Spectroscopic Investigation of Parsamian 21 and Development of Infrared Data Reduction Techniques

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Abstract

I have spent my time with the Konkoly Infrared Space Astronomy Group (KISAG) working on two projects. The first is a spectroscopic investigation of Parsamian 21, a star whose classification as a FU Orionis type pre-main-sequence star was questioned in a recent paper (Quanz et. al. 2007) [1]. I estimate a spectral type, confirm the detection of a Lithium I absorption feature and discuss the implications on the star's evolutionary status. I also report evidence that the star's well documented bipolar jets are precessing. The second project is a highly technical one in which I furthered the development of a data reduction pipeline for data from the near-infrared CAIN II camera on the Carlos S´anchez Telescope at the Observatorio del Teide in the Canary Islands. New data reduction techniques were developed to correct saturated, over-exposed, images so that they can be reliably used for photometry. This e ectively extends the dynamic range of the Mercury Cadmium Telluride (MgCdTe) detector in this camera, allowing relative photometry of stars much brighter than the standard stars around them, including many young stars of interest to KISAG.

Spectroscopic Investigation of Parsamian 21

1.1 Introduction

FU-Orionis systems are characterized by an increase in the brightness of a star by around 4 to 5 magnitudes (50 to 100-fold brighter) over a couple years and a decline back to quiescence over many decades. In fact, the initial outburst of the prototype star was so dramatic that for a time it was specualted that it may be some new kind of slow supernova. Now, the increase is attributed to light emitted in a disk of accreting material around the star, whose light output varies as it is related to the varying accretion of matter onto the star. A brief outline of star formation will illustrate the potential importance of this phenomenon in understanding star formation.

Star formation could be very loosely described in the following manner: A cloud of gas and dust contracts due to gravity until a protostar forms, onto which the cloud will continue to collapse so long as it is not prevented from doing so by the internal pressure of the gas, rotational momentum or the radiant energy of the forming star. Due to the rotational momentum of the cloud at the outset much of the gas and dust of the cloud will collapse into a disk orbiting around the star, rather than the star itself. In fact, the FU-Orionis phenomena is instrumental in depleting the disk's rotational energy and allowing accretion.

Young stars, from around ten-thousand to ten million years old, which are still embedded in the cloud from which they were born are necessarily faint or invisible in optical light which cannot eectively pass through the cloud. However, these objects are often quite bright in infrared (IR), as IR light from the star can pass through the cloud. IR light is also emitted from the disk around the star due to stellar heating and internal friction. Stars

A young star embedded deep in a dark nebula (evidenced by the total lack of background stars in left of the image as compared to the right) is accreting matter from a disc orbiting around it, and producing a jet which has plainly blasted through the nebula and now generates fluorescent knots of turbulent, ionized gas as it slams into the surrounding interstellar gas. These should not be confused with the re ection nebula at the bottom left which is not created by shocked, uorescing gas, but light reected from the central star o the wall of the cone-shaped cavity that has been carved out of the dark nebula by the jet.

FIGURE 1:
A FAMOUS IMAGE OF HERBIG-HARO OBJECT 47.

which are making the transition from this period of IR excess to being optically visible, from pre-main-sequence to the main-sequence, from birth to life, are well represented by a class of low-mass stars, known as T-Tauri stars. These stars typically have masses around 2 Msun or less. They are known to undergo frequent, rapid and irregular variations in luminosity. They are often associated with Herbig-Haro objects, created by bipolar, supersonic jets which are created as the star accretes matter from the disk. One of the most famous and revealing images of this phenomena is shown in Figure 1.

It is good to be familiar with the morphology of HH-47, as the same elements of this photogenic system (reection nebula, cone-shaped cavity, jets, etc.) can be identied in images of Parsamian 21, though perhaps less readily. A clear idea of what is seen in this picture allows a better understanding of the spectroscopic data presented in this paper.

