Dwarf Galaxy Archaeology Before and After Subaru/PFS

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with major input from PFS collaborators, including

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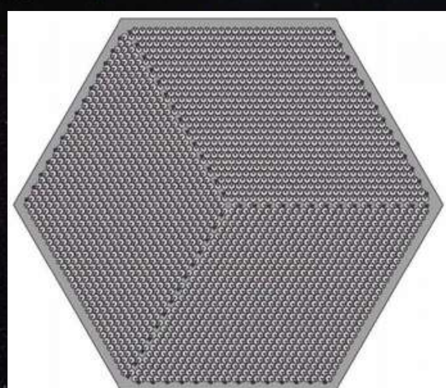
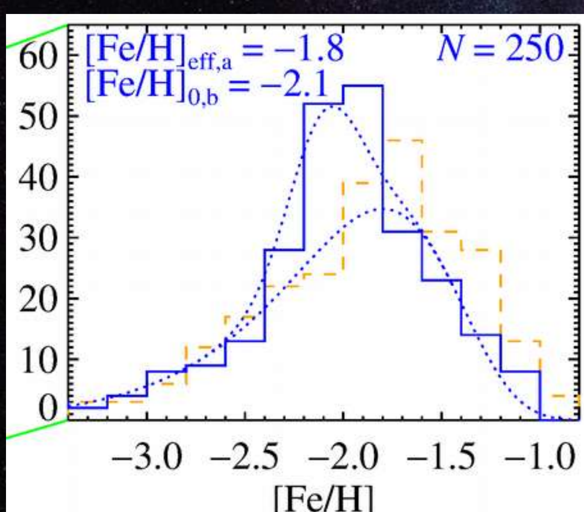
Kohei Hayashi 林航平
Naoyuki Tamura 田村 直之
Rosemary Wyse

SuMIRe Project
Subaru Measurement of Images and Redshifts

SUBARU TELESCOPE
National Astronomical Observatory of Japan

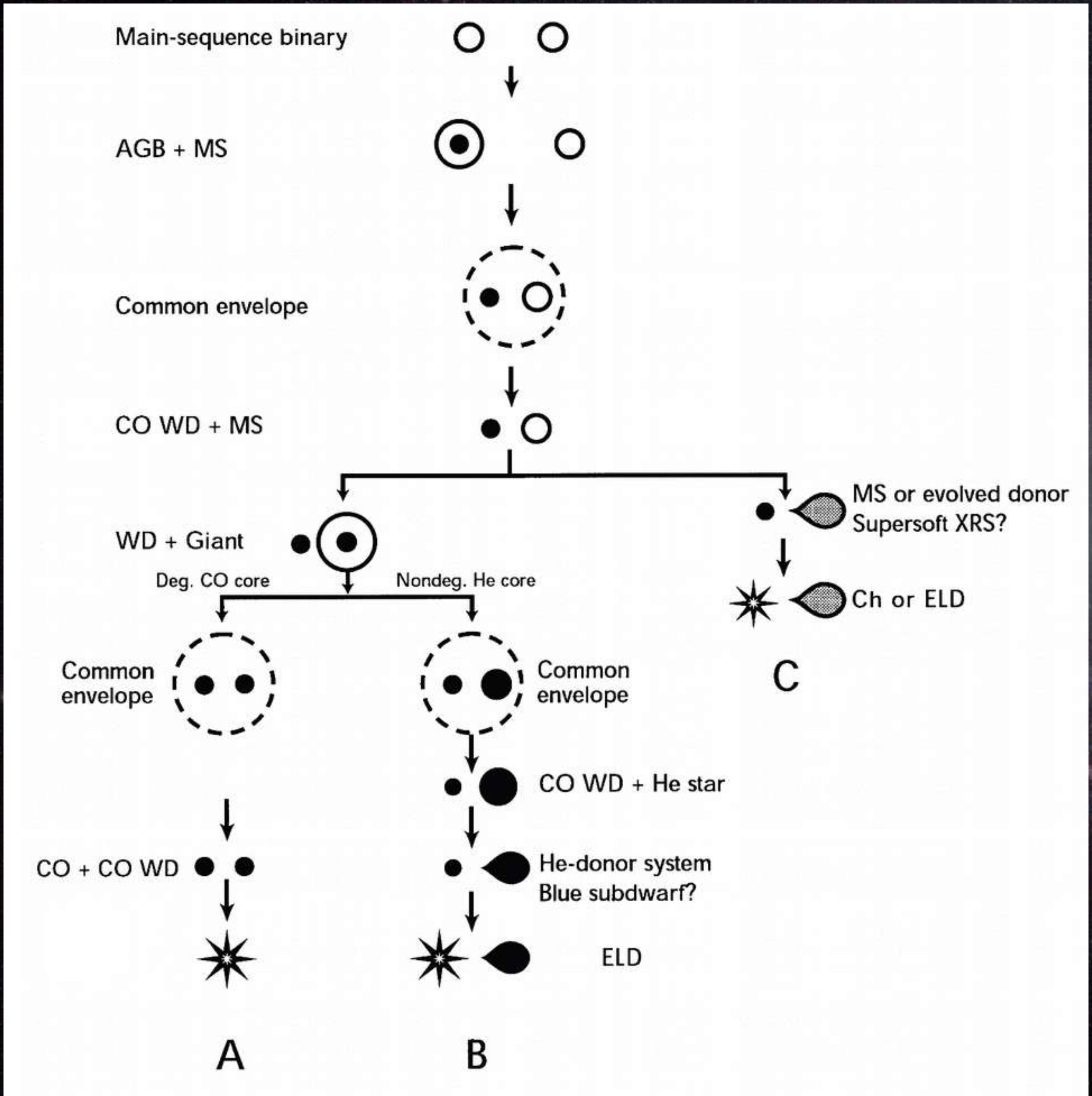
Outline





- **Before PFS:**
  - Iron-peak elements and the progenitors of Type Ia supernovae
- **PFS:**
  - Collaboration
  - Instrument
  - Survey design
- **After PFS:**
  - Dark matter density profiles
  - Abundance distributions

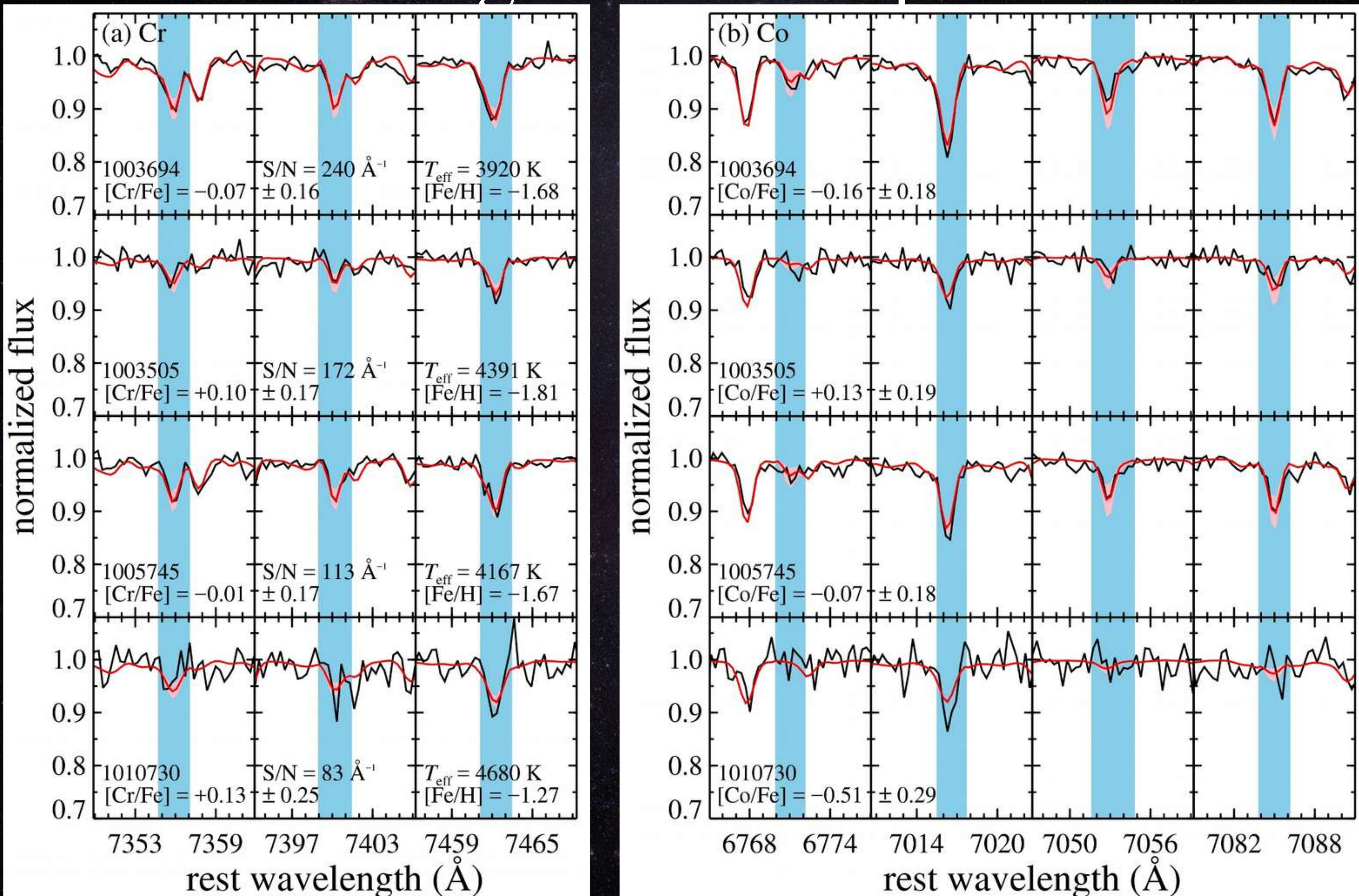
There is more than one way to explode a white dwarf.



Model	Mass	Components
A	M_{ch} or sub-M_{Ch}	double degenerate
B	sub-M_{Ch}	single degenerate
C	M_{Ch}	single degenerate

Yungelson & Livio 2000, ApJ, 528, 108

We measured Cr, Co, and Ni from existing DEIMOS spectra.



