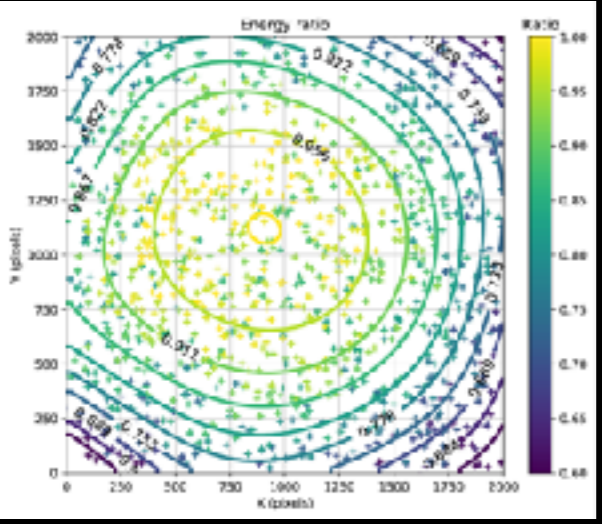
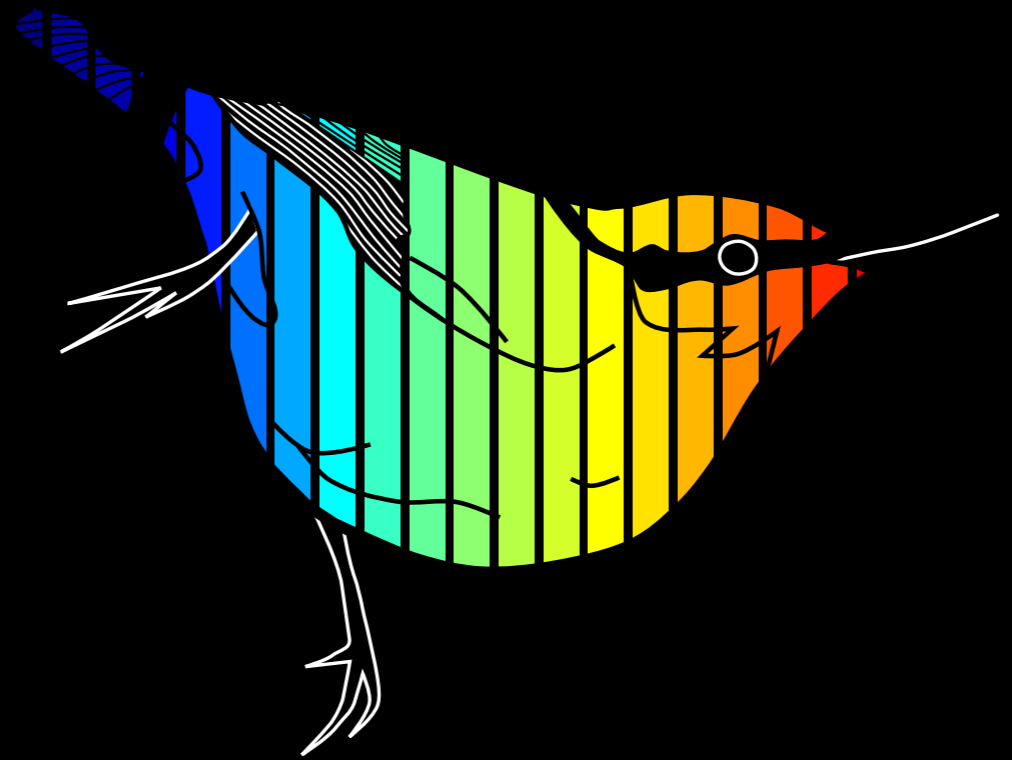


News from SITELLE...

Laurent Drissen

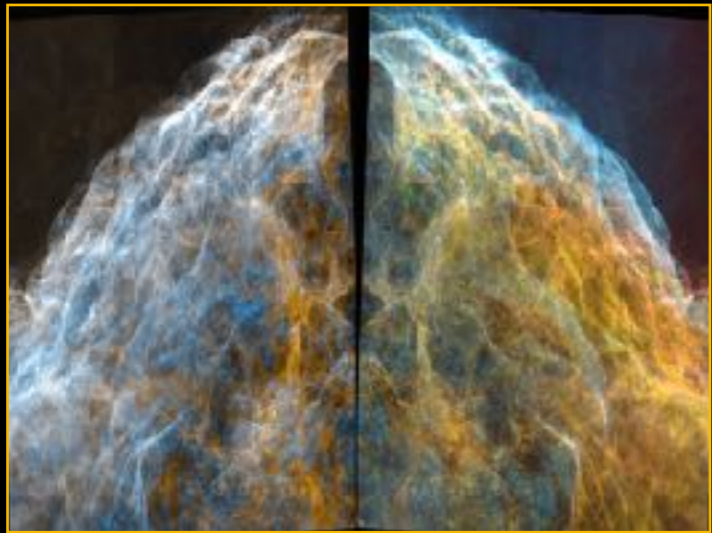


Engineering

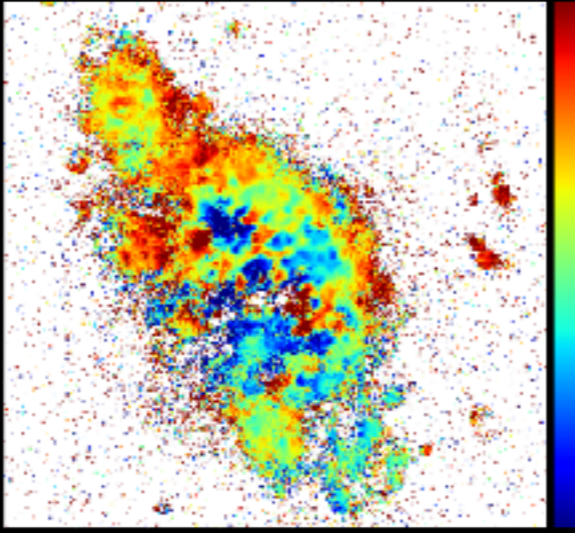


Software

0,001 Mpc



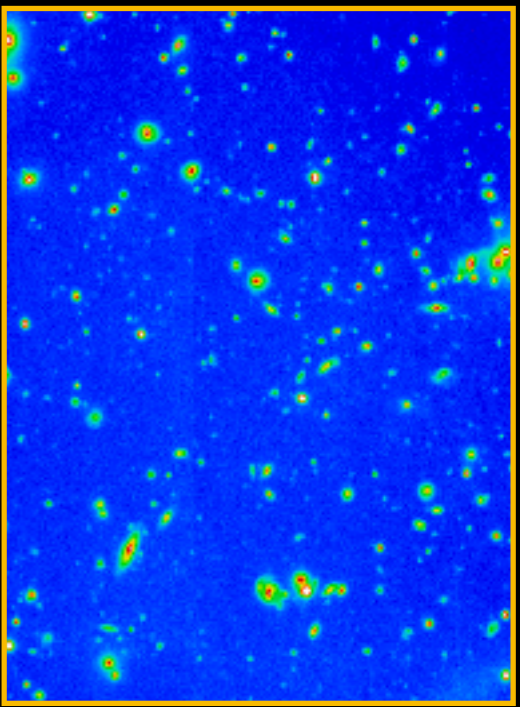
6.4 Mpc



100 Mpc



950 Mpc





SITELLE: an Imaging Fourier Transform Spectrometer for the Canada–France–Hawaii Telescope

Laurent Drissen,^{1,2,3,4*} Thomas Martin^{5,1,2}, Laurie Rousseau-Nepton,^{3,4}
Carmelle Robert,^{1,2,3,4} R. Pierre Martin,³ Marc Baril,⁴ Simon Prunet,^{4,5} Gilles Joncas,^{1,2}
Simon Thibault,^{1,2} Denis Brousseau,^{1,2} Julie Mandar,⁶ Frédéric Grandmont,⁶
Howard Yee⁷ and Luc Simard⁸

¹Département de physique, de génie physique et d'optique, Université Laval, Québec, QC G1V 0A5, Canada

²Centre de recherche en astrophysique du Québec, Montréal, QC H2C 3J2, Canada

³Department of Physics and Astronomy, University of Hawai'i at Hilo, Hilo, HI 96720, USA

⁴Canada-France-Hawaii Telescope, 65-1238 Mamalahoa Hwy, Kawaeia, HI 96743, USA

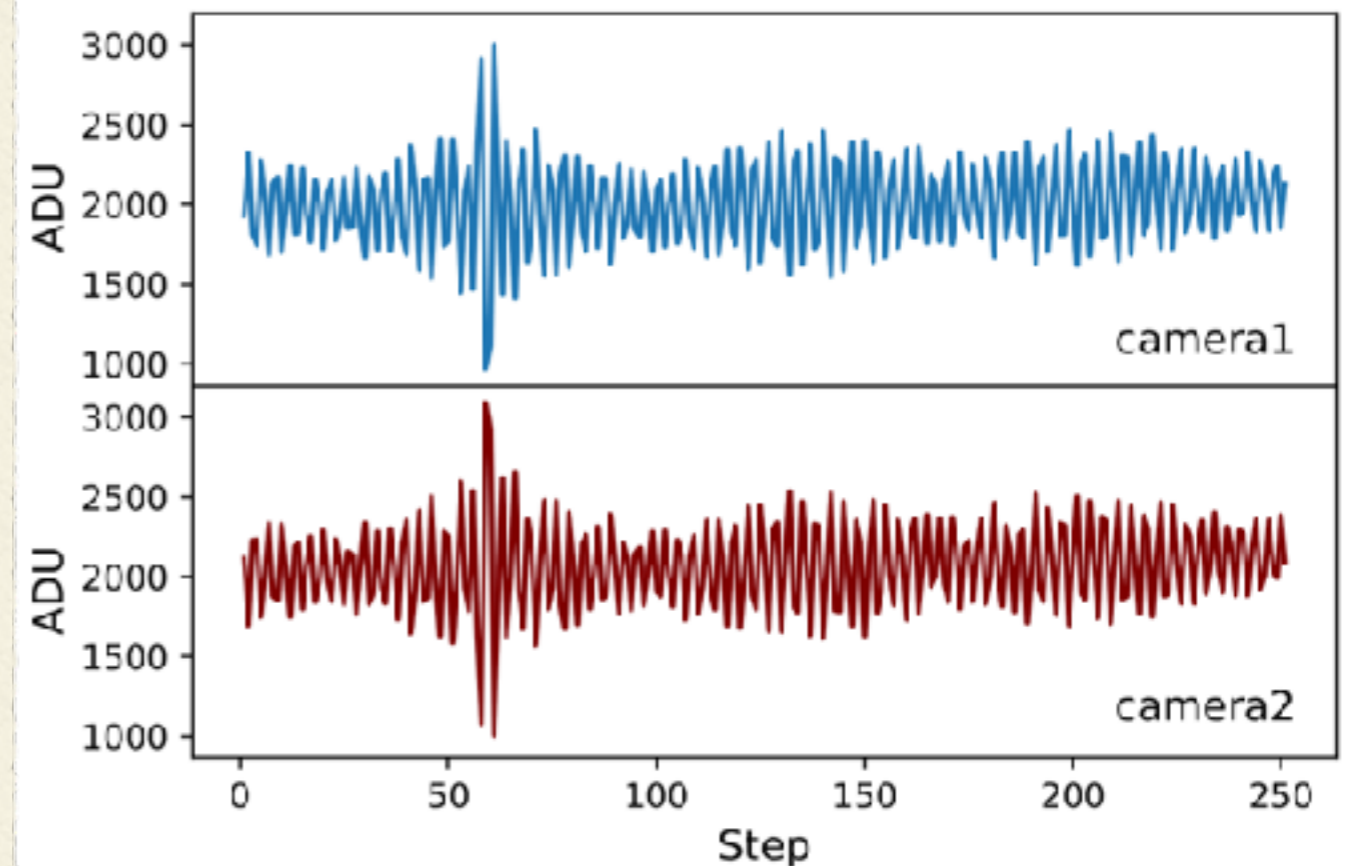
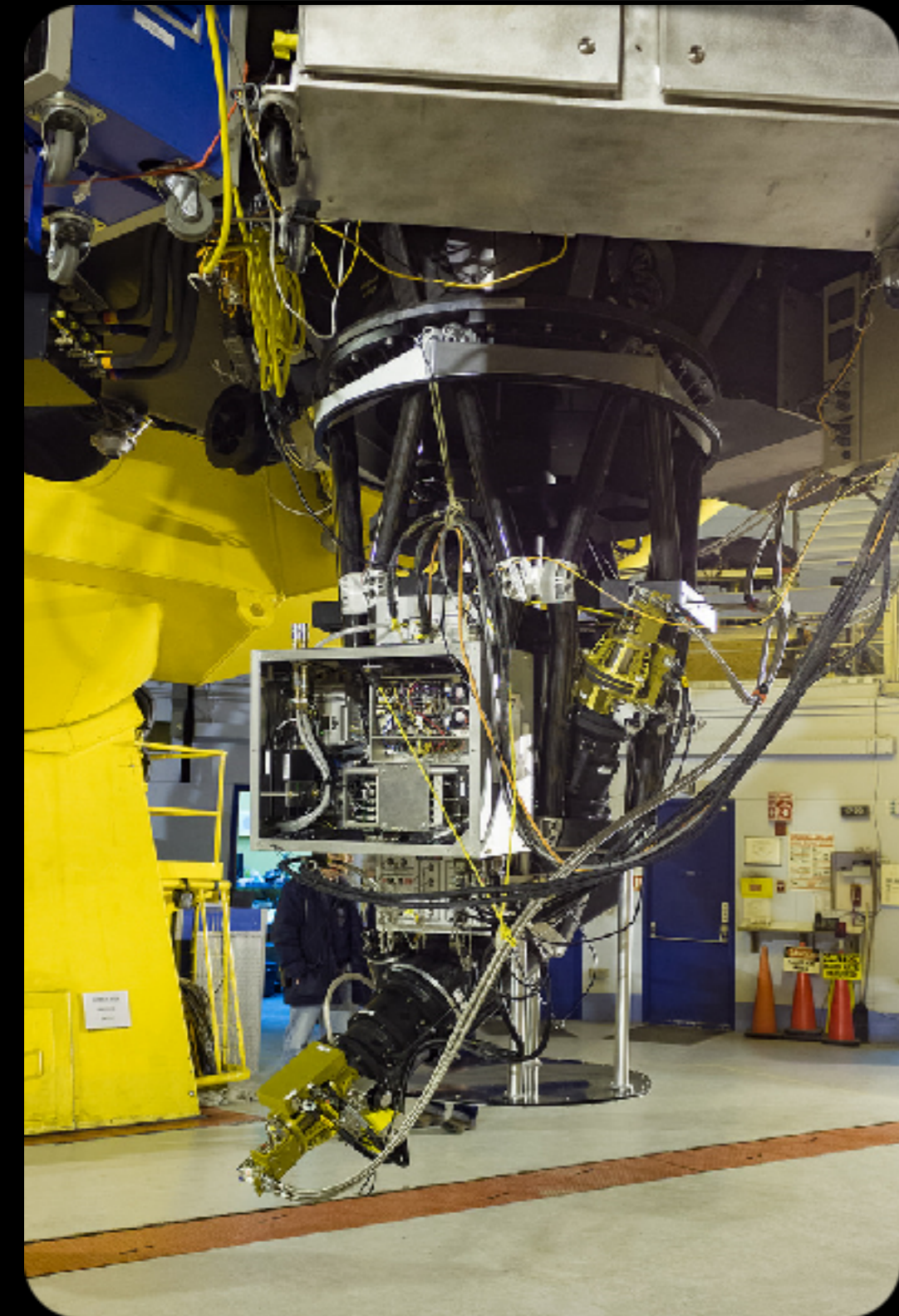
⁵CNRS and UPMC, UMR 7095, Institut d'Astrophysique de Paris, F-75014 Paris, France

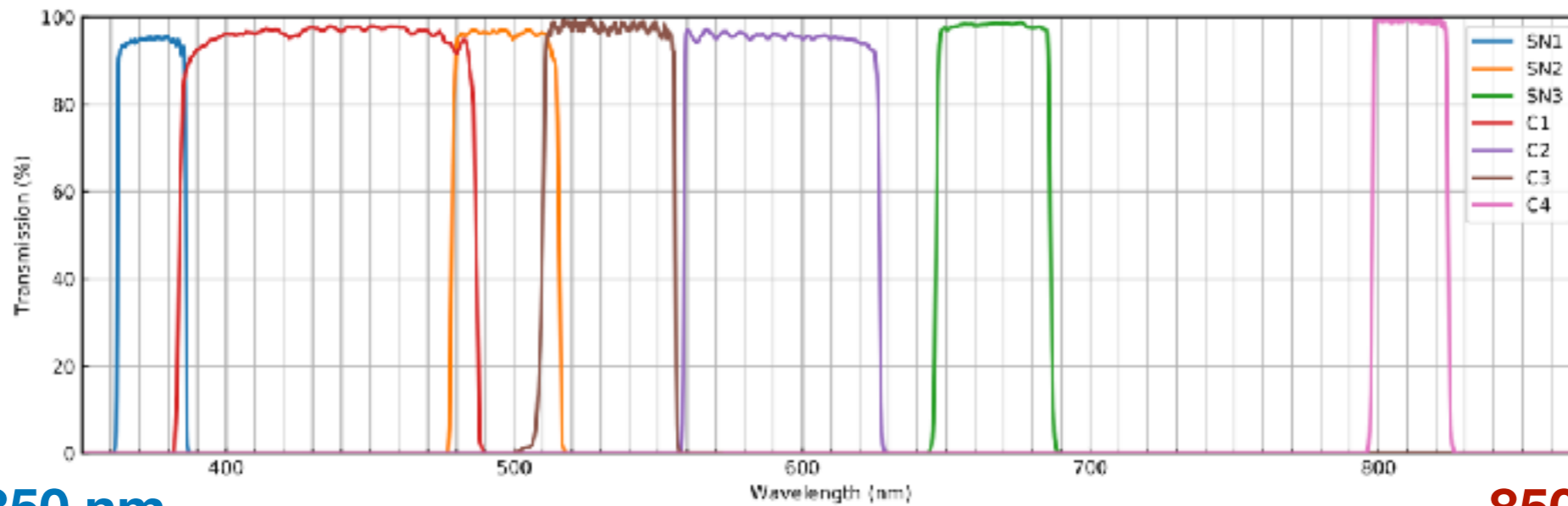
⁶ABB Inc., 3400 Rue Pierre-Armand, Québec, QC G1P 0B2, Canada

⁷Department of Astronomy and Astrophysics, University of Toronto, Toronto, ON M5S 3H4, Canada

⁸National Research Council Canada, 5071 West Saanich Road, Victoria, BC V9E 2E7, Canada

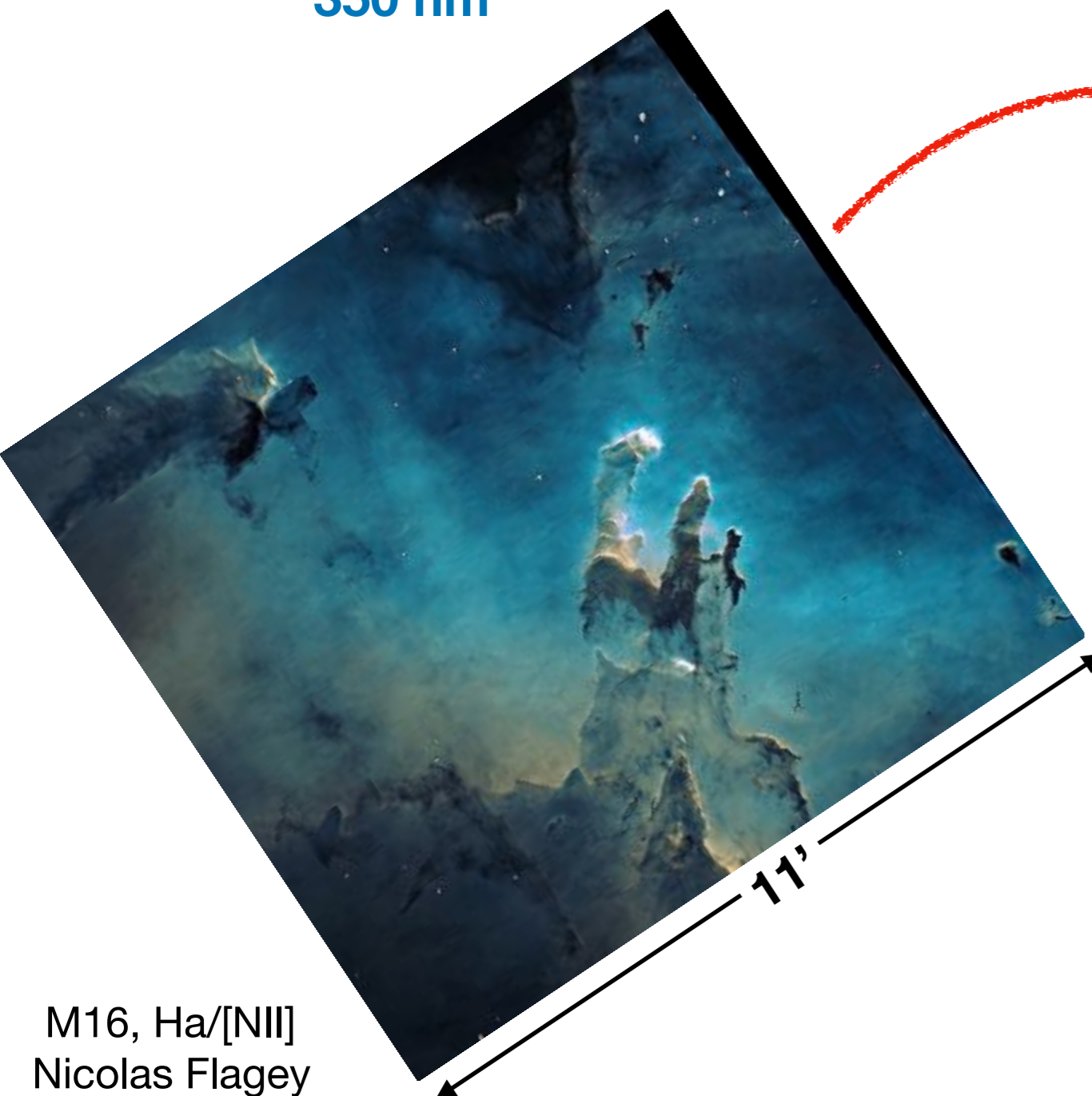
Accepted 2019 February 20. Received 2019 February 20; in original form 2018 November 13





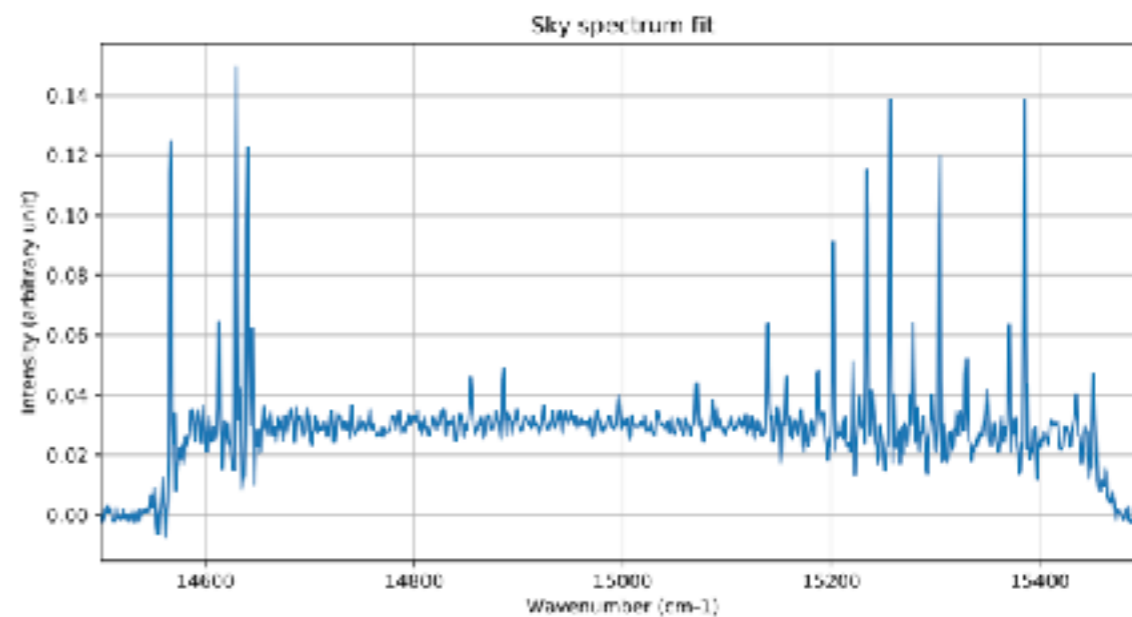
350 nm

850 nm



4 227 072 pixels

R=1 -10000



M16, Ha/[NII]
Nicolas Flagey

Mahalo nui loa, CFHT engineering, technical & science teams!

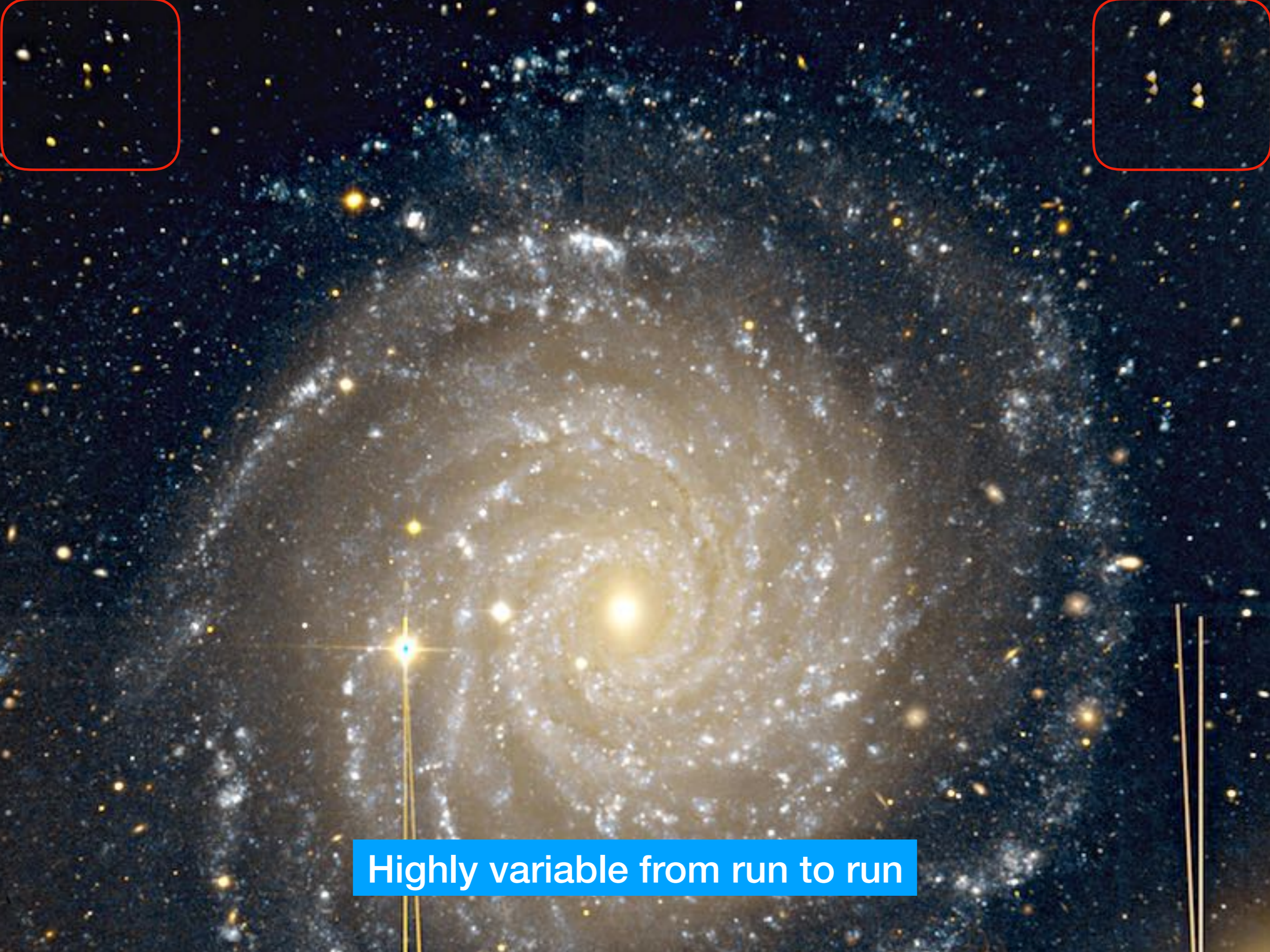


Marc Baril, Greg Barrick, Kevin Ho, Laurie Rousseau-Nepton, et al.

Mahalo nui loa, CFHT engineering, technical & science teams!



Simon Prunet (data reduction, software, filter scanning)

