Metallicities of Young Open Clusters with Debris Disks

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Abstract

We present first results of an optical ground-based spectroscopic program of young open clusters, including metallicities and radial velocities of F, G, and K dwarf cluster members. Our multi-object spectrograph observations from WIYN-Hydra and Magellan-MMFS complement MIPS 24 micron observations of 18 northern and southern clusters in the age range of 3 to 200 Myr, which were examined for excess MIR emission. The aim of this program is to consider the role that stellar metallicity may play in debris disk frequency and longevity.

Motivation

✧The goal of this ongoing project is to explore systematically the effects that stellar metallicity may have on debris disk longevity and "typical" disk evolutionary paths of late B and early A dwarf debris disks.

✧Self-consistent metallicities are needed to examine the dependence of debris disk occurrence on composition. We will produce a uniform set of global cluster abundances with small internal errors (~0.1 dex) to reduce systematic errors, which are crucial for inter-cluster comparisons. This will be accomplished using F, G, and K stars as tracers of global cluster metallicities.

✧A second, significant outcome of this study will be the establishment of radial velocity memberships for many assumed cluster stars in studies of excess MIR emission, which are heretofore unreported in the literature.

Observations

✧18 northern and southern open clusters in the age range of 3-200 Myr were observed with multi-object spectrographs: WIYN-Hydra, Magellan-MMFS, and CTIO-Hydra.

✧14 clusters were observed at 6400-6800A to allow coverage of youth-indicators, Li and H-alpha. Remaining clusters were observed at 6150-6400A.

✧Cluster metallicities are based on high S/N (~70-200), moderate-resolution [R(λ/Δλ)~13,000-15,000] spectra of F, G, and K cluster stars.

✧Clusters were observed at 24 microns with the Multiband Imaging Photometer for Spitzer (MIPS) for the presence of excess emission around B, A, and F stars by many workers.

Cluster	Age (Myr)	Disk Frequency of Early Type Stars	[Fe/H]	V_t Range Included* (km/s)
σ Orionis	2.5–3	0.15-0.20	0.10±0.11	27-34
λ Orionis	6	...	0.11±0.13	27-29
NGC 7160	10	0.08	0.20±0.13	-7 to -51
NGC 2232	30	0.53	0.14±0.14	25-26

Table 1. Ages, debris disk frequencies of early type stars, metallicities, and the range of radial velocities for program clusters.
*Stars were selected with radial velocities similar to those of early type cluster members, when possible.

Cluster	[Fe/H]	T_{eff} (K)	log g (cm/s²)	V_t (km/s)
σ Orionis				
star 87	0.14±0.08	4950	3.90	1.50
star 95	0.13±0.15	4700	3.90	1.50
star 23	0.18±0.09	6000	3.90	1.20
star 6	-0.06±0.11	4850	3.90	1.50
	0.10±0.11			
NGC 7160				
DG-62	0.18±0.14	6700	4.44	1.40
DG-895	0.25±0.15	6000	4.44	1.20
DG-64	0.20±0.12	6350	4.44	1.40
DG-61	0.18±0.11	6300	4.44	1.40
	0.20±0.13			
NGC 2232				
Lyra 431	0.11±0.12	5800	4.44	1.10
Lyra 76	0.16±0.15	5750	4.44	1.10
	0.14±0.14			
λ Orionis				
star 57	0.08±0.09	4950	3.90	1.40
star 24	0.10±0.09	5350	3.90	1.00
star 26	0.16±0.20	4975	3.90	1.50
	0.11±0.13			

Table 2. Metallicity determinations.
Note that $[Fe/H]=\log[N(Fe)/N(H)]-\log[N(Fe)/N(H)]_\odot$
Abundances of σ Ori are not expected to be affected by veiling (Gonzalez Hernandez et al. 2008).

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Select References
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Analysis

✧Stars were selected for analysis based on radial velocities consistent with cluster membership, by the presence of Lithium at 6708A, and H-alpha emission (in the younger clusters).

✧A curve-of-growth (equivalent width) LTE analysis was carried out to determine iron abundances using isolated Fe I lines.

✧Solar daylight-sky spectra were obtained during the same observing runs to permit an analysis differentially with respect to the Sun.

✧Abundances were determined using the LTE line abundance analysis code MOOG and Kurucz (ATLAS9) model atmospheres.

✧Initial effective temperatures were estimated with photometric color indices, and then refined by spectroscopic techniques.

✧Surface gravities (log g) were chosen to be values typical of pre-main sequence stars of similar ages and also by luminosity.

Preliminary Results & Discussion

✧Table 2 contains preliminary metallicities for bona-fide cluster members of four program clusters observed with WIYN-Hydra. The clusters presented have abundances comparable to solar metallicity within the errors, with small star-to-star dispersions.

✧Metallicities for the clusters are typically super-solar by 0.1-0.2 dex in [Fe/H], with typical uncertainties of 0.15 dex per star.

✧Surface gravity uncertainties are negligible for abundances derived with neutral Fe lines. For changes of 0.5 dex in log g, changes in [Fe/H] were 0.05 to 0.1 dex.

✧Disk frequencies for early type cluster stars from the literature are presented in Table 1. Forthcoming analyses of more clusters will permit the elucidation of possible correlations of disk frequencies with metallicity.

✧Remaining program clusters are expected to expand our range of metallicities since young clusters not observed with Spitzer have reported metallicities of $-0.3 < [Fe/H] < 0.3$.