Astronomical Observations with Implications for Nuclear Astrophysics: An SDSS-II Summary

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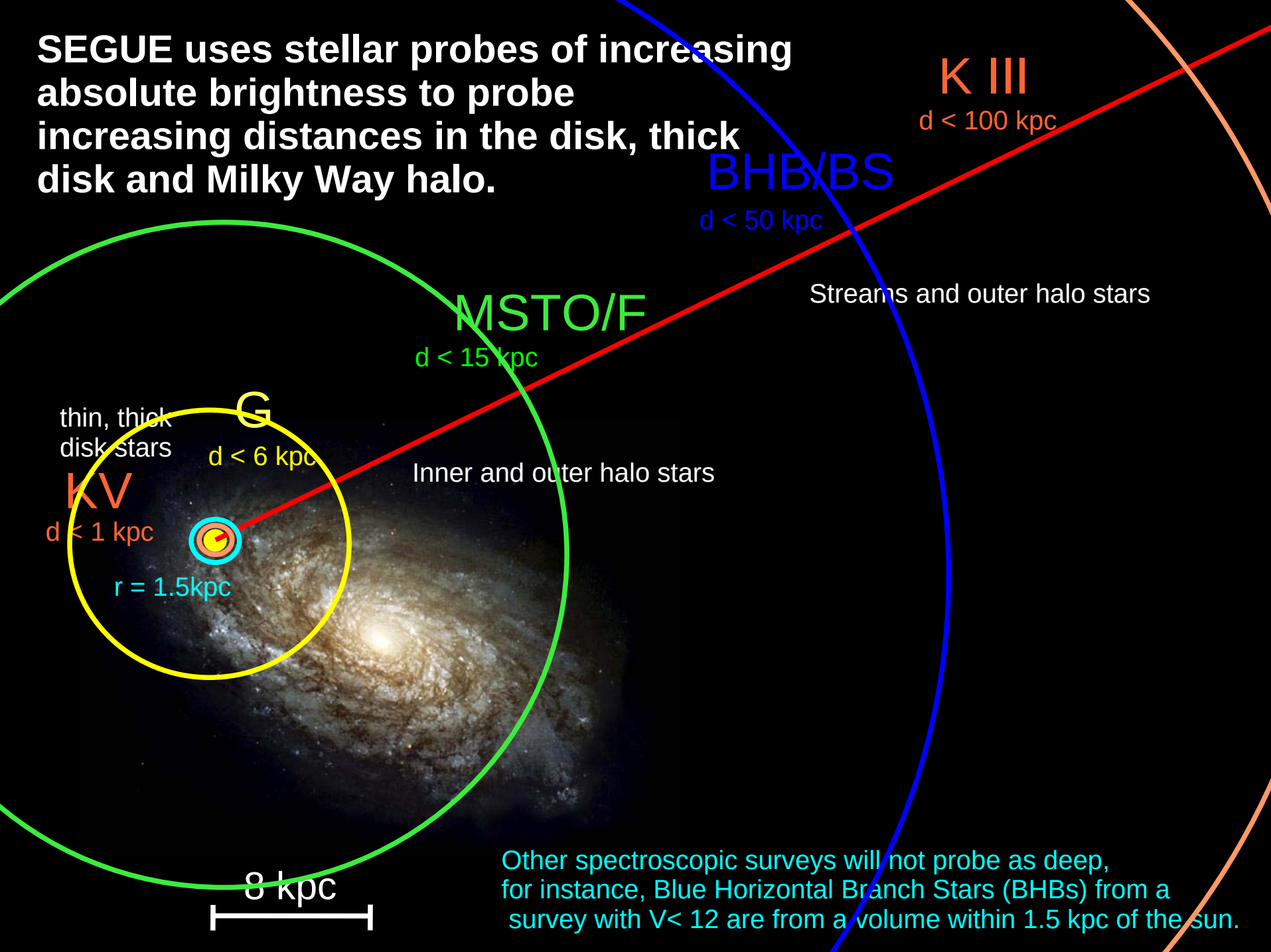
Present JINA Involvements

- SDSS-II (Sloan Extension, from July 2005 to July 2008)
  - SEGUE: Sloan Extension for Galactic Understanding and Exploration
    - Beers @ MSU coordinating JINA involvement
  - Supernova Survey
    - Garnavich @ Notre Dame coordinating JINA involvement)

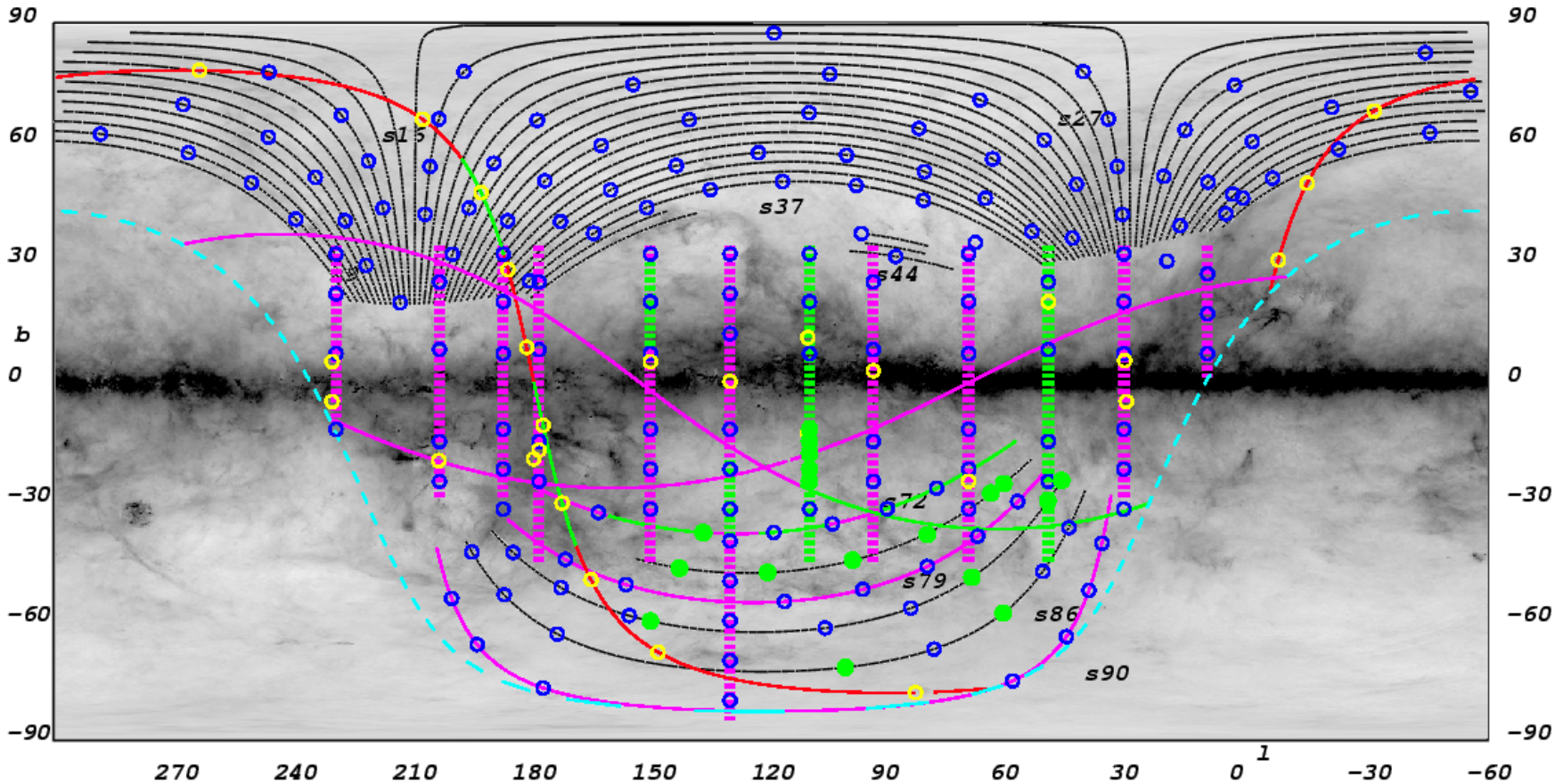
- International Collaborations
  - Australia (ARC grant to Asplund et al. / Skymapper Project)
    - Note: CEEC grant application was declined
  - Europe (Marie Curie Foundation CIFIST: Cosmological Impact of the First Stars; Bonifacio et al.)
  - Japan (close collaborations with Aoki et al.)

Summary of SEGUE and Supernova Survey

- **SEGUE**
  - **Obtain 3500 square degrees of new ugriz imaging at lower galactic latitude than SDSS-I ($|b| > 40^o$)**
  - **Obtain medium resolution spectroscopy (2.5 A) of 250,000 optimally selected stars for exploration of galactic structure and chemical evolution**
- **Supernova Survey**
  - **Discovery of intermediate redshift ($0.1 < z < 0.3$) Type Ia SN by intensive repeated scans of an equatorial stripe**
  - **A 2.5 degree wide region along the celestial equator, from roughly $-60 < RA < 60$, (SDSS Stripe 82) is imaged repeatedly for three months (September, October and November) in each of three years (2005-2007).**
  - **Confirmation of Type Ia status by (external) spectroscopic follow-up**
- **JINA's Financial Commitment**
  - **$250K, comprising $125K from Notre Dame, and $125K of "in kind" development work at MSU**
  - **MSU In Kind commitment is for development, testing, and refinement of SEGUE spectroscopic analysis pipeline (Teff, log g, [Fe/H])**
  - **Personnel: Beers (free) + ½ of JINA postdoc (Sivarani) + ½ of JINA grad student (Lee)**


SEGUE uses stellar probes of increasing absolute brightness to probe increasing distances in the disk, thick disk and Milky Way halo.
K III
d < 100 kpc
BHB/BS
d < 50 kpc
Streams and outer halo stars
MSTO/F
d < 15 kpc
thin, thick disk stars
G
d < 6 kpc
Inner and outer halo stars
KV
d < 1 kpc
r = 1.5kpc
8 kpc
Other spectroscopic surveys will not probe as deep, for instance, Blue Horizontal Branch Stars (BHBs) from a survey with V< 12 are from a volume within 1.5 kpc of the sun.