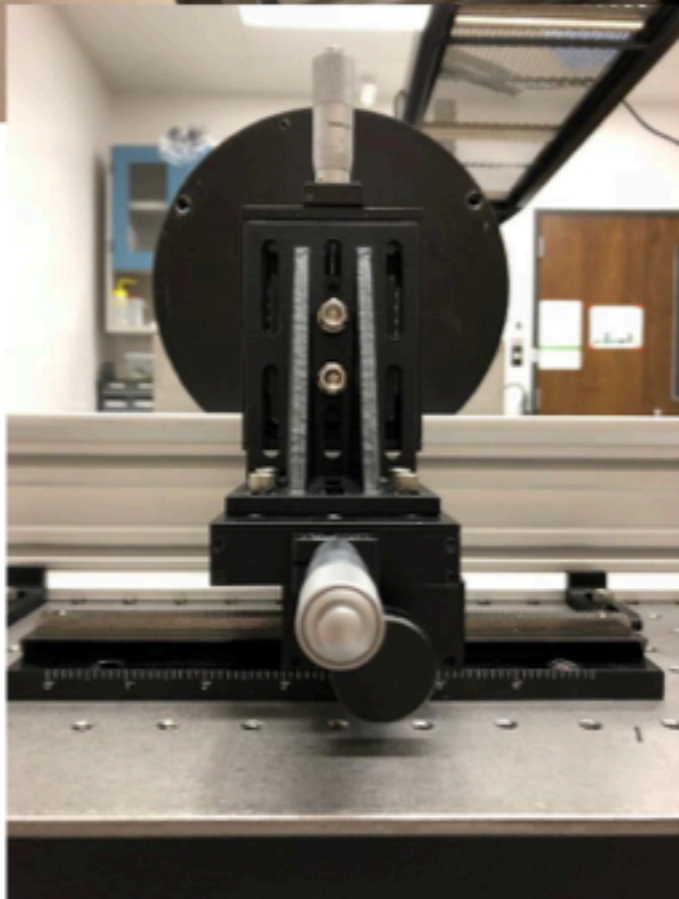
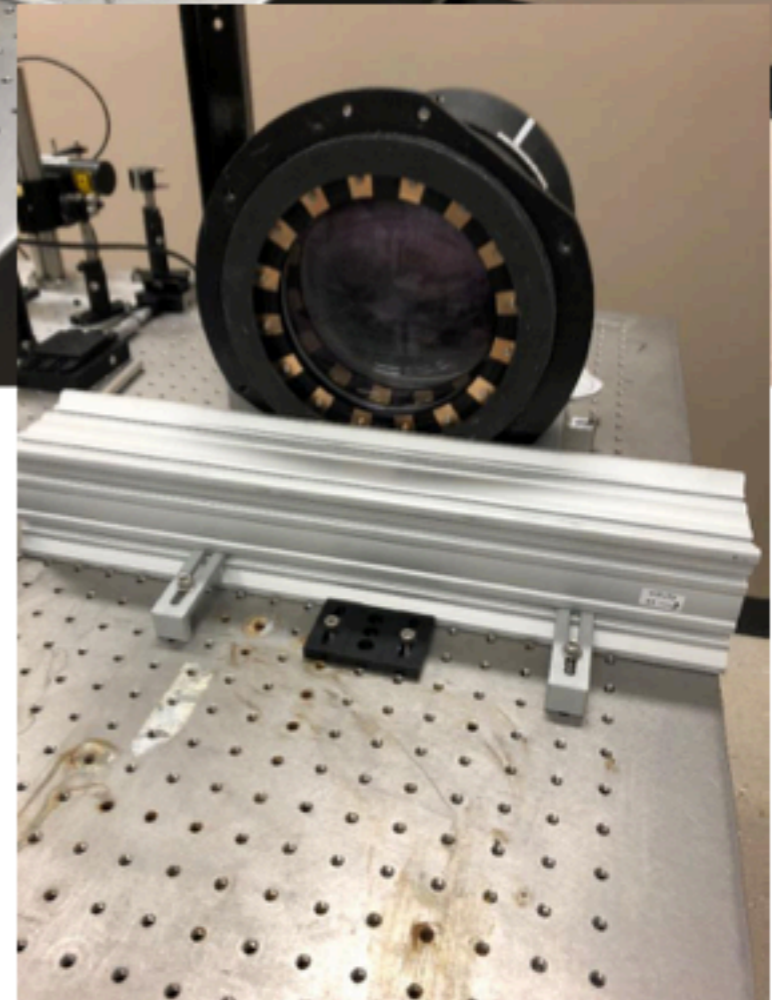
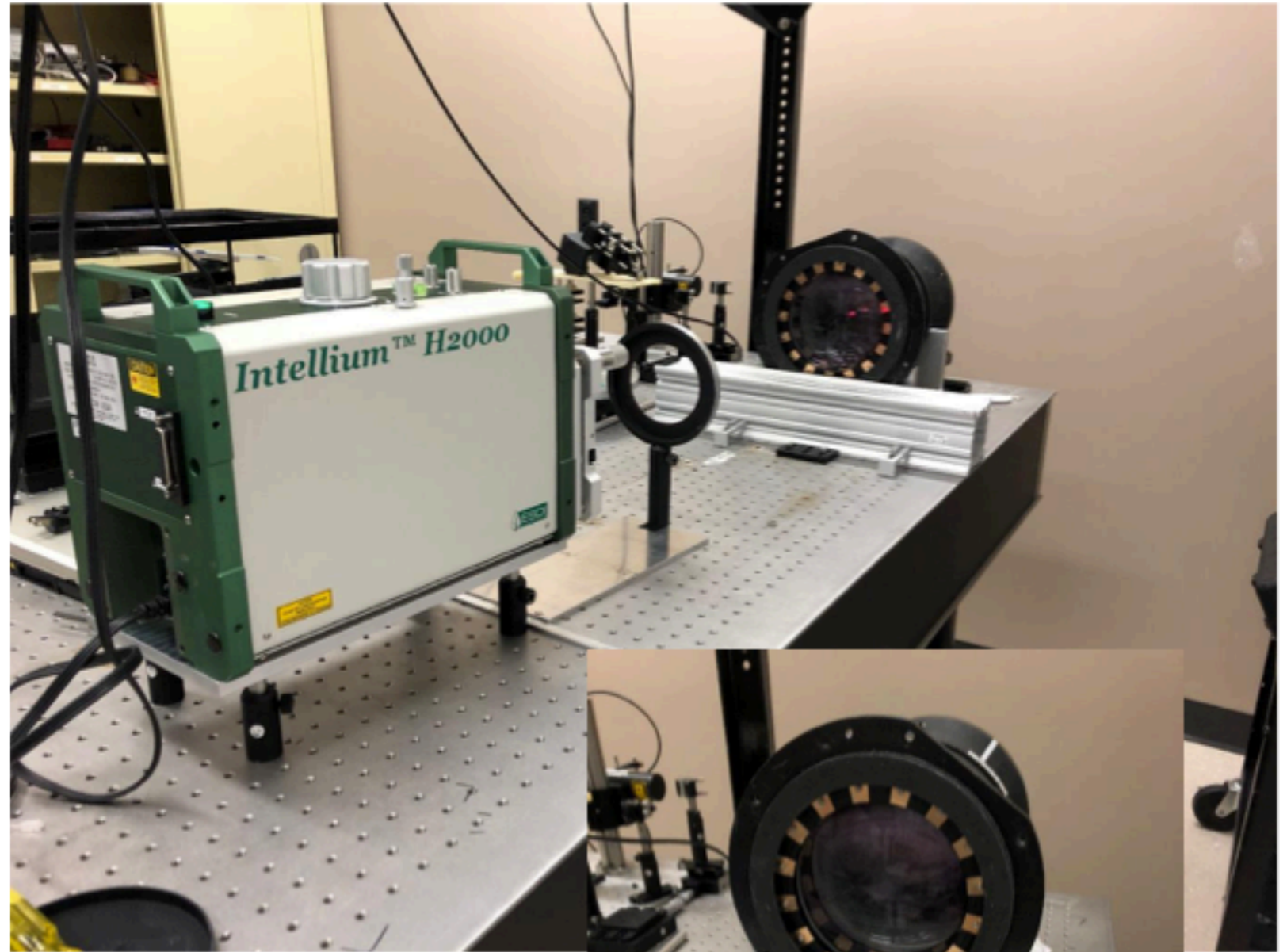
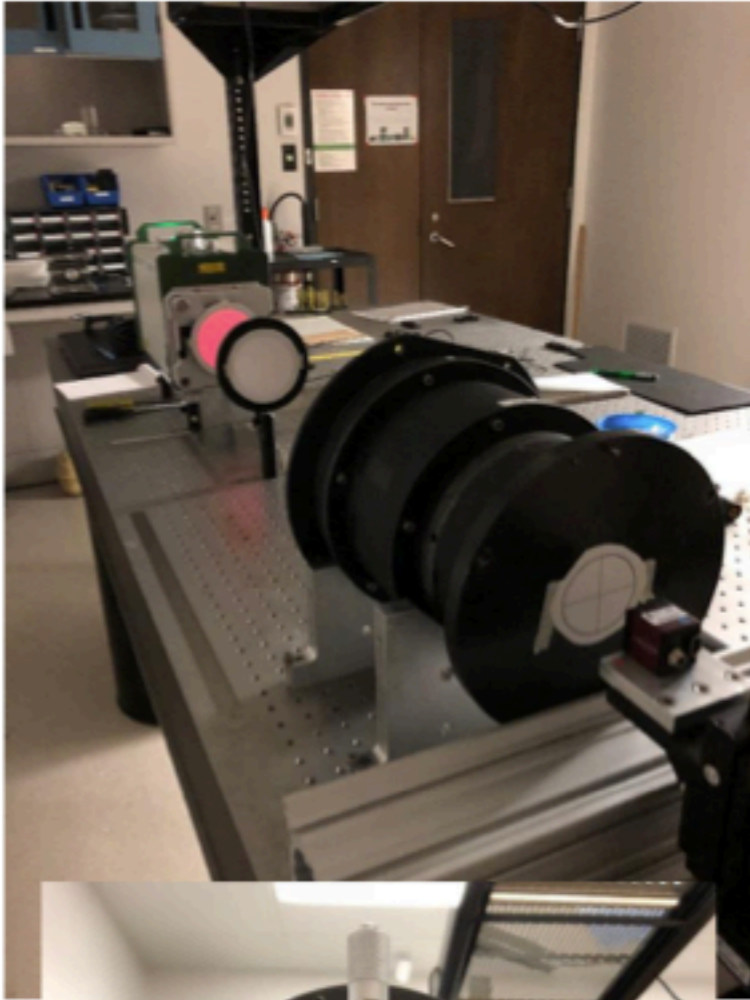


Highly variable from run to run

Optical tests (collimator), Mauna kea, Fall 2017



Optical tests (cameras), Laval, August 2018



DENIS
BROUSSEAU



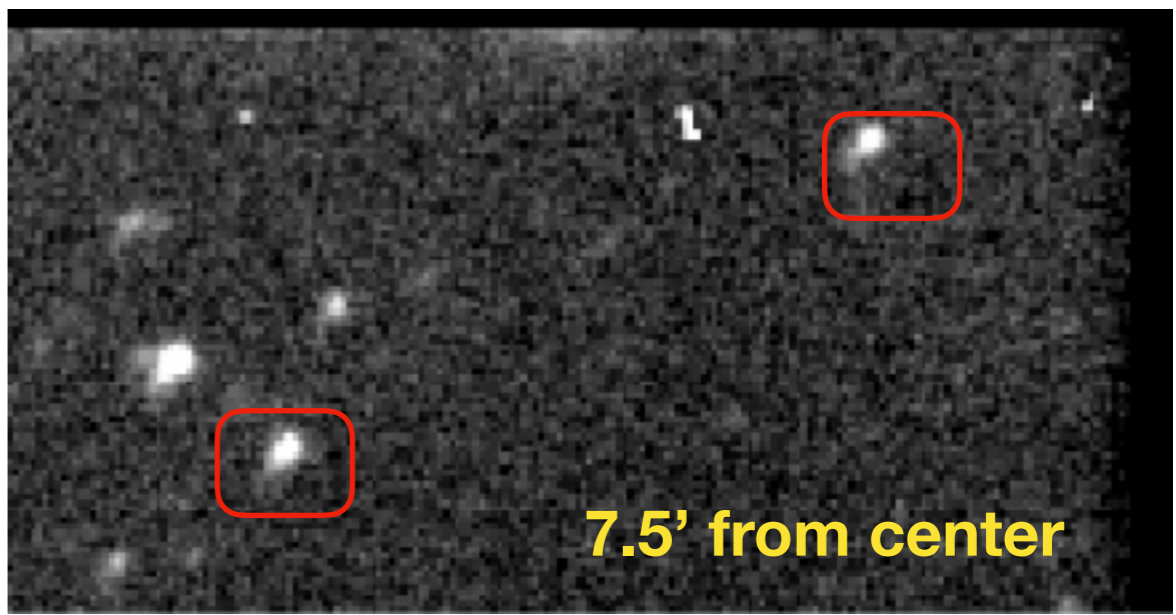
Telescope/SITELLE alignement work

(SITELLE is the instrument
with the **largest FOV (11' x
11')** ever installed at the
**Cassegrain -
MOS was 10' x 10')**

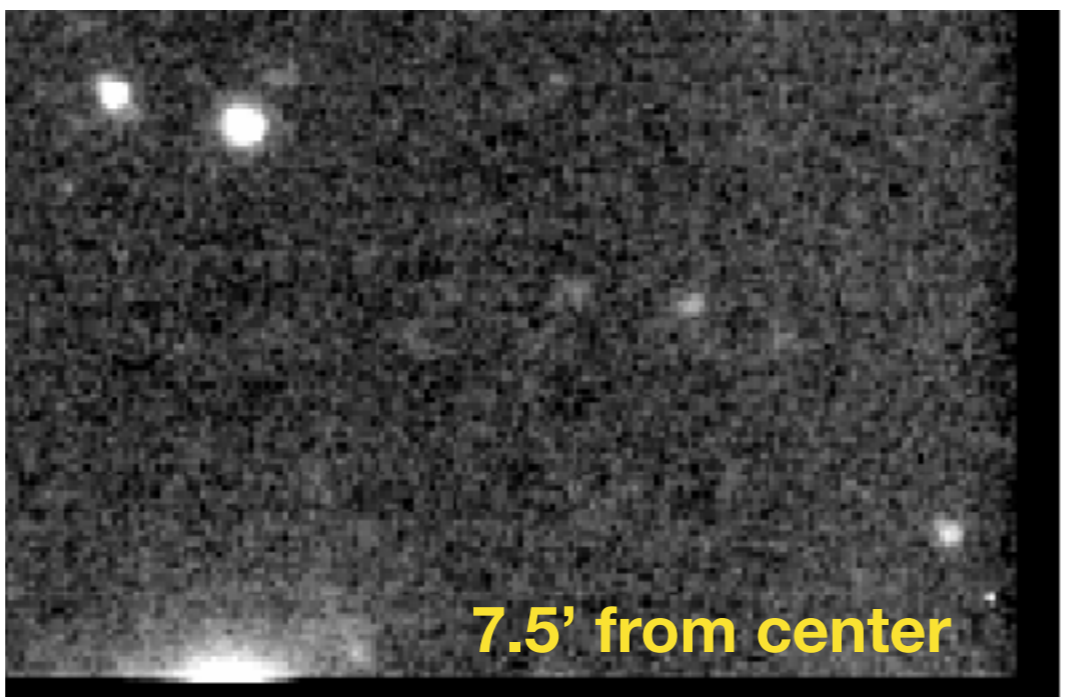


(The Happy Kitten Nebula)

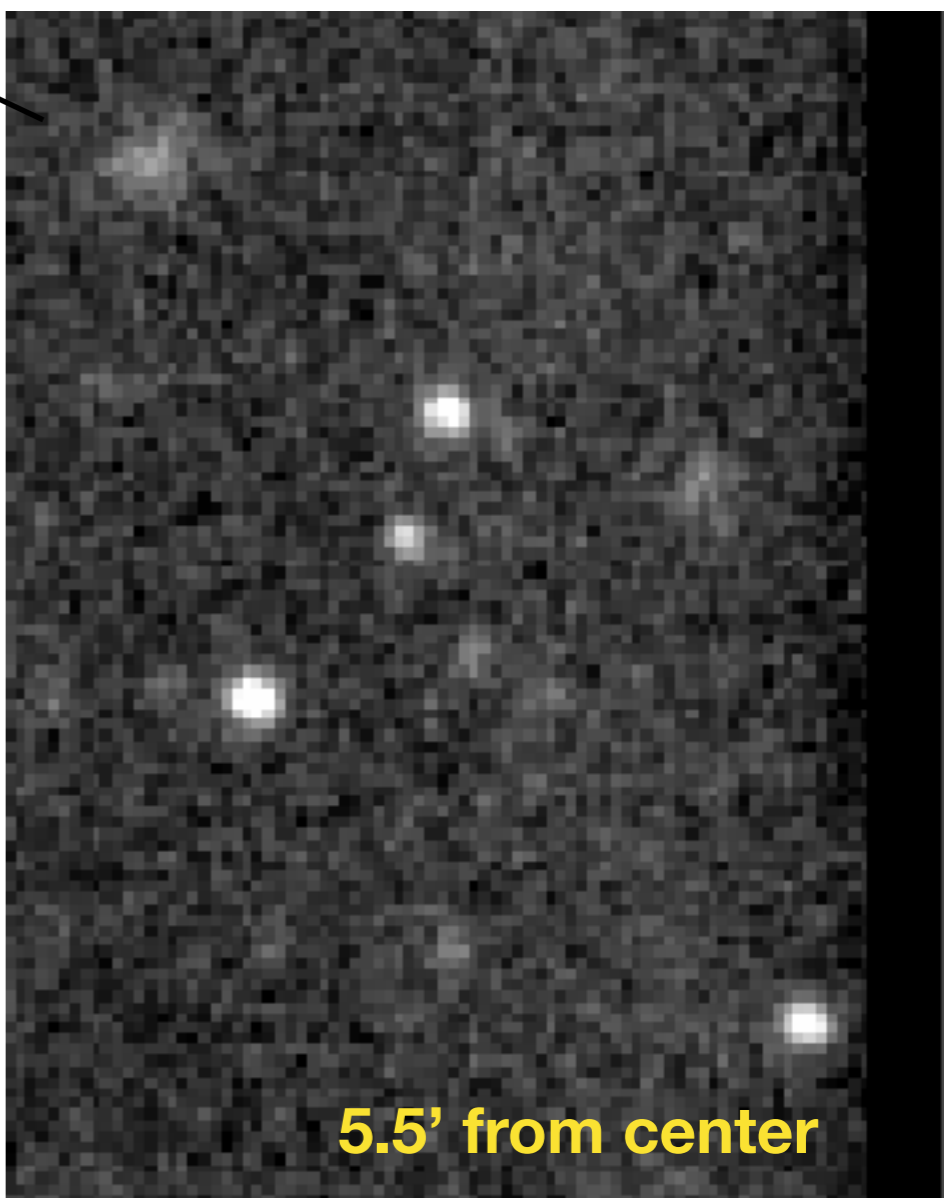
SN1 filter (375 nm),
2 hour cube,
April 2019



7.5' from center



7.5' from center



5.5' from center

7.5' from center



5.5' from center

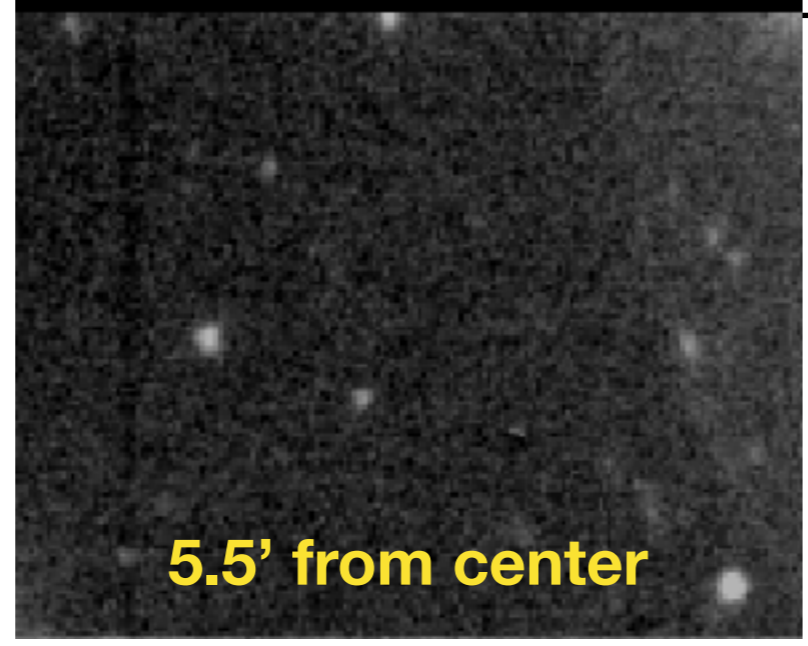
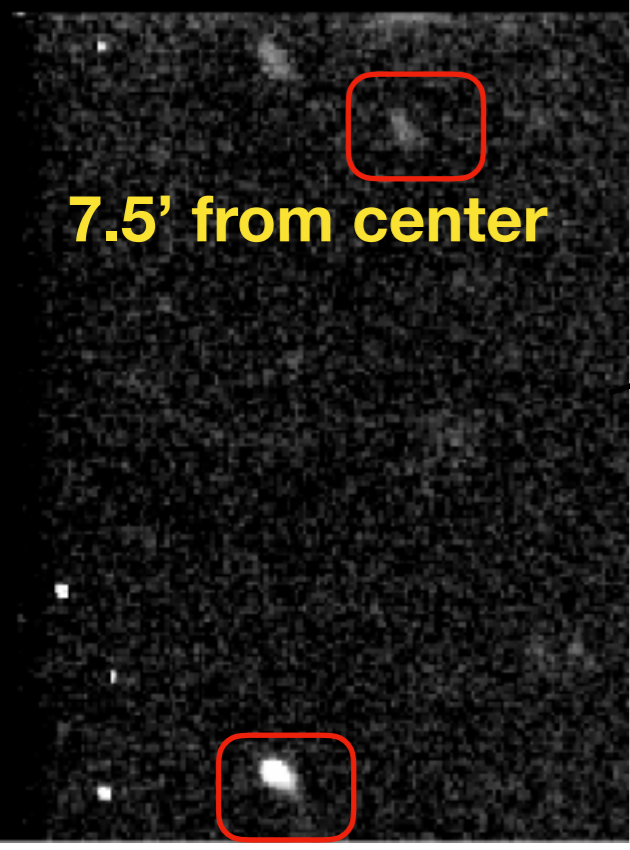
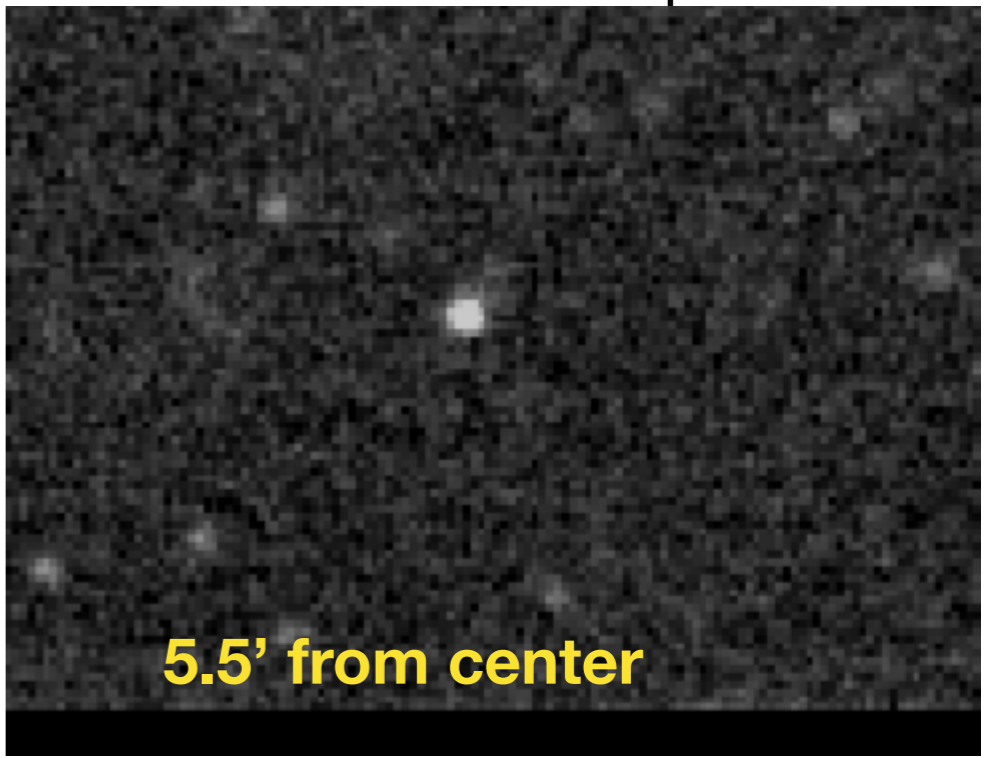
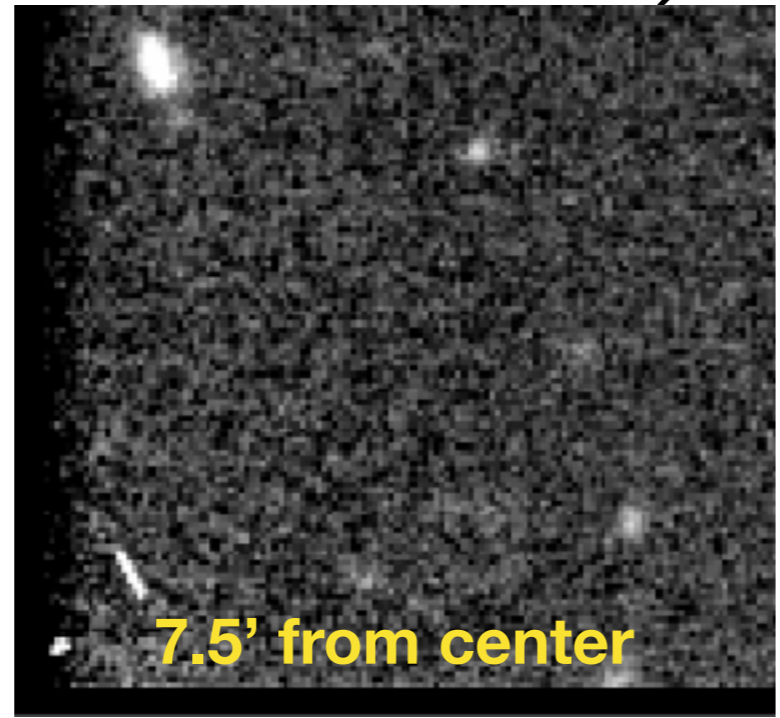
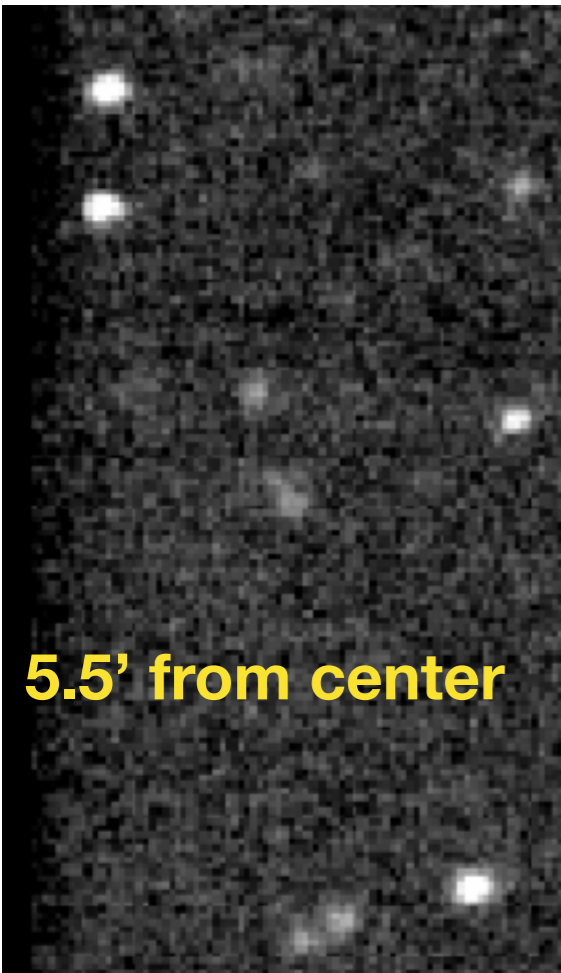


Image quality (See Marc Baril's poster)

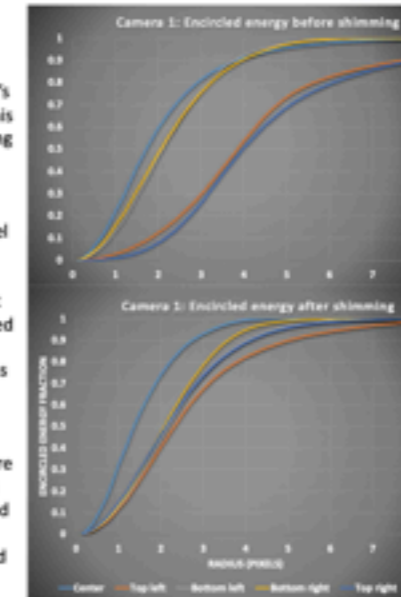
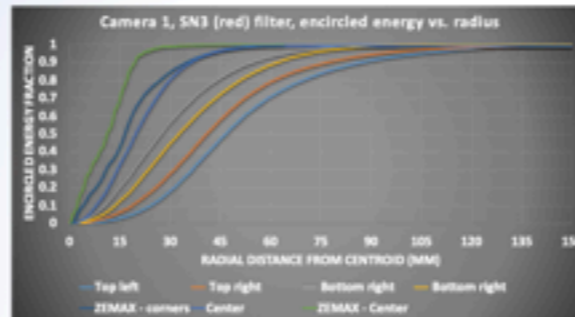
Overview

SITELLE's engineering and science team continue their efforts to obtain the most from this versatile instrument. Improvement of the unexpectedly poor IQ at the edges of the field has been the focus of our work since 2017.

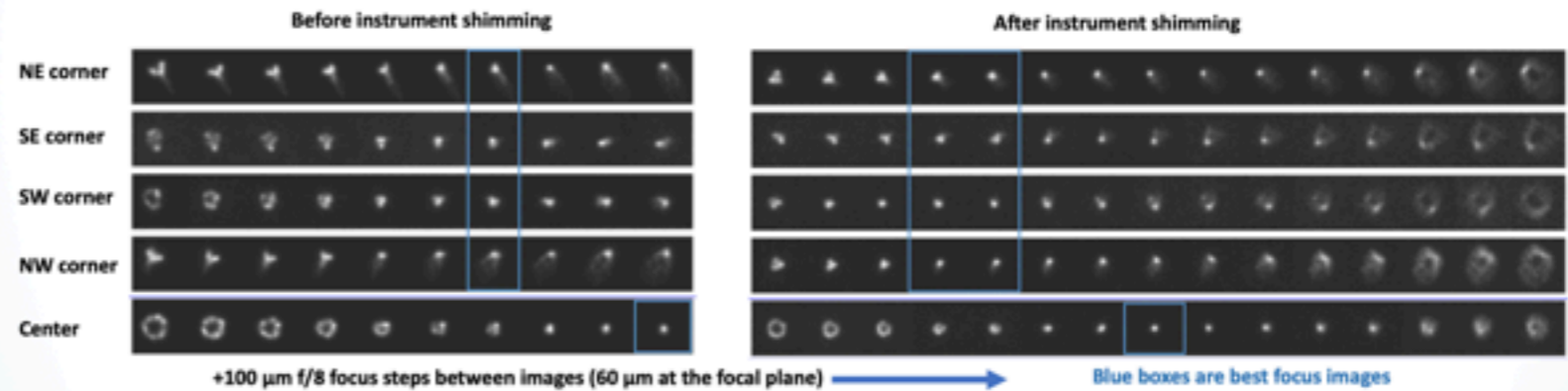
We are happy to report that the IQ has significantly improved, as a result of identification and correction of an error of the instrument tip/tilt with respect to the telescope optical axis. Further improvements will be realized by the 2019B semester with the installation of field flattening lenses on the detectors, underway as of this meeting (see bottom row of poster).

Instrument tilt

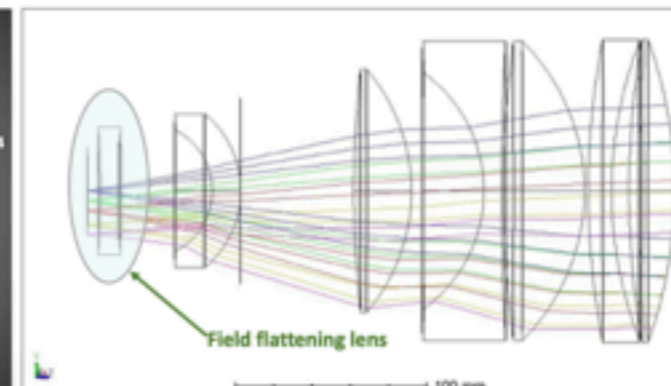
Although SITELLE's collimator optical axis had been verified to cross the center of the instrument's Cass mounting flange, the tilt of this axis w.r.t. the plane of the mounting flange was never tested until July 2018. At that time a tilt of 0.26° was identified, aligned roughly in the direction that the Zemax model produced through focus PSFs similar to what is seen on sky. However, the magnitude of the tilt was roughly half what was expected from the Zemax model to explain the on sky PSF. Nevertheless, brass shims, amounting to a 5 mm maximum shim thickness Δ , were installed to remove any possible effect. Comparison of the IQ before and after the change are shown in the images below and the encircled energy plots at right. The PSF is now much more symmetric around the field.



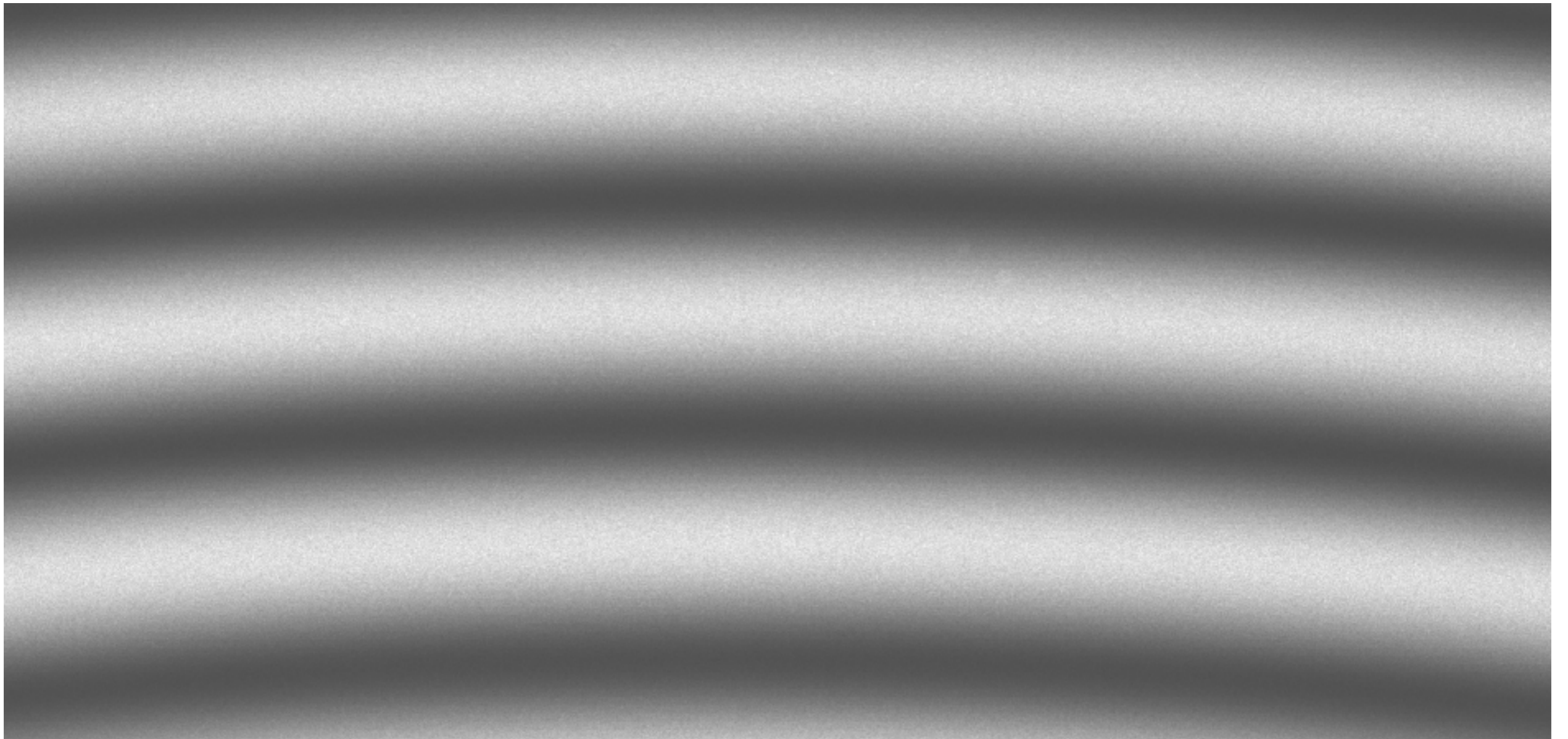
Above: The setup used to determine the alignment of SITELLE's collimator optical axis to the instrument mounting flange plane.



