity regions, compared ISM (Hao & Zhang, in preparation; Ling, Zhang, Xiang & Tang, 2008, submitted)
  - Proposed that the two microquasars in the galactic center (with stationary jets) harbor intermediate mass BH (10^4-10^5 solar masses) (Hao & Zhang, in preparation)
- Magnetars: neutron stars with surface magnetic fields exceeding the quantum limit (~10^{14} G)
  - Progenitor model: glitching radio pulsars increase their magnetic fields (Lin & Zhang 2004, ApJL)

Gamma-Ray Bursts

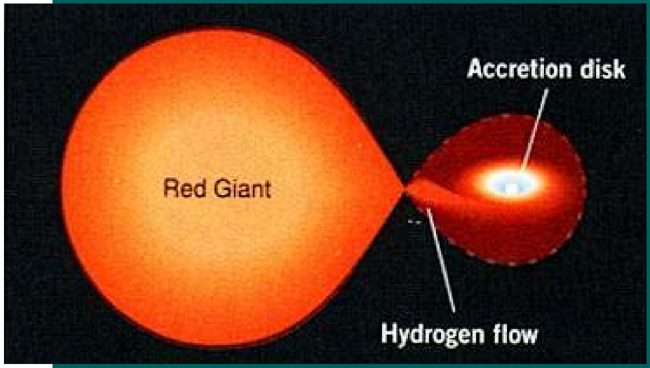
- Gamma-ray bursts
  - GRBs are predominantly produced at the early Universe; GRBs at z>10 already detected (Lin, Zhang & Li 2004, ApJ)
  - a GRB prompt optical emission model: optical delay caused by synchrotron cooling (Tang & Zhang 2006, A&A)
  - a GRB standard candle calibration method, cosmology model independent completely (Liang, Xiao, Liu & Zhang 2008, ApJ accepted)

Type-Ia Supernovae

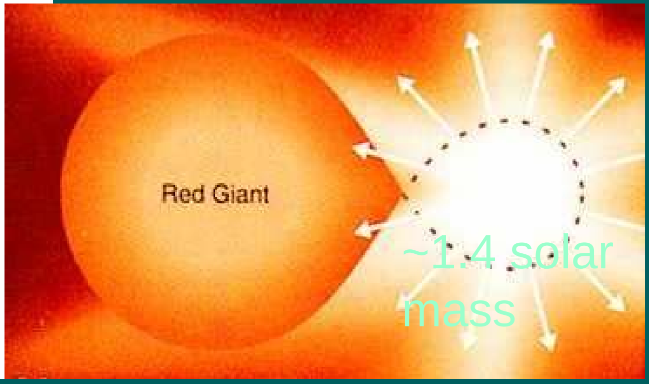




End point of a low-mass star (such as the Sun), after exhausting all its nuclear fuel