Kirby, Xie, Guo, Kovalev & Bergemann 2018, ApJS, 237, 18

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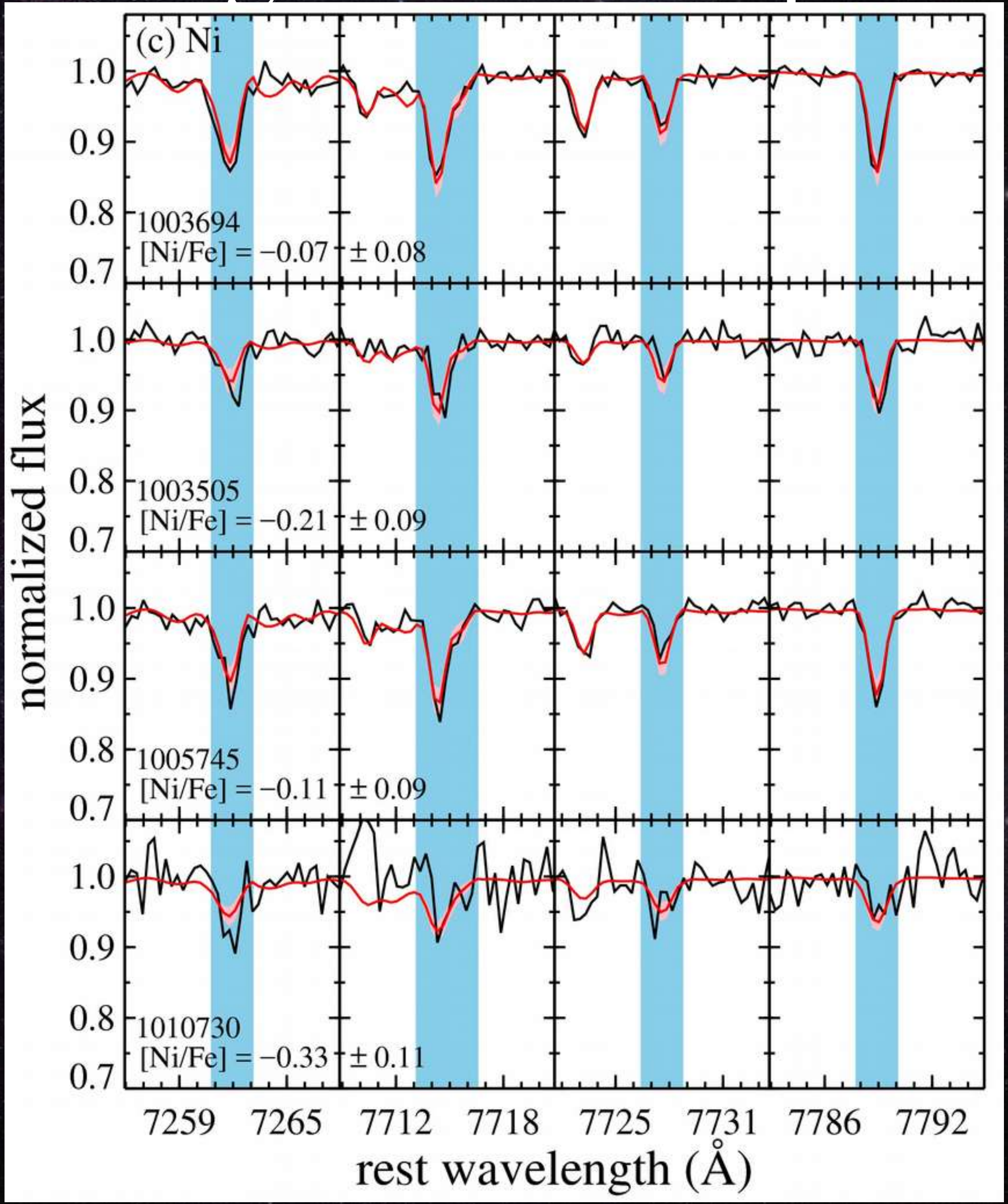
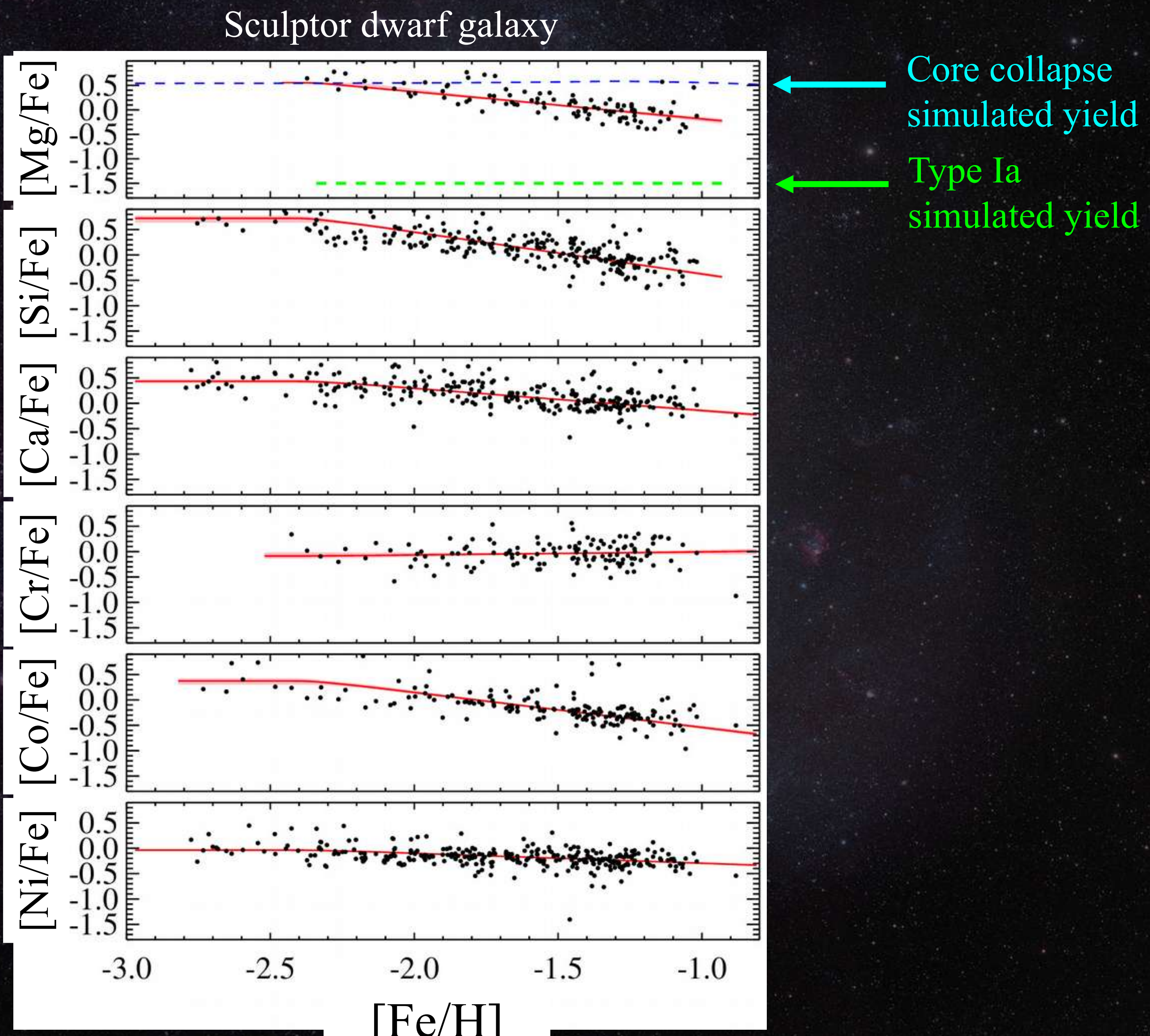
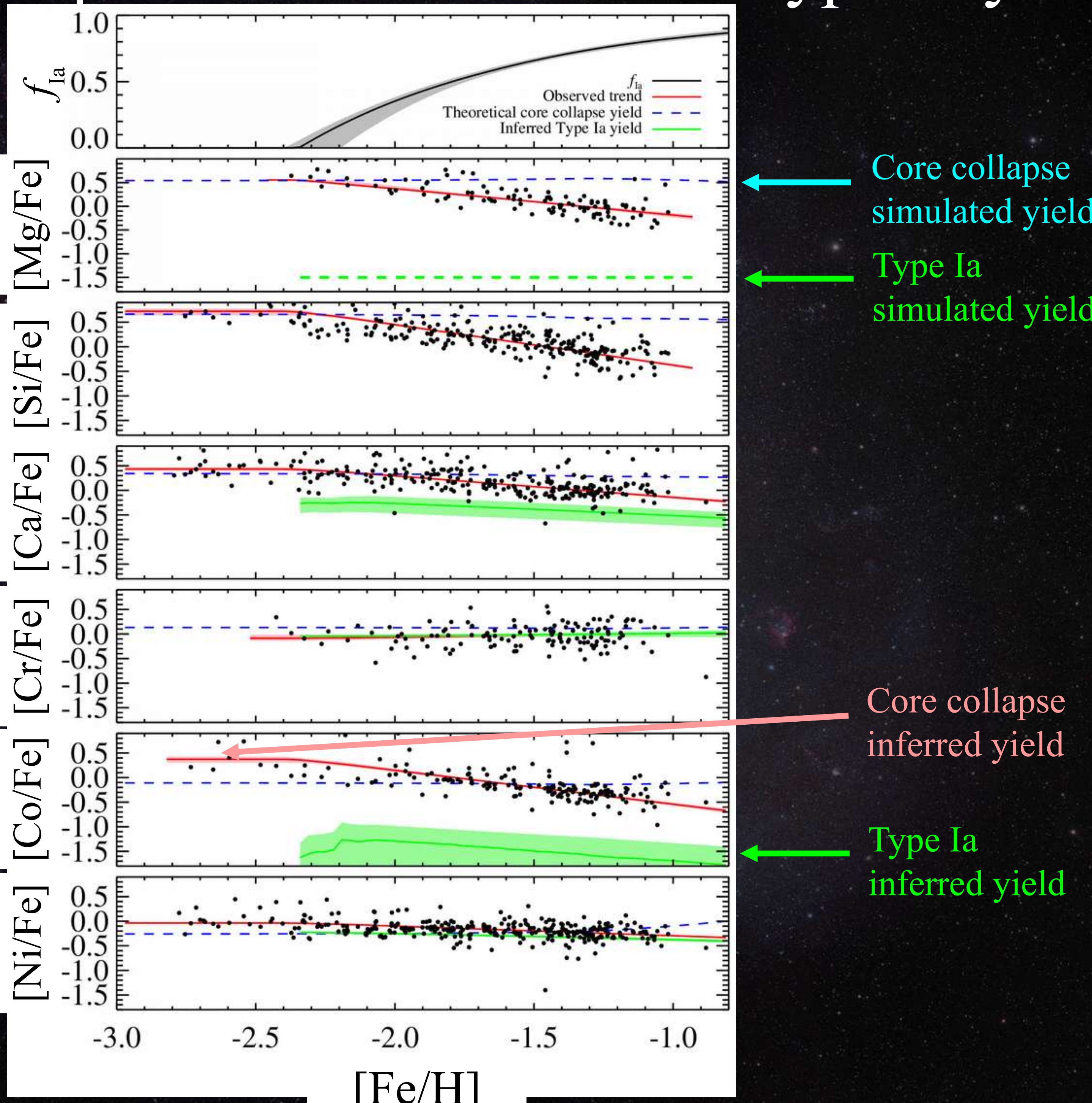


Kirby, Xie, Guo, Kovalev & Bergemann 2018, ApJS, 237, 18

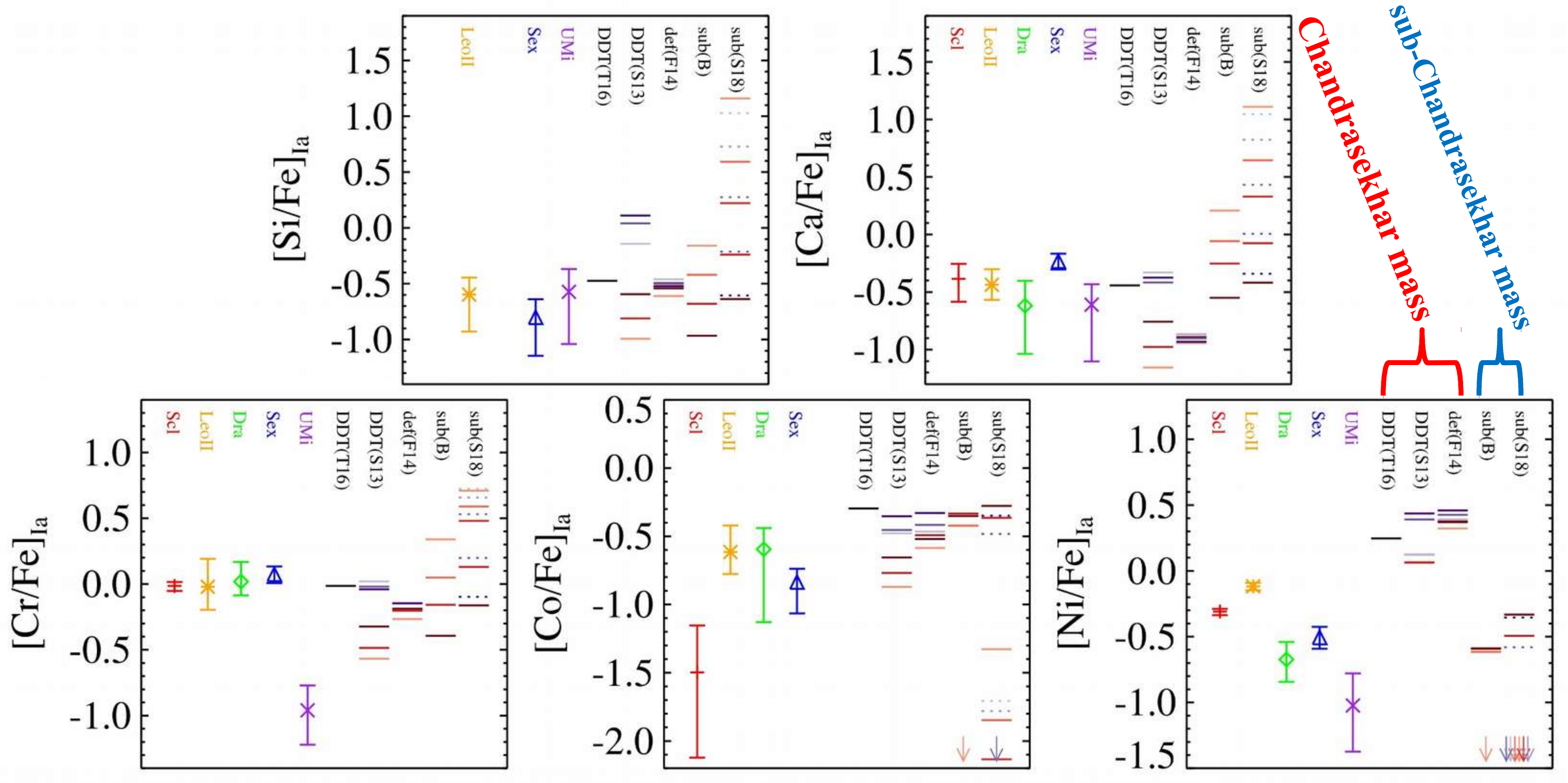
Sculptor's chemical evolution is easy to interpret.



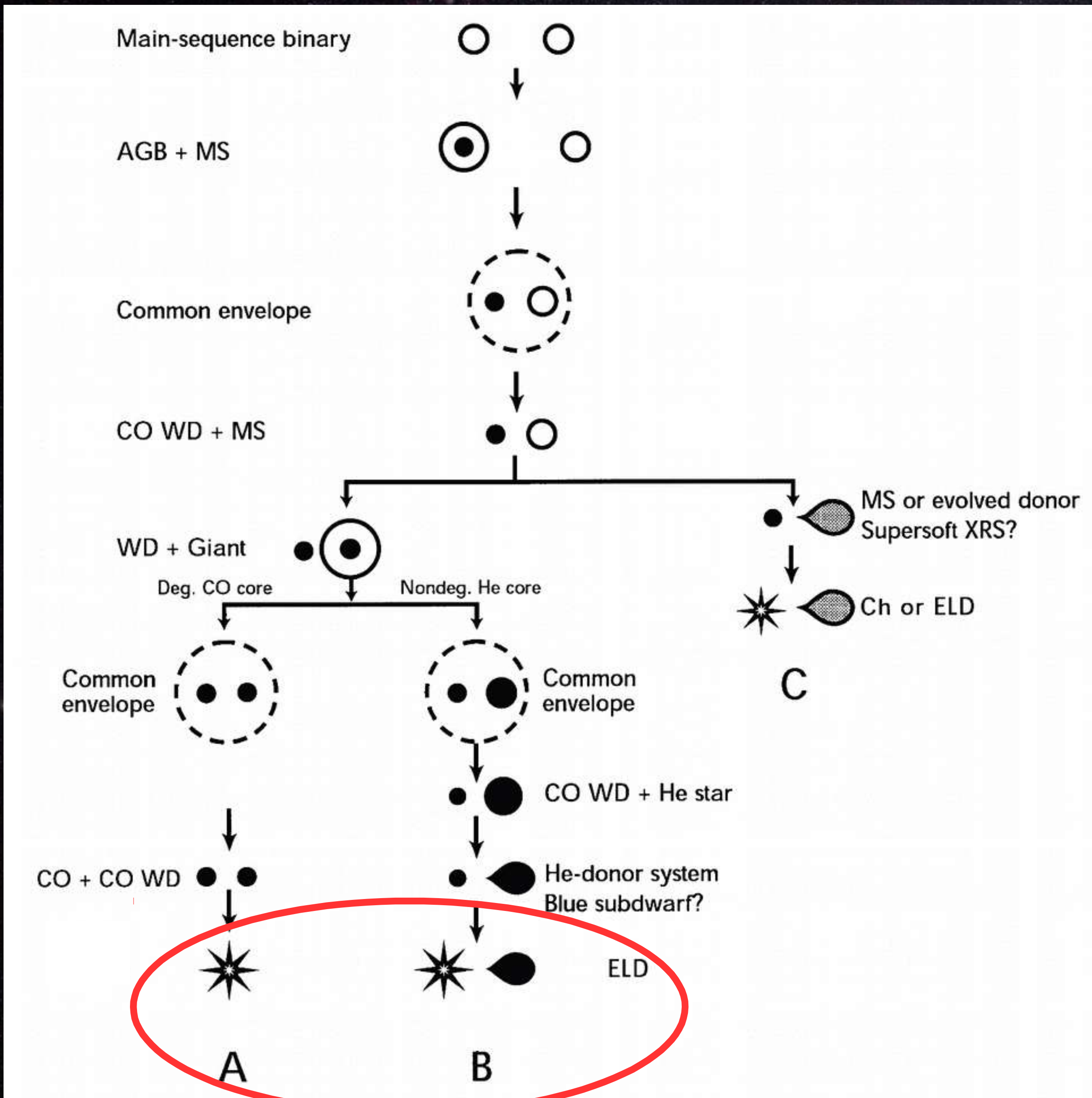
We used Sculptor's SFH to infer the Type Ia yield.