In this context it has been suggested that FU Orionis systems are T-Tauri systems which are undergoing a period of rapid accretion. The sudden increase in the luminosity of the system is attributed not to the star but to the inner part of the disk as it dumps mass onto the star at a much higher rate ($10^{-4} M_{Sun} = yr$ as opposed to 10^{-7}) implying a much larger internal friction. In the course of such an outburst a star can accrete as much as $0{:}01 M_{Sun}$.

As physical modeling of these accretion processes progresses observations of FU-Orionis outbursts can yield many useful constraints on the many variables involved in these complex systems which cannot otherwise be determined.

1.2 Observations and data reduction

1.2.1 Spectra

The spectra were obtained with the 3.5 meter telescope at Apache Point Observatory(APO) in New Mexico on October 13th, 2008. The Dual Imaging Spectrograph (DIS) was used with a 1.5 arcsecond slit and the R1200 and B1200 gratings producing a dispersion of 0.58 and 0.62 Angstroms/Pixel in the red and blue images, respectively. The spectral range covered was 3788-5050 and 6202-7382 Angstroms. Integration times were 15 minutes for each image, and four images were combined. Data were reduced using standard IRAF (cite) routines and techniques. Images were corrected for bias, ateld, and geometric distortion. They were wavelength calibrated using helium argon neon lamp exposures. One dimensional spectra with background regions subtracted were extracted for the star and two HH-Knots. It should be noted that a third HH-knot is embedded in the stellar spectrum, due to its proximity to the star. A standard star was observed and the spectra were corrected for wavelength dependence of detector sensitivity and reddening. The result is not expected to be truly spectrophotometric due to patchy cirrus, but should yield reliable emission and absorption line ratios.

1.2.2 GFP and HST Imagery

Goddard Fabry-Perot (GFP) images obtained by this author and Carol Grady at APO on the 15th of May 2007 are presented. These data were already published in A. Kospal et. al. 2008 [2]. Images were obtained both in H-Alpha at 6563 Angstroms and at 6590 Angstroms. By subtracting the o-band images from the H-Alpha image we were able to image the HH-knots near the star. Imagery from the Hubble Space Telescope (HST), previously published in the same paper is also included as a useful gure. I refer you to A. Kospal et. al. 2008 [2] for more details of the data reduction on both. (The pre-print is available at http://arxiv.org/abs/0710.1431)

1.3 Results

1.3.1 HST

2 Useful Texts

1. Solid State Physics, Ashcroft and Mermin
2. Principles of Magnetic Resonance, Charles P. Slichter
3. Semiconductors and Semimetals Volume 21, J. David Cohen and others
4. Semiconductor Devices Physics and Technology, S.M Sze

References

[1] Quanz S., Henning T., Bouwman J., van Boekel R., Juhasz A., Linz H.,Pontoppidan K. M., Lahuis F., 2007, ApJ, 668, 359
[2] A. Kospal, P. Abraham, D. Apai, D.R. Ardila, C. Grady, Th. Henning, A. Juhasz, D.W. Miller and A. Moor, 2008 MNRAS, 383, 1015-1028

Consumer Basket Analysis and Expected Co-Occurance of a Bipartite Graph

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This year, while a student in ELTE's MSc in Mathematics program, I was involved in a project with a post-doctoral fellow in which we attempted to find a theoretical approach to the problem of the expected co-occurrence of two vertices of a bipartite graph. This paper details our work so far and our future projects, as well as my experiences as a master's student and how they are related to the university's larger transition under the Bologna Process.

1. Introduction

For this past year, I have been enrolled in a Master's program in Mathematics at Eötvös Loránd University (ELTE) in Budapest. While this in and of itself might not be extraordinary, my situation was unique in that I was enrolled in a program which did not exist until this fall. Rather, the English-language master's program, of which I was a part, has been created as part of ELTE's transition away from the traditional Hungarian five-year undergraduate degree and towards a more "European" system.