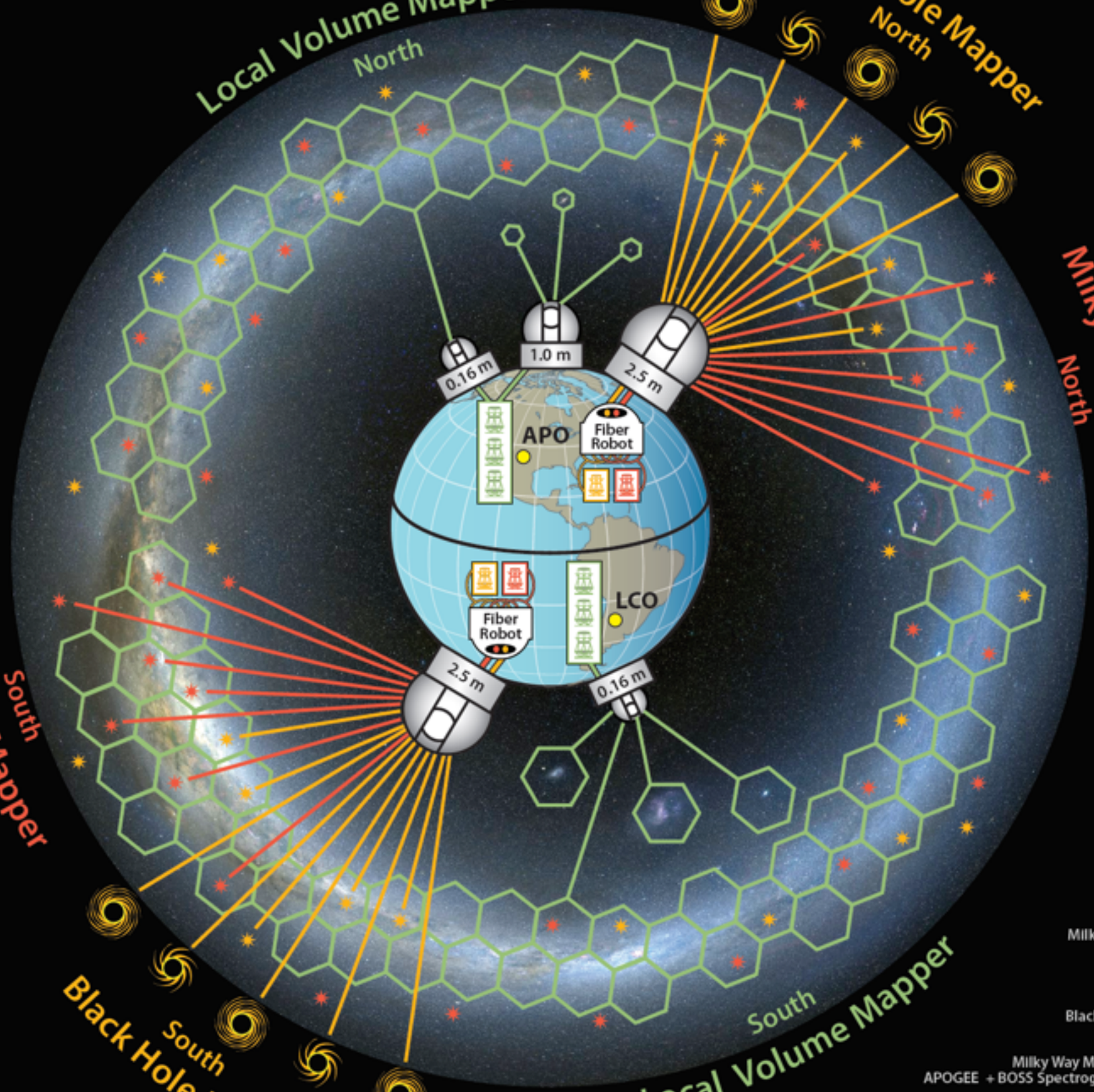
Juna A. Kollmeier

Carnegie Science

SDSS

SDSS-V

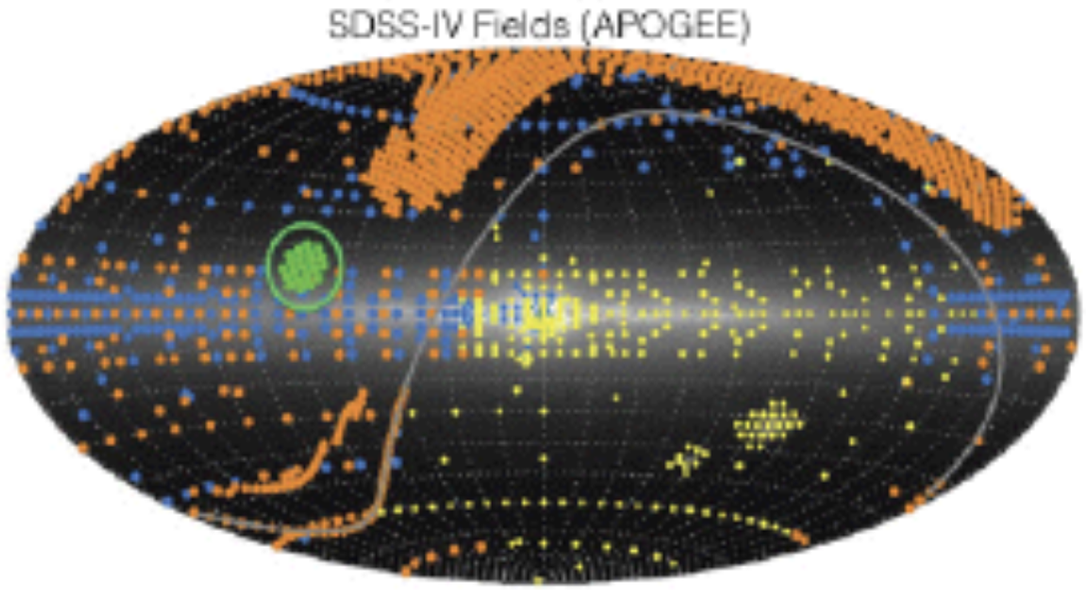

Local Volume Mapper
North
Black Hole Mapper
North
Milky Way Mapper
North
0.16 m
1.0 m
2.5 m
APO
Fiber Robot
LCO
Fiber Robot
2.5 m
0.16 m
South
Milky Way Mapper
South
Black Hole Mapper
South
Local Volume Mapper
Milky Way
Stars
Black Hole
Milky Way Mapper
APOGEE + BOSS Spectrographs
Black Hole Mapper
BOSS Spectrograph
Local Volume Mapper
Integral Field Spectrograph

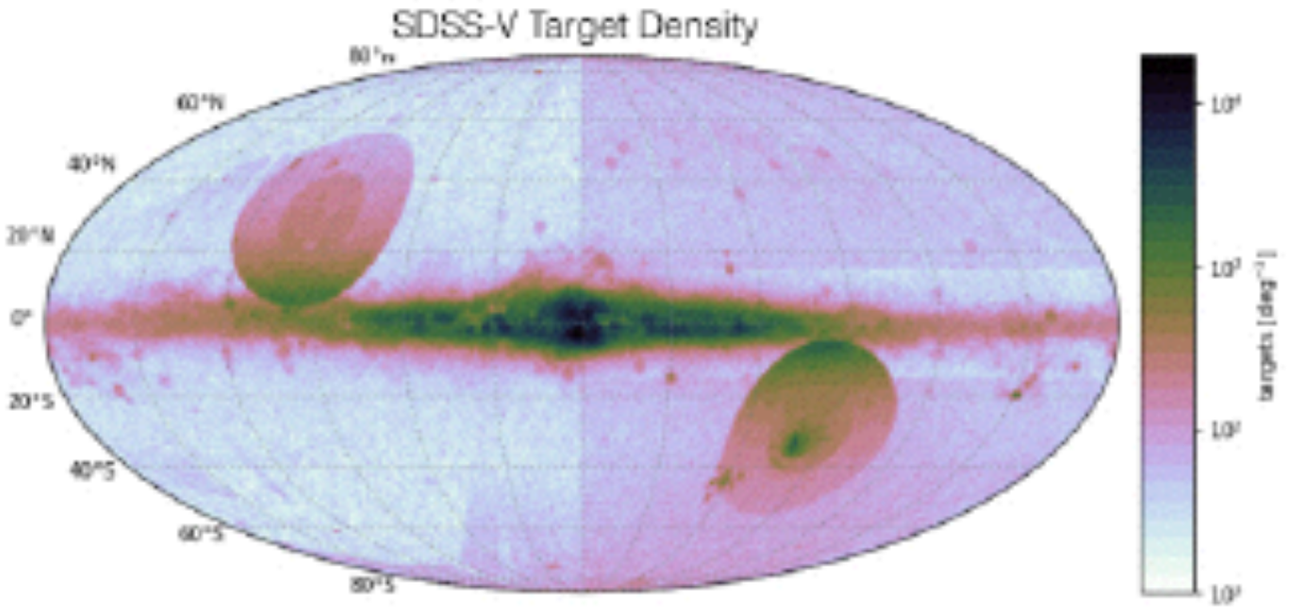
SDSS-V's 3 "Mappers"

Program	Science Targets	$N_{Objects}$ and/or Sky Area	Primary Spectral Range and Hardware	Primary Science Goals
Milky Way Mapper (MWM)	Stars across the Milky Way	>6M stars; all-sky	IR; APOGEE ($R \sim 22,000$) with fiber-positioning system	Understanding the formation of the Milky Way and the physics of its stars
Black Hole Mapper (BHM)	Primarily supermassive black holes	>400,000 sources; all-sky	Optical; e.g., BOSS ($R \sim 2000$) with fiber-positioning system	Probing black hole growth and mapping the X-ray sky
Local Volume Mapper (LVM)	ISM & stellar populations in the MW, Local Group, and nearby galaxies	>25M contiguous spectra over 3,000 deg^2	Optical; new integral field spectrographs covering 3600-10000Å at $R \sim 4000$	Exploring galaxy formation and regulation by star formation; feedback, enrichment, & ISM physics

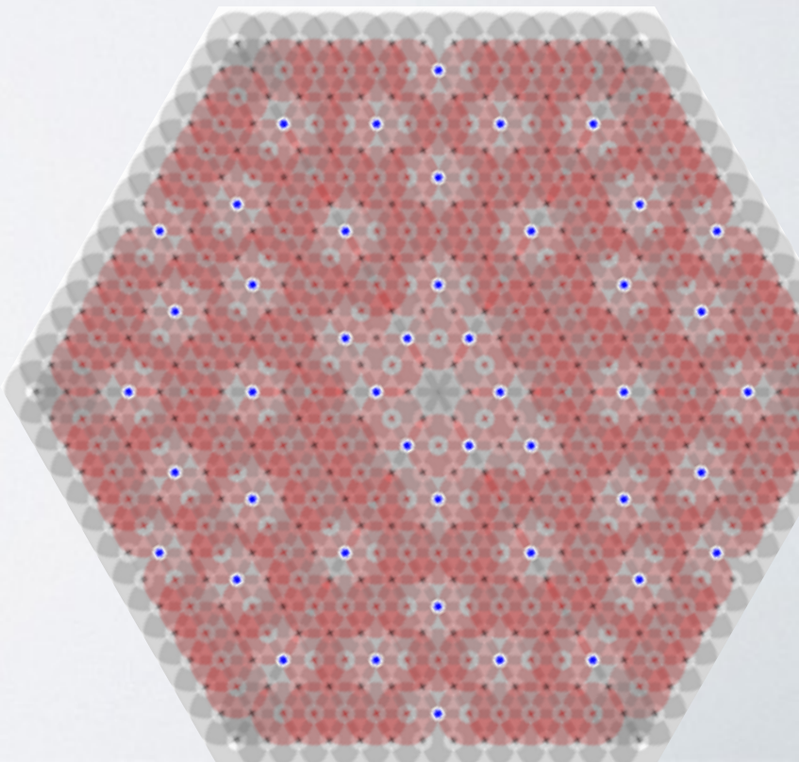
A rich data stream serving a very broad community!