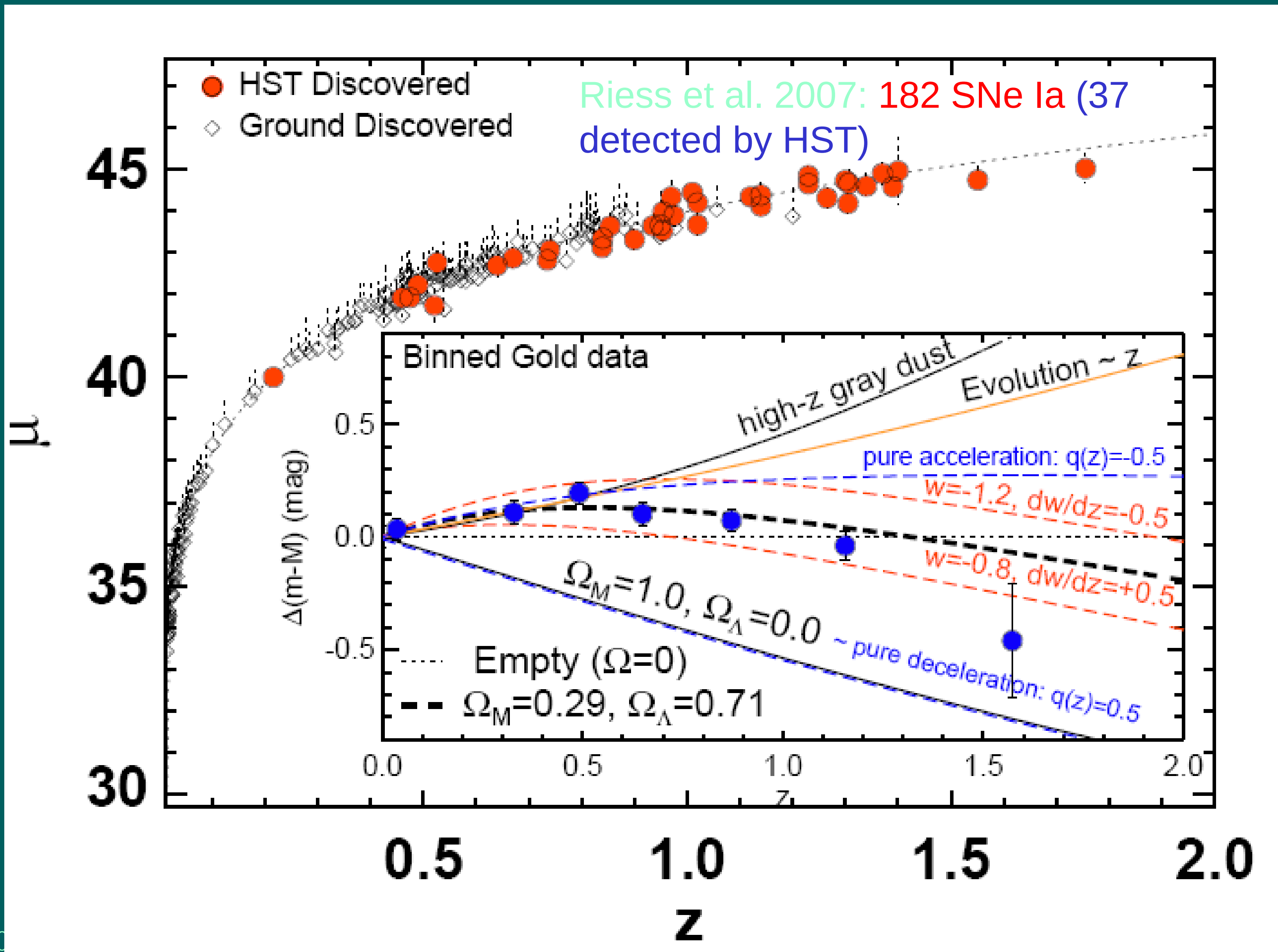


Mass increases by capturing material from its red-giant companion.



