COOL STARS
IN CLUSTERS AND ASSOCIATIONS:
Magnetic Activity and Age Indicators

Osservatorio Astronomico di Palermo "Giuseppe S. Vaiana"
Palermo, 20-23 May 1997

PROGRAM AND ABSTRACTS

This workshop has been made possible by the following grants and contributions, that are gratefully acknowledged.

Luxel Corporation
Assemblea Regionale Siciliana
Università degli Studi di Palermo

Scientific Organizing Committee: K. Koyama, T. Montmerle, R. Pallavicini (*co-Chair*), J. Pye, R. Rebolo, J.H.M.M. Schmitt, S. Sciortino (*co-Chair*), D. Soderblom, J. Stauffer, R. Stern

Local Organizing Committee: F. Damiani, G. Foderà Serio, A. Maggio, G. Micela (*Chair*) G. Peres, D. Randazzo

COOL STARS
IN CLUSTERS AND ASSOCIATIONS:
Magnetic Activity and Age Indicators

PROGRAM

Tuesday, May 20

08:30 - 09:30	Registration and Poster Set-up
09:30 - 09:45	Welcome addresses
09:45 - 10:45	Evolutionary Models and Age Determinations of Galactic Clusters *O. Straniero (Osservatorio Astronomico di Collurania)*
10:45 - 11:30	Coffee Break and Poster Session
11:30 - 12:30	Membership Determinations from Proper Motion Surveys *B. Jones (UCO/Lick Observatory)*
12:30 - 13:00	CCD Photometry of Open Clusters *J. R. Stauffer (Harvard-Smithsonian Center for Astrophysics)*
15:00 - 16:00	Rotation and Angular Momentum Evolution of Low-Mass Young Stars *J. Bouvier (Canada-France-Hawaii Telescope Corporation)*
16:00 - 16:20	Open Clusters: Constraints on Disk Age and Evolution *A. Bragaglia (Osservatorio Astronomico di Bologna)*
16:20 - 17:20	Coffee Break and Poster Session
17:20 - 17:50	Radial Velocities and Binaries in Open Clusters *J.C. Mermilliod (Institut d'Astronomie - Universite de Lausanne)*
17:50 - 18:10	Proper Motions and Photographic Photometry in the Field of the Southern Open Cluster NGC 2516 *G. Massone (Osservatorio Astronomico di Torino)*
18:10 - 18:30	Rotation of Late Type Stars in Young Clusters *S. Catalano (Osservatorio Astrofisico di Catania)*
18:30 - 18:50	A *ROSAT* Deep Survey of the Galactic Plane $180^\circ < l < 280^\circ$ *J. Pye (Leicester University)*

Wednesday, May 21

09:00 - 10:00	X-rays and Star Formation *E. Feigelson (Penn State University)*
10:00 - 10:30	ROSAT and Optical Observations of Pre-Main Sequence Stars Outside Star Forming Regions *R. Neuhäuser (MPE)*
10:30 - 11:30	Coffee Break and Poster Session
11:30 - 12:30	X-ray Flares and Magnetic Activity in Young Stellar Objects *T. Montmerle (Service d'Astrophysique CEA/DAPNIA/SAp)*
12:30 - 13:00	Observations of Embedded Sources with ASCA *K. Koyama (Kyoto University)*
15:00 - 16:00	Lithium in Young Clusters and Pre-Main Sequence Low-Mass Stars *R. L. Martín (Instituto de Astrofísica de Canarias & University of California at Berkeley)*
16:00 - 16:30	Above and Below the Substellar Boundary *G. Basri (University of California)*
16:30 - 17:30	Coffee Break and Poster Session
17:30 - 18.00	Chromospheric Activity in Young Clusters *B.P. Byrne (Armagh Observatory)*
18.00 - 18:20	X-Ray Emitting PMS Stars in Upper SCO-CEN: the X-Ray Faint Population *F. Favata (European Space Agency, Astrophysics Division)*
18:20 - 18:40	Discovery of the Sigma Orionis Cluster *F. Walter (SUNY Stony Brook)*
18:40 - 19.00	X-ray Based Survey for Isolated T Tauri Stars Near TW Hydrae *W. Hoff (Universitäts-Sternwarte Jena)*

Thursday, May 22

09:00 - 10:00 X-ray Emission from Young Clusters
S. Randich (European Southern Observatory & Osservatorio Astrofisico di Arcetri)
10:00 - 10:20 The Stellar Activity of Hyades and Praesepe
D. Barrado y Navascués (Center for Astrophysics)
10:20 - 11:00 Coffee Break and Poster Session
11:00 - 12:00 Evolutionary Models of Low Mass Stars
F. D'Antona (Osservatorio Astronomico di Roma)
12:00 - 12:20 Primordial Lithium: Keck Observations in M 92 Turn-Off Stars
C.P Deliyannis (Yale University)

14:30 - 23:00 Excursion and closing dinner

Friday, May 23

09:00 - 09:30 Loop Modelling of X-ray Coronae: Solar-Type Stars in Young Clusters and Associations
A. Maggio (Osservatorio Astronomico di Palermo)
09:30 - 10:00 X-Ray Observations of Old and Intermediate-age Open Clusters
T. Belloni (University of Amsterdam)
10:00 - 10:30 Chromospheric Activity in Old Clusters
L. Pasquini (European Southern Observatory)
10:30 - 11:00 Coffee Break
11:00 - 12:00 Discussion session on Optical Astronomy
Convenor: R. Rebolo (Instituto de Astrofísica de Canarias)
12:00 - 13:00 Discussion session on X-Ray Astronomy
Convenor: R. Stern (Lockheed Martin Solar and Astrophysics Laboratory)

15:00 - 19:00 Splinter sessions

High Resolution Spectroscopy of Weak-line T Tauri Star Candidates in Orion

J.M. Alcalá[1,2], E. Covino[1], R. Neuhäuser[2], M.Sterzik[2], W. Torres[3]

[1] *Osservatorio Astronomico di Capodimonte, 80131 Naples, Italy*
[2] *Max Planck Institut für Extraterrestrische Physik, 85740 Garching, Germany*
[3] *Center for Astrophysics, 60 Garden Street, Cambridge MA 02138, USA*

Abstract. Weak–line T Tauri stars (WTTS) are low–mass pre-main sequence (PMS) stars which lack both strong emission lines and IR excesses typical of classical T Tauri stars (CTTS). The PMS nature of WTTS is assessed on the basis of their location in or close to star forming regions (SFRs) and on the presence of a strong Li I λ 6708 Å absorption line. The optical follow-up observations of the ROSAT X-ray sources, have revealed hundreds of strong–lithium active stars widely spread in hundreds of square degrees in SFRs. These stars have been classified as WTTS in previous mid-resolution spectroscopic studies (Krautter 1997 and references therein). Assuming that these stars are located at the same distance as the SFR where they were found and by comparison with theoretical PMS evolutionary tracks in the HR diagram, their masses and ages are in the range for typical T Tauri stars ($0.15 < M/M_{\odot} < 2.5$; $10^5 < \tau/yr < 10^7$).

At present, the origin of the widely spread population of low-mass PMS stars in SFRs is matter of large debate and, in some extreme cases, their PMS nature has been even put into question (Briceño et al. 1997; Favata et al. 1997). The two main reasons for this are: first, the assumption of a single distance for stars widely spread in several square degrees in the sky may be unrealistic; second, stars in clusters like α Per and the Pleiades (about one order of magnitude older than typical WTTS), show Lithium absorption with a large scatter which can be attributed to the spread in masses and rotation rates (Soderblom et al. 1993). Because of the relatively low spectral resolution used for the prime identification of the widely discovered WTTS candidates (typically $\lambda/\Delta\lambda \approx 2000$), the LiI λ6708Å line is blended with the iron (FeI $\lambda\lambda$6703, 6705 and 6710 Å) lines and hence the lithium strength might be overestimated.

In this contribution, we present preliminary results of high-resolution ($\lambda/\Delta\lambda \approx 20{,}000$) spectroscopic observations of a sub–sample of the strong lithium stars found on the basis of the ROSAT all-sky survey (RASS) in the direction of the Orion SFR (Alcalá et al. 1996). The sub-sample seems to be manly composed by two types of stars namely, true low-mass PMS stars and Pleiades-like objects. On the basis of the strength of the Li I λ6708 Å line and radial velocity determinations we conclude that the stars previously classified as WTTS candidates represent the majority among the strong lithium stars found on the basis of the RASS in the Orion SFR. Possible mechanisms on the origin of the widely spread PMS stars are discussed.

References:

Alcalá J.M. et al. 1996, A&AS 119, 7
Briceño C. et al. 1997, AJ 113,740
Favata F. et al. 1997, A&A submitted
Krautter J. 1997 in proceedings of the 9th Cambridge Workshop
" Cool Stars and Stellar Systems", Eds. R. Pallavicini & A. Dupree, Vol. 109, 395
Soderblom et al. 1993 AJ 106, 1059

New $v\sin i$ Measurements in the Alpha Per Cluster

S. Allain[1], J. Bouvier[1], D. Queloz[2], M. Mermilliod[2], M. Mayor[2]

[1] *Observatoire de Grenoble, Grenoble, France*
[2] *Observatoire de Genève, Genève, Switzerland*

Abstract. The existence of both very slow and very rapid rotators in the young open cluster Alpha Per (50 Myr) is a challenge for PMS angular momentum evolutionary models. Models assuming solid body rotation require very long disk lifetimes to account for rotators with velocities of a few km s^{-1} at the Alpha Per cluster age. On the other hand models with core-envelope decoupling cannot reproduce very rapid rotators with velocities larger than 150 km s^{-1} .