PLATES —> ROBOTS

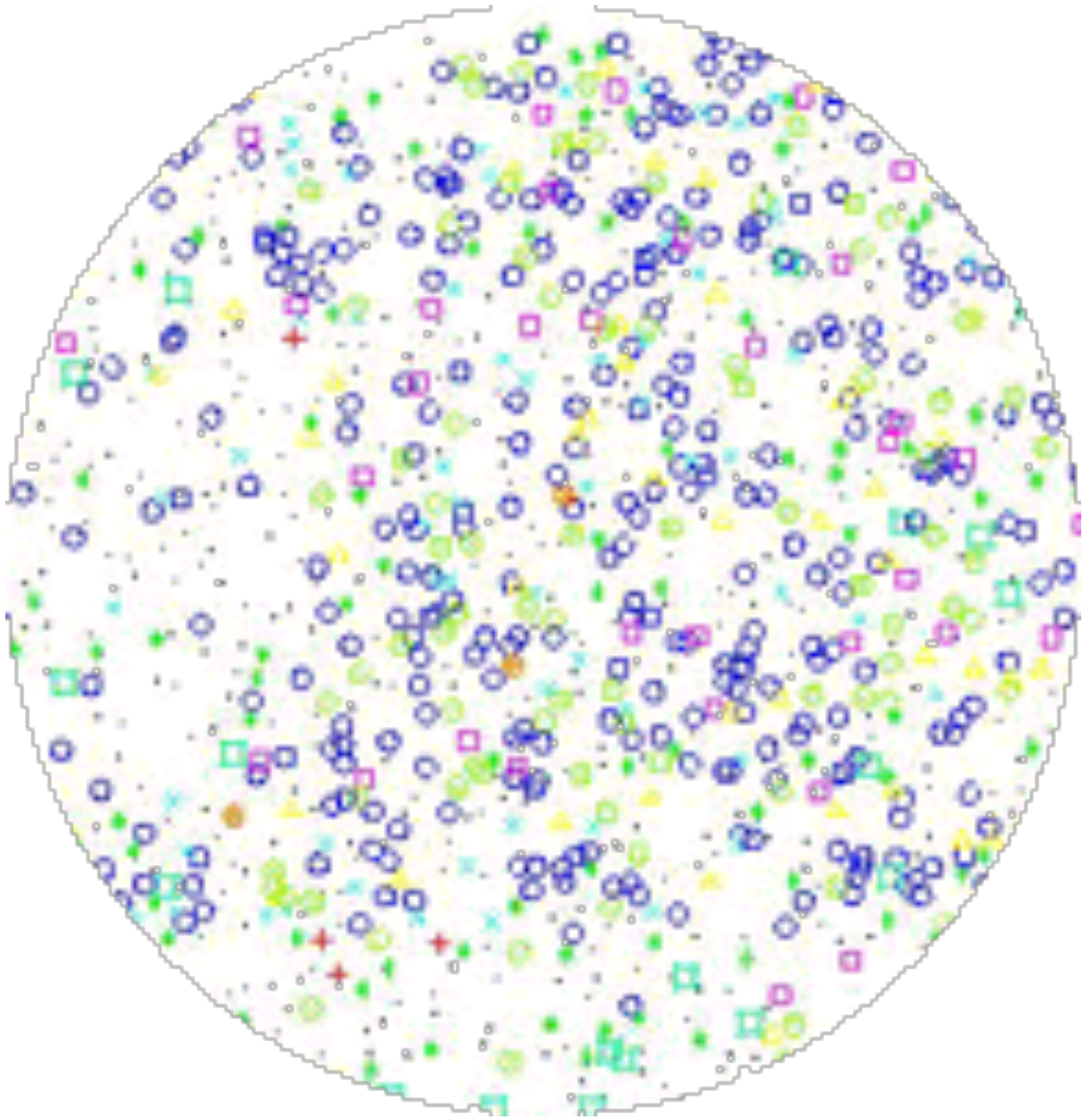


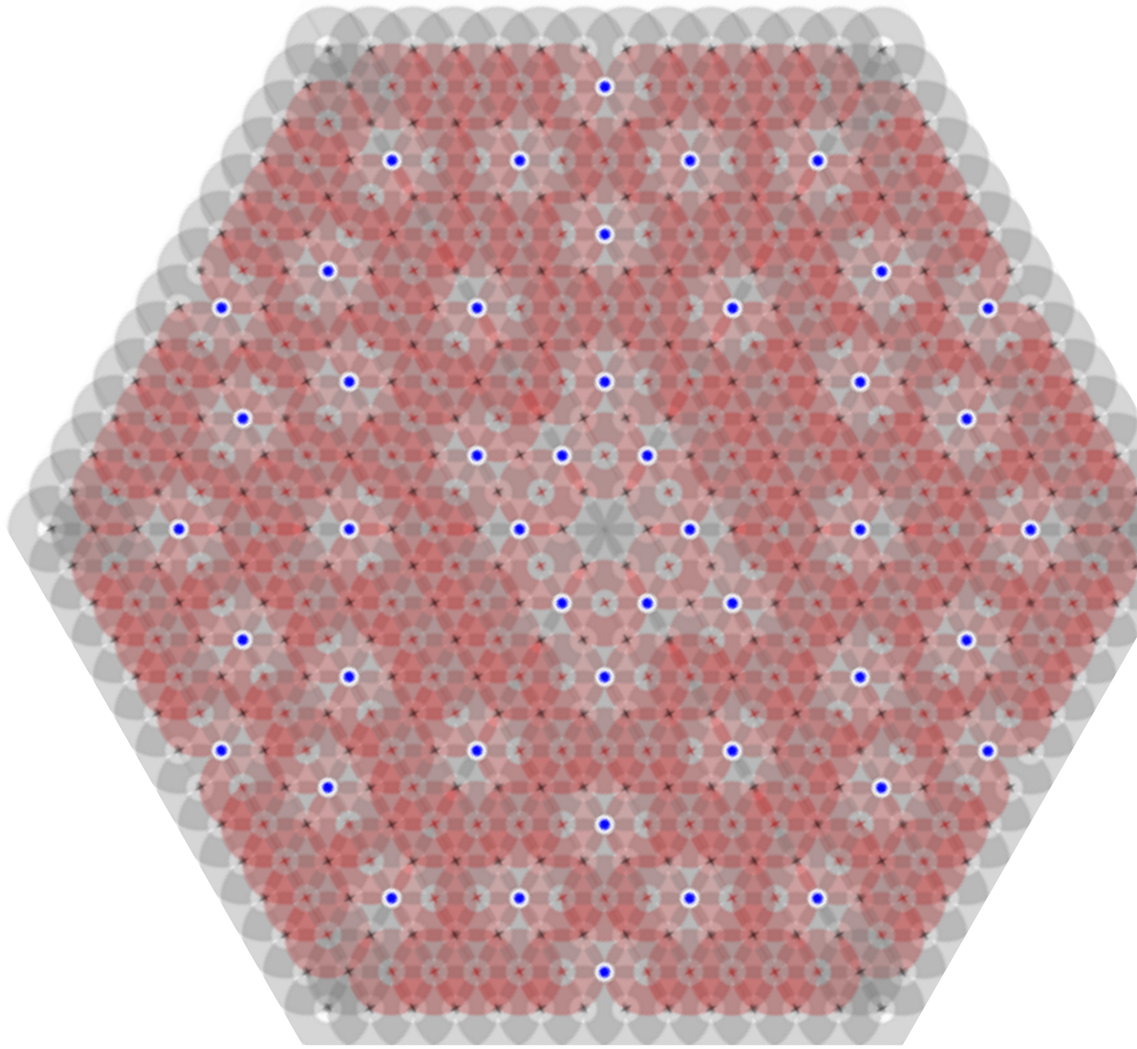


ALL Sky
Dust-Penetrating
Multi-epoch (1-60)
High-quality
spectroscopy

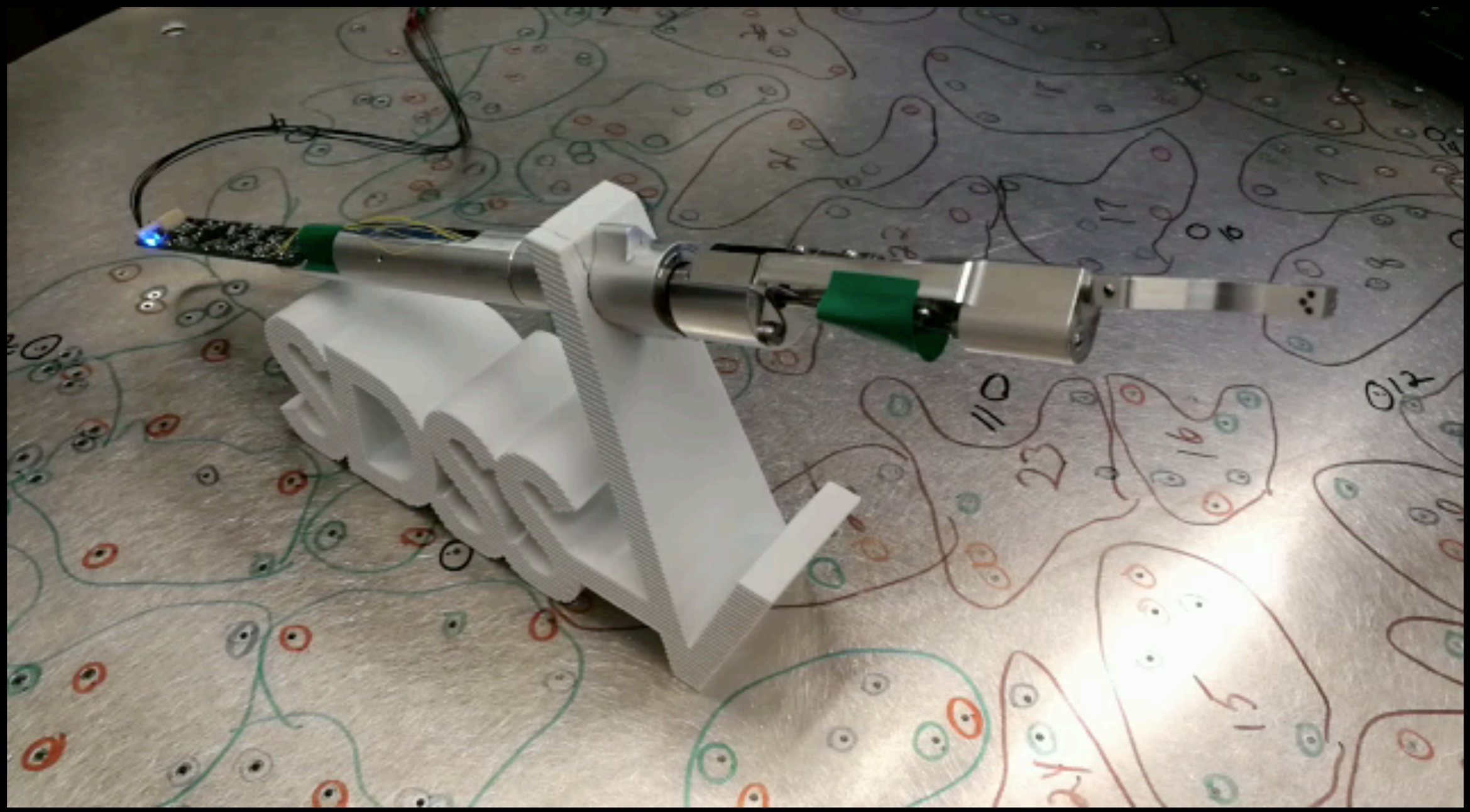


ROBOTIC FIBER POSITIONERS TO FEED SPECTROGRAPHS



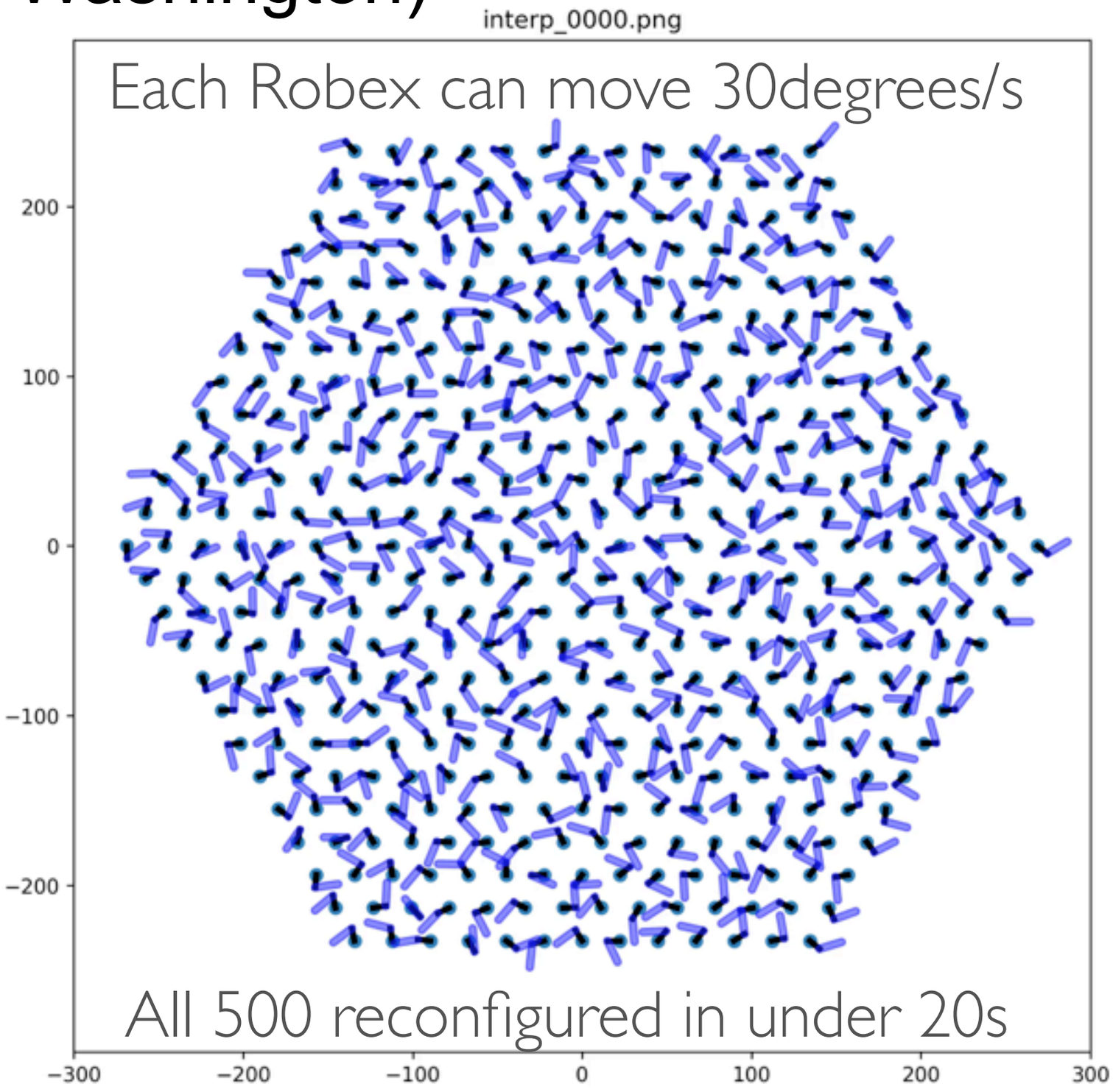


SDSS-V PROTOTYPE0!



Courtesy J-P Kneib & EPFL Team

Kaiju: A Highly Efficient Collision Avoidance Algorithm for SDSS-V Robotic Fiber Positioners — Conor Sayres (U. Washington)