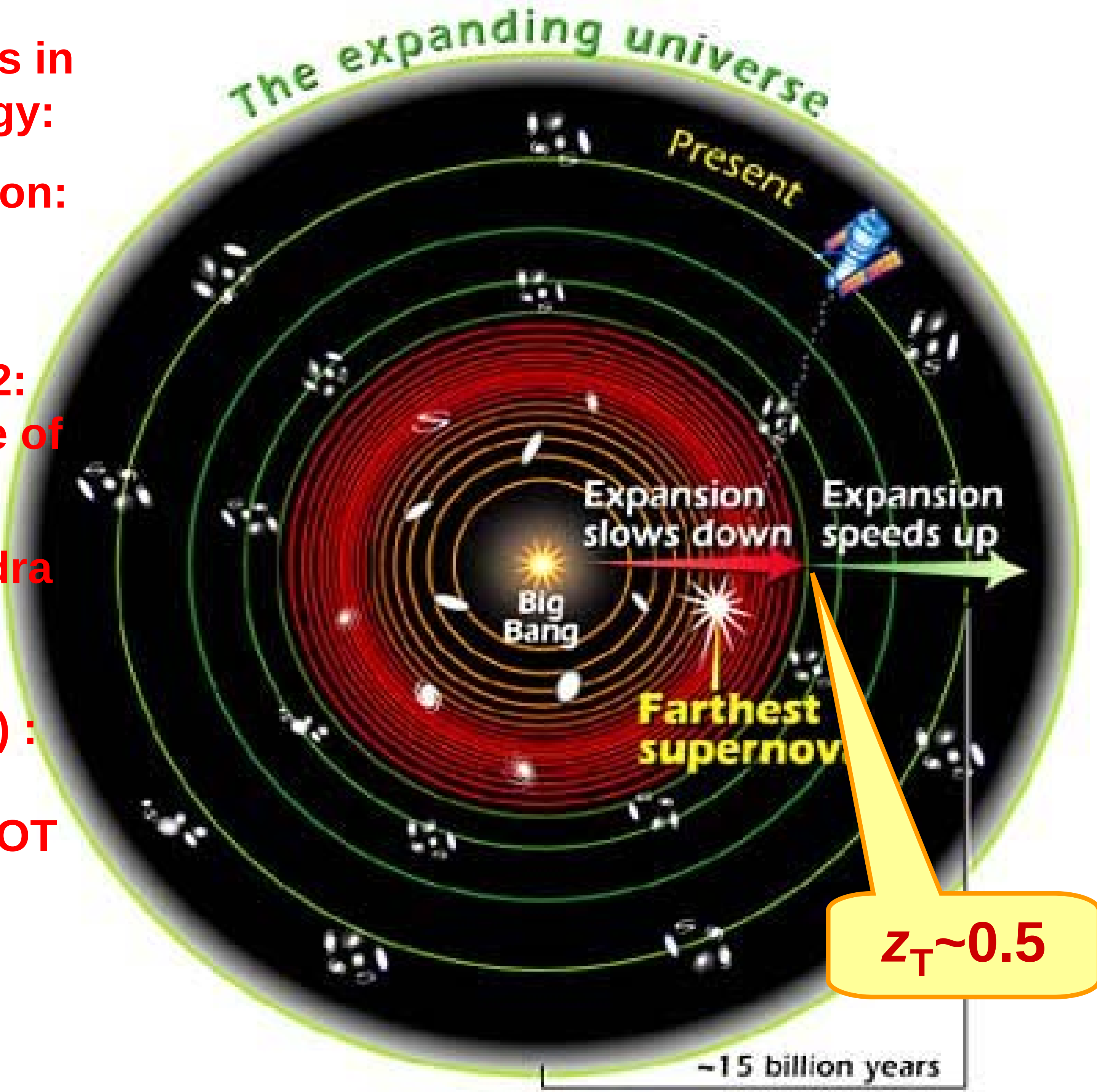
Mass reaches Chadra-limit of a WD: huge explosion with a **fixed** energy release.