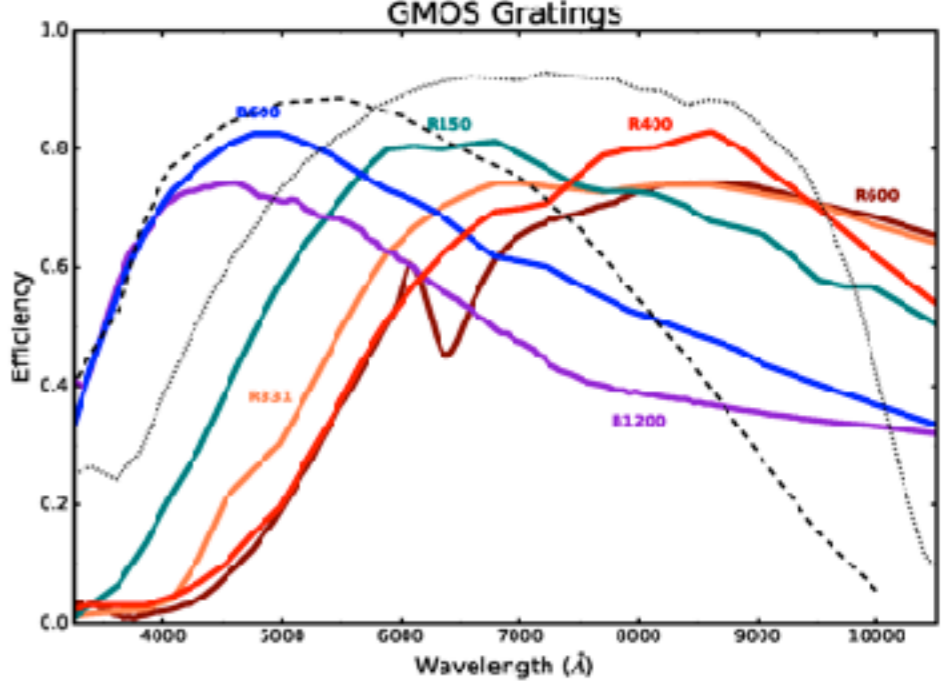
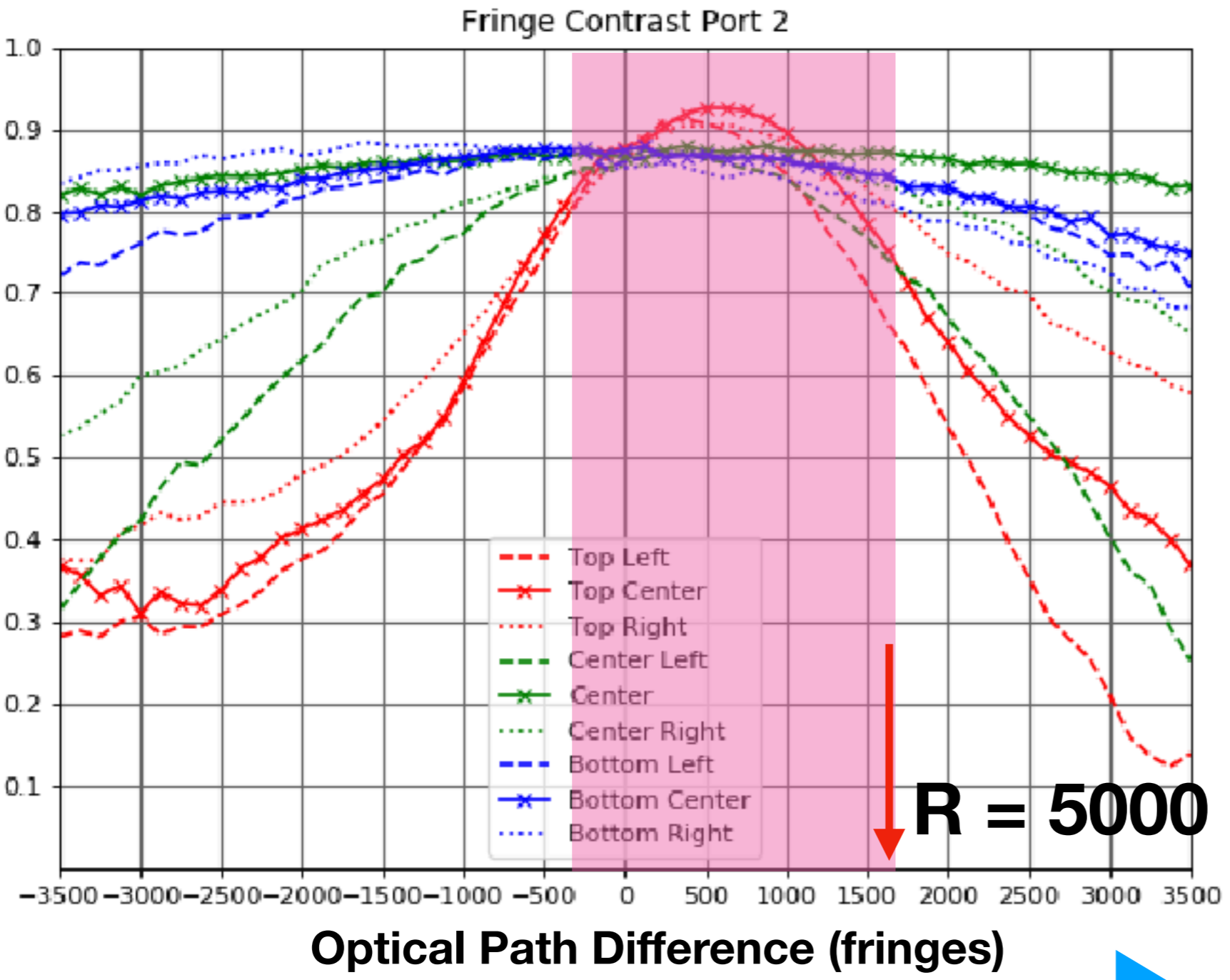
Further Improvement: Replace flat CCD window with lens to correct for field curvature. This will be ready to test at the start of 2019B semester.



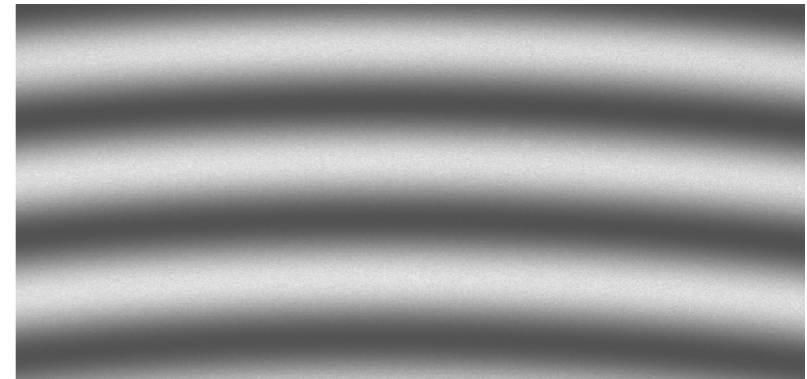
Modulation efficiency



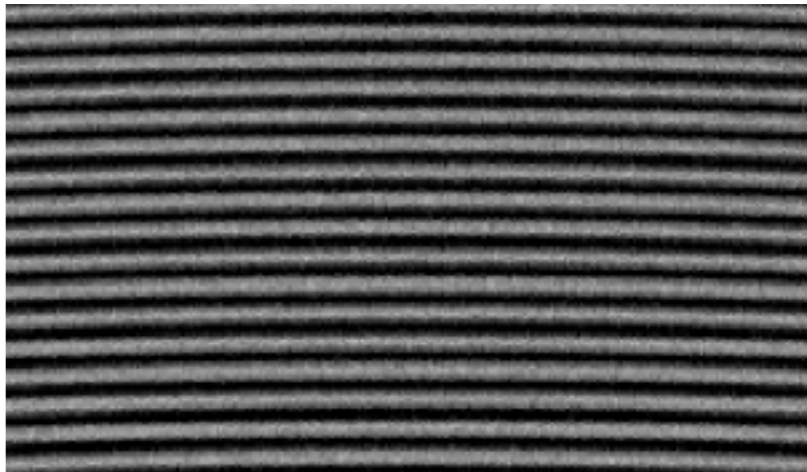
Modulation efficiency



Small OPD



Large OPD



Spectral resolution →



Software

ORBS
(data reduction)

ORCS
(analysis)

SITELLE's Level-1 data processing pipeline and calibration accuracy *(Level-2 now in use)*



T. Martin^{1,2*}, L. Drissen^{1,2}, S. Prunet³

¹*Département de physique, de génie physique et d'optique, Université Laval, 2325, rue de l'université, Québec (Québec), G1V 0A6, Canada*

²*Centre de Recherche en Astrophysique du Québec (CRAQ), Montréal (Québec), H3C 3J7, Canada*

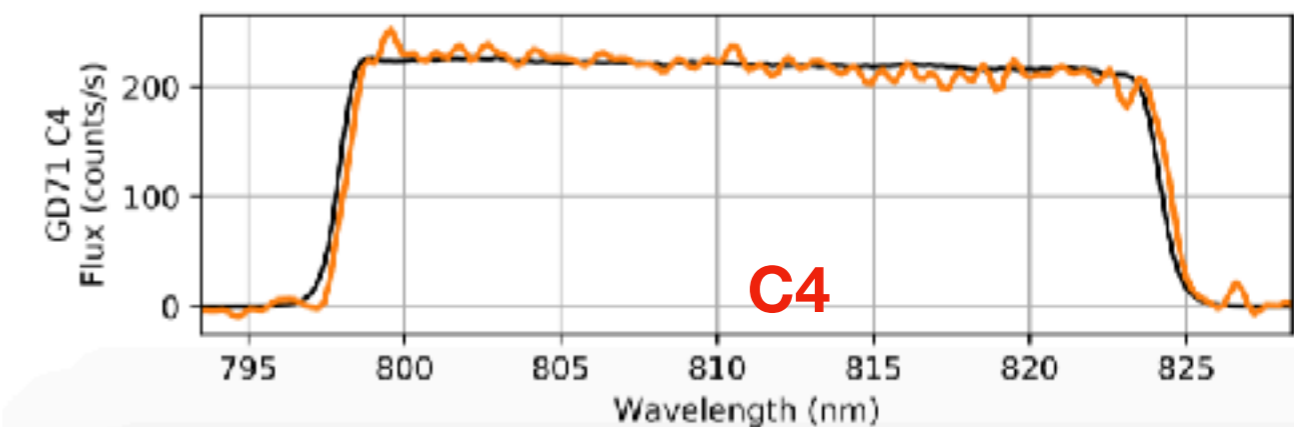
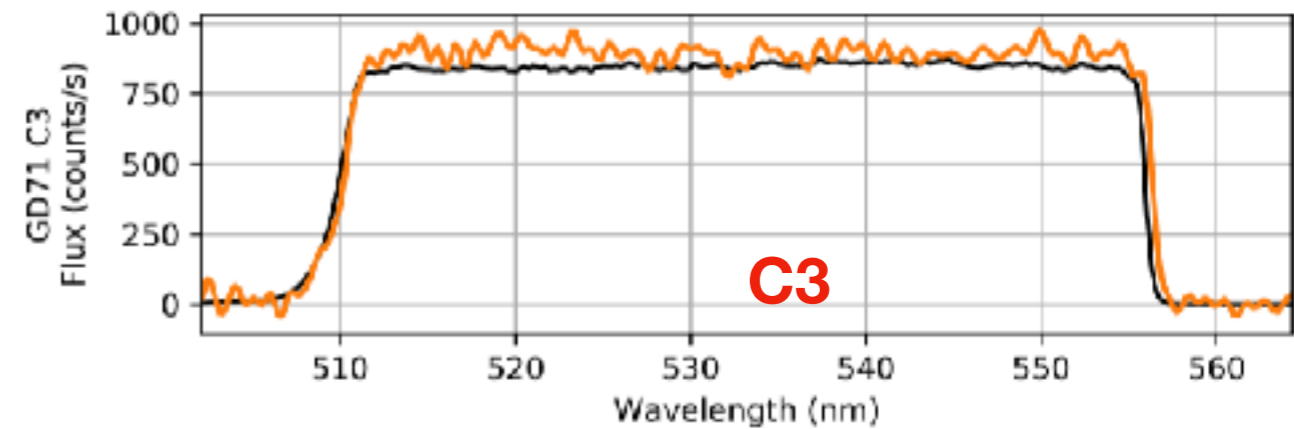
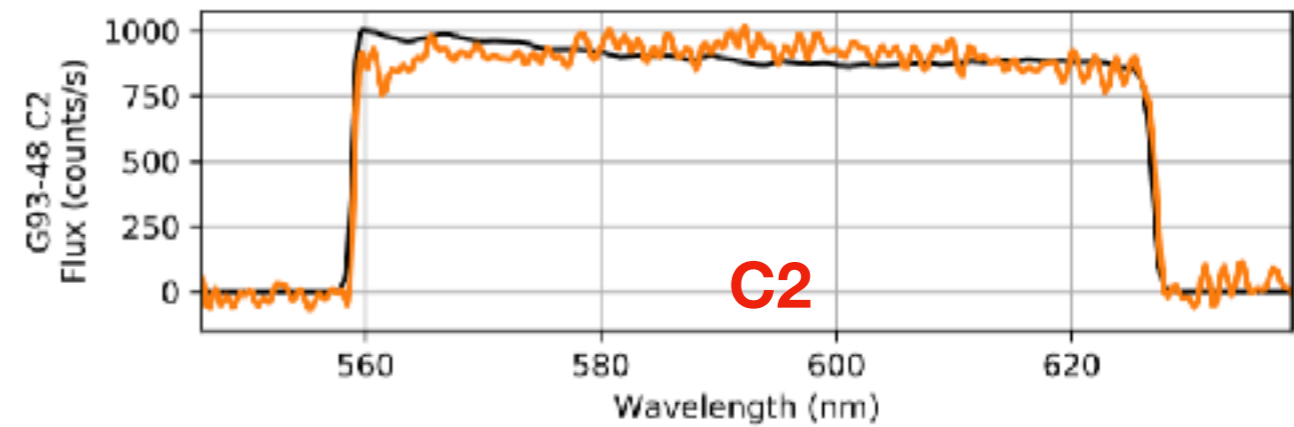
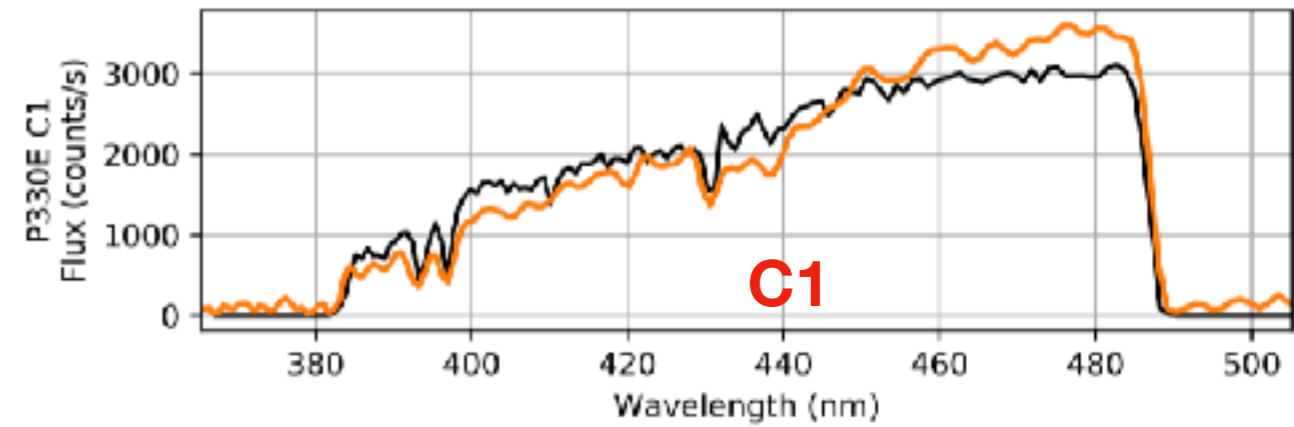
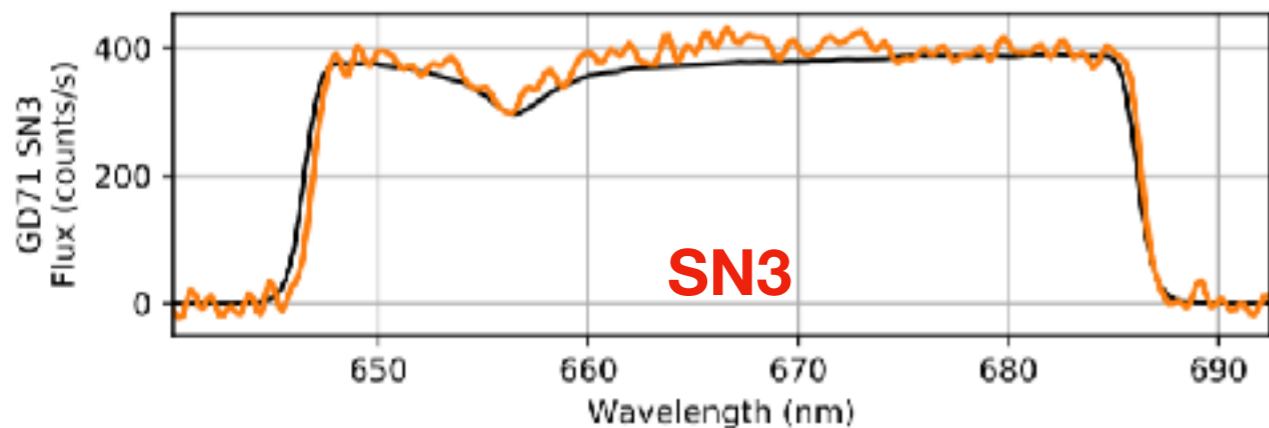
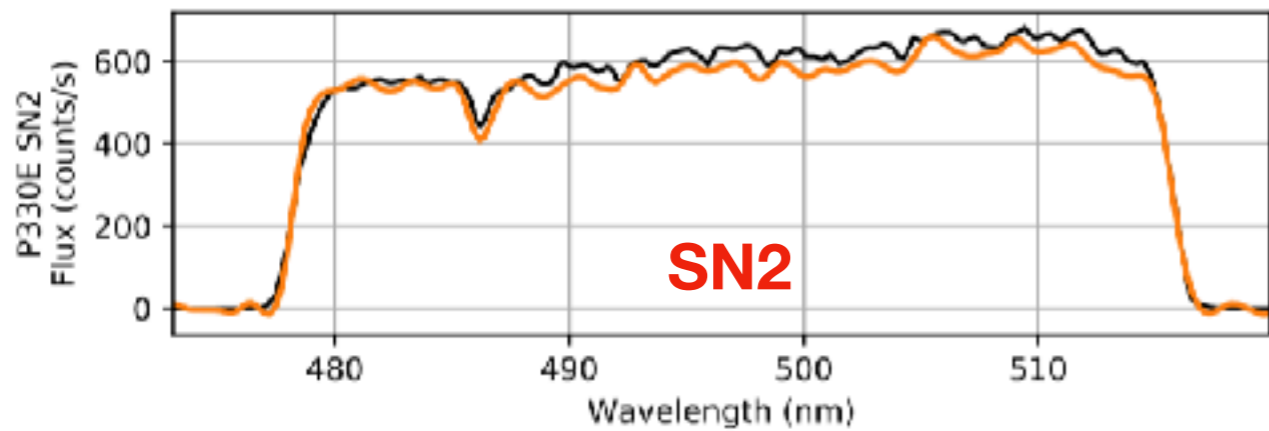
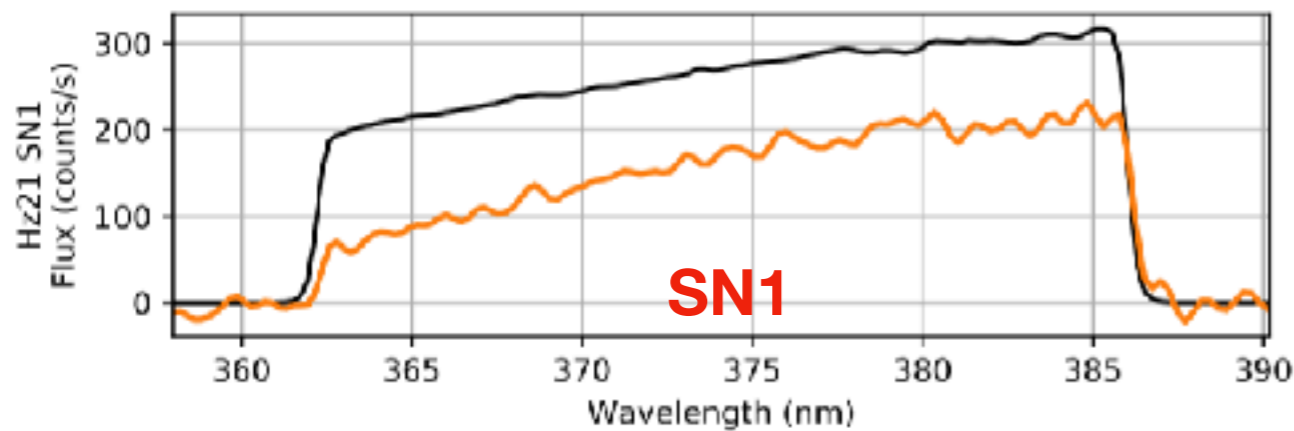
³*Canada-France-Hawaii Telescope, 65-1238 Mamalahoa Hwy, Kamuela, Hawaii 96743, USA*

Simulations vs. real spectra


- * Telescope
- * SITELLE optics
- * Michelson (ME)
- * Filters
- * CCDs

* Standard stars

(see Thomas Martin for details)



Orcs



2.4

Installation
Introduction
Examples

First basic examples

- Example of a single spectrum fit.
- How precise must be the input velocity parameter ?
- Extract the deep frame and use the WCS

Make a fit over an

[Docs](#) » [Examples](#) » Make a fit over an entire region of the field

[View page source](#)

Make a fit over an entire region of the field

This is a complete example of a fit over an entire region of interest (ROI). The different steps covered are :

1. Extraction of a deep frame and the WCS
2. Definition of the ROI with DS9
3. Fit of a single spectrum in order to get an initial guess on the velocity of the gas
4. Fit of the entire ROI
5. Visualization of the resulting maps

```
In [1]: %matplotlib inline
        from orcs.process import SpectralCube
        import pylab as pl
        import orcs.utils.io
        import numpy as np
```

```
In [?]: cube = SpectralCube('/home/thomas/M57_SN3_merged.cm1.1.0.hdf5', debug=False)
```

```
INFO| Data shape : (2048, 2064, 593)
INFO| Cube is in WAVENUMBER (cm-1)
INFO| Cube is CALIBRATED in wavenumber
```

Computer intensive!

Doppler

Line ratios

A multispectral analysis of the northeastern shell of IC 443

Alexandre Alarie,^{1*} Laurent Drissen,^{2,3}

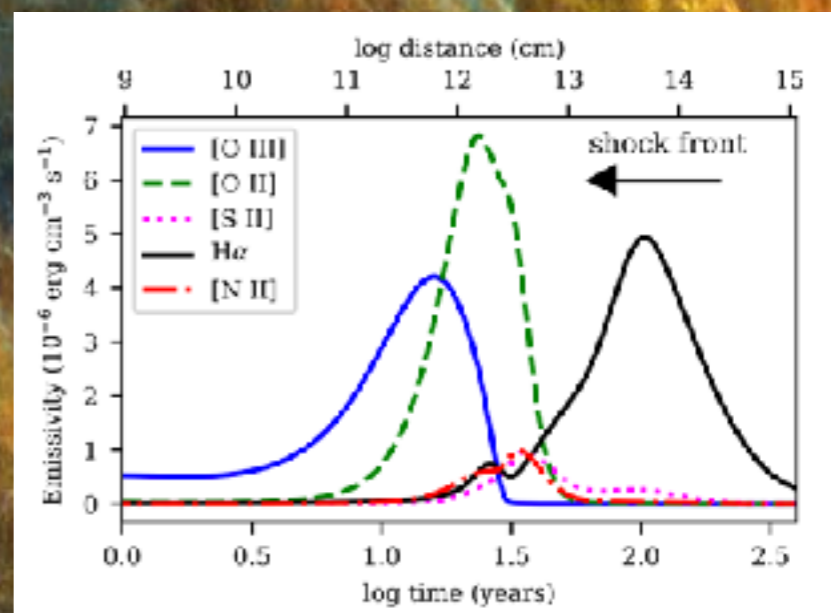
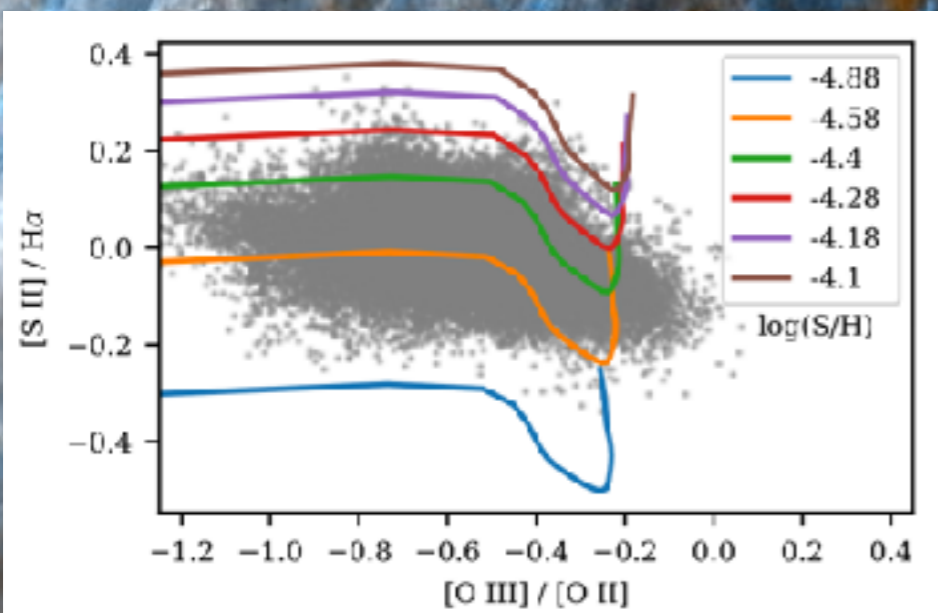
¹ Instituto de Astronomía, Universidad Nacional Autónoma de México, Apdo. Postal 70264, 04510 Mexico D.F., Mexico

² Département de physique, de génie physique et d'optique, Université Laval, Québec, Canada

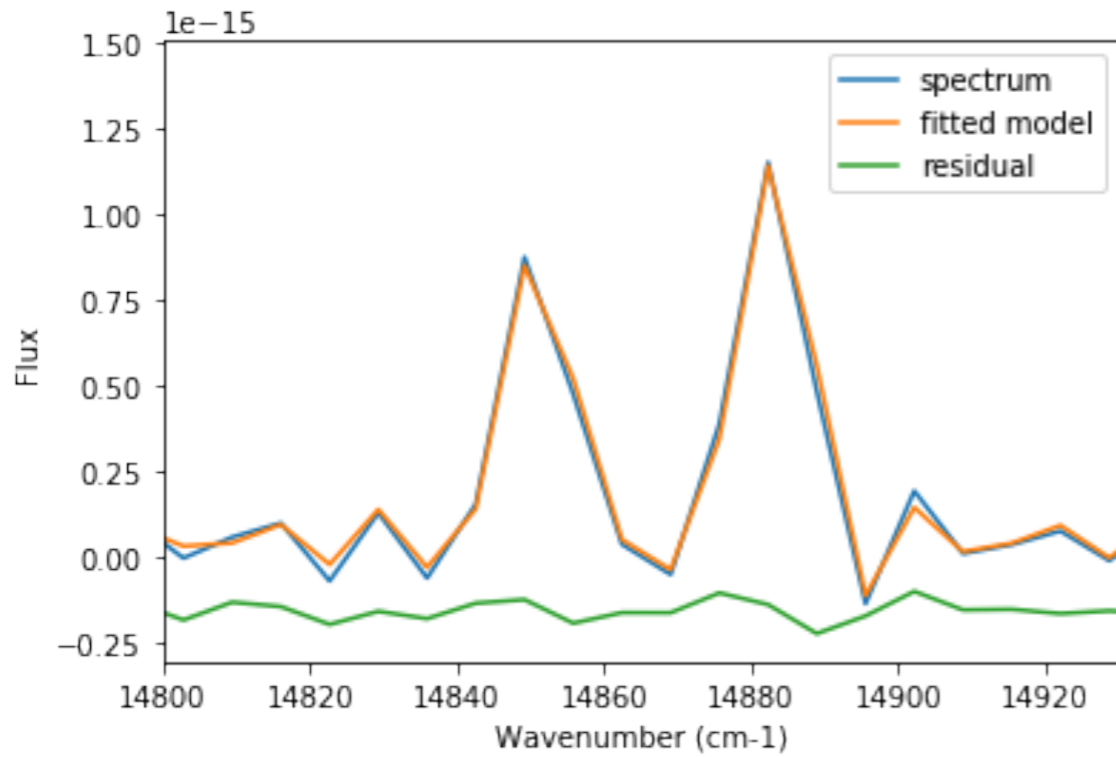
³ Centre de Recherche en Astrophysique du Québec, QC, G1V 0A6, Canada

³ Centre de Recherche en Astrophysique du Québec, QC, G1V 0A6, Canada

² Département de physique, de génie physique et d'optique, Université Laval, Québec, Canada

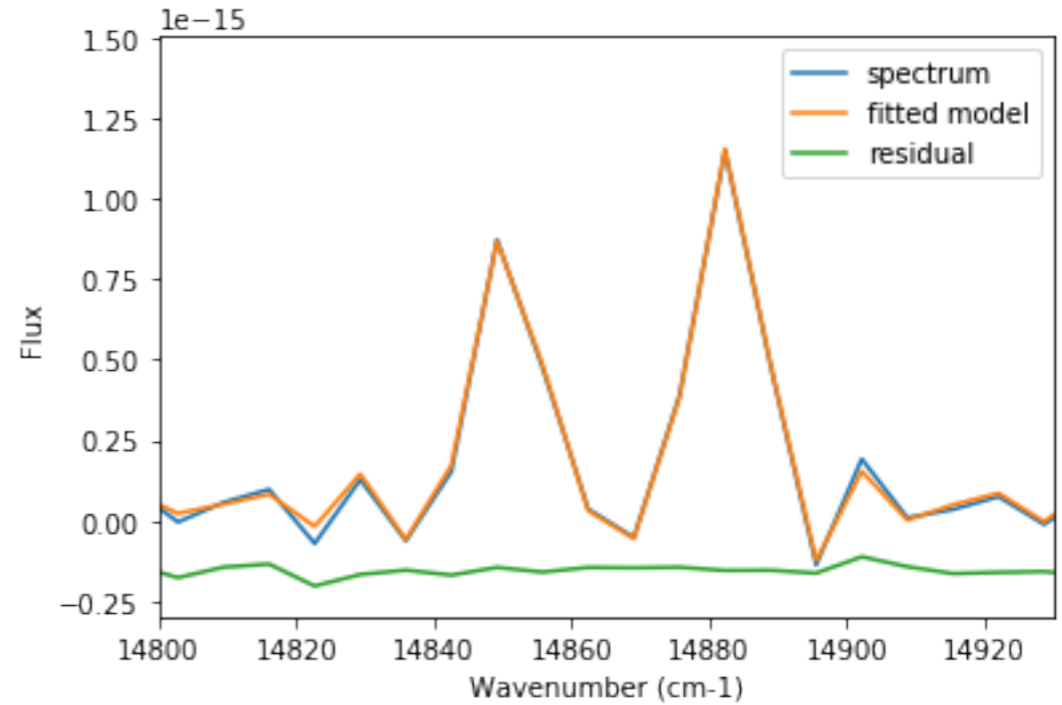


[SII] 6717,31 doublet

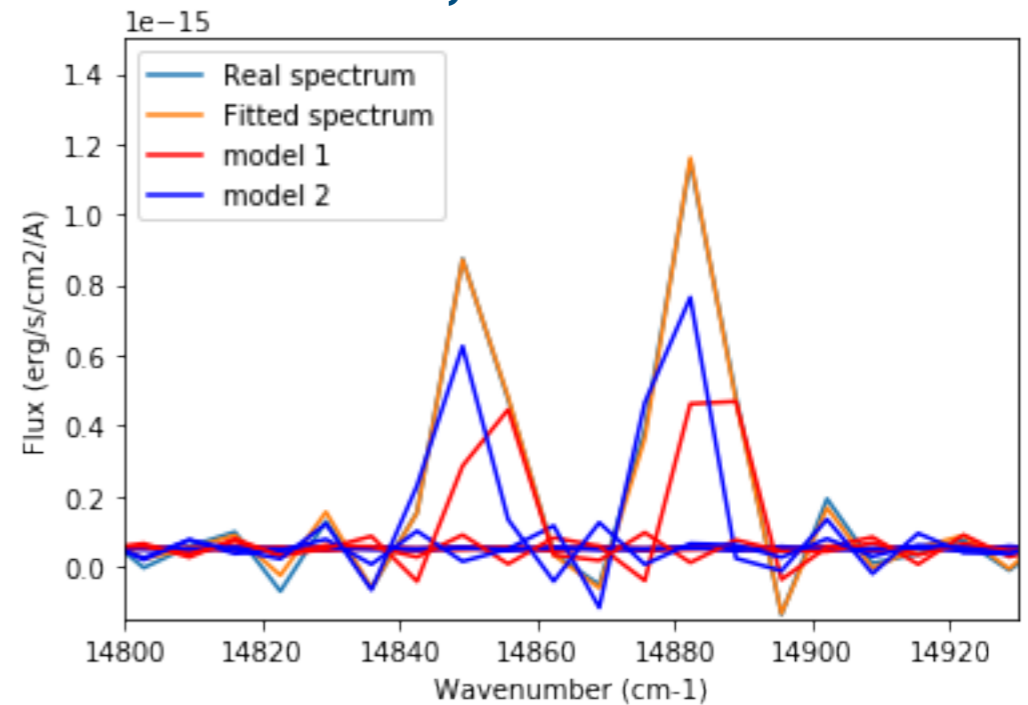


$\sigma = 120 \text{ km/s}$
sincgauss

SN3 filter, R = 1500 (fwhm ~ 200 km/s)