SEGUE observing plan and status as of April 2006



SDSS Imaging scan

Planned SEGUE scan (3500 sq deg)

Sgr stream planned scan

Completed SEGUE imaging

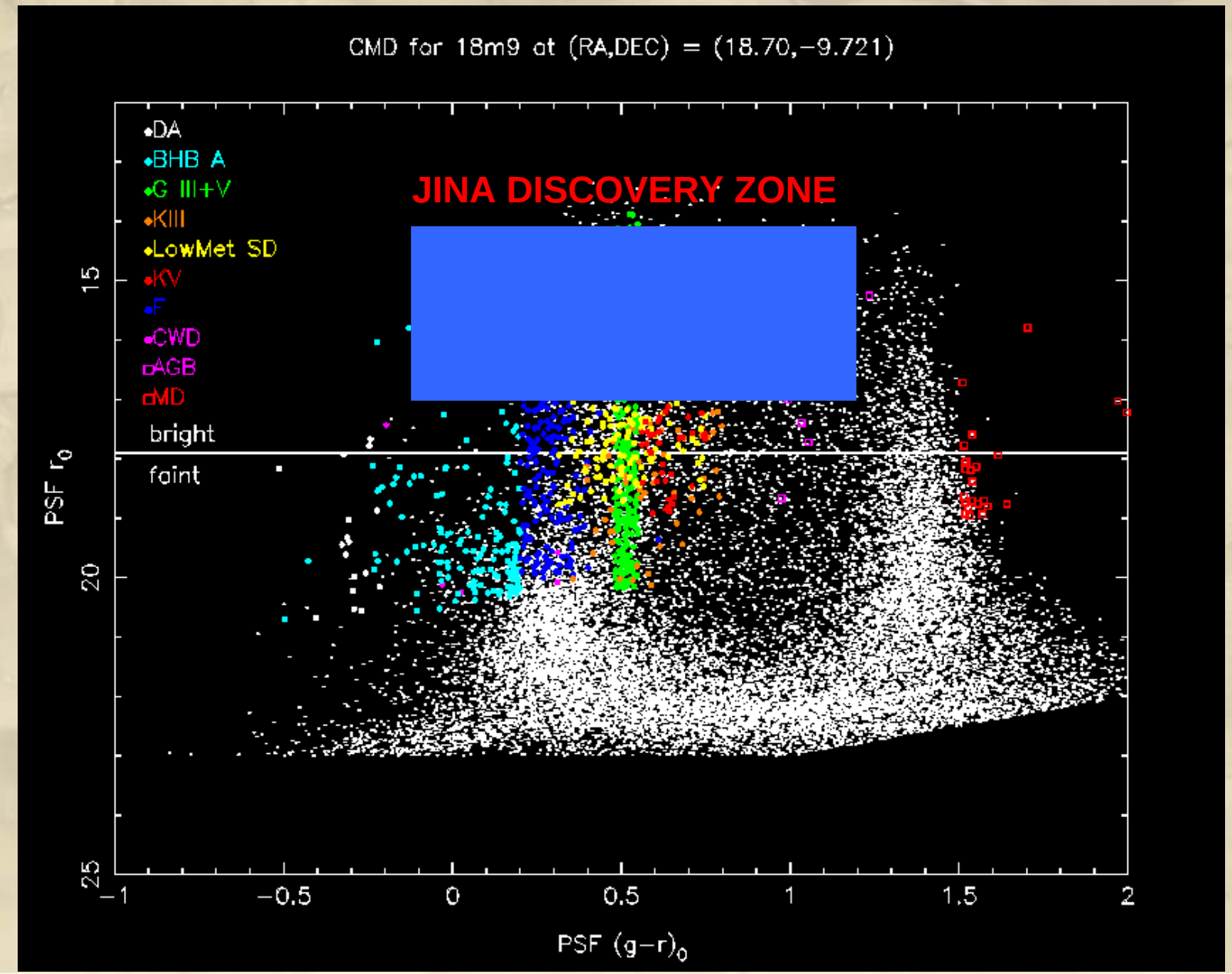
Declination = -20 degrees

Planned SEGUE grid pointings (200)

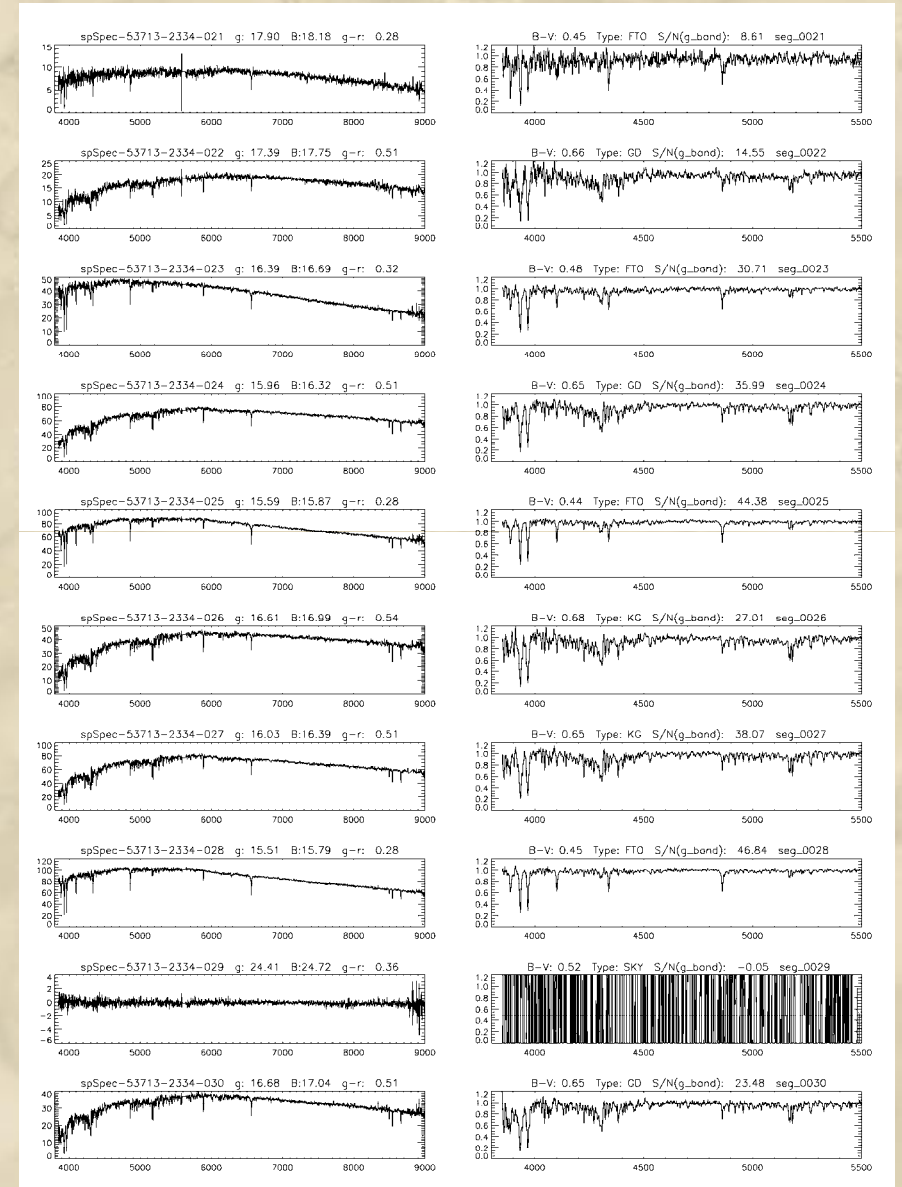
Planned targeted SEGUE pointings(60)

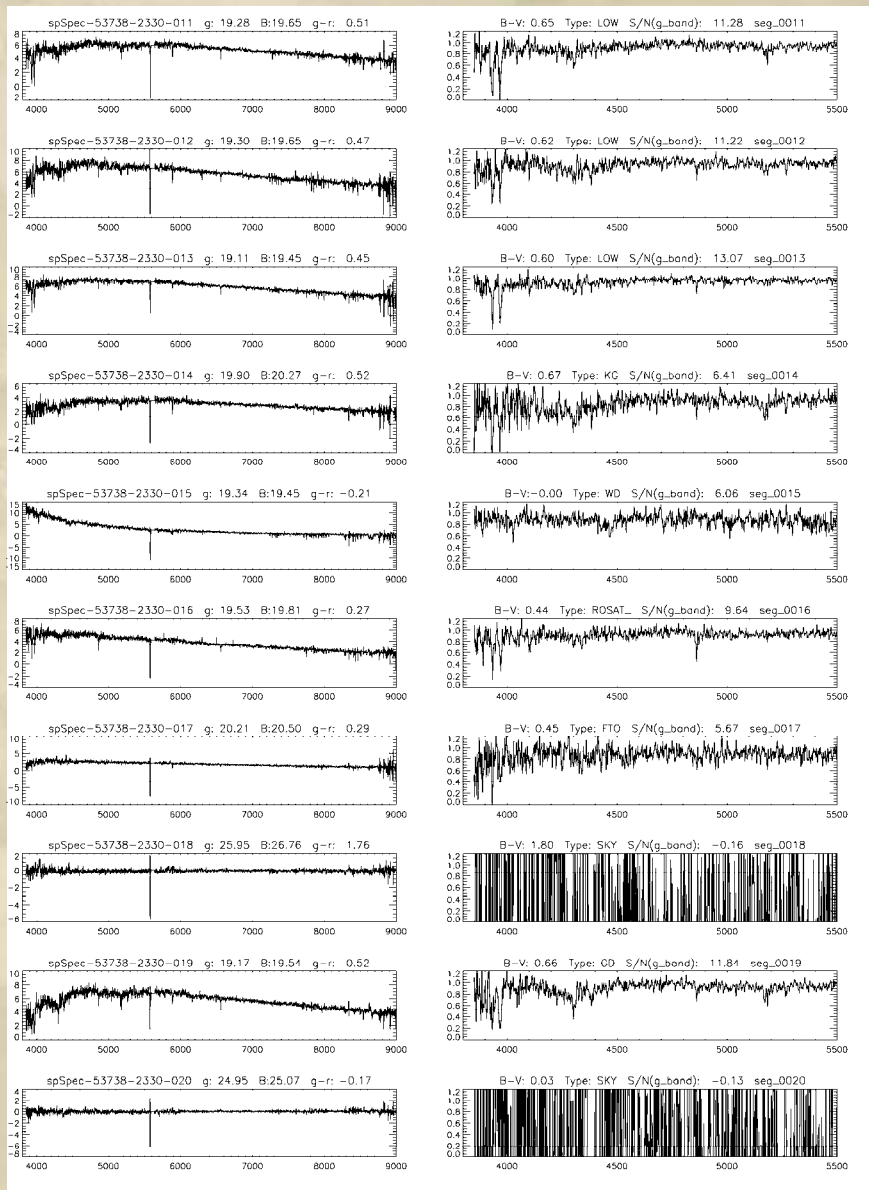
Completed SEGUE plate pointing

SEGUE Target Selection– “JINA-fied”

