

***Japan Academy Prize to:***

Masanori IYE  
TMT Project Director and Professor,  
National Astronomical Observatory

for “Observational Studies of the Early  
Universe”

***Outline of the work:***

There are three so-called dark riddles, namely “dark energy”, “dark matter”, and the “dark ages”, that remain unanswered in modern cosmology.

The scientific achievement by Prof. Masanori Iye sheds new light into questions surrounding one of these riddles-the dark ages. He and his group discovered the most distant galaxies at an estimated distance of 12.9 billion light years using the Subaru Telescope and statistically elucidated that the cosmic re-ionization of the Universe was completed at about 800 million years after the big bang. This epoch is referred to as the cosmic dawn of the dark ages.

About 13.7 billion years ago, our Universe began as an expanding ultra-hot and dense fireball called the “big bang”. The rapid expansion cooled the Universe to allow protons and electrons to recombine and form neutral hydrogen atoms 380,000 years later. The Universe then entered into a cold dark age dominated by dark matter, in which shining cosmic objects were nonexistent. The density fluctuation of the cold dark matter gradually grew due to its own gravity and the first generation stars and proto galaxies were born after 200-300 million years of the big bang. The ultraviolet radiation from newly formed hot stars warmed the once cooled intergalactic medium and the Universe itself was eventually re-ionized. This is the scenario predicted by modern theoretical analysis of the early history of the Universe. However, no one has ever witnessed this period.

The most conspicuous signals emitted from primordial galaxies are the hydrogen Lyman alpha photons. Prof. Iye developed special narrow band filters which transmit light through very narrow windows centered at 973 nm and 1006 nm each that enabled the survey of very distant and faint galaxies while limiting the interference from the glow of the Earth’s night sky. These two special filters were designed to find galaxies emitting red shifted Lyman alpha photons at red shift 7.0 and 7.3, respectively. Prof. Iye and his group made imaging survey through these filters attached to the Subaru Suprime-Cam and isolated candidates for the most distant galaxies based on their color. They eventually succeeded in confirming many distant galaxies through the spectroscopic observations using Subaru and Keck telescopes.

Prof. Iye and his group made elaborate population census of primordial galaxies at 12.65 billion years (red shift 5.7), 12.83 billion years (red shift 6.6), 12.88 billion years (red shift 7.0) and 12.92 billion years (red shift 7.2) in the past. They found that the number density of galaxies found by their Lyman alpha photons decreased significantly in this narrow 300 million year span extending toward higher red shift. This is attributed to the increase of neutral hydrogen in the intergalactic space that absorbs and scatters the Lyman alpha photons, making primordial galaxies hidden behind neutral hydrogen more difficult to observe. Prof. Iye and his group interpret this as the last phase of the cosmic re-ionization and have come to call it the

“cosmic dawn”.

This achievement in research second to none was realized with the development of specially designed filters attached to the unique wide-field Suprime-Cam of Subaru Telescope and carefully designed observing strategy.

In 2006, Prof. Iye and his group discovered the most distant galaxy IOK-1 at a record breaking distance of 12.88 billion light years and discussion of cosmic re-ionization ensued. The record was broken in 2011 by several groups but Prof. Iye’s group succeeded in recovering the world record in 2012 when they discovered SXDF-NB1006-2, a galaxy 12.92 billion light years away.

In addition to the achievements on the observational studies of the history of the early Universe, Prof. Iye played leading roles in various engineering projects in astronomy. He proposed and completed the active optics control scheme for the 8.2 m primary mirror of the Subaru Telescope. He also led the teams building the Faint Object Camera and Spectrograph (FOCAS) and the first generation Adaptive Optics system for Subaru Telescope during the 90s’. From 2002, he led the team developing the second generation adaptive optics system with laser guide star facility and succeeded in improving the vision of the Subaru Telescope by a factor of 10.

Prof. Iye has been awarded numerous prizes for these outstanding achievements. He gave invited talks at various international conferences, including a special plenary talk titled “High red shift galaxy surveys” at the 2008 SPIE symposia. He also made active contributions to the world astronomical community through organizing various international conferences and serving numerous committees.

### List of main publications

1. Iye, M., Iwamuro, F., Maihara, T., *et al.*, “Subaru First-Light Deep Photometry of Galaxies in A 851 Field”, PASJ (Publ. Astron. Soc. Japan), 52, 9 (2000)
2. Kodaira, K., Taniguchi, Y., *et al.*, “The Discovery of Two Lyman alpha Emitters beyond Redshift 6 in the Subaru Deep Field”, PASJ, 55, 17 (2003)
3. Iye, M., Shimasaku, K., Miyazaki, S., *et al.*, “ERO R1 in the Field of CL 0939 + 4713: Evidence for an S0-like Galaxy at  $z\sim 1.5$ ”, ApJ (Astrophys. J.), 590, 770 (2003)
4. Takami, H., Takato, N., Hayano, Y., Iye, M., *et al.*, “Performance of Subaru Cassegrain Adaptive Optics System”, PASJ, 56, 225 (2004)
5. Iye, M., Karoji, H., *et al.*, “Current Performance and On-Going Improvements of the 8.2 m Subaru Telescope”, PASJ, 56, 381 (2004)
6. Kashikawa, N., Shimasaku, K., *et al.*, “The Subaru Deep Field: The Optical Imaging Data”, PASJ, 56, 1011 (2004)
7. Iye, M., Takami, H., *et al.*, “Cassegrain and Nasmyth adaptive optics systems of 8.2-m Subaru telescope”, SPIE, 5639, 1 (2004)
8. Ouchi, M., Shimasaku, K., *et al.*, “The Discovery of Primeval Large-Scale Structures with Forming Clusters at Redshift 6”, ApJ, 620, L1 (2005)
9. Taniguchi, Y., Ajiki, M., *et al.*, “The SUBARU Deep Field Project: Lyman alpha Emitters at a Redshift of 6.6”, PASJ, 57, 165 (2005)
10. Minowa, Y., Kobayashi, N., *et al.*, “Subaru Super Deep Field with Adaptive Optics. I. Observations and