In the past years many observational campaigns were led to determine rotational rates at ZAMS ages. But due to upper limits set on $v\sin i$ determinations, many slow rotators still have undetermined $v\sin i$ (see e.g Soderblom et al. 1993 ApJS 85 315, in the Pleiades, Prosser 1992 AJ 103 488, in Alpha Per). Here we present the results of an observational campaign led with CORAVEL and the high-resolution spectrograph ELODIE (based at Observatoire de Haute-Provence, France). New accurate $v\sin i$ measurements were obtained in the spectral type range G0 – M0.

We present $v\sin i$ distributions for solar-type stars in the mass range 0.6 – 0.9 and 0.9 – 1.1 $M_\odot$. We apply a statistical inversion procedure to compute equatorial velocity distributions and determine true slow rotators fraction. We present the impact of these distributions on models of rotational evolution during the pre-main sequence.

Chromospheric Emission from Red Giants in Open Clusters

D. Barrado y Navascues and A. K. Dupree

Harvard-Smithsonian Center for Astrophysics

Abstract. Observation of the Ca II H and K lines (λ3933, λ3967) in red giants in M11 (NCG 6705) and NGC 6940 allows the strength of chromospheres and their behavior to be evaluated in a population that is well understood from the viewpoint of stellar evolution. Spectra in the Ca II lines have been obtained for giant stars in these clusters using HYDRA (a fibre positioner with bench spectrograph) at the 4-m telescope at KPNO; the multi-object capabilities of this instrument allowed about 20 red giant stars to be measured in each cluster. An order-separating interference filter gave a free spectral range: 3860–4025Å, and a spectral resolution of ~0.14 Å was achieved. Emission reversals are present in some objects. The reversal asymmetry and absolute flux in the chromospheric emission is determined as a function of effective temperature for stars on the red giant branch. Line profiles indicate the onset of mass motions that can lead to stellar winds and mass loss. The strength of the Calcium emission can test models of the evolution of magnetic dynamos on the red giant branch.

Lithium Abundance in Binaries of the M67 Open Cluster

David Barrado y Navascués[1], John R. Stauffer[1], Lee W. Hartmann[1], Suchitra Balachandran[2]

[1] *Harvard-Smithsonian Center for Astrophysics*
[2] *Lab. for Astrophysics National Air and Space Museum*

Abstract. We present a study of the lithium abundance in main-sequence and subgiant binary stars belonging to the M67 open cluster. Accurate abundances were estimated using equivalent widths and effective temperatures derived from (B–V) color indices. These indices were obtained performing a deconvolution of the observed photometry of the binaries, thus eliminating the effect on the color of the companion. Equivalent widths were also corrected of this effect.

We show that, statistically, as happen in other samples of binaries, M67 binaries have Li overabundances. This excesses appear independently of the evolutionary status. As happend in binaries of the Hyades cluster, binaries having synchronization between the orbital and the rotational periods tend to present larger abundances, although this is not always the case, contrary to the Hyades.

The Stellar Activity of Hyades and Praesepe

David Barrado y Navascués[1], John R. Stauffer[1], Charles F. Prosser[1], Sofia Randich[2,3]

[1] *Center for Astrophysics, 60 Garden Street, Cambridge MA 02138, USA*
[2] *European Southern Observatory, Garching*
[3] *Osservatorio Astrofisico di Arcetri, Firenze*

Abstract. We have tried to establish the reasons of the different X-ray properties of late type stars in Hyades and Praesepe. We have studied two different samples of stars; dF-dK Praesepe stars having actual and upper limits for their X-ray luminosities and dM Praesepe stars which have been not detected by ROSAT.

The measured radial velocities for both samples shows that contamination by spurious members cannot account for the differences in the level of coronal activity, since all stars studied here, and presumably most of the stars in the Randich & Schmitt (1995) sample, are real members.

Using simultaneously color-magnitude diagrams and the measured radial velocities, we have discovered new binaries in Praesepe for the dF-dK stars. The comparison of the fraction of binaries in Praesepe and Hyades, either for the group detected in X-ray or for that undetected, shows that Praesepe has more binaries. Specificly, it is remarkable the high binarity rate in the group having only upper limits for their X-ray luminosities. Since the observed levels of coronal activity, assumed equal sensitivity in the observations, are lower in Praesepe, it should be expected a smaller binarity rate in Praesepe than in Hyades. Moreover, we show that the detection rate for the binaries is higher in Hyades than in Praesepe.

Finally, the study of the statistical properties of the Hα line for the dM stars in both clusters shows that in fact Praesepe presents higher chromospheric activity for this kind of stars than Hyades. This result is also surprising, since we have compared a sample of undetected in X-rays Praesepe M dwarfs with Hyades M dwarfs having different levels of coronal activity. For this reason, one possible explanation for the differences in the X-ray properties between both coeval clusters, the existence of different distributions of the rotational velocities, seems unlikely.

All these data could pointed out to the possibility of a difference between the sensitivities of the ROSAT all-sky survey for Hyades and the ROSAT PSPC observations of the Praesepe. However, the problem still remains unsolved. Extensive studies of different properties which characterized late stars such as rotational velocities and periods, lithium abundances and different active indicators should be made in a large variety of open clusters in order to have a comprehensive perspective of the evolution of this type of stars. In particular, a similar comparison to that performed here with other clusters of the same age, such as Coma, can also add important evidences to solve the differences in the X-ray properties of coeval clusters.

Above and Below the Substellar Boundary

G. Basri

Astronomy Dept., University of California, Berkeley, CA, USA

Abstract. I discuss some of the most interesting results to come out of high resolution spectroscopy with the Keck telescope of very faint members of the Pleiades cluster. The first is the detection of the faint side of the main "lithium chasm", in which lithium is completely depleted by burning in the stellar interiors. On this side of the chasm, at the age of the Pleiades, one finds brown dwarfs. That is not the main point of interest here, however. Rather I focus on the age itself which is implied by the observations. It is 120±10 Myr for the Pleiades, as compared with the canonical age of 75 Myr. I believe this to be a general problem in the dating of young open clusters, explicable by convective core overshoot in the massive stars which were used to produce the ages. I claim that the "lithium age" is actually more reliable, and we may already see evidence of the same problem in Alpha Per. Returning briefly to the contentious issue of the age spread in the Pleiades, I point out the recent discovery of two very cool pre-main sequence stars which satisfy all the usual cluster membership criteria (but which I do not believe are actually cluster members). The final point of discussion is the rotational behavior of the faintest Pleiads, and the implications they have for the rotation-activity connection and the rotational history of the cluster.

X-Ray Observations of Old and Intermediate-age Open Clusters

T. Belloni

Astronomical Institute "Anton Pannekoek", University of Amsterdam and Center for High-Energy Astrophysics, Kruislaan 403, 1098 SJ Amsterdam, The Netherlands

Abstract. In 1993 the first X-ray observation of the old open cluster M 67 led to the discovery of X-ray emission from a sample of cluster stars, most of which resulted to be close binary systems. Following this discovery, a campaign to observe old and intermediate age open clusters has been started, together with a parallel campaign for optical follow up. The ultimate goal is to obtain homogeneous samples of active binaries in order to study the dependence of X-ray emission and chromospheric activity on stellar and binary parameters. The current results of the X-ray observations of M 67, NGC 752, NGC 188, NGC 6940 and IC 4651 are presented and discussed.

Primordial Lithium: Keck Observations in M 92 Turn-Off Stars

Ann Merchant Boesgaard[1], Constantine P. Deliyannis[2], Alex Stephens[3], Jeremy R. King[4]

[1] *University of Hawai'i at Mānoa*
[2] *Yale University*
[3] *University of Hawai'i at Mānoa*
[4] *Space Telescope Science Institute*

Abstract.
We present new Keck I/HIRES observations at R=45,000 (= 3 pixels) of six stars near the turnoff of the old, metal-poor globular cluster M92. In three of these stars we have doubled the S/N (to 40 per pixel) previously obtained by us (Deliyannis, Boesgaard, & King 1995 ApJ 452 L13) and we confirm, at a higher confidence level, our previous finding that star 18 has a Li abundance that is about a factor of 2 – 3 larger than those in stars 21 and 46. The Li abundance in star 18 is high compared to the halo field star plateau, and is similar to that in the remarkable Li-rich halo star BD+23:3912 (King, Deliyannis, & Boesgaard 1996 AJ 112, 2839). We have attempted to determine whether the excess Li in star 18 is due to less-than-average Li depletion in this star from an even higher initial abundance, as predicted by the Yale rotational models, or is due to the extraordinary action of Li production mechanisms in the material that formed this star. We have found no convincing evidence that favors Li production. Stars 18, 21, and 46 have identical Ba abundances, which argues against Li production carrying an s-process signature. These three stars have indistinguishable Ca, Cr, Fe, and Ti, which argues against supernova Li production (although we cannot rule out the possibility of a small Mg difference, which should be investigated further). The similarity in age of these cluster stars argues against cosmic ray Li production that requires age differences of Gyrs. While we have not fully exhausted all conceivable Li production possibilities (particularly exotic ones), at present, a more likely explanation is differential Li depletion from a (possibly significantly) higher primordial Li abundance.