Two sincs
65, 177 km/s



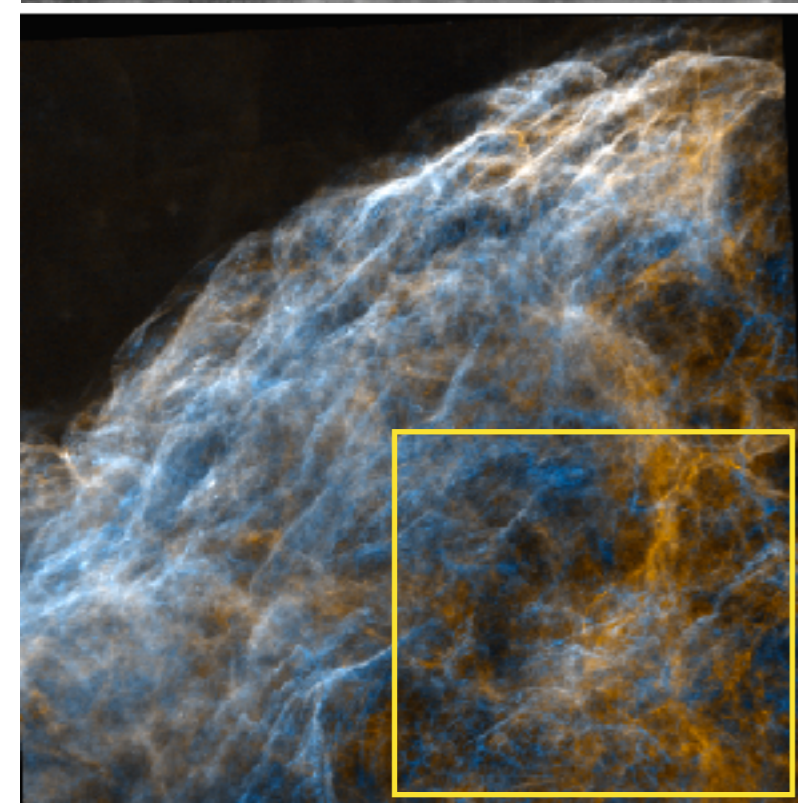
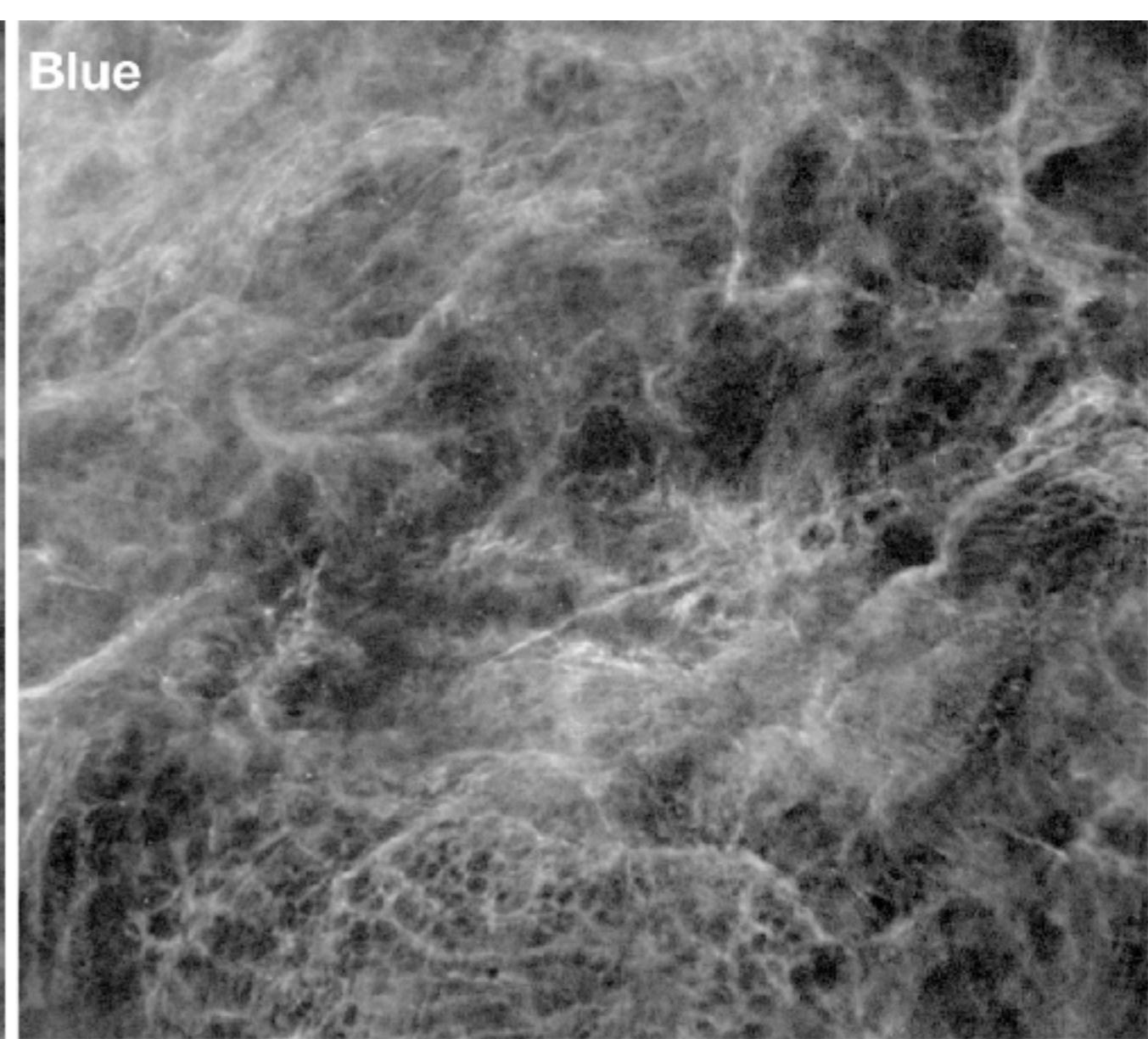
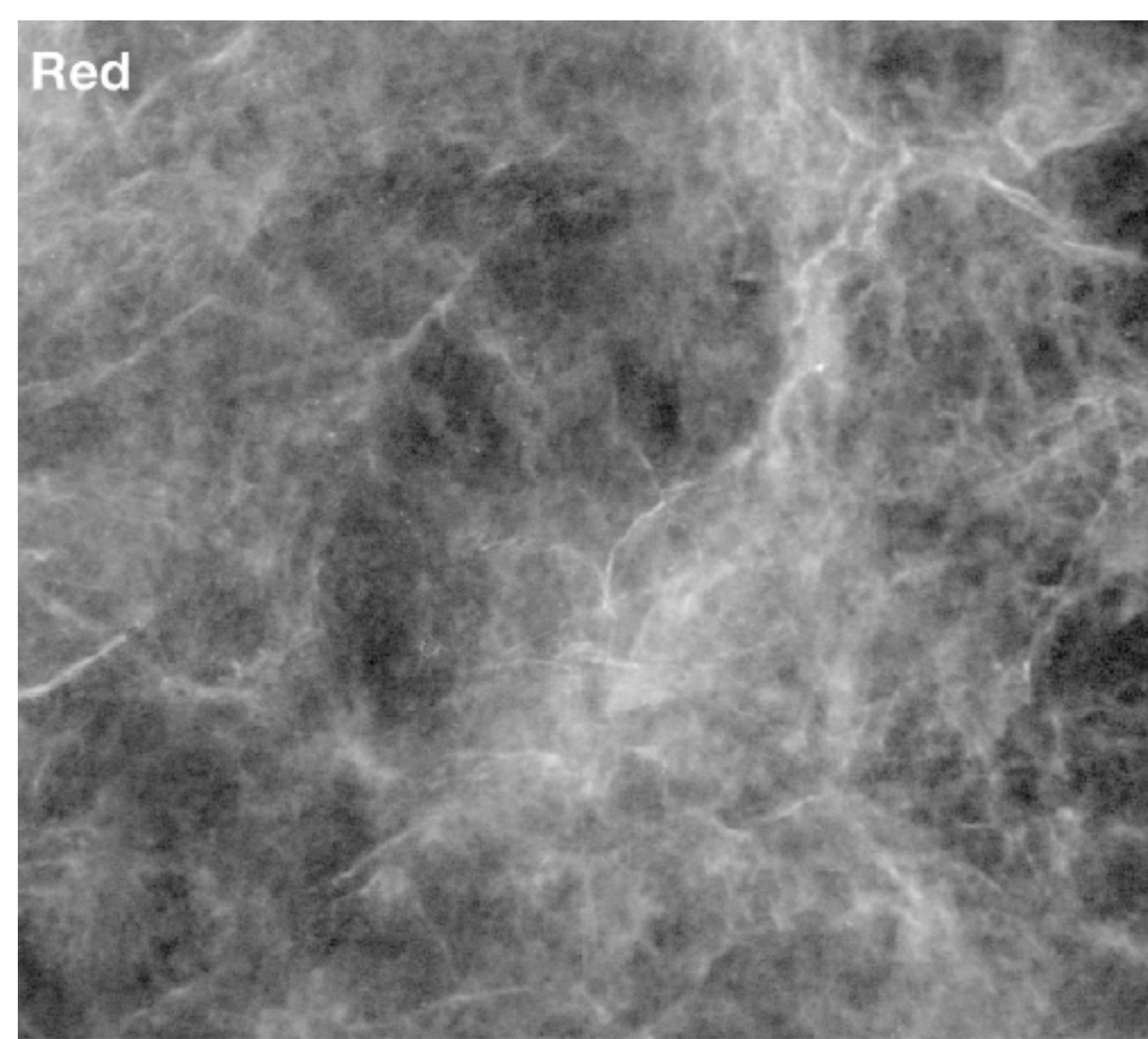
MNRAS 463, 4223–4238 (2016)
Advance Access publication 2016 September 14

Optimal fitting of Gaussian-apodized or under-resolved emission lines in Fourier transform spectra providing new insights on the velocity structure of NGC 6720

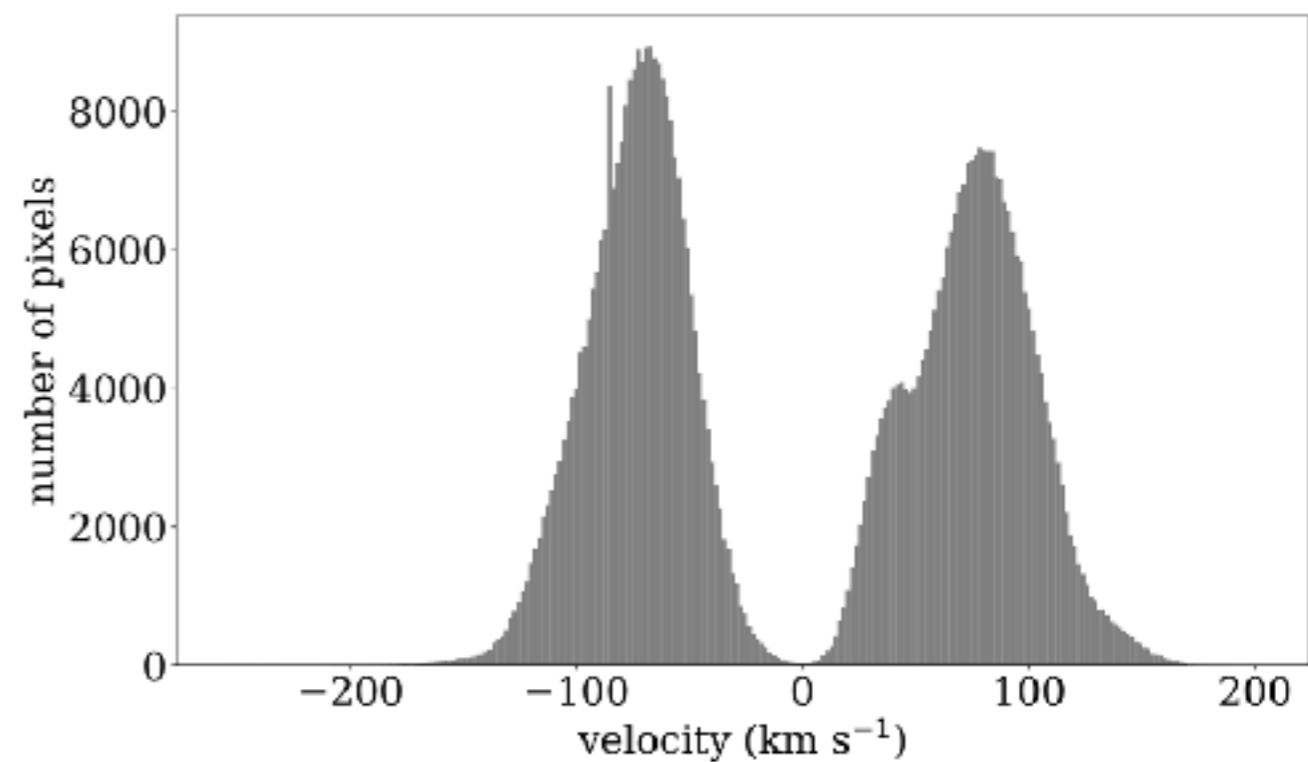
Thomas B. Martin,^{1*} Simon Prunet² and Laurent Drissen¹

¹Université Laval, 2325, rue de l'Université, Québec (Québec), G1V 0A6, Canada

²Canada-France-Hawaii Telescope, 65-1238 Maunakea Hwy, Kaneohe, HI 96743, USA

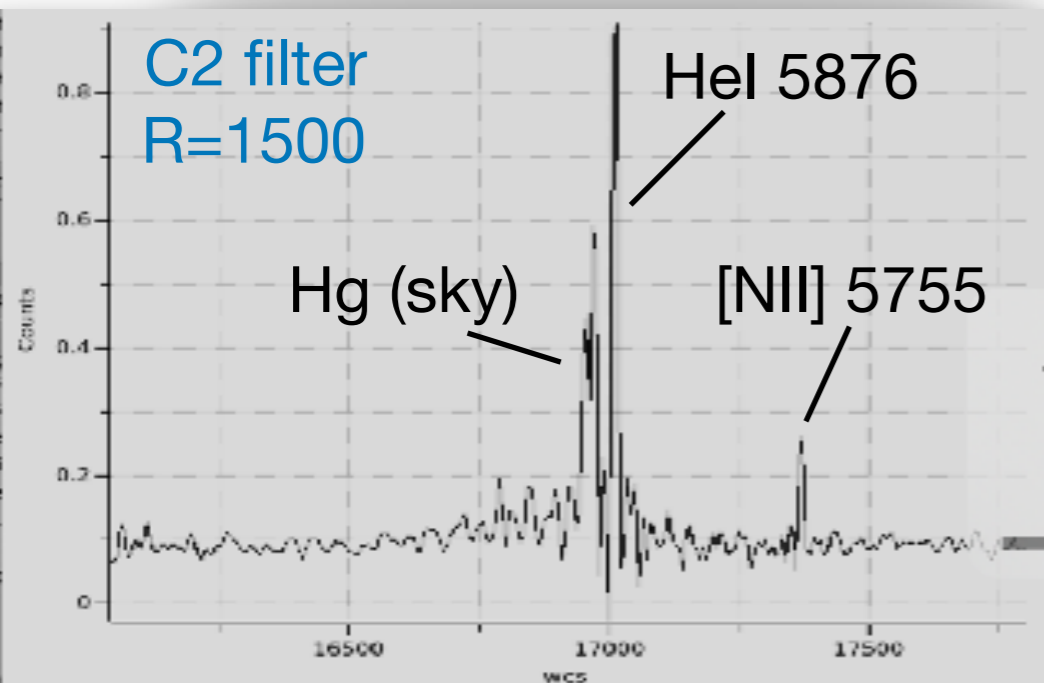
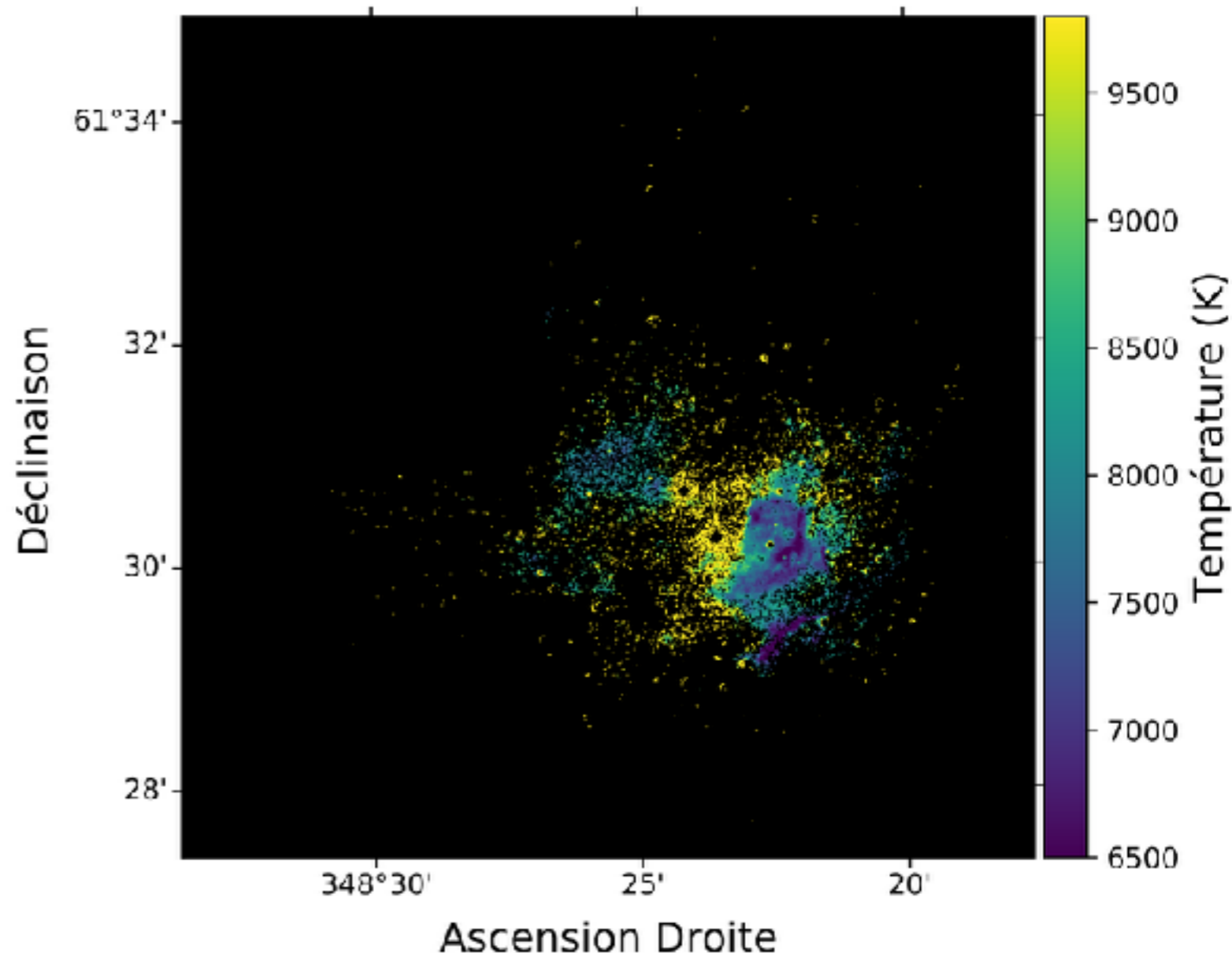
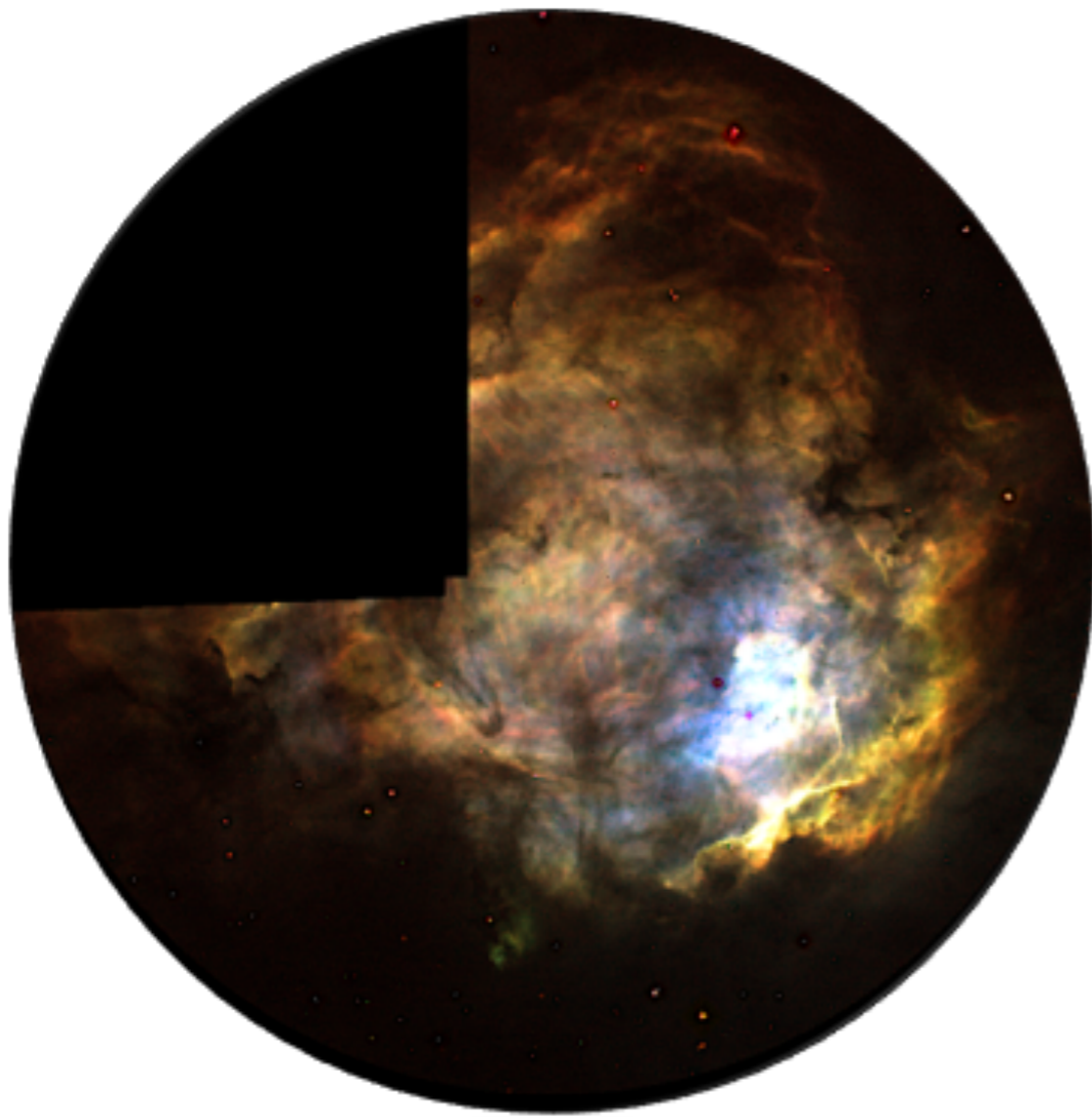


**2 velocity
components**

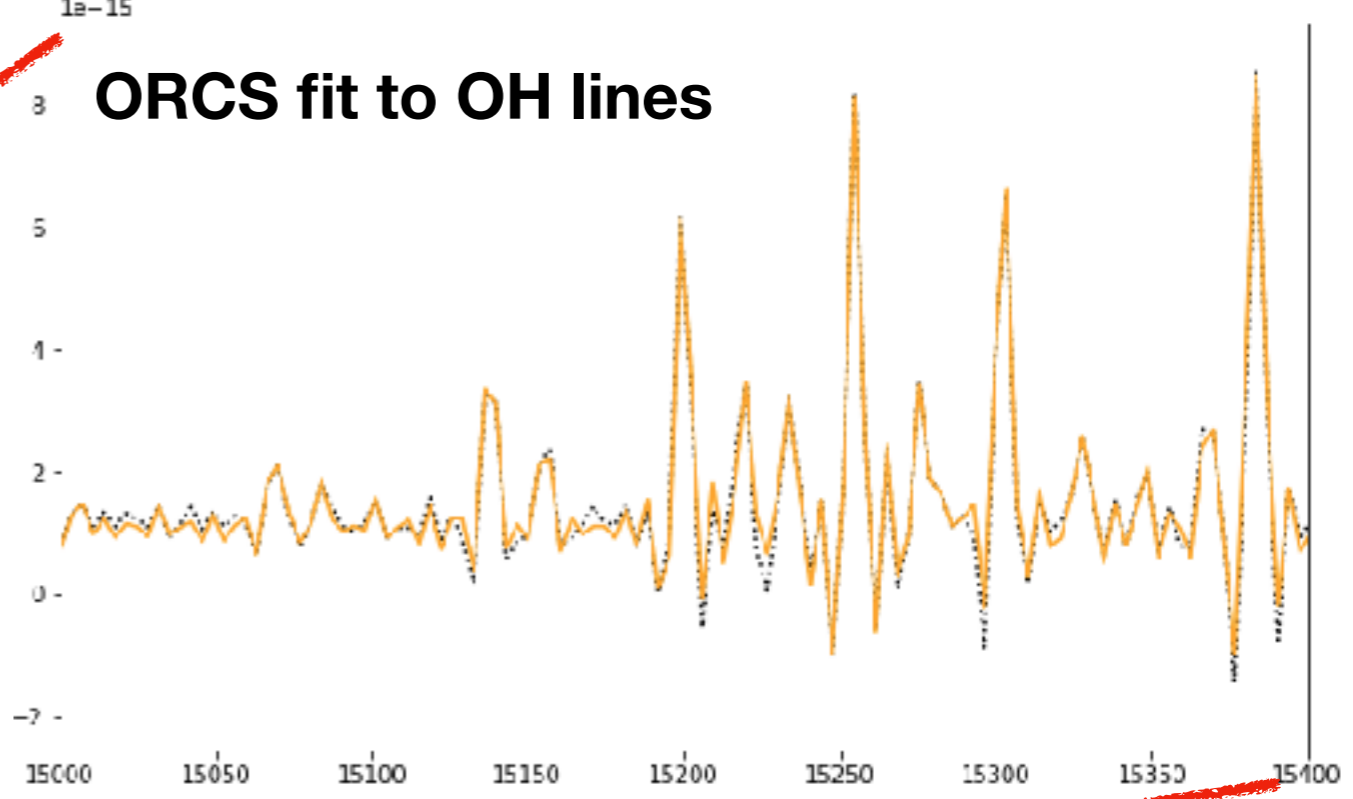
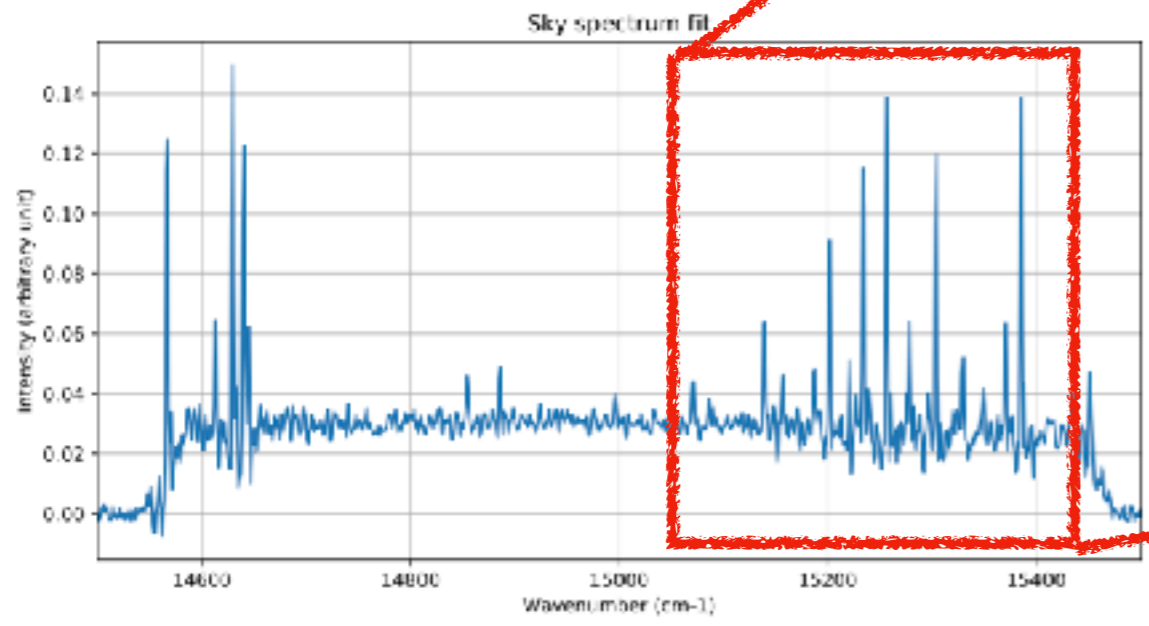


Thermodynamic study of the HII region Sh2-158

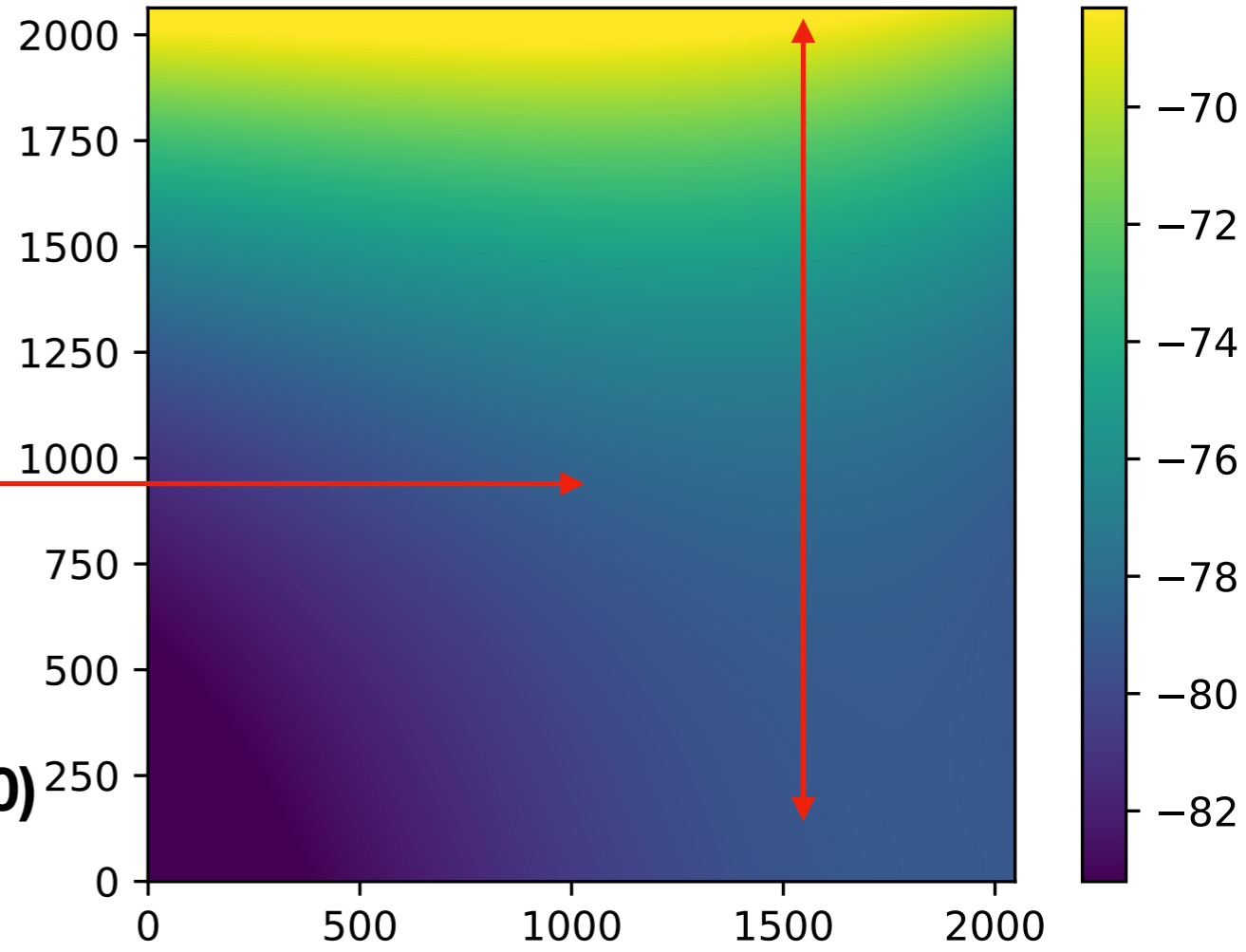
**Maxime Royer & Gilles Joncas
(U. Laval, Québec)**



Velocity calibration using atmospheric OH lines (SN3 filter)



Sky velocity map model (km/s)



Zero point (75 km/s): laser wavelength

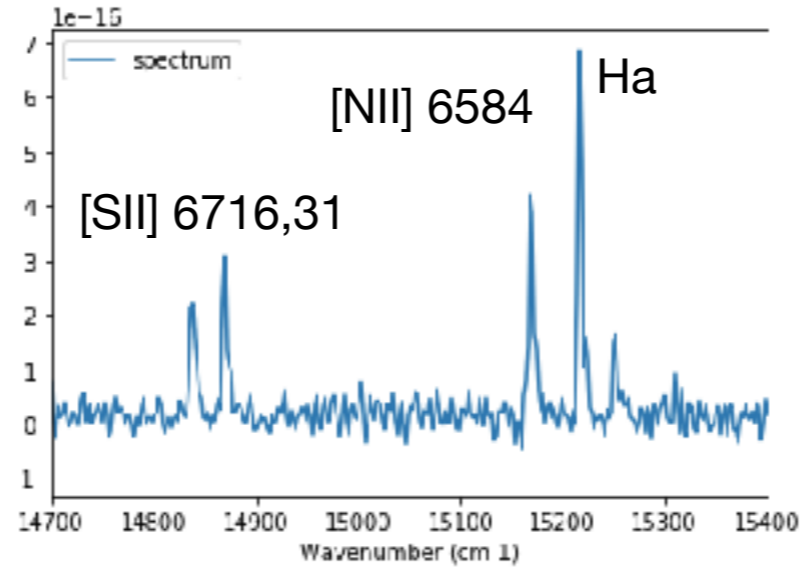
Gradient: instrument flexure

(Max. amplitude: 20% of ILS-FWHM @ R=5000)

(Central 8': 5% of ILS-FWHM @ R=5000)