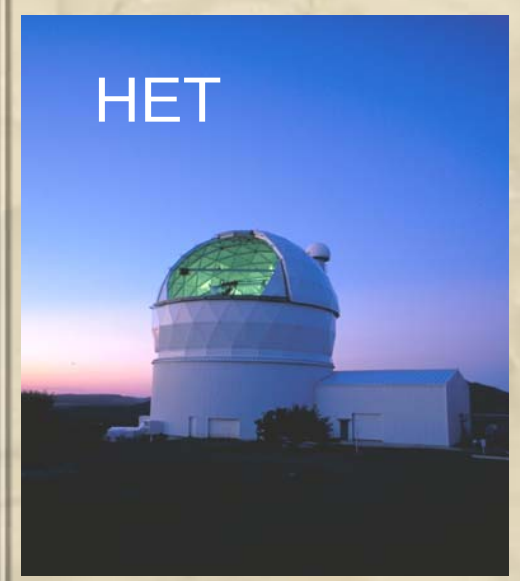


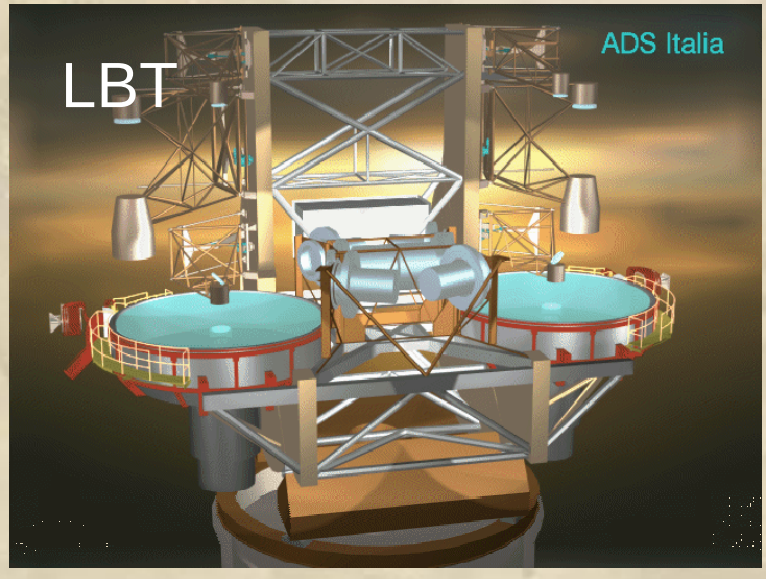
Example SEGUE Spectra

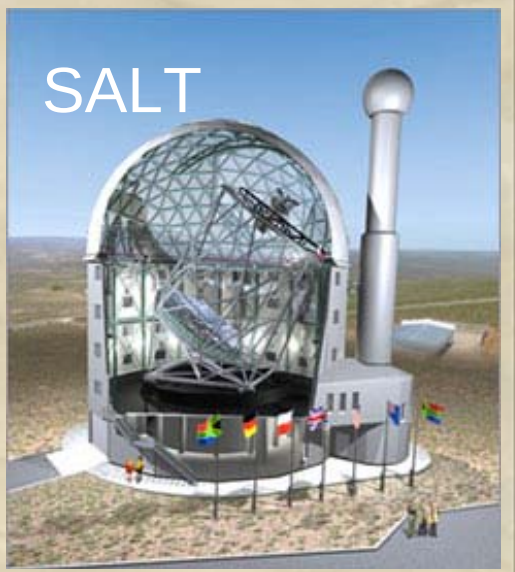




High-Resolution Follow-Up of SEGUE VMP Giants with B < 17







Present Status of SEGUE and Supernova Survey

- SEGUE
  - Tests of target selection algorithms carried out fall 2004 and spring 2005
  - Began taking data in July 2005
  - To date, approximately 1/3 of imaging (1500 square degrees) and 1/3 of spectroscopy (90,000 stars) observed
  - High-resolution follow-up of SEGUE stars for validation and refinement of spectroscopic pipeline underway (HET / Subaru / Keck)
- Supernova Survey
  - Tests of cadence, rapid processing (at APO) carried out fall 2004
  - Completed first of three planned sets of scans of Stripe 82 fall 2005
  - Discovery of over 100 Type Ia supernovae

Highlights of SDSS-I/SEGUE

- Discovery of large numbers of Metal-Poor stars
- Discovery of large numbers of Carbon-Enhanced Metal-Poor (CEMP) stars
- Discovery of new dwarf galaxies, and new debris streams

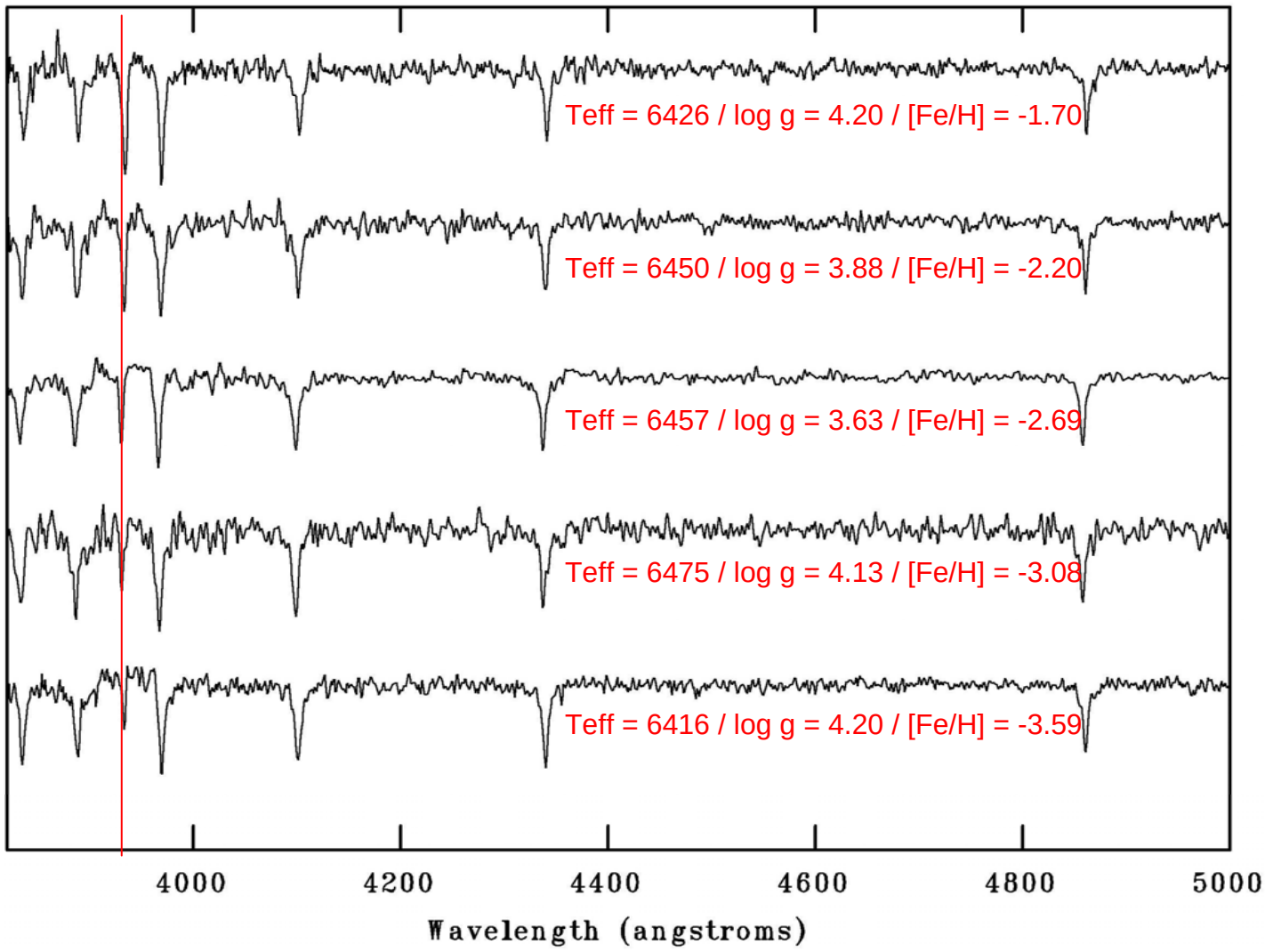
Likely Numbers of Detected MP Stars from SEGUE

- Actual numbers will depend on the shape of the halo Metallicity Distribution Function

–	[Fe/H] < -2.0	~ 20,000 (VMP)
–	[Fe/H] < -3.0	~ 2,000 (EMP)
–	[Fe/H] < -4.0	~ 200 ? (UMP)
–	[Fe/H] < -5.0	~ 20 ? (HMP)
–	[Fe/H] < -6.0	~ 2 ? (MMP)