Rotation and Angular Momentum Evolution of Low-Mass Young Stars

J. Bouvier

Canada-France-Hawaii Telescope Corporation, PO Box 1597, Kamuela, Hawaii 96743-1597, USA

Abstract. I will review recent results obtained on the rotational properties of cool stars close to the ZAMS. Significant advances have been made in the last year, in particular in the following areas:

i) the actual $v\sin i$ of slow rotators ($v\sin i < 10$ km/s) in the Alpha Persei and Pleiades cluster have been measured. For the first time, we have the complete $v\sin i$ distribution of cool stars in these 2 clusters, over the mass range 0.6-1.1 $M_\odot$, with no $v\sin i$ upper limits. From these, the distribution of equatorial velocities can be obtained. I will discuss what we can learn from them regarding the timescale for angular momentum transport in stellar interiors.

ii) measurements of $v\sin i$ for low-mass members of young MS clusters, with an age of 200-250 Myr, have been obtained. They fill the previously existing age gap between the Pleiades (80-100 Myr) and the Hyades (600 Myr), thus providing new constraints onto the braking rate of fast rotators on the early MS.

iii) the rotation rate of some of the lowest-mass stars, down to 0.1 $M_\odot$, have been measured in the Alpha Persei, Pleiades and Hyades clusters. I will review these results and discuss their implications for the dependence of angular momentum loss rate upon stellar mass on the early MS.

iv) the optical follow-up of ROSAT X-ray sources in star forming regions has provided a large number of new young stars, whose rotational periods or velocities have been measured. I will discuss the evolutionary status of these objects –T Tauri stars, post-T Tauri stars, or young field dwarfs?– which is currently under debate.

A High-Angular Resolution Survey of Low-Mass Binaries in the Pleiades Cluster

J. Bouvier, F. Rigaut, D. Nadeau

Canada-France-Hawaii Telescope Corporation, PO Box 1597, Kamuela, Hawaii 96743-1597, USA

Abstract. We have observed 144 G and K dwarf members of the Pleiades cluster to search for close multiple systems using CFHT's Adaptive Optics adaptor in the near-IR. We detected 22 binary systems and 3 triples, with a separation between 0.08 and 6.9 arcsec (11–910 AU). After correction for incompleteness, we derive a binary frequency in the orbital period range from 4.2 to 7.1 log days, of 28 $\pm$ 4% for G and K Pleiades dwarfs, similar to that of field G-type dwarfs (27%). The distributions of both orbital periods and mass-ratios of the Pleiades systems also appear similar to those of G dwarf binaries of the field. The binary frequency in the 100 Myr-old Pleiades cluster is much lower than that observed for Myr-old pre-main sequence (PMS) stars in the Taurus-Auriga cloud. We argue that this difference does *not* result from the evolution of the binary systems during the pre-main sequence. Instead, we suggest that the low Pleiades binary frequency is typical of stellar populations formed in dense protoclusters, while the higher binary frequency observed among Tau-Aur PMS stars is more typical of loose T associations. The implication is that most field stars are born in dense protostellar clusters.

All 144 surveyed stars have known rotational velocities. Based on the current beliefs that i) the rotation rate of Pleiades late-type dwarfs is largely dictated by the lifetime of their pre-main sequence circumstellar disks and that ii) the evolution of the disks is affected by the presence of a close companion, we searched for a relationship between rotational velocity and binarity among Pleiades G and K dwarfs. We find no significant difference between the distribution of rotational velocities of single and binary stars. Unless current models of PMS angular momentum evolution are flawed, this indicates that the presence of a companion within a distance of 10-1000 AU does not prevent accretion from occurring onto the primary at a rate similar to that observed for single PMS stars. For the closest systems, this implies that accretion must proceed from the *circumbinary* disk onto the central stars. For slightly wider systems, it suggests that the truncated circumstellar disks of the primary and of the secondary are fed by an external (circumbinary) reservoir of mass.

Open Clusters: Constraints on Disk Age and Evolution

A. Bragaglia[1], M. Tosi[1], G. Marconi[2]

[1] *Osservatorio Astronomico, via Zamboni 33, I-40126 Bologna, Italy*
[2] *Osservatorio Astronomico, I-00040 Monte Porzio (Roma), Italy*

Abstract. Galactic open clusters are excellent tools to understand the evolution of our Galaxy from both the chemical and dynamical point of view. They are among the very few galactic objects for which meaningful distances can be derived over a large range. They can be observed in various regions of the galactic disk characterized by different star formation histories. Moreover, they span a range of ages from a few million to several billion years. Therefore, open clusters can provide information on the chemical abundances in the disk and relative gradients at different epochs, the average stellar ages at different galactic locations, the absolute age of the disk, the interactions between thin and thick disks. Especially important to test the early phases of disk evolution are the old clusters (age more than about 1 Gyr).

We have undertaken a project aimed at deriving in a homogeneous way the age of a selected sample of old clusters by comparing deep colour-magnitude diagrams with the corresponding synthetic diagrams (and luminosity functions) based on various sets of self-consistent stellar evolution tracks. This method allows us to simultaneously derive the age, reddening and distance modulus of each cluster, and the theoretical uncertainty related to the adopted stellar models. We also get an indication of the cluster metallicity from the best-fit models.

We have already obtained results on NGC 7790 (young), NGC2243, NGC2506 and NGC6253 (intermediate age), and Cr261 (among the oldest open clusters, similar in age to NGC6791). We also have data for NGC6603 (young) and Be21 and Be22 (old).

Chromospheric Activity in Young Clusters

P. Brendan Byrne

Armagh Observatory, College Hill, Armagh BT61 9DG, N. Ireland

Abstract. I discuss observations of chromosphere and transition regions of the late-type component of young open clusters made with optical/infra-red ground-based telescopes and with IUE and HST. The implications of these data for understanding activity in both the cluster populations of late-type stars and that in the solar neighbourhood are examined.

Radio Emission from *ROSAT* Discovered Young Stars in and Around Taurus-Auriga

Lee Carkner[1], Eric Mamajek[1], Eric Feigelson[1], Ralph Neuhäuser[2], Rainer Wichmann[3] and Joachim Krautter[3]

[1] *Dept. of Astronomy & Astrophysics, Pennsylvania State University, University Park PA 16802*

[2] *Max Planck Institut für Extraterrestrische Physik. 85740 Garching b. München, Germany*

[3] *Landessternwarte Heidelberg, Königstuhl 10, 69117, Heidelberg, Germany*

Abstract. An 8.4 GHz VLA survey of 91 recently discovered lithium-rich late-type stars from the *ROSAT* All-Sky Survey and pointed observations is presented. These objects lie in the vicinity of the Taurus-Auriga star-forming region (d $\simeq$ 140 pc), however some are dispersed nearly 30° from known active star-forming cloud cores. This sample represents a spatially-complete, flux-limited population of X-ray bright young stars both within and away from the primary Tau-Aur stellar nurseries. Of the 91 sources, 29 are detected in this radio survey with a sensitivity limit of ~0.15 mJy. If they are at the distance of the star forming clouds, we find 32% of widely distributed young stars with $L_X \geq 5\times10^{28}$ ergs s^{-1} have radio luminosity densities in excess of 3.5×10^{15} erg $s^{-1}Hz^{-1}$. This detection rate, the ranges of radio and X-ray luminosities and L_R/L_X ratios are consistent with known young weak-lined T Tauri stars (ages $\sim 10^6$ yr) which reside *within* the Taurus molecular clouds, but is considerably higher than a zero-age main sequence population such as the Pleiades (age $\simeq 7\times10^7$ yr). The radio properties thus support the pre-main sequence classification of the stars. They fit well among other active young stars on the empirical L_R vs. L_X diagram, implying that solar type gyro-synchrotron activity is the radio emission mechanism.

The Low-Mass Pre-Main Sequence Population among the ROSAT X-ray Selected Stars in the Chamaeleon Cloud Complex

E. Covino[1], J.M. Alcalá[1], S. Allain[2],J. Bouvier[2,3], J. Krautter[4], L. Terranegra[1]

[1] *Osservatorio Astronomico di Capodimonte, Napoli, Italy*
[2] *Laboratoire d'Astrophysique, Observatoire de Grenoble, France*
[3] *CFH Telescope Corporation, Kamuela, HI USA*
[4] *Landessternwarte Heidelberg, Germany*

Abstract. We report the results of a high–resolution (R $\approx$ 20,000) spectroscopic study on a sample of some 70 stars, classified as new weak–line T Tauri stars on the basis of the ROSAT all–sky survey, found widely spread over a large area which covers the Chamaeleon dark cloud complex.

We derive equivalent widths for the lithium λ 6708 Å, as well as radial and rotational velocities for these stars. By applying a strict criterion based on the value of lithium excess with respect to Pleiades stars of the same spectral type, we are able to discriminate between *bona-fide* pre-main sequence (PMS) stars and possible *contaminating* active field stars in the original sample.

The majority of the stars in the original sample are indeed confirmed to be truly young, PMS stars (most with estimated ages less than 5×10^6 yr), while the remaining appear to be relatively older (probably Pleiades–like), foreground, active main–sequence stars.

A clear segregation in radial velocity is observed between the strong–lithium and the weak–lithium stars, with the former showing, in most cases, radial velocities in the interval 12<RV [km/s] < 18, consistent with the radial velocity distribution observed for stars in the Cha I dark cloud, and the latter having somewhat different and more widely spread radial velocities. The two samples also show somewhat different kinematical and rotational properties, thus providing stronger evidence that they belong to distinct stellar populations in different evolutionary stages.

These observations confirm the existence of some very young stars far from the main Chamaeleon clouds, while no clear evidence is found for the presence of post-T Tauri stars in our sample.

Evolutionary Models of Low Mass Stars

F. D'Antona

Osservatorio Astronomico di Roma

Abstract. I review the evolution of low mass stars and brown dwarfs ($2 \leq M/M_{\odot} \leq 0.015$) through the nuclear burning stages which they pass: the deuterium burning phase (all masses) from which the "stellar" evolution starts; the lithium burning phase ($M \gtrsim 0.06 M_{\odot}$); the location of the hydrogen burning ($M \gtrsim 0.08 M_{\odot}$) main sequence phase.

