RevMexAA (Serie de Conferencias), **16**, 85–88 (2003)

MASS ACCRETION ONTO LOW MASS STARS AND THE SEARCH FOR PLANETS AROUND YOUNG STARS

Matilde Fernández

Instituto de Astrofísica de Andalucía, CSIC, Granada, Spain

Ralph Neuhäuser

Max-Planck-Institut für extraterrestrische Physik, Garching, Germany

RESUMEN

Las estrellas de baja masa, similares al Sol, se pueden observar en el infrarrojo próximo y en el visible cuando todavía están sufriendo un proceso intenso de acreción de materia. El modelo de acreción magnetosférica, en boga hoy en día, explica muchos de los resultados observacionales, pero deja algunas cuestiones abiertas. En este punto la espectroscopía de alta resolución nos puede proporcionar informacióon cuantitativa sobre las regiones involucradas en el proceso. Sin embargo, el bajo brillo de estas estrellas, sus tipos espectrales tardíos, la escala de tiempo de su variabilidad, así como el cociente señal a ruido requerido, hacen imprescindible el acceso a un telescopio de las características del GTC.

En el momento en el que las partes más internas del disco desaparecen (las directamente relacionadas con el proceso de acreción), comienza la última etapa del sistema estrella–disco, en la que presumiblemente se forman planetas en torno a la estrella. Si tenemos en cuenta la relación de brillo entre el planeta y la estrella, esta etapa es precisamente la más favorable para la detección de planetas a través de imagen directa. Con el GTC ha de ser posible detectar planetas del tipo de Saturno en el intervalo de longitudes de onda del infrarrojo cercano.

ABSTRACT

Low mass, solar-type stars are still undergoing a strong mass accretion process by the time they can be studied at visible and near-infrared wavelengths. Although the magnetospheric accretion model can explain many of the observational results that concern these stars, there are still important unresolved questions. High resolution optical spectroscopy can provide us with quantitative information about the regions involved in the mass accretion process. Because of the low brightness of the stars, their late spectral types, the time scale of their variability, and the S/N and resolution required, the GTC is an optimum candidate for these kinds of projects.

By the time the inner parts of the accretion disk disappear, the last stage of the star–disk evolution begins, during which planet formation is supposed to take place. Because of the brightness ratio of the planet to the star, this stage of planet formation and contraction is the most suitable for detecting planets by direct imaging. In the near-infrared wavelength range, the detection of young Saturnlike planets should be possible with the GTC.

Key Words: **STARS: FORMATION — PLANETARY SYSTEMS: FORMATION — STARS: PRE-MAIN-SEQUENCE**

Science with the GTC 10-m Telescope (Granada, España, 5-8 febrero 2002)
Editors: José Miguel Rodríguez Espinosa, Francisco Garzón López & Verónica Melo Martín

1. MASS ACCRETION ONTO LOW MASS STARS

Although the hypothesis of the stars being formed in clouds of gas and dust was proposed hundreds of years ago, we still do not fully understand what is going on at very short distances from the star during the mass accretion process. The size of the region where this process takes place is of several stellar radii (this is more than an order of magnitude smaller than the best resolution that the VLTI will achieve). Therefore we still need to apply indirect tools, such as spectroscopy, in order to study such regions. Spectroscopy really helps, because the velocities and temperatures involved are very different from the photospheric ones, and that allows us to distinguish both of them without problems.

There have been several theories that have tried to explain the way mass accretion proceeds. Matter

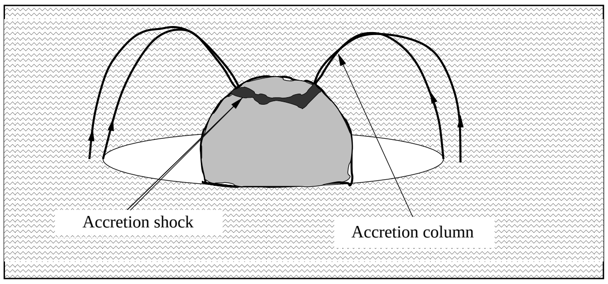

Fig. 1. Schematic diagram of the accretion process on a young low mass star. The magnetic lines of the stellar magnetosphere connect the star and the inner parts of the disk.

from the envelope falls onto the so-called accretion disk and then moves through the disk until it reaches the star. Some years ago it was thought that the disk would touch the star (the boundary layer model), but an increasing number of observations brought about a change this model, and the scenario that is nowadays accepted proposes an inner hole in the disk, as shown in Figure 1. As the matter reaches the inner parts of the disk, it follows the lines of the stellar magnetic field and finally falls at high latitudes onto the surface of the star. The matter here constitutes the accretion column. This is the so-called magnetospheric accretion model.