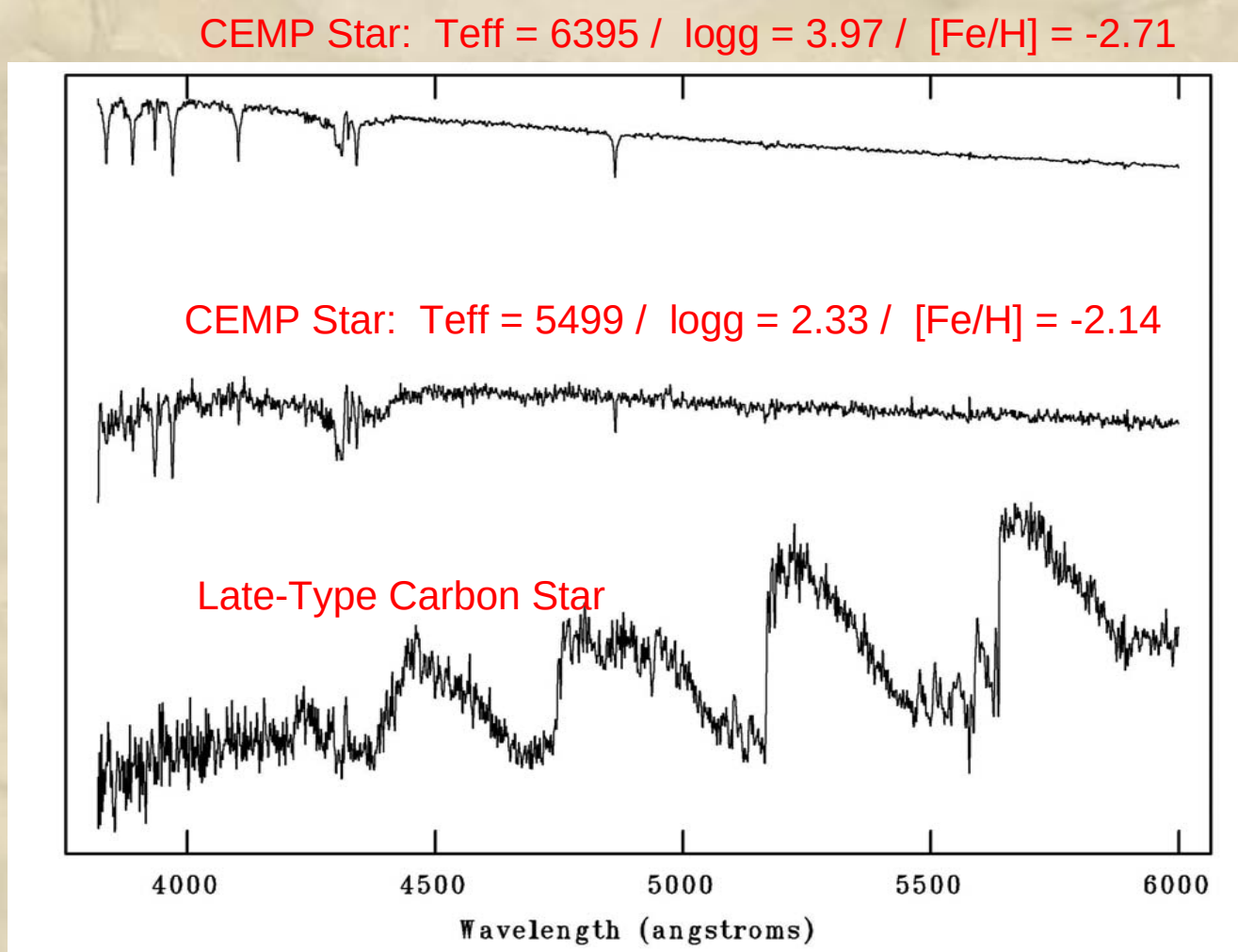
- Tests indicate we expect to find ~ 5000 CEMP stars among the SEGUE sample of MP stars

Example Main-Sequence Turnoff Stars of Low Metallicity

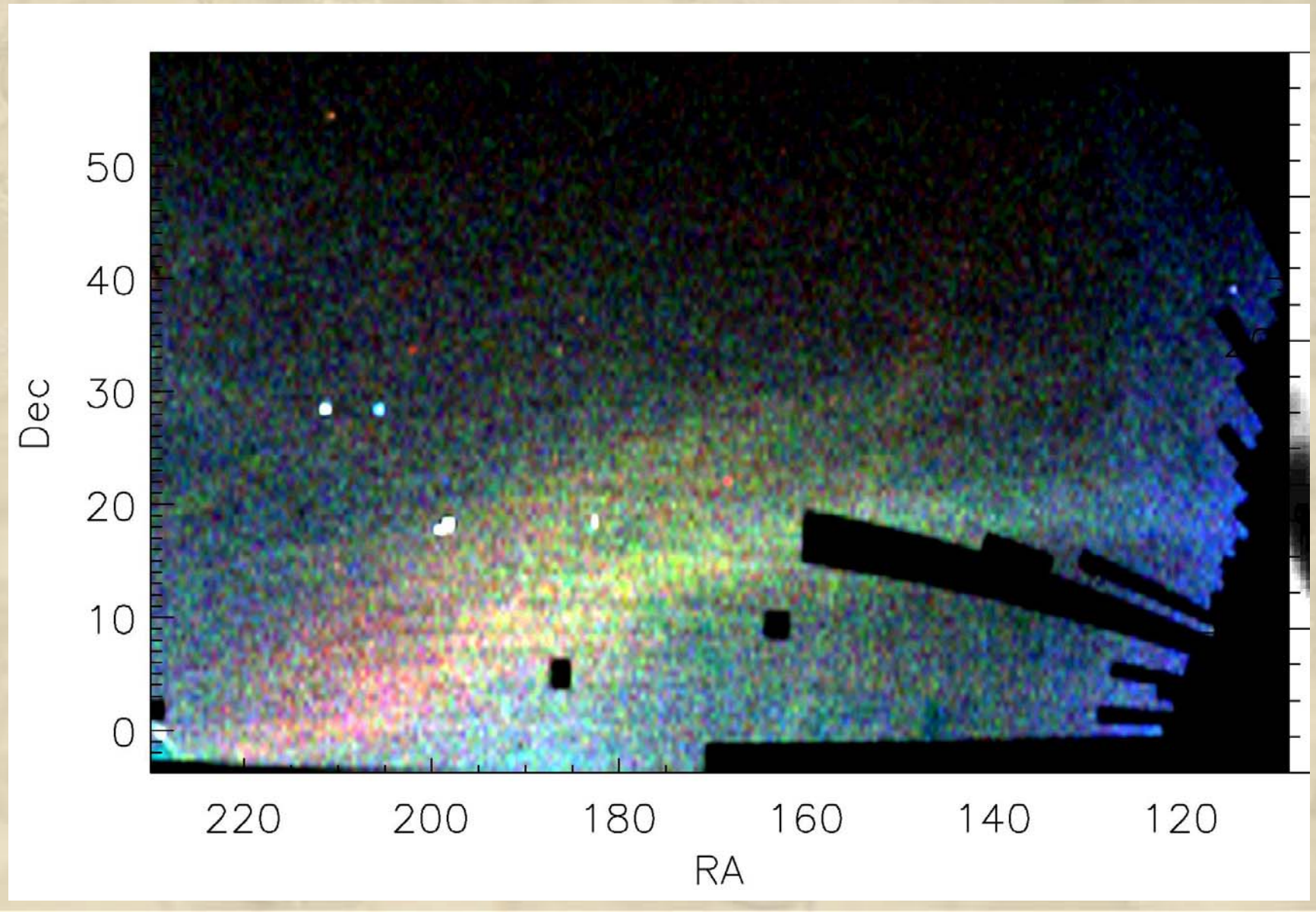


Example Spectra – Carbon-Enhanced Metal-Poor (CEMP) Stars

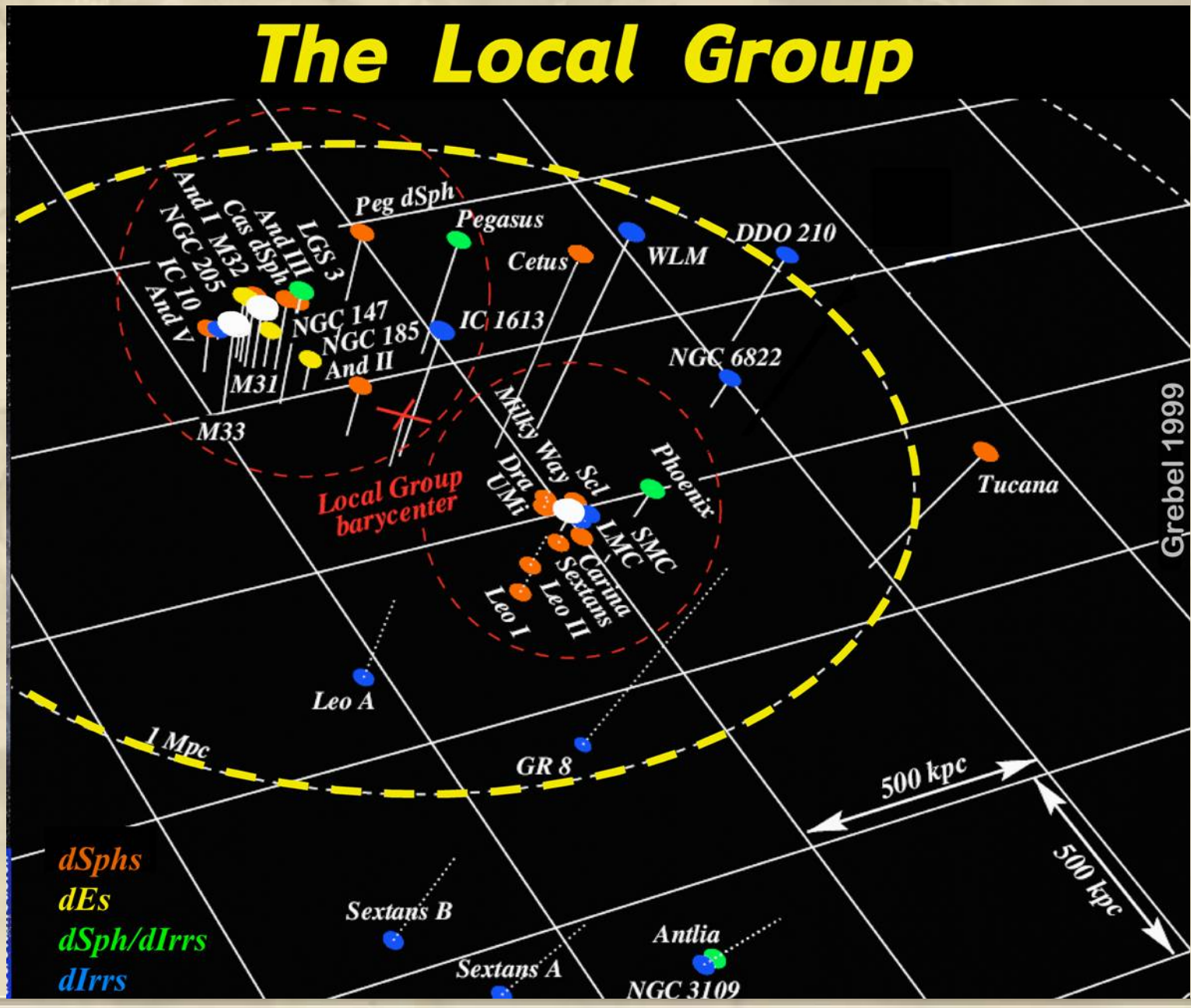
- Three spectra are shown, non-continuum normalized
- Upper two panels are examples of CEMP stars of different Teffs
- Lower panel is a late-type carbon star