The inferred yields favor sub-Chandrasekhar mass Type Ia supernovae.



The yields favor sub-M_{Ch} explosions.



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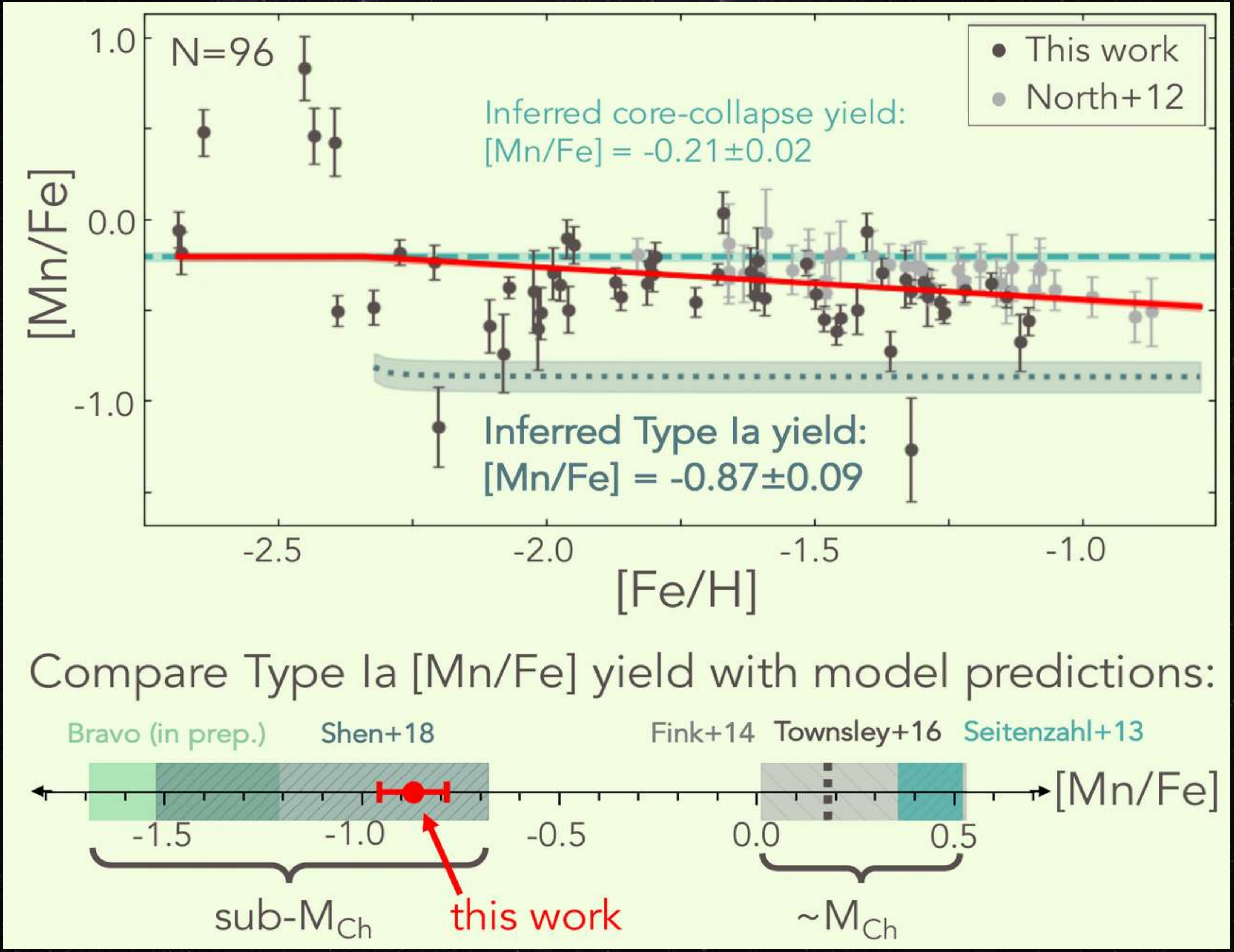
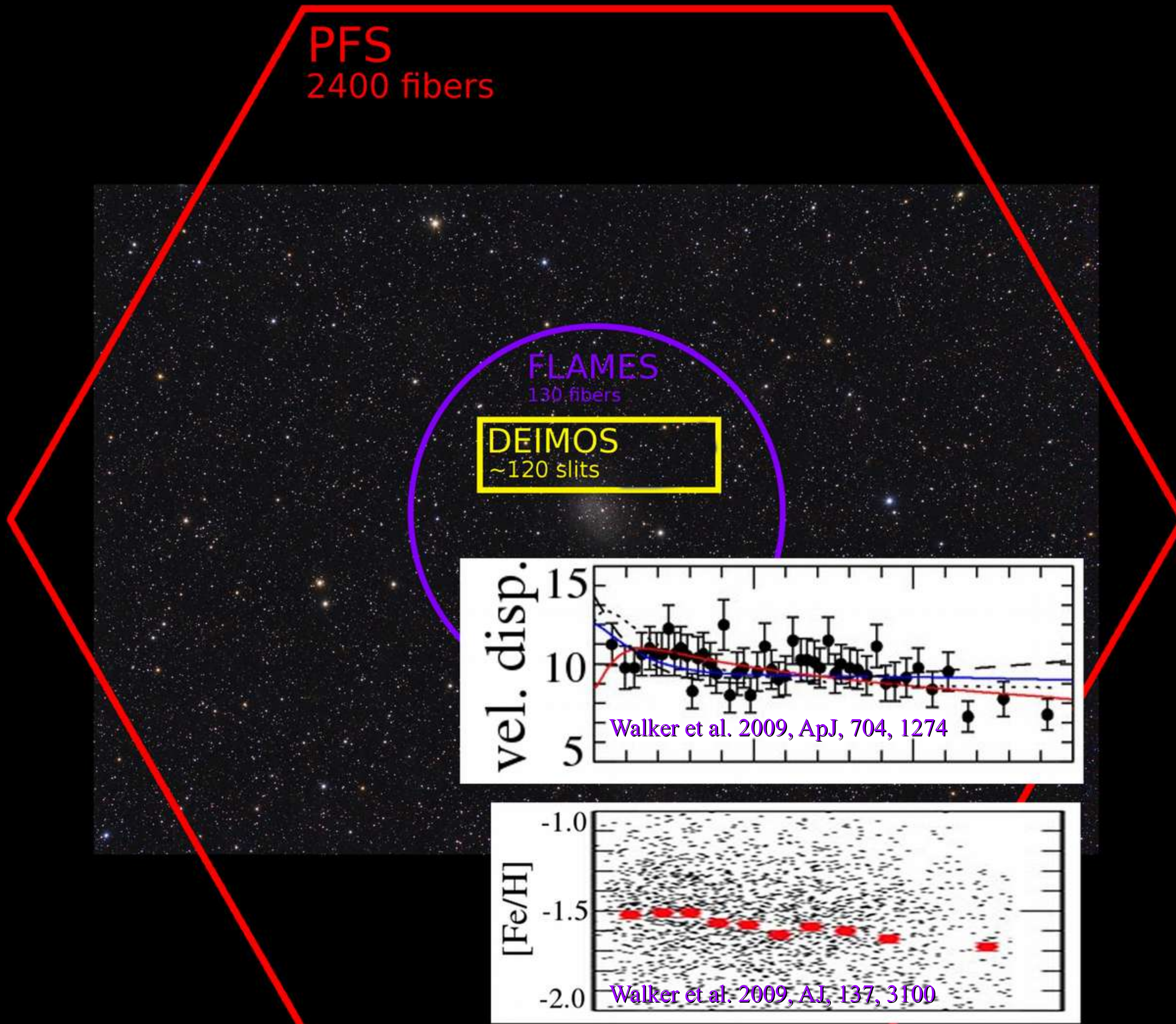
Yungelson & Livio 2000, ApJ, 528, 108

Manganese is even more constraining than nickel.



Poster by Mia de los Reyes

PFS applied to the Fornax dSph

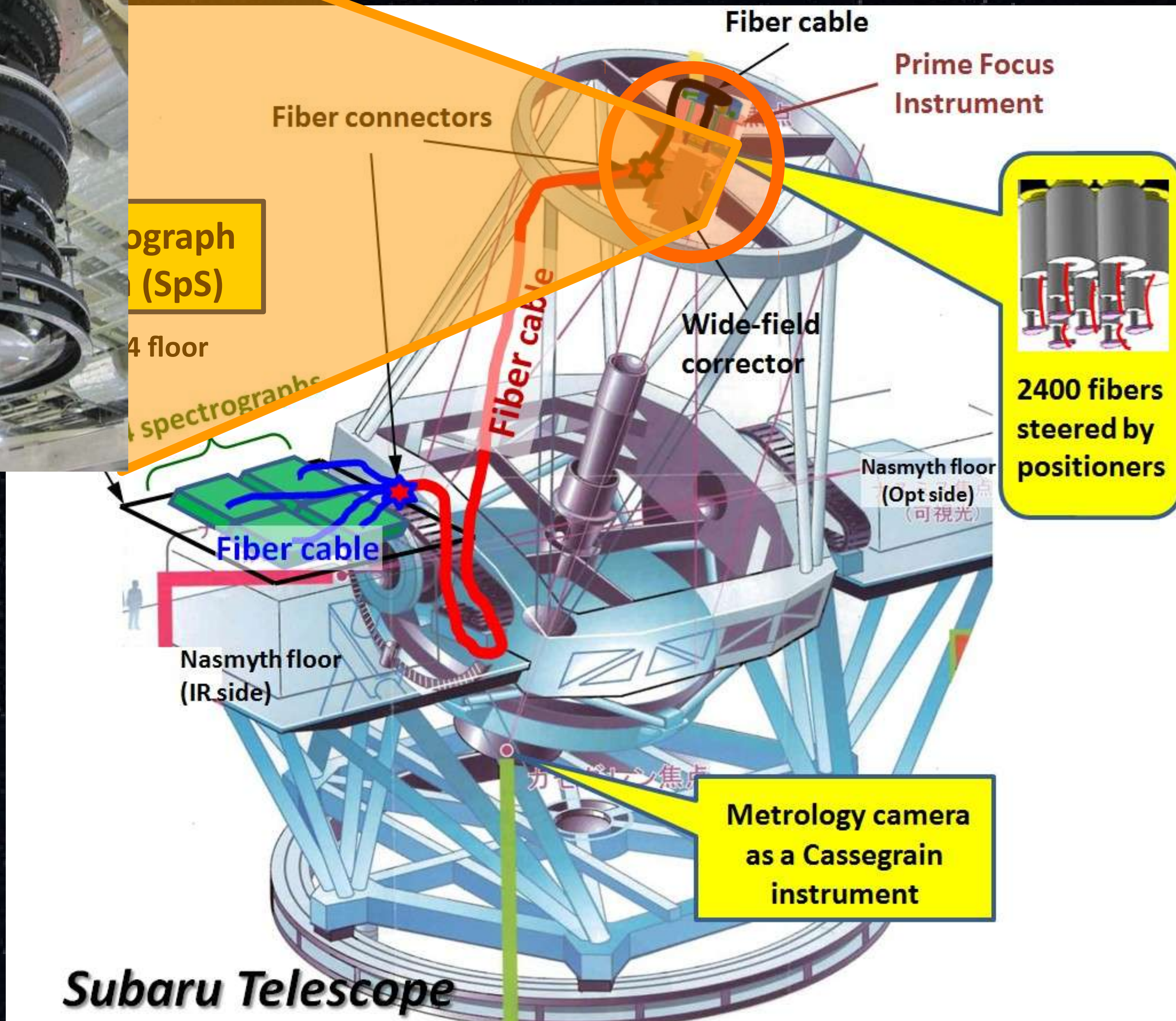


PFS Papers

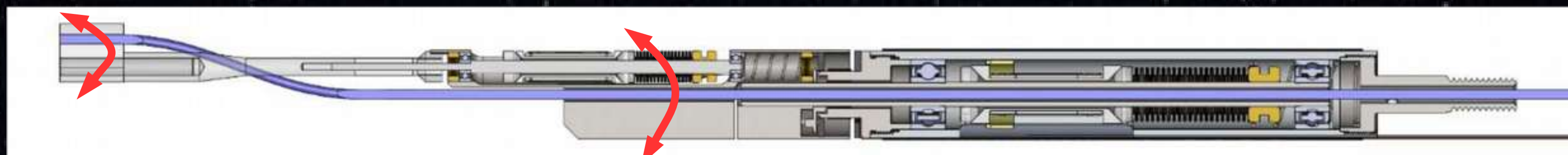
- Takada et al. 2014, PASJ, 66, R1
  “Extragalactic science, cosmology, and Galactic archaeology with the Subaru Prime Focus Spectrograph”
- Sugai et al. 2015, JATIS, 035001
  “Prime Focus Spectrograph for the Subaru telescope: massively multiplexed optical and near-infrared fiber spectrograph”
- Tamura et al. 2016, Proc. SPIE, 9908 1M
  “Prime Focus Spectrograph (PFS) for the Subaru Telescope: Overview, recent progress, and future perspectives”
- Tamura et al. 2018, Proc. SPIE, 10702 1C
  “Prime Focus Spectrograph (PFS) for the Subaru Telescope: Ongoing integration and future plans”
- http://pfs.ipmu.jp/blog

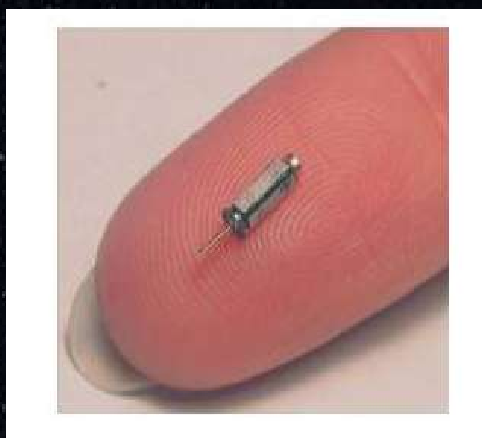
PFS Collaboration

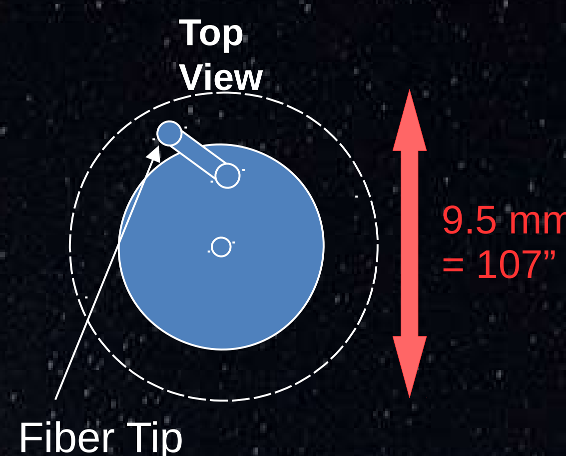
PFS Instrument Overview: Prime Focus Instrument



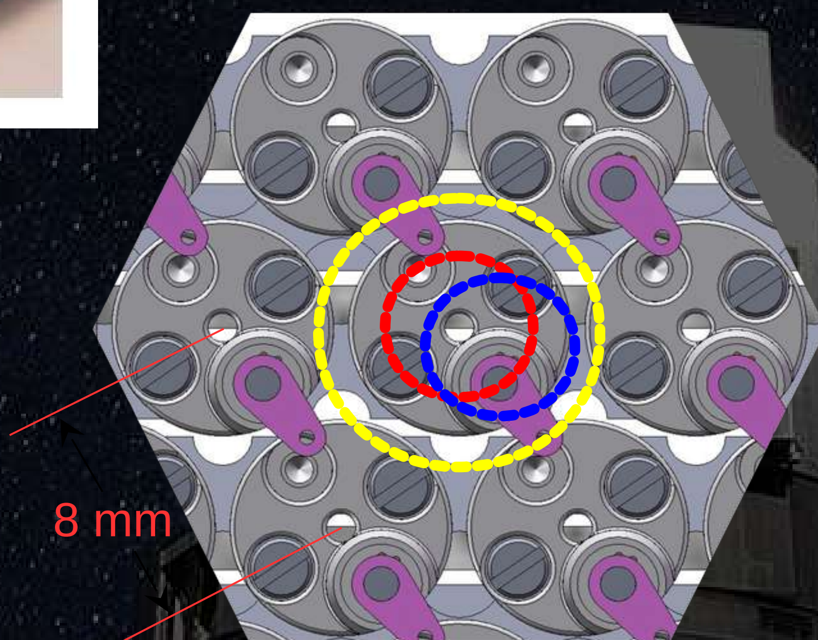
Fibers are positioned with “Cobras,” built at Caltech/JPL.