Supernovae Ia Cosmology

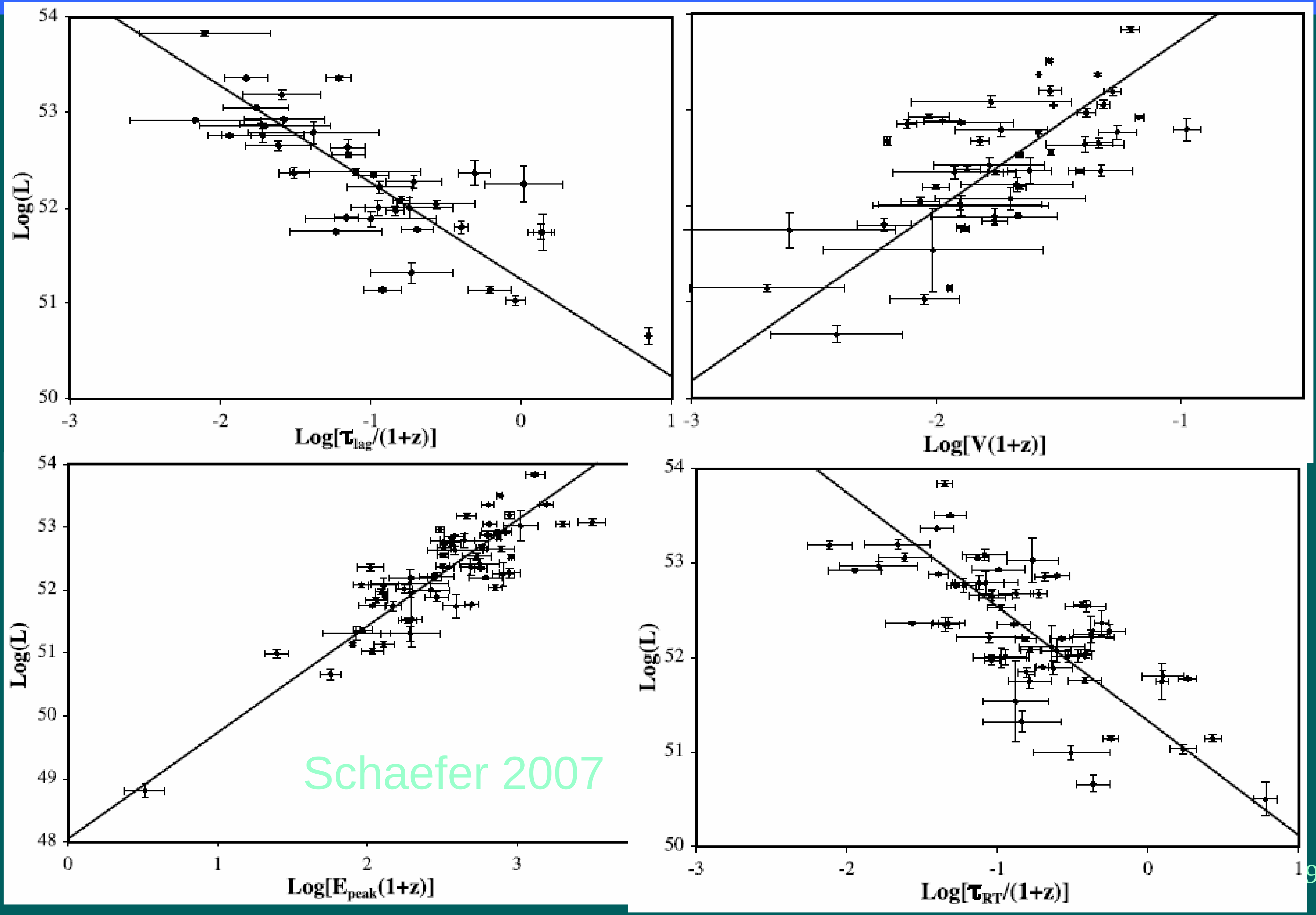


Disadvantages in SN cosmology:

1. Dust extinction: calibration problem
2. Z_{MAX} ~ 1.7 – 2: limited range of the Universe
3. Super-Chandra SN2003fg (Howell et al. 2006, *Nature*) : some SN Ia events are NOT standard candles.



GRBs as “standard” candles



Schaefer 2007

GRB cosmology: probe of early Universe

- Flux and redshift (z) are measured GRB quantities
- From the previous relations, one can infer the absolute "luminosity" of each GRB
- Flux + luminosity → "luminosity" distance d_L, which is a function of cosmological parameters:
- Therefore, if many sets of [d_L, z] are measured, cosmological parameters can be determined.
  - GRRs can be used to study the evolution of the Universe to much larger distances than with supernovae Ia data.

$$d_L = cH_0^{-1}(1+z)\int_0^z dz' \left[(1+z')^3\Omega_M + \Omega_\Lambda\right]^{-1/2}$$

Problems in conventional GRB cosmology (1)

- In order to calibrate the parameters in each "standard" candle (luminosity relation), the luminosity distance of the GRB must be calculated by assuming a particular cosmology model.
  - The "standard" candle in cosmology dependent, thus cosmology parameters determined depends upon the assumptions made on the cosmology parameters.
    - This is the so-called "circularity" problem in GRB cosmology.

