Observing CII in external galaxies with upGREAT

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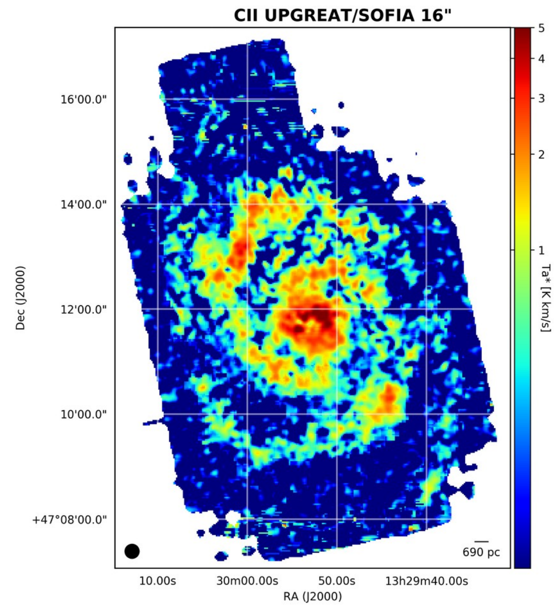
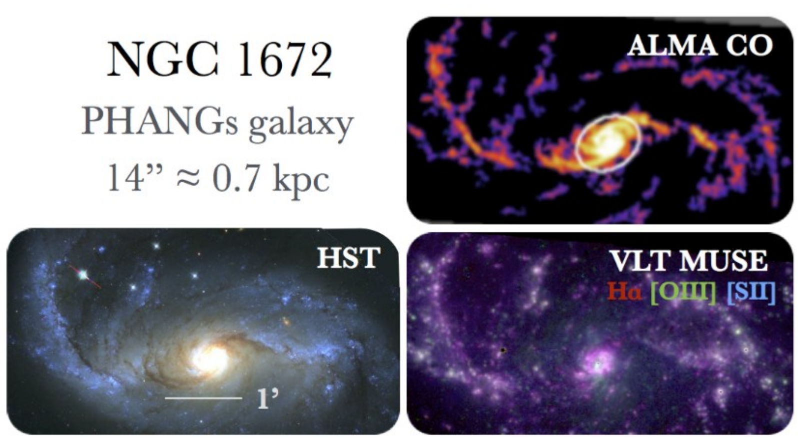
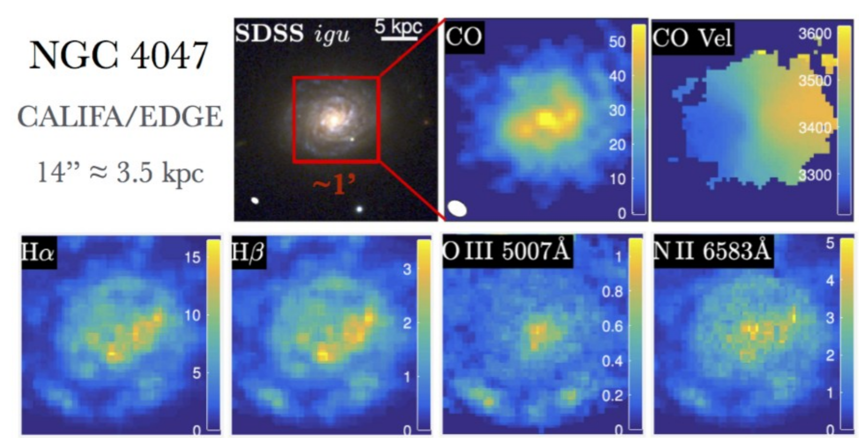
Large projects observing CII in external galaxies

- **Large impact program observing CII in M51**



- **Galaxy survey extending 49 PHANGS and EDGE-CALIFA galaxies with CII measurements**



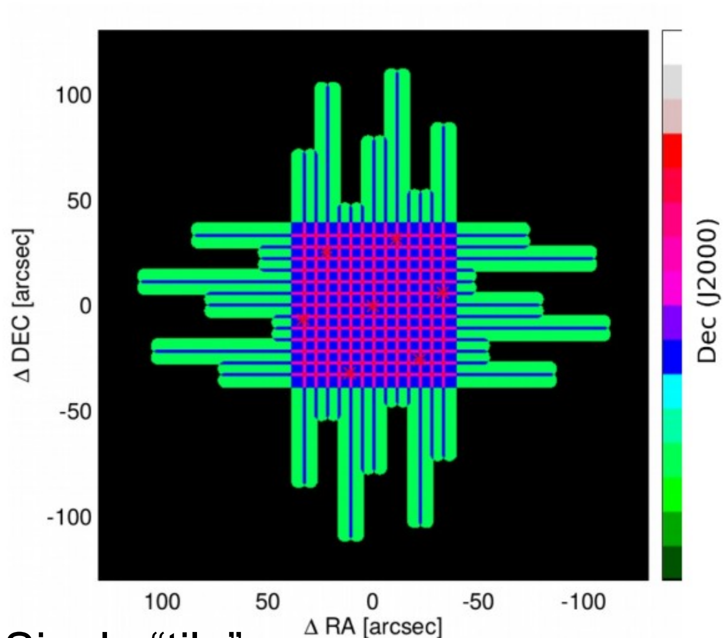


Schinnerer and Leroy et al. in prep.

Bolatto et al. 2017

Efficient mapping mode with upGREAT

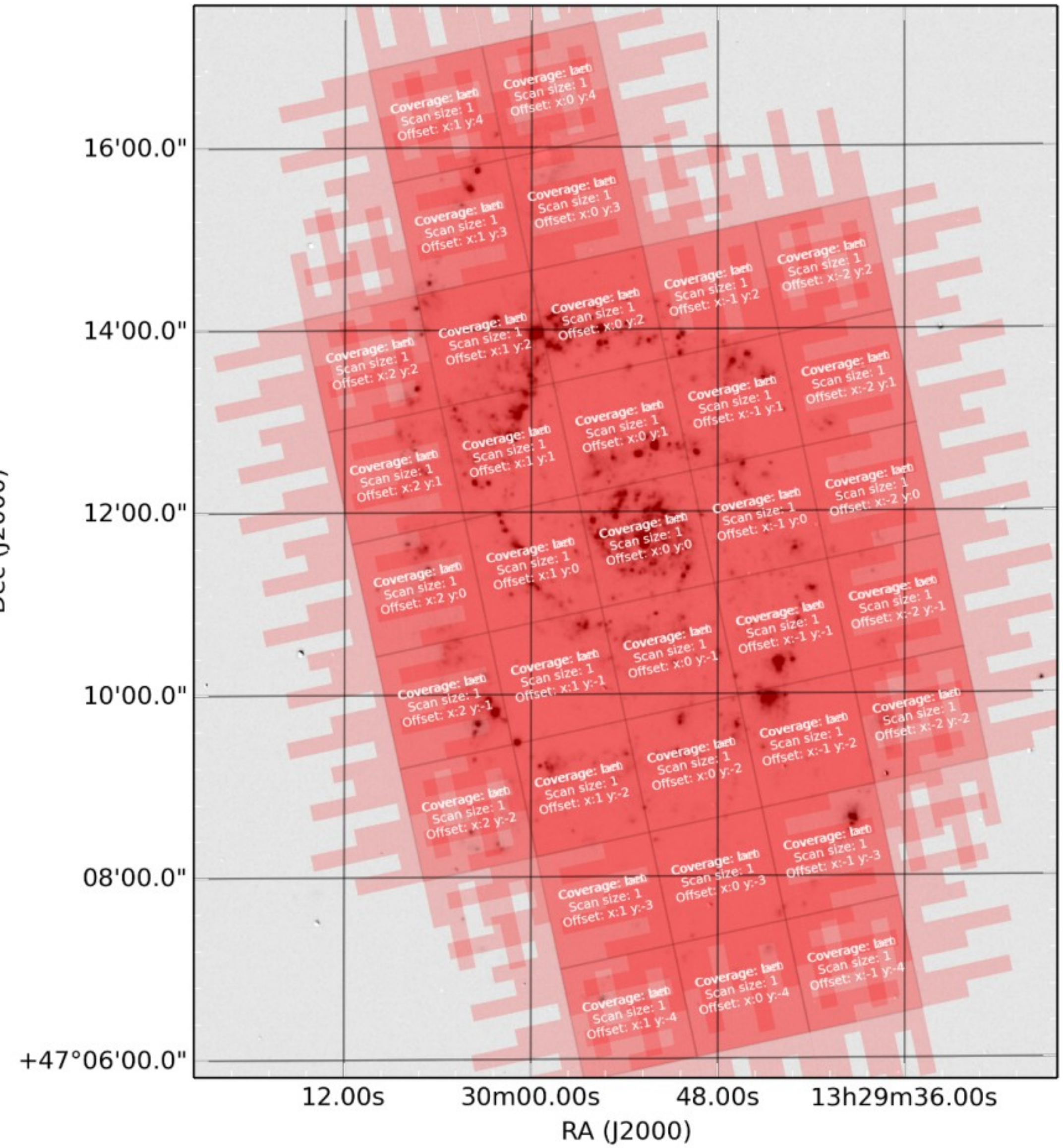
Array OTF Footprint



Single “tile”:
  overhead factor 2

Larger maps:
  overhead # “open sides”

2 modes:
  totalpower (a=sqrt(1+1/N)
  chopped: (a=2)