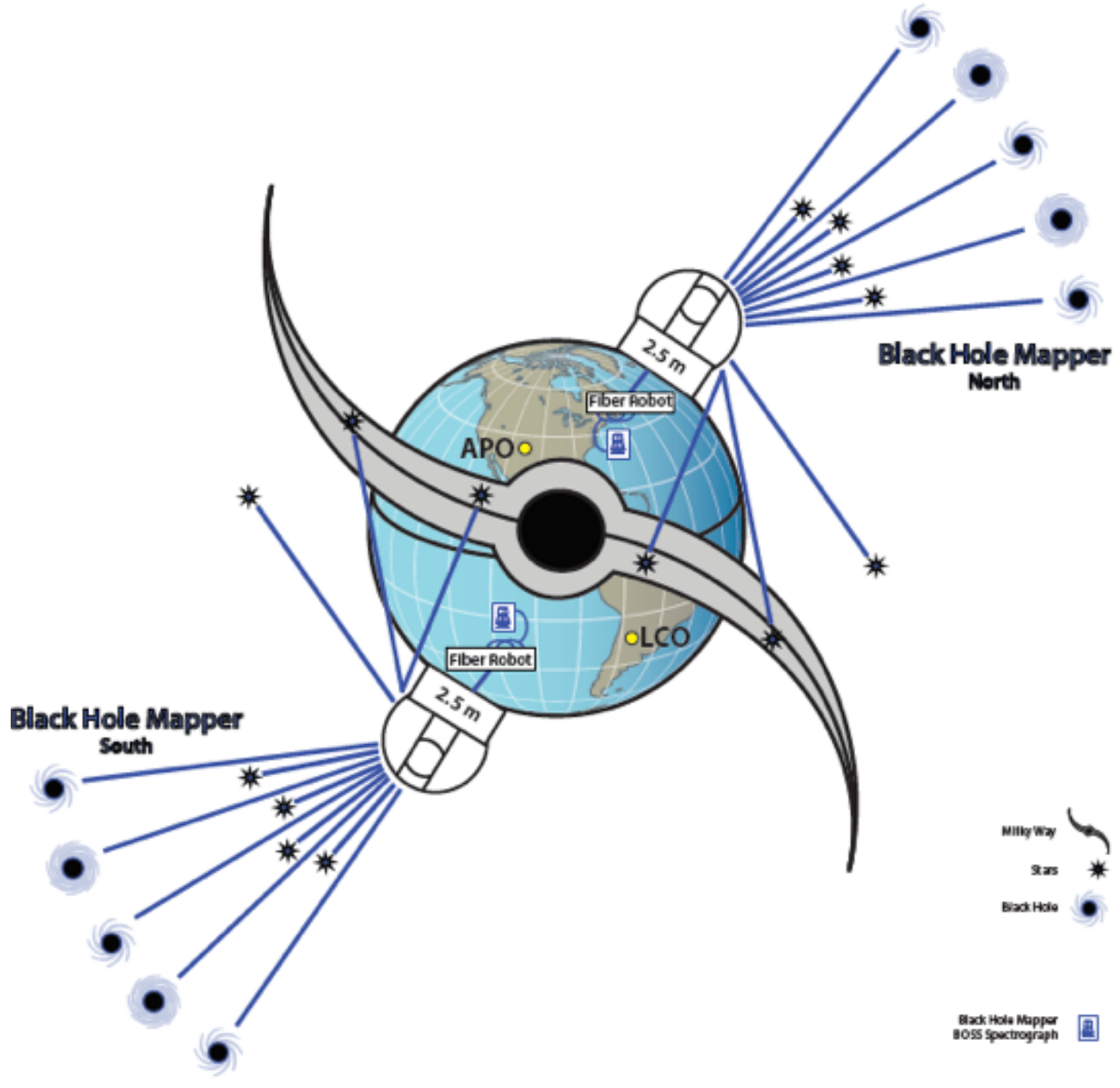
SDSS-V PROTOTYPE I!

- New prototypes tested in December/ January
- Fiber Positioning System successful PDR in November 2018
- Call of Tender for the robots has gone out (January)

Final design review at the end of Q2!

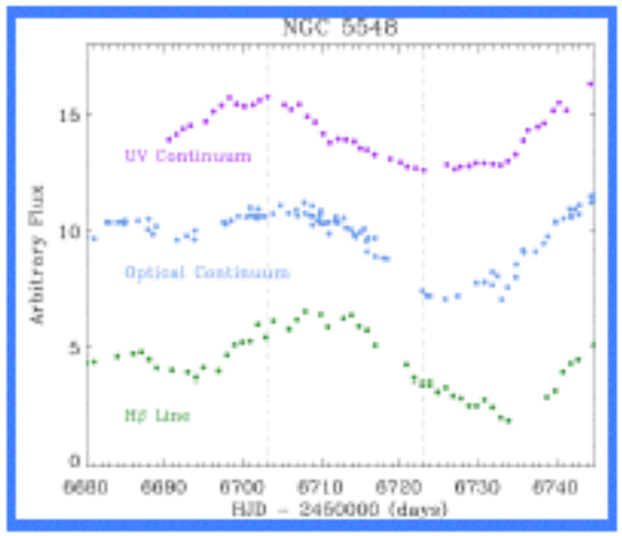
Ready in mid-2020 will commission as soon as SDSS-IV completes

BLACK HOLE MAPPER: BHM

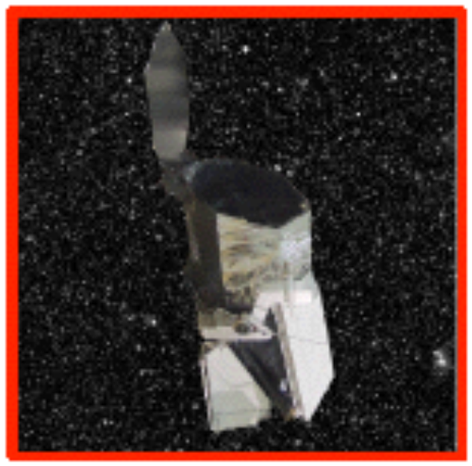


BLACK HOLE MAPPER:

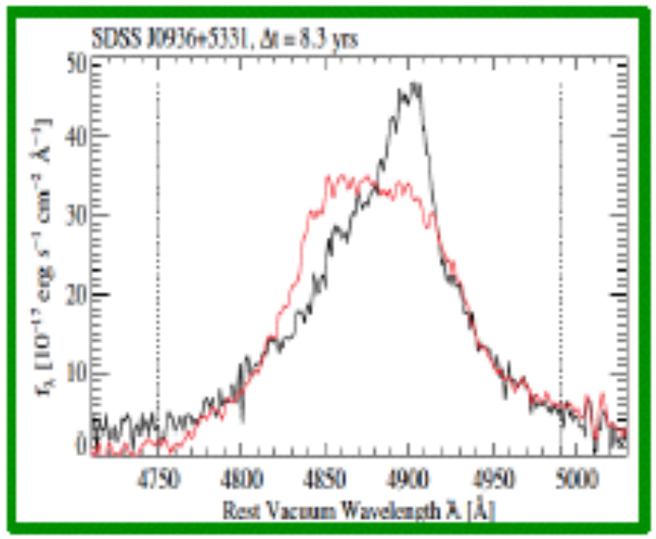
UNDERSTANDING BLACK HOLE GROWTH



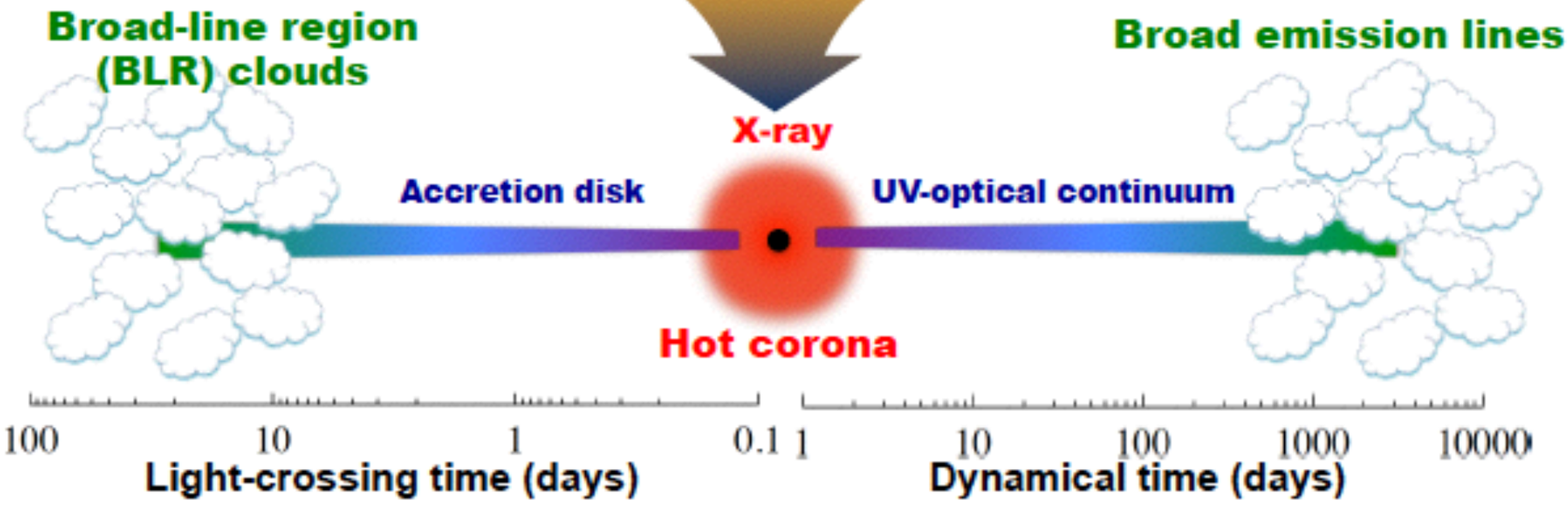
Reverberation Mapping
Measuring BLR sizes and BH masses



eROSITA
Probing the hot X-ray corona



Multi-epoch Spectroscopy
Probing dynamical changes in the BLR

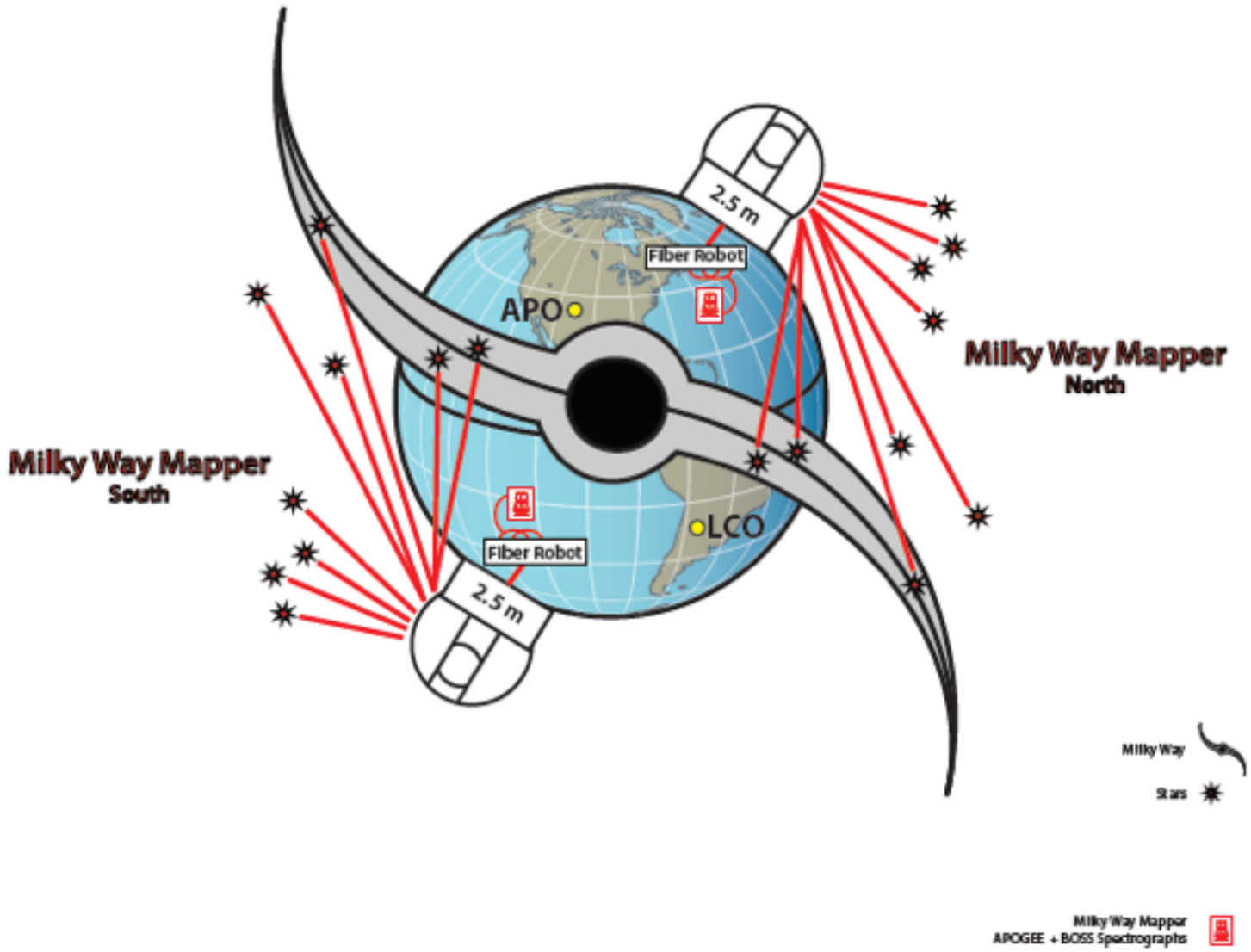


BHM Time-Domain Survey Outline

Spectral time-domain astrophysics of quasars: BH masses, binarity, accretion and events, BLR dynamics, outflows, etc. Broad range of time-sampling/cadence, days to decades.

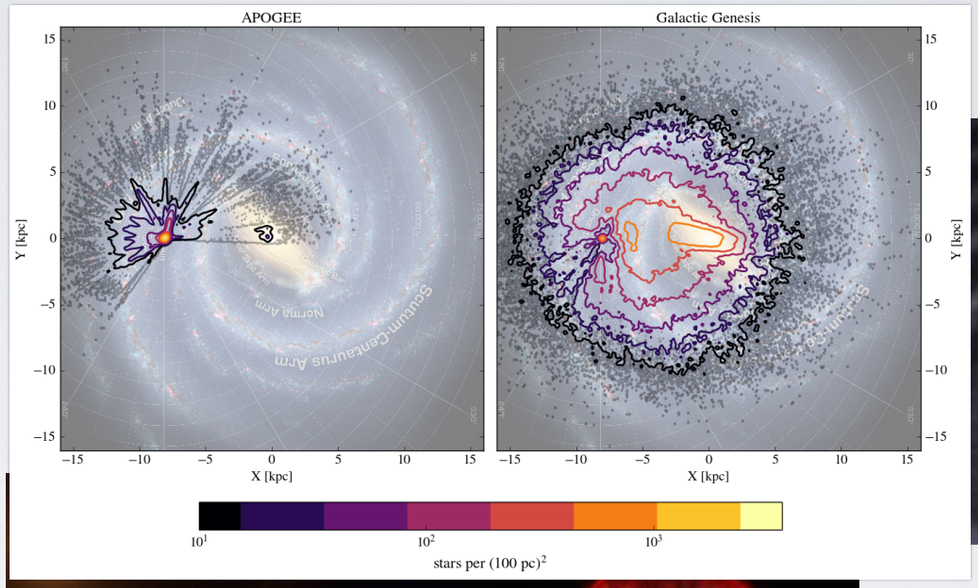
- For >20,000 quasars, 2-3 epochs during AS4 plus earlier-epoch SDSS spectra, sampling ~1-10 year timescales, e.g., transition times of changing look quasars, BAL disappearance and emergence, etc. *(wide/low-cadence tier; ~3000 deg^2)*.
- For >2000 quasars, 12 epochs during ~2 years of AS4, probing down to ~1-month to 1-year timescales, adding unfolding BLR structural and dynamical changes *(medium tier; ~300 deg^2)*.
- Reverberation mapping (RM) for ~1000 quasars in 5 fields, >10^2 epochs, sampling down to days to weeks; lags between continuum and BLR emission yield BH masses; premier RM sample at high L, z. (high-cadence tier; ~30 deg^2)