Problems in conventional GRB cosmology (2)

- The circularity problem may be eased by fitting the parameters of the luminosity relation simultaneously with the parameters of the cosmology model in question.
  - However this way the two sets of parameters are coupled together.
    - The circularity problem still exists, but less serious than before.
- Supernovae cosmology depends upon the availability of many low-z events, in order to calibrate its standard candle.
- However, due to the lacking of sufficient low-z GRBs, self-calibration of the GRB “standard” candles is not possible.

A Cosmology Independent Calibration of GRB Luminosity Relations and the Hubble Diagram

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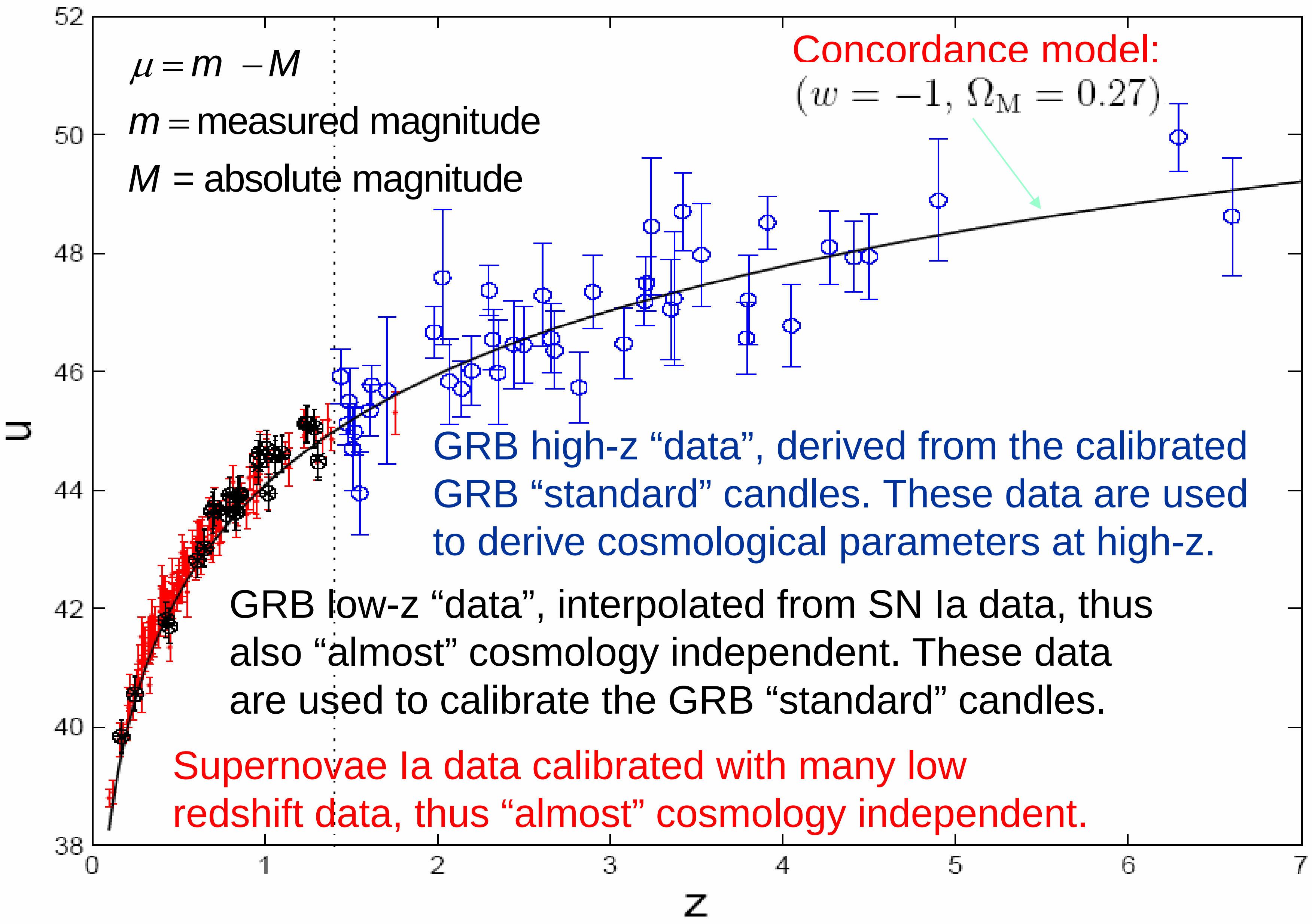
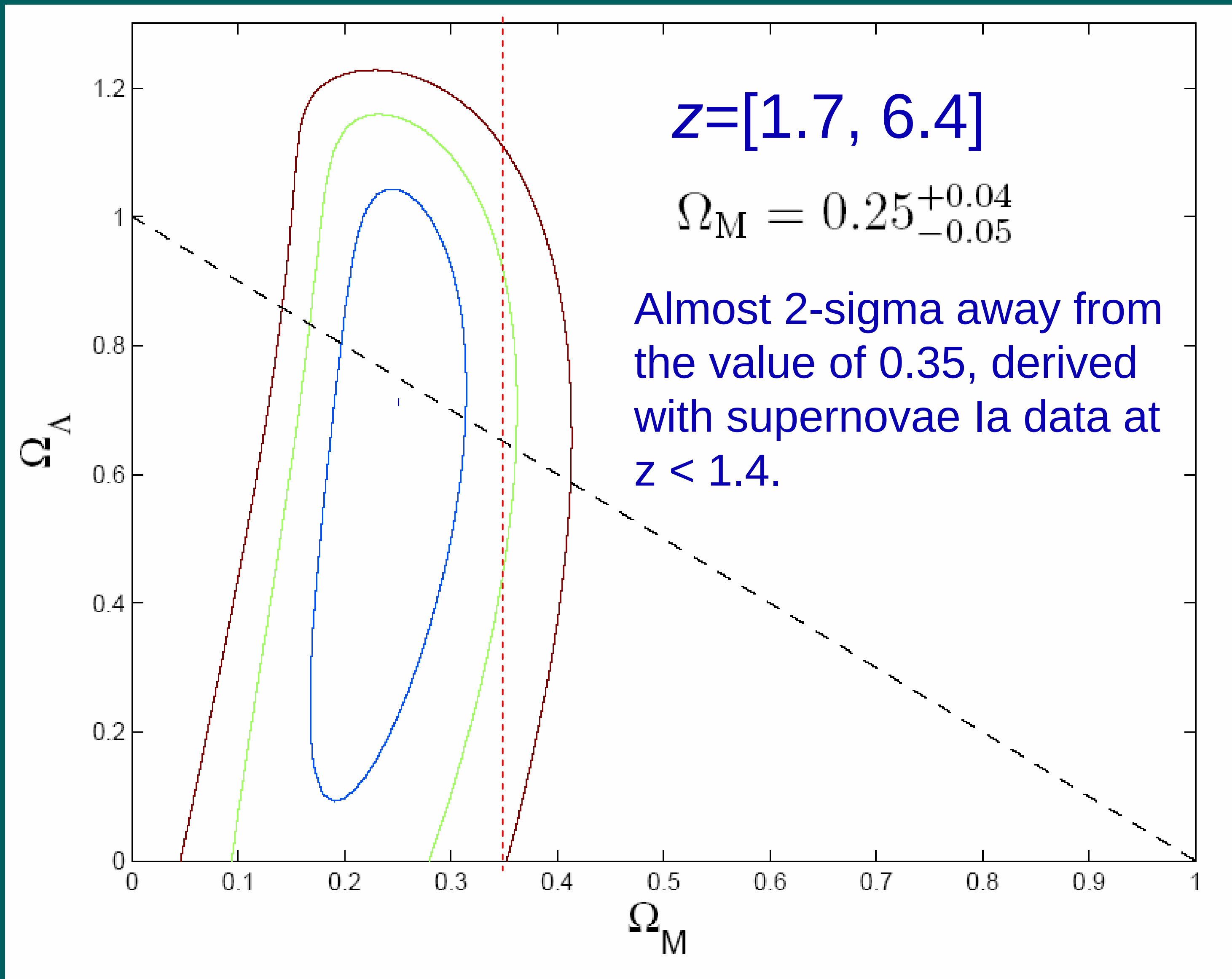
Cosmology-Independent GRB Hubble Diagram