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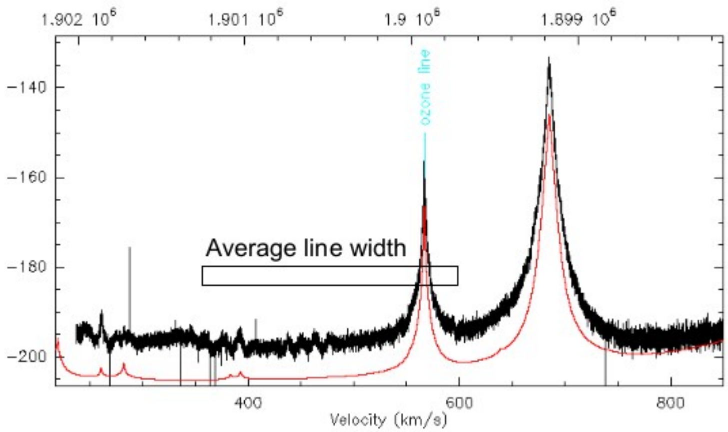
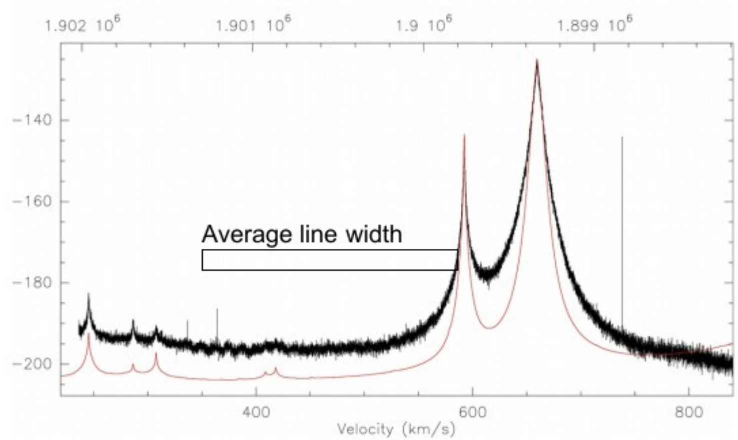
Atmospheric absorption lines

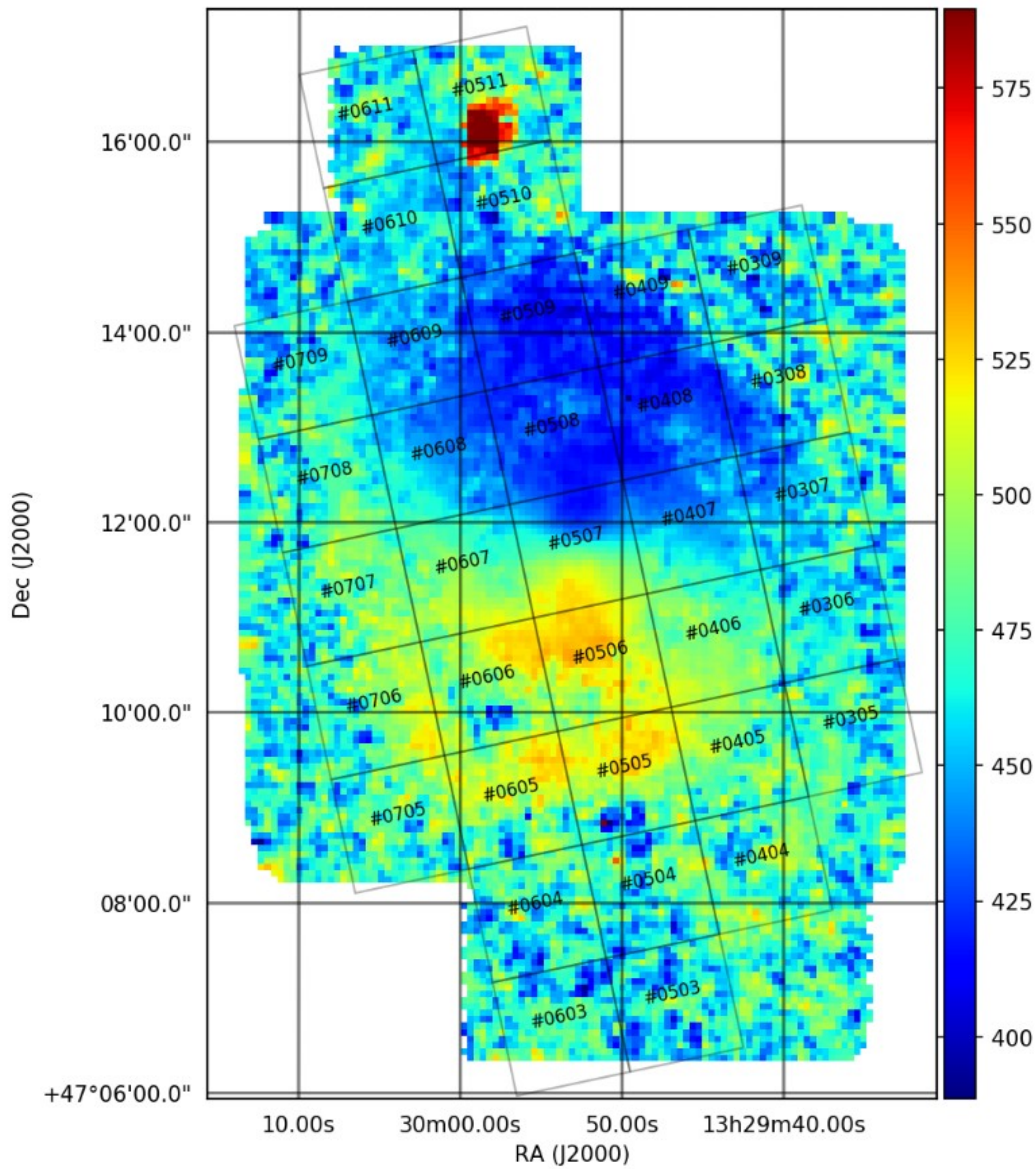
May 2016



February 2017



Central CO velocity



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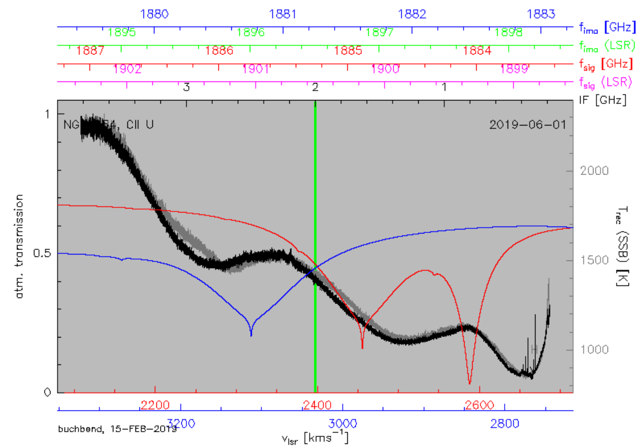
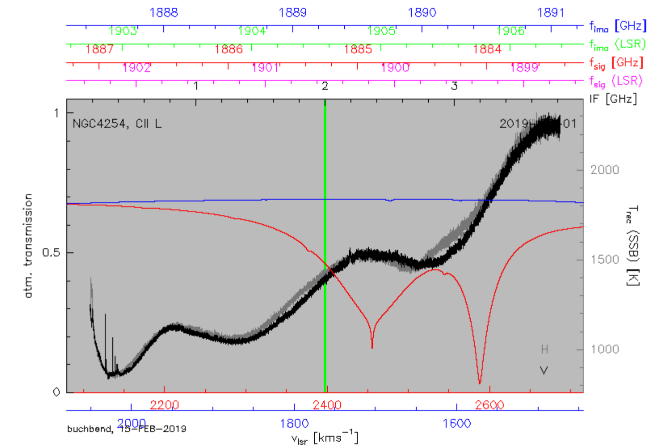
Atmospheric absorption lines

LSB

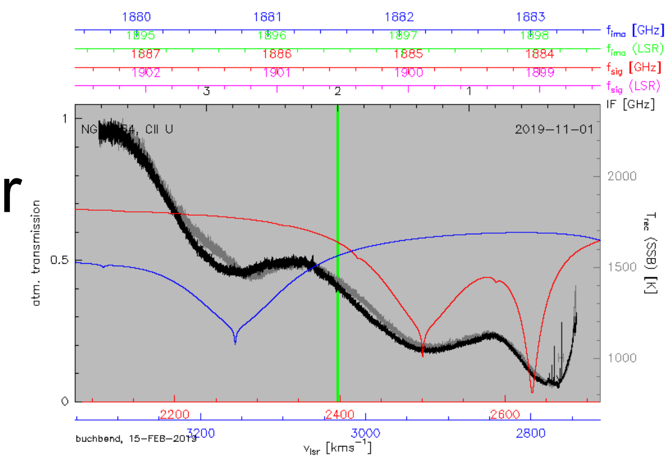
USB

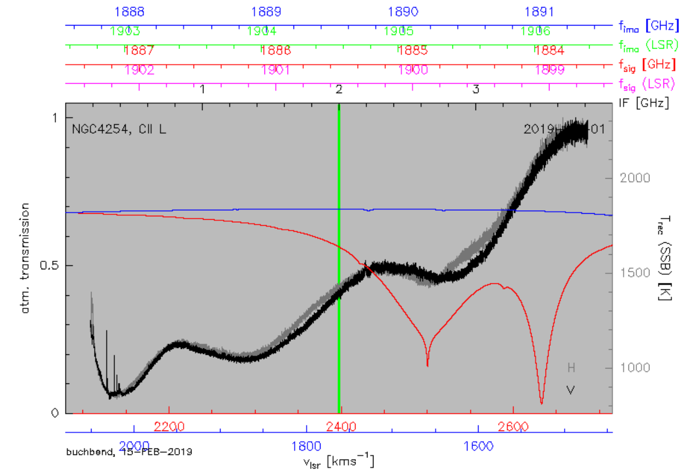
June





November





→ For some sources the date of the observations make a difference

Channel based weights

- **Problem**:

  Large projects like M51 average data from different times of the year.

  → When all channels have the same weight a larger bandwidth is effected by the atmospheric line in the averaged (gridded) data.

- **Solution**:

  Implement channel based weights for gridding and averaging.

- **Kalibrate:**

  Use of atmospheric model (AM) to determine the transmission at the time of the observations from regular measurements of the SKY for every channel in the spectrum.

  → We can use the calculated transmission as a weight to down weight the channels with low transmission and thus higher noise.