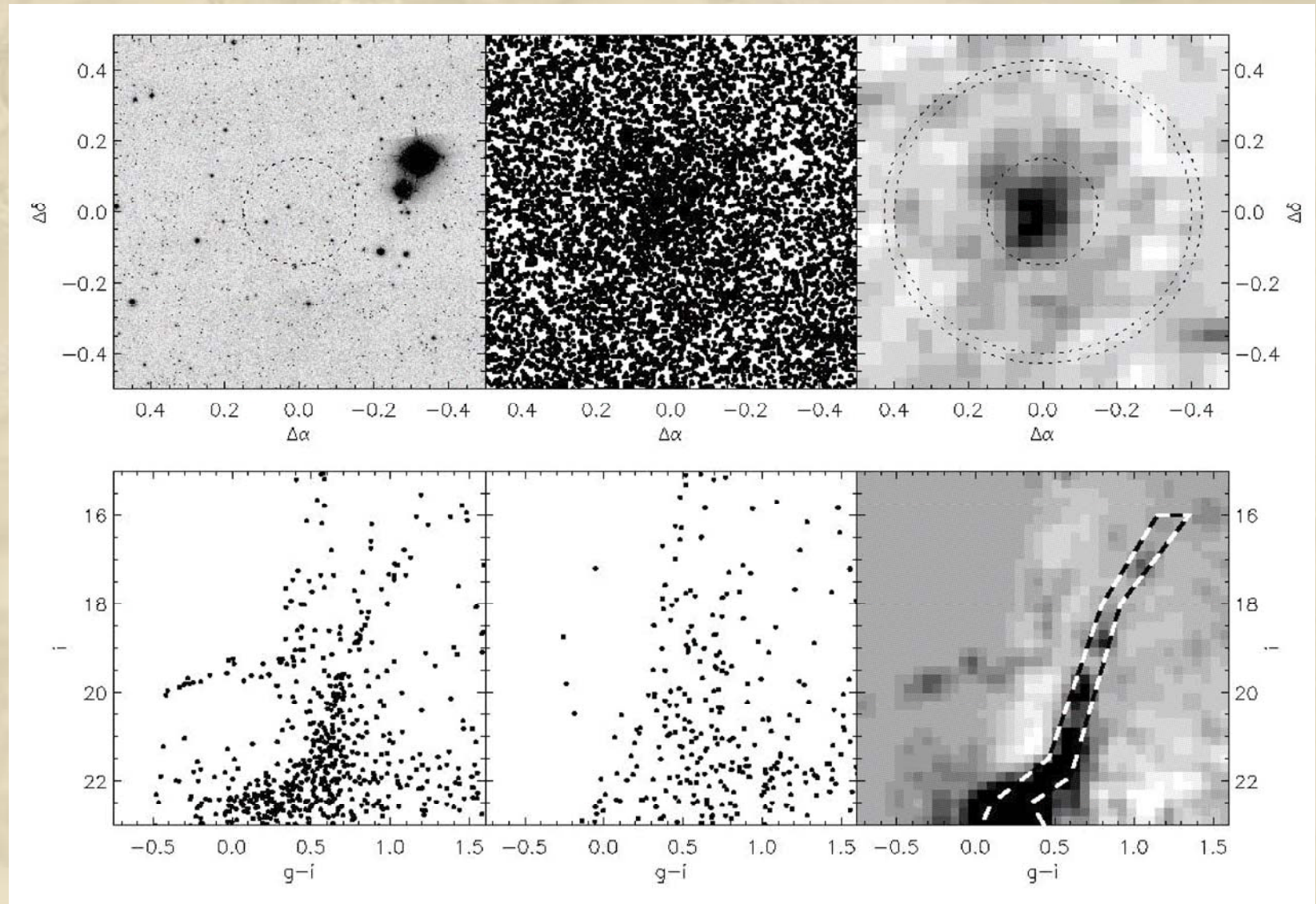
A Field of Streams in SDSS-I DR5



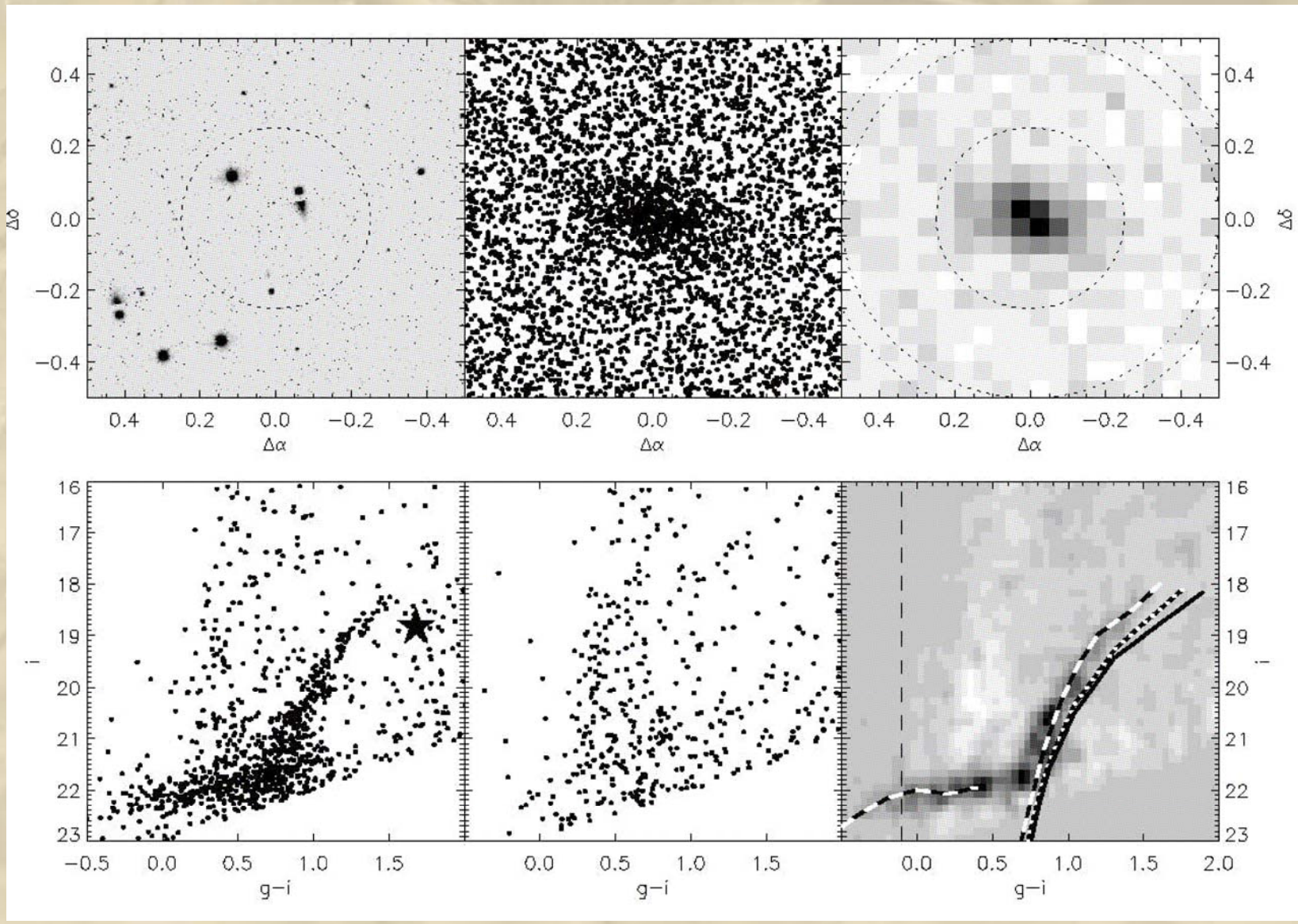
The Known Member Galaxies of the Local Group