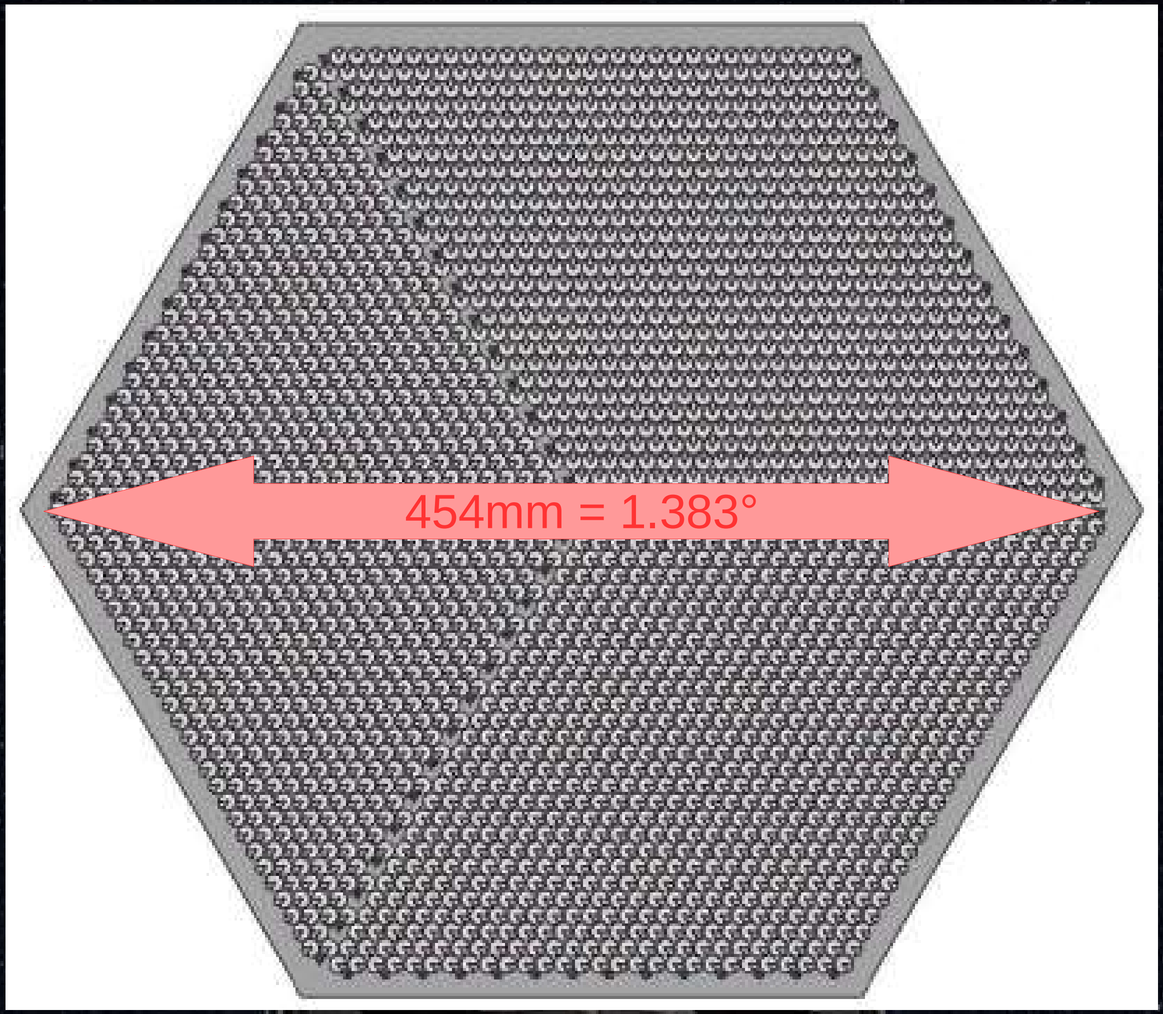




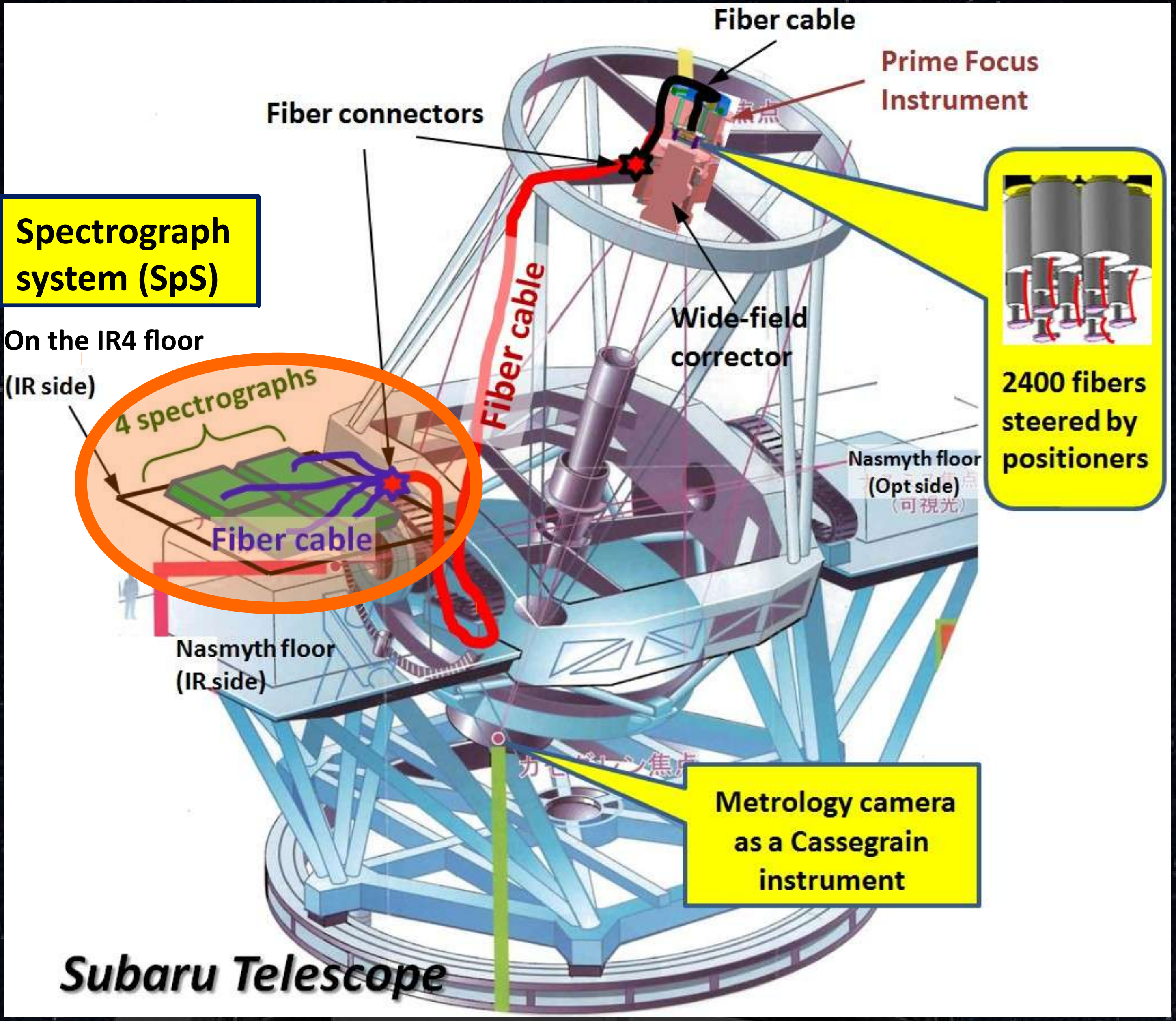
Fiber diameter:
100 μm ≈ 1.1”