Implementation in CLASS and `kalibrate`

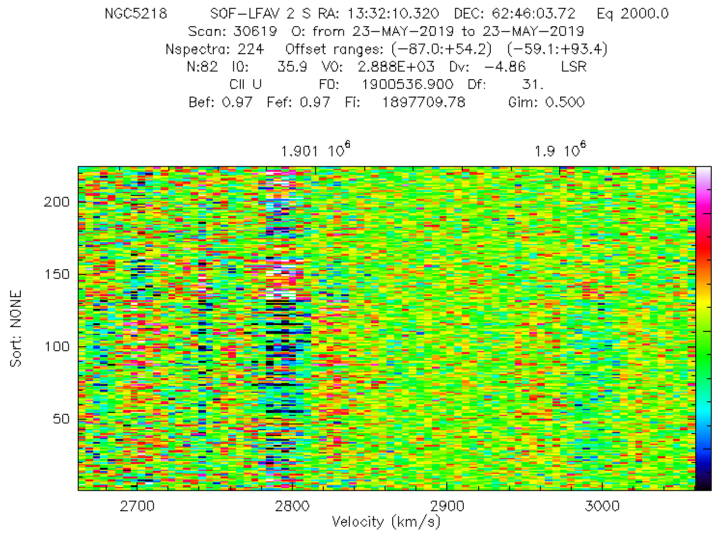
Associated arrays:

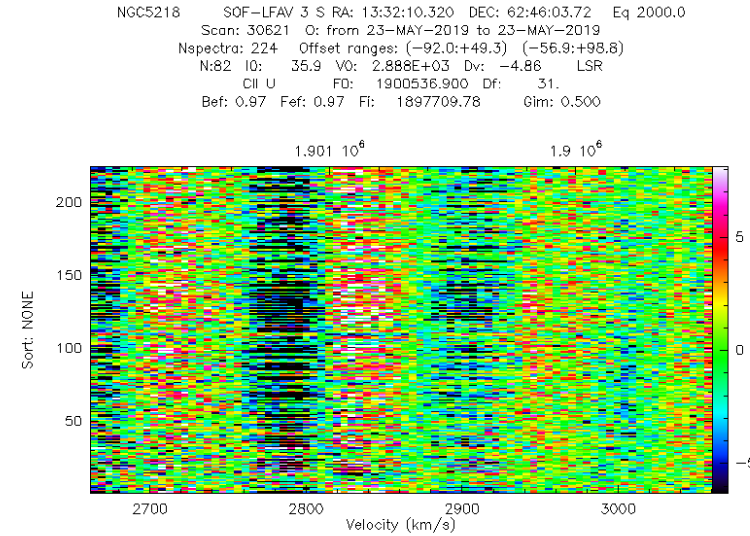
Relatively new concept in Class:
- store arrays in parallel to the “ry” data for a spectrum.
- these arrays undergo the same transformation as the original spectrum.
- Special arrays: Line window, weight, blank,…
- Also user defined arrays

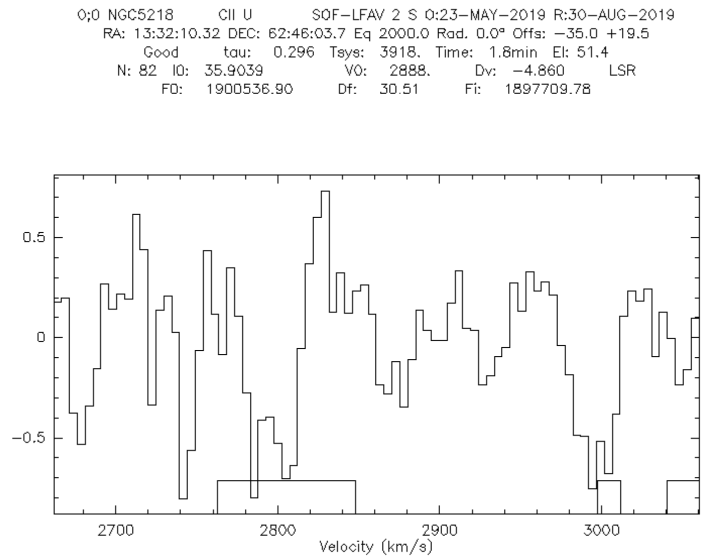
Pseudo Class code:

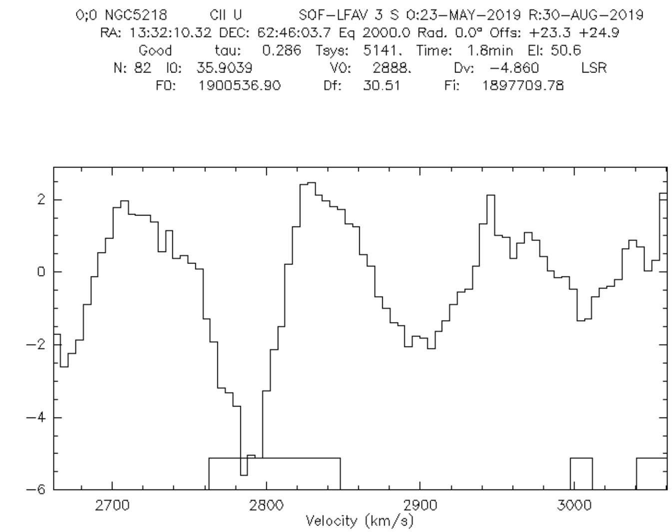
```
values[i] = weight[i] * data[i]
set weight equal
table data_weight new
xy_map data_weight

values[i] = weight[i]
table weight new
xy_map weight

let final data_weight/weight
```

Detecting problematic spectra









Detecting problematic spectra

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Galaxy observations with broad and weak lines are very sensitive to baseline perturbations.

Large projects like the CII M51 map have > 1e6 Spectra.

→ Need of good automatic detection of problematic spectra

Problems:

- comparison of measured baseline rms and theoretical Receiver noise is not always indicative at the original Resolution

- often baseline features are “hidden in the noise”

Solution:

→ continuously smooth a spectra and compare the reducution in noise

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Detecting problematic spectra

Radiometer Formula

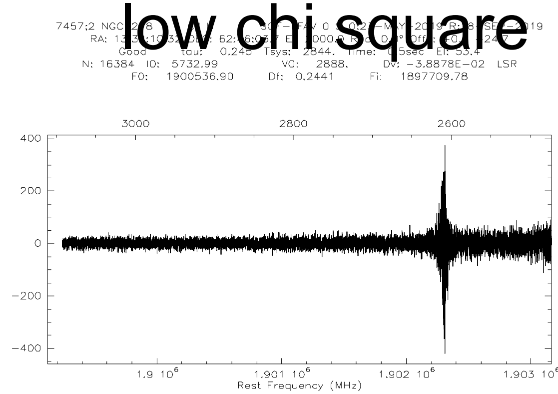
$$\sigma = \alpha \frac{T_{sys}}{\sqrt{\Delta \nu \cdot t}} e^{\frac{\tau}{\sin El}}$$

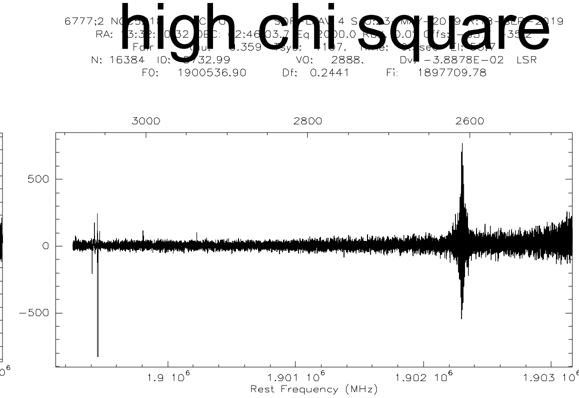
Smoothing a spectra by factor 2 should lower the baseline rms by $\sqrt{(2)}$

