A Quarter-Century (Almost) of Spectra from FAST

Jessica Mink,[1] Jaehyon Rhee,[2] Sean Moran,[2] and Warren Brown[2]
[1]*Smithsonian Astrophysical Observatory, Cambridge, MA, USA;*
`jmink@cfa.harvard.edu`

[2]*Smithsonian Astrophysical Observatory, Cambridge, MA, USA*

Abstract. Since January 1994, the FAST Spectrograph on the 1.5-meter Tillinghast Reflector on Mt. Hopkins in Arizona has taken over 180,000 object spectra on almost every clear night when the moon isn't up. Over 150,000 of those spectra of galaxies, stars, and even a few solar system objects, processed through a very slowly evolving pipeline and individually checked, are searchable and available online. We have expanded the pipeline's capabilities and are processing data in configurations that were left to the PI's to process in the past and metadata is being updated for consistency among the spectra. We are in the process of releasing them in a VO-compatible archive. The current version of the data reduction pipeline is described and spectral characteristics of the archived data are summarized.

1. The Instrument

The SAO FAST Spectrograph (Fabricant et al. 1998) is a high-throughput optical spectrograph mounted at the Cassegrain focus of the 1.5-meter Tillinghast Reflector at Fred L. Whipple Observatory on the ridge of Mt. Hopkins in Arizona. It has a 3-arcminute-long slit and is typically operated at resolutions between 1 and 6 Å. In its most common configuration, with a 300 line/mm grating and a 3.0 arc-second wide slit, it offers 4000 Å of spectral coverage at 3 Å resolution. 600 and 1200 line/mm gratings can also be used with narrower apertures for increased resolution over smaller spectral ranges. Optics are primarily reflective, yielding up to 26% throughput, and graphite-epoxy composite construction results in low flexure and good focus stabilty to maximize it.

2. The Pipeline

Since first light in January, 1994, FAST has had 4 different CCD detectors, but we have run pretty much the same pipeline (Tokarz & Roll 1997) since the beginning. Until recently, only data observed in the standard configuration using a 300-line/mm grating over a wavelength range of 3400-7200 Å has been reduced, but we are now reducing everything and working backward through the raw data to complete the reduced archive.

- **FASTLOG** creates a digital log for the night, which is separately archived.
- **FASTSORT** sends the raw data for a night to separate reduction directories for each configuration observed.

- **FASTHEAD** is run in each reduction directory to make sure that the FAST configuration is really the same for each spectrum image match
- **ROADRUNNER**, an IRAF CL script, processes the images in each of those reduction directories. Originally, the pipeline extracted the object spectrum, and then applied a wavelength solution using a calibration per object spectrum taken with a HeNeAr lamp, the spectrum of which is shown in Figure 1. Since 2005, we have applied the wavelength solution to the entire image and then extracted the object spectrum from the resulting image, which is also archived.
- **BEEPBEEP**, another IRAF CL script, finds the object on the slit and extracts a one-dimensional sky-subtracted spectrum. That spectrum, the raw spectrum, the sky spectrum from adjacent parts of the slit, and and a variance spectrum are saved in a FITS file. **XCSAO** (Kurtz & Mink 1998) cross-correlates the sky-subtracted spectrum against a standard set of template spectra to find a velocity. The user checks the results with **QPLOT**, using the result from an alternative template or manually repairing the spectrum and re-cross-correlating it before assigning a rough quality of Q for good, ? for questionable, or X for bad).
- **FASTARC** adds the resulting spectrum metadata to a catalog and moves the spectra to the data archive.