Nevertheless, this model is not able to explain all the observations, for example, there are some discrepancies concerning the broad emission components, supposedly form in the magnetospheric accretion flow (Alencar & Basri 2000). Moreover, high resolution spectroscopy of the helium lines (Beristain, Edwards, & Kwan 2001) indicated the existence of an extra-hot wind for some of the stars of their sample.

With the goal of putting more constraints on the magnetospheric accretion model, we began the study of some Fe lines of a sample of classical T Tauri stars with high mass accretion rates. With this project, we aim to follow the work done by Beristain, Edwards, & Kwan (1998) on DR Tau. These authors selected a set of pairs of Fe lines with which they could evaluate the optical depth, column density and the kinetic temperature of some of the regions involved in the mass accretion process—in particular, of the post-shock gas close to the stellar surface, which is supposed to be the origin of the narrow component observed in the Fe lines, and of the infalling gas in the accretion column (or maybe the region coupling the inner disk to the stellar magnetic field), where the broad component of the lines is likely to be formed.

Beristain et al. (1998) applied their method to DR Tau. Their observations were carried out at the 4 m Mayall Telescope at KPNO, but not all the lines were observed simultaneously because they gathered data taken over several years and were therefore possibly affected by the strong variability of the star. Nevertheless, the study is very interesting and presents a quantitative method of probing the star–disk interface in the accretion process. For this reason, we decided to follow their technique. But we soon discovered that, because of the small equivalent widths of the Fe lines, a very good signal-to-noise indeed is required, and preferably at high spectral resolution. Considering the brightness of nearest T Tauri stars (about 12 magnitudes in the V band), the project can hardly be carried out on 2–4 meter telescopes. Some of our best spectra were taken at a 2 m telescope using an echelle spectrograph, with $\lambda/\Delta\lambda$ = 23000. With 45 min integration time we are having lot of problems with lines bluer than 5000 angstrom. Moreover, it is not advisable to integrate for more than 5 or 6 hr, because we would be affected by the star (and inner disk) variability, which we also want to study. Nevertheless, such integration times would be required if we wanted to increase the spectral resolution to about 50000. Therefore, we conclude that a telescope of the size of the GTC is required.

The need for a larger telescope is even greater as we move down in the mass scale: we have shown recently (Fernández & Comerón 2001) that an object close to the substellar limit shows spectral features pointing to a strong mass accretion process. It would be very interesting to check whether accretion onto these kinds of objects follows the model proposed for low mass stars. This object in particular, at $V = 21$ mag, is beyond the reach of 4 m telescopes. Even at the VLT, an integration time of a few hours would be needed with UVES.

If the observations are done with an echelle spectrograph, other very interesting lines will be also observed: those related to the mass loss process that simultaneously takes place.

2. SEARCHING FOR PLANETS AROUND YOUNG STARS

Many extrasolar planet candidates have been already detected indirectly through their influence on the radial velocity of stars, but so far there have been very few ways of confirming their nature: transit events (Charbonneau et al. 2000) and the detection the planet's atmosphere (Charbonneau et al. 2002). Direct imaging detection of planets, which would be another possibility, is still difficult because of the lim-

Science with the GTC 10-m Telescope (Granada, España, 5-8 febrero 2002)
Editors: José Miguel Rodríguez Espinosa, Francisco Garzón López & Verónica Melo Martín

Science with the GTC 10-m Telescope (Granada, España, 5-8 febrero 2002)
Editors: José Miguel Rodríguez Espinosa, Francisco Garzón López & Verónica Melo Martín

ited dynamical range: planets are too faint and too close to bright stars.

One can try to avoid the problem of the dynamical range by searching for planetary companions around nearby stars. At distances of 30 pc or less, the projected size of our Solar System would be greater than 1 arcsec. However, the problem is only partially solved. Nearby stars are usually too old, so that their planets are too faint for direct detection with current technology. Let us consider, as an example, the brightness of Jupiter in comparison to that of a 0.2 solar mass star. Their brightness difference can easily exceed 17 mag in the visible and in the near-infrared.

Nevertheless, there is a way to solve this problem: young planets are still self luminous owing to on-going accretion and/or contraction and are sufficiently bright for direct detection. Pre-main sequence stars also exhibit a similar luminosity evolution: they are brighter when they are younger, but their brightness decreases at a much slower rate than the planet's luminosity. The ratio between the luminosity of a 1 $M_{\rm Jup}$ planet and that of a 0.2 $M_\odot$ star is plotted in Figure 2, for ages between 10^6 and 10^{10} yr. The data have been computed from the calculations of Burrows et al. (1997, see their figure 7), following the idea of Brandner et al. (1997). The best age for their detection is between 1 and 10 million years. It will become increasingly harder to detect a planet next to an older pre-main sequence star or close to a main sequence star, in comparison to young pre-main sequence stars. The wavelengths that are more suitable for the detection are the H and K infrared bands, where the brightness difference between young stars and young planets is expected to be the lowest (Burrows et al. 1997; Allard & Hauschildt 1995) and also for technical reasons: good near-infrared detectors and the availability of adaptive optics.

