

Raven Science Cases



Célia Blain and Raven Team

Subaru Telescope Seminar, Feb 5th 2014

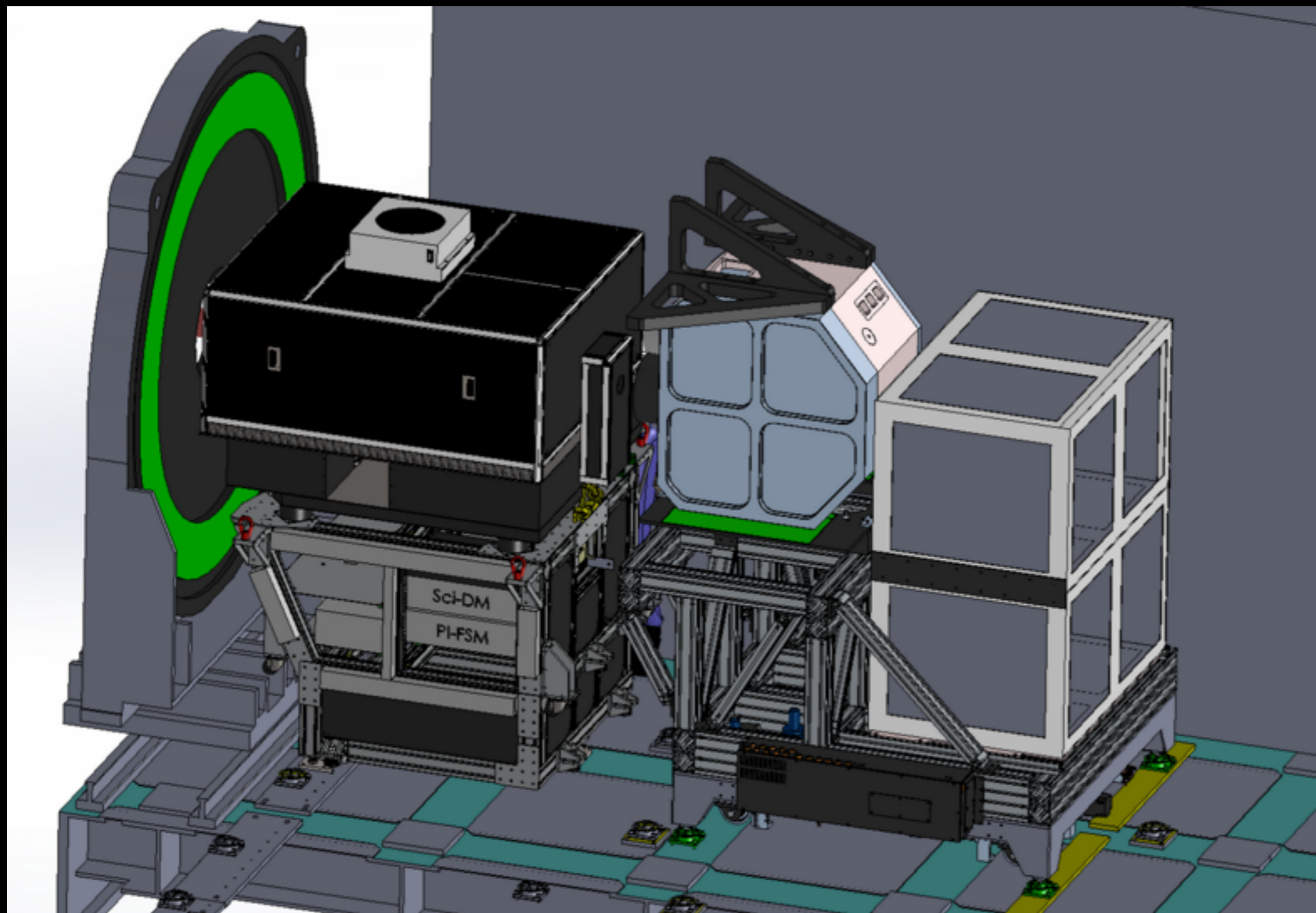


Summary

- Instrument overview
- Science requirements
- Why developing real science cases for Raven?
- Schedule
- Target observability
- Science case melting pot
- Science case samples