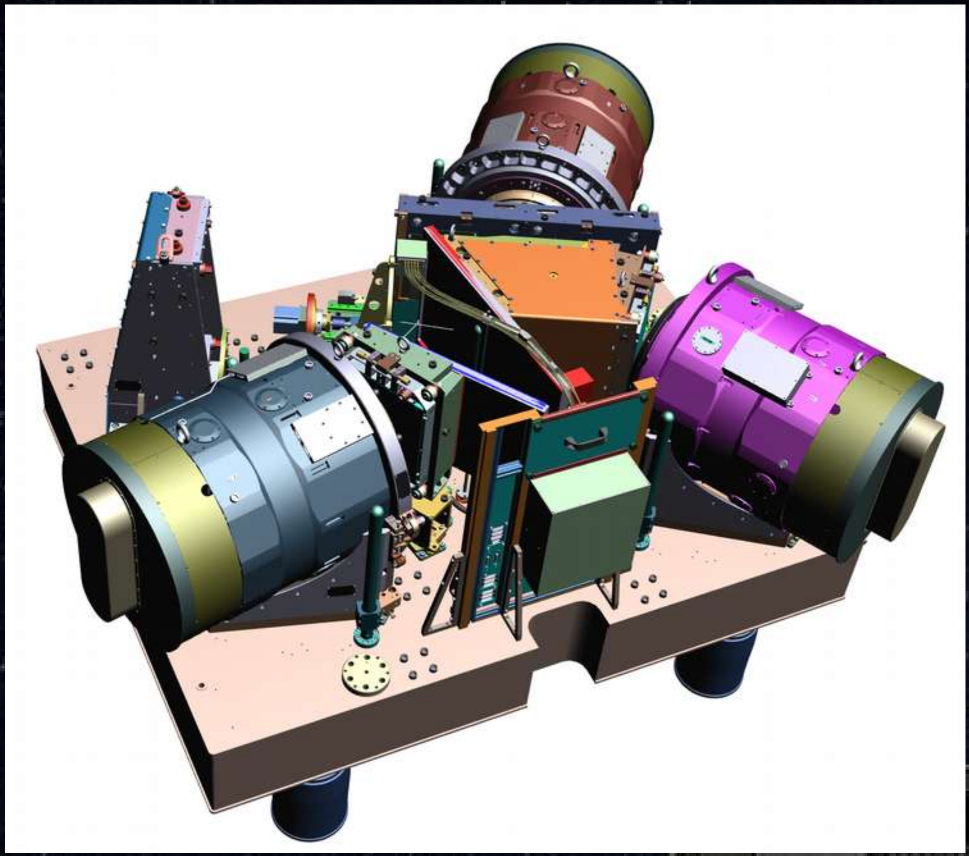
2394 Cobras distributed over 1.24 deg^2

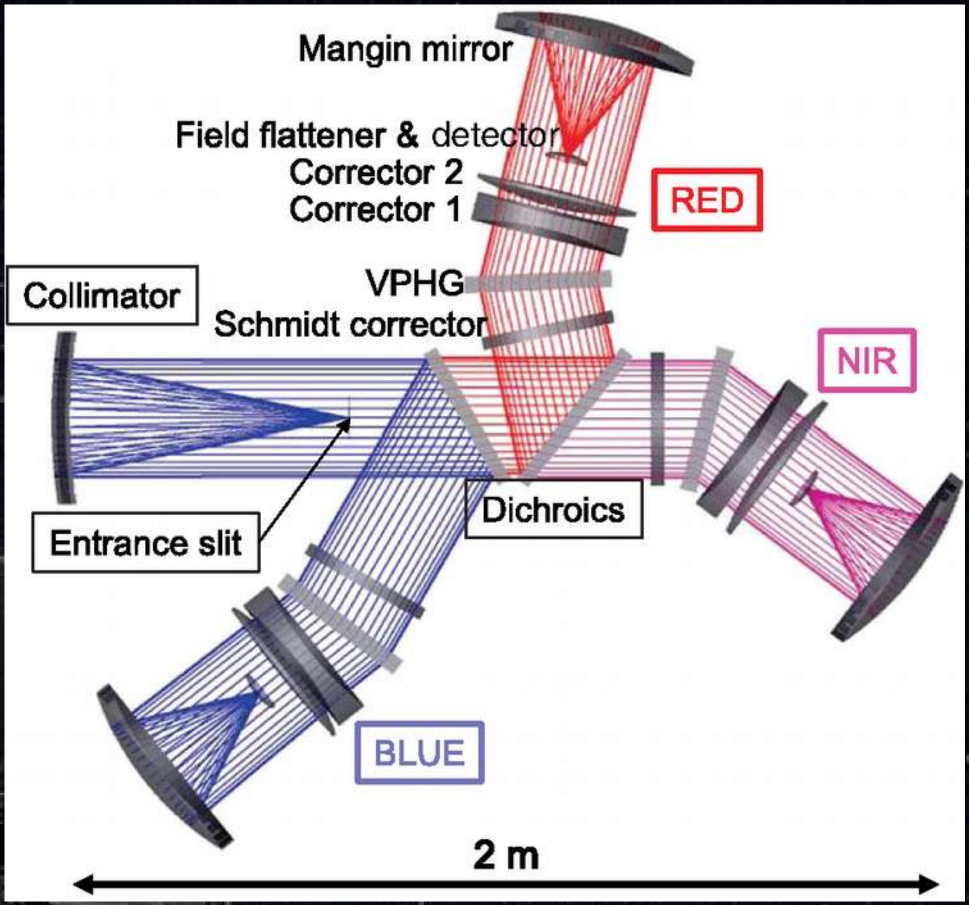


PFS Instrument Overview: Spectrographs



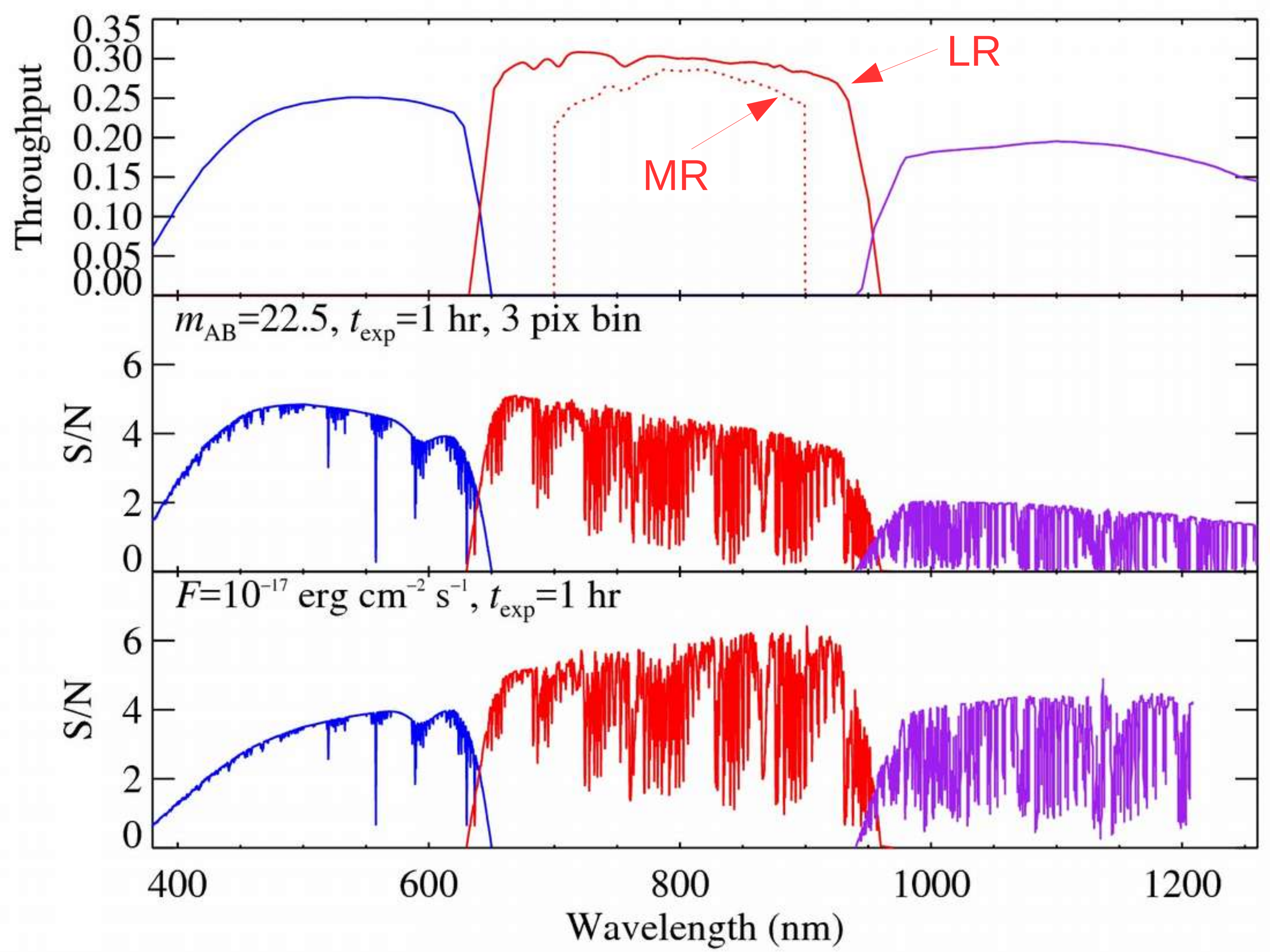
There are 12 spectrographs.



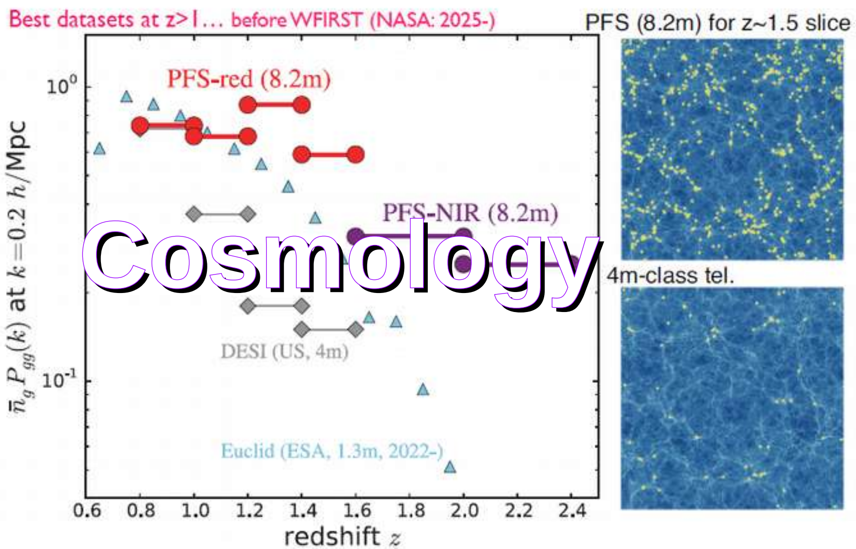


PFS has wide wavelength coverage.

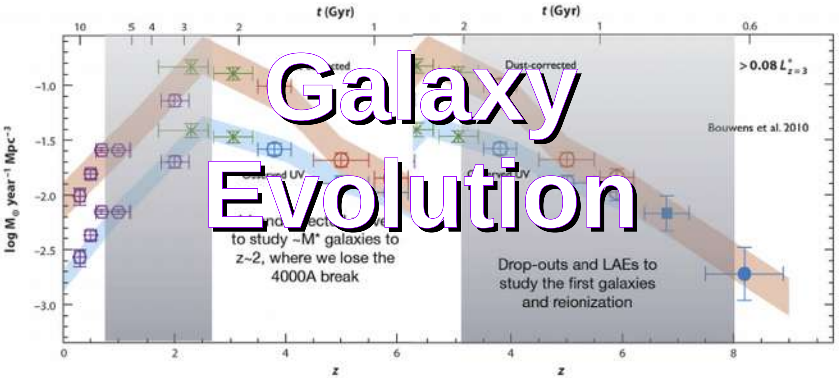
	Blue	Red (LR)	Red (MR)	Infrared
Wavelength range	380-650 nm	630-970 nm	710-885 nm	940-1260 nm
Resolution (FWHM)	2.7 Å	2.7 Å	1.6 Å	2.7 Å
Resolving power (*R*)	~1900	~3000	~5000	~4100



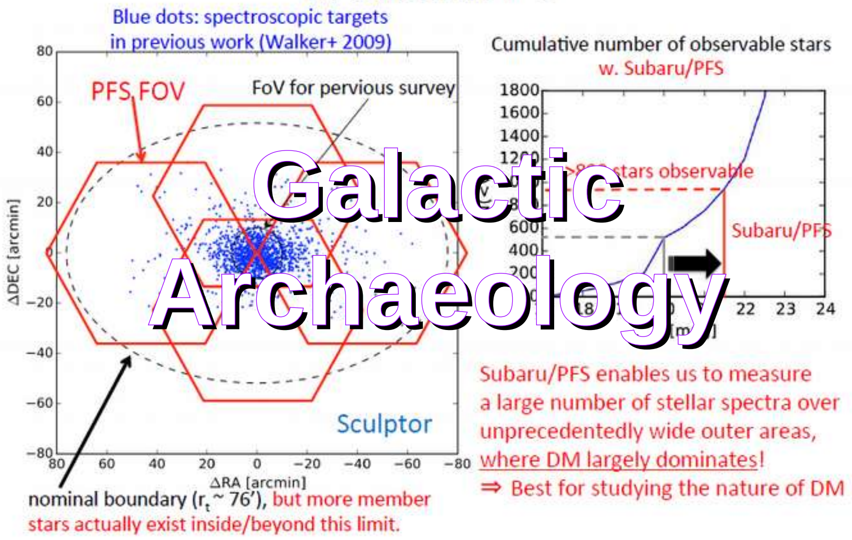
The Survey has three science pillars.



The wide wavelength coverage (NIR arm) of PFS is **unique** and perfectly suited to study galaxy evolution from the **epoch of peak star formation** rate density and black hole activity all the way to the **epoch of reionization**.



Wide & deep survey of MW dwarf galaxies w. Subaru/PFS

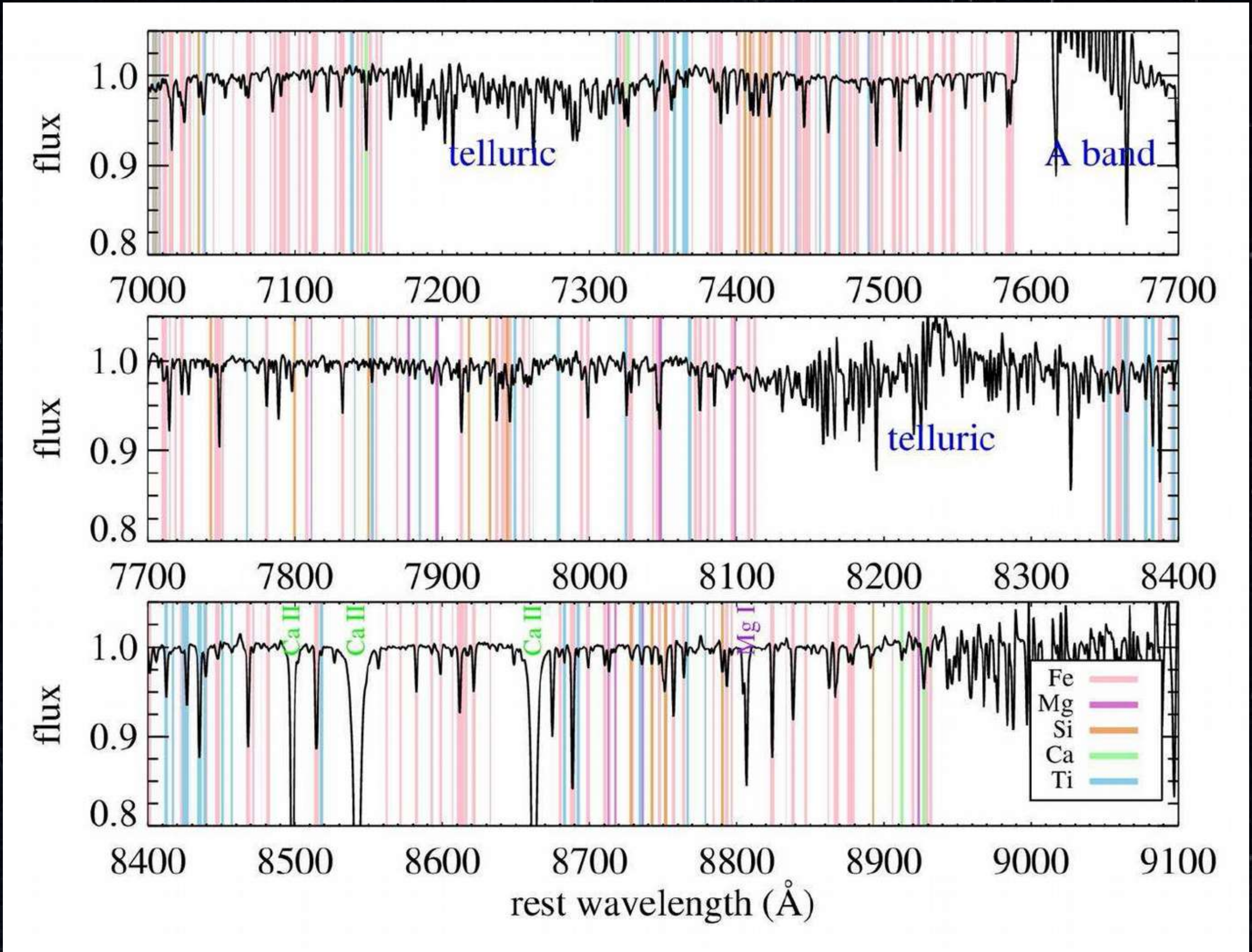


Subaru/PFS enables us to measure a large number of stellar spectra over unprecedentedly wide outer areas, where DM largely dominates!
⇒ Best for studying the nature of DM

Galactic Archaeology

- Chair: Masashi Chiba 千葉柾司
- Co-chairs: Judy Cohen, Rosemary Wyse

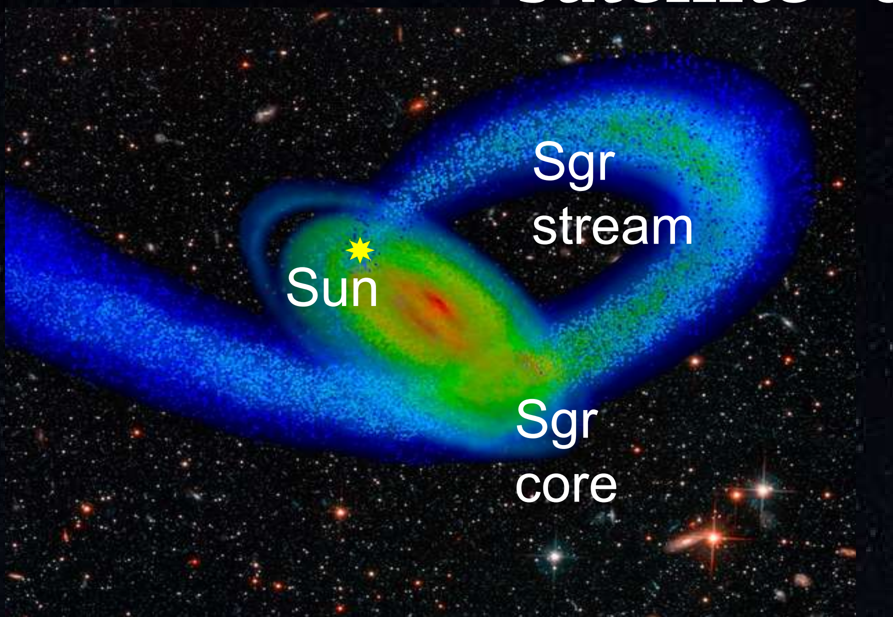
The red MR mode allows for α abundances.

