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FINAL Progress Report
for
Physical Properties of Gas Disks Around Shell Stars With and Without Dust

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Highlights: Analysis of archival IRAS and IUE data has resulted in:

1. Identification of 8 new A star proto-planetary candidates,
2. Detection of a mass outflow event around β Pic. The presence of mass outflow events has subsequently been confirmed by the 1991 July HST observation,
3. Confirmation of the suggestion by Waters et al. (1988) that 51 Oph is a protoplanetary system similar to β Pic with the detection of high density, high velocity, collisionally ionized accreting gas in the line of sight toward this star.

END

Indentification of New Proto-Planetary Candidates:

Circumstellar Dust Around HR 10, a Proposed β Pictoris Star: Following identification of accreting gas in Ca II toward the early A star HR 10 (HD 256), we examined IRAS data for this star and obtained IUE low dispersion spectra. The star was detected in IRAS Faint Source Survey Data and using the ADDSCAN/SCANPI software at 12 and 25 μm and marginally detected at 60μm. The IUE data are consistent with a spectral type of A2 with E(B-V)=0.01 assuming a galactic average (Savage and Mathis 1979) extinction law. With this spectrum, it is clear that HR 10 has an infrared excess beginning at 12μm and consistent with free-free emission and thermal emission from dust. Overall the IR colors of this star resemble Vega rather than β Pic. A paper on this star appeared in the Ap.J. (Letters) **366**, L87.

Identification of β Pictoris Analogs: A survey of IUE and IRAS data for previously identified A and B shell stars resulted in the measurement of a weak IR excess consistent with free-free emission for HD 93563, and detection of low velocity, accreting gas in 3 systems, HD 93563, σ Her (with a Vega-like IR excess), and 51 Oph (which has a peculiar IR excess discussed by Waters et al., 1988). Detection of accreting gas in one system apparently lacking solid debris, as well as the detection in one system with evidence for comparatively distant debris suggested that the accreting gas might be associated with Be-type mass ejection events rather than erosion of a proto-planetary disk. And Ap.J. paper was published on this topic (**367**, 296.).

Identification of New A Star Proto-Planetary Candidates: We have used the IRAS Faint

Source Survey database and ADDSCAN/SCANPI software to survey 2 stellar populations: 1) all 62 A stars in Woolley's (1970) catalog of stars within 25 pc of the Sun, and (2) 100 A stars with $4.5 \leq V \leq 5.5$ and $v \sin i \geq 100$ km s^{-1}. Previously only 11 of the stars in the Woolley sample were detected in 3 or more IRAS band passes using the IRAS PSC. Using the FSSDB and ADDSCAN/SCANPI software we detect 29 stars in at least 3 band passes. If typical of the galaxy, more than 16% of A stars have IR colors consistent with circumstellar debris. We report 5 newly identified systems, HD 29573, 78045, 84121, 159492, and 193571. We also find IR colors indicating circumstellar dust around 3 of the fainter A stars, HD 110411, HD 143894, and HD 125473. All 8 of the newly identified systems have IR colors resembling Vega rather than β Pic. A paper has been submitted to the Ap.J. (Letters) on 1 April 1992.

In an extension of this study, we have examined an additional 204 fainter high $v \sin i$ A stars using the Faint Source Survey Database and the ADDSCAN/SCANPI software in early April 1992. Analysis of this data will continue after the end of this ADP study under the auspices of a newly approved ADP study.

β Pic:

Mass Outflows Around β Pic: Analysis of archival IUE spectra suggested the presence of low-velocity outflow events (to -50 km s^{-1}) in 2 IUE spectra obtained in 1987 at a time of minimal mass accretion toward the star. These observations represent the first detection of mass outflows from a Main Sequence A star. An Ap.J. Letter was published on this topic (**371**, 27.).

Low Density CS Gas Toward β Pic: HST GHRS observations of the candidate proto-planetary system β Pic have revealed 2 low-density ($n \leq 10^3$ cm^{-3}) components at 10.3 and 28: km s^{-1}. Neither component agrees with the predictions of the local interstellar wind model (Crutcher 1982) for the location of interstellar features in this line of sight. Examination of the nearest, bright A star to β Pic, α Pic, suggests that the interstellar absorption toward that star is in agreement with the model, to within the resolution of the IUE, and assuming the +10 km s^{-1}offset in the LWP spectra noted between GHRS and IUE data. This result suggests that the components are indeed circumstellar. The 28: km s^{-1} feature is blended with high-density infalling gas at IUE's resolution, and is thus not amenable to further study. We have examined archival IUE spectra to determine whether there is any evidence for variation in the 10.3 km s^{-1} feature. Such variability would be an unambiguous signature of a circumstellar origin. Archival spectra, obtained in 1986, when the high-density infalling gas was at a minimum, suggest a marginal detection of such variability. These data need to be confirmed with additional higher S/N observations, such as can be provided by the HST. A poster paper summarizing our results was presented at the AAS meeting in Seattle, WA in May 1991. (B.A.A.S. **23**, 914).