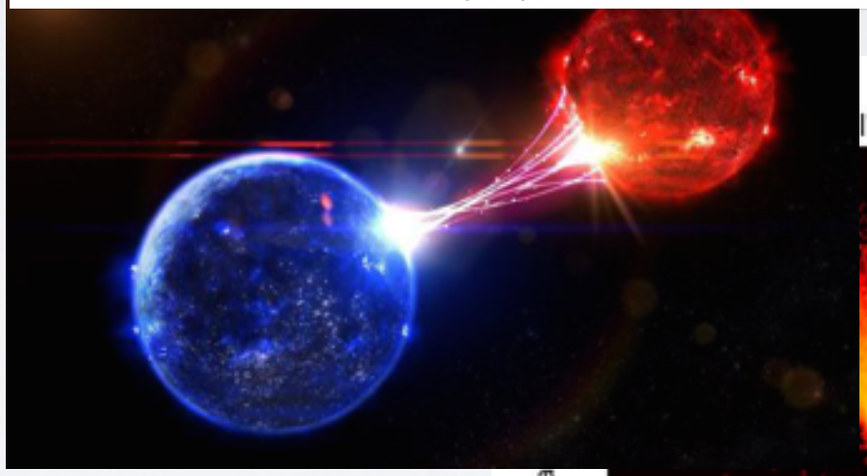
Milky Way Mapper: MWM

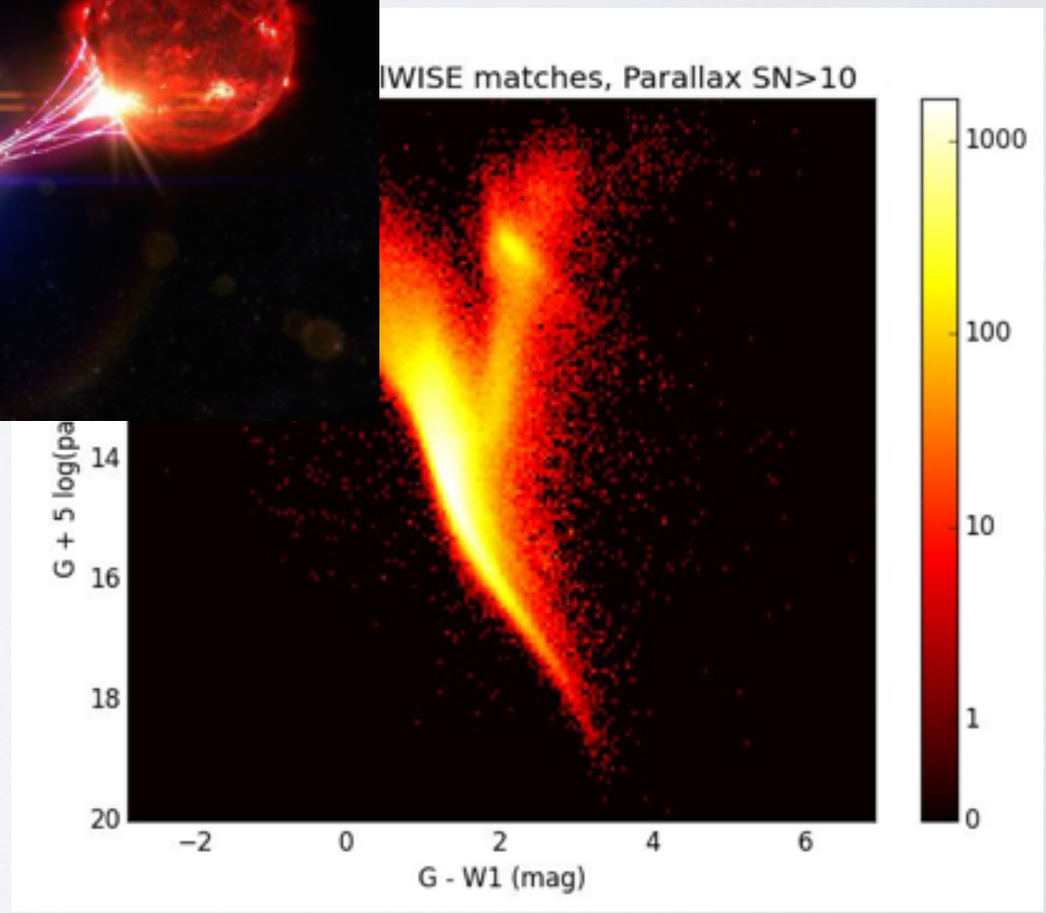


SCIENCE GOALS (GENERAL)

- 1) How did the Milky Way's disk form?
- 2) How do stars live, evolve, and die (and affect transient/GW universe)?
- 3) What stars host planets?
- 4) What IS the stellar multiplicity across the HR diagram? Role of binaries in Stellar Evolution
- 5) Origin of Supernovae and the heavy elements



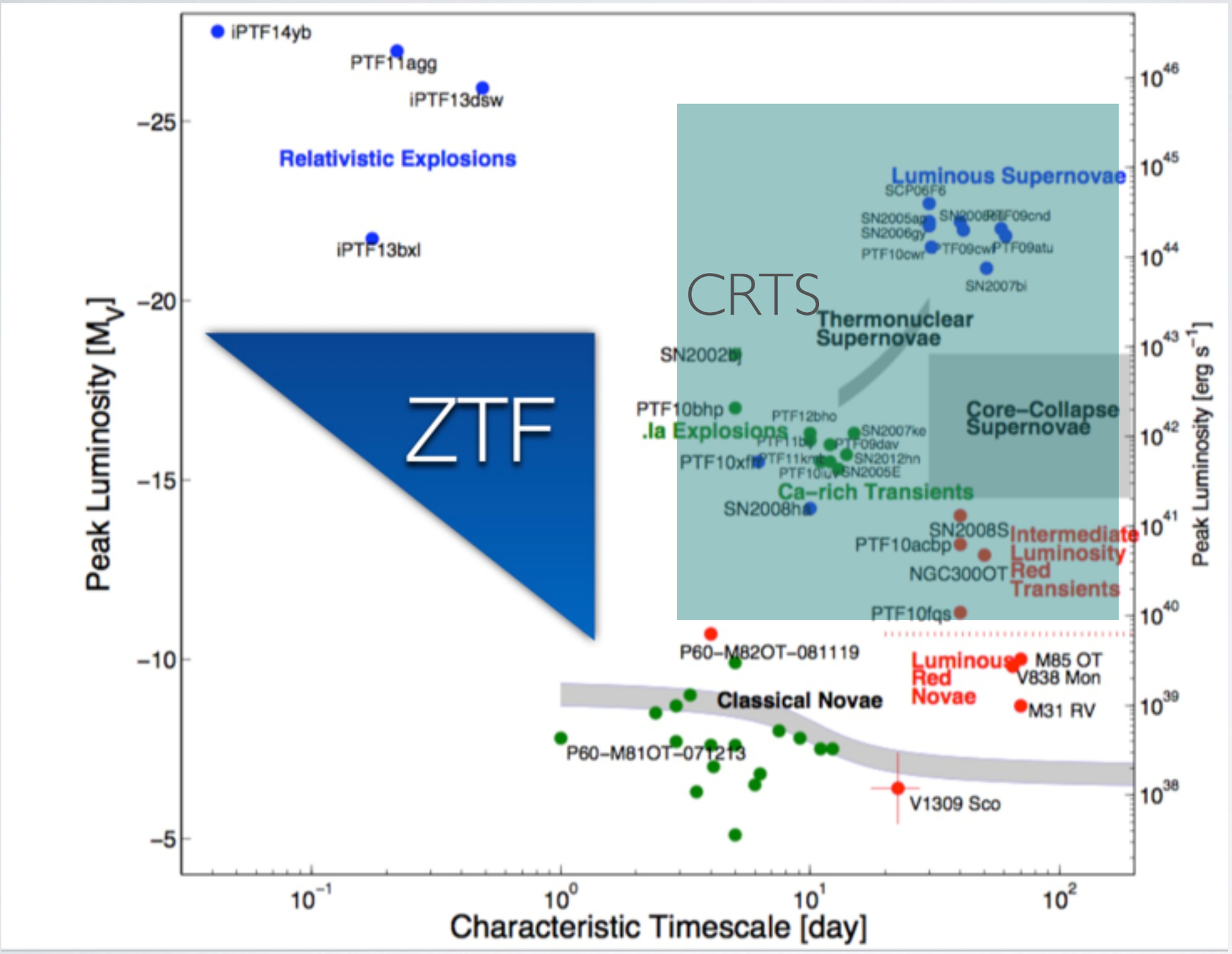




From D. Lang

Galactic Genesis & Stellar Astrophysics Targeting Classes				
Instrument	**Selection**	**$N_{Targets}$**	**N_{Epochs}**	**Comments**
Galactic Genesis Survey: mapping the dusty disk				
APOGEE	$H<11$, $G-H>3.5$	4,800,000	1	dust-extinguished disk
APOGEE	$\|z\|<200$ pc, $H<11$, d<5 kpc	125,000	1	to complete high-res ISM map
Binaries with Compact Objects: enumerating the populations of binaries with white dwarfs, neutron stars, or black holes, selected by variability				
BOSS	PTF, ZTF, *Gaia* variability	30,000	3	binaries with WDs, NSs, and BHs
BOSS	*Gaia* parallaxes	30,000	1	wide WD+MS/RGB binaries
Solar Neighborhood Census: observing all stars within 100 pc, giving the best probe of low-mass stars, whether in single or binary systems				
APOGEE, BOSS	d<100 pc, $G<20$, $H<12$	400,000	2	1000× increase in volume & stars
White Dwarf Chronicle: using white dwarfs and their evolved companions to measure the SFH and age-metallicity relation				
BOSS	$G<20$	300,000	3	15× increase in sample size
TESS Exoplanet Host Candidates: observing all TESS short-cadence targets in the CVZs				
APOGEE	$H\leq13.3$	300,000	1–8	all short-cadence targets & planet hosts
Binaries Across the Galaxy: measuring environmental dependence of binary fraction in the disk, bulge, halo, and stellar clusters; probing the brown-dwarf desert beyond solar-type stars				
APOGEE	$H<13.4$, $N_{Epoch}\geq6$ by the start of SDSS-V	60,000	6–18	gives orbits with 24–40 epochs for all targets with long APOGEE baselines
Gaia Astrometric Binaries: characterizing rare systems that have good astrometric orbits but limited other information, from *Gaia*'s sample of > 10 million stars				
APOGEE, BOSS	$d<3$ kpc	200,000	1	rare types of systems
TESS Red Giant Variability: measuring spectroscopic properties for red giants in TESS that have seismic and/or granulation lightcurve signatures				
APOGEE	$H<12.5$	250,000	1	stars with at least 80 days of TESS observation
Massive, Convective Core Stars: combining dynamic and asteroseismic measurements of binary OBAF stars in the TESS CVZs and characterizing their multiplicity				
APOGEE	$H<12$	200,000	2	detection of single vs. binary systems
APOGEE		500	25	>10× increase in current sample size
Young Stellar Objects: quantifying the stellar populations in star-forming regions, including identifying sources of ionizing radiation and characterizing the binary frequency				
APOGEE	$H<12$, $d<1$ kpc	20,000	12	nearby star-formation regions
APOGEE	$H<12$	3,500	8	high-mass star-formation regions
APOGEE	$H<12$, $\|b\|<2°$	10,000	2	massive young stars in the Galactic Plane
APOGEE	$H<13$	10,000	2	Central Molecular Zone

TRANSIENTS!