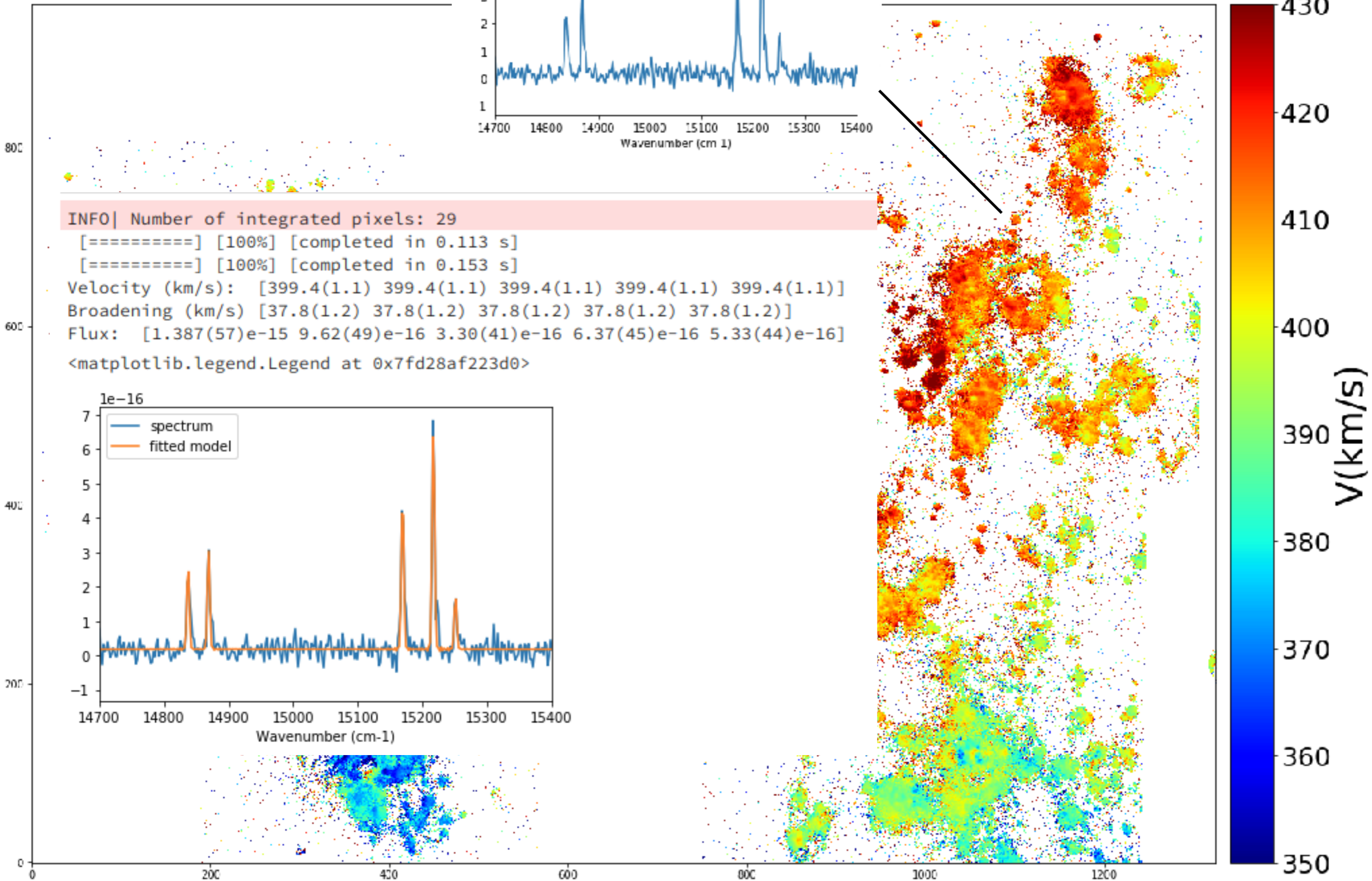
ORCS:

- flux, velocity,
- width (& errors) map



Supernova remnant

M101 velocity map



INFO| Number of integrated pixels: 29

[=====] [100%] [completed in 0.113 s]

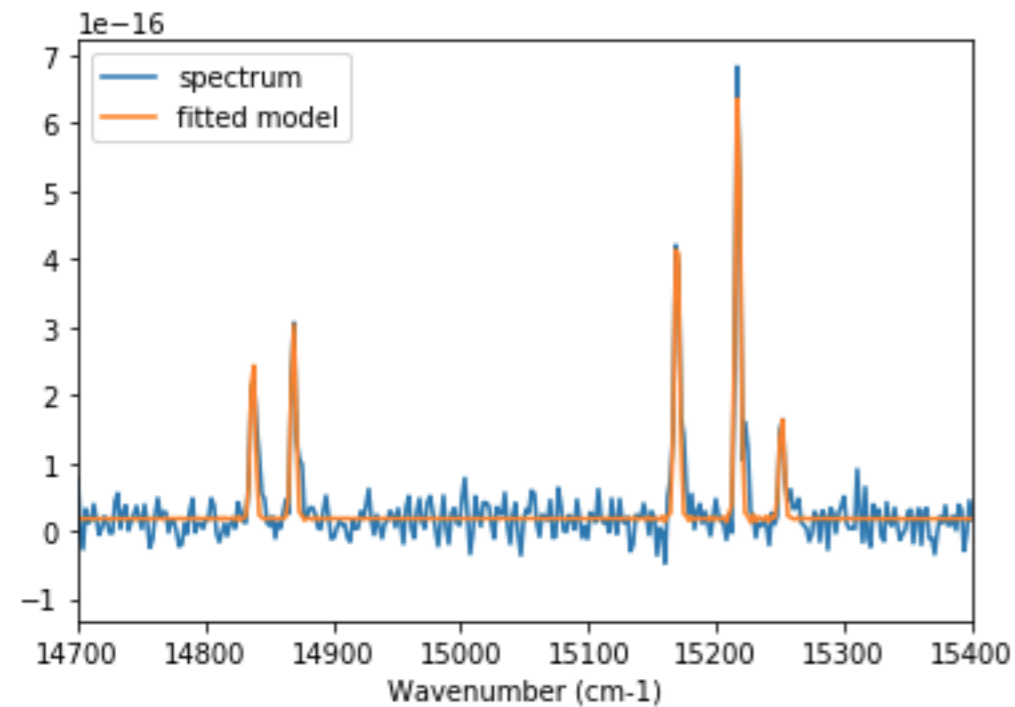
[=====] [100%] [completed in 0.153 s]

Velocity (km/s): [399.4(1.1) 399.4(1.1) 399.4(1.1) 399.4(1.1) 399.4(1.1)]

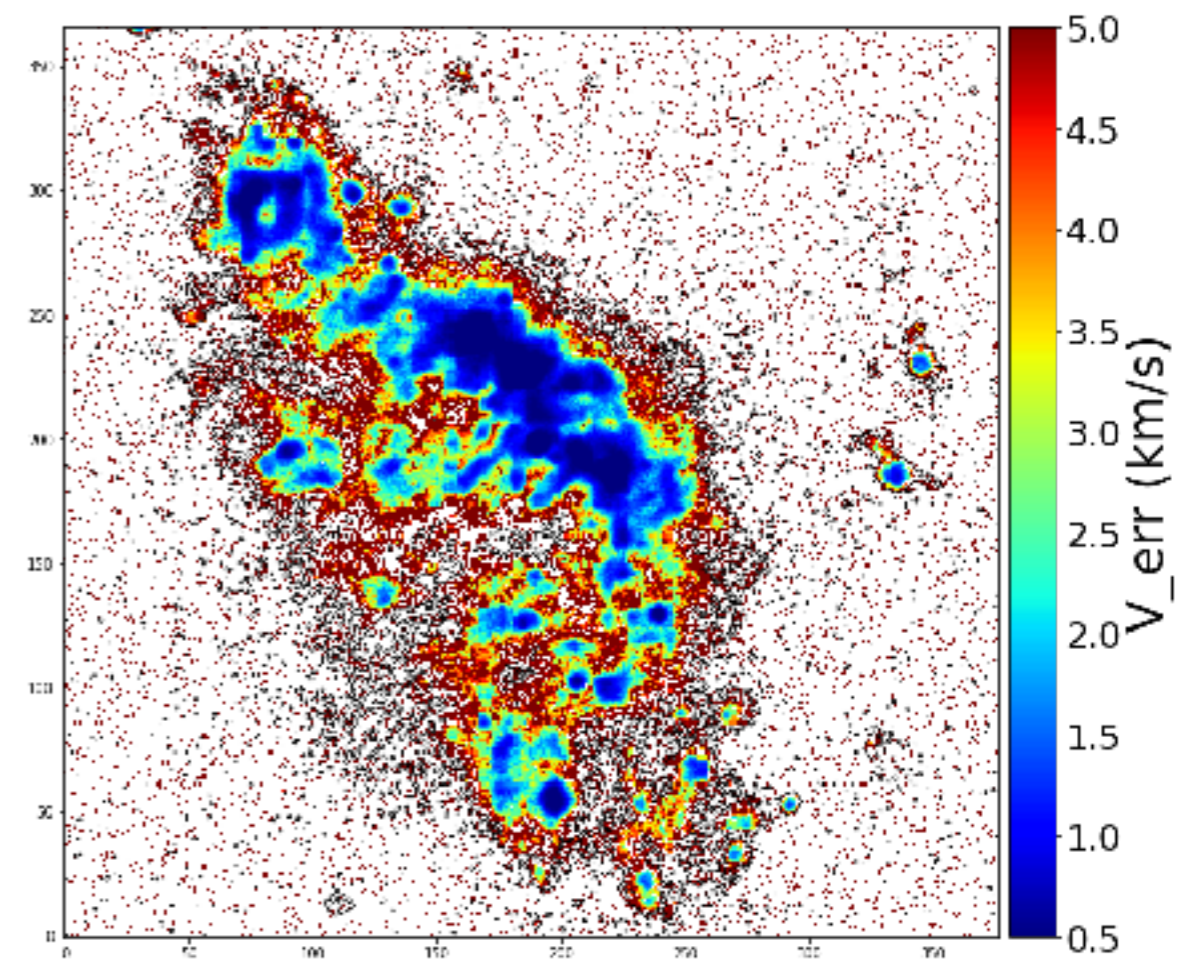
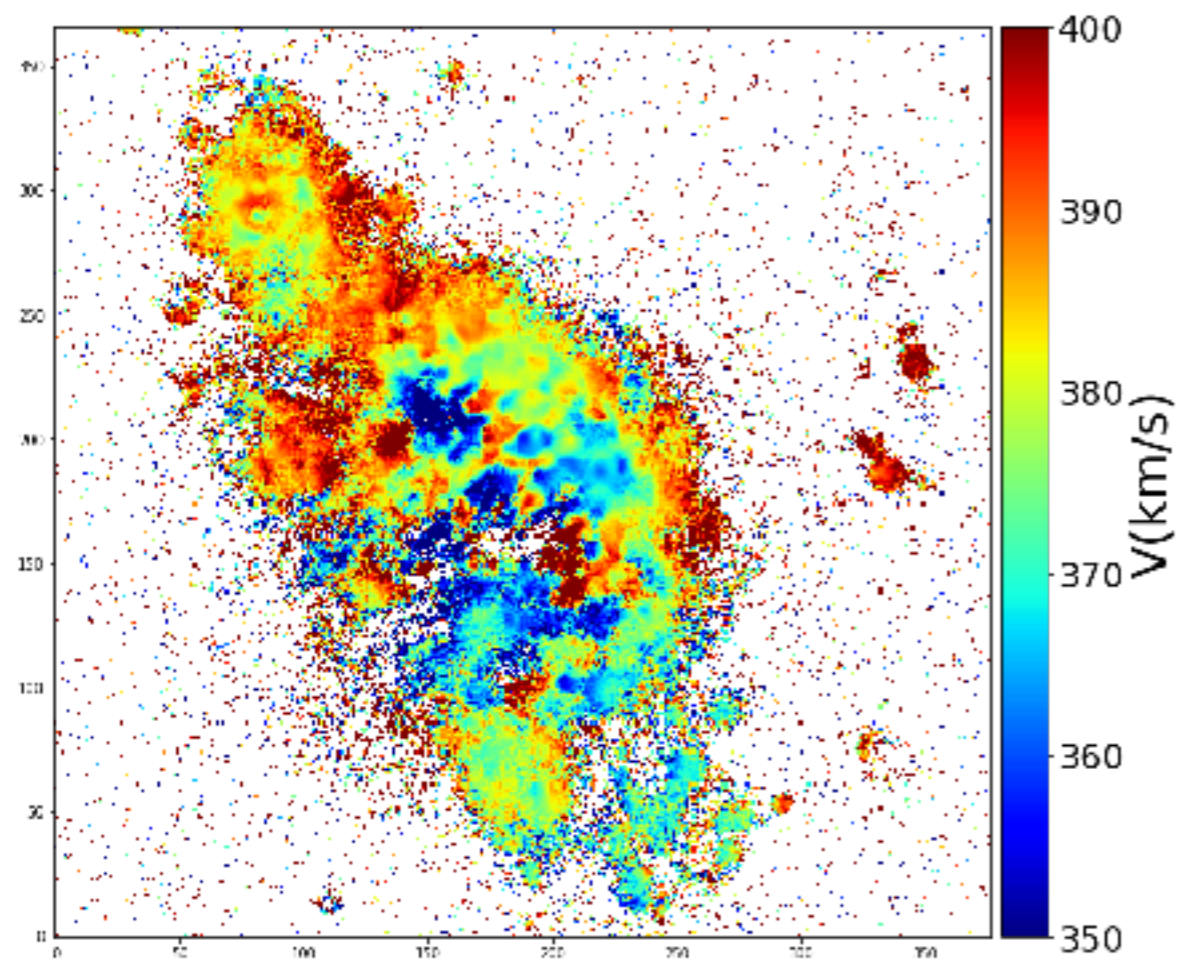
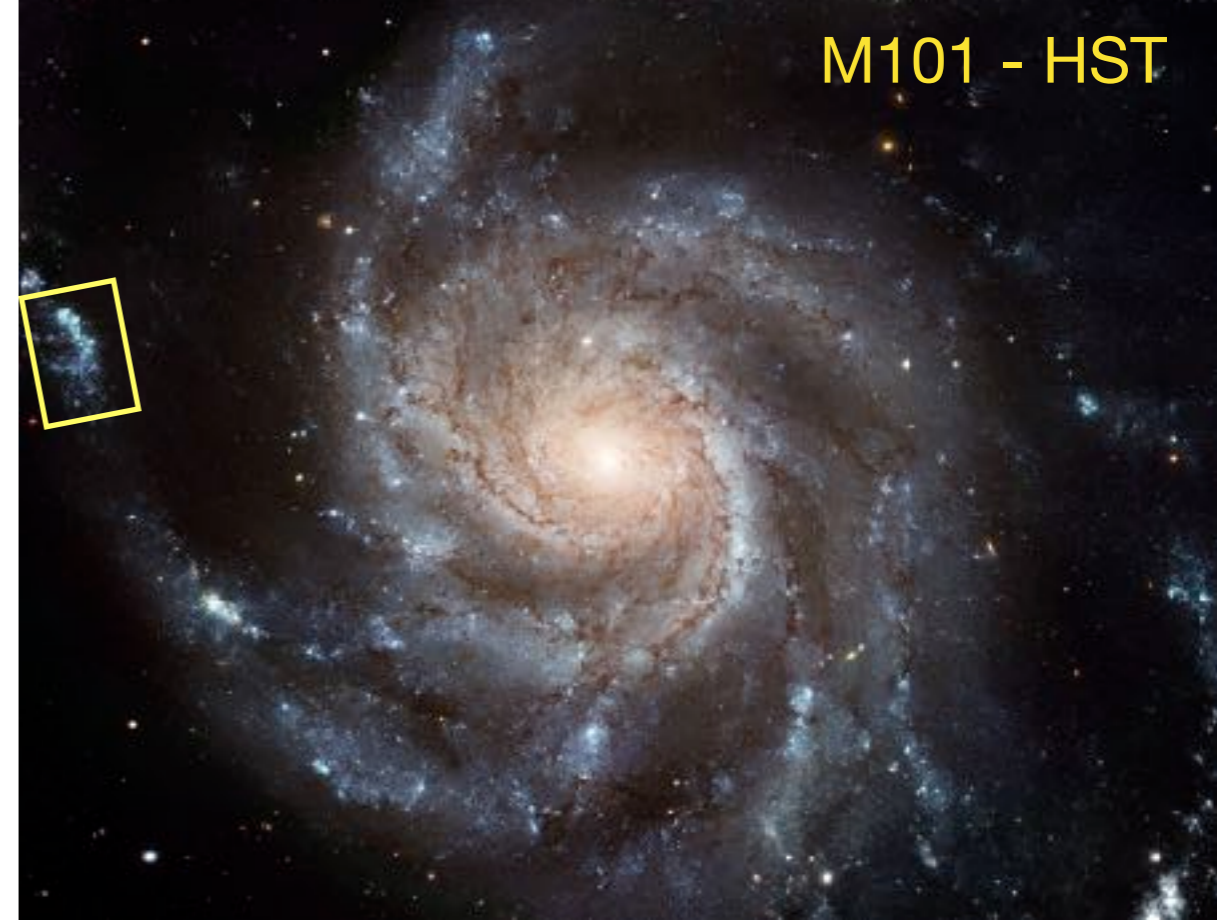
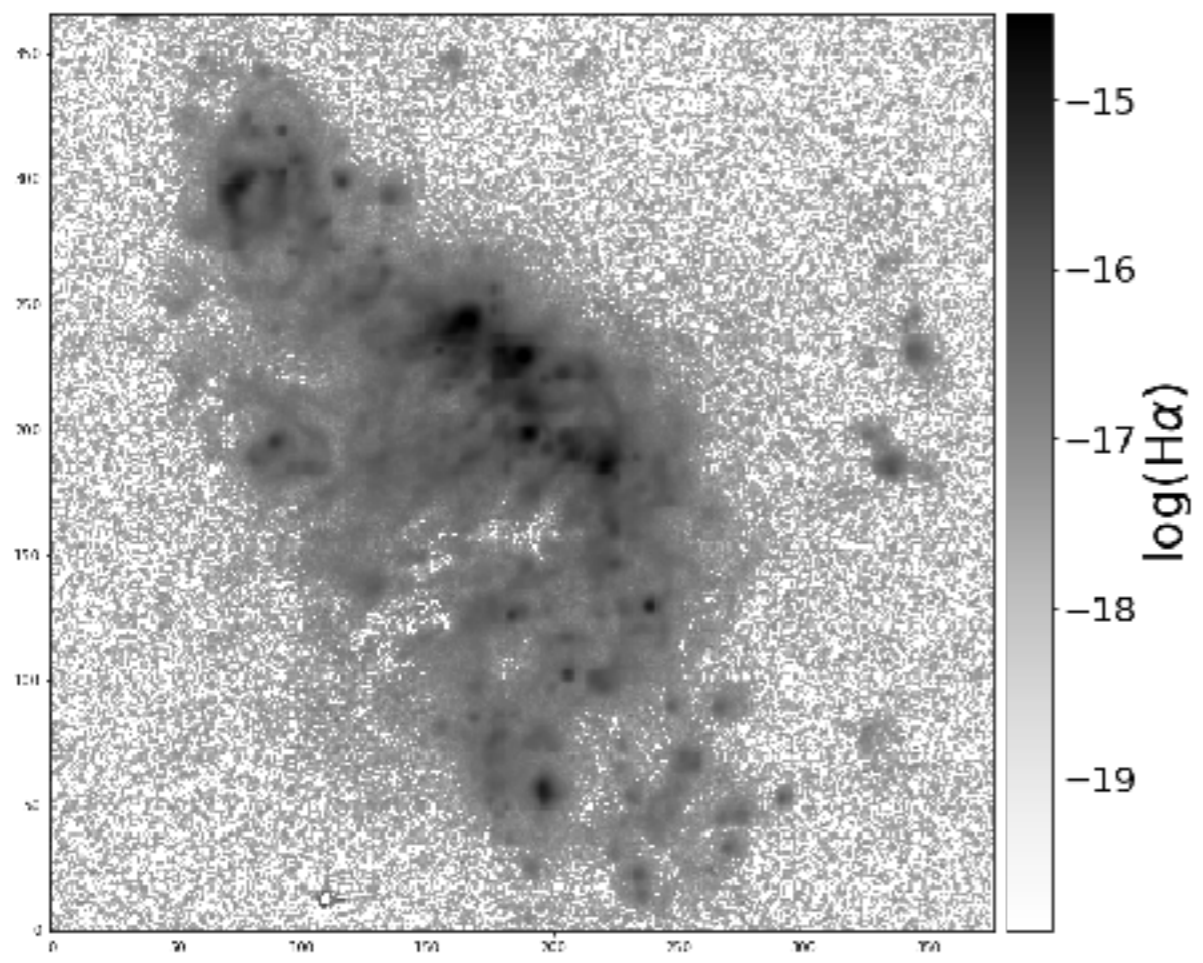
Broadening (km/s) [37.8(1.2) 37.8(1.2) 37.8(1.2) 37.8(1.2) 37.8(1.2)]

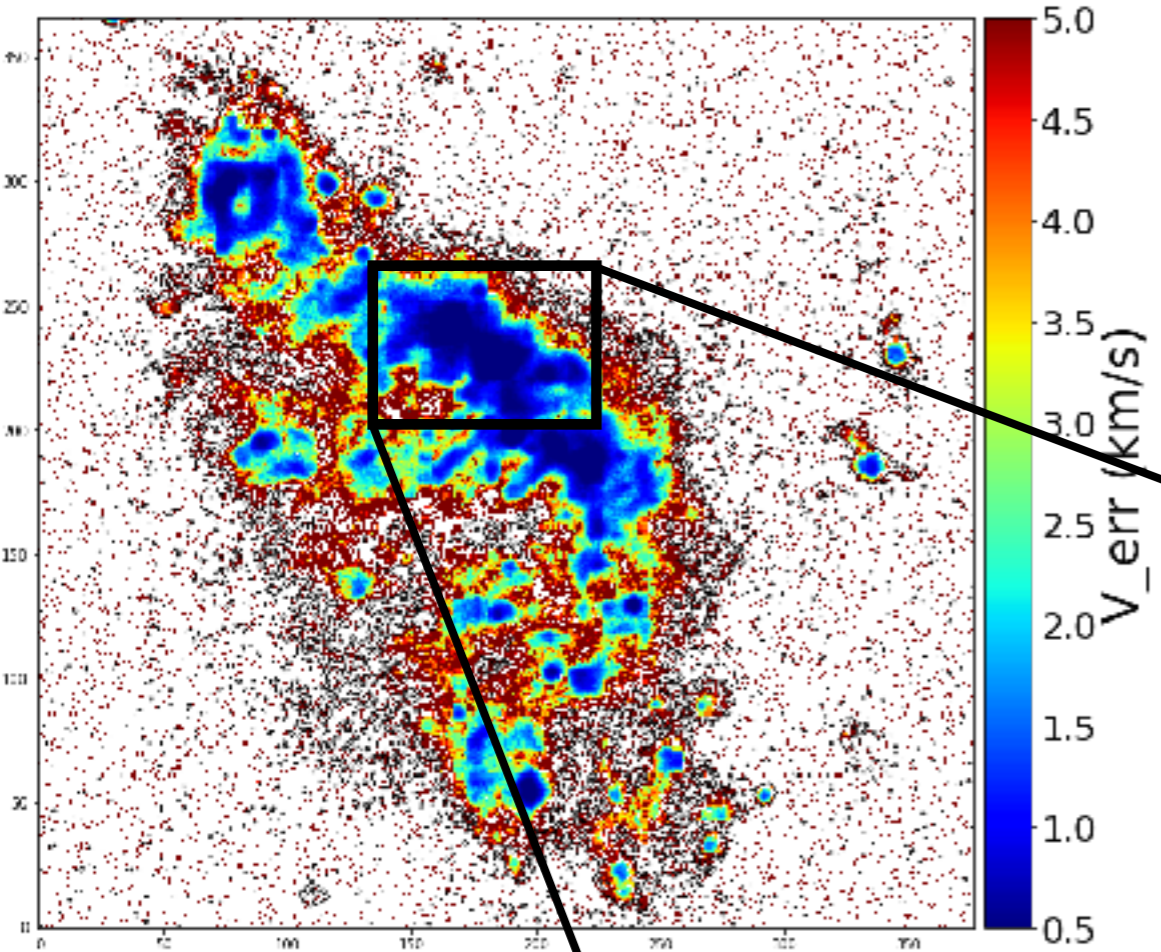
Flux: [1.387(57)e-15 9.62(49)e-16 3.30(41)e-16 6.37(45)e-16 5.33(44)e-16]

<matplotlib.legend.Legend at 0x7fd28af223d0>

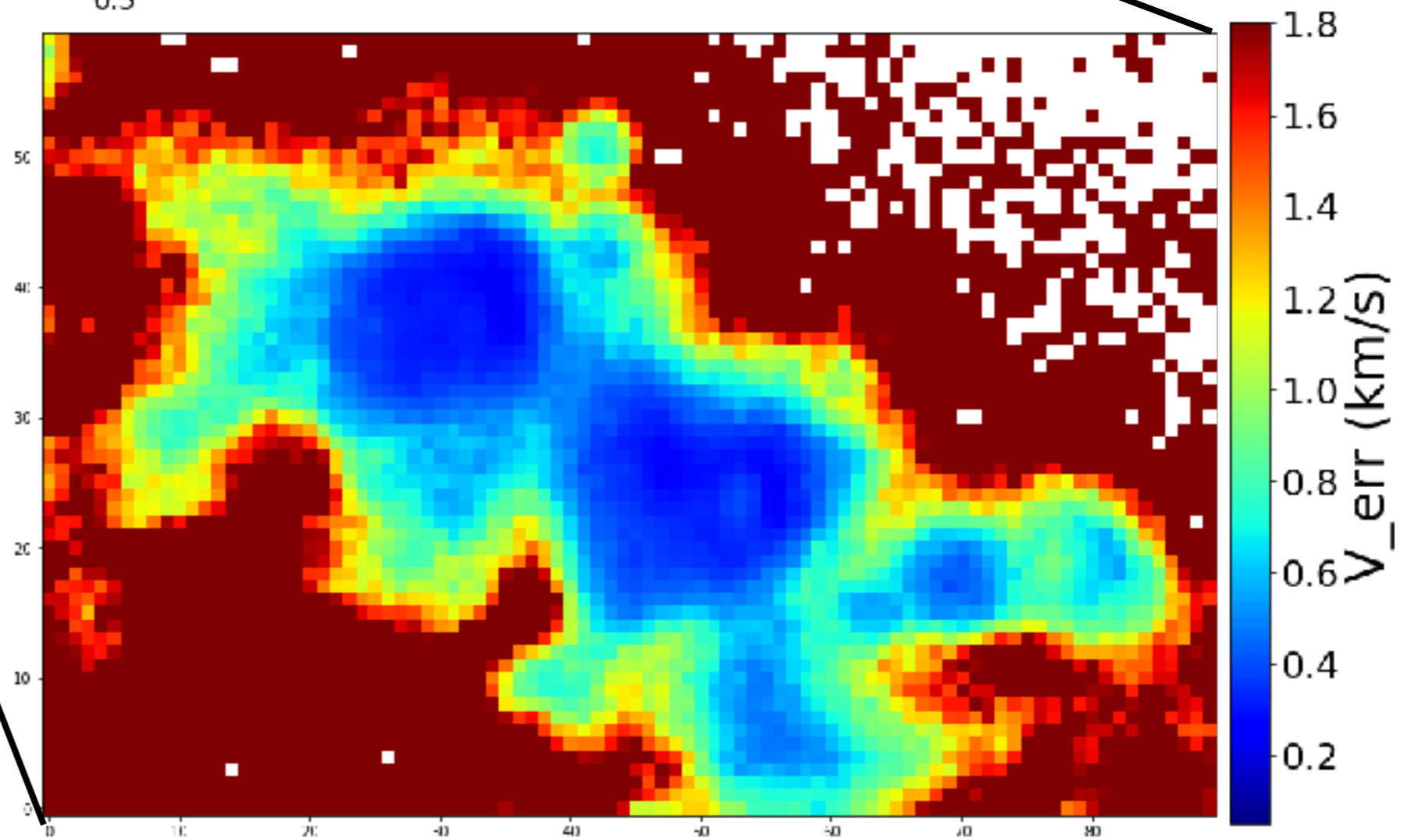


M101 - HST

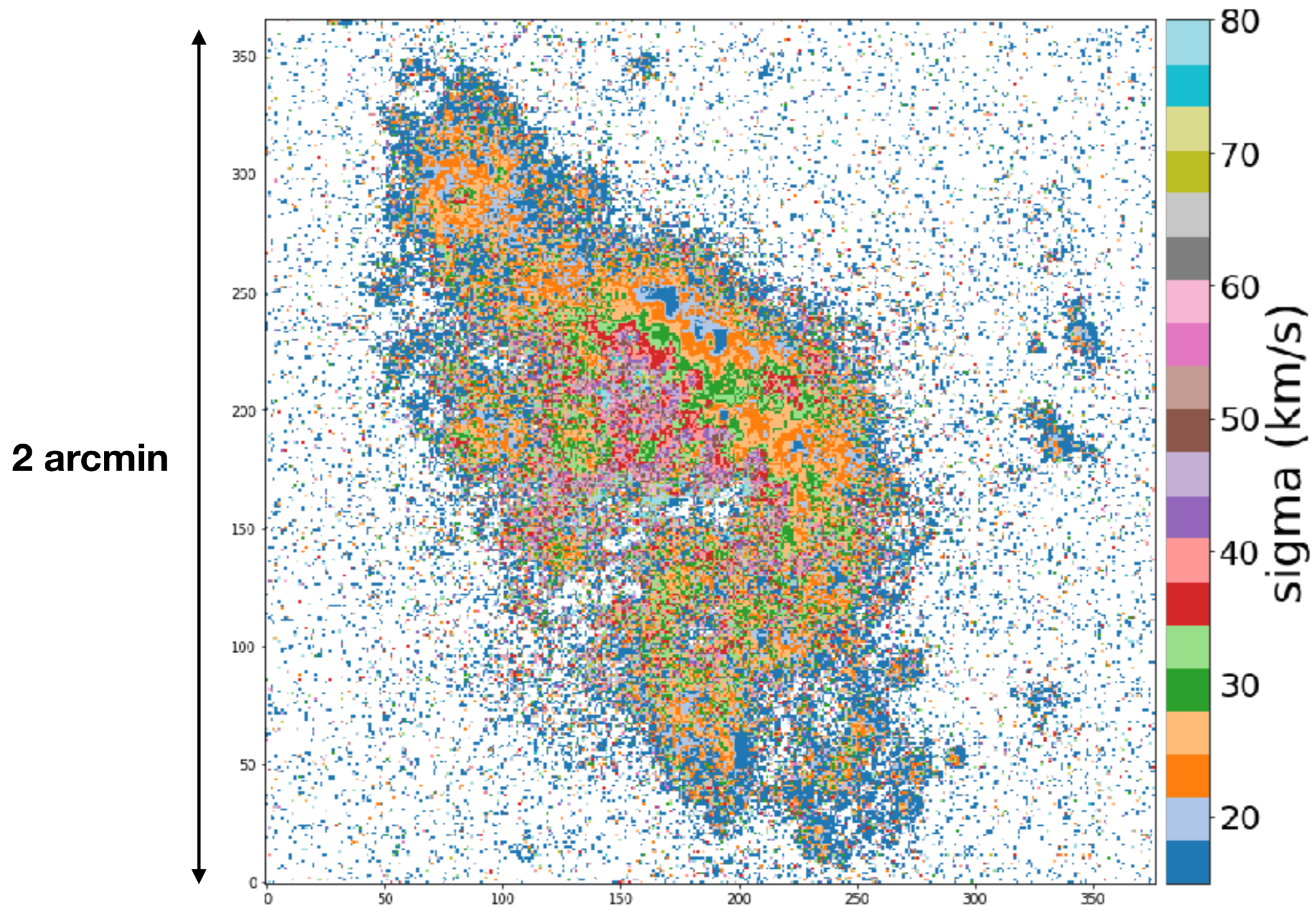




Velocity error

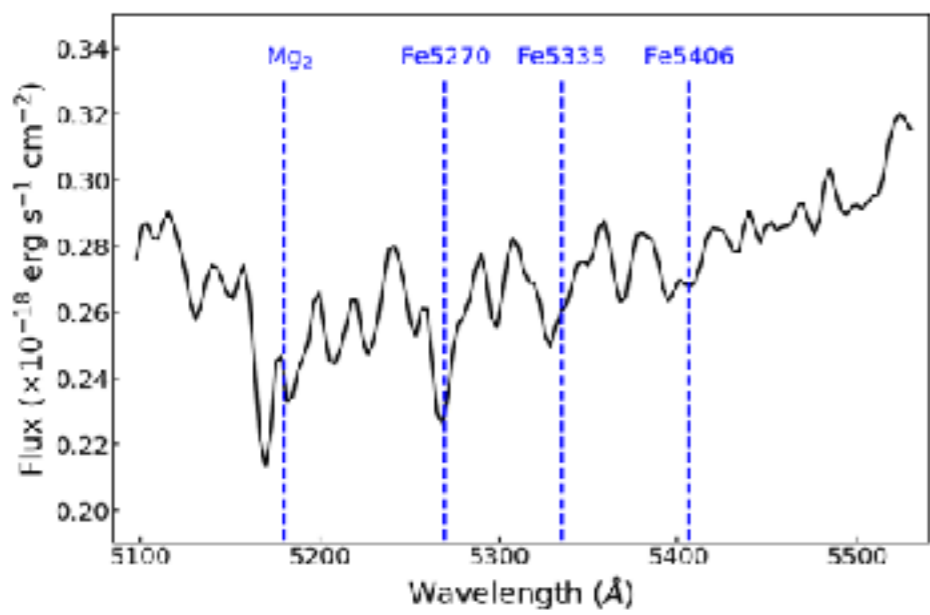
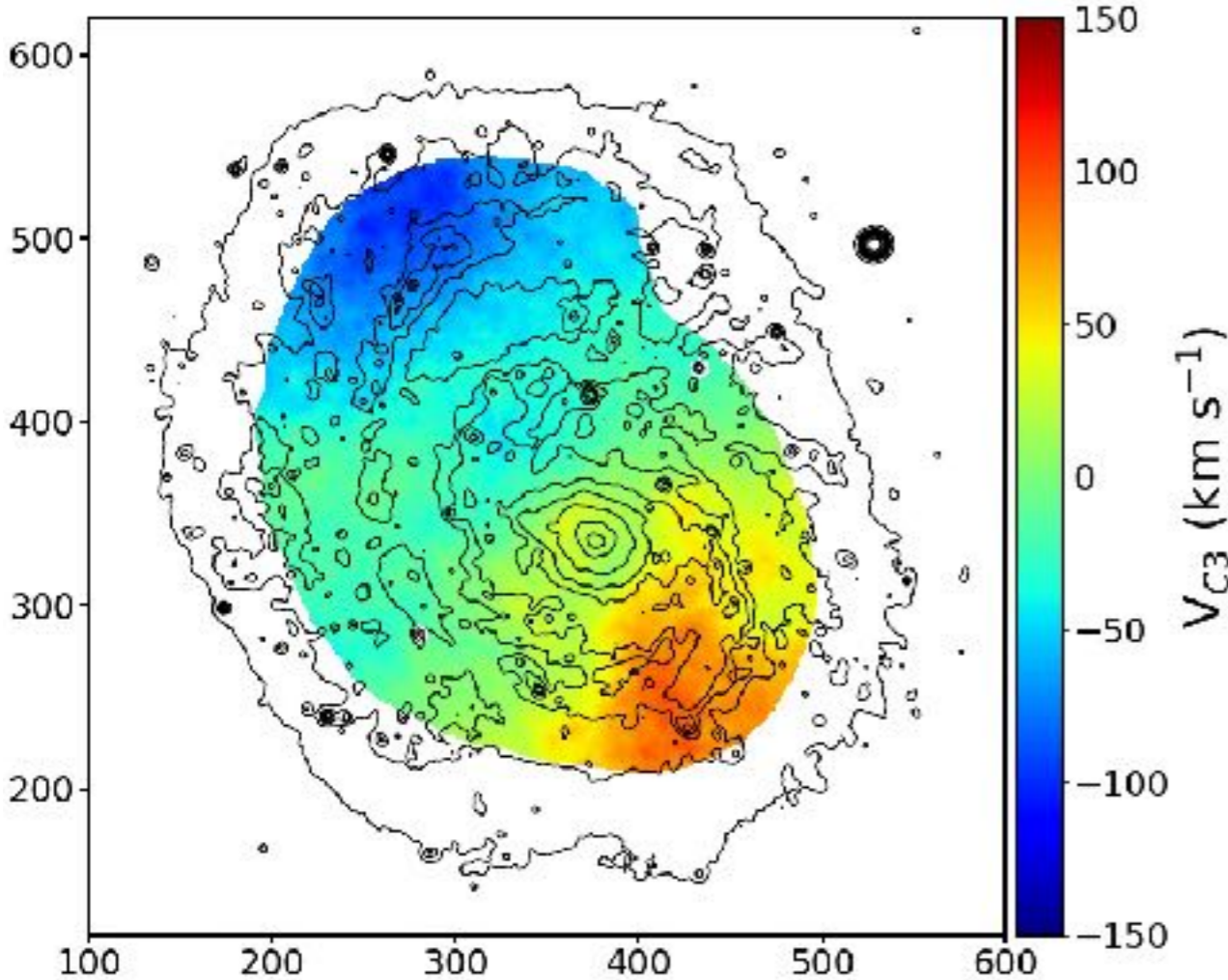


Line width





Carmelle Robert (U. Laval, Québec)



STAR-FORMING REGIONS IN NEARBY GALAXIES WITH SITELLE STELLAR BACKGROUND – ABSORPTION LINES

UNIVERSITÉ
LAVAL

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⁴Laboratoire d'Astrophysique de Marseille, France

SITELLE: 11"x11" FoV
0.32"/pixel
4 million spectra
350 to 900 nm (filters)
R = 1 to 30000

The imaging Fourier transform spectrometer SITELLE, at the Canada-France-Hawaii Telescope, is ideal to study HII regions from their emission lines, as done with the project SIGNALS¹. Nevertheless, this study requires in many cases to consider first other components on the line of sight, mainly the stellar populations within the galaxy. As shown here, SITELLE can also measure absorption lines from stellar populations.