Dating of pre−−main sequence young populations passes through comparison with the theoretical isochrones. The uncertainties in modeling convection affect the age and *age spread* determination. Deuterium burning for the low mass stars may play an important role in determining the resulting luminosity functions. Brown dwarfs are relatively luminous in the pre–main sequence phases, so young stellar populations may result to be the best environment to find them.

Lithium pre main sequence depletion, although modeled as accurately as possible, is intrinsically uncertain in $0.5 \lesssim M/M_{\odot} \lesssim 1.1$, as the depletion occurs at the border between the convective envelope and the radiative core, whose location is very dependent on the opacities and on the convection model in *non rotating* stars. Rotation and rotational evolution affects lithium depletion in two main ways: through *structural* effects and through the transport of chemicals associated with transport of angular momentum through the convective – radiative boundary.

The main sequence model location of the low and lowest mass stars is still an open problem for stellar models. Till agreement between theoretically predicted colors and observations is reached, models must be semiempirically calibrated on standard sequences (such as the Pleiades) if they are then to be used to derive age information on other stellar samples.

Lithium at the Turnoff of the Old Open Cluster M 67, and the Physical Cause of the Lithium Gap

Constantine P. Deliyannis[1], Jeremy R. King[2], Ann Merchant Boesgaard[3]

[1] *Yale University*
[2] *Space Telescope Science Institute*
[3] *University of Hawai'i at Mānoa*

Abstract. Wide field multi-object high resolution spectroscopy can address the *cause* of the decade-old stellar evolutionary problem known as the Li gap or Li dip, a severe main sequence Li depletion in F stars within a few hundred K in T_{eff}. This Li gap points to a fundamental failure of the standard stellar evolution theory. Additional mechanisms, such as mass loss, microscopic diffusion, and various types of slow mixing including wave-driven mixing and rotationally-induced mixing have all been proposed to explain the gap. Subgiants of the old open cluster M 67 have evolved out of the gap, and their deepening convection zones can potentially reveal the signature(s) of the dominant mechanism. We present observations of 54 stars near the turnoff of M 67, obtained simultaneously in January 1996 with the 3.5-m WIYN telescope and Hydra multi-object fiber fed spectrograph. The Li decline in our M 67 subgiants argues strongly against diffusion, and weakly against mass loss. But complementary information from Li, Be, and B observations in field stars argue strongly against mass loss (and also strongly against diffusion). All these types of observations strongly support a slow mixing mechanism, such as rotationally-induced mechanism, which can also create large Li variations in otherwise identical stars. The importance of short-period binaries is also discussed, and implications for cosmology are mentioned.

Lithium in the Globular Cluster NGC 6397

Constantine P. Deliyannis[1], Julie A. Thorburn[2], Eric P. Rubenstein[1], Michael Rich[3], Jerome A.Orosz[4]

[1] *Yale University*
[2] *Yerkes Observatory*
[3] *Columbia University*
[4] *The Pennsylvania State University*

Abstract. We present new CTIO 4m/Argus Lithium observations of about 20 stars near the turnoff of the old, metal-poor globular cluster NGC 6397. The stars were observed simultaneously at R = 20,000 and S/N = 50 – 100 was achieved. These cluster observations are consistent with the Li-T_{eff} pattern observed in field subgiants: a Spite Li plateau between the turnoff and T_{eff} = 5600 K; a rapid dilution by an order of magnitude in Li at about T_{eff} = 5500 K; a diluted plateau at 5400 – 5000 K; and rapid Li decline for $T_{eff} \leq 5000$ K, which is probably due to in situ giant branch mixing. These trends are compared to stellar models with dilution. It is also found that, in the Spite Li plateau, seven stars with identical B – V color show considerable scatter in their Li abundances, by at least a factor of 2 – 3. Comparable scatter is also seen in the globular cluster M 92. The discovery of scatter in the Spite plateau Li abundances of globular clusters differs from previous reports of Li scatter in halo field stars in that the globular cluster samples are homogeneous. From the NGC 6397 results we conclude that extremely metal-poor Spite plateau stars of identical mass and age in a globular cluster environment need not show the same Li abundance. Possible implications for stellar Li depletion, Galactic Li production, cluster self-contamination, and big bang nucleosynthesis are discussed.

The Evolutionary Status of High-Lithium Cool Dwarfs in the Solar Neighborhood

F. Favata[1], G.Micela[2], S. Sciortino[2]

[1] *European Space Agency, Astrophysics Division, P.O. Box 299, 2200 AG Noordwijk, The Netherlands*
[2] *Istituto ed Osservatorio Astronomico di Palermo, Piazza del Parlamento 1, 90134 Palermo, Italy*

Abstract. We have used the newly available precise Hipparcos parallaxes to study the evolutionary status of a number of high-lithium, active late-type dwarfs present in the solar neighborhood, by placing the stars on evolutionary tracks thus estimating their age. The various uncertainties involved in the process are discussed in detail. We also discuss the consequence, among other things, for current models of lithium depletion, on the basis of these accurate ages, as well as the possible hypotheses about the origin of these rather young stars.

X-Ray Emitting PMS Stars in Upper SCO-CEN: the X-Ray Faint Population

F. Favata[1], S. Sciortino[2], F. Damiani[2], G. Micela[2]

[1] *European Space Agency, Astrophysics Division, P.O. Box 299, 2200 AG Noordwijk, The Netherlands*
[2] *Istituto ed Osservatorio Astronomico di Palermo, Piazza del Parlamento 1, 90134 Palermo, Italy*

Abstract. We have performed an X-ray survey of the upper Sco-Cen star forming region, combining a deep ROSAT HRI pointing performed explicitely for this purpose with shallower ROSAT PSPC and HRI pointings from the public archive. Tens of X-ray sources are detected, down to limiting X-ray luminosities about one order of magnitude fainter than previously reported (on the basis of *Einstein* IPC data) for weak-line T-Tauri stars (WTTS) in the region. Even at these deep limiting fluxes, the $\log N - \log S$ diagram for the detected sources shows no evidence for flattening, implying that the WTTS population may still be severely under-sampled. While optical observations which will lead to complete identification of the counterparts to the X-ray sources are under way, the available limited optical and X-ray evidence points toward most of detected X-ray sources being PMS stars. The implications of the presence of a large population of relatively X-ray faint PMS sources in star-forming regions is discussed.

X-rays and Star Formation

Eric Feigelson

Penn State Dept. of Astronomy & Astrophysics, Pennsylvania State University, University Park PA 16802

Abstract. High-sensitivity X-ray and radio continuum studies of low-mass pre-main sequence stars demonstrate that T Tauri and protostars exhibit high levels of magnetically-induced flare activity. The high energy photons, energetic particles and shocks produced in these flares may have significant effects on the stellar environment. X-ray ionization of the molecular cloud core, infalling envelope, and circumstellar disk may variously impede gravitational collapse and increase disk accretion. X-ray ionization of the disk corona may assist magnetic rotational star-disk coupling and magnetocentrifugal disk-outflow coupling. MeV protons from the flares may explain the unusually high particle track densities seen in some meteoritic grains and, through spallation, may be responsible for meteoritic isotopic anomalies. Flare shocks may cause melting of meteoritic chondrules. Thus, in situ high-energy processes in YSOs observed in the X-ray/radio bands may be fundamentally related to the astrophysics of star formation, protostellar accretion and outflows, and solar nebula phenomena recorded in the meteoritic record.

X-ray and Optical Observations on the Star Forming Region NGC 2264

E. Flaccomio[1], C. Corbally[2], F. Damiani[1], F. Favata[3], F.R. Harnden Jr.[4], G. Micela[1], S. Sciortino[1], J. Schachter[4], A. Tomaney[2]

[1] *Istituto e Osservatorio Astronomico di Palermo*
[2] *Vatican Observatory*
[3] *European Space Agency, Astrophysics Division*
[4] *Harvard-Smithsonian Center for Astrophysics*

Abstract. We present an HRI observation on the star forming region NGC 2264. The analysis has detected more than 40 X-ray sources with L_x in the range $10^{30} - 10^{31}$ erg/sec. The high spatial resolution of the detector allows us to resolve sources that were confused in the IPC and PSPC observations.

We have performed photometric observations in the BVR and I bands of the Johnson-Cousin system at the VATT on the central region of the HRI field of view were the density of X-ray sources is highest. We have obtained photometry for 530 stars with $V \leq 22$. From the X-ray properties and from the photometry we have selected ~ 150 stars as possible cluster members. We discuss the implications of our results on the Initial Mass Function.

CCD Photometry of Late-Type Stars in the Young Open Cluster Stock 2

D.C. Foster[1], P.B. Byrne[1] W.R.J. Rolleston[2]

[1] *Armagh Observatory, College Hill, Armagh BT61 9DG, N. Ireland dcf@star.arm.ac.uk, pbb@star.arm.ac.uk*
[2] *Dept. of Pure and Applied Physics, The Queen's University of Belfast,Dept. of Pure and Applied Physics, Belfast BT7 1NN, N. Ireland R.Rolleston@Queens-Belfast.ac.uk*

Abstract. We present the results of the first BVRI photometry of late-type stars in the young open cluster Stock 2. A total area of 21x5x5 arcmin was observed in October 1995 using the JKT on La Palma. Using theoretical isochrones obtained from D'Antona & Mazzitelli (1994), and allowing for observational and other uncertainties, we identify 27 candidate members from their positions on colour-magnitude diagrams. From comparisons with known star densities of members of the Pleiades we estimate the contamination of the selection due to background stars to be large.