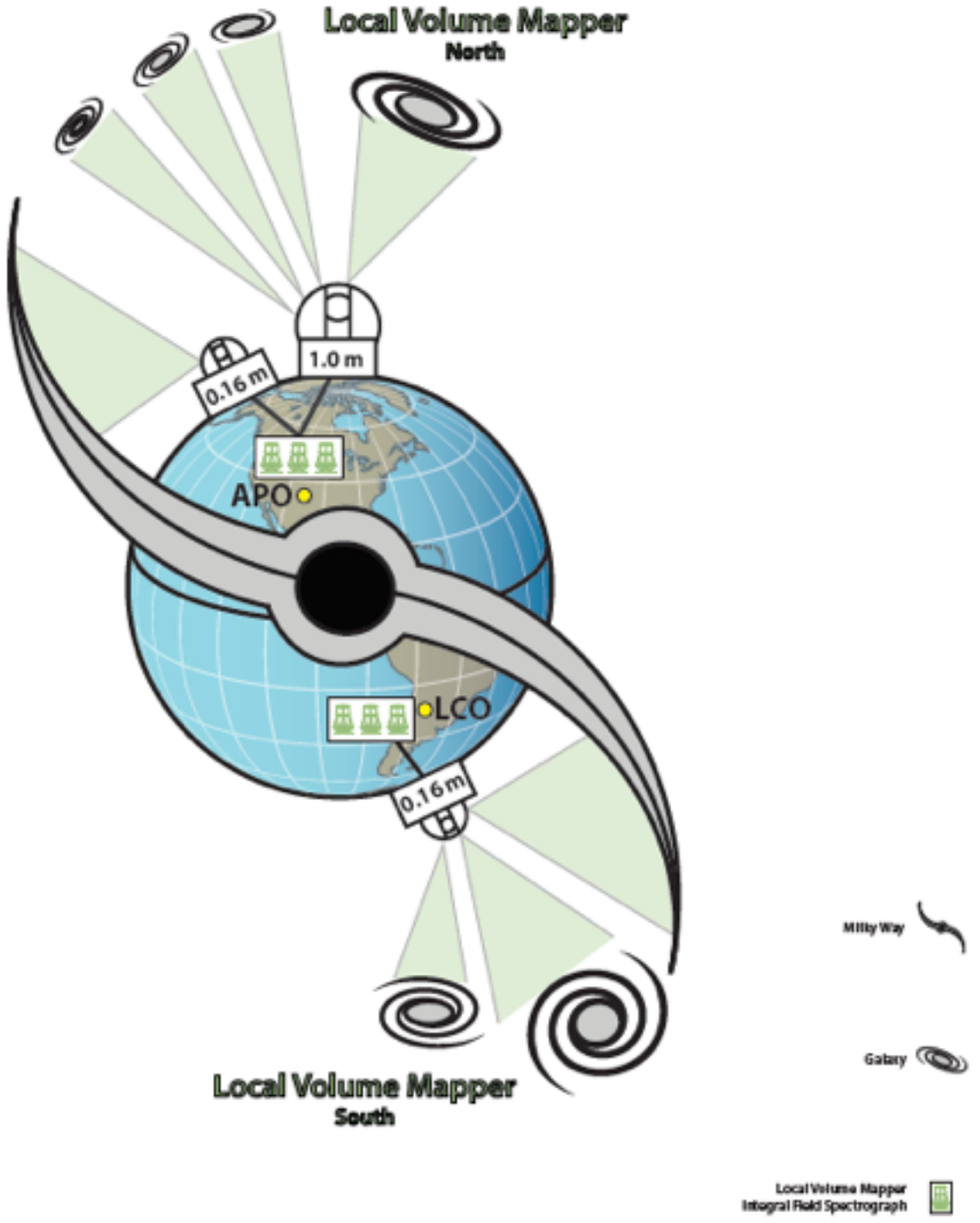
Wouldn't it be nice to settle BASIC questions like: What are Type Ia SNe (and what are they NOT)?

B. Penpraese

Local Volume Mapper: LVM

Using different telescope sizes and an array of IFU-coupled spectrographs at *R*~4000 and 3600-10000Å, we survey:

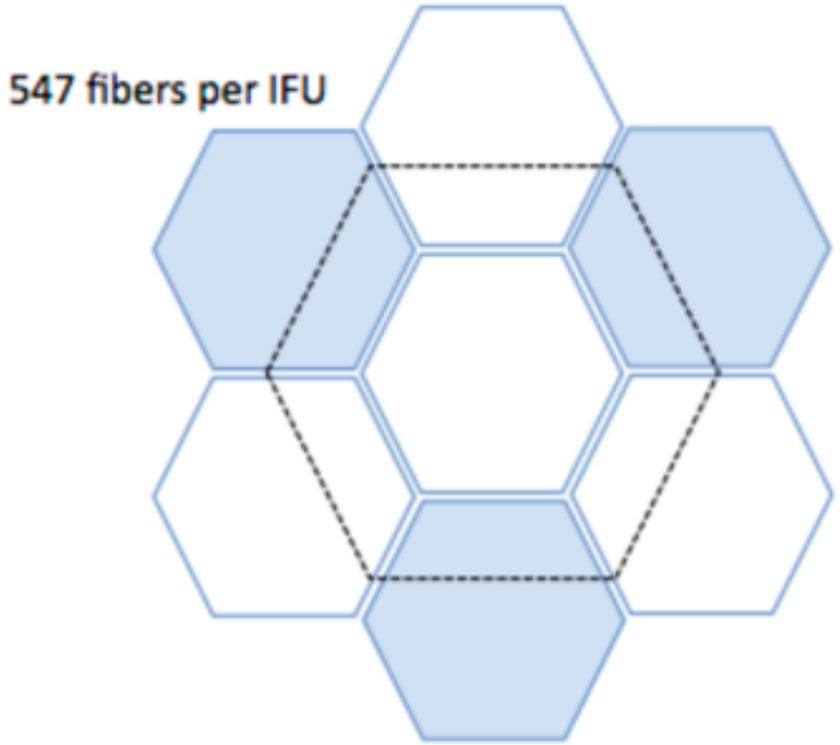
- 2800 sq. deg. in the MW @ 0.1-1 pc resolution,
- 300 sq. deg. in the MW 10x deeper,
- LMC & SMC @ 10 pc resolution,
- M31 & M33 @ 20 pc resolution, and
- 12 nearby galaxies (D≲5 Mpc) @ 50 pc resolution

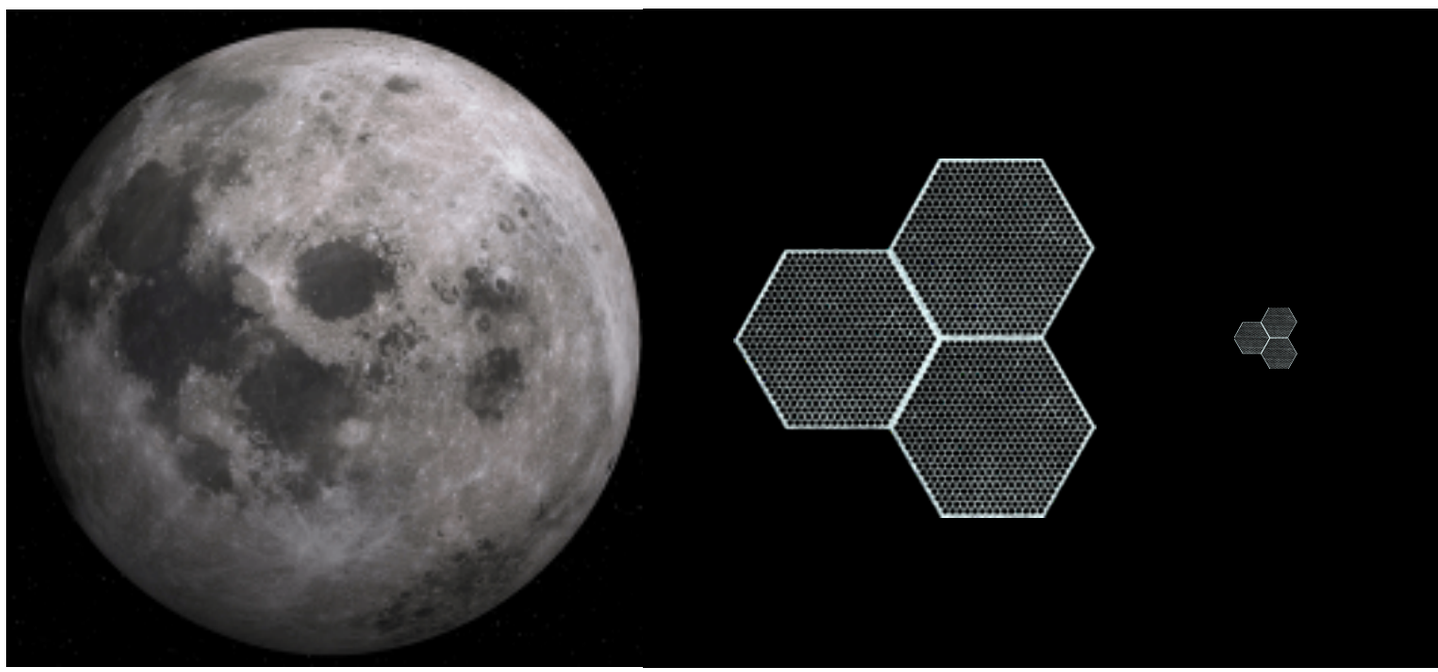


LVM hardware

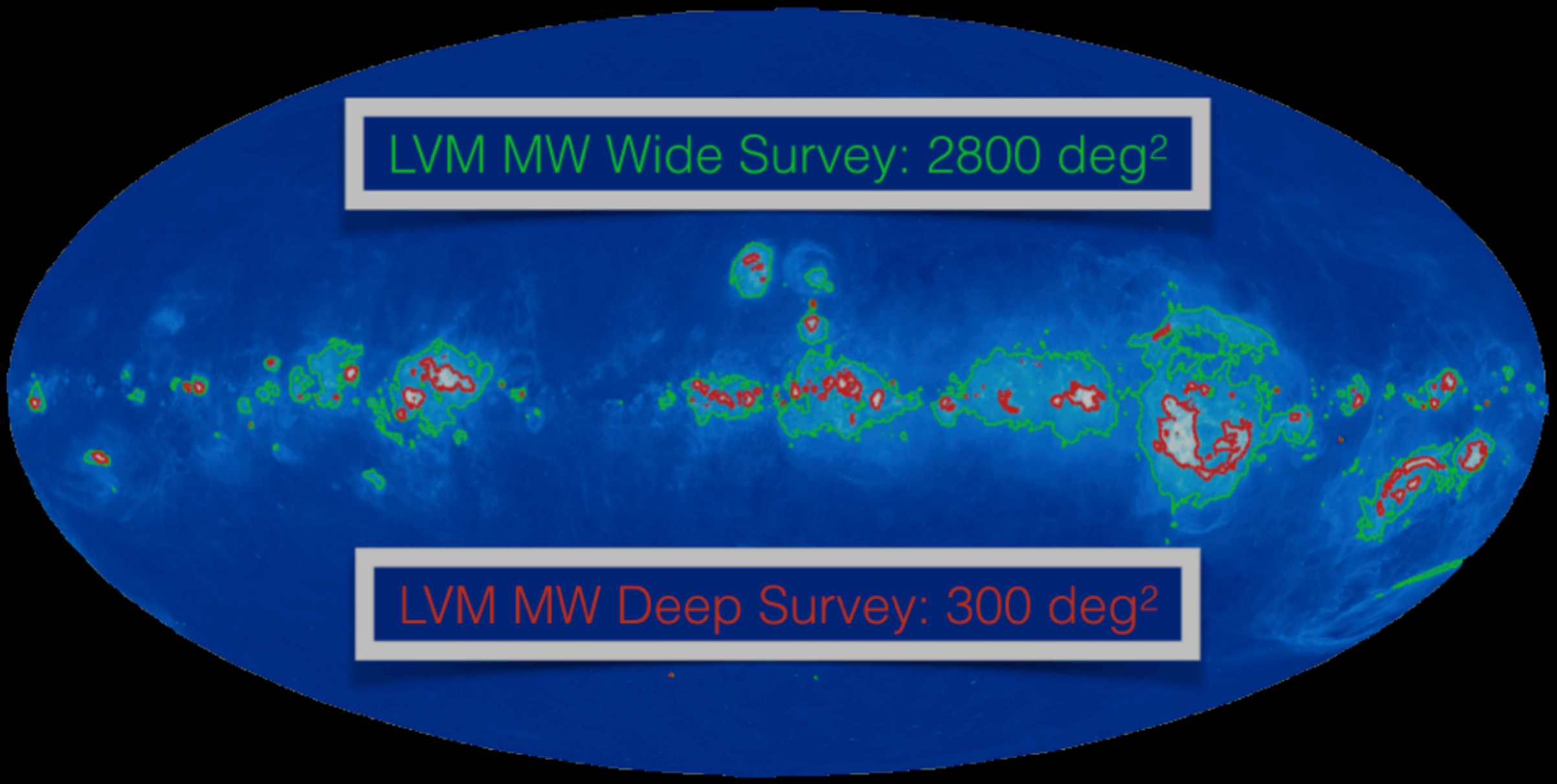
IFU design

- 3 x 547 hexagonal non-abutted lenslet coupled IFUs arrays.
- 309 calibration fibres.
- Based on highly-successful MaNGA design.
- 490 arcmin2 @ 0.16 m
- 12 arcmin2 @ 1 m