Two New Dwarfs from SDSS

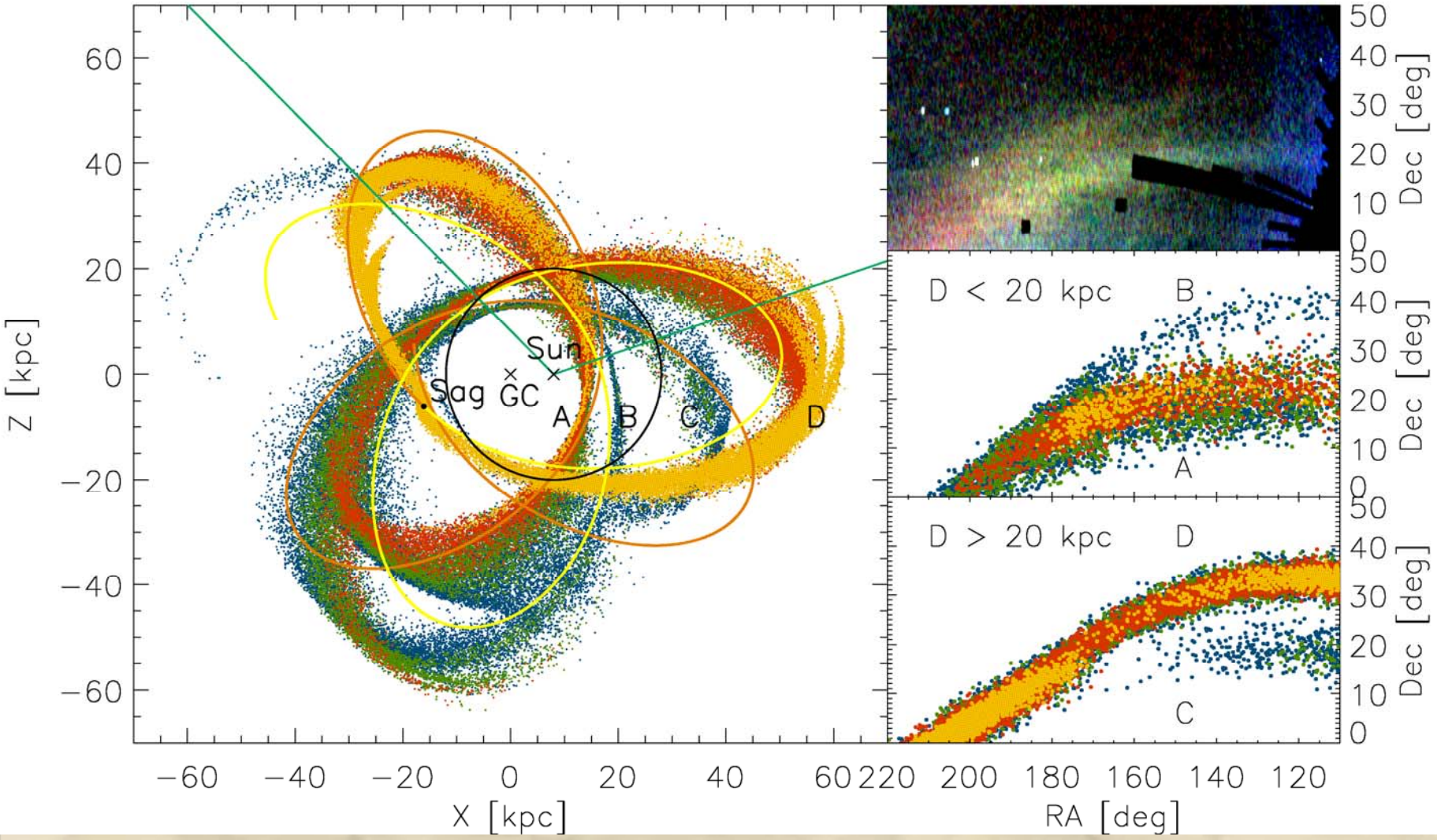


A New Dwarf Spheroidal Galaxy in Bootes

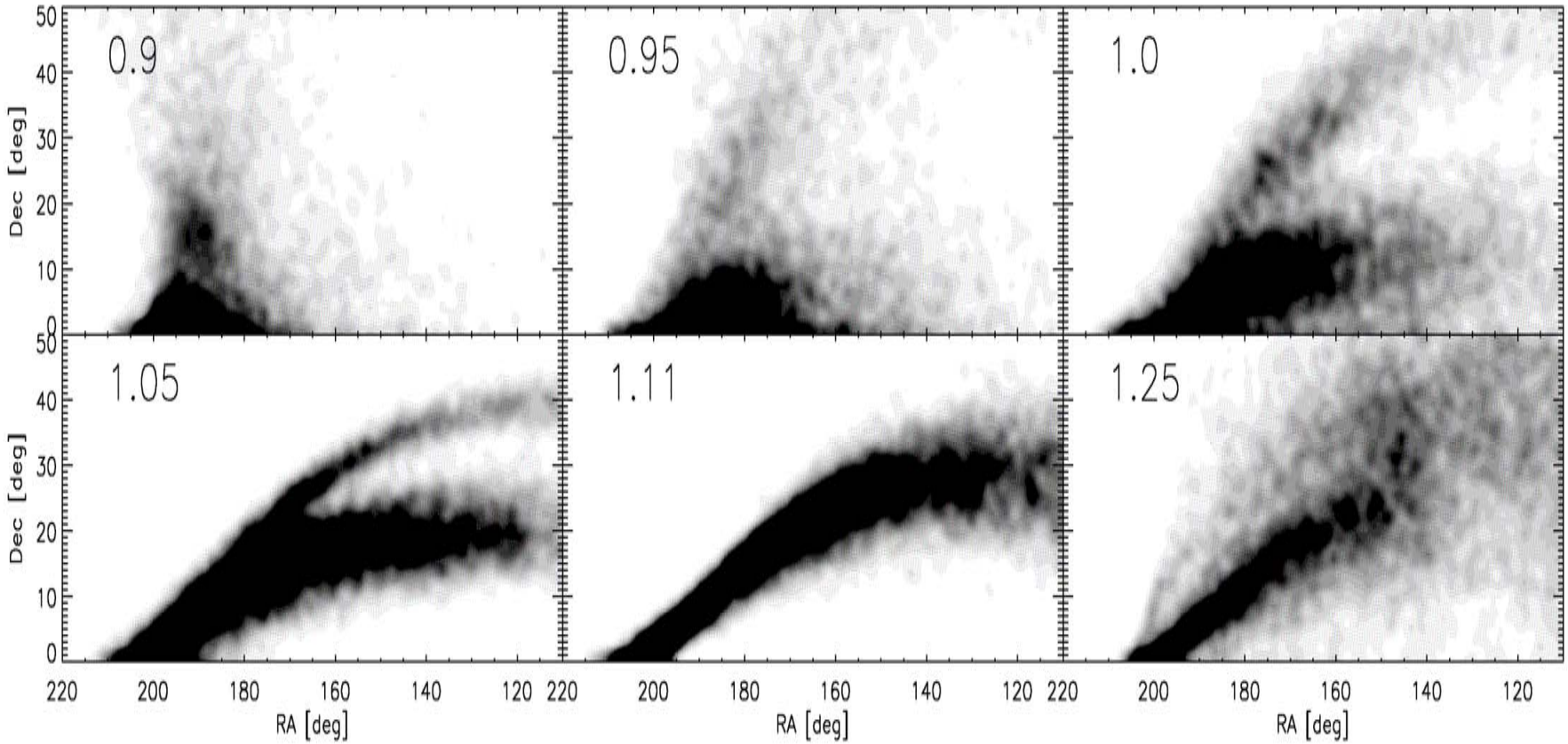


A New Dwarf Spheroidal Galaxy in Canes Venatici

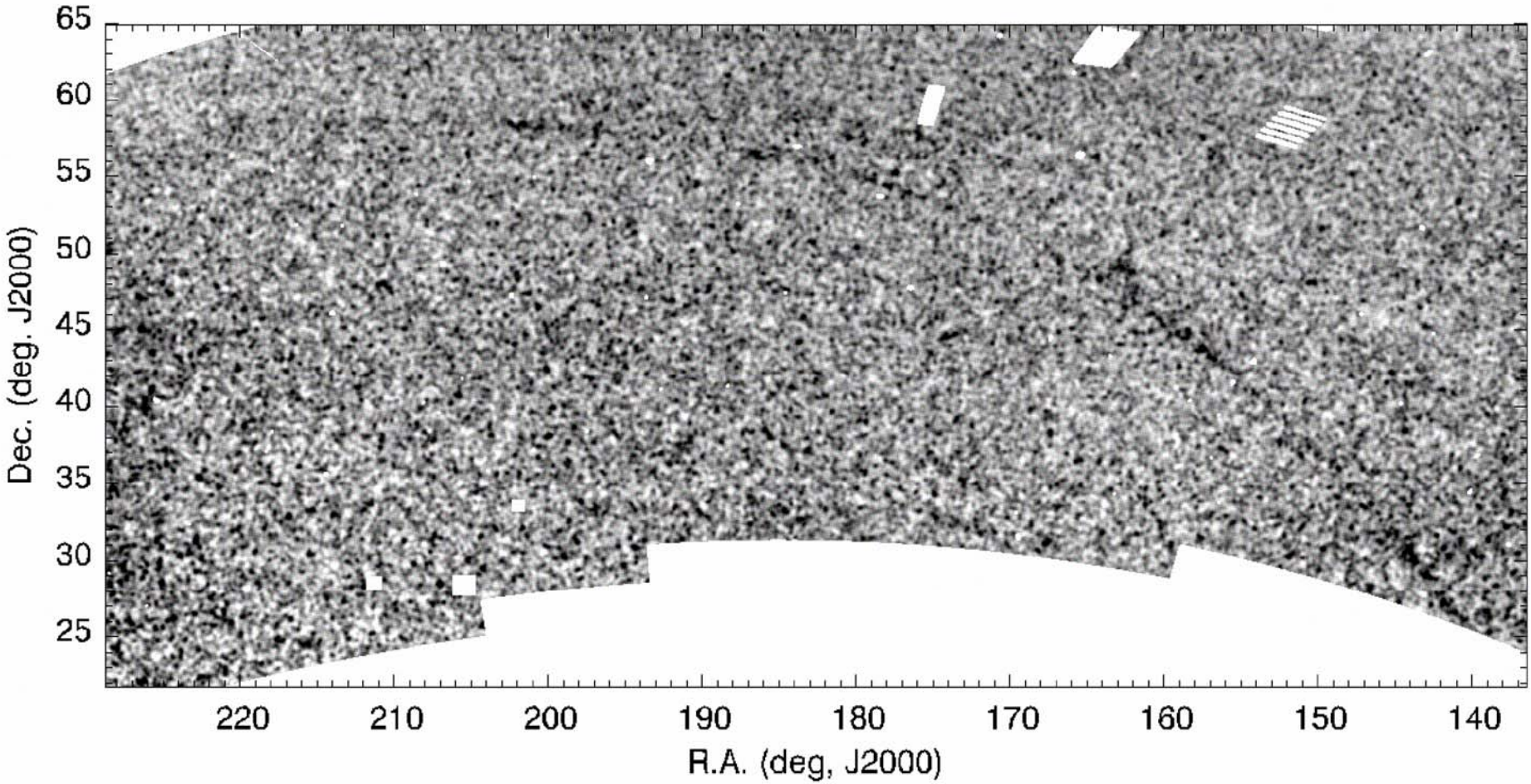
Predictions for Sagittarius Stream



Constraints on the Shape of the Milky Way Dark Matter Halo From the Sagittarius Stream