¹Star formation, ionized gas and Neutral Abundance Legacy Survey: Large program to observe ~40 galaxies with a mean resolution of 20 pc.

NGC 4214 at 3 Mpc – Spectra from this dwarf galaxy are dominated by HII region emission, but still stellar absorption lines are noticeable.

SITELLE image from the combination of the dichroic interferograms for the 3 filters: SN1 (365-385 nm), SN2 (482-513 nm), and SN3 (647-685 nm). Vicens et al. in prep.

Fig. Top: The spectrum of the bright central HII region in NGC 4214. The SITELLE sinc instrumental profile is easy to notice (in red, a fit of the emission lines obtained with DRCS). As for all the HII regions in this galaxy, we see no signature from stars (e.g. an absorption profile beneath the H β emission line) and no [NII]. **Bottom:** The integrated spectrum of 200 pixels located North-East of the central HII region, where the galaxy continuum flux is important. It clearly shows absorption lines from the galaxy stellar populations, with some diffuse ionized gas emission.

NGC 628 at 7 Mpc – A typical SAc spiral galaxy.

SITELLE image, Rousseau-Nepton et al. 2018.

Fig. The spectrum of an HII region located near the center of NGC 628. **Top:** Before the subtraction of an average spectrum for the galaxy stellar populations. The stellar pop. spectrum was created by combining all pixels in the galaxy disk with no H α emission. A variation of the stellar pop. spectrum within the galaxy was not observed. The stellar pop. spectrum is shown in color, after being scaled to the region continuum level. **Bottom:** After the subtraction of the stellar pop. spectrum. The effect is important on H α and H β , the extinction, and the gas diagnostic emission lines ratios.

NGC 3344 at 9 Mpc – A massive spiral galaxy with an important diffuse ionized gas component.

SITELLE image, Massey et al. submitted.

Fig. The H β line for an HII region after the subtraction of 30000 stellar population spectra. While the technique used to subtract the stellar pop. in NGC 628 may not truly take into account the presence of the young stellar pop. ionizing each HII region, it is still useful. Considering that: 1) We scale the average stellar pop. to the continuum level of the region, therefore we partially include more than just the old stellar pop.; 2) Tests for the subtraction of stellar pop. spectra from 30000 revealed that the exact proportion of the young and old population spectra has a negligible effect on the emission lines; for example, it affects B(V) by less than 0.1 dex; and 3) The true picture is rather complex considering the relative distribution of the populations, gas, and dust.

NGC 3344 at 9 Mpc – The global background (80) spectra from pixels in rings with different galactocentric radii (GC0). The ring widths are selected for S/N_{GC0} = 25. About 3000 emission regions (HII regions and supernovae remnants) have been masked before the selection of the 80 pixels. Absorption lines from the stellar populations do not show up at all because of an important diffuse ionized gas component.

Fig. The H α /H β emission lines ratio of supernovae remnant candidates in NGC 3344. **Right:** Before the 80 subtraction. **Left:** After the global (red) and local (blue) 80 subtraction. The local 80 is the sum of pixels surrounding the individual candidates. The scatter in the plots is explained by the complex distribution of the diffuse ionized gas. The subtraction of the 80 remains important in order to study the extinction and the gas emission lines.

NGC 1637 at 11 Mpc – C3 filter.

SITELLE C3 (510-553 nm) image. Maza⁴ et al. in prep.

Fig. The SITELLE C3 filter was tested with NGC 1637 (R=1800 2.8"). Shown here is a spectrum (after blurring to reach S/N=25) in the galaxy disk with its fit (in red) from PPAE using Milnes stellar population templates, to derive the velocity parameters. These data will also be useful to isolate the stellar pop. in order to obtain better constraints for the HII regions and to describe the galaxy evolution and the origin of its asymmetry.

NGC 7479 at 30 Mpc – Lots of absorption along the bar!

SITELLE image, Svard et al. in prep.

Fig. Top: The spectrum of 30 pixels in the bar near the galaxy center: the stellar populations signature is responsible for a broad H β absorption. **Bottom right:** The H β absorption line map (the emission component has not been removed yet).

Fig. The velocity map and rotation curve based on the C3 filter absorption lines. Pixels at the light center (in red in the rotation curve and galaxy image) are clearly out of the dynamical center (yellow +).

Fig. Spectrum of an HII region in the galaxy bar: no [OIII]!



Kinematic Modeling of HighMass Galaxies

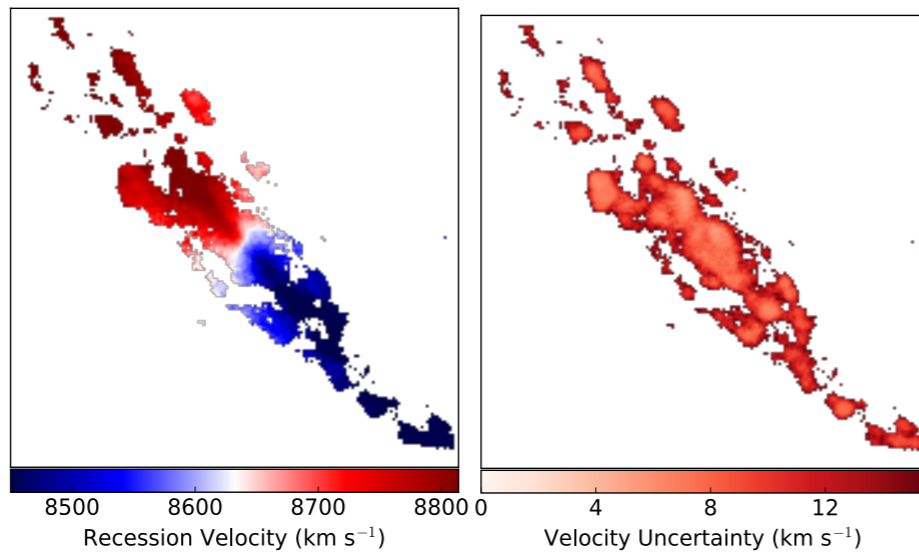
Dhruv Bisaria (Queen's University, Kingston, Canada)

We investigate the late accretion hypothesis as an explanation for the unusual gas-richness of the HighMass sample, which contains 34 galaxies with masses of at least 10^{10} solar masses, but large atomic gas fractions ($0.24 < GF < 9.2$). 20/34 have GF greater than unity.

Accretion is vital to galaxy evolution and could explain the H I abundance within these galaxies (the other, non-mutually excluding, hypothesis being inefficient star formation). We obtained velocity fields for three galaxies with SITELLE for the Master's thesis and on another, UGC 9334, in April 2019.

We then analyzed the velocity fields with DiskFit by applying rotation-only, bisymmetric (bar-like), and radial flow models. UGC 7899 was found to most likely exhibit bar-like flows, which is what is reported here. This work further constrained the kinematics of these galaxies

SITELLE
Velocity
Maps

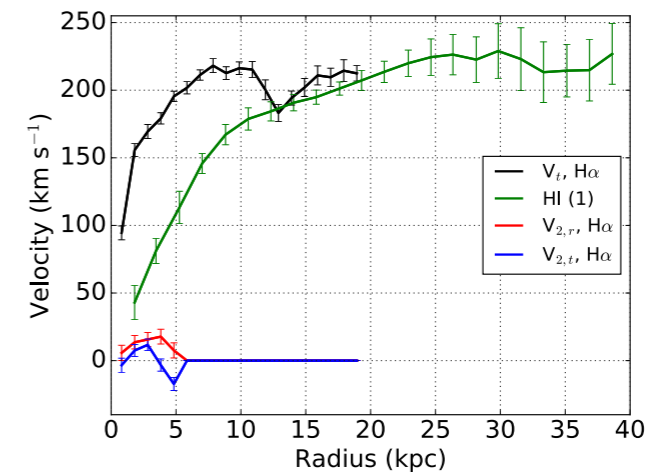
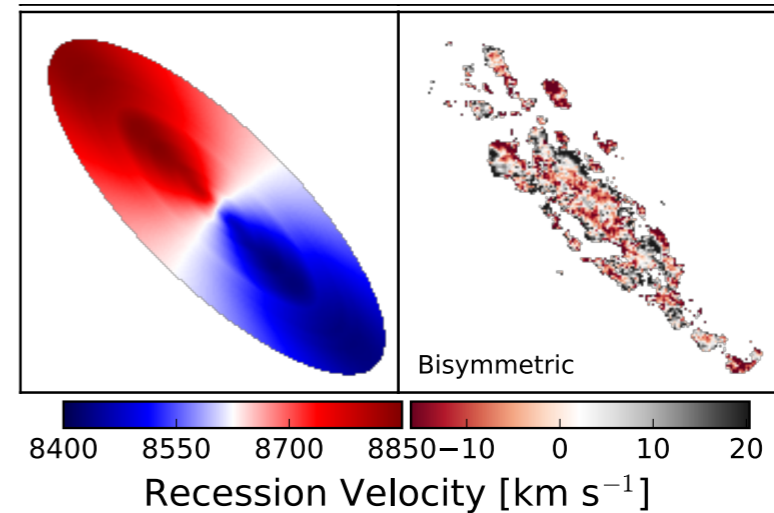


UGC 7899

+



(KS+Sellwood 07
Sellwood+KS 15)



Rotation
Curves

+ fitted position angle, inclination,
center, bar position angle, etc

Other galaxies in this work: UGC 8475, UGC 9037, UGC 9334



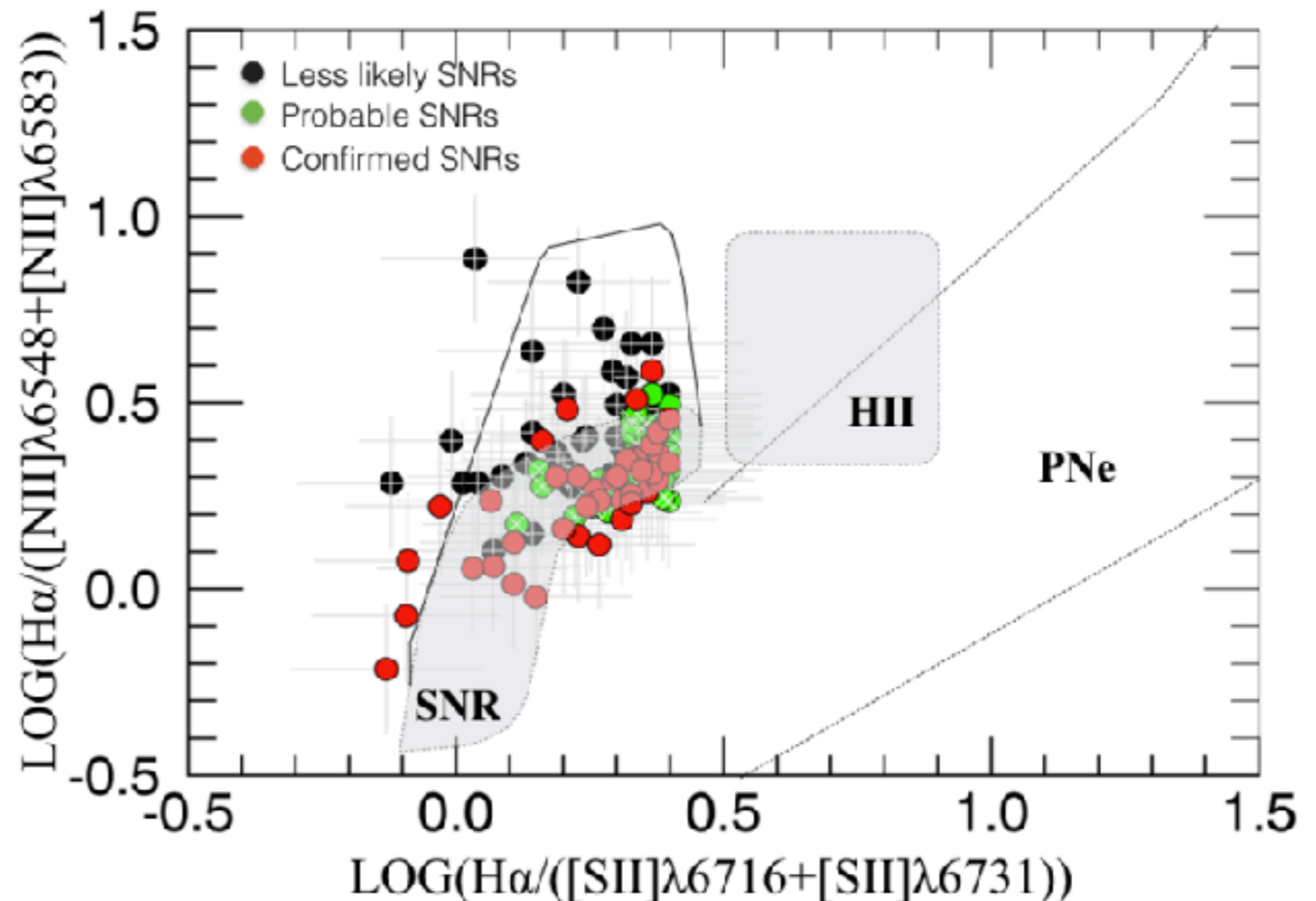
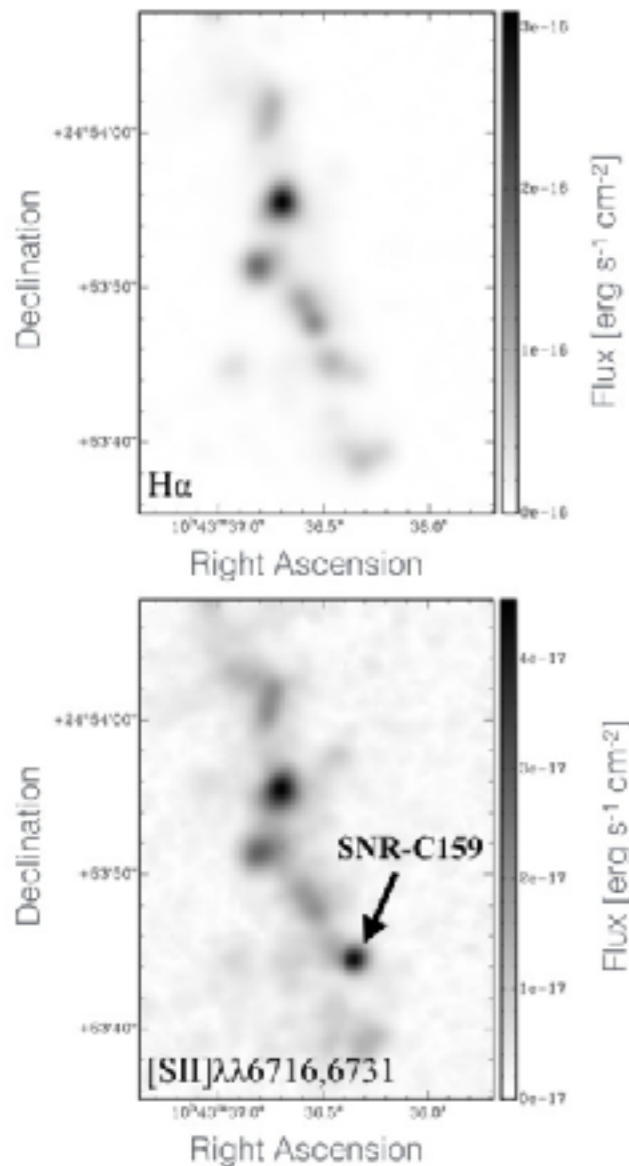
3D Optical Spectroscopic Study of NGC 3344 with SITELLE: I. Identification and Confirmation of Supernova Remnants

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Searching for intergalactic star forming regions in Stephan's Quintet with SITELLE. I. Ionised gas structures and kinematics

S. Duarte Puertas¹, J. Iglesias-Páramo^{1,2}, J. M. Vilchez¹, L. Drissen^{3,4}, C. Kehrig¹, and T. Martín^{3,4}

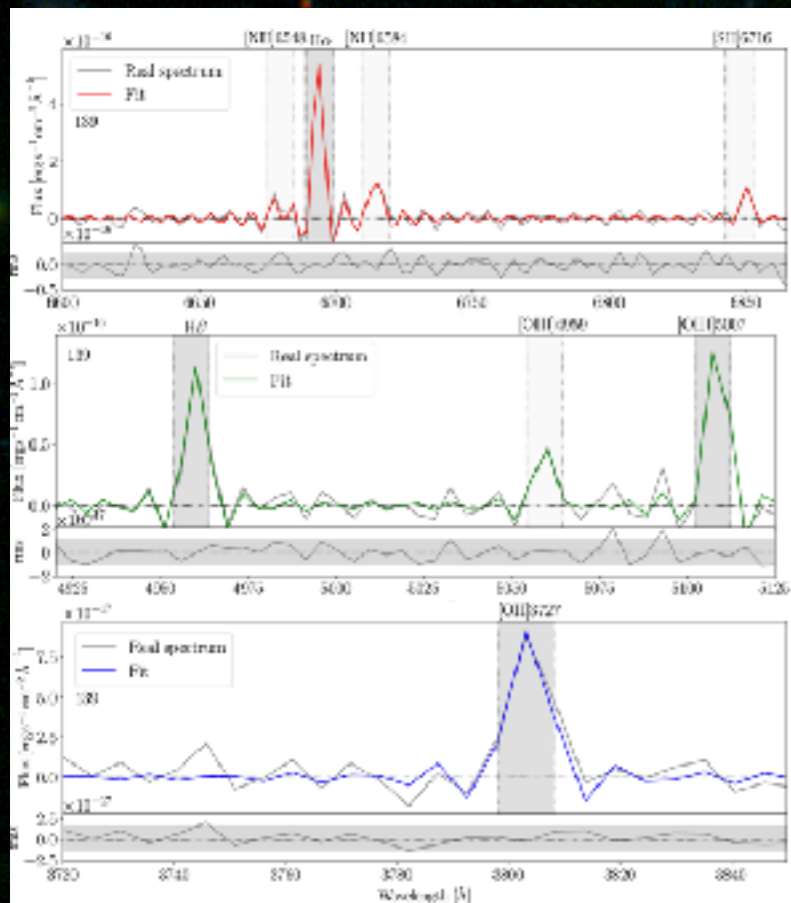
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e-mail: selvini@iaa.es

² Estación Experimental de Zonas Áridas - CSIC, Ctra. de Sacramento s.n., La Cañada, Almería, Spain

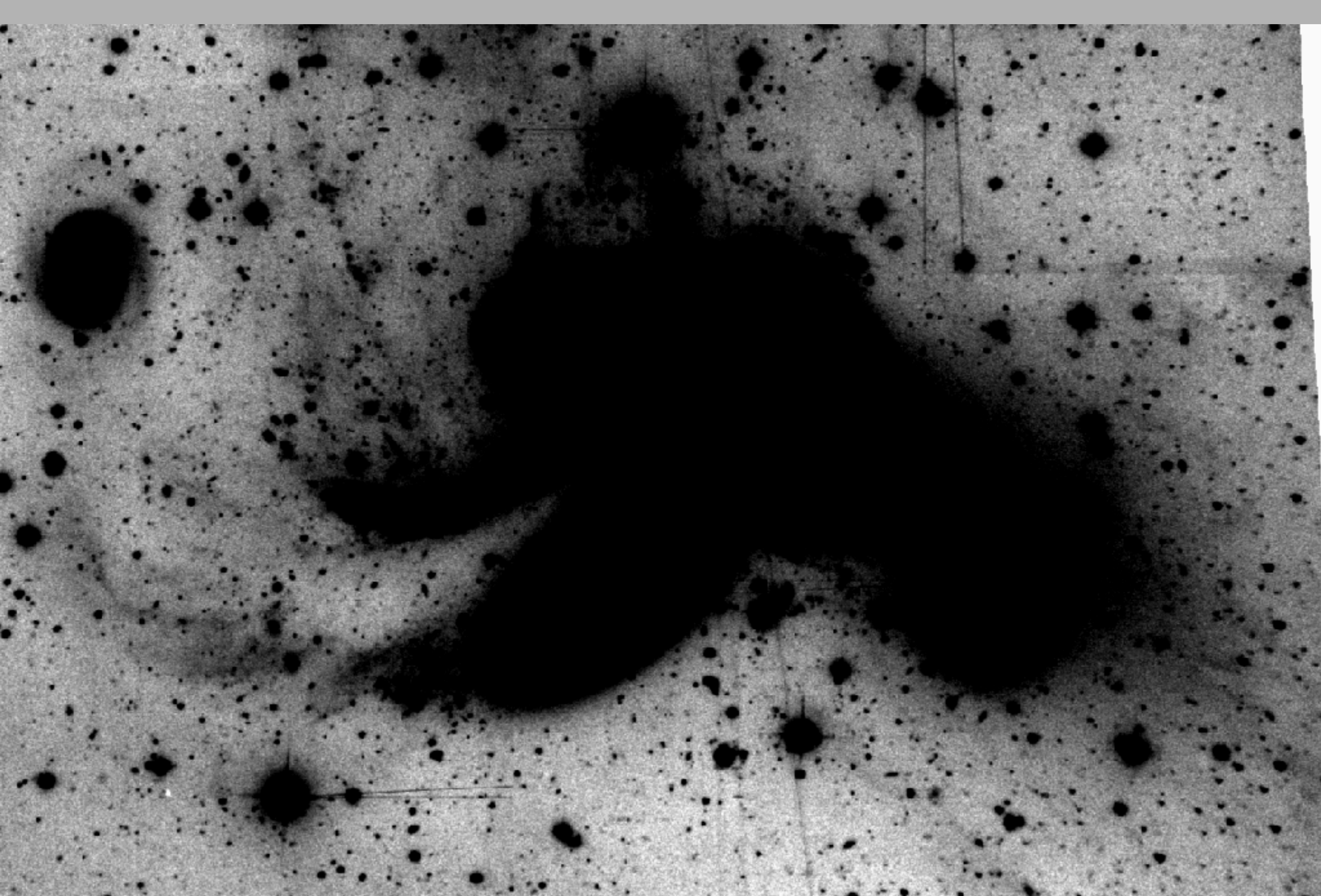
³ Département de physique, de génie physique et d'optique, Université Laval, Québec (QC), G1V 0A6, Canada

⁴ Centre de recherche en astrophysique du Québec

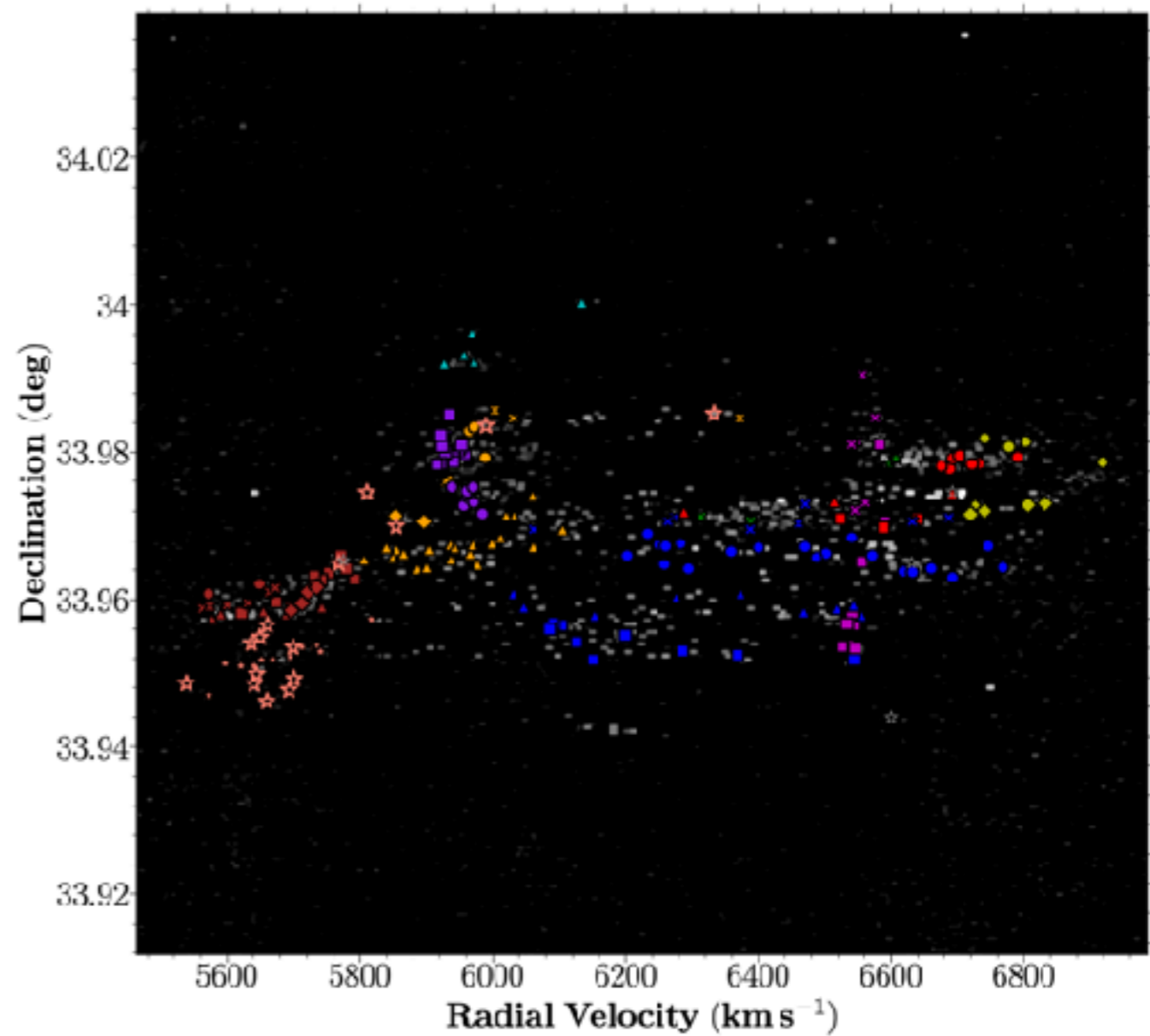
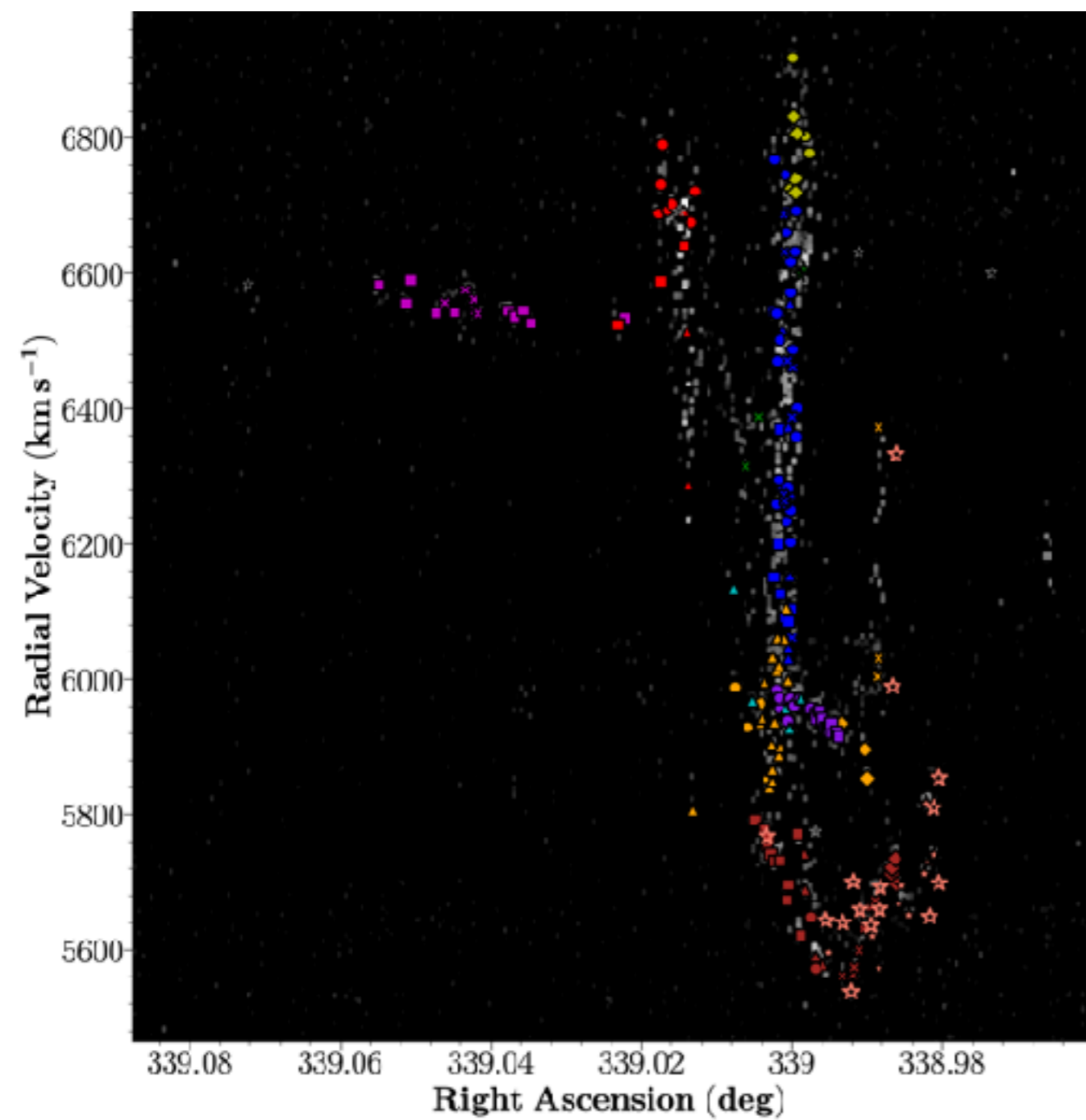
Received April 12, 2019; accepted April 12, 2019