OBSERVING GALAXIES AT THE "ENERGY INJECTION SCALE"



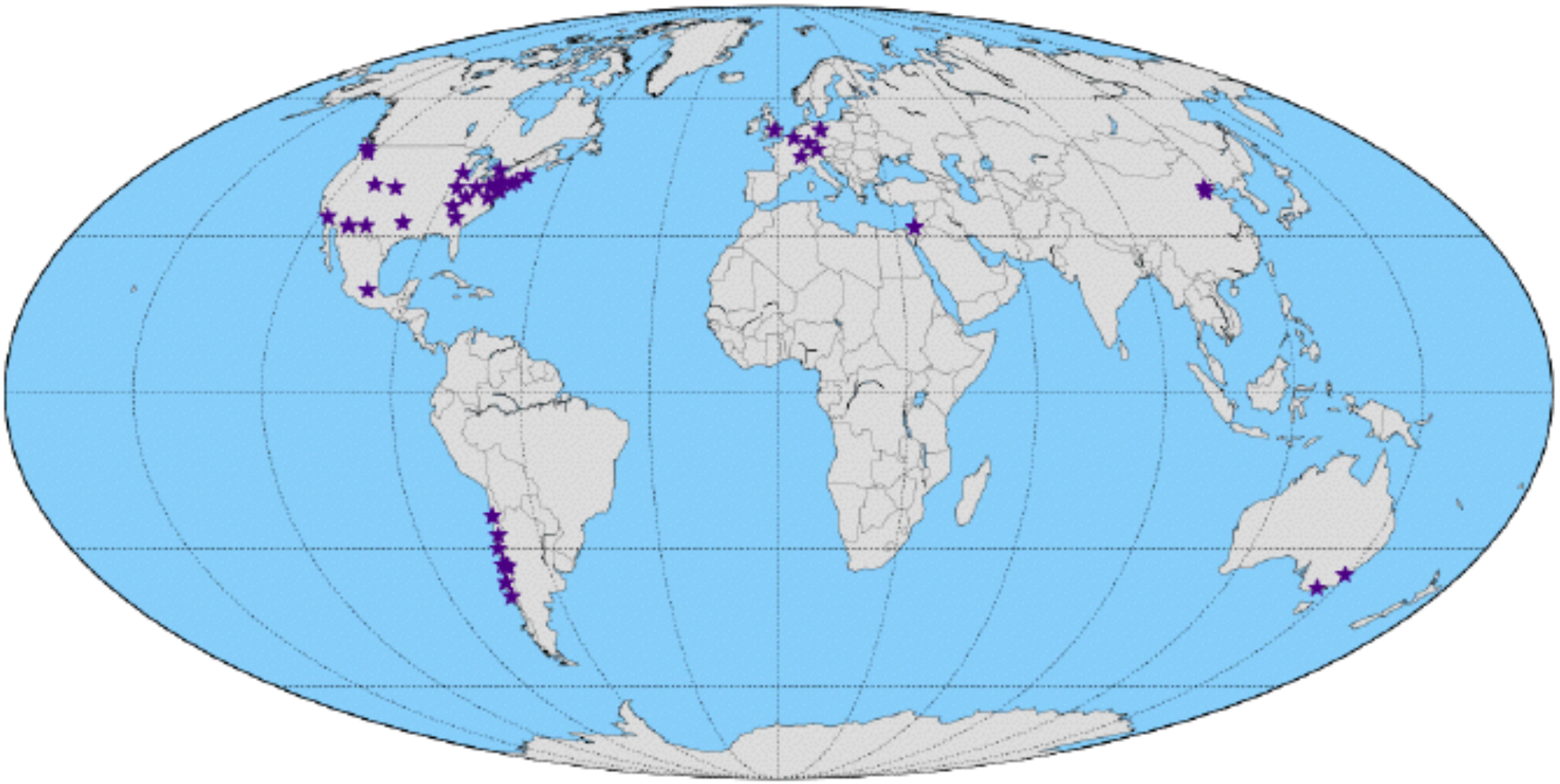
Cosmological Zoom-In Observations!

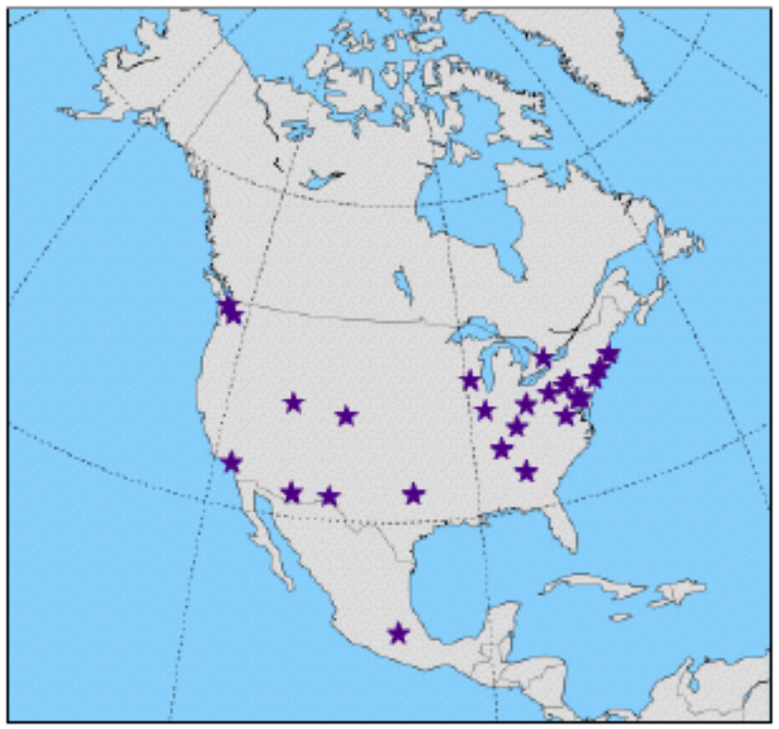
Juna Kollmeier, Carnegie Observatories

INSTITUTIONAL PARTNERSHIP

SDSS Collaboration Matrix	MOU Signed/Out for Signature	MOU in Draft/Iteration	Prospective Institutions
FULL MEMBERS	CU Boulder Harvard MPE MPIA NMSU OSU NAOC Yale CNTAC	Carnegie Wisconsin STSCI UofA JHU UNAM U of Toronto SAO	NOAO! INAF
3 Slot Members	AIP PSU Flatiron UIUC	UVA	Caltech MIT
Individual (1-2) slot Members	University of Washington (2) TCU, TAU (2) Vanderbilt, KIAA, U. Warwick, NYU, KU Leuven, Columbia, U. Penn,York University, University of Victoria, U. Pittsburgh, Georgia State	Monash University EPFL ANU	Oxford Nanjing U. SHAO

Partner Institutions





ARC Board of Governors

: Mike Crenshaw (GSU)

Advisory Council

: Keivan Stassun (Vand, SAPG)
eth (UU)
e Conroy (Harvard)
chinerer (MPIA)
Wu (NAOC)
oltzman (NMSU)
Jrry (Yale)
Weinberg (OSU)
Comerfeld (CU)
Erakleous (PSU)
as Steinmetz (AIP)
Blanton (NYU, GPG)
Wong (UIUC)
Mulchaey (OCIS)
i Fan (UofA)

SDSS-V

Central Project Office

Director: Juna Kollmeier (OCIS)

Project Scientist: Hans-Walter Rix (MPIA)

Spokeperson: Gail Zasowski (UU)

Project Manager: Solange Ramirez (OCIS)

Lead Sys. Engineer: Stefanie Wachter (OCIS)

Instrument Development

Focal Plane System	Local Volume Mapper
P. Pogge, C. Brandon, T. O'Brien (OSU)	N. Konidaris (OCIS), C. Froning (UT)

Data Processing Team

Principal Data Sci.: J. Brownstein (UU)

CAS: A. Thakar (JHU)

Observatory Operations

Las Campanas Observatory: J. Crane, D. Osip (OCIS)

Apache Point Observatory: M. Klaene, J. Downney (APO)

Ops. Software: J. Sanchez-Gallego, C. Sayres (UW)

Survey Execution

Milky Way Mapper (MWM)	Black Hole Mapper (BHM)	Local Volume Mapper (LVM)
Prog. Lead: Jennifer Johnson (OSU) GG Survey Scientists: M. Ness (MPIA) & J. Bird (Vand) SA & SSA Survey Scientists: N. De Lee (NKU) & A. Tkacheno (Leuven)	Prog. Lead: Scott Anderson (UW) Survey Scientists: A. Merloni (MPE) & Y. Shen (UIUC)	Prog. Lead: Niv Drory (UT) Survey Scientists: K. Kreckel (MPIA), G. Blanc (OCIS), E. Pelegrini (UH)

Scientific Working Groups

White Dwarfs: B. Gaensicke	XRB/Compact Binaries: A. Schwope	Star Formation: J. Kauffman
Stellar Models: C. Conroy	Reverberation Mapping: K. Horne	LVM Milky Way:TBD
Dust Mapping: E. Schlafly	X-ray Clusters: N. Clerc	LVM ISM: M. Seibert
TESS/Planet Host: J. Teske	QSO Physics: M. Eracleous	LVM Stellar Populations: K. McQuinn
TESS/PLATO: S. Hekker	Machine Learning: B. Bovy, A. Casey	LVM Cold Gas: E. Schinnerer
TESS/Astero: J. van Saders		

Technical Advisory Group

Chair: Douglas Finkbeiner (Harvard)

Davis Hogg (NYU)

Jim Gunn (Princeton)

David Weinberg (OSU)

Connie Rockosi (UCSC)

Mike Blanton (NYU)

David Schlegel (LBL)

Matt Johns (MJI)

Steve Majewski (UVa)

Spectroscopic Surveys: 2020

Spectroscopic Survey Facilities around the Year 2020								
Survey (facility)	N_{target}	R_{spec}	N_{res}	$\bar{\lambda}[\mu m]$	Ω_{sky}	N_{epoch}	Timeframe	$m_{primary}$
SDSS-V	7×10^6	22,000 2,000	500	1.51-1.7 0.37-1	4π	$4-60$	2020-2024	$m_H \leq 12$ $m_G \leq 18$
Gaia (RVS)	2×10^6	8000	270	0.85-0.87	4π	~ 60	2013-2020	$m_G \leq 12$
Gaia-ESO	0.1×10^6	17,000	140	0.55& 0.85	0.02π	~ 1	2013-2018	$m_G \leq 17$
GALAH	0.8×10^6	28,000	400	0.40- 0.85	π $\lvert b \rvert \geq 10$	~ 1	2015-2020	$m_G \leq 13$
WEAVE	0.8×10^6	5,000 & 20,000	1000	0.37-0.9	$\sim \pi$	$\sim 1-2$	2018-2023	$m_G \leq 19$
DESI	8×10^6	3,000	5000	0.36-0.98	$\sim \pi$ $\lvert b \rvert \geq 25$	$\sim 1-2$	2019-2024	$m_G \leq 19$
LAMOST	8×10^6	1,800	4000	0.4-0.9	0.5π	~ 1	2010-2020	$m_G \leq 16$
4MOST	10×10^6	5,000 & 20,000	1600 & 800	0.4-0.9	1.5π	$1-2$	2023-2028	$m_g \leq 21$ $m_V \leq 16$
APOGEE-1& -2	5×10^5	22,000	300	1.51-1.7	0.5π	~ 4	2011-2019	$m_H \leq 12$
PFS	1×10^6	3,000	2400	0.4-1.6	0.05π	1	2018-2021	$m_g \leq 22$
MOONS	2×10^6	5,000 & 20,000	1000	0.6-1.8	0.05π	1	2020-2025	$m_g \leq 22$ $m_H \leq 17$

O + IR ; ALL SKY ; TIME DOMAIN!