High-z cosmology parameters



Many GRBs are expected at z > 10

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GAMMA-RAY BURSTS ARE PRODUCED PREDOMINATELY IN THE EARLY UNIVERSE

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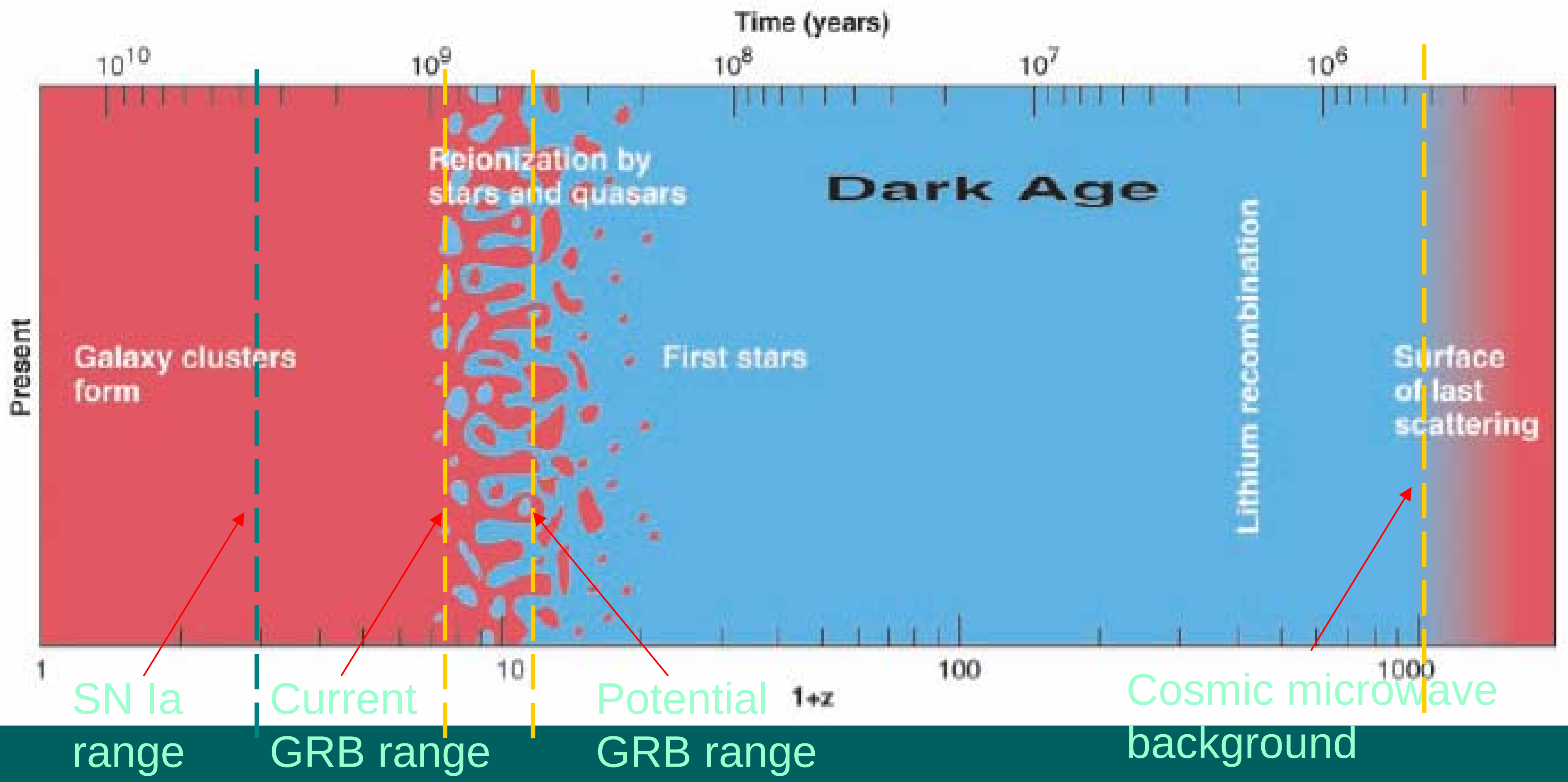
ABSTRACT