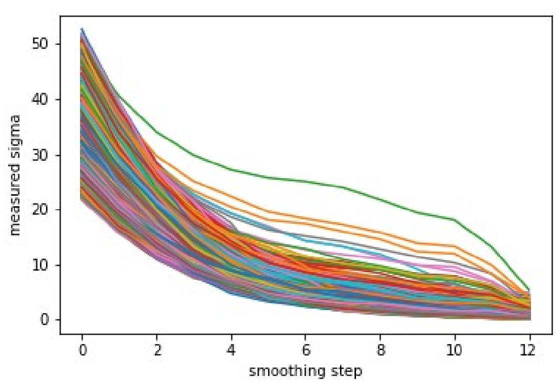
low chi square

high chi square

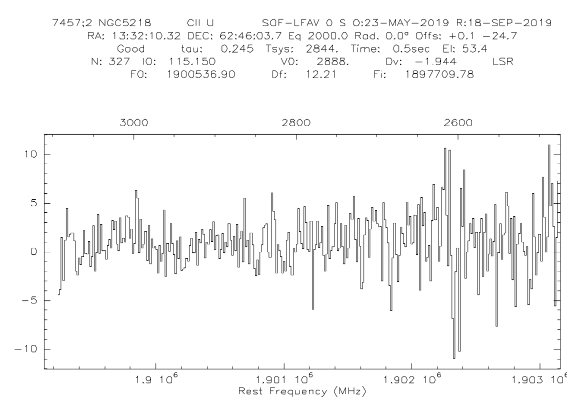
High res

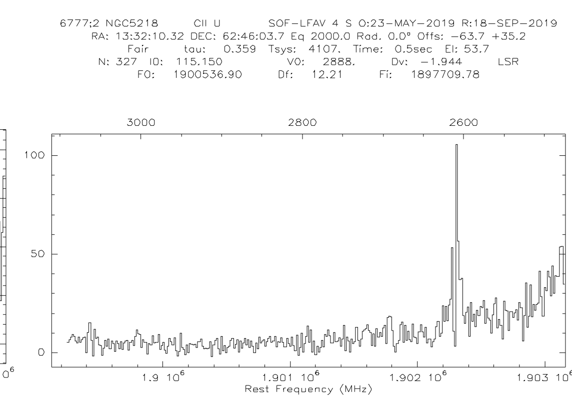






Low res





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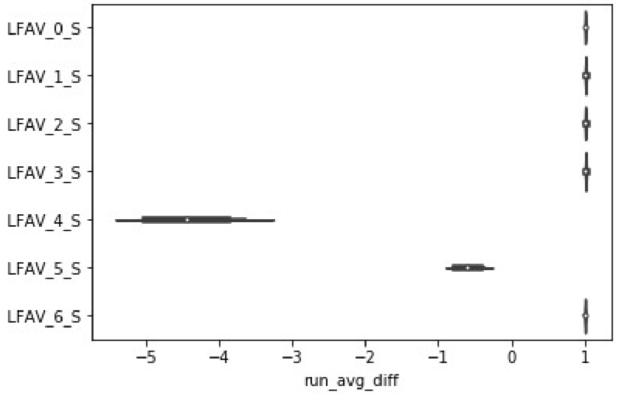
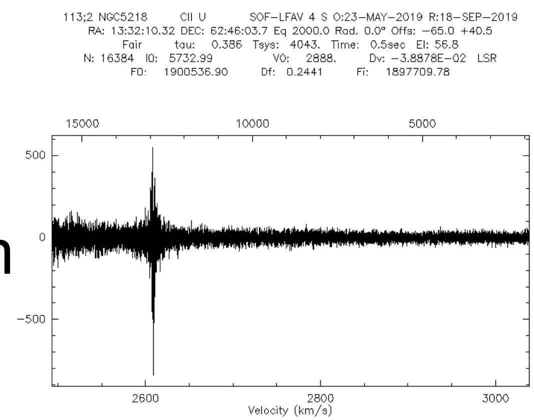
Detecting problematic spectra

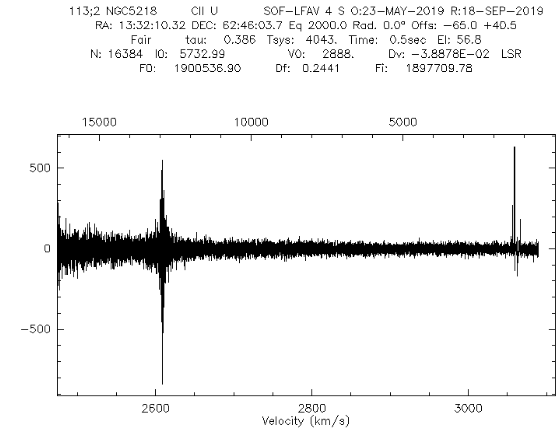


No Deviation from Radiometer formula

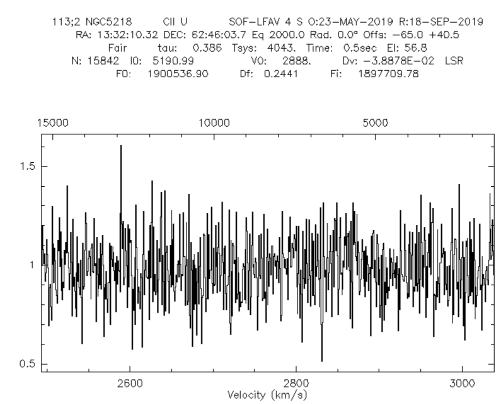
Local deviation from Radiometer formula

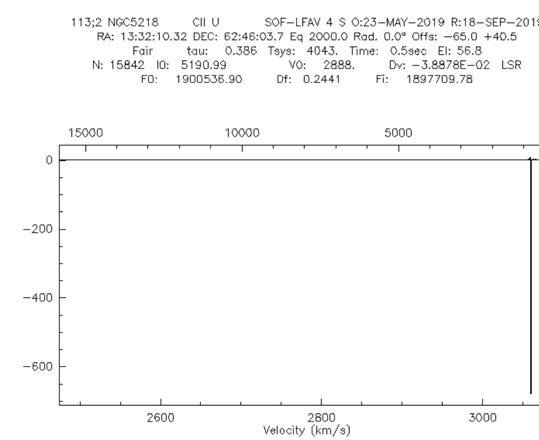
Original spectrum





Local RMS divided by local radiometer noise

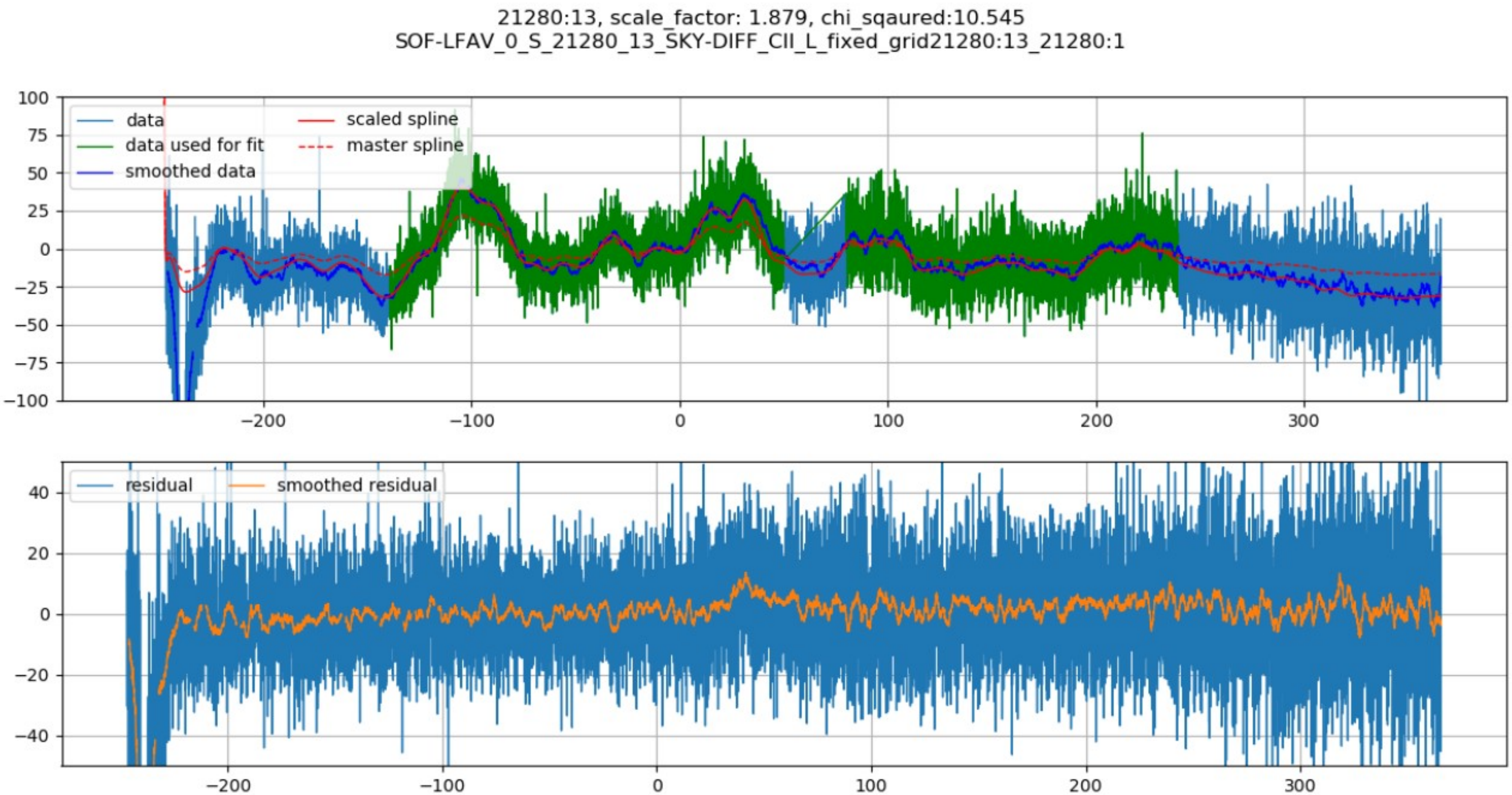




Baseline reduction with splines

- Background: HIFI HEB correction
- Assumption is that the baseline features are stable over the course of the observation and are just scaled versions of each other

- **Dashed red line is the orginal SKY-DIFF spline**
- **Solid red line is the scale SKY-DIFF spline. In this case it was scaled by a factor of 1.879**
- **Chosen sky-DIFF is the difference between the OFFs (scan:subscan) 21280:13 and 21280:1**