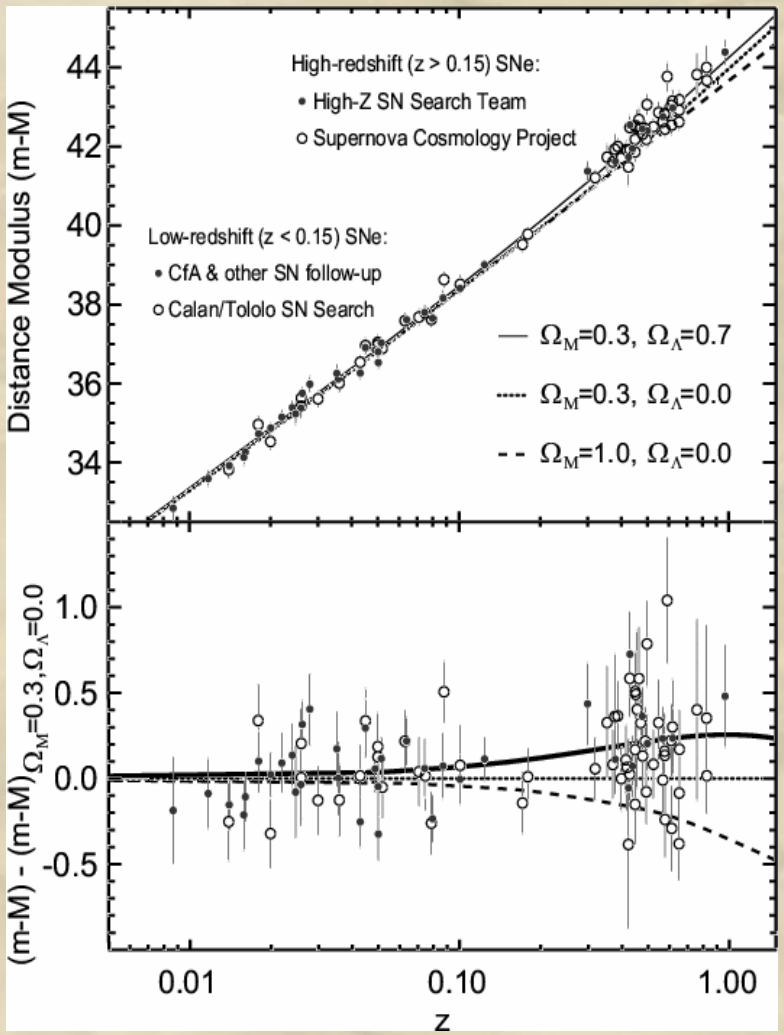


A New Stream Discovery

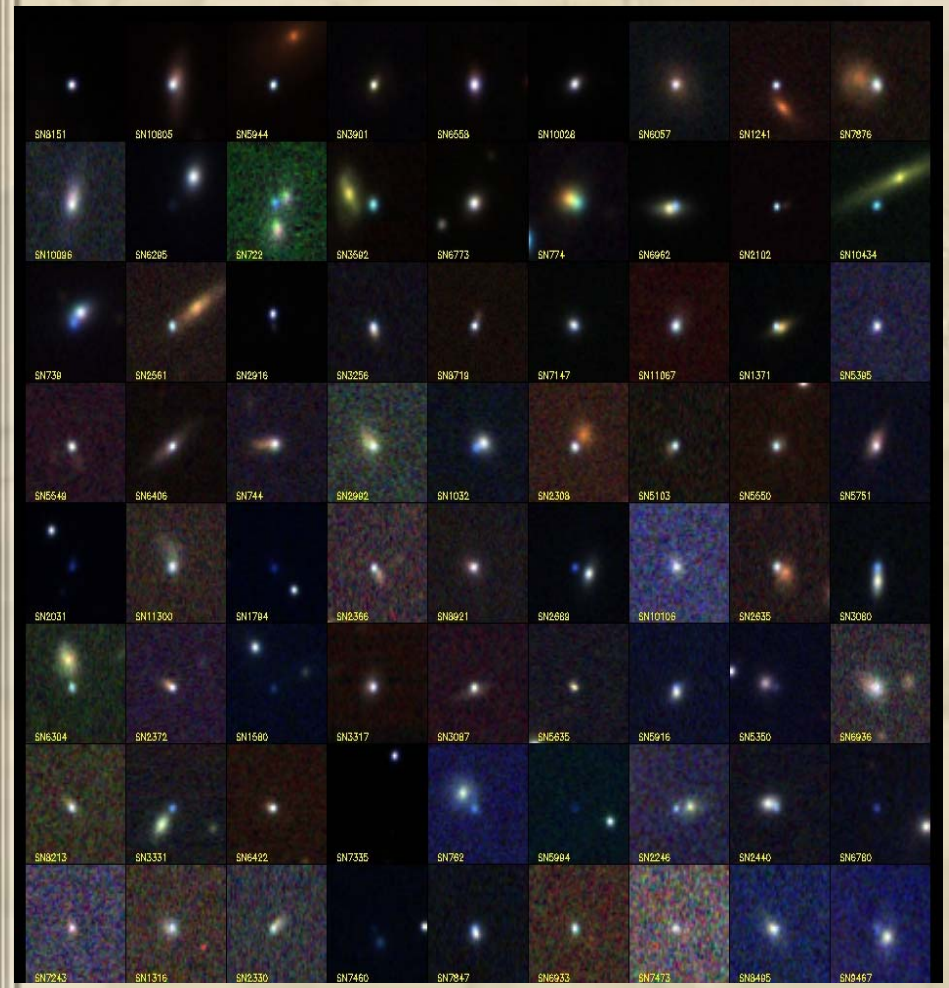


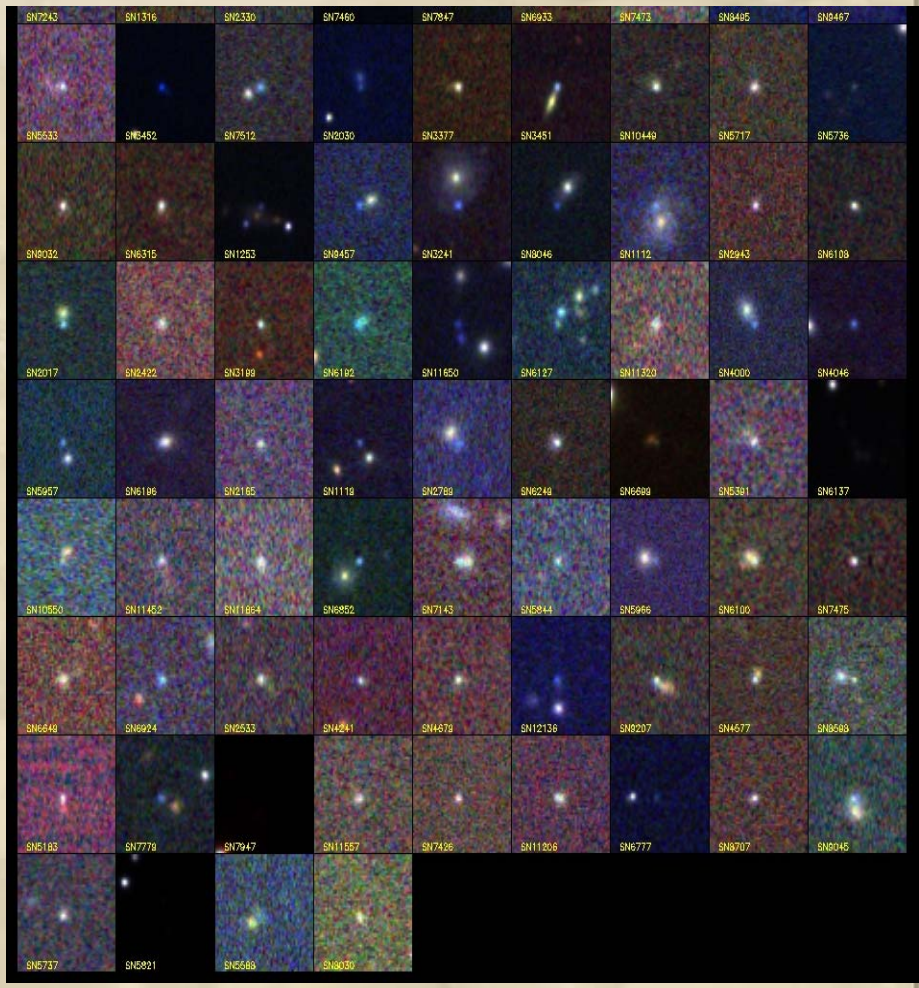
Highlights of Supernova Survey

SDSS-II images of a Type Ia supernova on the rise (top) and near maximum light (bottom)



139 Spectroscopically Confirmed Type 1a SN from Fall 2005

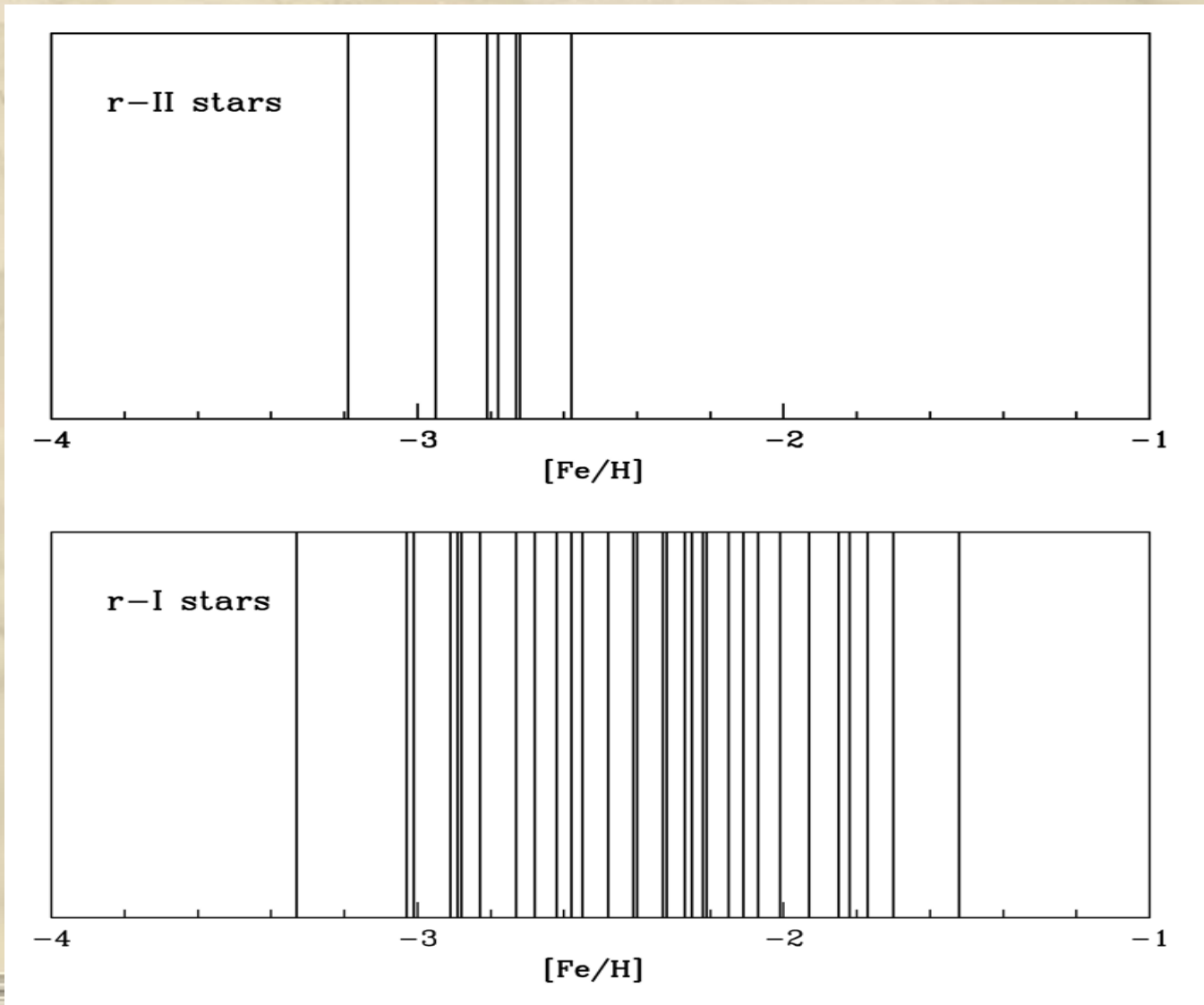




Other Research Highlights

- Discovery of 8 r-II and 35 r-I MP stars from HERES (Barklem et al. 2005) and distribution with [Fe/H]
- CEMP stars from HERES, their absolute frequency with [Fe/H], and possible association with high-mass (nearly zero-metallicity) progenitors
- Discovery of a [Fe/H] = -3.5 CEMP star that is presently on the TP-AGB (Masseron 2006)
- SOAR 4.1m NIR (K-band) observations of CO lines in CEMP stars
- New observations of Li in EMP stars