An X-ray Superflare from an Embedded Protostar

N. Grosso

Service d'Astrophysique CEA/DAPNIA/SAp Centre d'Etudes de Saclay 91191 Gif-sur-Yvette Cedex

Membership and Proper Motions of the Open Cluster Stock 2 from the GSC 2 Plate Archive

G. Hawkins[1], A. Spagna[2], F. Favata[3]

[1] *Space Telescope Science Intitute, Baltimore, MD, USA*
[2] *Osservatorio Astronomico di Torino, Italy*
[3] *European Space Agency, Noordwijk, the Netherlands*

Abstract. We present results of a membership study of the galactic open cluster Stock 2 (316 pc, l=133 degrees, b=-1.7 degrees) derived from proper motions obtained from the plate archive of the second Guide Star Catalog: POSS I (epoch 1952), Palomar Quick V (epoch 1983) and POSS II (epoch 1987 - 1993). Magnitudes have been derived in the passbands of the plates. A 4x4 degree square region has been studied, on the basis of previous studies which suggested a cluster extension of several degrees. We process stars to a limit on the Quick V plate of magnitude 19.5, faint enough to include cluster stars of type M at the bottom of the main sequence.

We discuss the methods used for object detection, astrometric and photometric calibration, and for proper motion evaluation. Results on the Stock 2 cluster, including a Vector Point Diagram, are shown.

X-ray Based Survey for Isolated T Tauri stars near TW Hydrae

W. Hoff[1], J. M. Alcalá [2], M. F. Sterzik [2]

[1] *Astrophysikalisches Institut und Universitäts-Sternwarte Jena*
[2] *Max-Planck Institut für Extraterrestrische Physik, Garching*

Abstract. The classical T Tauri star TW Hya belongs to a small group of low-mass young stellar objects far away from any star forming region in the sky. Two further members of this group are the weak-line T Tauri stars CoD $-29°8887$ and Hen(3)-600. The objects of this group show the spectroscopic characteristics of T Tauri stars (TTSs), but they are not associated to any molecular cloud like the majority of known TTSs does. Therefore, these objects are called *isolated* TTSs.
The origin of isolated TTSs is not clear at present. One possible explaination is that these stars formed out of small cloudlets that are part of a turbulent giant molecular cloud complex. The remnants of these cloudlets were rapidly dissipated after star formation took place (Feigelson 1996). In this case the isolated TTSs belong to co-moving groups of YSOs.

From the detailed investigation of X-ray sources of two deep ROSAT PSPC observations pointed at TW Hya and CoD $-29°8887$, we know that there are no further TSSs within the viewing angle of ROSAT (Hoff et al. 1997). Hence, to investigate the possible presence of other TTSs in a larger area around the isolated TTSs, we obtained X-ray data from the RASS in $6° \times 6°$ fields centered at the TTSs TW Hya, CoD $-29°8887$ and Hen(3)-600. These fields overlap and cover the whole region between these objects. About 160 X-ray sources were detected in these ROSAT fields with a high confidence level. For all sources we took finding charts from the Digitized Sky Survey to identify stellar-like counterparts. On the basis of their X-ray properties and the cross-identification with stellar (SIMBAD, HST-GSC) and extragalactic (NED) databases, we pre-selected potential TTS candidates from the counterpart list.

The spectroscopic follow-up observations were carried out with the B&C spectrograph at the ESO 1.52-m telescope at La Silla, Chile, to investigate the nature of our candidates. We find that four objects can be clearly classified as new isolated TTSs, and some others are tentatively post T Tauri stars or active Pleiades-like objects.

References:

Feigelson E.D.: 1996 Astrophysical Journal, 468, 306
Hoff W., Henning Th., Pfau W.: submitted

Membership Determinations from Proper Motion Surveys

Burton Jones

UCO/Lick Observatory, University of California, Santa Cruz

Abstract. The advent of large telescopes has made possible the detailed study of faint, low mass stars in clusters. This has emphasized the need for means to identify faint cluster members. Although the identification of the more luminous stars of a cluster is straightforward, the identification of the low-luminosity members in an unbiased way is difficult, and usually makes use of the fact that cluster members share nearly a common space motion. The most efficient means of finding low-luminosity stars is the measurement of proper motions. Various techniques have been used to assign proper motion cluster membership probabilities to stars in the region of a cluster. These techniques are reviewed, as well as the reliability and appropriateness of the methods. Current and future surveys are discussed. A compilation of recent determinations of cluster membership studies will also be given.

Observations of Embedded Sources with ASCA

Katsuji Koyama

Department of Physics, Kyoto University, Sakyo-ku, Kyoto 606

Abstract. Protostars or Class I infrared sources are generally embedded deep in the molecular cloud and/or dense circumstellar accreting gas. Therefore they are invisible with soft X-rays. We report the hard X-ray images of these embedded protostars with the ASCA satellite. From the center of the R Corona Australis (R CrA) molecular cloud (called the Cornet cluster), we found hard X-ray point sources. One of the sources, probably the embedded far-infrared source R1, exhibited a powerful X-ray flare. These phenomena are similar to, but with a significantly higher temperature than, those seen in T Tauri stars. The flare spectrum is unusual, showing a broadened or double emission-line structure between 6.2 and 6.8 keV. The flux of this source decrease much with the second and third observations made one years after , instead other class I sources became the brightest. Consequently, the Cornet cluster is found to be highly variable in the hard X-rays. The rho Ophiuchi dark cloud also harbors several X-ray emitting class I sources, one (EL29) exhibited typical flare and another (WL6) showed sinusoidal variation with no spectral change. The latter would be due to the rotation of the star. From NGC1333, we also found hard x-ray sources, but these did not coincide with the previous known protostar candidates except one, possibly the hard X-rays are due to new protostars. Since X-rays are unexpected from current protostellar theory, these ASCA observations should have a significant impact on our understanding of star formation and the earliest phases of stellar evolution. Although the sample clouds is still limited, we also found several example of no X-rays from protostars in other clouds.

Lithium, Rotation, and Activity in Chamaeleon T Tauri Stars

A. Magazzù[1], J.M. Alcalá[2], E. Covino[3]

[1] *Osservatorio Astrofisico di Catania, Catania, Italy*
[2] *Max-Planck-Institute für Extraterrestrische Physik, Garching, Germany*
[3] *Osservatorio Astronomico di Capodimonte, Napoli, Italy*

Abstract. We have calculated the lithium abundance from high-resolution spectra of about 70 stars, identified as weak-T Tauri star candidates from a lower-resolution study of a sample of optical counterparts of sources from the ROSAT all-sky survey in the Chamaeleon star forming region. First results on the correlation between lithium abundance, projected rotational velocity, and activity indicators are reported, for the objects which have been confirmed to be *bona-fide* pre-main sequence stars. The influence of the rotation on lithium depletion is also discussed.

Loop Modelling of X-ray Coronae: Solar-Type Stars in Young Clusters and Associations

A. Maggio, G. Micela, G. Peres

Istituto e Osservatorio Astronomico "G.S. Vaiana", Palermo, Italy

Abstract. The disk-integrated X-ray emission from late-type stars originates from hot coronal plasmas most likely confined in closed magnetic structures, of the kind clearly observed on the Sun. The complex plasma temperature stratification in such structures can be described quite accurately using hydrostatic coronal loop models, which can be adopted to predict the X-ray emission, and ultimately to fit the observed X-ray spectra. The spectral analysis with loop models allows us to get physical insight into the properties of stellar coronae, including indications on the loop geometry and on the plasma heating, and hence to study how the coronal structures change with the ageing of the stellar magnetic activity. In this context, we present preliminary results from the analysis of ROSAT/PSPC spectra of selected G-type stars in young open clusters and associations.

Rotation of Late Type Stars in Young Clusters

E. Marilli, S. Catalano, A. Frasca

Osservatorio Astrofisico di Catania, Viale A. Doria 6, I-95125 Catania, Italy

Abstract. We present here results on V-band photometry of 35 late type dwarf stars in the young open clusters: Pleiades, α Persei, and Coma Berenices obtained at Catania from 1992 to 1996.
We searched for periodic light variation using two different methods. We applied the CLEAN algorithm (Roberts et al., AJ 93, 968, 1986) to the periodogram analysis, which allows to reject aliases generated by incompleteness of the data sampling and by the finite time span of the observations. We also used the string-length method avilable on IRAF, to check the CLEAN results. We have detected rotation periods for 15 stars among the 16 Pleiades observed, 11 over the 15 α Persei and 3 over the 4 Coma. The periods range from 8 to 36 hours for α Persei, from 0.5 to 4 days for the Pleiades and from 4 to 10 days for the Coma stars. The histogram of the statistical frequency of rotation period gives a clear evidence, even for the present limited sample of G-K stars, of the rotation decay with age. We argue that the spread around the mean period for each cluster could be the remnant of the initial angular momentum distribution.
The dependence of magnetic activity from the rotation rate is investigated using the X-ray flux as activity diagnostic. Faster rotators appear to be more active, as already shown by previous investigations. We noticed also a tendency for faster rotators to show light curve of larger amplitude, indicating a stronger activity also at photospheric level.

Lithium in Young Clusters and Pre-Main Sequence Low-Mass Stars

E.L. Martín

Instituto de Astrofísica de Canarias

Astronomy Department, University of California at Berkeley

Abstract. The abundance of the light-element Li in young stars is a major tool for testing stellar evolution theory. Since pre-main sequence (PMS) evolution depends strongly on stellar mass, it is convenient to discuss separately the behaviour of lithium for different masses. In this work, I consider three mass bins as the most representative:

1.2–1.0 $M_\odot$: there is no significant PMS Li depletion, probably because the deep convective PMS phase does not lasts long enough. After reaching the ZAMS, these stars experience Li depletion which might be related to angular momentum loss or some other non-standard mixing mechanism.

0.9–0.7 $M_\odot$: there is significant PMS Li depletion. Standard evolutionary models cannot explain the observed dispersion of Li abundances for stars of similar age, mass and metallicity. Non standard models, including rotation, are needed for explaining the observations.