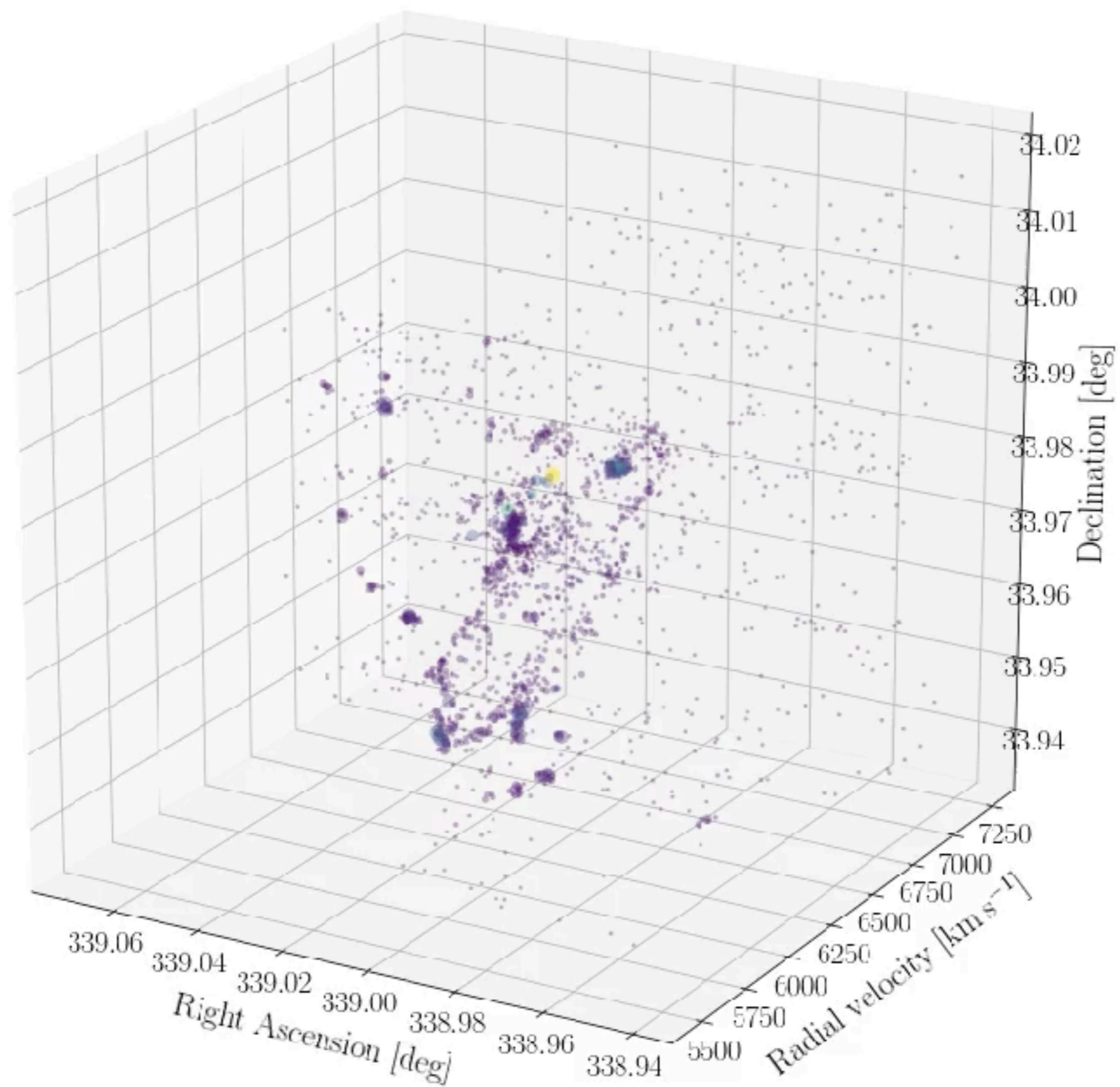


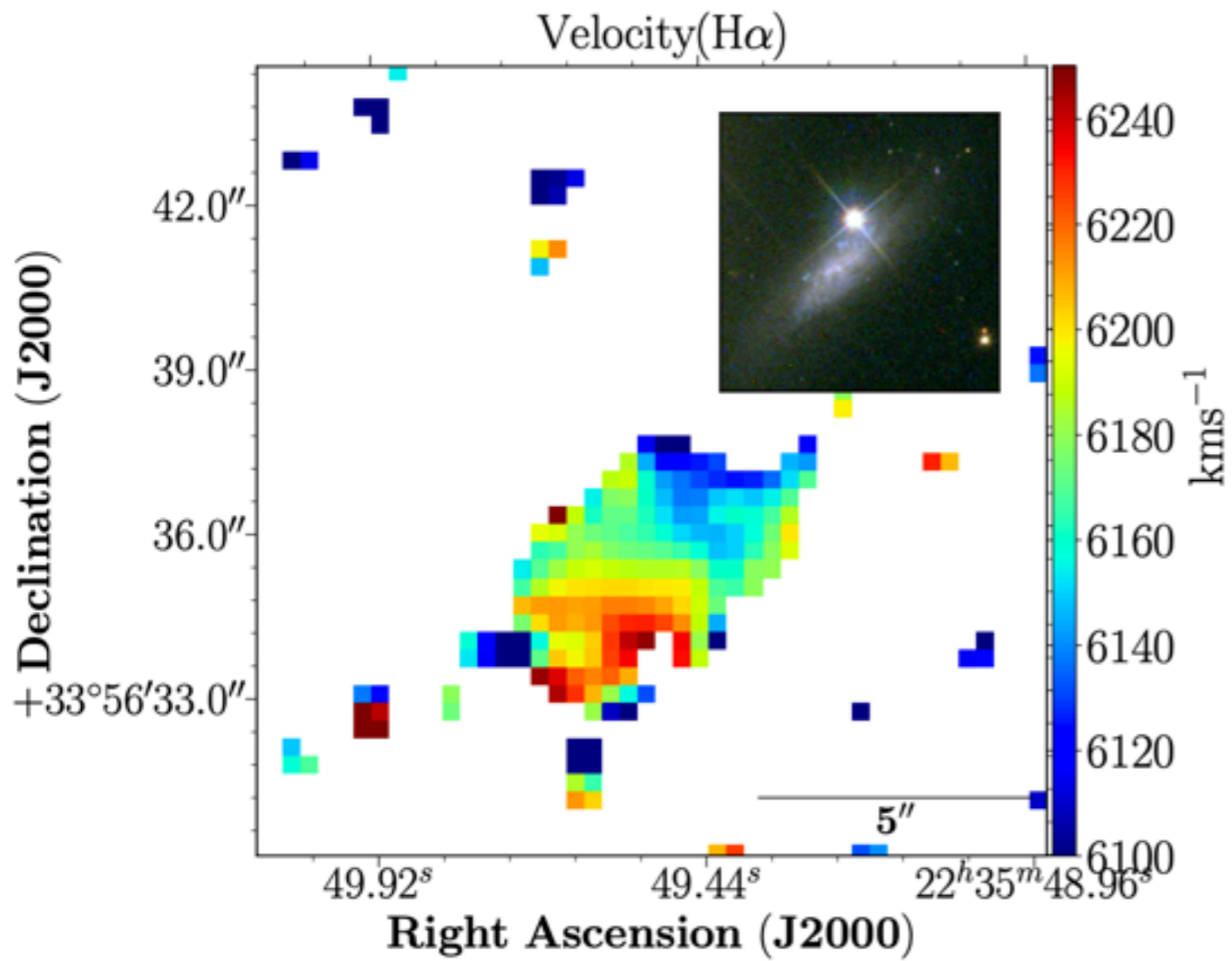
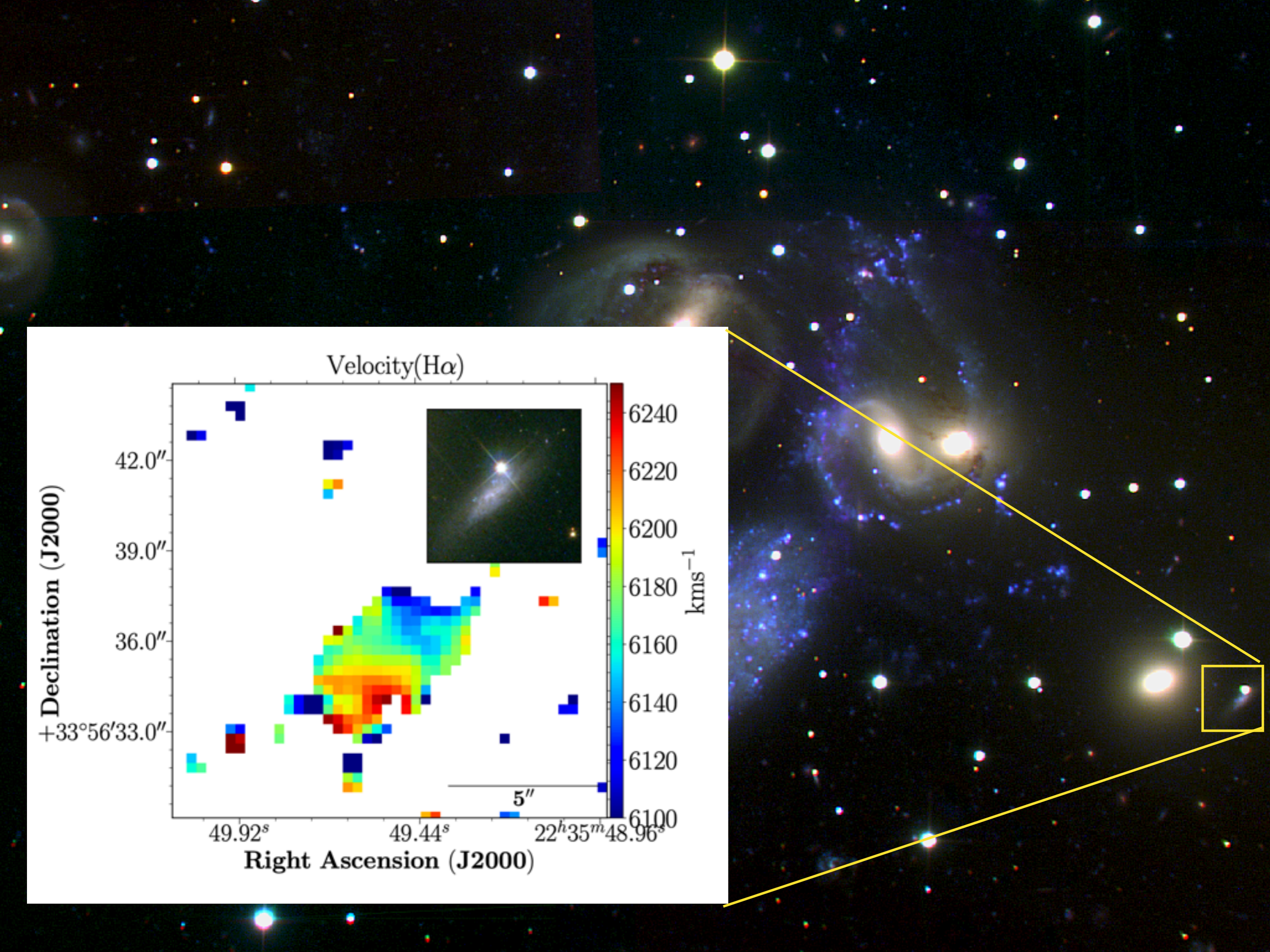
SITELLE Deep (SN1, SN2, SN3: 370 /490/660 nm)



Deep image (Sum of all interferograms), SN2 filter (480 m)

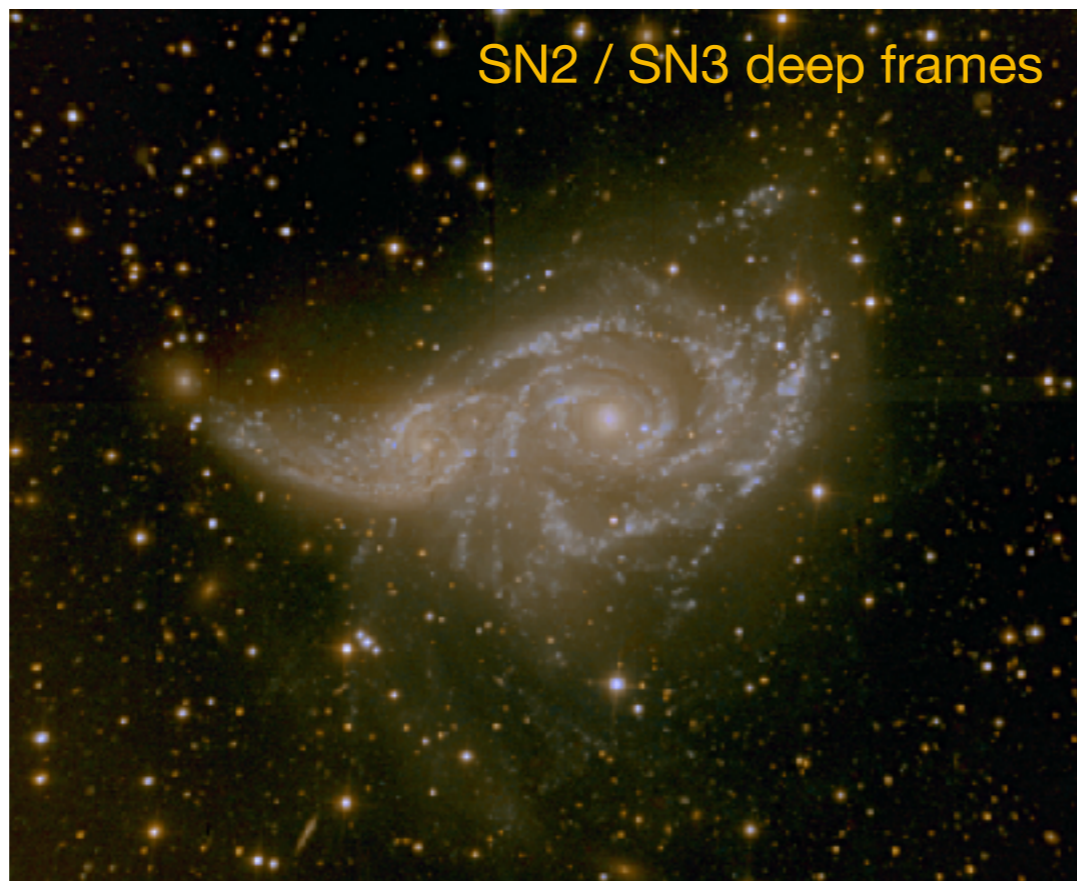




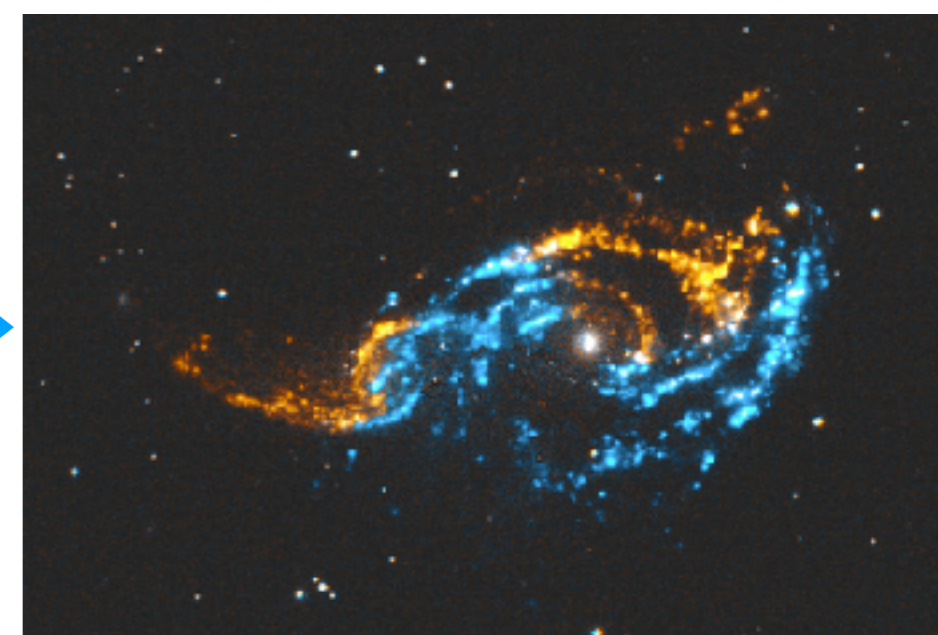
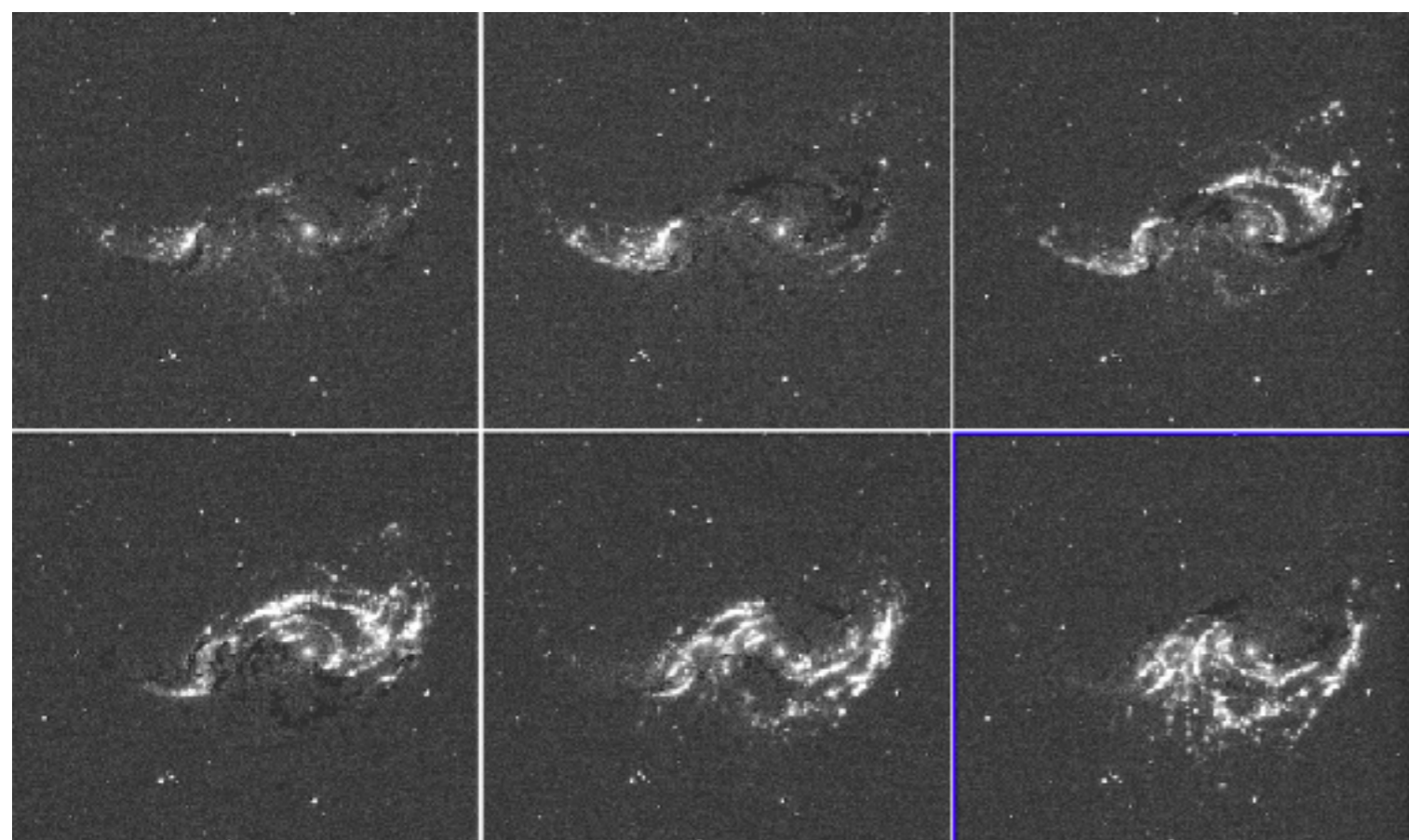
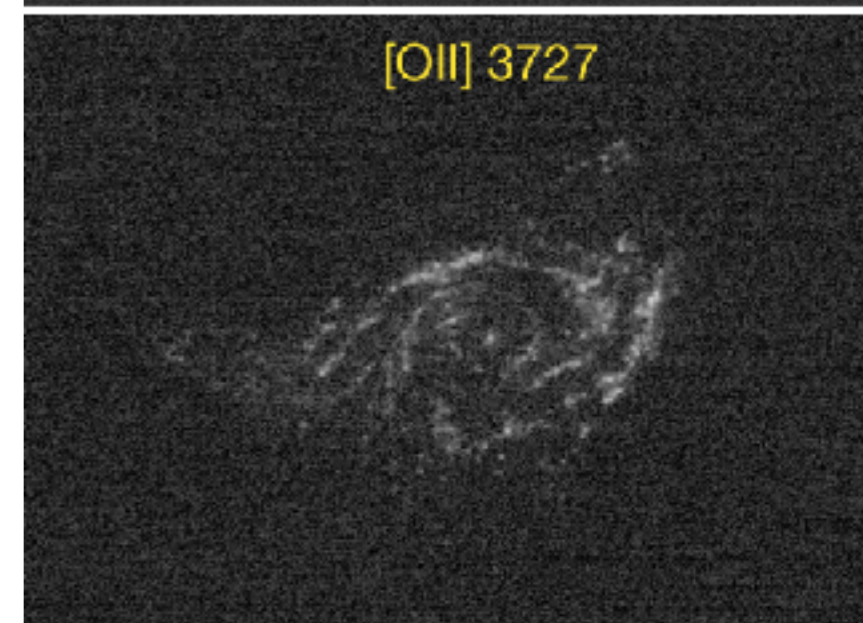
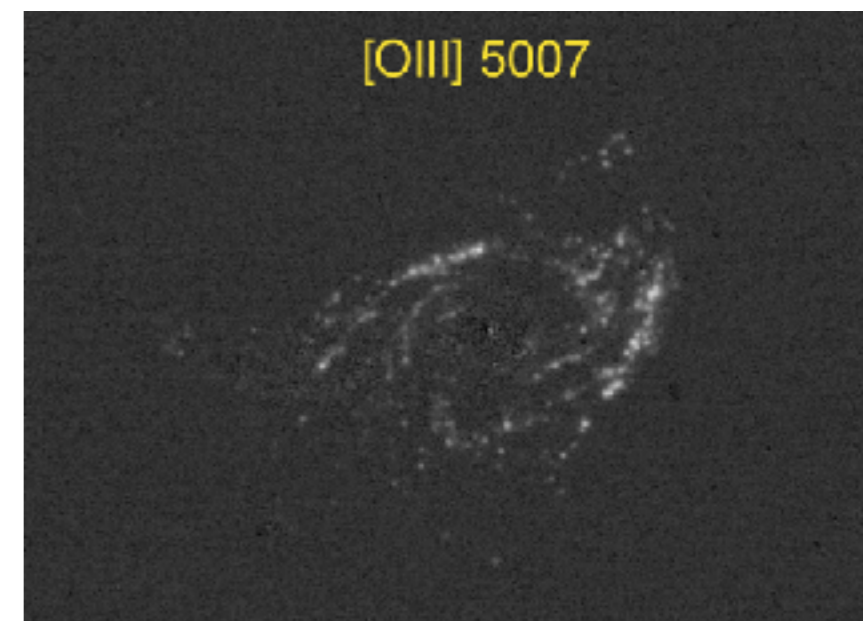




SN2 / SN3 deep frames



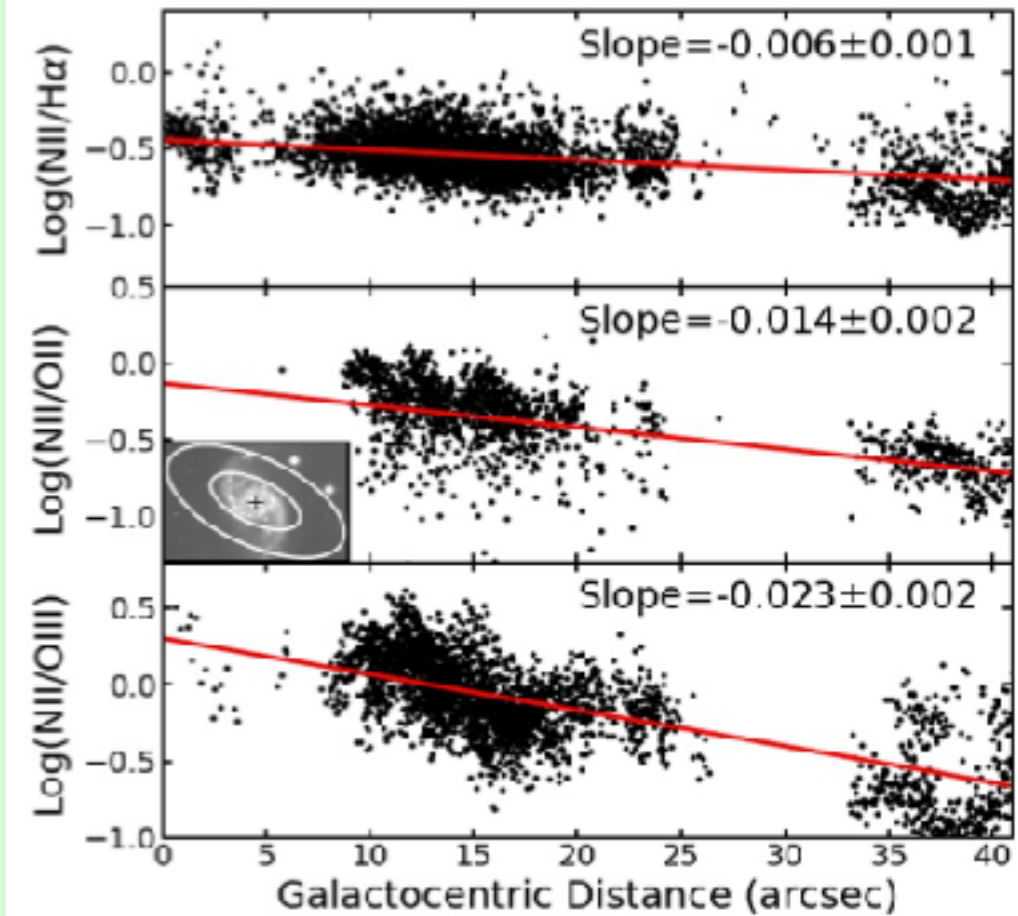
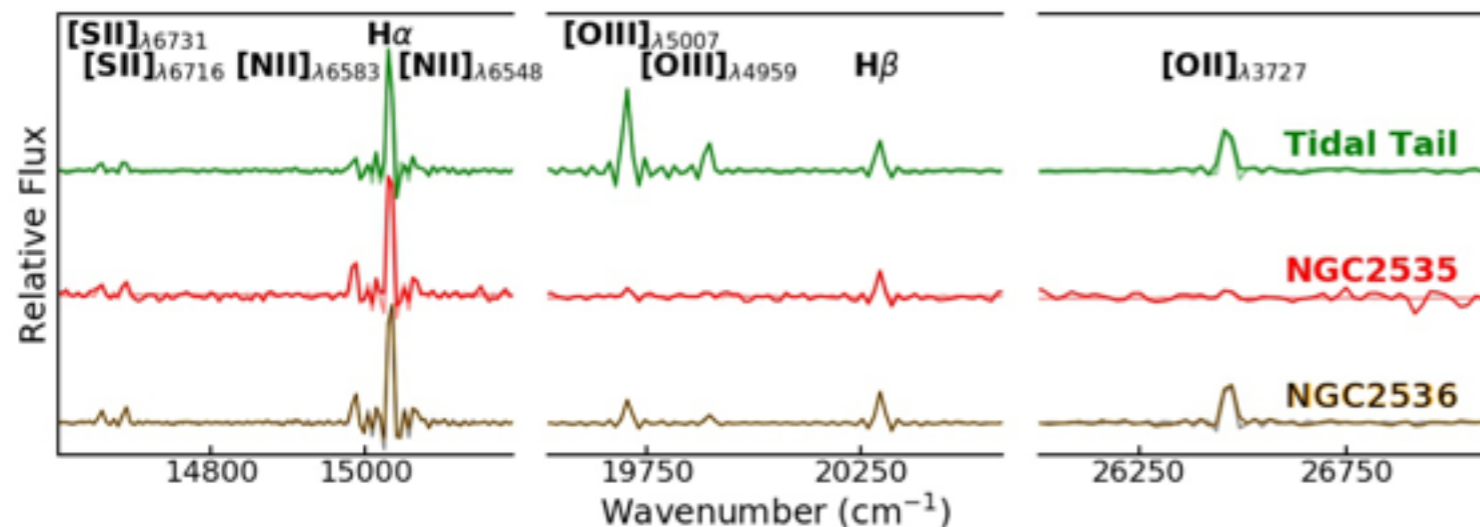
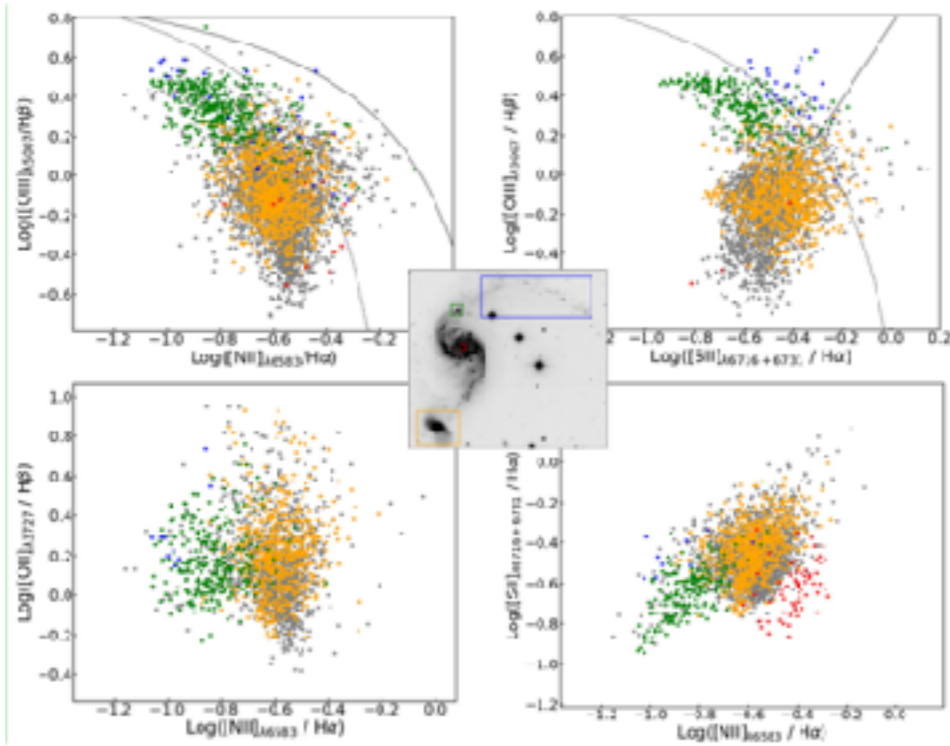
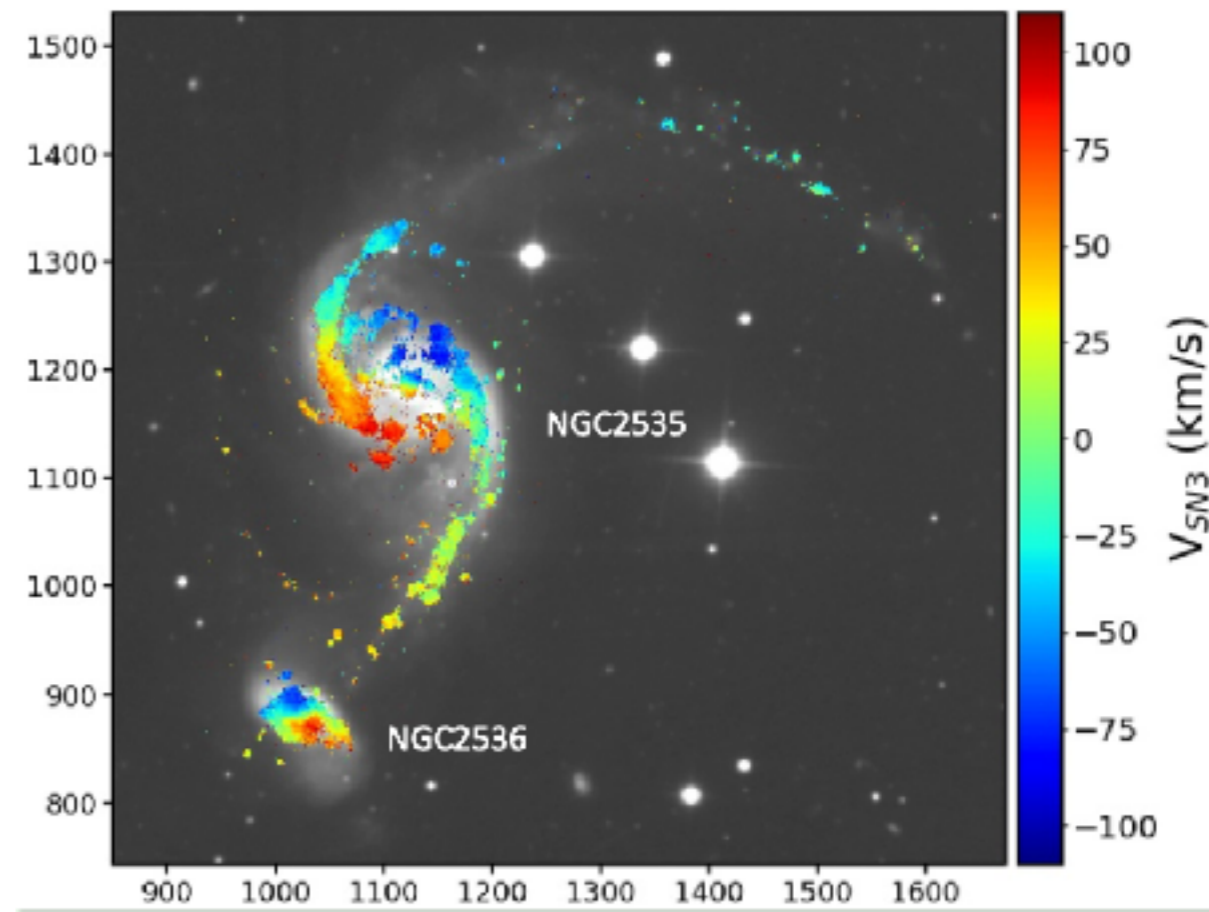
NGC 2207 / IC 2163