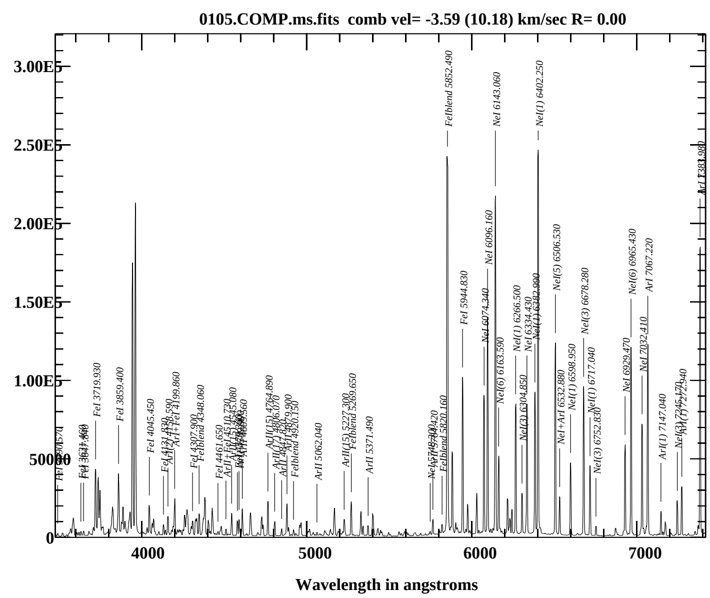

Figure 1. HeNeAr lamp FAST spectrum used for wavelength calibration

3. How FAST Has Been Used

Because FAST is only accessible to astronomers at the Smithsonian Astrophysical Observatory and Harvard University, time is available for long-term projects which can extend over several years. Table 1 lists archived information from some of those projects.

Table 1. Some Large FAST Observing Projects

Spectra	Program	P.I.
8078	AGN Monitoring	John Huchra (Trichas et al. 2012)
7927	Supernovae	Robert Kirshner (Blondin et al. 2012)
7668	2MASS Redshift Survey	John Huchra (Huchra et al. 2012)
6602	CfA Redshift Survey	Huchra and Geller (Huchra et al. 1999)
4488	Updated Zwicky Catalog	Emilio Falco (Falco et al. 1999)
3817	White Dwarfs	Warren Brown (Brown et al. 2013)
3627	Pre-Main Sequence Stars in Orion	Nuria Calvet (Sicilia-Aguilar et al. 2004)
2045	X-ray Groups	Andy Mahdahvi (Mahdavi & Geller 2004)
1593	Local Universe Mass Function	Ken Rines (Rines et al. 2003)

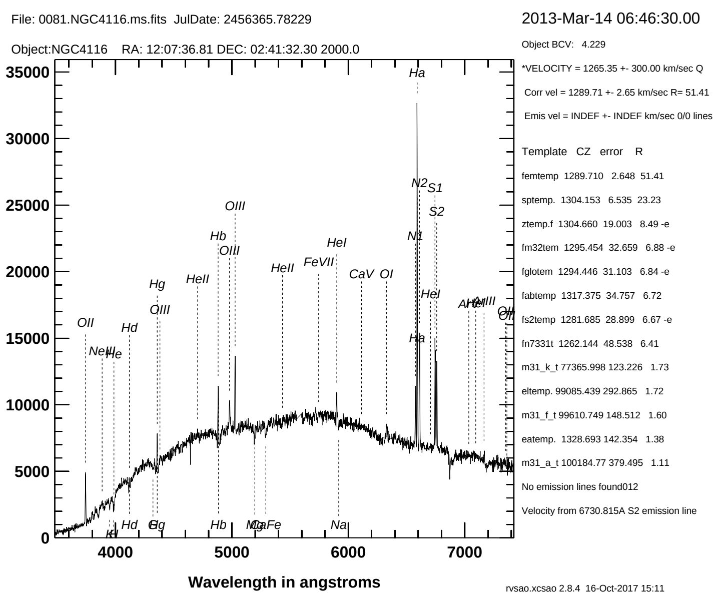

Figure 2. Archived FAST spectrum of the galaxy NGC4116 with XCSAO results

4. Sampled Archived FAST Spectra

Two typical spectra from our archive demonstrate the resolution of FAST. Figure 2 is a spectrum of NGC 4116 showing many strong emission lines which are labelled to aid in evaluating the radial velocity fit. Figure 3 shows a typical white dwarf stellar spectrum with strong hydrogen Balmer lines using a 600 line/mm grating tilted to give high resolution over a blue range. Results of correlation against stars with a range of spectral types are shown. While spectra of all configurations back to 2011 have been processed, we are currently working on older data.

Acknowledgments. Thanks to those who observed these objects and to Susan Tokarz and Bill Wyatt, who reduced a majority of the archived data.