The feasibility of this project was already demonstrated with the ground-based direct imaging detection of an extrasolar planet candidate (Neuhäuser et al. 2000), more than 9 mag fainter than its primary star, TWA-7, a young star of the TW Hydrae association. Nowadays, direct imaging can be considered as a technique that allows us to probe systems with wide separations for which radial velocity methods are not sensitive.

Which are the target stars? Among the 1–10 Myr-old pre-main sequence stars, the weak-line T Tauri stars seem to be much more suitable targets than classical T Tauri stars. Classical T Tauri stars, being young, are still undergoing a strong mass accretion process (we have talked about them in the first part of this presentation). Weak-line T Tauri stars, on the other hand, have lost the inner part (if not most) of their disks and are at the contraction stage towards the main sequence.

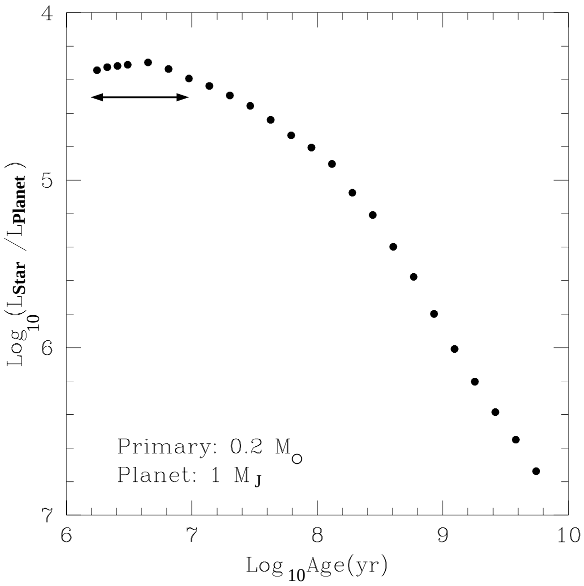

Fig. 2. Time evolution of the luminosity ratio of a 0.2$M_\odot$ star to a 1 M_J planet. The arrow shows the time interval that is more adequate for the detection of the planet.

Why do we need a 10 m telescope? When talking about very young stars, the distances involved are above 50 pc. The TW Hydrae association, which contains 30 stars and is at about 60 pc, is the nearest association of young stars, and the famous star forming regions of Taurus, Lupus, and Chamaleon are at 140 pc. For a planet like Saturn orbiting a very young K-type star, both with an age between 1 and 10 million yr, a 16 mag difference is expected. At the distance of Taurus, this means $K \sim 23$–24 mag for the planet. From our experience at a 2 m telescope, an integration time of about 20 hr would be needed, plus the overheads, which would be quite high because of the short exposures (to avoid saturation effects owing to the brightness of the primary star). On a 10 m telescope the same observation would take about one hour (plus overheads). This would mean not only that the sample of target stars would increase, but also that we would be able to detect planets with smaller masses.

By studying planets around young stars, we can learn about the origins of our own Solar System, and also about the theories of planet formation (which, for example, predict migration of the giant planets to the positions in which they are observed nowadays) using the spectroscopic techniques.

REFERENCES

Alencar, S., & Basri, G. 2000, AJ, 119, 1881
Allard, F., & Hauschildt, P. H. 1995, ApJ, 445, 433
Beristain, G., Edwards, S., & Kwan, J. 1998, ApJ, 499, 828
Beristain, G., Edwards, S., & Kwan, J. 2001, ApJ, 551, 1037
Brandner, W., Alcalá, J. M., Frink, S., & Kunkel, M. 1997 Messenger, 89, 37
Burrows, A., Marley, M., Hubbard, W. B., Lunine, J. I., Guillot, T., Saumon, D., Freedman, R., Sudarsky, D., & Sharp, C. 1997, ApJ, 491, 856
Charbonneau, D., Brown, T. M., Noyes, R. W., & Gilliland, R. L. 2002, ApJ, in press
Charbonneau, D., Brown, T. M., Latham, D. W., $ Mayor, M. 2000, ApJ, 529, L45
Fernández, M., & Comerón, F. 2001, A&A, 380, 264
Neuhäuser, R., Brandner, W., Eckart, A., Guenther, E., Alves, J., Ott,T., Huélamo, N., & Fernández, M. 2000, A&A, 354, L9

Science with the GTC 10-m Telescope (Granada, España, 5-8 febrero 2002)
Editors: José Miguel Rodríguez Espinosa, Francisco Garzón López & Verónica Melo Martín

Matilde Fernández: Instituto de Astrofísica de Andalucía, CSIC, Apdo. 3004, E-18080 Granada, Spain (matilde@iaa.es)
Ralph Neuhäuser: Max-Planck-Institut für extraterrestrische Physik, Giessenbachstrasse 1, D-85740 Garching, Germany (rne@mpe.mpg.de)