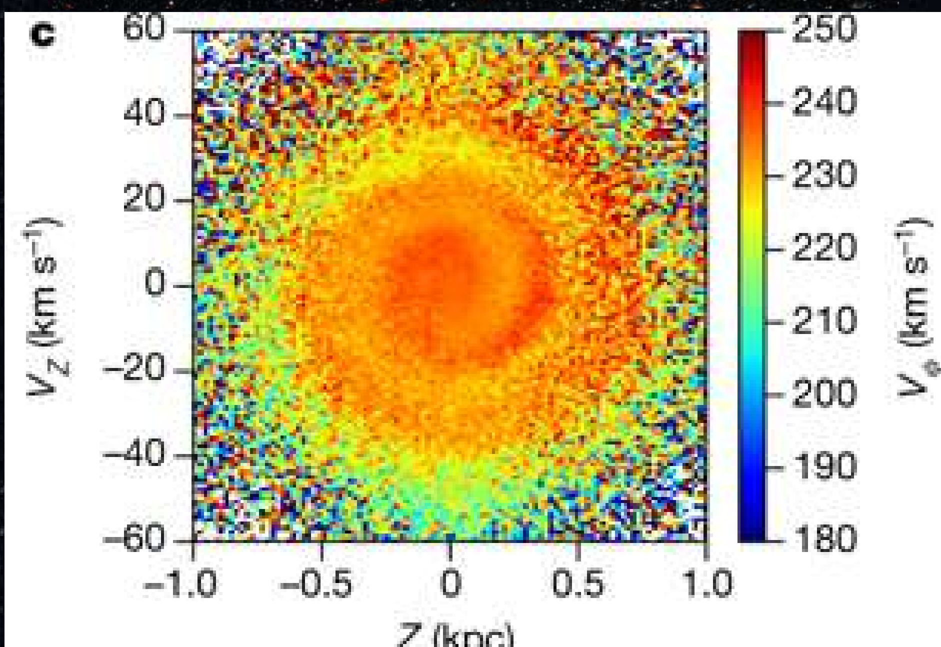


Galactic Archaeology Survey Plan

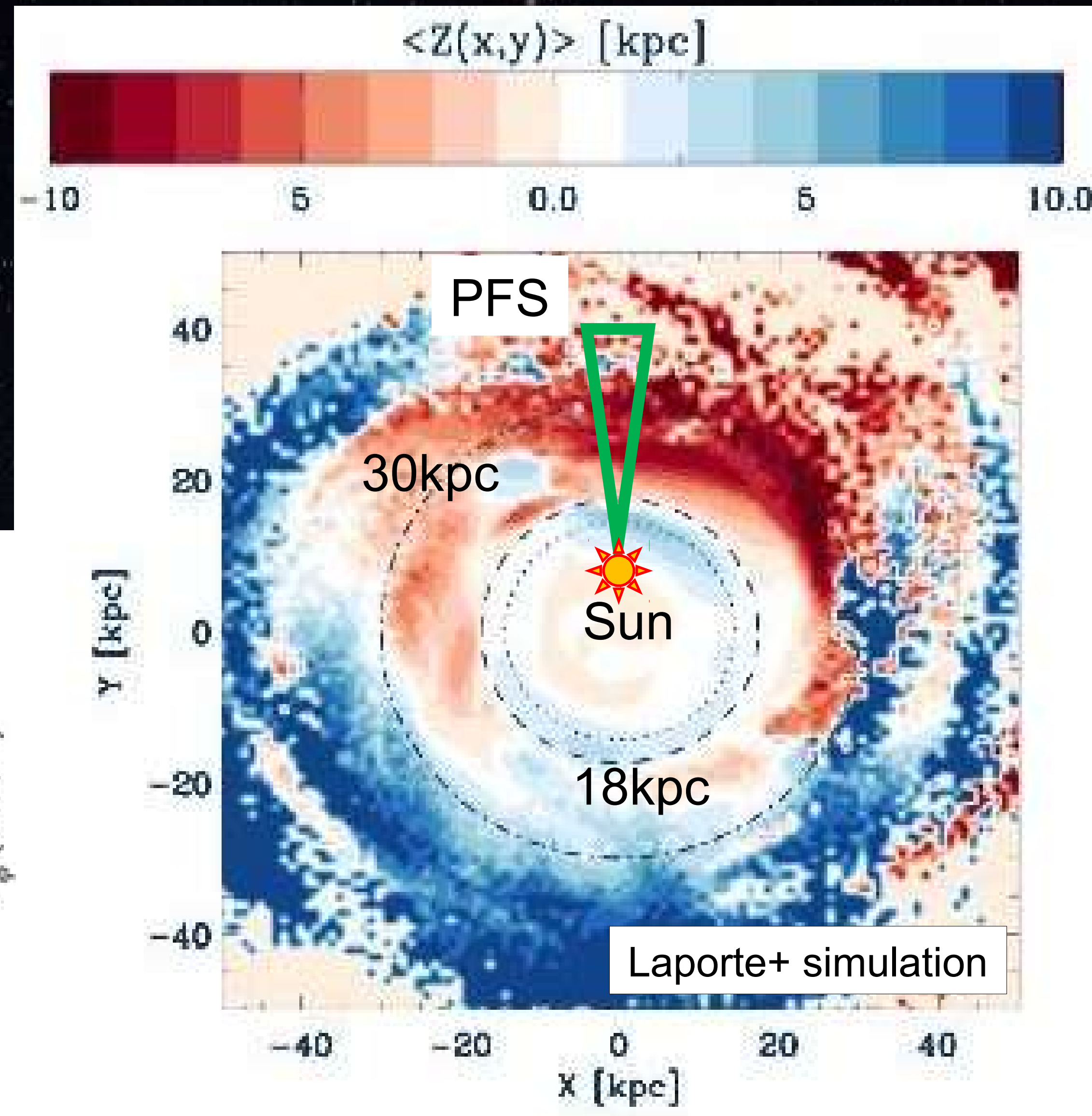
Survey	Mag. Range (mag)	Exp. (hr)	No. Fields	Survey (nights)	Comments
MW halo	$g < 22$	3	14	5.3	$b = +60$, $l = 90, 270$
MW outer disk	$g < 22$	3	44	16.5	$l = 180$
MW streams	$g < 22$	3	24	9	Field of streams
MW dSph	$g < 22$	3	22×2	16.5	BooI, For, Scl, UMi, Sex, Dra
dIrr	$g < 22.5$	4	1×2	1	NGC 6822
M31 halo	$i < 22.3$	5	34	21.6	HSC sample
Total			162	70	

PFS will measure the dynamical effects of satellite+disk interaction.



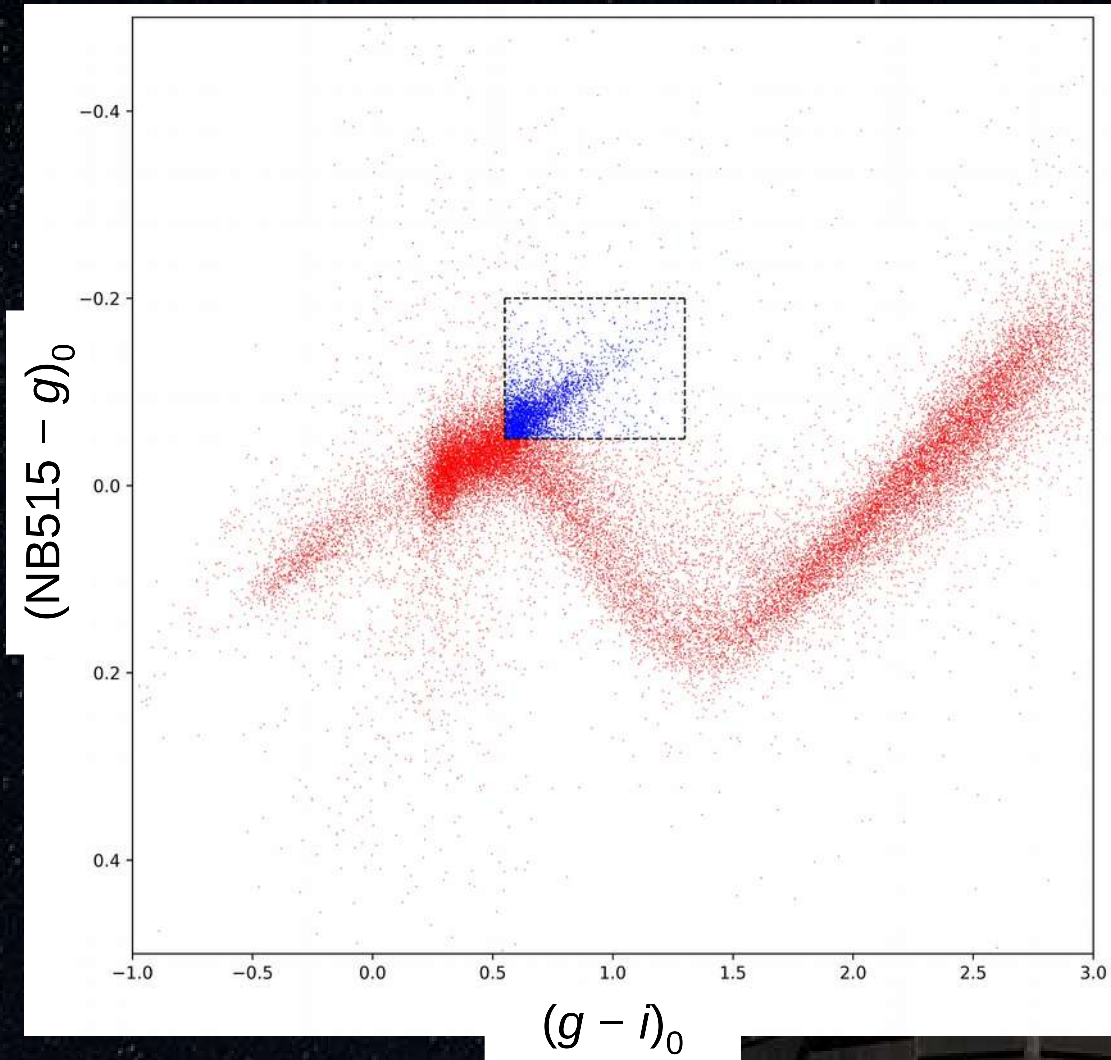


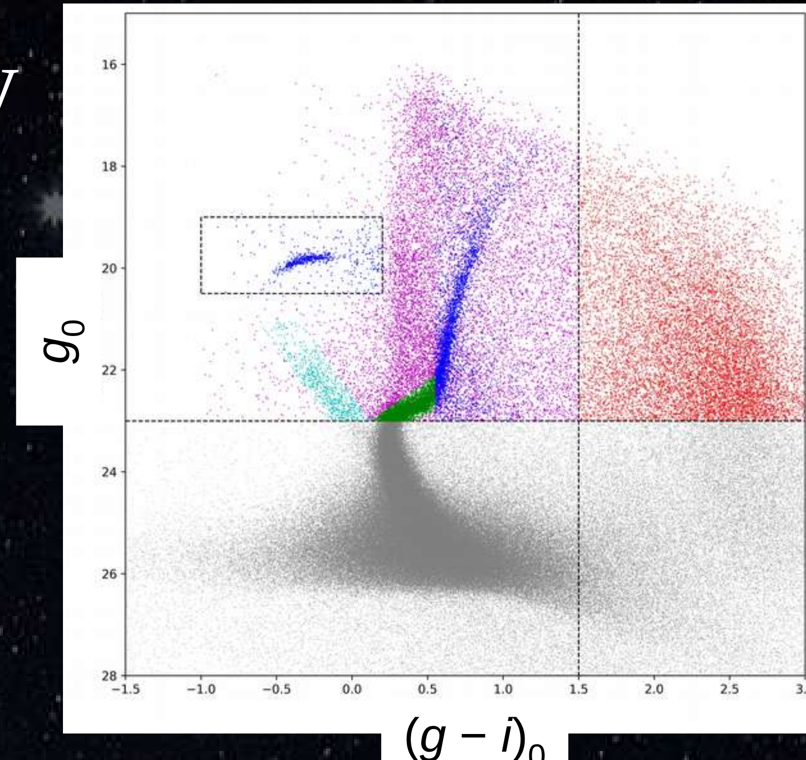
Antoja et al. 2018, Nature, 561, 360

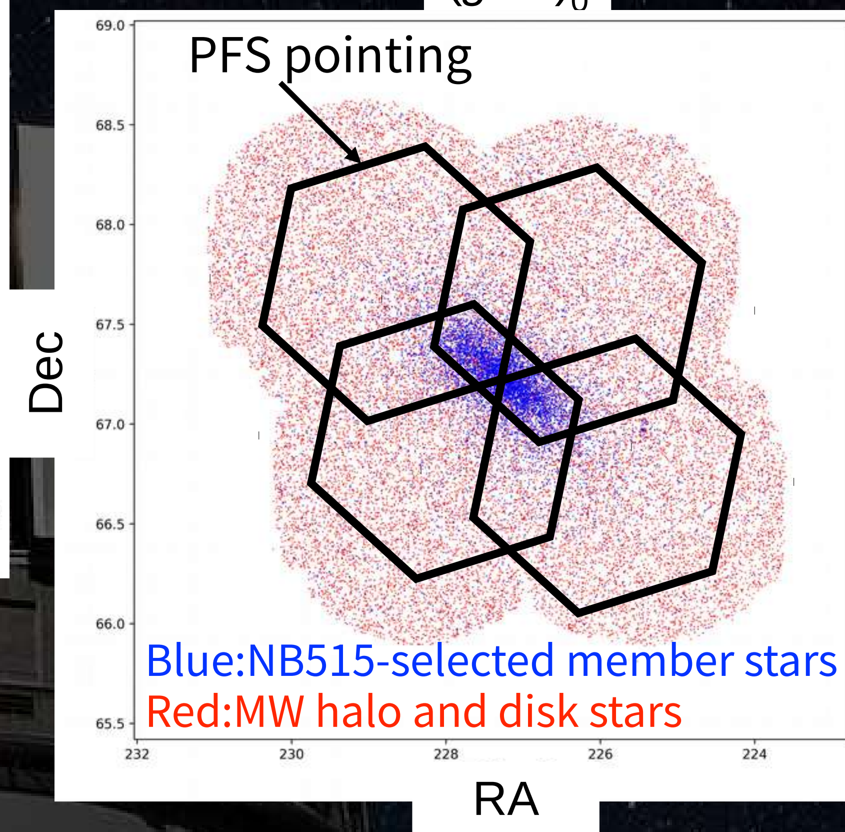


Laporte et al. 2018, MNRAS, 481, 286

Contaminants are excluded by narrow-band photometry.