Ronan Higgins

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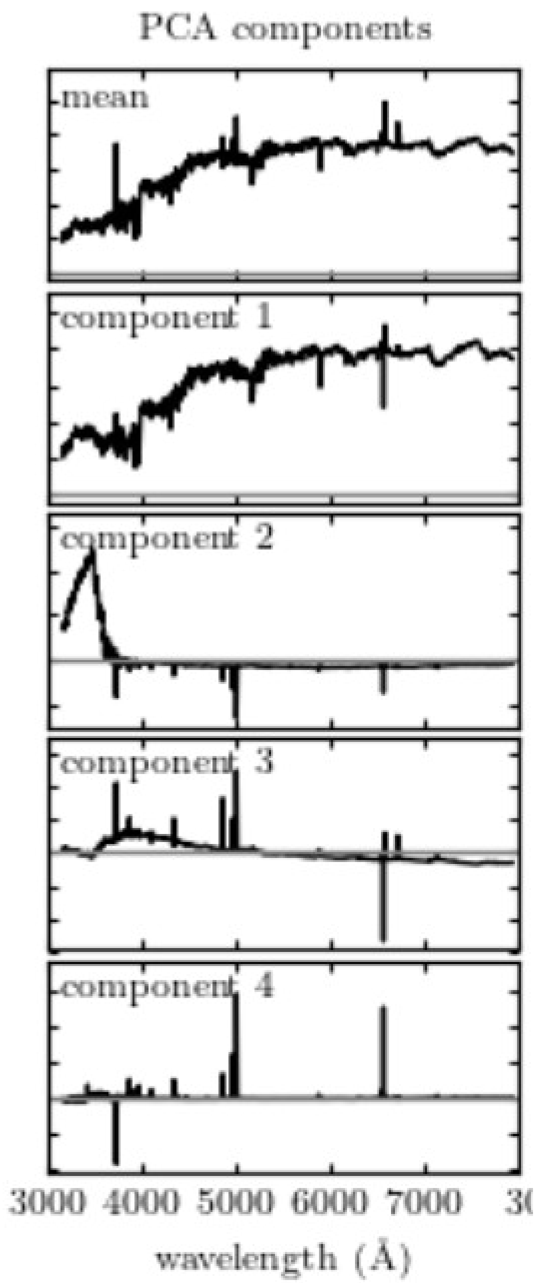
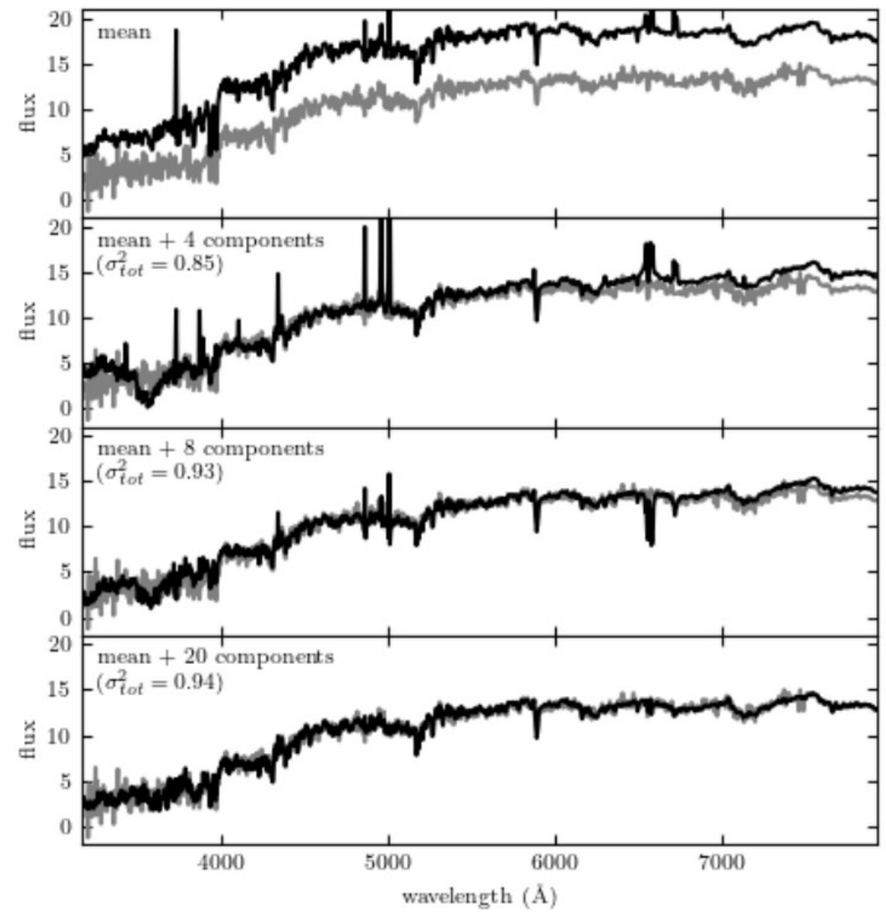
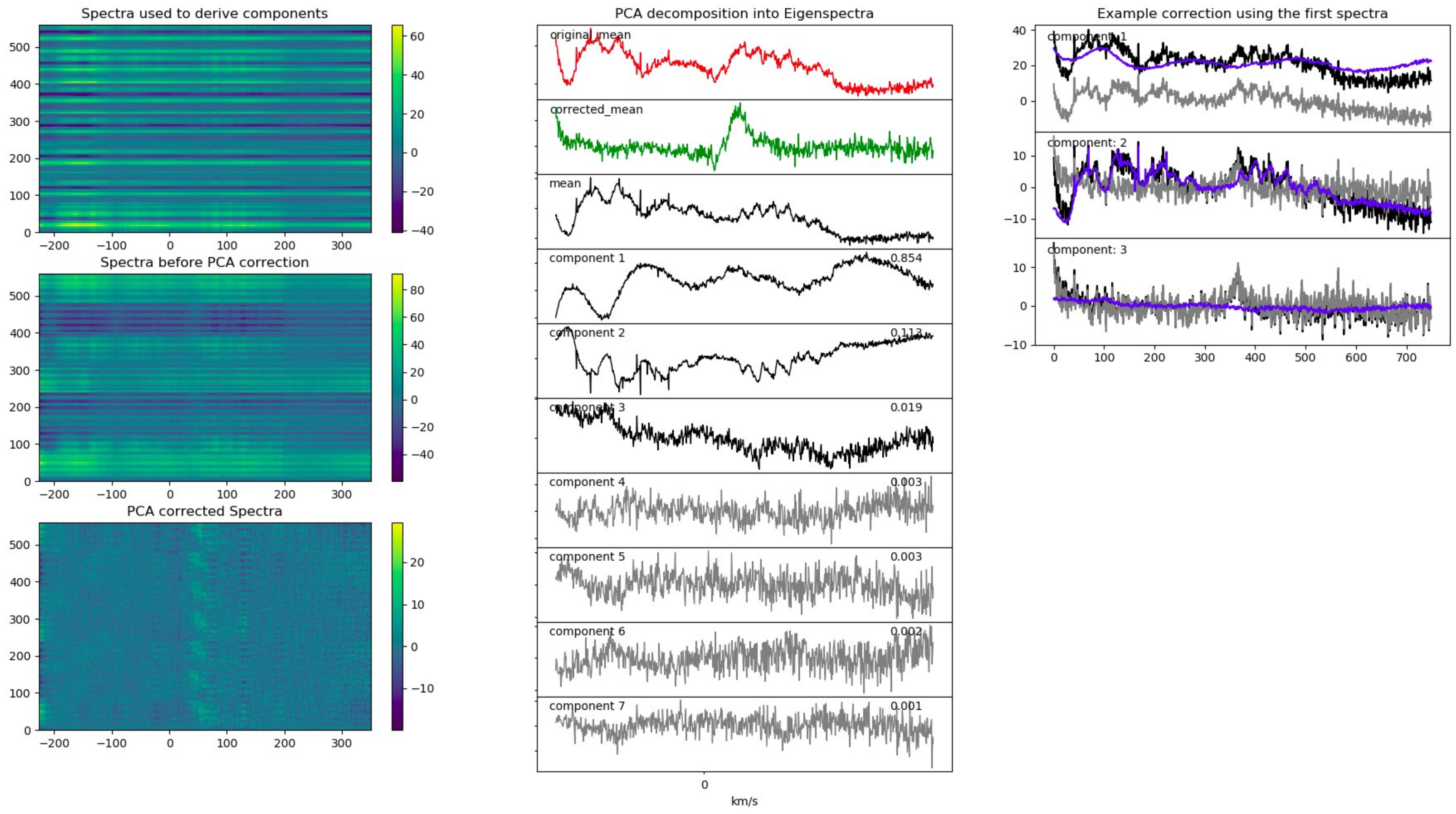
Novel approach for baselining: PCA decomposition