0.6–0.1 $M_\odot$: there is large PMS Li convective burning. Standard models do not fit well the abrupt drop of Li abundances. Age plays the major role here, and rotation does not. Consequently, the Li abundance is a good clock for dating individual stars as well as stellar associations or clusters.

As we see from the discussion above, the pattern of Li abundances in young stars constitutes a major challenge to PMS evolutionary theory. Usually the most important parameters of PMS stars (age, mass) are inferred from comparison with standard evolutionary tracks in the HR diagramme. The uncertainties involved in this procedure are large and can lead to wrong conclusions. Alternatively, a Li versus spectral type representation can be constructed using spectroscopic data alone, and it is useful for deriving the age distribution of young low-mass stars in star-forming regions.

How Many Weak-T Tauri Stars are there in Taurus-Auriga?

E.L. Martín[1,2] and A. Magazzù[3]

[1] *Instituto de Astrofísica de Canarias, Tenerife, Spain*
[2] *Astronomy Department, University of California at Berkeley, USA*
[3] *Osservatorio Astrofisico di Catania, Catania, Italy*

Abstract. We present intermediate-resolution spectroscopic observations of 30 optical counterparts of X-ray sources detected by ROSAT in the Taurus-Auriga star-forming region, classified as weak-T Tauri stars (WTTS) on the basis of low-resolution spectra (Wichmann et al. 1996, A&A, 312, 439). The WTTS status of each one of them has been verified following spectroscopic criteria. The higher resolution allows us to be more accurate in establishing the WTTS nature. The implications of our results for the age and spatial distribution of pre-main sequence stars in Taurus-Auriga is discussed.

Rotating Stellar Models and Lithium Depletion

Luiz Themystokliz S. Mendes[1], Francesca D'Antona[2], Italo Mazzitelli[3]

[1] *Departamento de Física - ICEx - UFMG, Caixa Postal 702, 30161–970 Belo Horizonte (MG), Brazil*
[2] *Osservatorio Astronomico di Roma, I-00040 Monte Porzio, Italy*
[3] *Istituto di Astrofisica Spaziale, CNR, C.P. 67, I-00044 Frascati, Italy*

Abstract. The ATON stellar evolution code has been modified to include rotation, in the way devised by Endal & Sofia (1976). As a preliminary application of this improved code, we have run some rotating stellar models to investigate the effects of rotation on the Lithium depletion of low mass, pre-main sequence stars. The models were run with rigid body rotation, no angular momentum loss and redistribution, and under two prescriptions for convection, namely the mixing length theory [MLT] and the turbulent convection introduced by Canuto & Mazzitelli (1991) [CM]. The calculations show that rotation *increases* the Lithium depletion for both MLT and CM, a result which is expected from the theory since rotating stars behave as non-rotating stars of lower mass and so must experience greater Lithium depletion. However, this result seems to be in disagreement with the observational data on low mass, pre-main sequence stars such as those from the Pleiades cluster (García López *et al.* 1994).

Radial Velocities and Binaries in Open Clusters

Jean-Claude Mermilliod

Institut d'Astronomie Universite de Lausanne

Abstract. Radial and rotational velocities have been determined with the CORAVEL scanner for F5-K0 stars in all open clusters closer than 200 pc from both hemispheres. The total number of stars observed is larger than 1000. For most open clusters, these data sets form the only systematic long-term surveys made up to now in this spectral-type range. The aim was to study the membership, find new member stars, discover spectroscopic binaries and determine their orbital elements. As a by-product, we have access to the rotational velocities, as measured by the half-width of the cross-correlation function. Coravel observations of X-ray sources in the southern-hemisphere open clusters confirm the membership of many candidates. We shall present the results for overall binary characteristics along the main sequence for eccentricity, period, mass function f(m), and distribution of rotational velocities, and discuss also the effects of duplicity on the observed X-ray fluxes.

Improvements to the present data can be made by extending the systematic survey to fainter stars, including the halo stars, which cannot be made with the telescopes used for this work. Systematic IR imaging would be very important to find double stars that cannot be detected with radial velocities (too large a separation). High precision radial velocity surveys to discover lower mass companions (down to brown dwarfs or giant planets) would also be very important to check the 100% companion hypothesis.

X-Ray Observations of ζ Sculptoris

G. Micela[1], F. Favata[2], R. Pallavicini[1], J. Pye[3], S. Sciortino[1]

[1] *Istituto e Osservatorio Astronomico di Palermo*
[2] *European Space Agency, Astrophysics Division,*
[3] *Department of Physics and Astronomy, Leicester University*

Abstract. We present preliminary results from two deep HRI ROSAT exposures on the ζ Sculp open cluster. This cluster, younger than the Pleiades, has photometric indicators that imply a metal-poor cluster (Epstein and Epstein 1985, Wasterlund et al. 1988). Instead high resolution spectroscopic observations (Edvardsson et al. 1995) results in a metal abundance higher than solar. Furthermore many cluster members show chromospheric emission typical of young stars.

The analysis of the HRI observations results in a high number of X-ray sources consistently with the young age of the cluster. The time sampling of the pointings allow us to study the source variability on time scale from hours up to 6-12 months.

References

de Epstein A. E. & Epstein I. 1985, AJ, 90 1211
Edvardsson B. et al. 1995, 293, 75
Westerlund B. et al. 1988, A&AS, 76 101

X-ray Flares and Magnetic Activity in Young Stellar Objects

Thierry Montmerle

Service d'Astrophysique CEA/DAPNIA/SAp Centre d'Etudes de Saclay 91191 Gif-sur-Yvette Cedex

Abstract. Recent observations by ROSAT and ASCA have shown the widespread X-ray activity of low-mass Young Stellar Objects (T Tauri stars and protostars). X-ray spectra, in particular from ASCA, have shown that plasma temperatures may reach extremely high values (up to 10^8 K), with some evidence that the highest temperatures are reached in protostars. I will review recent results obtained by ROSAT and ASCA in molecular clouds and star-forming regions, emphasizing the emerging case of X-ray emission of protostars, its links (or lack of ?) with magnetic fields, and various consequences, including the physical state of the early solar system.

Proper Motions and Photographic Photometry in the Field of the Southern Open Cluster NGC 2516

F. Morale[1], G. Massone[2], M. G. Lattanzi[2]

[1] *Osservatorio Astronomico di Palermo*
[2] *Osservatorio Astronomico di Torino*

Abstract. NGC 2516 is one of the most prominent open clusters of the southern sky. With a distance of about 400 pc, an age of $\sim 10^8$ year, and the presence of several interesting and peculiar objects within the boundaries of the cluster, NGC 2516 has been a favourite target for photometric and spectroscopic studies. Moreover, in spite of its low galactic latitude (-16 deg), the background field in not dramatically crowded, and good segregation of bright cluster members (on the brighter end of the main sequence) based on photometry and spectroscopy is rather easy. More difficult is the identification of fainter members required, for instance, for the definition of the faint end of the main sequence, and for the study of the cluster luminosity function. Also, more interesting issues have followed the results of the Rosat survey, with the discovery of a cospicuous number of soft X-ray sources associated with low luminosity stars in the direction of the cluster.

An important tool for the segregation of faint open cluster members is (relative) proper motions; this method is indipendent from photometric and spectroscopic membership criteria. In this paper, that is part of a more general project of observation and comparison of astrophysical parameters in open clusters, we deal with the determination and the analysis of new proper motions and photographic B and V photometry for 3000 stars in a 1 x 1 degree field centered on NGC 2516. The goal is to produce reliable cluster members down to apparent magnitude B 16, which corresponds to an absolute B magnitude of 6.8 at the cluster, and therefore reaching, at least, the brigthest K V members. Fifteen plates taken with 4 different southern telescopes and spanning an epoch difference of more than one century have been scanned with PDS n. 2 at the Space Telescope Science Institute in Baltimore and reduced with standard astrometric and photometric s/w of Torino Observatory. The derived proper motions have an accuracy of 1 mas/year for stars of brigth and intermediate magnitude; for B 15.5 the accuracy is down to 2-3 mas/year, but still good enough to identify more than two hundred probable cluster members.

ROSAT and Optical Observations of Pre-Main Sequence Stars outside Star Forming Regions

Ralph Neuhäuser

Max-Planck-Institut für extraterrestrische Physik, D-85740 Garching, Germany,
I: rne@mpe-garching.mpg.de

Abstract. With the spatially complete but flux-limited ROSAT All-Sky Survey (RASS), two-thirds of the previously known weak-line T Tauri stars (wTTS) and only one sixth of the classical T Tauri stars (cTTS) were detected in the near-by Taurus star forming region. With ground-based optical follow-up observations of unidentified RASS sources, many late-type stars with lithium 6708Å absorption were identified as RASS counterparts. High-resolution spectra confirm high lithium abundances in many of them, and also yield their rotational and radial velocities. Also, quite a number of older, more evolved - but still active - zero-age-main-sequence (ZAMS) stars are detected, which are not concentrated towards star forming clouds or the Gould Belt. So far, up to ~ 100 new wTTS (and also a few cTTS) are found in any of the star forming regions studied: Taurus, Orion, Lupus, ScoCen, Chamaeleon, and R CrA. They do show more lithium than ZAMS stars of the same spectral types and rotational velocities. Hence, these new stars really are young, i.e. pre-main sequence stars. Most of the new wTTS are located on or near clouds, but some are isolated, i.e. several degrees off any remnant cloud material. We discuss possible sites and modes of origin of such object.

P1724 and RXJ0511.2+1031 – Run-away T Tauri Stars ?