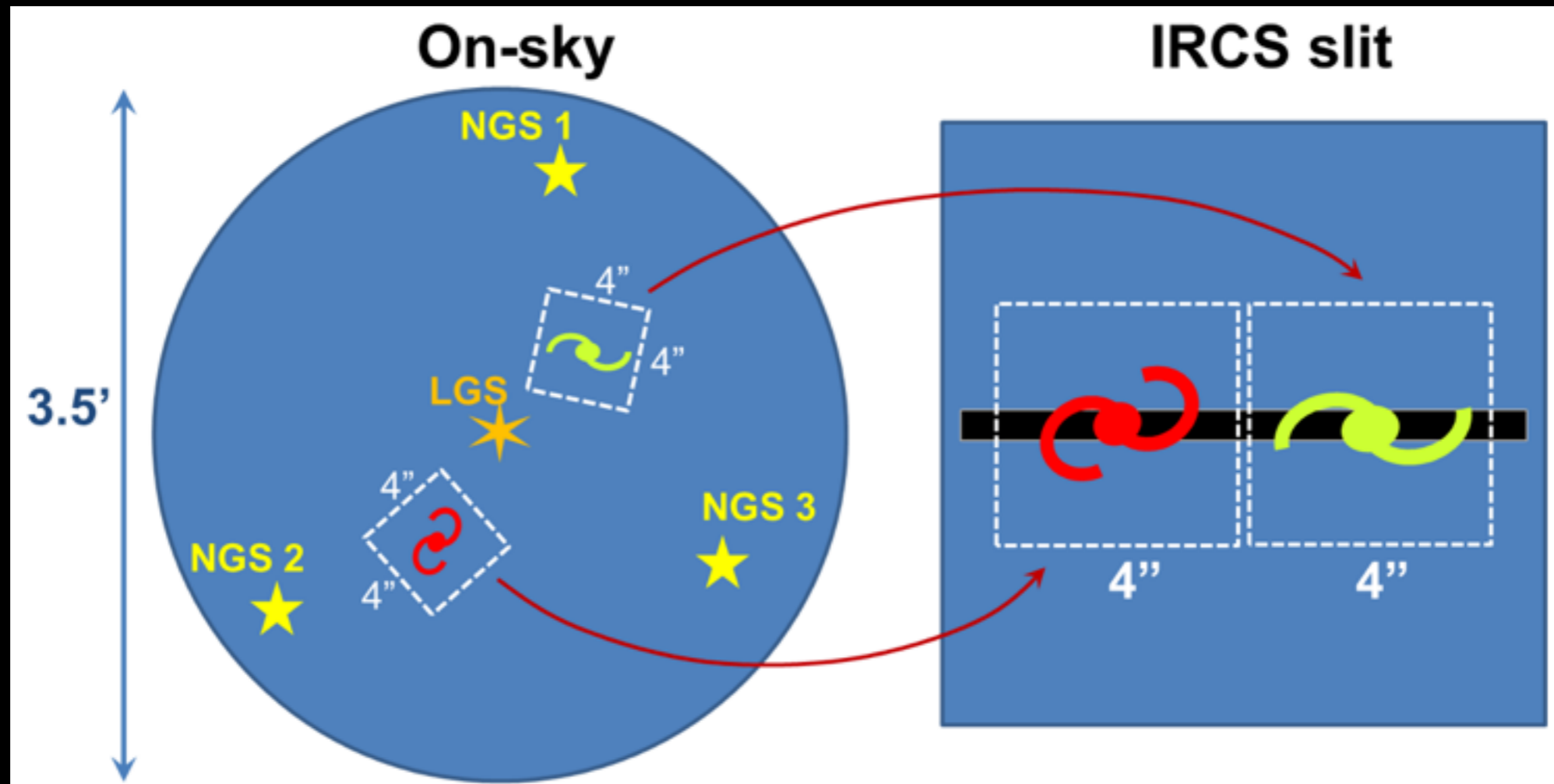


Raven

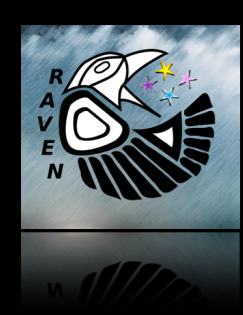




Raven science requirements



- 2 science targets are reimaged on the IRCS slit
- Each target can be positioned on the slit by moving the pickoff arms
- Each target can be rotated with the K-mirror



Raven science requirements

- Raven feeds IRCS spectrograph $\lambda = 0.9 - 4.1 \mu\text{m}$ $R = 100-20000$
 - Two science targets spread over a $3.5'$ FoR are reimaged on the IRCS slit.
 - $4''$ FoV per science channel (position angles can be selected independently)
 - Minimum science targets separation is $\sim 10''$
 - Northern sky (Zenith angle $< 60 \text{ deg}$ - LGS limitation)
 - Target must be observable in reasonable exposure time
 - Raven needs 3 NGS with $R < 15$
- > on-axis LGS is available to increase sky coverage
- so Raven can work with 2 NGS + 1 LGS but not optimum for tomography
- Targets will benefit from being at low Galactic latitude, as it is much easier to find a suitable NGS asterism
- > Raven's science cases limit: astronomers imagination!!!



Science cases for Raven

Why?

- The specificity and complexity of each science case can help push the design limit of Raven
- Must show to the astronomy community that MOAO can produce cutting edge scientific results
- Ideally, should consider science cases that:
 - > offer a multiplex gain/simultaneity with respect to other AO systems
 - > require angular coverage that exceeds what is offered by competing AO systems ($\sim 20 \pm \text{arcsec}$).



Raven engineering/science observing schedule

- Engineering nights:

- ★ May 13-14th 2014: first engineering run - 2 nights (S14A)

- ★ August 2014: second engineering run - 3 nights (S14B)

—> Science could be done during engineering runs if the system perform without issues.
Raven can run in GLAO mode without tomography.

- Science nights:

- ★ Deadline for proposals for S14B (Aug. to Jan.) is March 7th 2014

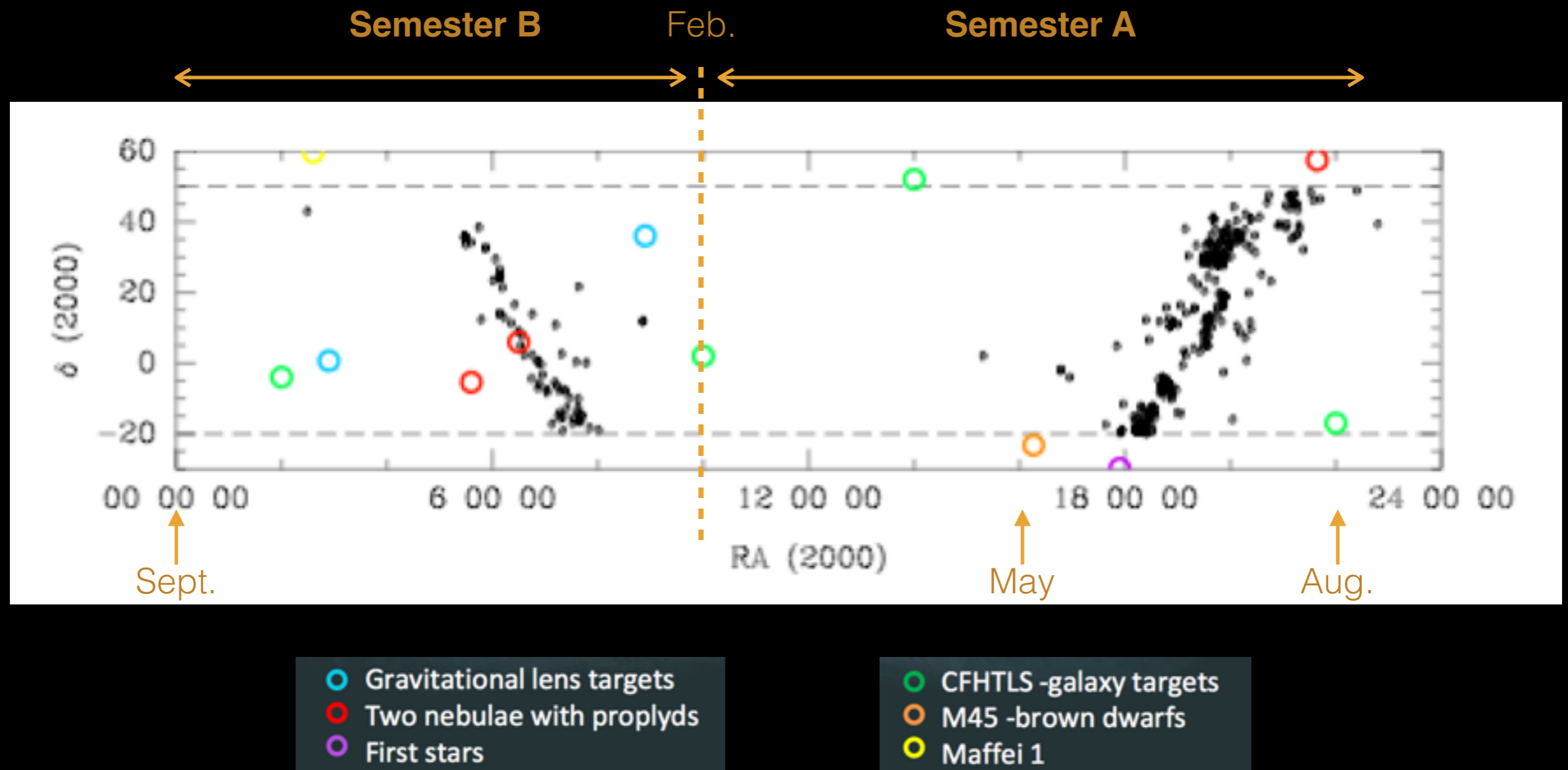
- ★ Deadline for proposals for S15A (Feb. to July) is September 2014

!!! Project funding end mid-2015 !!!



Observability

Engineering fields (black dots) and science case observability ...

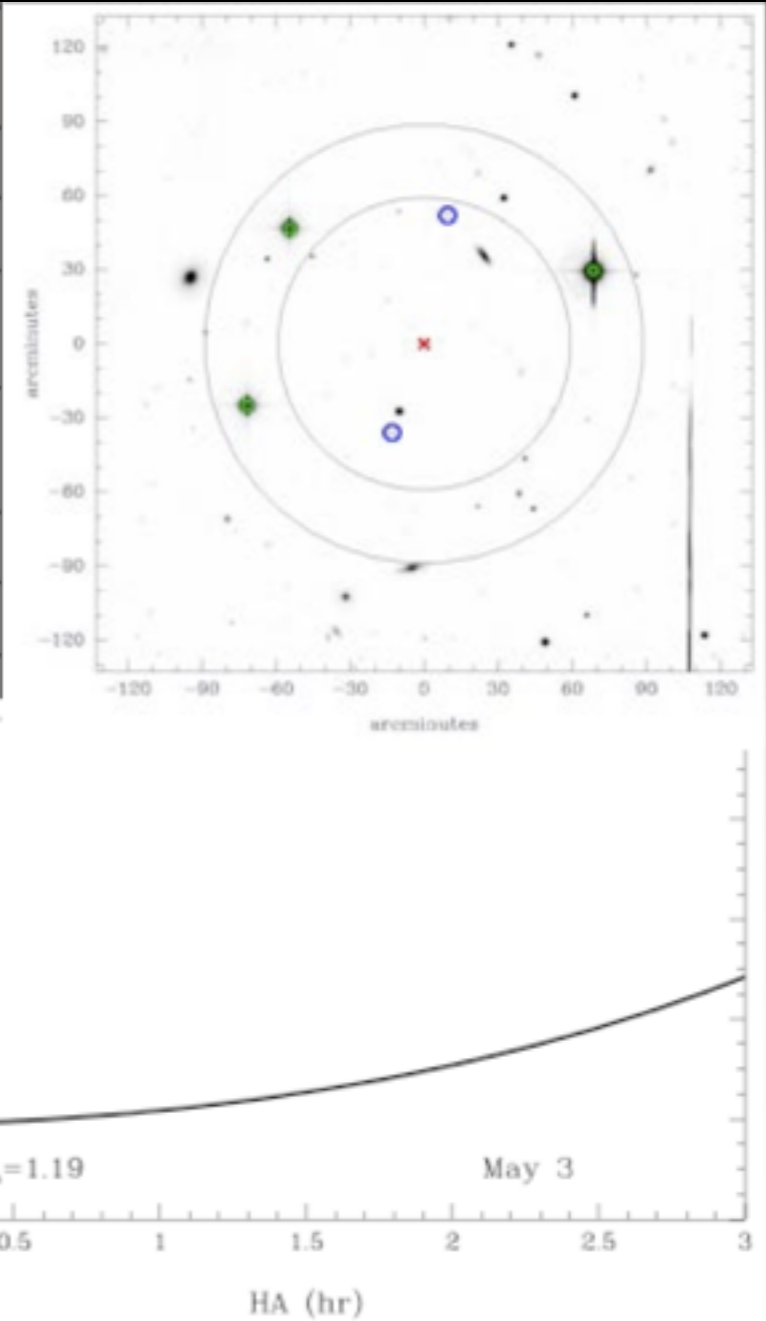




Observability (continued)