The Accreting Circumstellar Plasma Around β Pic: Major support for the origin of the accreting gas around this star in evaporating cometesimals has been provided by the apparent

detection of progressively higher degrees of ionization with increasing radial velocity, and the apparent detection of features similar to the discrete absorption features seen in Ca II at velocities in excess of 200 km s^{-1} in Al III (Lagrange et al. 1987; Beust et al 1989). However, the HST observations of β Pic do not provide evidence for Al III absorption extending to higher velocities than seen in Fe II or Mg II. As a result we have re-examined the archival IUE data for β Pic. The initial report of extremely high velocity Al III was based on a 1σ detection in one spectrum and is highly sensitive to the choice of quiescent state comparison spectrum. Use of an average spectrum based on the 4 most quiescent IUE spectra in the archive reveals no significant Al III absorption for velocities in excess of +200 km s^{-1}, which is consistent with the HST data, and suggests that the evaporating cometesimal model for the accreting material may be either incomplete or incorrect. This analysis will be combined with the HST data obtained in July 1991. A paper on this topic is currently in preparation and will be submitted by mid-1992.

UV Studies of Other Systems:

Accreting Gas Around 51 Oph: We present a more comprehensive analysis of the circumstellar gas around 51 Oph. Inspection of archival IUE data, which have been supplemented by additional spectra obtained under our on-going 14th episode IUE program BPNCG, reveal variable, accreting gas visible in Fe II and Mg II with velocities as large as 90-100 km s^{-1} (heliocentric) or 100-110 km s^{-1} with respect to the system. The accreting gas has number densities and electron number densities comparable to those observed toward β Pic. We also find Al III, Si IV, and C IV absorption over the same velocity range as the circumstellar Fe II. The presence of Si IV and C IV around a B9.5 star is consistent with appreciable collisional ionization of the circumstellar gas. The presence of high number-density, high velocity, accreting gas in the same system as a debris disk strongly suggests that 51 Oph is a proto-planetary system closely resembling β Pic in both system components and in orientation. A poster paper on the archival data was presented at the Jan. 1992 A.A.S. meeting (B.A.A.S. **23**, 1378.). An Ap.J. (Letter) paper incorporating the archival data and new IUE observations made in late March 1992 has been prepared and will be submitted in mid-April 1992.

II. Publications Resulting from this Grant:

Cheng, K.-P., Grady, C.A., Bruhweiler, F.C., and Kondo, Y. 1990, "A Search for β Pictoris Analogs", in *Evolution in Astrophysics: IUE Astronomy in the Era of New Space Missions*, Kondo, Y., and Wamstekker, W., editors, ESA SP-310, 227.

Grady, C.A., Bruhweiler, F.C., and Kondo, Y., 1990, B.A.A.S. 22, 1256.

Cheng, K.-P., Grady, C.A., Bruhweiler, F.C., and Kondo, Y. 1990, B.A.A.S. 22, 1255.

Grady, C.A., Bruhweiler, F.C., Cheng, K.-P., Chiu, W.A., and Kondo, Y. 1991, "Circumstellar Disks of β Pictoris Analogs", *Ap. J.*, **367**, 296.

Cheng, K.-P., Grady, C.A., and Bruhweiler, F.C., "A Search for Circumstellar Dust Around HR 10, a Proposed β Pictoris Star", 1991 *Ap. J. (Letters)*, **366**, 87.

Bruhweiler, F.C., Kondo,Y., and Grady, C.A. 1991, "Mass Outflow in the Nearby Proto-Planetary System, β Pictoris", *Ap. J. (Letters),* **371**, 27.

Grady, C.A., Bruhweiler, F.C., Kondo, Y., Boggess, A., and Silvis, J.M.S. 1991, B.A.A.S. 23, 914.

Cheng, K.-P., Bruhweiler, F.C., Kondo, Y., and Grady, C.A. 1992, "Newly Identified Main Sequence A Stars with Circumstellar Dust", *Ap. J. (Letters),* , (submitted 1 April 1992).

Silvis, J.M.S. and Grady, C.A. 1991, "Collisionally Ionized Gas Around the Proto-Planetary Candidate Star 51 Oph", *B.A.A.S.*, **23**, 1378.

Silvis, J.M.S. and Grady, C.A. 1992, "The Circumstellar Gas Around 51 Oph: A Candidate Proto-Planetary System Similar to β Pic", *Ap. J. (Letters),* (in preparation).