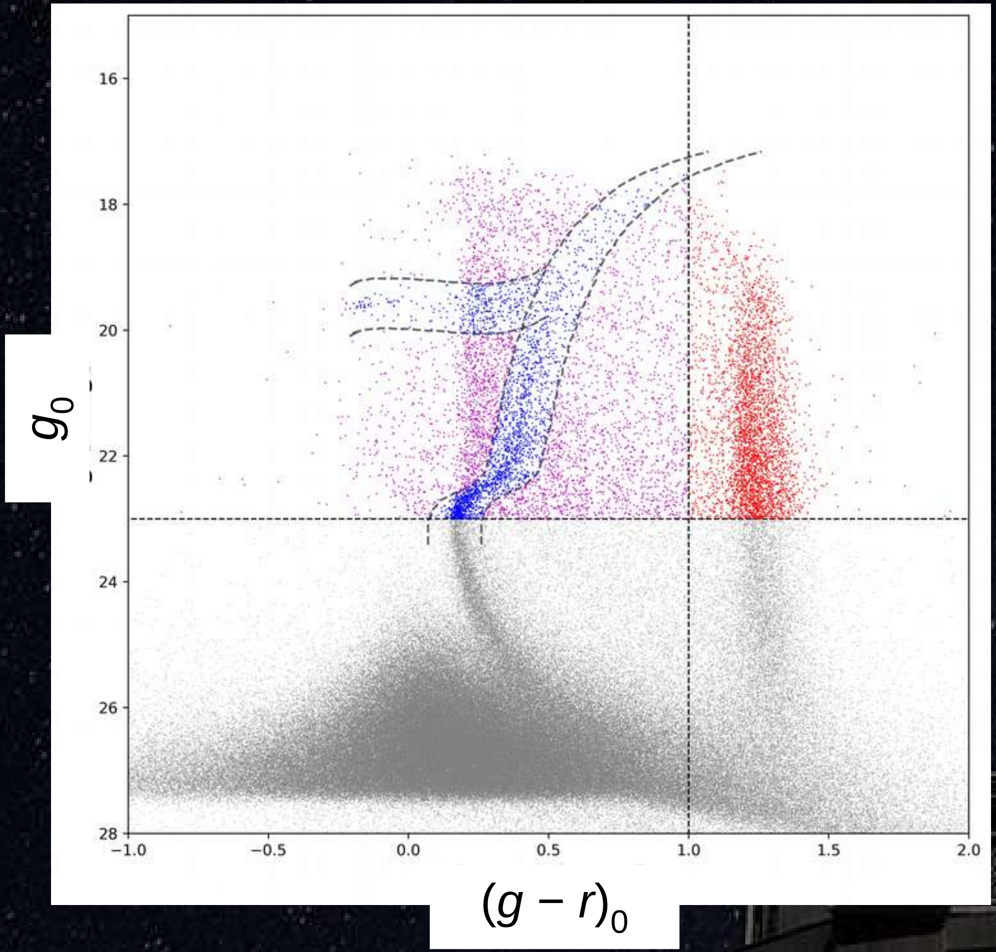


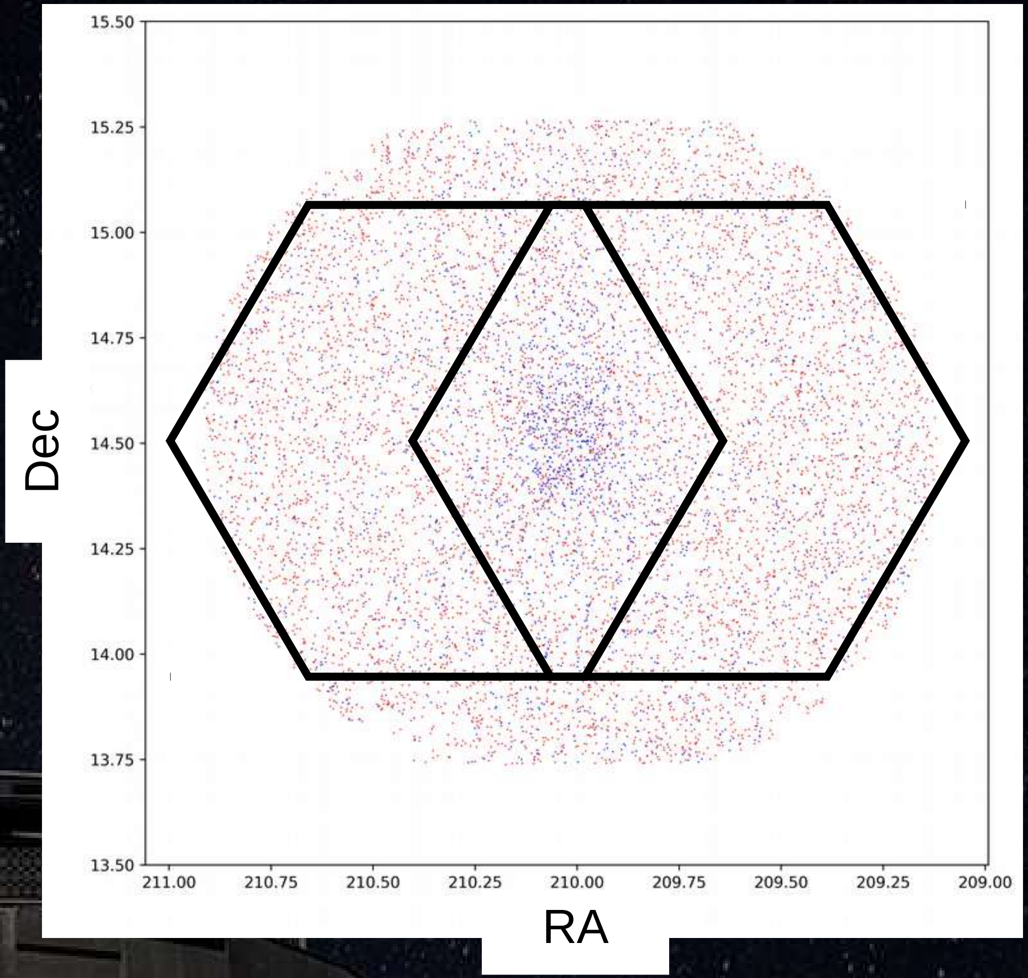




credit: Kohei Hayashi 林航平

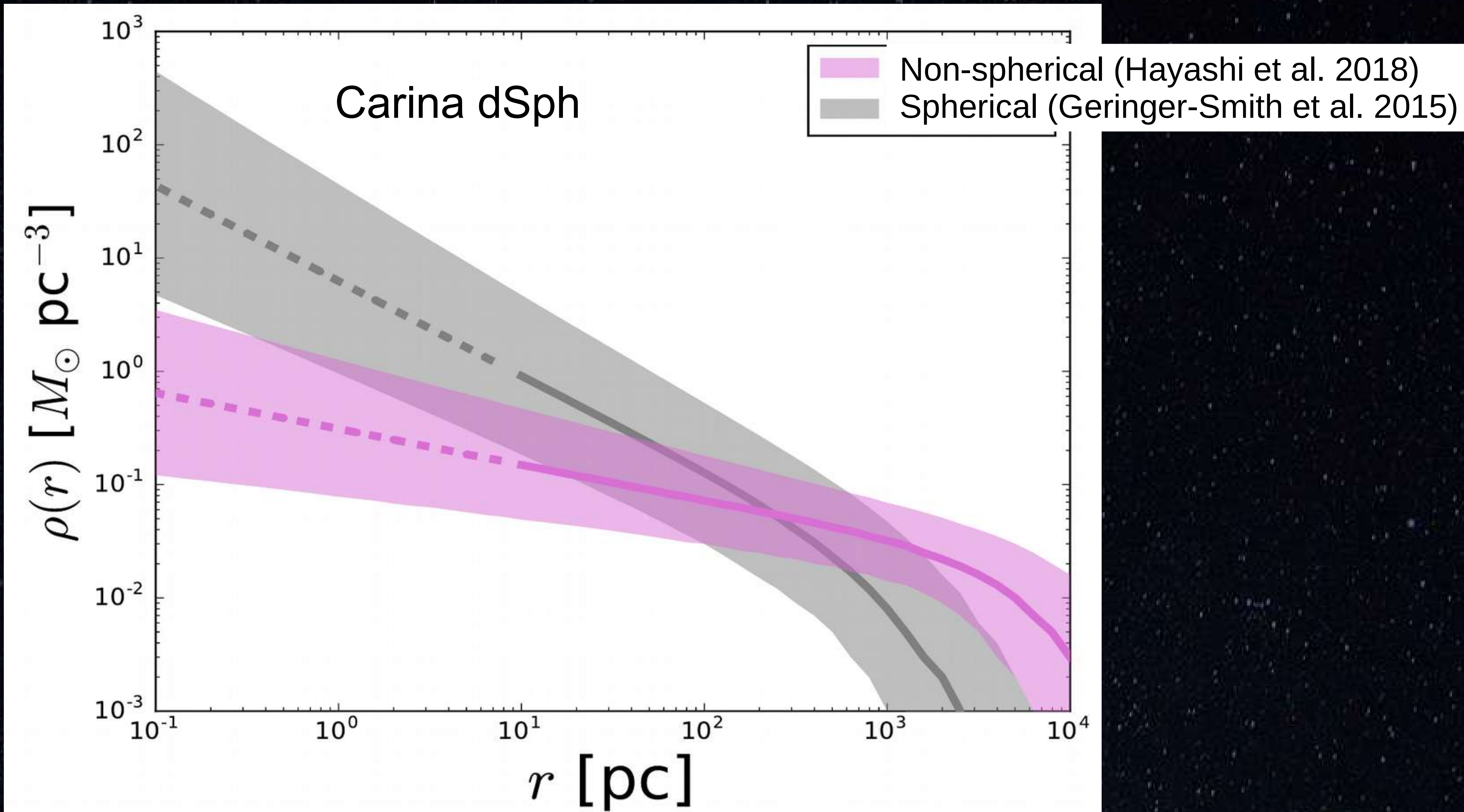
The survey will include an ultra-faint dwarf: Boötes I.





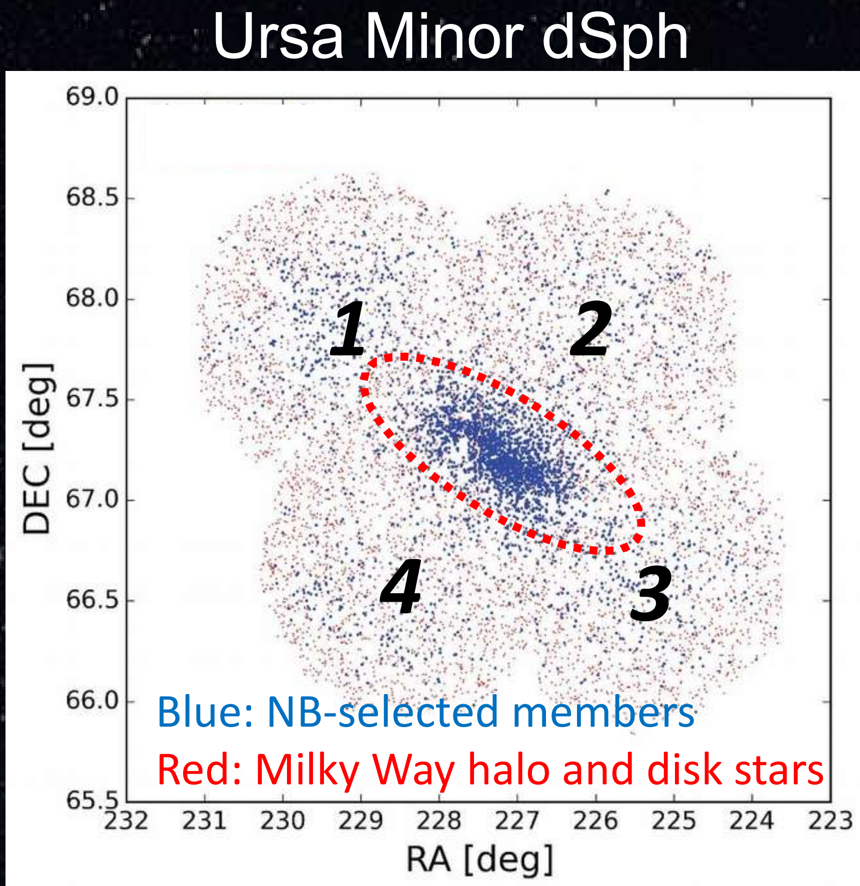
credit: Kohei Hayashi 林航平

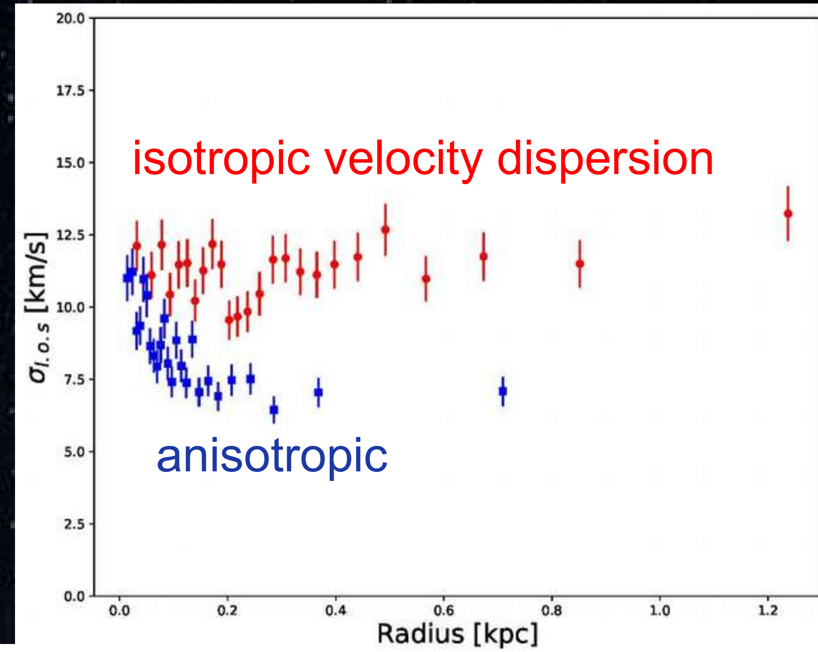
Dark matter mass profiles before PFS are poorly constrained.