Field Center (RA, DEC 2000J)	14:27:10.4	+52:34:20	
Min. Airmass	1.19	LGS Required?	preferred
NGS mag (R)	13.1	14.4	14.3
NGS distance to field center	72"	76"	75"
IRCS Mode	Grism	Science Wavelength	K-band (P α @ z=0.15)
Target Magnitude	2×10^{-19} erg/cm ² /s		2×10^{-19} erg/cm ² /s
Strehl Ratio	30%		30%
EE (150 mas)	42%		42%
Required S/N	10		10
Sensitivity	4×10^{-19} erg/cm ² /s		4×10^{-19} erg/cm ² /s
Exposure Time	8 hr		8 hr

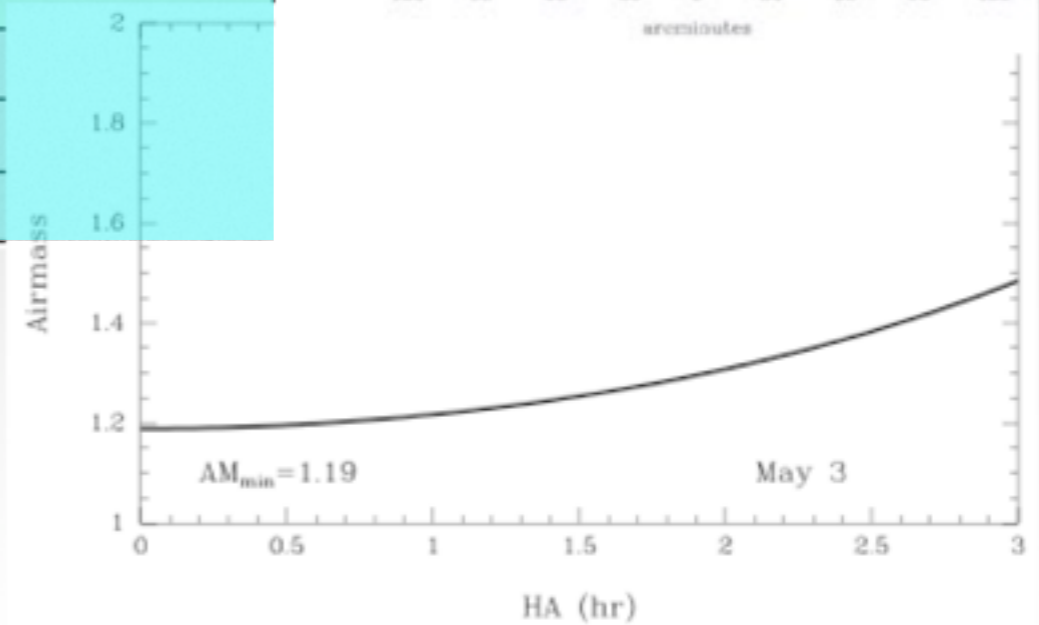
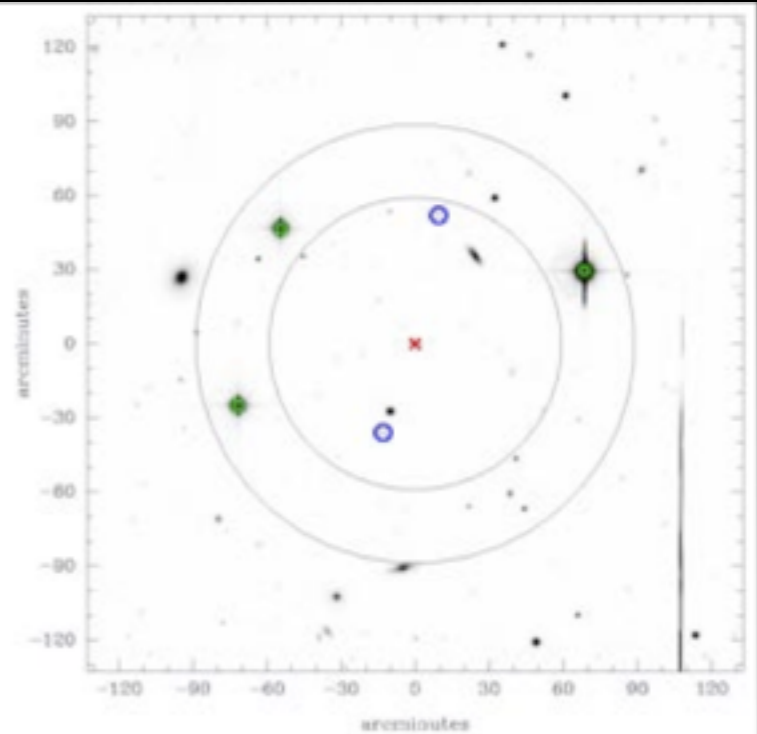
expl: Kinematics of galaxy
asymmetries





Observability (continued)

Field Center (RA, DEC 2000J)	14:27:10.4	+52:34:20	
Min. Airmass	1.19	LGS Required?	preferred
NGS mag (R)	13.1	14.4	14.3
NGS distance to field center	72"	76"	75"
IRCS Mode	Grism	Science Wavelength	K-band (P α @ z=0.15)
Target Magnitude	2×10^{-19} erg/cm ² /s	2×10^{-19} erg/cm ² /s	
Strehl Ratio	30%	30%	
EE (150 mas)	42%	42%	
Required S/N	10	10	
Sensitivity	4×10^{-19} erg/cm ² /s	4×10^{-19} erg/cm ² /s	
Exposure Time	8 hr	8 hr	



expl: Kinematics of galaxy asymmetries



Raven science cases melting pot

- Finding first stars - metal-poor stars in the galactic centre (K. Venn, T. Brown)
- The stellar population of Maffei I (T. Davidge)
- High redshift gravitationally lensed galaxies (K. Bandara)
- Studying high-Z QSO host galaxies (Y. Minowa)
- Initial mass function in starburst clusters in MW and nearby galaxies (C. Yasui)
- Proplyds in the Orion and Rosette nebulae (T. Beck, R. Mann)
- Extreme star formation and super stellar clusters (O. Lai, D. Gratadour, D. Rouan)
- Pulsating variables in nearby galaxies (N. Matsunaga)