Ralph Neuhäuser[1], Guillermo Torres[2], Sabine Frink[3], Elvira Covino[4], Juan M. Alcalá[1]

[1] *Max-Planck-Institut für extraterrestrische Physik, D-85740 Garching, Germany, I: rne@mpe-garching.mpg.de*
[2] *Center for Astrophysics, 60 Garden Street, Cambridge MA02138, USA*
[3] *Astronomisches Recheninstitut, Mönchhofstr. 12-14, D-69120 Heidelberg, Germany*
[4] *Osservatorio Astrofisico di Capodimonte, Napoli, Italia*

Abstract. The weak-line T Tauri star P1724 (HBC 452) is located just 15′ north of the Trapezium cluster in Orion. With our high-resolution spectra, we measure its radial velocity to be 25 $km\ s^{-1}$, i.e. consistent with Orion membership. Previous proper motion studies of T Tauri stars in the general direction of Orion have concluded that the probability of membership of P1724 to Orion lies between 0 % and 97 %. In fact, the proper motion of P1724 points away from the Trapezium, as also confirmed by our new proper motion data with $\sim$ 100 yrs epoch difference (STARNET = GSC1.2 + AC). Hence, P1724 may have been ejected (in a three-body encounter) out of the Trapezium as a run-away T Tauri star. Its spectral energy distribution identifies P1724 as a naked T Tauri star, which may have lost its disk during the encounter. Its HR diagram age is consistent with its 3D velocity ($\sim$ 10 km/s relative to the Trapezium) and its current distance from the Trapezium.

The ROSAT X-ray source RXJ0511.2+1031 has been identified as a weak-line T Tauri star with spectral type K7 and strong lithium absorption, W_λ(Li)= 0.65Å. It is located in the λ Ori region and its radial velocity indicates that it moves towards us with $\sim$ 10 km/s relative to Orion. RXJ0511.2+1031 appears to be a single T Tauri star with small rotational velocity, just as expected for a run-away T Tauri star, which just got ejected.

Lithium in solar-type stars in the old cluster M67

R. Pallavicini[1], L. Pasquini[2], S. Randich[2]

[1] *Osservatorio Astronomico di Palermo, Italy*
[2] *European Southern Observatory, Garching, Germany*

Abstract. We present high resolution observations of main sequence stars in the solar age, solar metallicity open cluster M67. For the first time we show conclusively that a spread in lithium abundances exists among solar-type stars belonging to this cluster. This implies that standard models with only convection as a mixing mechanism can hardly account for the spread at each colour, and that the Li abundance is not a good age indicator for solar-type stars. The comparison of Li abundances in M67 (age $\sim 4.7 \times 10^9$ yrs) with those in the younger Hyades cluster ($\sim 7 \times 10^8$ yrs) shows that the less depleted stars in M67 have a Li content only ~ 0.25 dex below similar stars in the Hyades. Considering the ~ 4 Gyrs difference between the two clusters, this indicates that standard lithium destruction mechanisms are very inefficient (if present at all) in many solar-type stars during most of their main sequence lifetime. On the other hand, almost 40% of our sample stars show a significant Li depletion, with values comparable to the Sun. Our sample also includes one SB2 binary, for which a very high Li abundance was previously reported. We found an abundance significantly higher than in single stars, but our spectra are inconsistent with those previously published.

Chromospheric Activity in Old Clusters

Luca Pasquini

European Southern Observatory, Karl Schwarzschild Str. 2, D-85748 Garching bei München, BRD

Abstract. Observations of chromospheric activity in stars belonging to old clusters are extremely interesting to investigate a variety of topics, like age-activity correlation in main sequence stars, the nature of the mechanism heating the chromosphere of evolved stars, the relationship between stellar activity and massive winds. All these topics have deep implications for stellar evolutionary models. Only recently, however, data for evolved stars in a few old (Open and Globular) clusters are becoming available. The solar age, solar metallicity cluster M67 is the best studied, and the results for this cluster are discussed in detail.

The available observations show that chromospheric activity mostly depends on the stellar effective temperature, but some dependence on the stellar mass is possibly present.

With respect to line asymmetries, Open and Globular Clusters stars show a different behavior, but the problem if Hα emission in G.C. giants is produced by mass losses or chromospheric emission is not solved yet.

The potentiality of new ESO instruments on this topic are briefly reviewed.

Sun as a Star: Yohkoh Data Analysis for the Solar-Stellar Connection.

G. Peres[1], F. Reale[1], S. Orlando[1], R. Rosner[2], H. Hudson[3]

[1] *Istituto ed Osservatorio Astronomico, Piazza del Parlamento 1, 90134 Palermo, Italy*
[2] *Department of Astronomy and Astrophysics, University of Chicago; Enrico Fermi Institute, Chicago*
[3] *Solar Physics Research Corp. Tucson, Arizona*

Abstract. This work takes advantage of the X-ray data provided by Yohkoh, and in particular by the SXT telescope, to compare the X-ray observations of active stars with those of the Sun and to analyze them with similar methods. Our scope is to study the features that other late type stars' coronae may have in common with the solar corona, and which differences exist. In other words we aim at studying the solar-stellar connection.

From couples of SXT images taken in two filters we first obtain the differential emission measure of the entire corona observed and then we synthesize solar X-ray spectra analogous to the stellar ones taken with non-solar instruments. Our approach allows a somehow direct comparison of solar and stellar observations, as well as the use of similar techniques of analysis.

We present results pertinent to ROSAT/PSPC data, some examples of relevance for ASCA/SIS observations and discuss future applications.

A *ROSAT* Deep Survey of the Galactic Plane $180° < l < 280°$

J.P. Pye,[1] J.E. Morley,[1] R.S. Warwick,[1] J. Pilkington,[2]
G. Micela,[3], S. Sciortino,[3] F. Favata,[4]

[1] *Department of Physics and Astronomy, Leicester University, University Road, Leicester LE1 7RH, UK*
[2] *Royal Greenwich Observatory, Madingley Road, Cambridge, CB3 0EZ, UK*
[3] *Istituto ed Osservatorio Astronomico, Piazza del Parlamento 1, 90134 Palermo, Italy*
[4] *Astrophysics Division, European Space Agency, Postbus 299, 2200 AG Noordwijk, Netherlands*

Abstract. We have performed a moderately deep soft X-ray (0.1–2 keV) survey of the Galactic Plane using pointed observations with the *ROSAT* Position Sensitive Proportional Counter (PSPC). The survey is more than an order of magnitude more sensitive than previous X-ray surveys near the galactic plane. The data consist of 9 fields each of ≈ 10 ks exposure, pointed at positions on or very close to the galactic plane ($|b| < 0.3°$) in the longitude range $180° \lesssim l \lesssim 280°$. This region has relatively low X-ray absorbing material out to distances of several hundred parsecs and presents less source-confusion problems than at other longitudes. The total sky area surveyed was 2.5 deg^2; this yielded 93 sources, 89 of which were detected only in the 'hard' (0.4–2.0 keV) band. Eight sources were detected in both 'soft' (0.1–0.4 keV) and hard bands. In the hard band, the survey coverage is $\gtrsim 90$ per cent for sources brighter than 0.002 count s^{-1} ($\sim 2 \times 10^{-14}$ erg cm^{-2} s^{-1}), but falls steeply below this value, with the weakest sources being ~ 0.001 count s^{-1}. The median limiting flux is ≈ 0.0013 count s^{-1} ($\sim 1.3 \times 10^{-14}$ erg cm^{-2} s^{-1}). There are 65 sources with hard-band count rates > 0.002 count s^{-1}. We present the catalogue of X-ray sources and the number–flux relations ($\log N - \log S$), and compare the measured number–flux relations with predictions of galactic (stellar) and extragalactic populations. Only four sources have possible identifications from the SIMBAD database. Work is in progress to identify the optical counterparts; multi-band CCD photometry has been obtained for most of the fields.

The Velocity Distribution in Pleiades and the Measurements of Small $v\sin i$

D. Queloz[1], S. Allain[2], J. C. Mermilliod[3], J. Bouvier[4], M. Mayor[1]

[1] *Observatoire de Geneve, Switzerland*
[2] *Observatoire de Grenoble, France*
[3] *Institut d'Astronomie de l'universite de Lausanne, Switzerland*
[4] *CFHT, USA*

Abstract. More than half of G and K dwarfs in Pleiades are slow rotators and most of them have only upper limits. Recent $v\sin i$ measurements have been carried out with the ELODIE spectrograph of the Observatoire de Haute-Provence. With the high stability of the spectrograph and the careful calibration of the cross-correlation technique all slow rotators in Pleiades are now resolved. The $v\sin i$ distribution has been transformed into a rotational velocity distribution and compared to predictions of theoretical models. This observations put some new constrains on the angular momentum evolution of solar type stars.

X-ray Emission from Young Clusters

Sofia Randich[1,2]

[1] *European Southern Observatory, Garching*
[2] *Osservatorio Astrofisico di Arcetri, Firenze*

Abstract. ROSAT PSPC and HRI have allowed to carry out sensitive X-ray surveys of several "young" open clusters, with young meaning in the 3×10^7 – 6×10^8 years age interval. This plenty of data enabled to define in more detail the preliminary picture of X-ray emission from late-type stars deriving from early *Einstein* observations of the Pleiades and the Hyades. At the same time, new questions have been raised by ROSAT observations.

I will first review the database which is now available; then, I will discuss the major results, focussing on the dependence of X-ray emission on age, rotation, mass, Rossby numbers, metallicity. The X-ray luminosity distribution functions (XLDF) of the various clusters (and of stars at different spectral–types within the same clusters) will be compared. Different questions will be addressed, such as: Is the dependence of X-ray activity on age only due to the dependence of rotation on age? Or is some other parameter playing a role? What are the possible causes for the so-called hyper-saturation?
Finally, I will discuss how ROSAT observations have allowed to identify a large amount of new candidate members not only in poorly studied clusters, but also in clusters which had been fairly well surveyed by means of traditional optical methods.