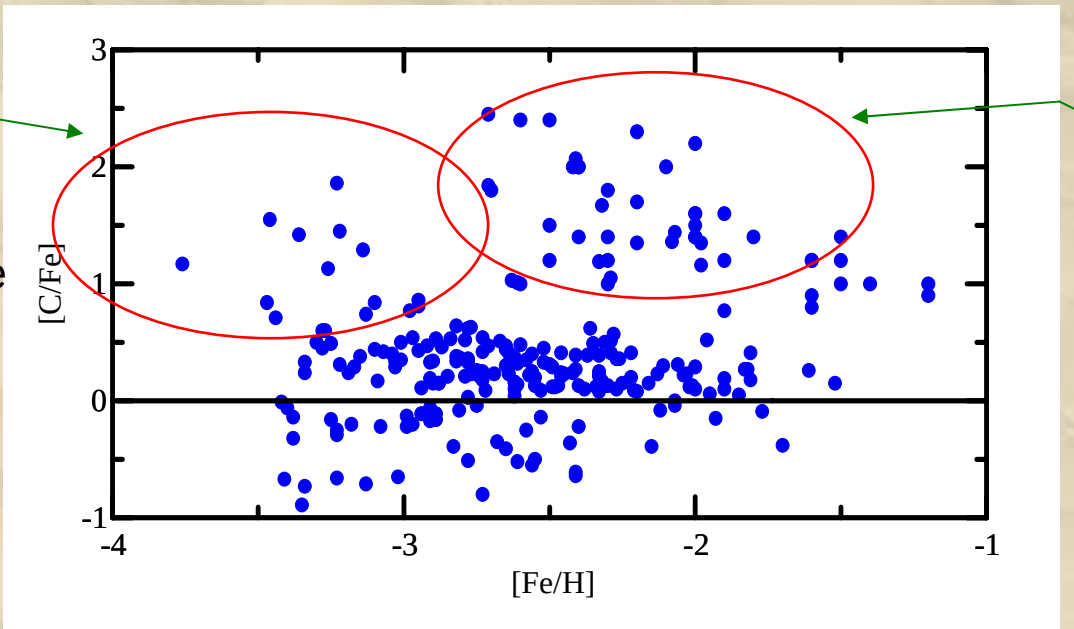
Distribution of [Fe/H] for R-process Enhanced Stars from HERES



The Origin of Carbon in the Universe – New Insights from Carbon-Enhanced Metal-Poor Stars

Among the most metal-deficient (iron-poor) stars in the Galaxy, JINA scientists have discovered that a large fraction of them – on the order of 20-25% -- exhibit strong absorption lines due to the presence of molecular carbon. CH, CN, and C_2 bands are quite prominent in medium-resolution optical spectra of these objects.

Carbon in these stars is likely created by massive first-generation stars in the early Universe



Carbon in these stars is likely created by nucleosynthesis in intermediate mass Asymptotic Giant Branch stars

High resolution spectroscopy with the European VLT 8m telescope has been used to verify the carbon abundances of these stars, and to produce a sample from which the absolute frequency of their occurrence can be derived as a function of metallicity, [Fe/H]. The observed distribution of [C/Fe] vs / [Fe/H] is shown above, based on work by Barklem et al. (2005).

Plans for Near Future

- **August 2006: Produce "value added catalog" of SDSS-I stellar parameters, based on at least partially completed calibration information (> 100,000 stars)**
- **Sep 2006: Initiate VLT survey (in collaboration with CIFIST) of additional EMP stars for extended studies of Li abundances**
- **Sep 2006: Initiate SOAR/OSIRIS survey of ~ 50-100 CEMP stars in near-IR, in order to obtain C, O, and $^{12}C/^{13}C$ abundances**
- **Dec 2006: Complete HET / Subaru / Keck high-resolution spectroscopic study of ~ 150 SEGUE stars, in order to validate assignment of atmospheric parameters**
- **Dec 2006: Complete population of JINA stellar abundance database**
- **Jan 2007: Initiate HET-RES survey of 2000-3000 brighter (g < 17) giants with [Fe/H] < -2.0, in hopes of finding ~ 100-150 r-II stars, ~ 300-500 r-I stars, numerous CEMP-s and CEMP-no stars**
- **Jan 2007: Initiate SOAR/Goodman survey of ~ 1000 HES, HK-II, and CEMP stars to obtain optical spectroscopy of most interesting remaining MP candidates from these surveys**

Example of Value-Added Catalog Output

SDSS STAR	RA (DEG)	DEC (DEG)	G_MAG	G-R	~B-V	VEL	FEH	SIGF	NF	LOGG	SIGG	NG	TEFFA	SIGT	NT
52518-0737-001	336.810840	12.047003	18.428	1.08	1.26	-24.4	-1.14	...	1	...	...	0	4279	...	0
52518-0737-030	337.549880	12.628333	17.338	0.41	0.56	-2.5	-1.00	0.22	5	3.82	0.28	4	5845	64	2
52518-0737-032	337.552970	13.147942	18.399	0.77	0.93	-36.0	-1.08	0.37	4	4.42	0.52	3	4766	...	1
52518-0737-039	337.488620	12.759767	19.220	0.52	0.65	-46.0	-2.05	1.48	2	3.95	0.80	3	5375	...	1
52518-0737-047	336.371220	12.346197	17.415	0.49	0.65	-73.7	-0.67	0.11	5	3.84	0.14	4	5607	21	2
52518-0737-065	336.663620	12.607524	20.903	0.76	0.88	56.8	-0.78	...	1	4.15	0.00	3	4732	...	1
52518-0737-075	337.092970	12.769260	16.007	0.29	0.44	-217.7	-1.44	0.22	5	3.31	1.19	2	6220	158	2
52518-0737-080	337.035320	12.970552	18.716	0.03	0.19	-351.8	-1.33	0.99	2	4.36	...	1	7631	164	2
52518-0737-086	336.298600	12.112614	17.997	0.40	0.58	-109.4	-1.02	0.31	5	3.59	0.39	4	5844	32	2
52518-0737-094	336.297150	12.284820	18.463	0.72	0.91	-1.9	-1.12	0.39	4	4.10	0.55	3	4986	...	1
52518-0737-112	336.478040	12.656192	19.099	0.89	1.07	-67.7	-2.01	0.73	2	1.40	0.40	3	4575	...	1
52518-0737-128	336.043610	12.122969	17.736	0.43	0.57	-7.8	-1.04	0.42	4	3.68	0.59	3	5664	...	1
52518-0737-129	336.095300	12.053612	20.473	0.52	0.67	-291.4	-1.55	...	1	4.36	0.04	2	5391	...	1
52518-0737-178	336.018120	13.123265	16.768	0.26	0.40	-262.4	-2.06	0.16	4	3.74	0.26	2	6390	92	2
52518-0737-235	335.638350	13.102211	15.973	0.43	0.58	-116.9	-0.75	0.06	5	3.82	0.08	4	5774	46	2
52518-0737-237	335.615940	13.010118	16.588	1.01	1.18	-46.3	-1.02	...	1	3.89	0.41	2	4377	...	0
52518-0737-241	335.526850	11.932741	16.831	0.31	0.47	-27.7	-1.24	0.46	4	3.71	0.64	3	6154	...	1
52518-0737-249	335.492610	12.278062	18.428	1.09	1.26	11.8	-1.11	...	1	...	...	0	4278	...	0
52518-0737-267	335.176260	12.736045	17.511	0.41	0.56	57.3	-0.93	0.21	5	3.79	0.26	4	5822	35	2
52518-0737-283	335.349100	12.182276	20.142	0.82	0.98	-37.5	-1.88	0.65	2	2.74	0.35	3	4580	...	1
52518-0737-286	335.276540	12.043587	20.624	0.73	0.86	-80.3	-0.06	...	1	5.53	...	1	4961	...	1
52518-0737-288	335.093170	12.234200	16.629	0.23	0.37	-124.4	-1.83	0.14	3	3.80	0.19	2	6593	51	2
52518-0737-313	334.837850	13.114356	17.457	0.39	0.54	10.0	-1.16	0.35	5	3.81	0.45	4	5884	110	2
52518-0737-322	335.336110	14.301547	16.887	0.51	0.67	-40.6	-0.47	0.09	4	4.47	0.13	3	5544	...	1
52518-0737-324	335.003250	13.971341	17.385	1.03	1.22	15.2	-0.54	...	1	...	...	0	4342	...	0
52518-0737-361	335.517290	14.330617	18.814	0.96	1.12	-70.4	-2.30	...	1	3.55	0.44	2	4454	...	0
52518-0737-362	335.531240	14.218181	16.835	0.42	0.58	-11.1	-0.55	0.23	4	4.20	0.32	3	5988	...	1
52518-0737-372	335.419960	14.191317	17.485	0.72	0.89	-44.3	-0.80	0.15	4	4.44	0.20	3	4986	...	1

Actually, this is a HIGHLY abbreviated version of the VAC, which will also include additional photometry, astrometry, spectral classification, distances, spectral indices, and notes on peculiarities of individual stars.

Plans for Moderate Future

- **July 2007: DR6 public release (1st public release of SEGUE / Legacy data)**
- **July 2007: Value added catalog of stellar parameters to accompany SEGUE / Legacy releases**
- **July 2008: DR7 public release, and additional value added catalog**
- **July 2008: End of SDSS-II**
- **July 2008: Beginning of SDSS-III – Instrumentation and efforts being discussed NOW**
  - **ASEPS: All Sky Extra Solar Planet Search (piggy back fibers)**
  - **Possibility of many tens of millions of stars with SDSS-resolution spectroscopy (synergy with GAIA, SIM, WFMOS, etc)**
- **July 2009: DR8 public release, and final value added catalog**

A Zoom-In on the SDSS-I DR5 Data Release