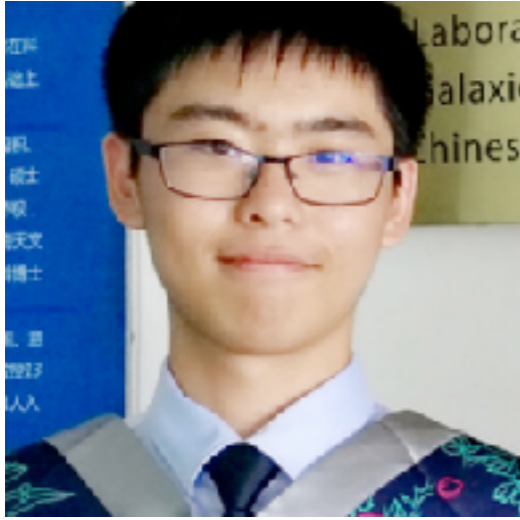


Interacting galaxies - Arp 82

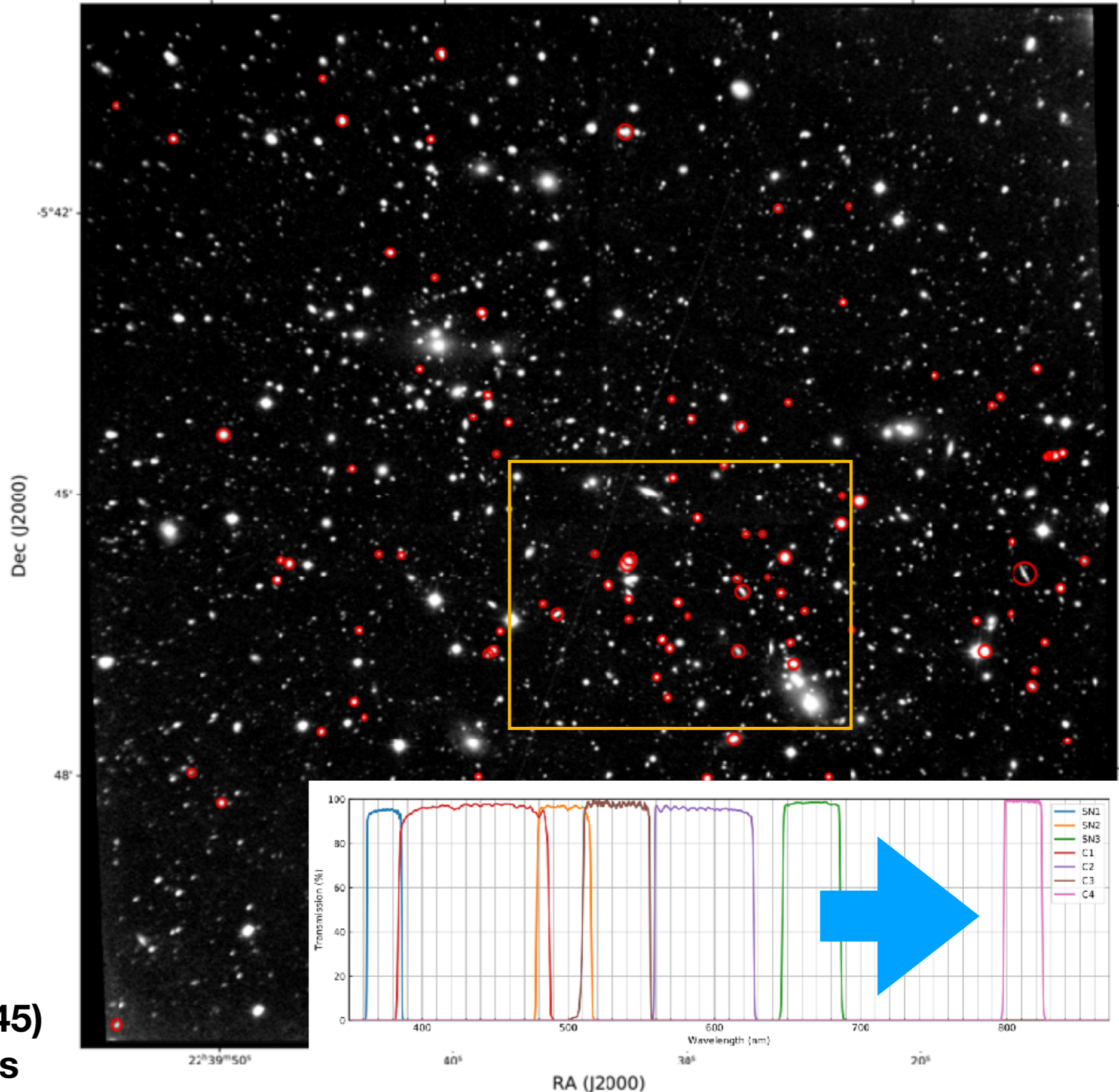
Prime Karera
(U. Laval)



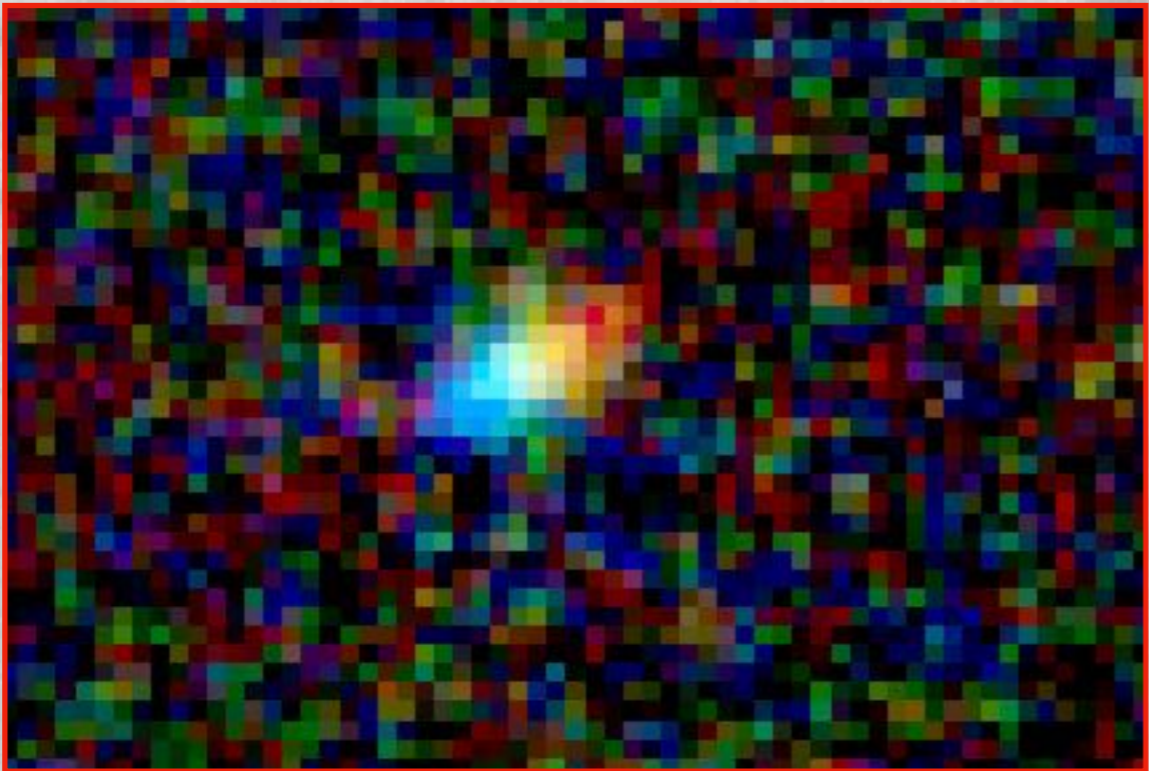
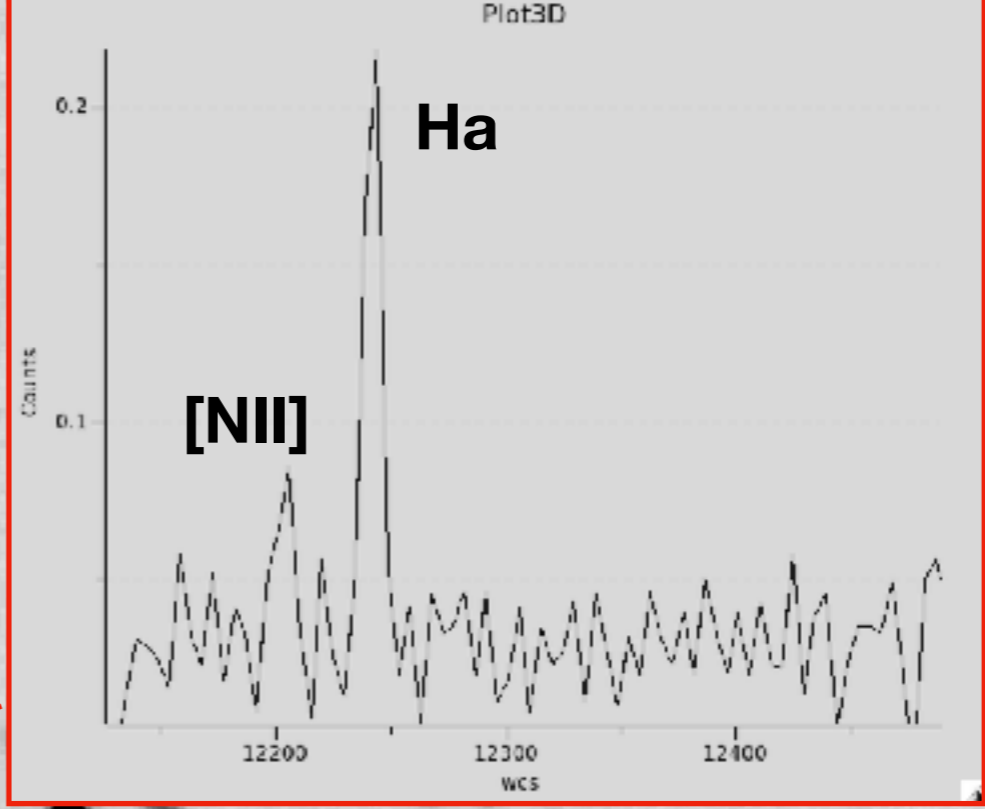
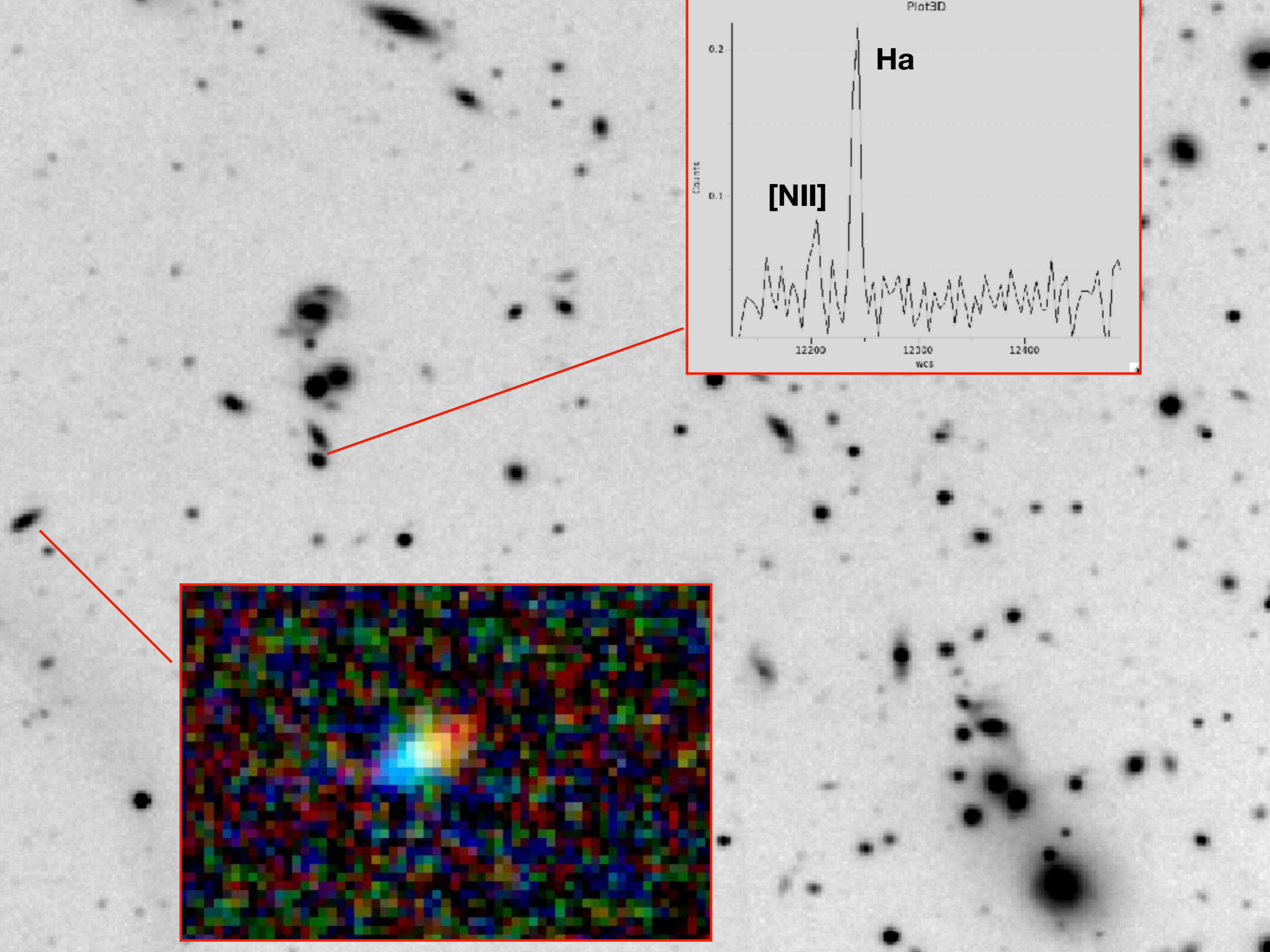
Qing Liu, Howard Yee, et al.
(U. of Toronto)



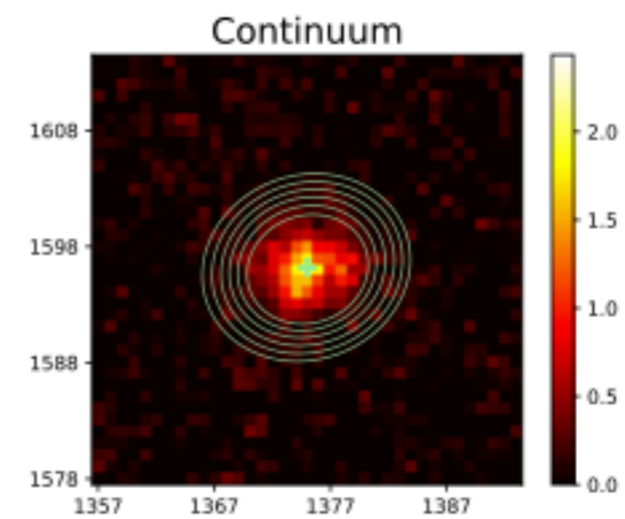
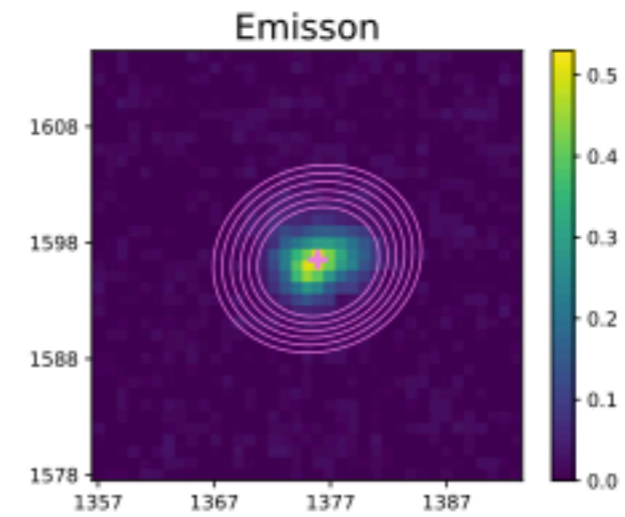
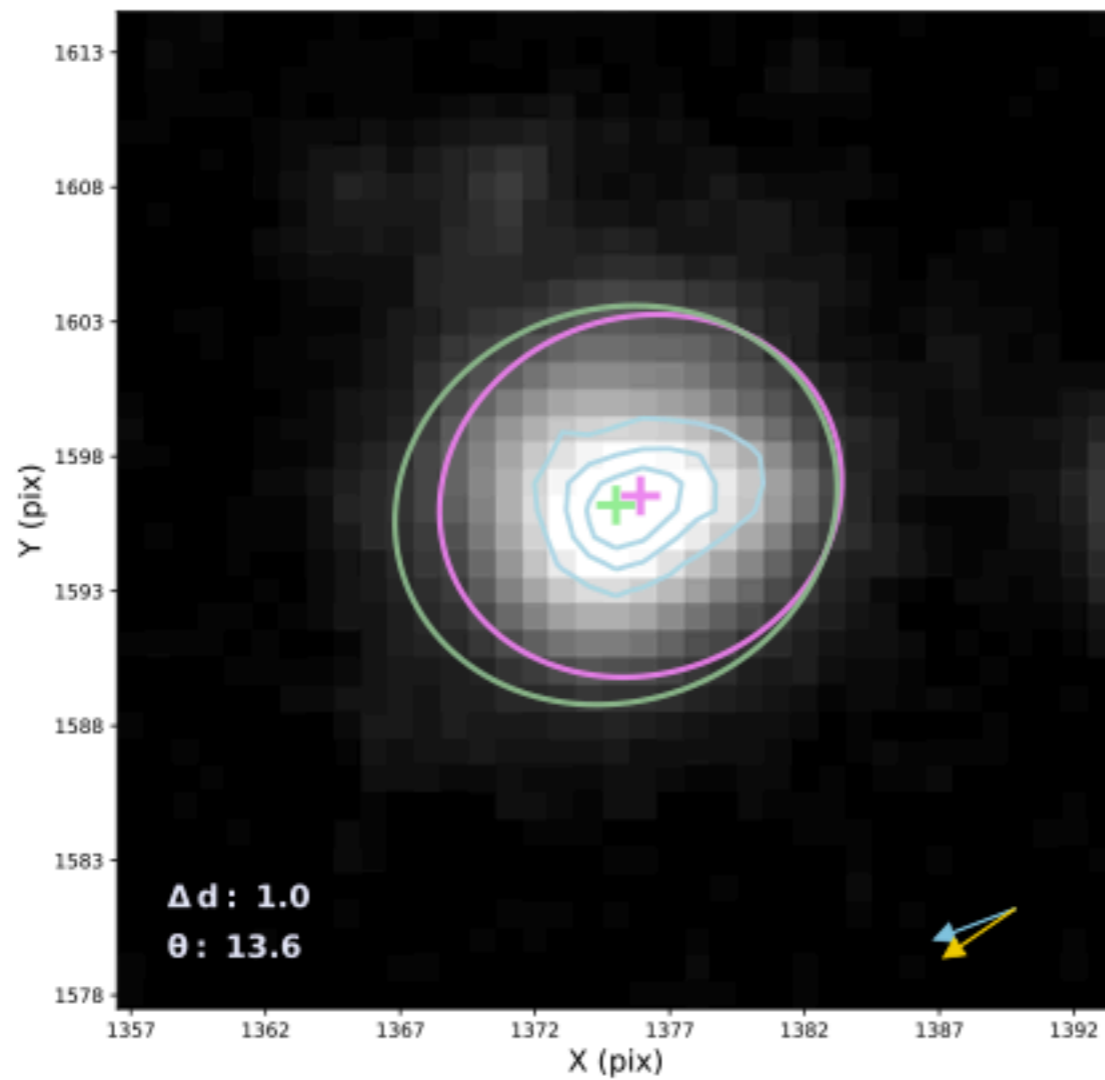
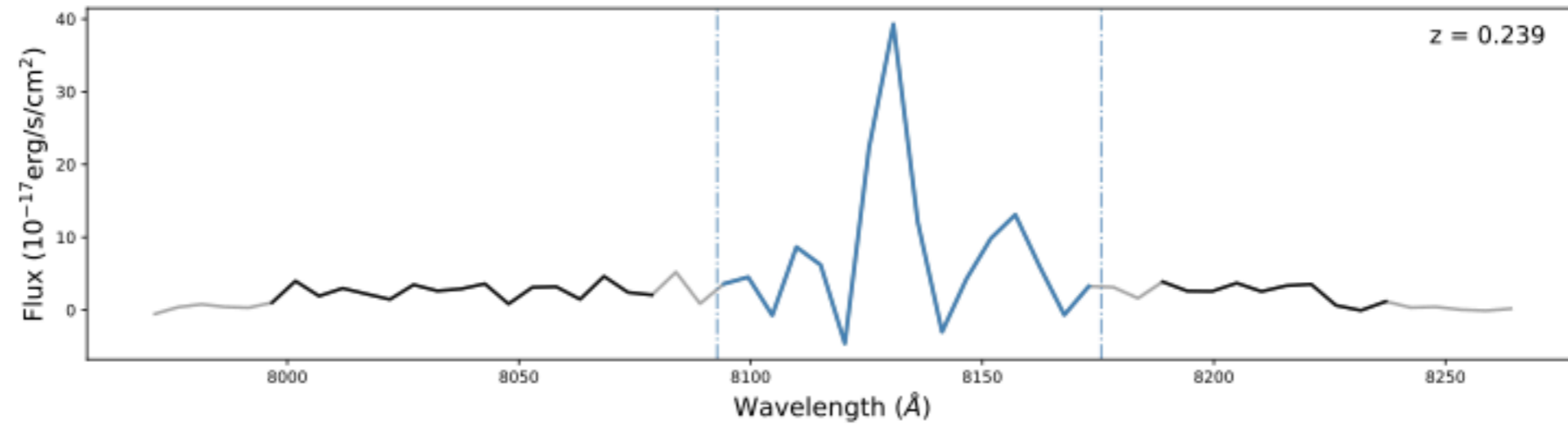
The Emission-line Galaxy Population in Rich Galaxy Clusters



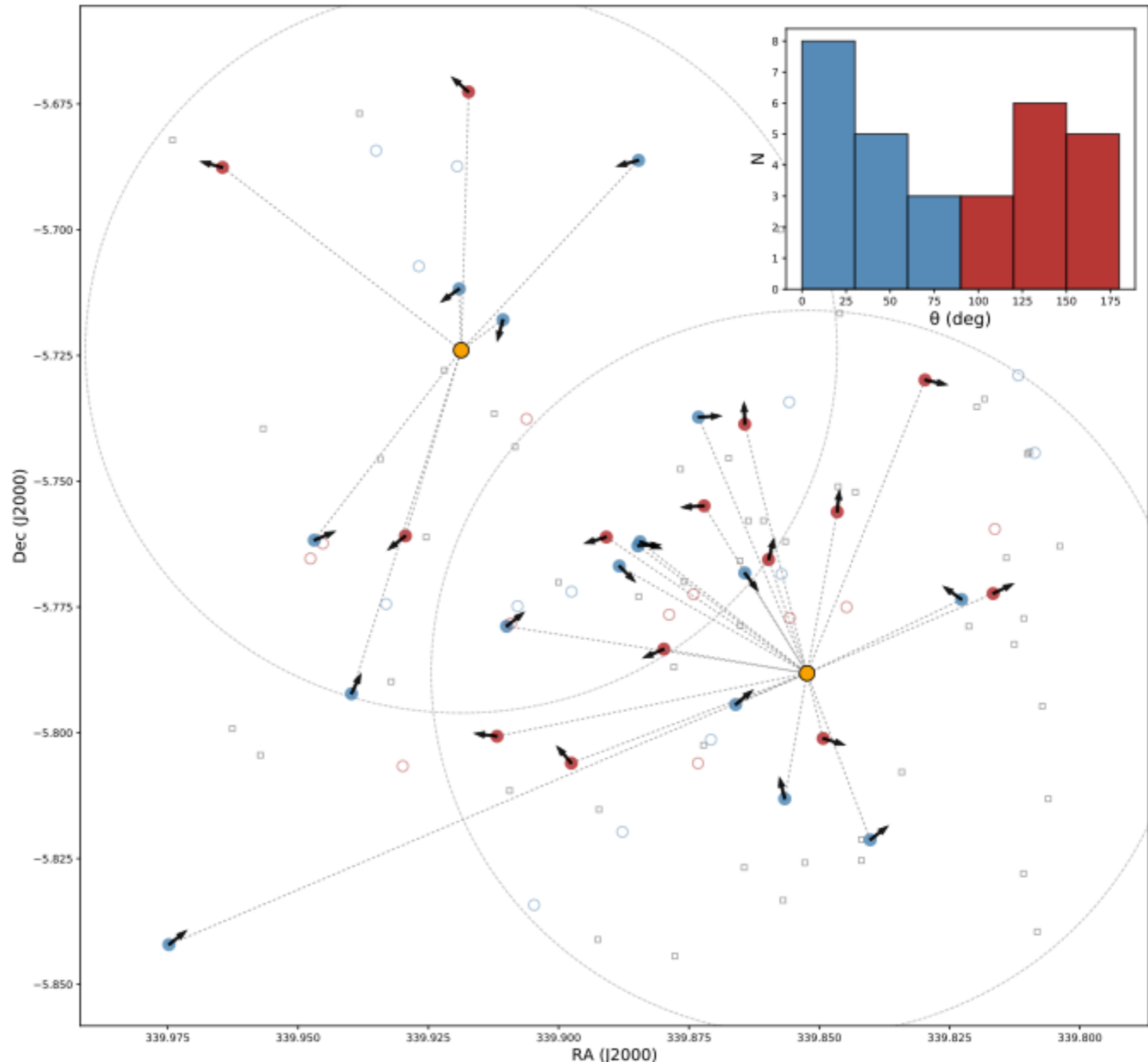
**Abell 2465 ($z=0.245$)
colliding clusters**



A2465 - Offsets (emission vs continuum)

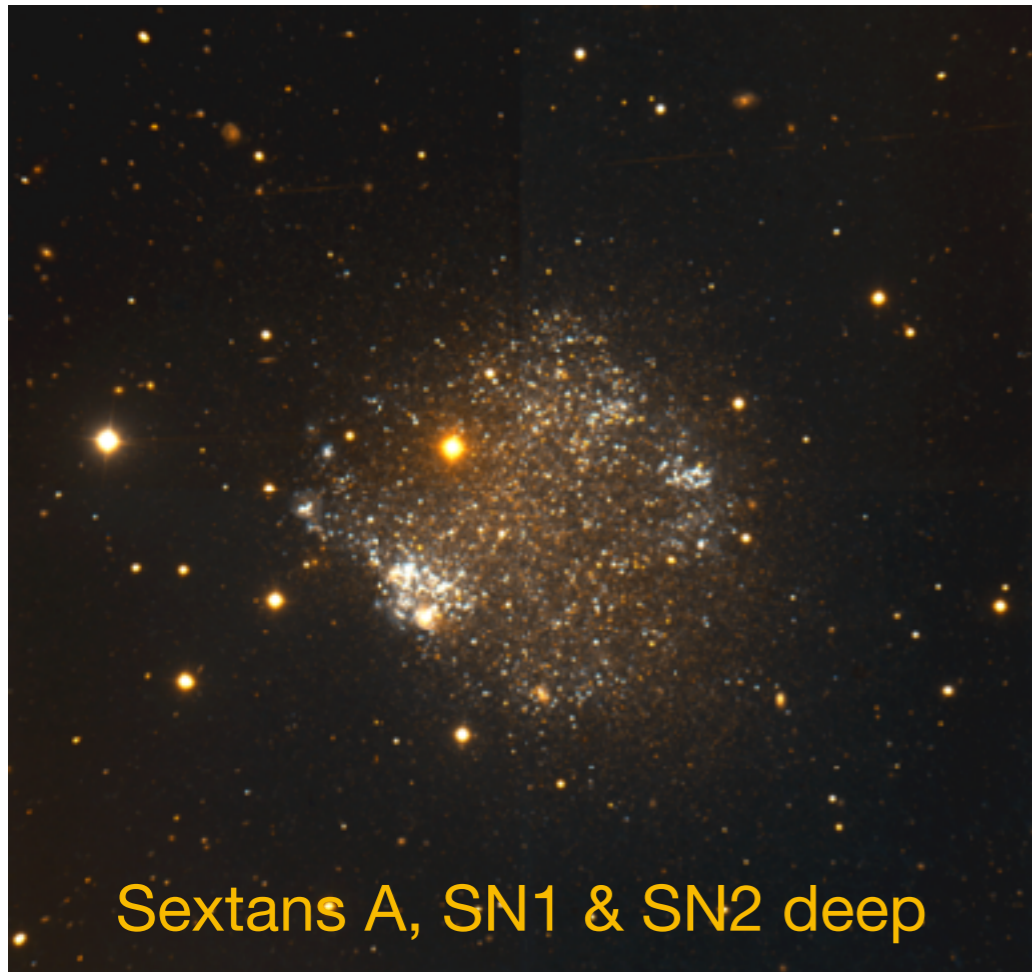


A2465 - Offsets (emission vs continuum)





SIGNALS PI:
Laurie Rousseau-Nepton



Sextans A, SN1 & SN2 deep

CFHT

2019 May 27 - 30

LARGE PROGRAM AT THE CANADA-FRANCE-HAWAII TELESCOPE

SIGNALS
STAR FORMATION, IONIZED GAS, AND NEBULAR ABUNDANCES LEGACY SURVEY

WORKSHOP

DATE
MAY, 27 - 30, 2019

VENUE
UNIVERSITÉ LAVAL
QUÉBEC CITY

FOR
SIGNALS COLLABORATION DISCUSSION FORUM
DATA PRODUCTS, ANALYSIS AND TRAINING
STUDENT INVOLVEMENT IN THE SURVEY
DATABASE AND COMMUNICATION PLANING

INFO

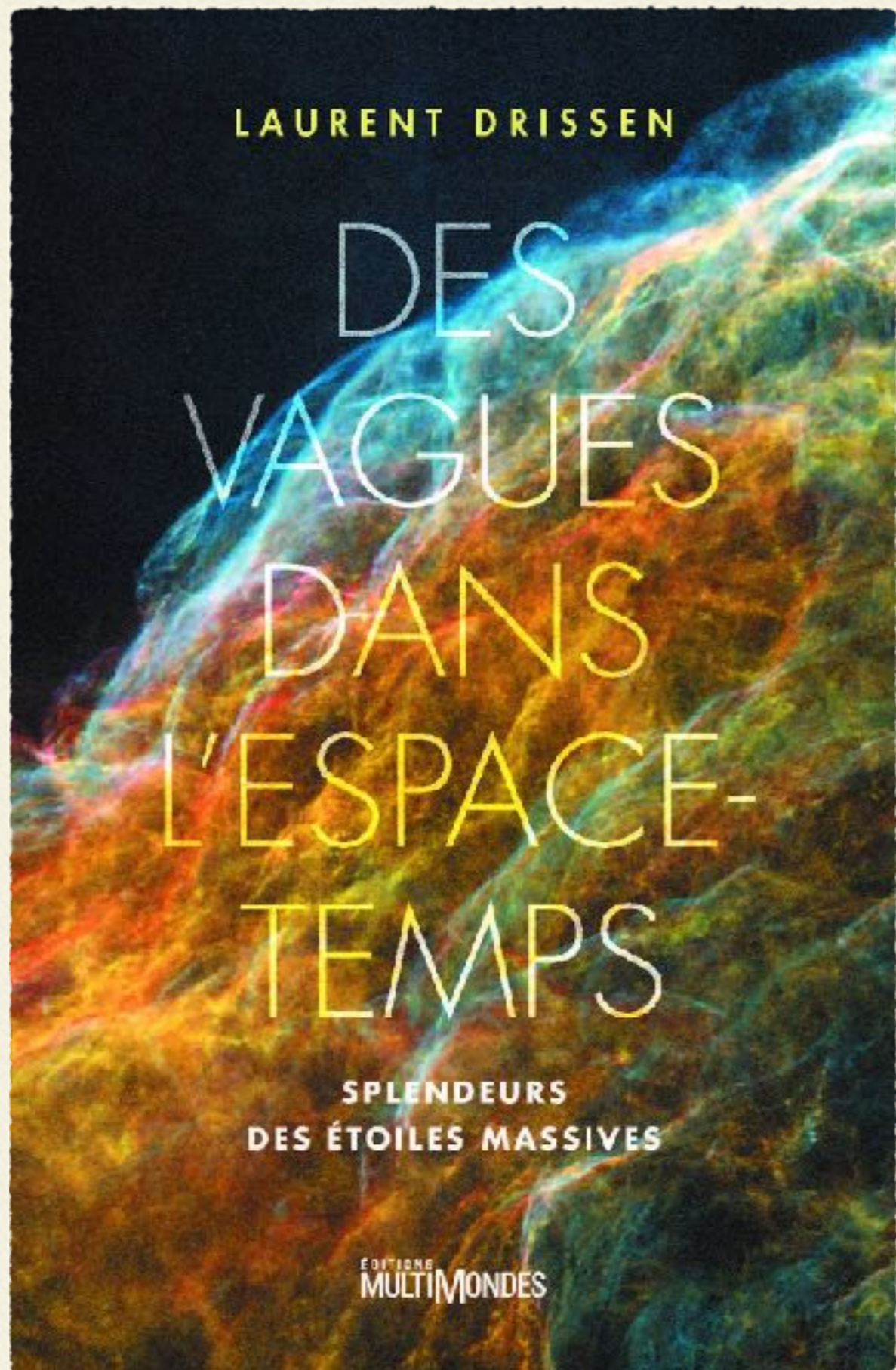
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WWW.ASTRO.PHY.ULVAL.CA/WS19/SIGNALS.HOME.HTML
WWW.SIGNAL-SURVEY.ORG

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En librairie le 13 juin!



Figure 0.1 - Deux nébuleuses observées lors de la mise en service de SIFELLE au télescope Canada-France-Hawaï. En haut, la nébuleuse de la Lyre, une nébuleuse planétaire résultant de l'éjection à faible vitesse des couches externes d'une étoile à peine plus massive que le Soleil. En bas, une petite région de IC 443 (la nébuleuse de la méduse), un reste de supernova issu de l'explosion rapide d'une étoile massive, il y a environ 15 000 ans. Les couleurs reflètent la proportion relative d'hydrogène, d'azote, d'oxygène et de soufre dans le spectre des nébuleuses.

Crédit: Laurent Drissen, Wei-Hao Wang, Alexandre Aïme / Télescope Canada-France-Hawaï