Vanderplas et al, proc. of CIDU, pp. 47-54, 2012.
http://www.astroml.org

Example PCA decomposition



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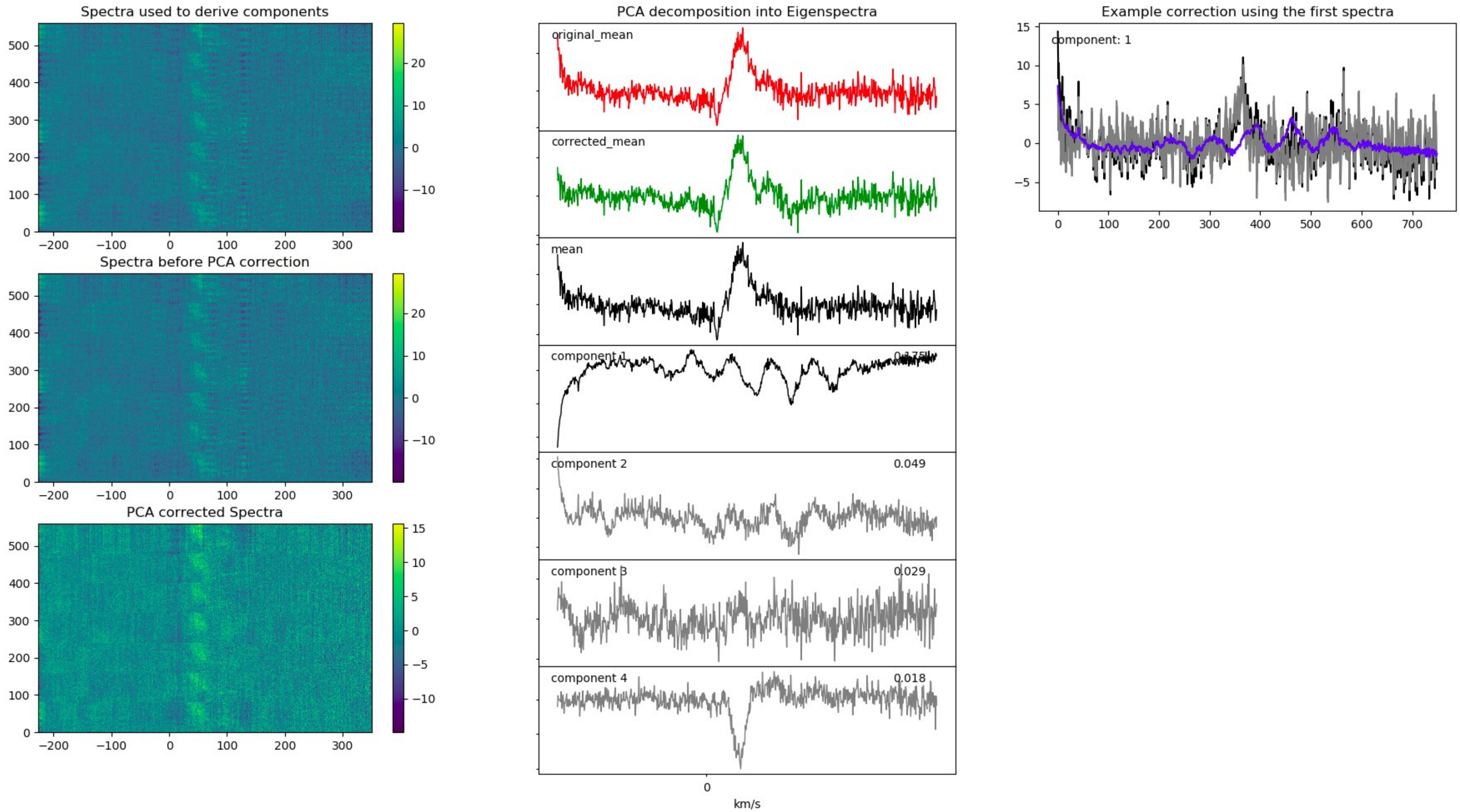
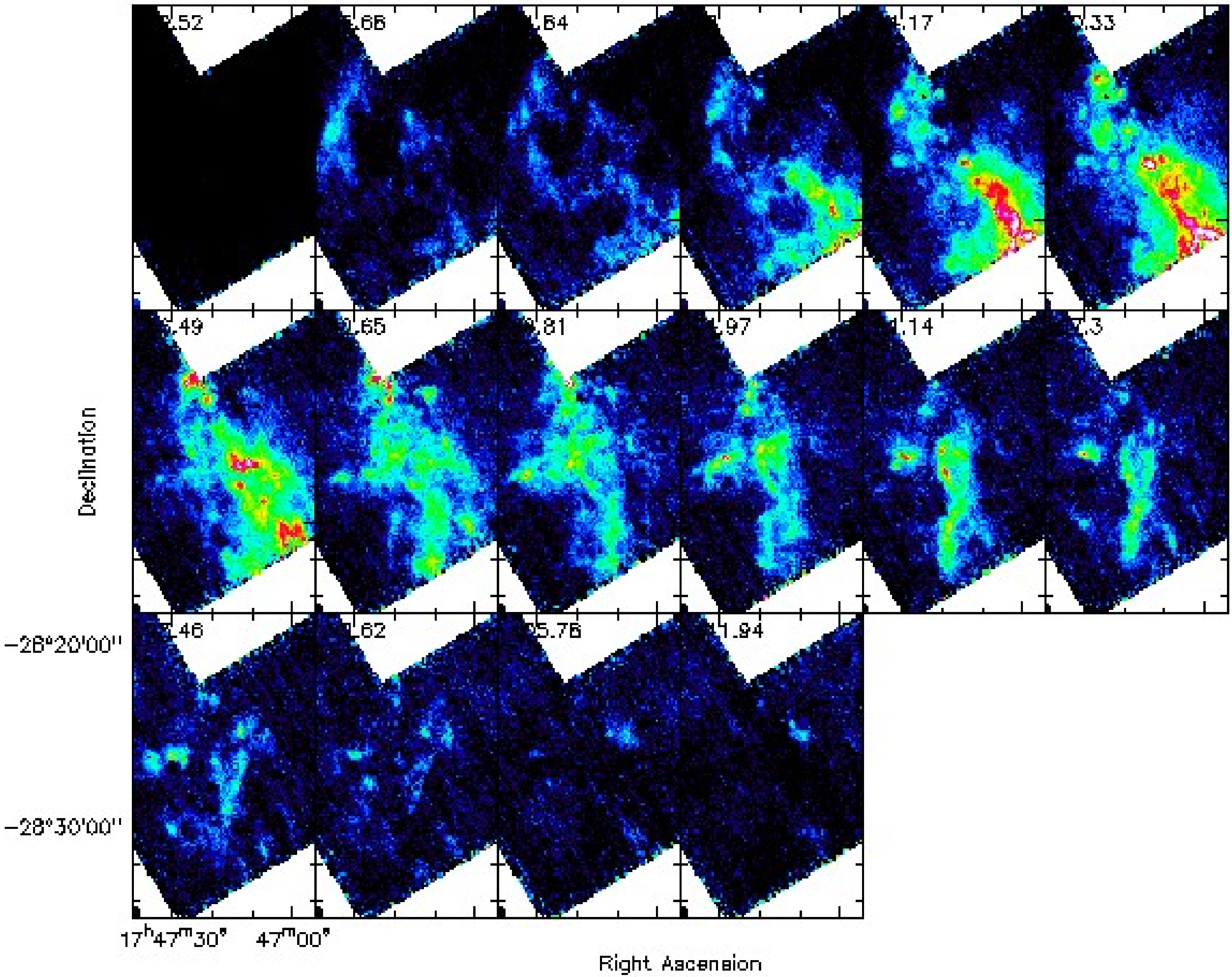
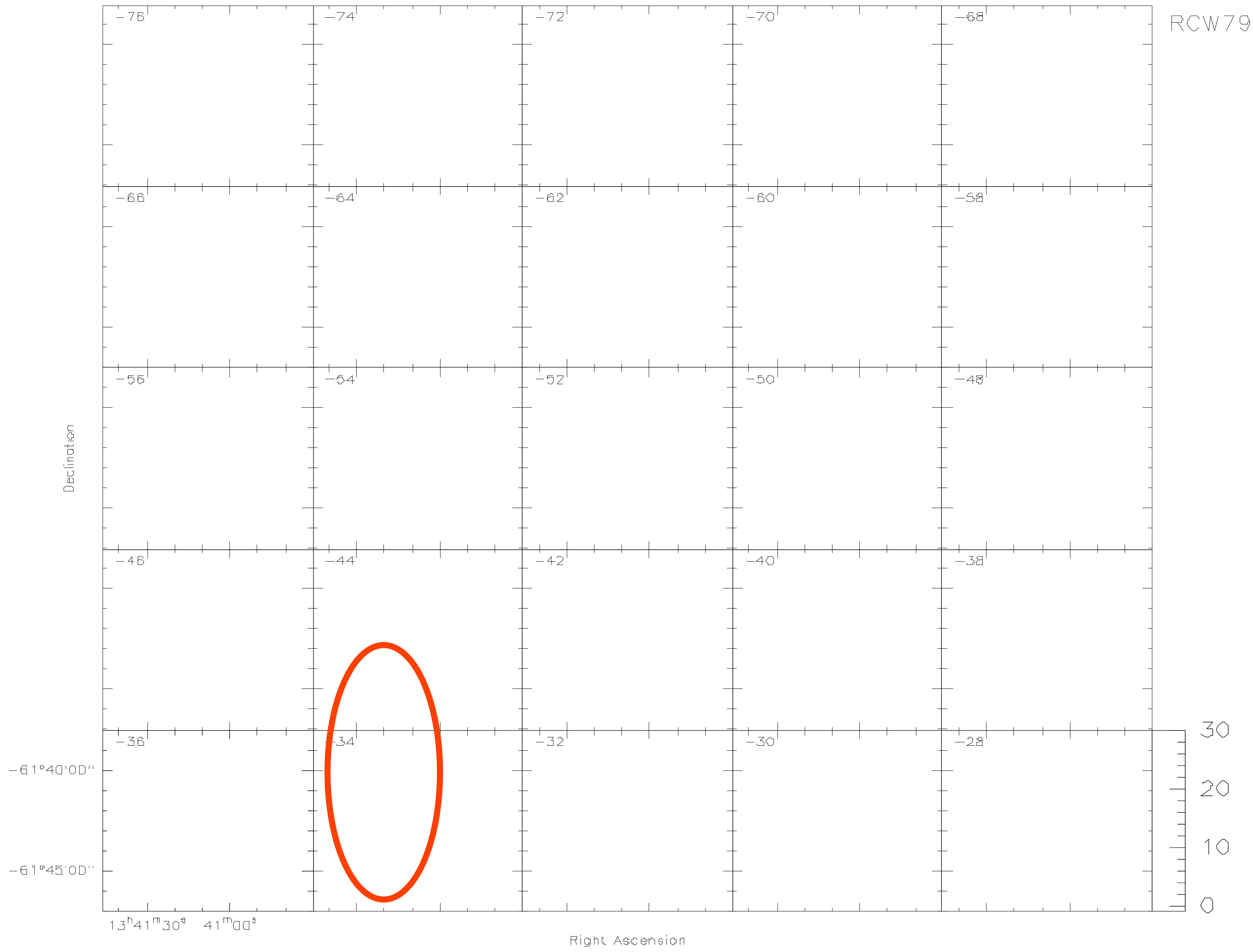
Example PCA decomposition