It is known that some observed gamma-ray bursts (GRBs) are produced at cosmological distances and that the GRB production rate may follow the star formation rate. We model the BATSE-detected intensity distribution of long GRBs in order to determine their space density distribution and opening angle distribution. Our main results are: the lower and upper distance limits to the GRB production are $z \approx 0.24$ and >10, respectively; the GRB opening angle follows an exponential distribution and the mean opening angle is about 0.03 radians; and the peak luminosity appears to be a better standard candle than the total energy of a GRB.

Subject headings: early universe — gamma rays: bursts — stars: formation

What can GRB cosmology tell us?



GRB cosmology can probe the evolution of the Universe during the first a few percent of its lifetime, when stars and galaxies just begin to form.

Future Perspectives of GRB cosmology

- Need more GRB candles distributed through out the whole Universe
- Better calibrated standard candles
  - Our method relies on SNe Ia as standard candles
  - However, SNe Ia still need to be calibrated beyond Cepheid variables
- Jim Condon of NRAO suggested of making absolute measurement on the Hubble parameter by water maser measurements of Seyfert galaxies
  - To allow SNe Ia cosmology more reliable up to z=2, and then GRB cosmology trust-worth up to z>6

Sun-Black Hole-Gamma-ray burst connection

- Similar atmospheric structures between the Sun and accreting black hole systems
  - Magnetic energy release dominates both types of systems at enormously different scales (Zhang et al. 2000, Science)
- Similar non-linear dynamical processes in X-ray radiations between the Sun, accreting black holes and gamma-ray bursts (Zhang 2007 Highlights in Astronomy; Tang & Zhang, in preparation)
  - Dynamo, MRI and magnetic reconnections

SDSS AGNs

- Excluded QSO space periodicity hypothesis and 3-D space association between QSOs and galaxies (Tang & Zhang 2006, ApJ)
- Evidence for continuous broad line region(s) evolution from narrow line Seyfert I galaxies to extremely broad line Seyfert I galaxies (Zhu & Zhang, in preparation)
  - Accurate black hole mass measurements, independent from the broad line measurements, are needed to understand the nature of broad line region s in AGNs
    - Water maser measurements are the key!

WMAP, SDSS and NVSS

- WMAP: non-Gaussianity and correlation with EGRET (Liu & Zhang 2005, ApJ; 2006, ApJL)
- Significant linear & positive correlation between SDSS galaxy number counts and WMAP average temperature (Wang & Zhang, in preparation)
- Correlations between WMAP large scale features with NVSS galaxy number counts and SDSS galaxy photometric redshift distribution (Fan & Zhang, in preparation)
- Large spatial scale flux (temperature) excess in WMAP high galactic latitude map
  - Tony Readhead of Caltech mentioned statistically significant flux excess

Summary

- After my own brain storming, I found (rather surprisingly) that there are many synergy and common interests between my research group (IHEP & THCA at large) and the US delegates.
- I therefore welcome and look forward to collaboration with the US delegates.
  - Students, postdocs, and visiting scientists exchange
  - Joint research projects & proposals (WMAP, CBI, SDSS, NVSS, SVOM, POLAR, GLAST, LAMOST, etc.)
  - Joint scientific workshops

Many thanks!

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