- First Implications”, *ApJ*, 629, 29 (2005)
11. Kawai, N., Kosugi, G., *et al.*, “An optical spectrum of the afterglow of a gamma-ray burst at a redshift of  $z = 6.295$ ”, *Nature*, 440, 184 (2006)
  12. Shimasaku, K., Kashikawa, N., *et al.*, “Ly alpha Emitters at  $z = 5.7$  in the Subaru Deep Field”, *PASJ*, 58, 313 (2006)
  13. Totani, T., Kawai, N., *et al.*, “Implications for Cosmic Reionization from the Optical Afterglow Spectrum of the Gamma-Ray Burst 050904 at  $z = 6.3$ ”, *PASJ*, 58, 485 (2006)
  14. Totani, T., Kawai, N., *et al.*, “Implications for Cosmic Reionization from the Optical Afterglow Spectrum of the Gamma-Ray Burst 050904 at  $z = 6.3$ ”, *PASJ*, 58, 485 (2006)
  15. Kashikawa, N., Shimasaku, K., *et al.*, “The End of the Reionization Epoch Probed by Ly alpha Emitters at  $z = 6.5$  in the Subaru Deep Field”, *ApJ*, 648, 7 (2006)
  16. Iye, M., Ota, K., *et al.*, “A galaxy at a redshift  $z = 6.96$ ”, *Nature*, 443, 186 (2006)
  17. Yoshida, M., Shimasaku, K., *et al.*, “Luminosity Functions of Lyman Break Galaxies at  $z \sim 4$  and  $z \sim 5$  in the Subaru Deep Field”, *ApJ*, 653, 988 (2006)
  18. Stockton, A., McGrath, E., Canalizo, G., Iye, M., *et al.*, “Morphologies of Two Massive Old Galaxies at  $z \sim 2.5$ ”, *ApJ*, 672, 146 (2008)
  19. Ota, K., Iye, M., *et al.*, “Reionization and Galaxy Evolution Probed by  $z = 7$  Ly $\alpha$  Emitters”, *ApJ*, 677, 12 (2008)
  20. Furusawa, H., Kosugi, G., *et al.*, “The Subaru/XMM-Newton Deep Survey (SXDS). II. Optical Imaging and Photometric Catalogs”, *ApJS*, 176, 1 (2008)
  21. Ouchi, M., Shimasaku, K., *et al.*, “The Subaru/XMM-Newton Deep Survey (SXDS). IV. Evolution of Ly $\alpha$  Emitters from  $z = 3.1$  to  $5.7$  in the  $1 \text{ deg}^2$  Field: Luminosity Functions and AGN”, *ApJS*, 176, 301 (2008)
  22. McGrath, E., Stockton, A., Canalizo, G., Iye, M., *et al.*, “Morphologies and Color Gradients of Luminous Evolved Galaxies at  $z \sim 1.5$ ”, *ApJ*, 682, 303 (2008)
  23. Ouchi, M., Ono, Y., *et al.*, “Discovery of a Giant Ly $\alpha$  Emitter Near the Reionization Epoch”, *ApJ*, 696, 1164 (2009)
  24. Ota, K., Ly, C., *et al.*, “Spitzer Space Telescope constraint on the stellar mass of a  $z = 6.96$  Ly $\alpha$  emitter”, *PASJ*, 62, 1167 (2010)
  25. Ouchi, M., Shimasaku, K., *et al.*, “Statistics of 207 Ly $\alpha$  Emitters at a Redshift Near 7: Constraints on Reionization and Galaxy Formation Models”, *ApJ*, 723, 869 (2010)
  26. Kashikawa, N., Shimasaku, K., *et al.*, “Completing the Census of Ly-alpha Emitters at the Reionization Epoch”, *ApJ*, 734, 119 (2011)
  27. Rusu, C. E., Oguri, M., *et al.*, “SDSS J133401.39 + 331534.3: A New Subarcsecond Gravitationally Lensed Quasar”, *ApJ*, 738, 30 (2011)
  28. Hibon, P., Kashikawa, N., Willott, C., Iye, M., *et al.*, “Search for  $z \sim 7$  Ly $\alpha$  Emitters with the Suprime-Cam at the Subaru Telescope”, *ApJ*, 744, 89 (2012)
  29. Shibuya, T., Kashikawa, N., Ota, K., Iye, M., *et al.*, “The First Systematic Survey for Ly $\alpha$  Emitters at  $z = 7.3$  with Red-sensitive Subaru/Suprime-Cam”, *ApJ*, 752, 114 (2012)
  30. Ota, K., Iye, M., “Subaru FOCAS survey of  $z = 7-7.1$  Ly $\alpha$  emitters: a test for  $z \sim 7$  Ly $\alpha$  photometric luminosity functions”, *MNRAS (MonNotRoyAstron.Soc)*, 423, 444 (2012)
  31. Ota, K., Richard, J., Iye, M., *et al.*, “A search for  $z = 7.3$  Ly $\alpha$  emitters behind gravitationally lensing clusters”, *MNRAS*, 423, 2829 (2012)

## Review Papers

1. Iye, M., “High redshift galaxy surveys”, *SPIE (International Soc. Optics & Photonics)*, 7016, 1 (2008)
2. Iye, M., “Subaru studies of the cosmic dawn”, *Proc. Japan Acad. Ser. B*, 87, 575 (2011)