SGRB2_CMZ reduced with pca decompositon



RCW79: baseline 5 reduction



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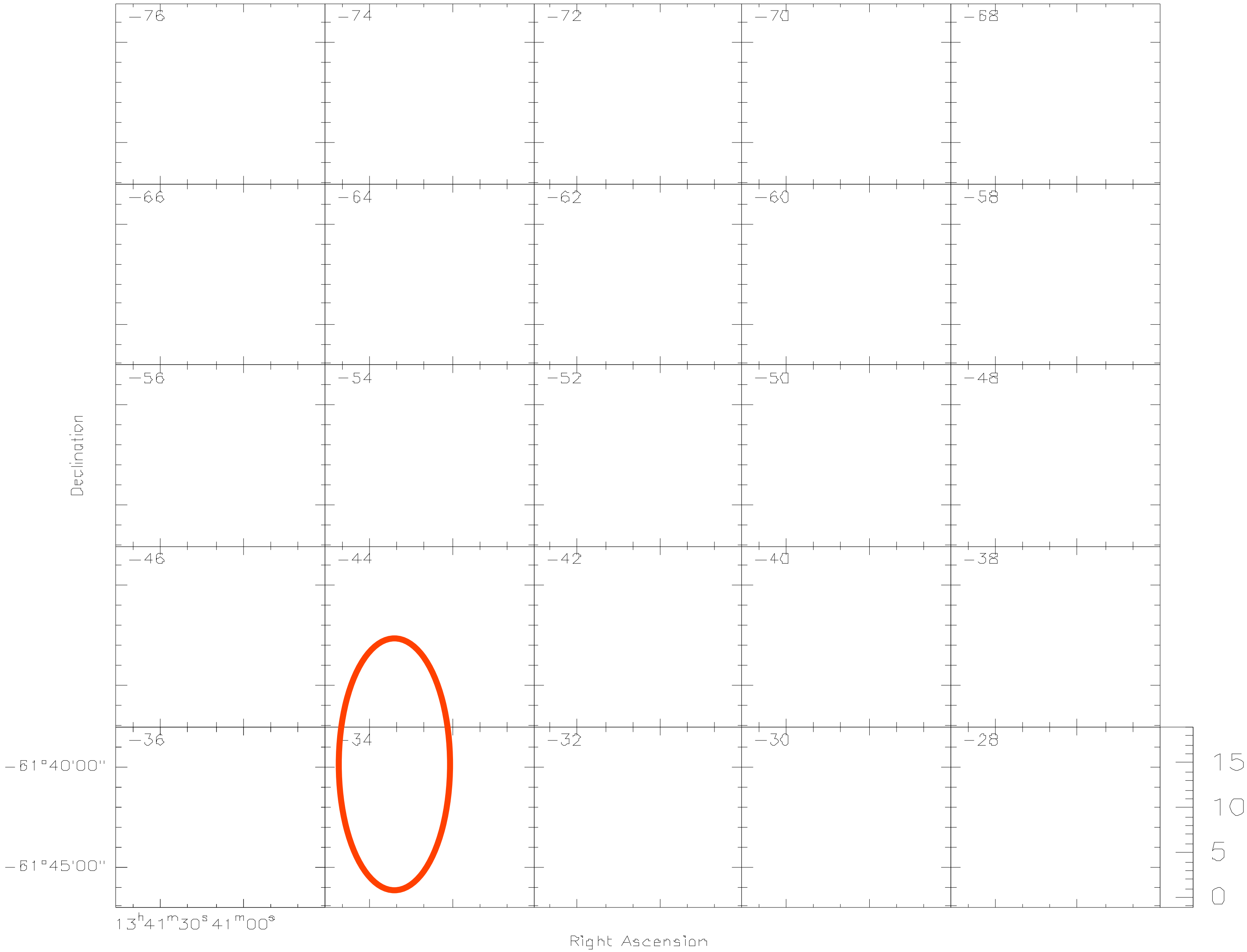
PCA component reduction



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PCA decomposition not always a silver bullet

- Components reflect the variation away from the **mean** of a dataset

  → Only baseline features that vary between spectra are described by the components.

- In case of stable baseline problems the PCA decomposition is blind to the features.

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PCA decomposition for extra galactic data

In `array_otf_chopped` mode we observe the OFF position Repeatedly for a short duration. But current kalibration Only exports an average OFF position per OTF scan.

→ Write out each OFF observation individually
→ Same frequency as the ON observation. Ideal to determine variations in the data.

Potentially start using `array_otf_totalpower` mode and correct baseline instabilities with pca decomposition.

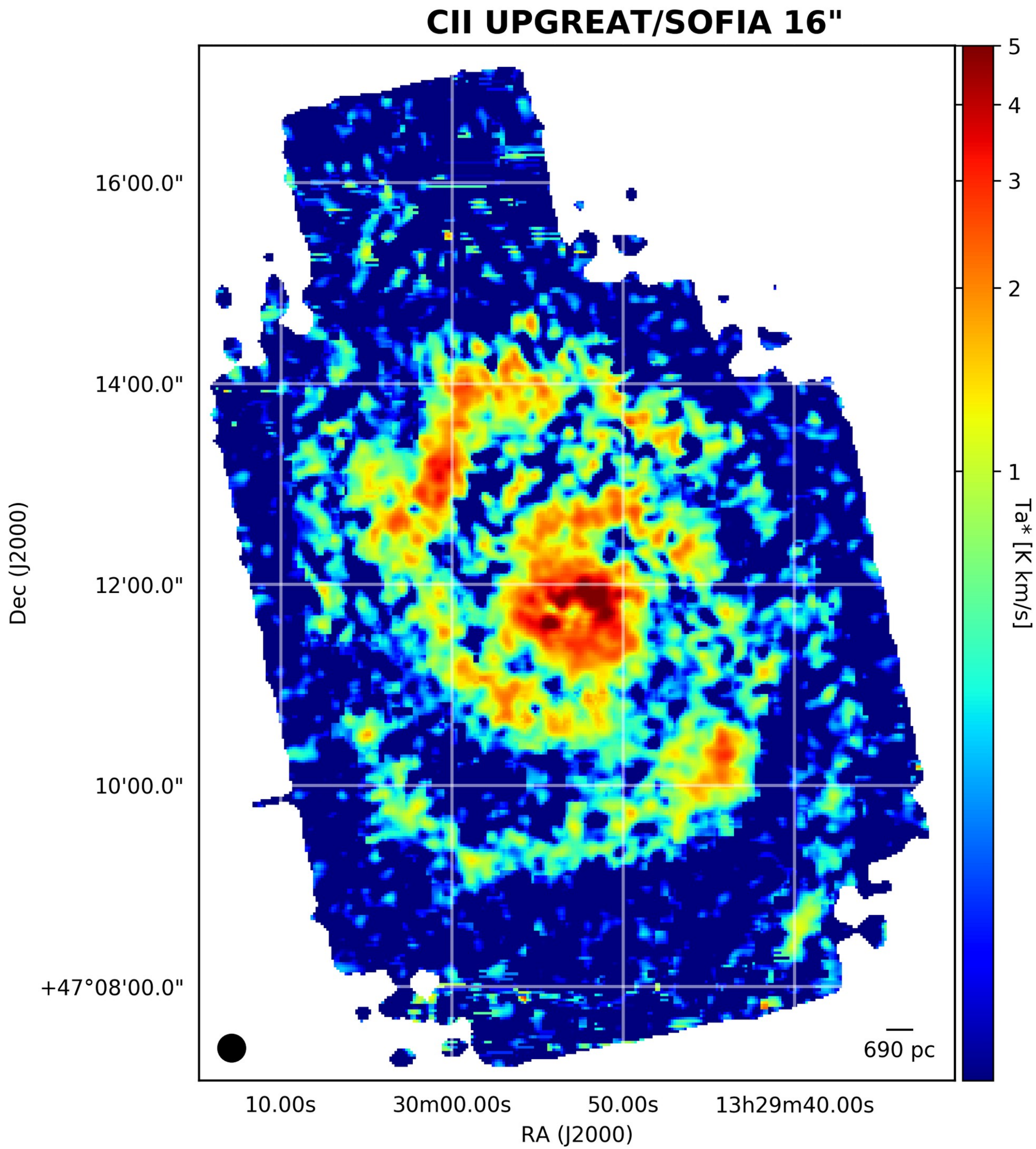
→ Higher observing efficiency:

$$\alpha = \sqrt{\left(1 + \frac{1}{N}\right)}$$

Outlook to scientific exploitation of the M51 CII data in the scope

Monika Ziebarts

PhD thesis.



Observing CII in external galaxies with upGREAT

- To understand galactic disks, we need to understanding the **spiral structure** and the interrelation between gaseous and stellar components, and their connection to the star formation Process.

- **Velocity resolved observations** are needed to separate the different phases of the ISM in spiral arms so we can study the **upstream** and **downstream** parts of the **spiral arms** via their different velocities.

- We can study the compression of molecular gas and the onset and effects of star formation at the **downstream side** of the spiral arms.

- With a [CII] map of an entire galaxy that has an angular resolution sufficient to **separate arm from inter-arm regions** and with enough velocity resolution one can separate the phases of the ISM across spiral arms.

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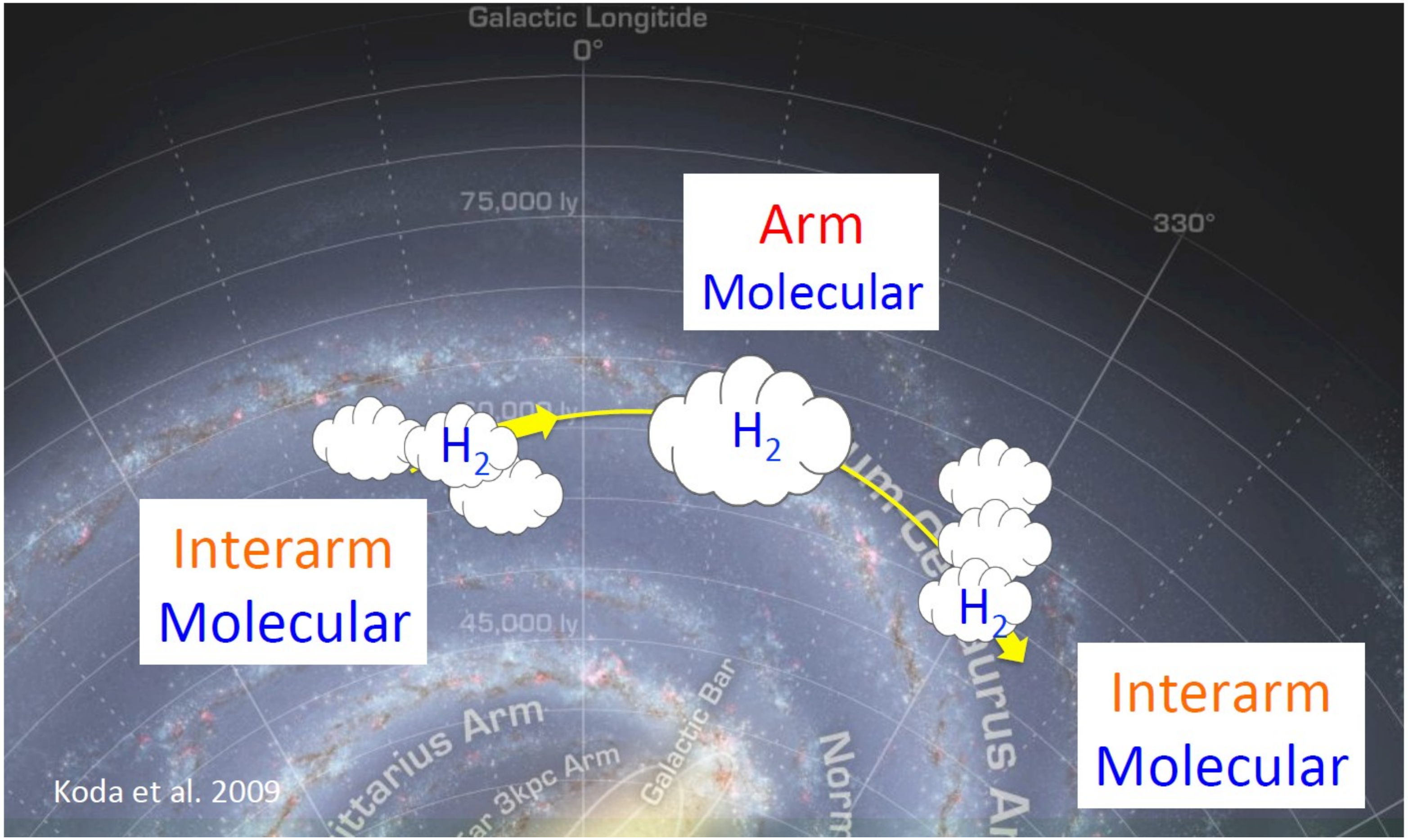