Raven science cases

melting pot (continued)

- Brown dwarfs ([Q. Konopacky](#))
- Star formation at galactic center ([T. Do](#))
- Simultaneous spectroscopy for organic molecules in exo-planetary environment ([H. Terada](#))
- Probing globular clusters in the bulge region ([M. Chiba](#))
- Young star cluster candidates in the Galactic Center ([T. Yoshikawa](#))
- Kinematics of galaxy asymmetries ([D. Andersen](#))
- Kinematics of magnified galaxies in massive cluster fields ([M. Ammons](#))
- Search for young/intermediate age stars in the Galactic Center region ([S. Nishiyama](#))

Intra-Galactic sc case

- Finding first stars - metal-poor stars in the galactic centre (K. Venn, T. Brown)
- Brown dwarfs (Q. Konopacky)
- Star formation at galactic center (T. Do)
- Proplyds in the Orion and Rosette nebulae (T. Beck, R. Mann)
- Simultaneous spectroscopy for organic molecules in exo-planetary environment (H. Terada)
- Probing globular clusters in the bulge region (M. Chiba)
- Young star cluster candidates in the Galactic Center (T. Yoshikawa)
- Extreme star formation and super stellar clusters (O. Lai, D. Gratadour, D. Rouan)
- Search for young/intermediate age stars in the Galactic Center region (S. Nishiyama)

Extra gal. sc case

- The stellar population of Maffei I (T. Davidge)
- High redshift gravitationally lensed galaxies (K. Bandara)
- Studying high-Z QSO host galaxies (Y. Minowa)
- Initial mass function in starburst clusters in Milky Way and nearby galaxies (C. Yasui)
- Pulsating variables in nearby galaxies (N. Matsunaga)
- Kinematics of galaxy asymmetries (D. Andersen)
- Kinematics of magnified galaxies in massive cluster fields (M. Ammons)



First stars

(K. Venn, T. Brown)

Stellar evolution contributes to the metal content increase in the universe.

—> the oldest stars in a galaxy are often expected to be the **more metal-poor stars**, located in the galactic center.

Finding and analyzing a large sample of metal poor stars will allow:

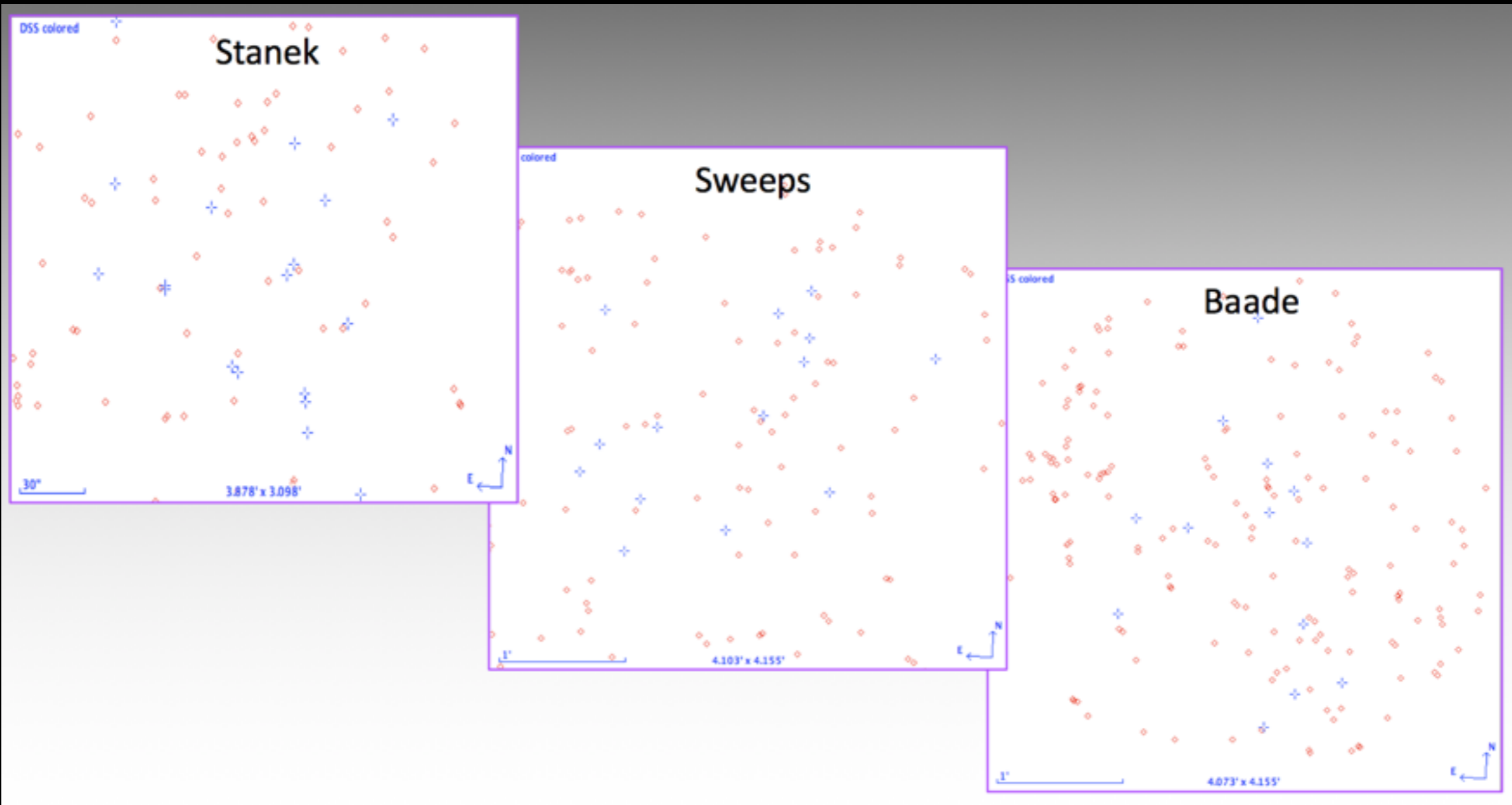
- To examine the **physical properties of the first stars** (mass, radius, luminosity, chemistry...) through high quality IR spectra (ECHELLE mode).
- Such surveys will provide important observational constraints to **understand metal-free stars and star formation in the early universe**.