Stellar Flaring Loops

F. Reale, G. Micela, G. Peres, R. Betta, S. Serio

Istituto ed Osservatorio Astronomico, Piazza del Parlamento 1, 90134 Palermo, Italy

Abstract. Stellar flares are often detected in X-ray observations of stellar clusters. We propose and test a procedure tailored to analyse extensively and systematically stellar flares, which yields a reliable estimate of the dimensions of the coronal flaring loops and of the presence of a significant heating during the flare decay. The method is based on the analysis of the decay phase, using the light curve and indicators of the temperature evolution, and has been developed and tested successfully on spatially-resolved solar flares. We illustrate the application on flares observed with ROSAT/PSPC.

CCD Photometry of Open Clusters

John R. Stauffer

Harvard-Smithsonian Center for Astrophysics

Abstract. I will concentrate primarily on two subjects: the impact of mosaic CCD cameras on open cluster photometry and recent efforts to determine rotational periods for low mass stars in young open clusters.

Until quite recently, photometric surveys of nearby open clusters were greatly hampered by the relatively small physical size of CCD's. Individual clusters were either too nearby (so that their angular extent on the sky is so large that it would take a painfully large number of CCD frames to "tile" the cluster) or they were too distant (so that the stars of "interest" may be quite faint and it either takes a long time to do the program because the integration times are long or the program can't be done). That has changed greatly now, particularly with the introduction of mosaic-CCD cameras at several sites. I will briefly review the characteristics of some of these cameras, and provide examples of what can be done.

Even without mosaic-CCD cameras, it is possible to pursue photometric rotational periods of stars in nearby open clusters with CCD cameras on small telescopes. Several groups have been working on this topic, and I will report on their results in IC2602, the Pleiades, M35 and other clusters.

Evolutionary Models and Age Determinations of Galactic Clusters

Oscar Straniero, Alessandro Chieffi and Marco Limongi

Osservatorio Astronomico Collurania Via Mentore Maggini, Teramo, Italy

Abstract. Stellar evolution is the most powerful tool used to derive the age of many astronomical objects. The stellar clock, coupled with photometric and spectroscopic observations of galactic clusters, is widely used to understand the history as well as the present structure of our galaxy. Moreover, it provides constraints to cosmology, dynamical evolution of spiral galaxies, chemical evolution of matter and the like. However, since laboratory experiments in stellar conditions are very difficult, stellar physics is largely investigated by means of pure theory, with few experimental probes.

The current status of the research on stellar evolution is reviewed in conjunction with the problems of dating the various stellar populations of our galaxy.

Intermediate Age Open Cluster NGC 6940 and IC 4651 as Seen through the X-ray window

G. Tagliaferri[1], T. Belloni[2]

[1] *Osservatorio Astronomico di Brera, Via Bianchi 46, I-22055 Merate, Italy (gtagliafmerate.mi.astro.it)*
[2] *Astronomical Institute "Anton Pannekoek", University of Amsterdam and Center for High-Energy Astrophysics, Kruislaan 403, 1098 SJ Amsterdam, The Netherlands*

Abstract. In contrast to younger clusters, clusters with an age greater than ~ 1 Gyr are not expected to contain rapidly rotating single late-type stars, and therefore strong X-ray sources: in this respect, old and intermediate-age open clusters may appear to be of little interest to the X-ray observer. For these reason, the attention has been concentrated mainly on young clusters (30 to 700 Myr). However, there are stars older than ~ 1 Gyr that show rapid rotation: these are members of close binary systems, where tidal interaction prevents the stars from losing angular momentum; well-known examples are the RS CVn binaries. Thus, the observation of relatively old open clusters allows to study homogeneous samples of such binaries.

Here we present the results of soft X-ray observations of the intermediate-age open clusters NGC 6940 and IC 4651 performed with the ROSAT PSPC.

In the NGC 6940 we detected 16 sources, four of which are identified with member stars of the cluster and four with active field stars. The remaining eight, most likely of extragalactic nature, need to be identified through optical follow-up. As in the case of old clusters such as M 67 and NGC 752, a high fraction of the detected members are binaries: in NGC 6940 three out of four of the identified members are among the only six binaries known in the cluster. All four sources have X-ray luminosities typical of RS CVn binaries. However, only two of the three detected binaries have system characteristics typical of active X-ray binaries. The high X-ray luminosity of the other two sources needs to be explained. All four identified members are red giants, in agreement with the presence of a saturation level.

In the case of IC 4651, although the analysis is still in progress, we detected 25 X-ray sources, eight of which are identified with catalog stars. Of these, two are members of the cluster; a single line spectroscopic binary and a binary blue straggler. For the other stars we lack the membership information, however four of them seem to belong to the cluster.

We confirm the results found in other old open clusters, i.e. that binaries are still very active coronal sources at an age larger than 1 Gyr, and that good spatial resolution images in the X-ray band are a powerful tool to investigate their evolution in clusters of different ages.

ASCA Observations of X-ray from YSOs

Yohko Tsuboi

Cosmic Ray Group, Dept. of Physics, Kyoto Univ. Kitashirakawa-Oiwake-Cho, Sakyo, Kyoto 606-01, Japan

Abstract. With the hard X-ray sensitivity of ASCA, we obtained results striking our basic understanding for star formation.

1. We detected hard X-rays from class I sources deeply embedded in the Rho-Oph cloud. From these objects, we found bipolar flows with the radio observations. These put the sources to be protostars at dynamical mass accretion phase. One of the sources (EL29) shows a flare associated with a heat-up and cooling, while another (WL6) exhibits sinusoidal variation with no large spectral change. The later would be due to the spin rotation of the protostar. The sinusoidal period is about 1 day, which is shorter than the spin period of T Tauri stars (TTSs) of $\sim$3–7 day, which are more evolved than protostars.

2. We detected a giant flare from the WTTS, V773 Tau. The X-ray count rate rose by more than 2 orders of magnitude and then showed an near-exponential decay with a time scale of about 8 ks. The peak luminosity was recorded to be 1×10^{33} ergs s^{-1} for a distance of $\sim$150 pc. The plasma flared up to incredibly high temperature for a star, $\sim$9 keV, and then decreased to $\sim$6 keV. The absorption column of the flare component was larger than that of the quiescent component, which indicates about 3.6×10^{22} H cm^{-3} at the peak, and decreased. As have been seen in some cool stars, in the decay phase, we found the apparent change of the metal abundance for the first time in young stars.

The WIYN Open Cluster Study: Deep Photometry of NGC 188

T. von Hippel, T.[1], A. Sarajedini, A.[2], Constantine P. Deliyannis[3]

[1] *University of Wisconsin*
[2] *NOAO*
[3] *Yale University*

Abstract. We present a description of a large study of open clusters which is being undertaken at the WIYN telescope. We also present our early results on the old (age $\geq$ 5 Gyrs) open cluster NGC 188. We have studied this cluster at the KPNO 0.9m telescope to obtain wide field UBVRI photometry of the bright stars, and at the WIYN telescope to obtain much deeper VI photometry, to V $\geq$ 24. We present color magnitude diagrams spanning $\approx$ 13 magnitudes in V, vastly improving upon previous, mostly photographic, work. We use the observed color magnitude diagram to determine the age, distance and reddening of NGC 188. We also report on the low mass main sequence luminosity function and the cluster white dwarf luminosity function.

Discovery of the Sigma Orionis Cluster

Frederick M. Walter[1], Scott J. Wolk[2], M. Freyberg[3], J.H.M.M. Schmitt[3]

[1] *SUNY Stony Brook Astronomy Program, State University of NY, Stony Brook, NY 11794-2100, USA*
[2] *Harvard Smithsonian, Center for Astrophysics, 60 Garden St., Cambridge, MA 02138, USA*
[3] *Max Planck Institut für Extraterrestrische Physik. 85740 Garching, Germany*

Abstract. We report the discovery of a significant clustering of young low mass stars in the vicinity of sigma Orionis. The region is rich in X-ray sources. Followup optical spectroscopy shows that most are low mass pre-main sequence (PMS) stars. Using multi-object spectroscopy and wide-field CCD imaging, we have mapped the square degree surrounding Sigma Orionis.

In the immediate vicinity of sigma Ori we find

- over 80 X-ray sources positionally coincident with bright stars ($10<V<16$).
- over 100 low mass PMS stars identified from spectroscopy.
- a clustering of the PMS stars, with an inferred central density of 300 stars/pc^3.
- a clearly defined PMS locus, with an age of 2 Myr, ranging from $V=10$ down to $V>18$.

This cluster may be an older analog of the Orion Nebula Cluster. We will discuss the properties of these stars, and implications for the early evolution of dense clusters.

The Pre-Main Sequence Population of the Gum Nebula: Cometary Globule 31

Scott J. Wolk[1] Frederick M. Walter[2]

[1] *Harvard Smithsonian, Center for Astrophysics, 60 Garden St., Cambridge, MA 02138, USA*
[2] *SUNY Stony Brook Astronomy Program, State University of NY, Stony Brook, NY 11794-2100, USA*

Abstract. We report the initial results of our study of X-ray sources in the Gum nebula. For this presentation we have concentrated on a single cometary globule, #31. We have found about 30 X-ray sources in the 3 square degree region surrounding this globule. Photometric investigations found that 80% of the X-ray sources have a pre-main sequence (PMS) star within 30". Further, these PMS stars all lie about a common locus indicating an age of less than a few million years.

We continue to carry out a more global study of the colors across the globule. To date, photometry of over 6000 stars has been carried out. We find a well defined main sequence for the fiducial distance of 450pc. There is a small fraction (about 5%) of stars which lie above the main sequence. We are using these data to study star formation in the environment of small clouds.

Index