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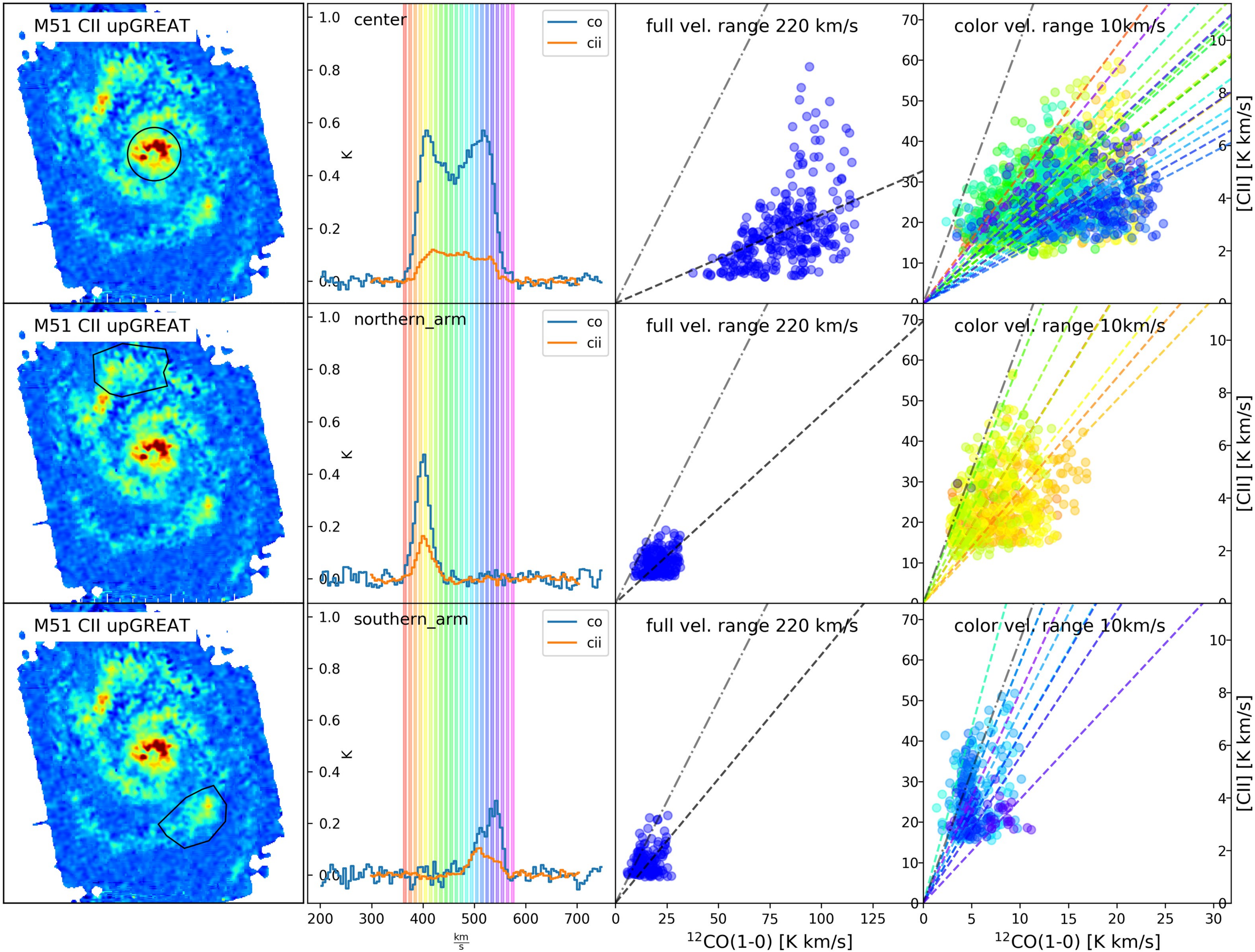
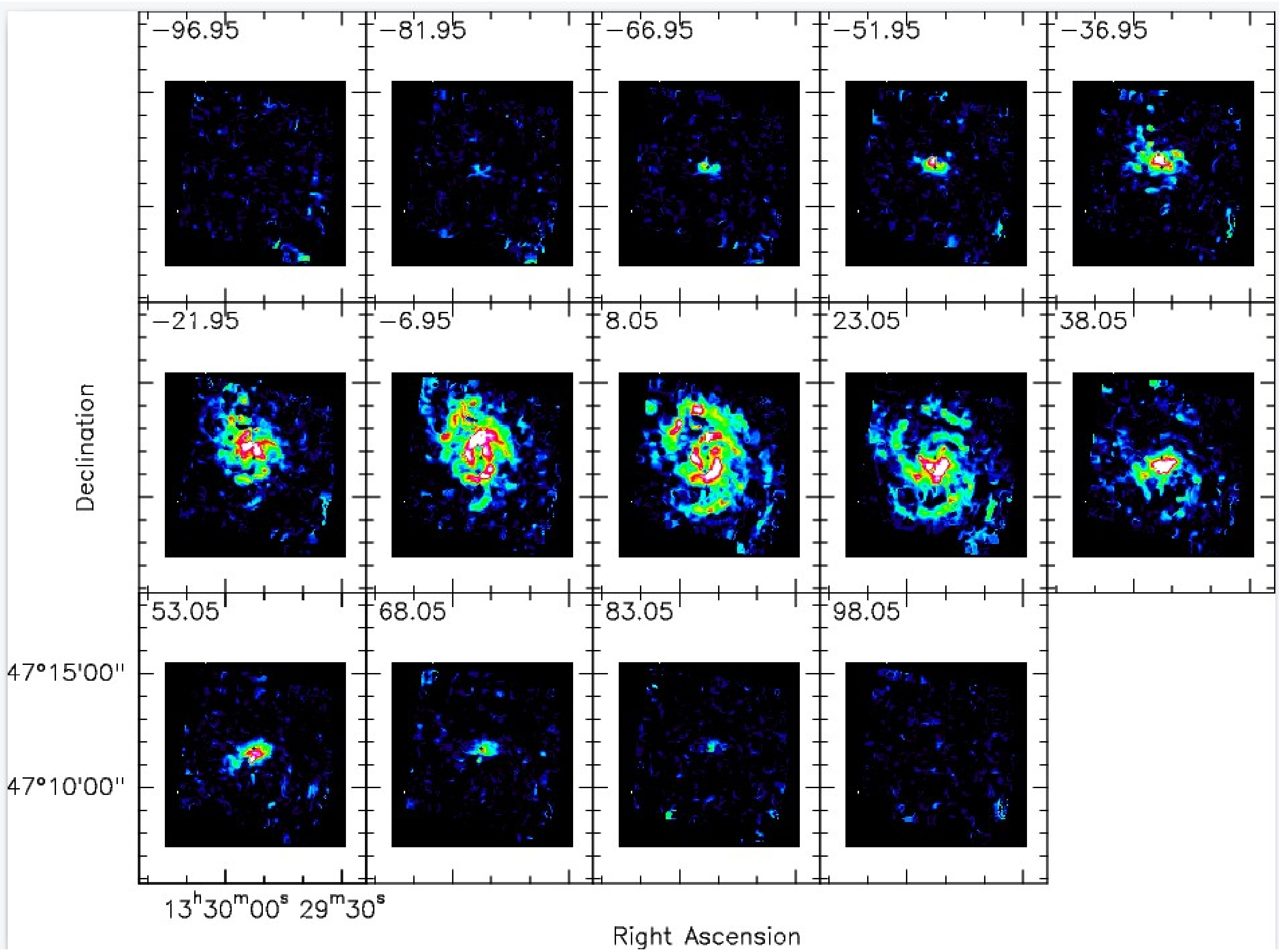


M51 CII upGREAT
center
co
cii
full vel. range 220 km/s
color vel. range 10km/s
northern_arm
southern_arm
K
km/s
^{12}CO(1-0) [K km/s]
[CII] [K km/s]

Further steps

- **Recenter the spectra to remove the effect of galaxy rotation**



- **Study the correlation between HI, CO and CII for individual velocity segments and different regions of the galaxy with the goal to segment different phases of the spiral arms in velocity.**

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Thank you for your attention

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