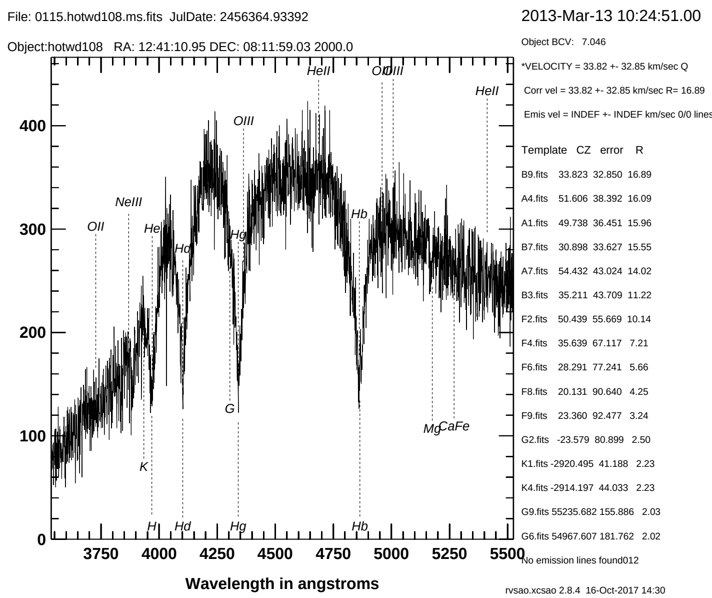

Figure 3. Archived FAST spectra of a white dwarf with XCSAO results

References

Blondin, S., Matheson, T., Kirshner, R. P., Mandel, K. S., Berlind, P., Calkins, M., Challis, P., Garnavich, P. M., Jha, S. W., Modjaz, M., Riess, A. G., & Schmidt, B. P. 2012, AJ, 143, 126. `1203.4832`

Brown, W. R., Kilic, M., Allende Prieto, C., Gianninas, A., & Kenyon, S. J. 2013, ApJ, 769, 66. `1304.4248`

Fabricant, D., Cheimets, P., Caldwell, N., & Geary, J. 1998, PASP, 110, 79

Falco, E. E., Kurtz, M. J., Geller, M. J., Huchra, J. P., Peters, J., Berlind, P., Mink, D. J., Tokarz, S. P., & Elwell, B. 1999, PASP, 111, 438. `astro-ph/9904265`

Huchra, J. P., Macri, L. M., Masters, K. L., Jarrett, T. H., Berlind, P., Calkins, M., Crook, A. C., Cutri, R., Erdoğdu, P., Falco, E., George, T., Hutcheson, C. M., Lahav, O., Mader, J., Mink, J. D., Martimbeau, N., Schneider, S., Skrutskie, M., Tokarz, S., & Westover, M. 2012, ApJS, 199, 26. `1108.0669`

Huchra, J. P., Vogeley, M. S., & Geller, M. J. 1999, ApJS, 121, 287

Kurtz, M. J., & Mink, D. J. 1998, PASP, 110, 934. `astro-ph/9803252`

Mahdavi, A., & Geller, M. J. 2004, ApJ, 607, 202. `astro-ph/0402161`

Rines, K., Geller, M. J., Kurtz, M. J., & Diaferio, A. 2003, AJ, 126, 2152. `astro-ph/0306538`

Sicilia-Aguilar, A., Hartmann, L. W., Briceño, C., Muzerolle, J., & Calvet, N. 2004, AJ, 128, 805

Tokarz, S. P., & Roll, J. 1997, in Astronomical Data Analysis Software and Systems VI, edited by G. Hunt, & H. Payne, vol. 125 of Astronomical Society of the Pacific Conference Series, 140

Trichas, M., Green, P. J., Silverman, J. D., Aldcroft, T., Barkhouse, W., Cameron, R. A., Constantin, A., Ellison, S. L., Foltz, C., Haggard, D., Jannuzi, B. T., Kim, D.-W., Marshall, H. L., Mossman, A., Pérez, L. M., Romero-Colmenero, E., Ruiz, A., Smith, M. G., Smith, P. S., Torres, G., Wik, D. R., Wilkes, B. J., & Wolfgang, A. 2012, ApJS, 200, 17. `1204.5148`