—> Targets: Sweeps, Baade and Stanek windows.



First stars

(K. Venn, T. Brown)



Exposure time $\sim 4h$

Extreme star formation and super stellar clusters

(D. Gratadour, O. Lai)

- Merging galaxies = most intense bursts of star formation
- Gravitational potential perturbation
 - gas falls to the center of the potential
 - burst of star formation

Star formation rate : 100-1000 M_{\odot} / year (i.e. 100-1000 x the Milky Way)

—> Studying SSCs = studying the stellar evolution

- Ideal case of synchronous stellar evolution
- Different ages in the same galaxy : fine grained temporal evolution
- Wide mass and luminosity coverage
- Can study the link between the starburst and the AGN





The stellar population of Maffei I

(T. Davidge)

The 'Maffei' group consists of two concentrations centered on IC 342 and Maffei 1
—> has not been extensively studied as it is at a low Galactic latitude.

Observations in the IR are essential to suppress differential reddening.

Targets: Maffei I, Maffei II and IC342

Science program:

- Probing the SFH of Maffei 1
- Checking mass distribution and stellar content of the nucleus of Maffei 1
- Search for intermediate age clusters in low mass IC342 and calibrate AGB evolution in metal-poor environments



Simultaneous spectroscopy for organic molecules in exo-planetary environments

(H. Terada)

Could allow to trace:

(i) Organic molecules in protoplanetary disks

Goal: Atmospheric calibration at IR.

For atmospheric correction, a reference star is observed with similar airmass, location on the sky, and close time interval.

Simultaneous observation of the reference star is ultimate methodology for perfect cancellation of the atmosphere condition.

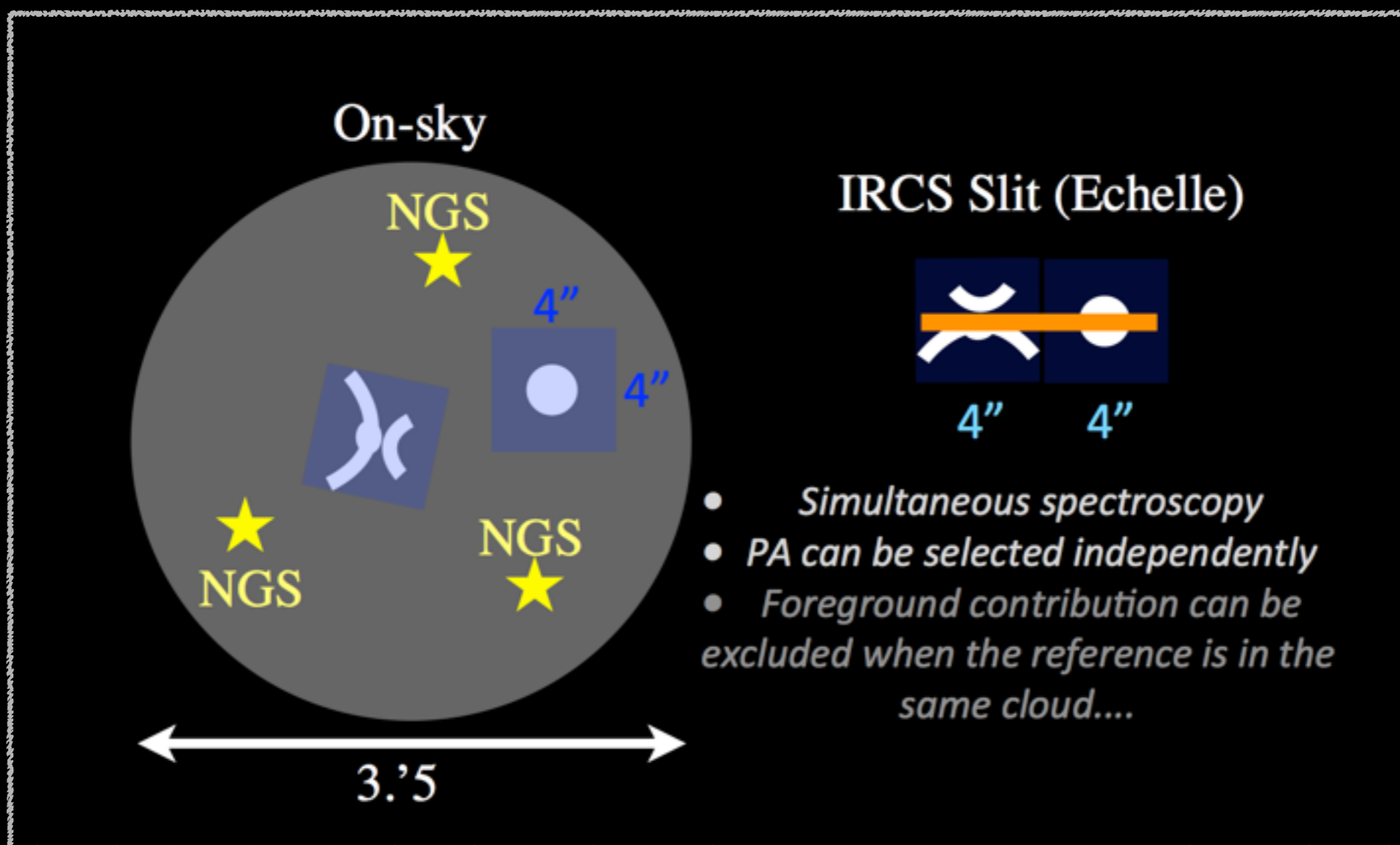
—> could allow to trace warm molecular volatile gases.