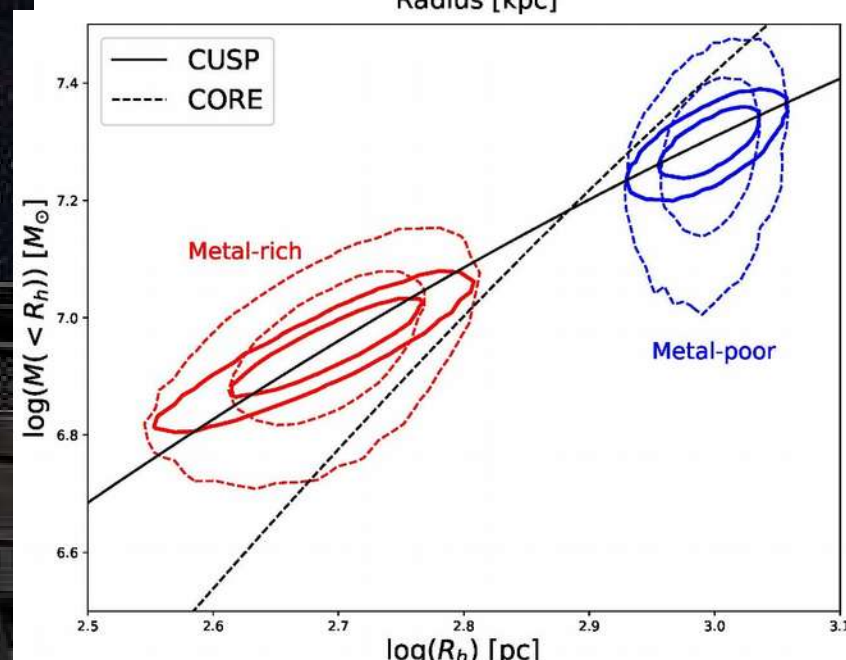


Hayashi et al. 2018, MNRAS, 481, 250

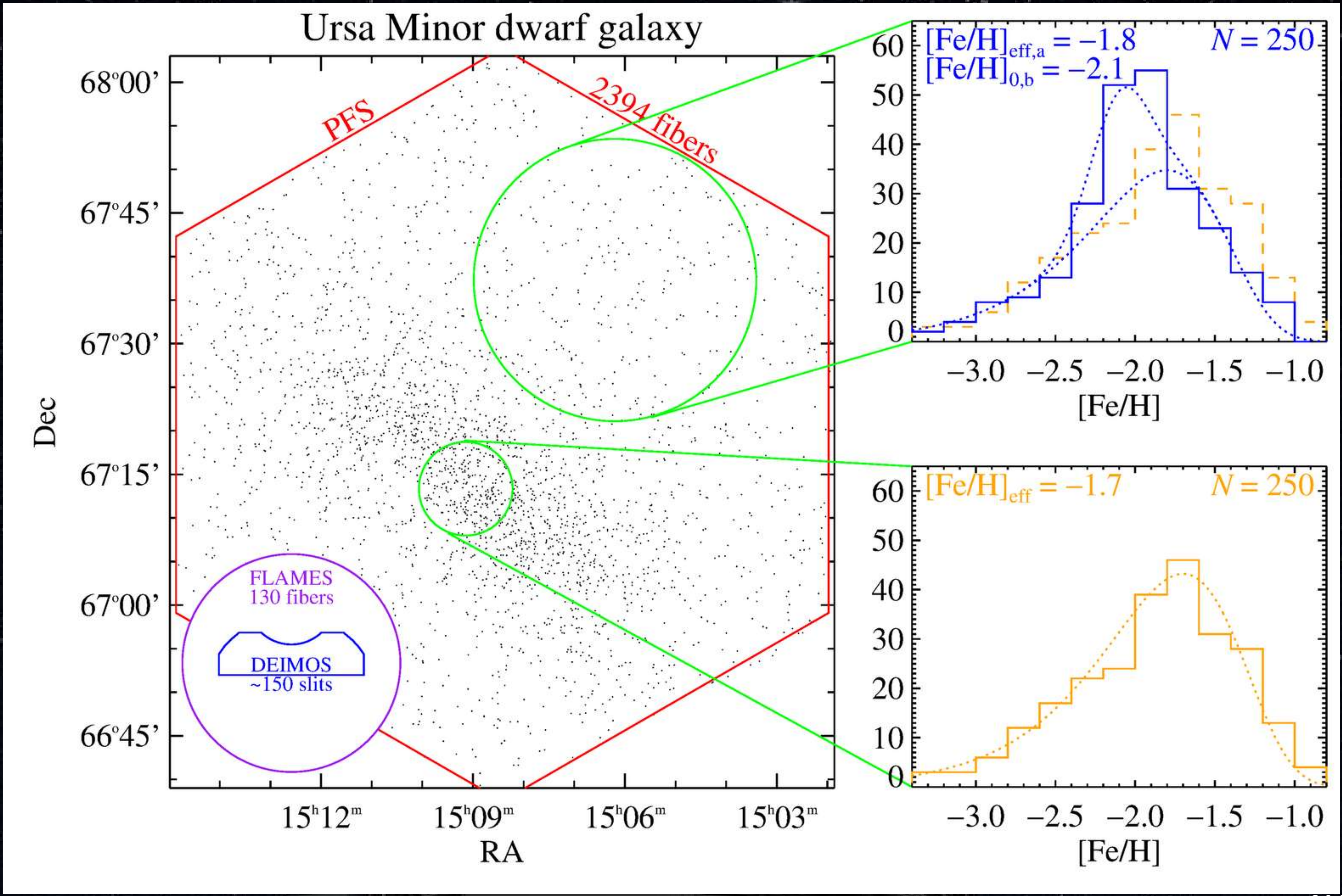
PFS will measure the dark matter profile of dSphs.



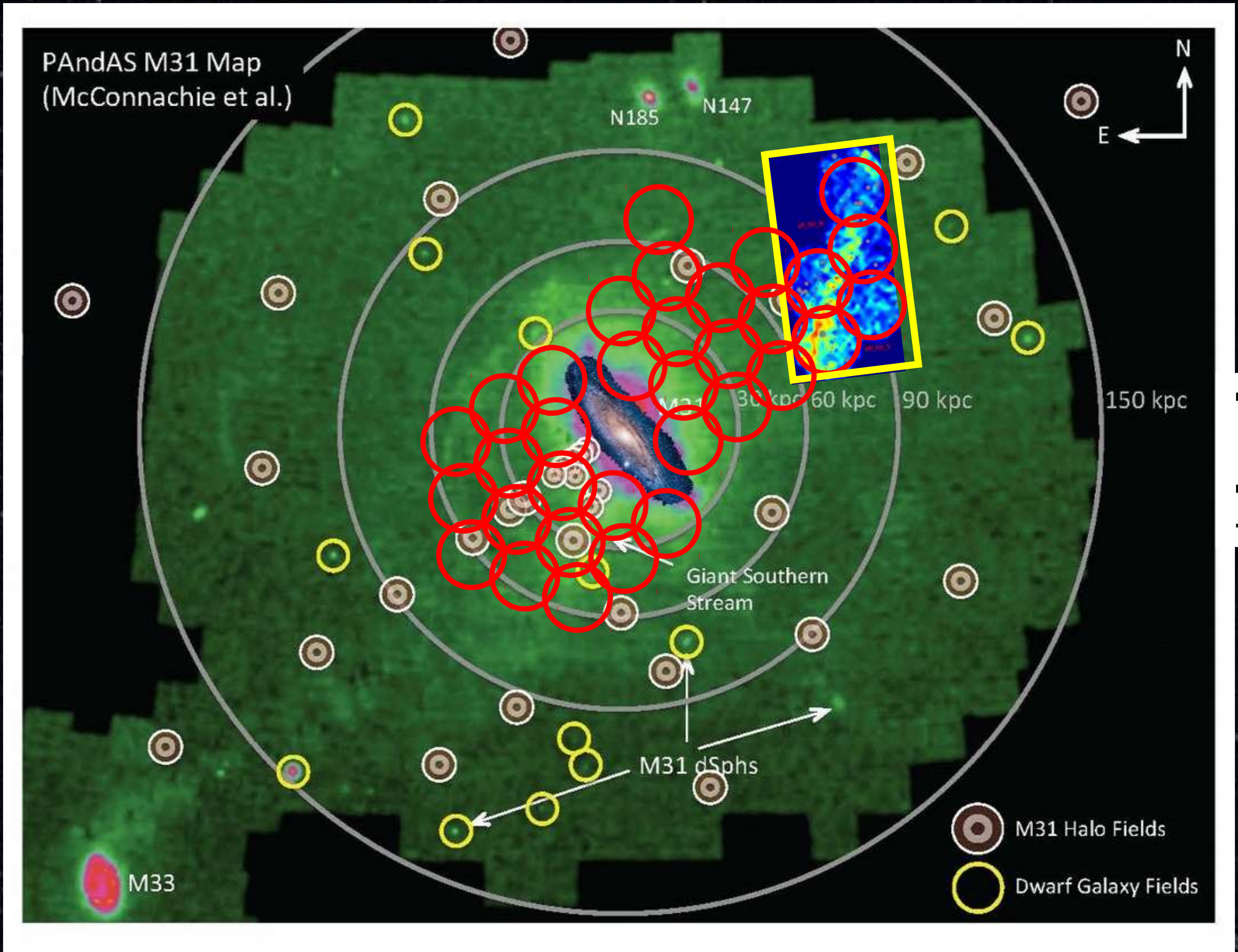


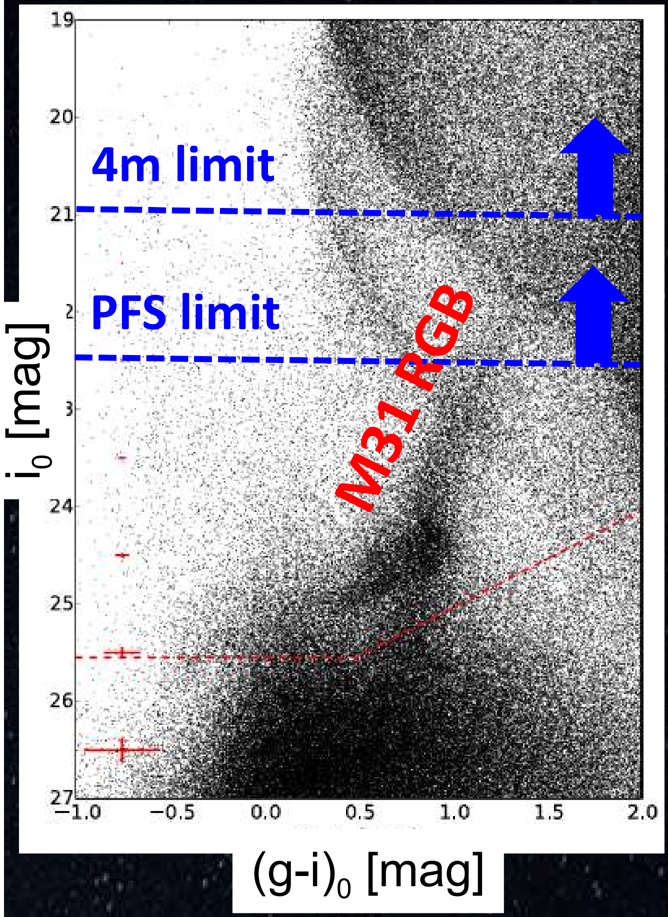


PFS can detect chemical substructure.



PFS will survey M31's stellar halo.

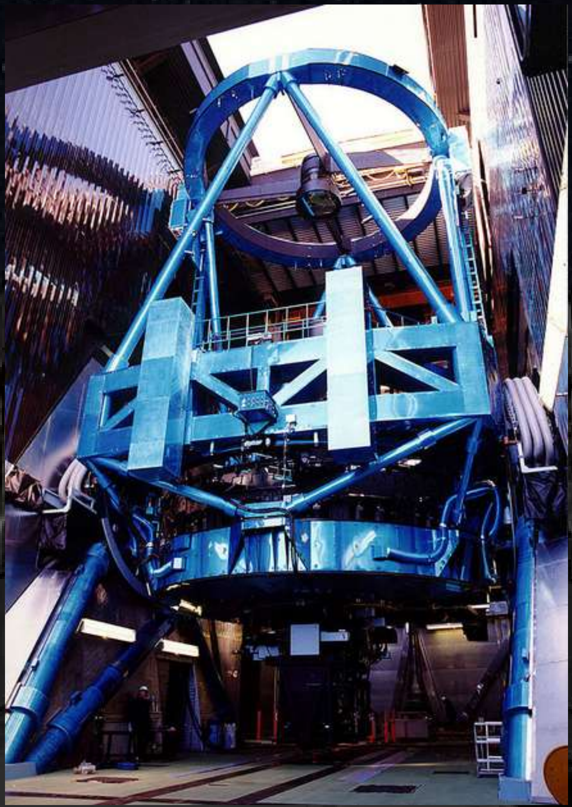




Talk by Ivanna Escala at 14:40 today

Timeline

Now	Construction
August 2019	On-sky commissioning
Fall 2021	Science survey (300-360 nights) begins
2026 or later	Science survey concludes



Competition and Complementarity

Project	**Science Case**	**Fibers**	**FOV** (deg^2)	**Wavelength Range** (nm)	**Resolving Power** (R)	**Telescope**	**First Light**
PFS	GA, cosmology, galaxy evolution	2394	1.2	380-1260	1900-4100 (5000 mode)	Subaru 8 m	2021
DESI	cosmology	5000	8	360-980	1500-4000	Mayall 4 m (dedicated)	2019
MOONS	GA and galaxy evolution	1000	0.14	640-1800	5000, 9000, 20000	VLT 8 m	2020
WEAVE	GA	800	3.1	400-950	5000, 20000	WHT 4 m (dedicated)	2020
4MOST	GA and galaxy evolution	2436 812	4.1	370-950 393-679	4000-7800 18,500	VISTA 4 m (dedicated)	2022
eBOSS	cosmology	1000	7	360-1000	2000	APO 2.5 m	2014
HETDEX	cosmology	150 IFUs (230 fibers each)	0.11	350-550	700	HET	2013
Euclid	cosmology	slitless	0.54	1100-2000	250	Euclid 1.2 m (space)	2021

Conclusions

- Abundances of iron-peak abundances in dwarf galaxies point to **sub-Chandrasekhar mass Type Ia supernovae**.
- PFS will have **2394 fibers** covering 1.2 deg^2, 380-1260 nm.
- It will observe the MW disk+halo, M31 halo, and **7 dwarf galaxies out to r_{tidal}**.
- PFS will
  - Resolve the **core/cusp** problem
  - Discover **chemical substructure** in dwarf galaxies
  - Quantify the impact of Sagittarius and other **accretion events**
  - Characterize the **accretion history** of M31's stellar halo