WHAT IS MSE's 10x ADVANCE IN THIS LANDSCAPE?

Juna Kollmeier, Carnegie Observatories

Spectroscopic Surveys: 2025

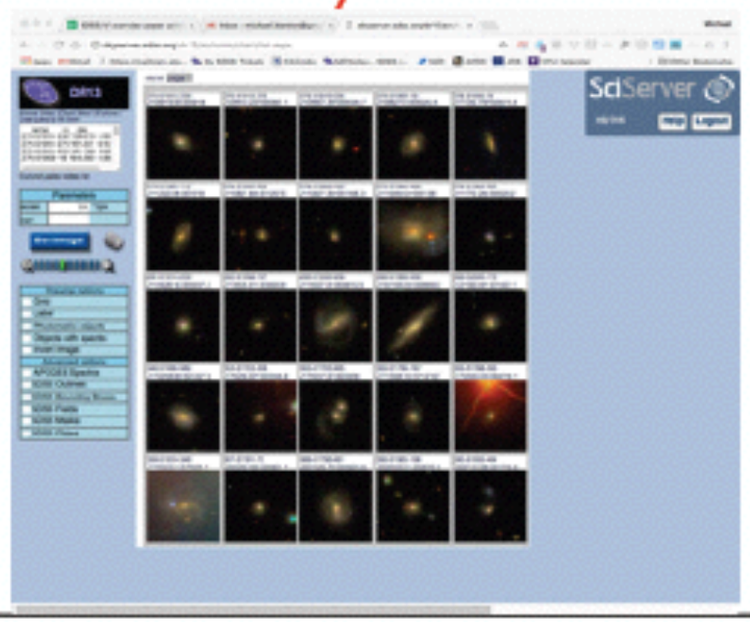
Future Facility	Big Advance
LSSTSpec?	
ELTspecs?	(see Warren's talk)
SphereX	Space! 10^9!
Other?	Other?
MSE	THIS GROUP!

Power of the Public Data

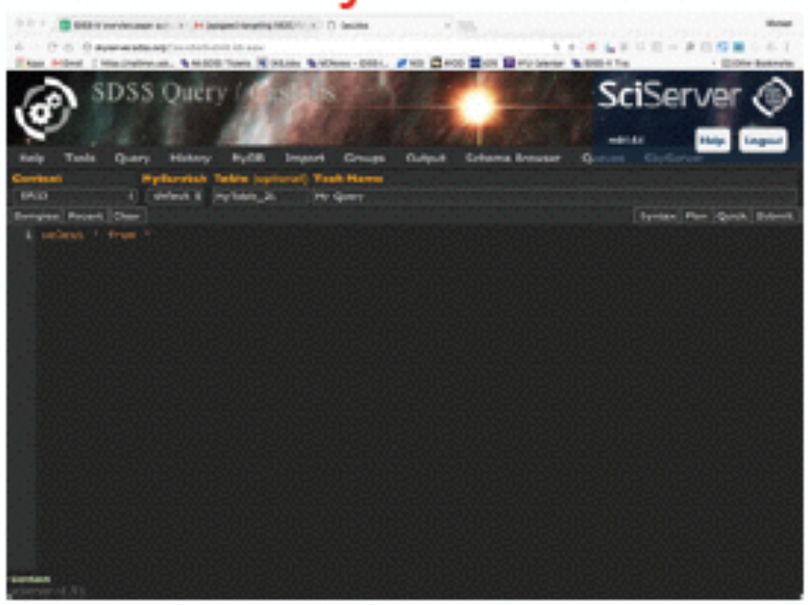
- First in 2001, latest in July 2018 (DR15), next planned in July 2019
- Large science impact:
  - *> 7,000 papers involving SDSS data*
  - *~ 80% are outside collaboration*
- Comprehensive system serving many audiences:
  - *millions of queries per year*
  - *500 helpdesk requests per year*
  - *1000s of students*

Science Archive Server

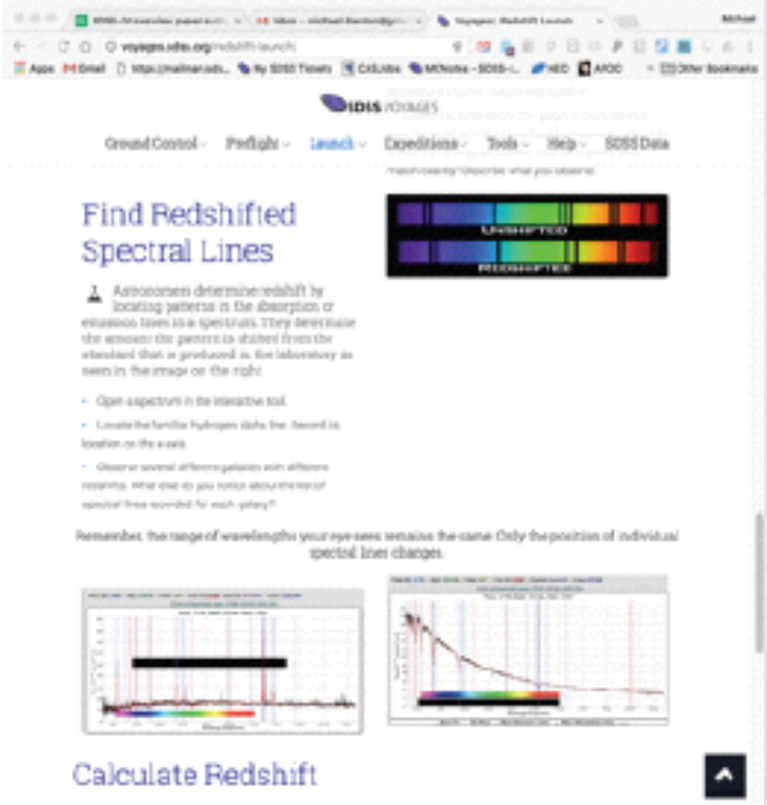
SkyServer



CasJobs



Voyages



See talk by S. Juneau

Michael Blanton, Center for Cosmology and Particle Physics, New York University

IF YOU LOVE YOUR DATA SET IT FREE

Juna Kollmeier, Carnegie Observatories

In launching the Data Driven Discovery Institute, investigators were asked to contribute "Influential Works"

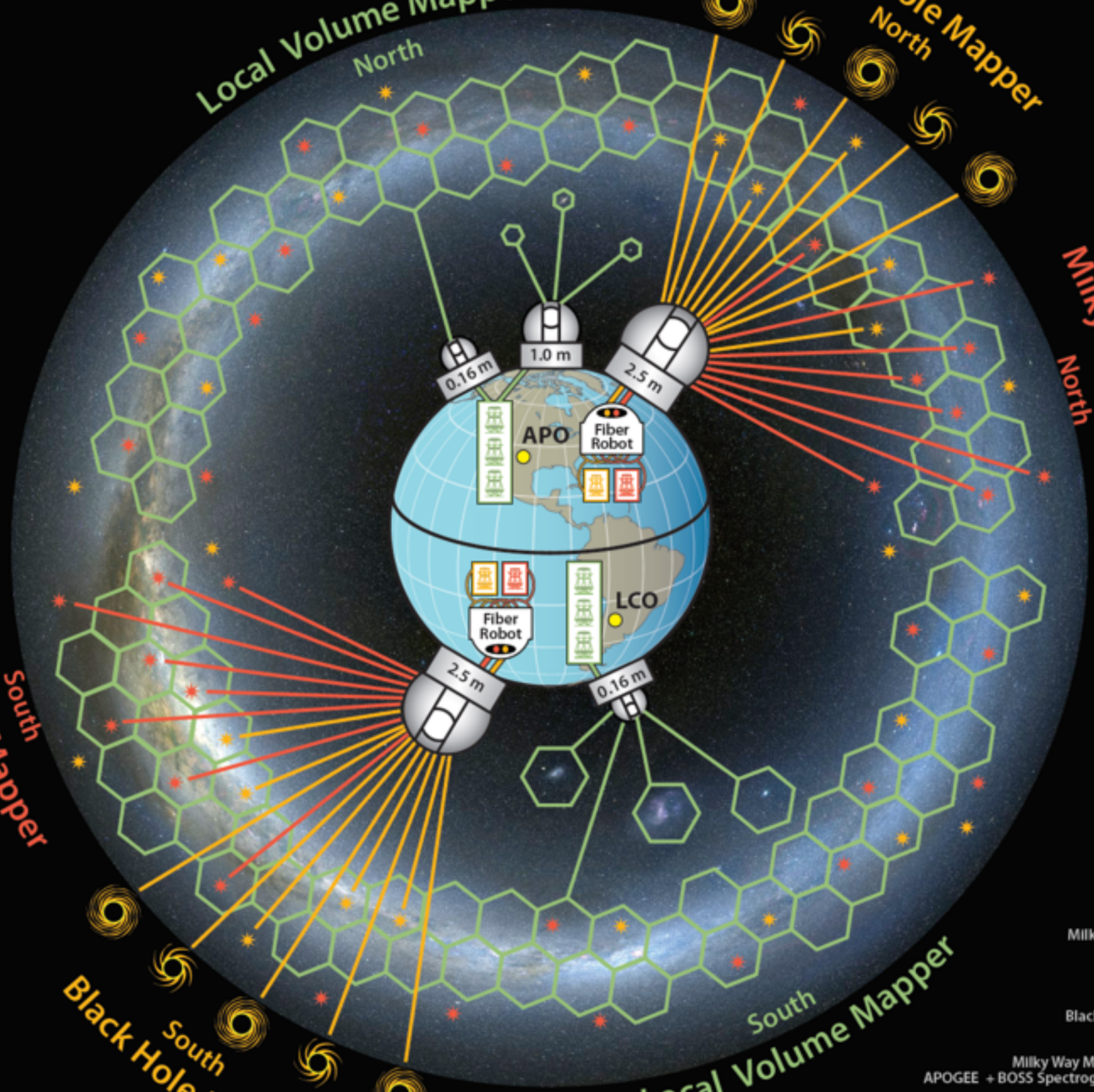
~5000 Works Submitted & Analyzed

Resulting analysis "A Preliminary Review of Influential Works in Data-Driven Discovery" — Stalzer & Mentzel (2015)

Making your data USABLE has wide-ranging benefits!

Citation
MapReduce[1]
Fourth Paradigm[2]
Elements of Statistical Learning[3]
Initial sequencing of the human genome[4]
A mathematical theory of communication[5]
Sloan Digital Sky Survey[6]

SDSS-V


Local Volume Mapper
North
Black Hole Mapper
North
Milky Way Mapper
North
0.16 m
1.0 m
2.5 m
APO
Fiber Robot
LCO
Fiber Robot
2.5 m
0.16 m
South
Milky Way Mapper
South
Black Hole Mapper
South
Local Volume Mapper
Milky Way
Stars
Black Hole
Milky Way Mapper
APOGEE + BOSS Spectrographs
Black Hole Mapper
BOSS Spectrograph
Local Volume Mapper
Integral Field Spectrograph