Simultaneous spectroscopy for organic molecules in exo-planetary environments

(H. Terada)

Concept for detection:



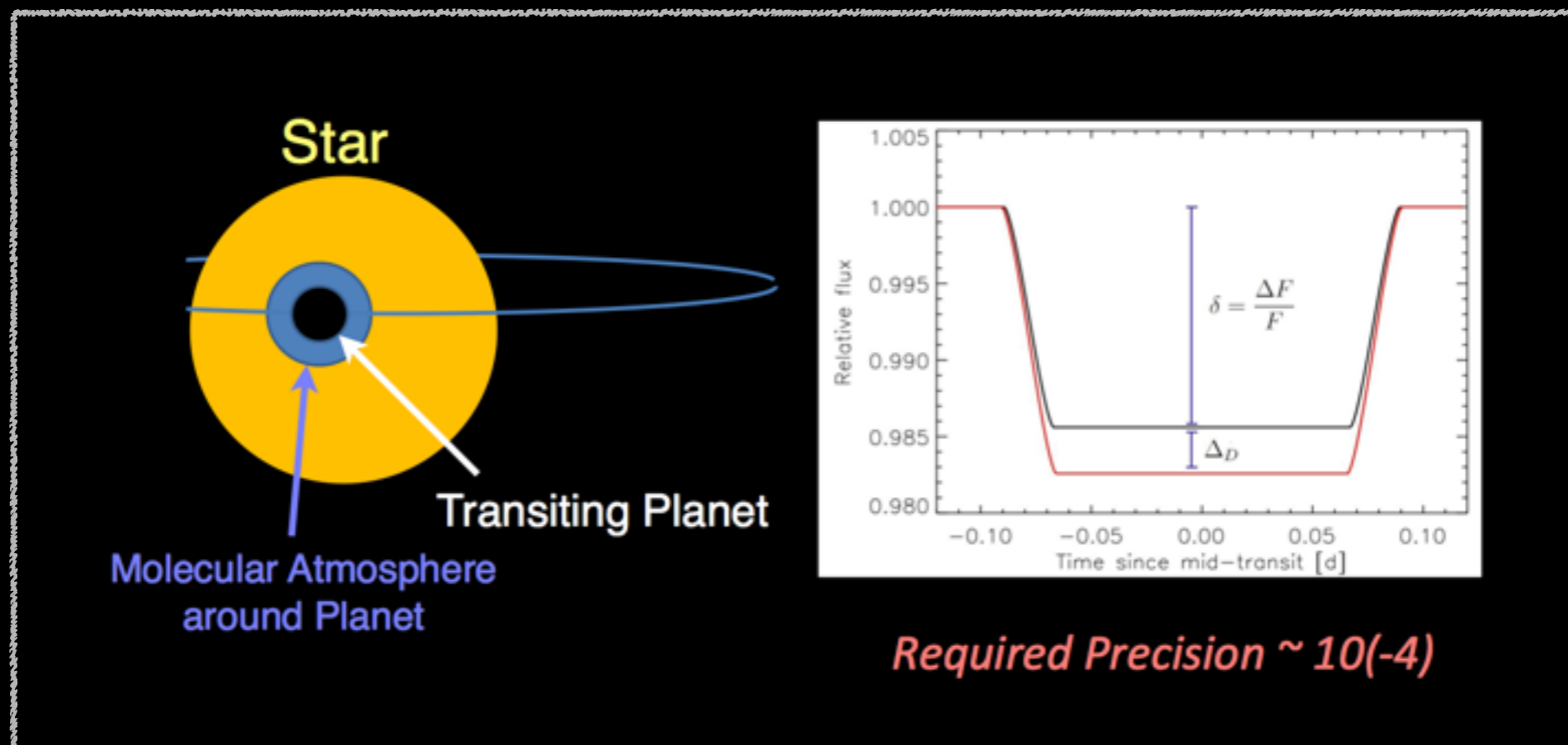


Simultaneous spectroscopy for organic molecules in exo-planetary environments

(H. Terada)

(ii) Exo-planetary atmosphere in transiting systems

Use AO to keep the star very effectively at the same location of the infrared array and do precise photometry.





High redshift gravitationally lensed galaxies

(K. Bandara)

Science goals:

- Obtain detailed dynamical information and star formation rate for a representative sample of high redshift galaxies
- Study the internal properties of high redshift galaxies in order to understand galaxies formation (dynamical state, star formation history and chemical abundances)
- Establish a relationship between high redshift galaxies and the present galaxies population

How?

- Use the flux and spatial resolution advantage offered by the gravitational lensing
- Study a sample of gravitationally lensed galaxies which are representative of the normal population for high redshift universe.
—> target sample selected from the Sloan Lens ACS Survey : med to high redshift galaxies ($z > 0.5$) which are gravitationally lensed by lower redshift galaxies
- Obtain the information through the exploitation of nebular emission lines ($H\alpha$, $H\beta$, $[OIII]$, $[NII]$)



Proplyds in the Orion and rosette nebulae

(R. Mann, T. Beck)

Science goal:

The spectral analysis of proplyds in the Orion nebulae could give access to information regarding disks masses and evolution in region representative of a true sun-like formation process (gas-to-dust ratio).

How?

Protoplanetary disks, or “proplyds”, have been observed around many young stars in several nebula (Taurus, Orion, Rosette, etc..)

The spatial characteristic of most of these disks can be resolved at the scale of our solar system. Astronomical evidences show that our own solar system originated near a massive star in a region similar to Orion.



Star formation at the galactic center

(T. Do)

- Population of young stars (4-6 Myr) exist in the hostile environment around the supermassive black hole at the galactic center (within 0.5 pc).
The existence of these stars is a challenge for the current star formation theories.
 - Progress have been made to identify these stars but detailed abundances are still missing due to the lack of high spectral resolution observations.
 - The question of binaries have also been nearly unexplored due to lack of spectral monitoring (central to many dynamical models related to the evolution of these stars)
- > With Raven multi-object observation + IRCS high spectral resolution : large impact on the study of these stars origins and star formation in extreme environments



Brown dwarfs

(Q. Konopacky)

- BDs are lowest mass product of the star formation process.
($13 M_{\text{jup}} < \text{BDs} < 0.08 M_{\text{sun}}$)
- They have a **unique substellar nature** which give them unique interior and atmospheric physics.

It has been demonstrated that spectra of young BDs have many similarities to spectra of young giant gas planets.

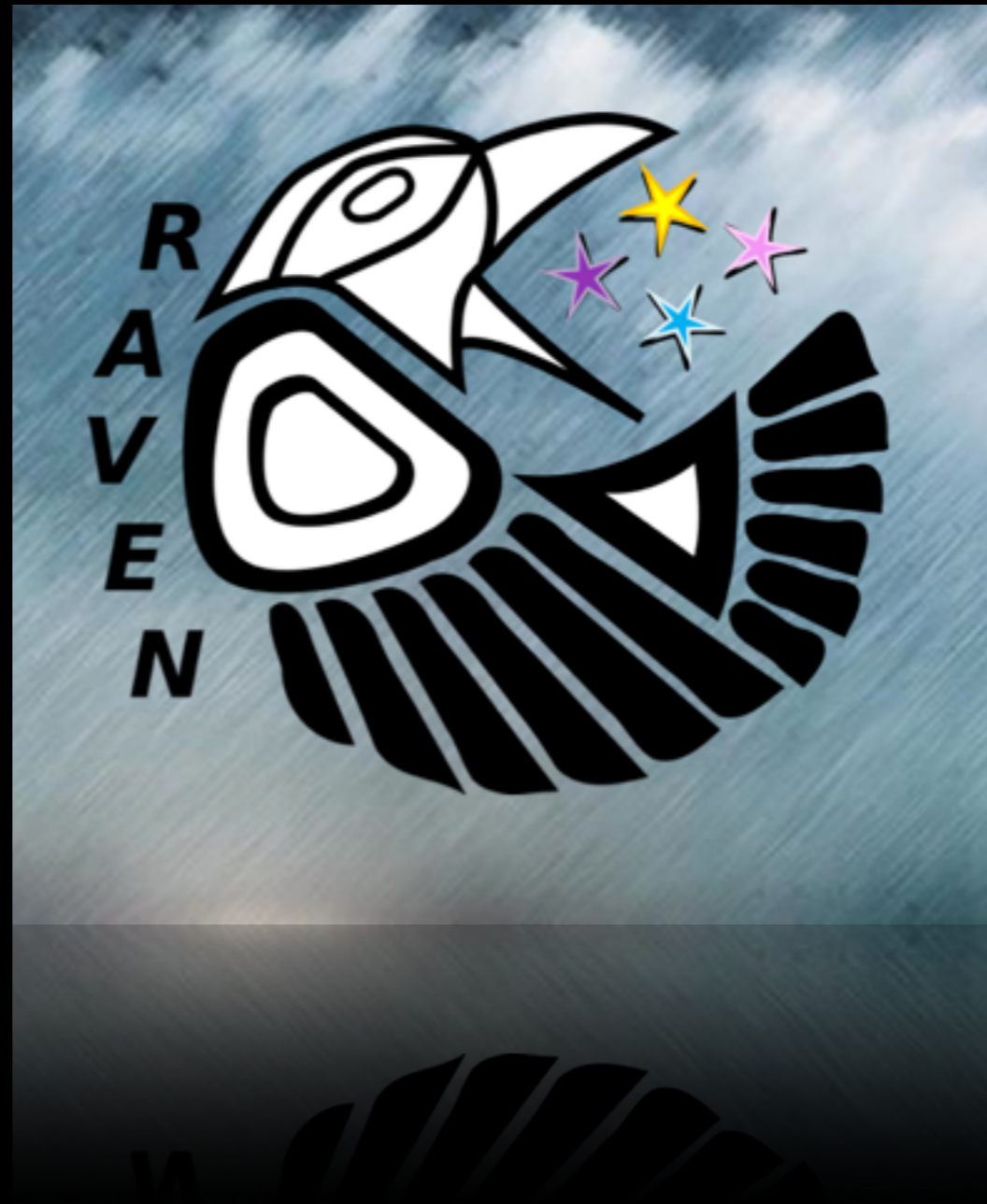
- > Understanding BDs is critical for **understanding star formation as a whole.**
- > Detailed characteristics of BDs can help **characterizing newly imaged exoplanets.**



Brown dwarfs

(continued)

- Various models existent regarding BDs formation (competitive accretion, turbulent fragmentation...)
 - Properties of BDs in the youngest, densest clusters can help confirm / refute models (many models uncertainties for BDs in the earliest ages)
 - Raven multiplexing + IRCS high spectral resolution is ideally suited for young BDs in dense clusters environments.
- > Provide a library of high resolution young BDs spectra (spectral template for comparison to field objects)
- > Kinematic characterization of a large population of cluster BDs (provides radial velocity measurements which are the 3rd dimension motion for 3D kinematic maps)
- > Help to evaluate difference between BDs and stars to **constrain the star formation theories**



- ★ Raven website: <http://web.uvic.ca/~ravenmoa/>
 - ★ Science case document from science case meeting in Sendai is available on Raven's website in [/Publications/Past meetings](#) section
- > sample science cases with science/technical justifications ...

Thank you



Observability (continued)

Field Center (RA, DEC 2000J)	14:27:10.4	+52:34:20	
Min. Airmass	1.19	LGS Required?	preferred
NGS mag (R)	13.1	14.4	14.3
NGS distance to field center	72"	76"	75"
IRCS Mode	Grism	Science Wavelength	K-band (P α @ z=0.15)
Target Magnitude	2×10^{-19} erg/cm ² /s		2×10^{-19} erg/cm ² /s
Strehl Ratio	30%		30%
EE (150 mas)	42%		42%
Required S/N	10		10
Sensitivity	4×10^{-19} erg/cm ² /s		4×10^{-19} erg/cm ² /s
Exposure Time	8 hr		8 hr

expl: Kinematics of galaxy
asymmetries

