PROCESSING AND VISUALIZING 3D INFRARED DATA
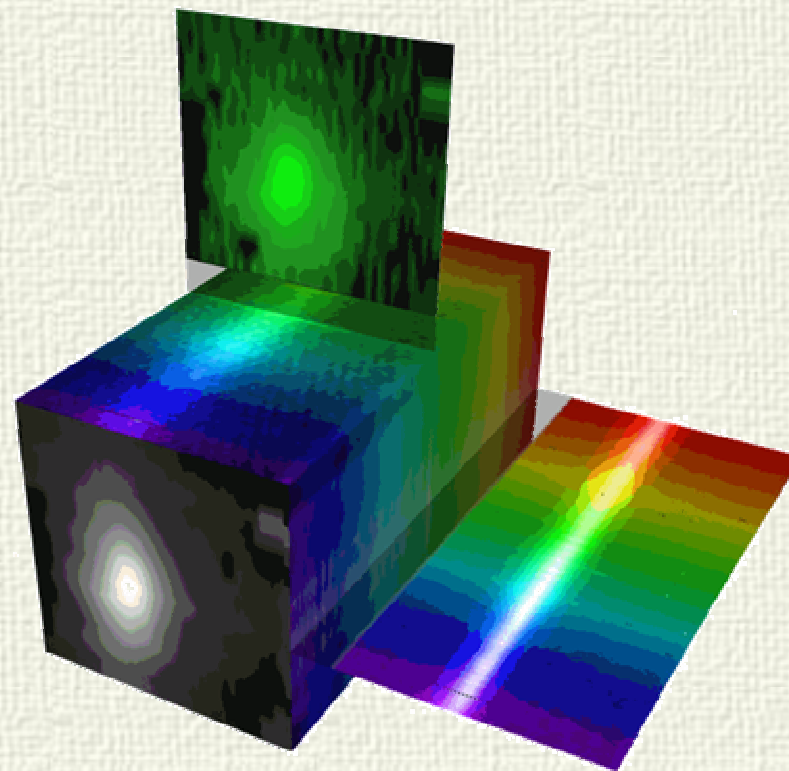
some ideas, a few tools and an example of application

Giovanni Cresci (MPE)
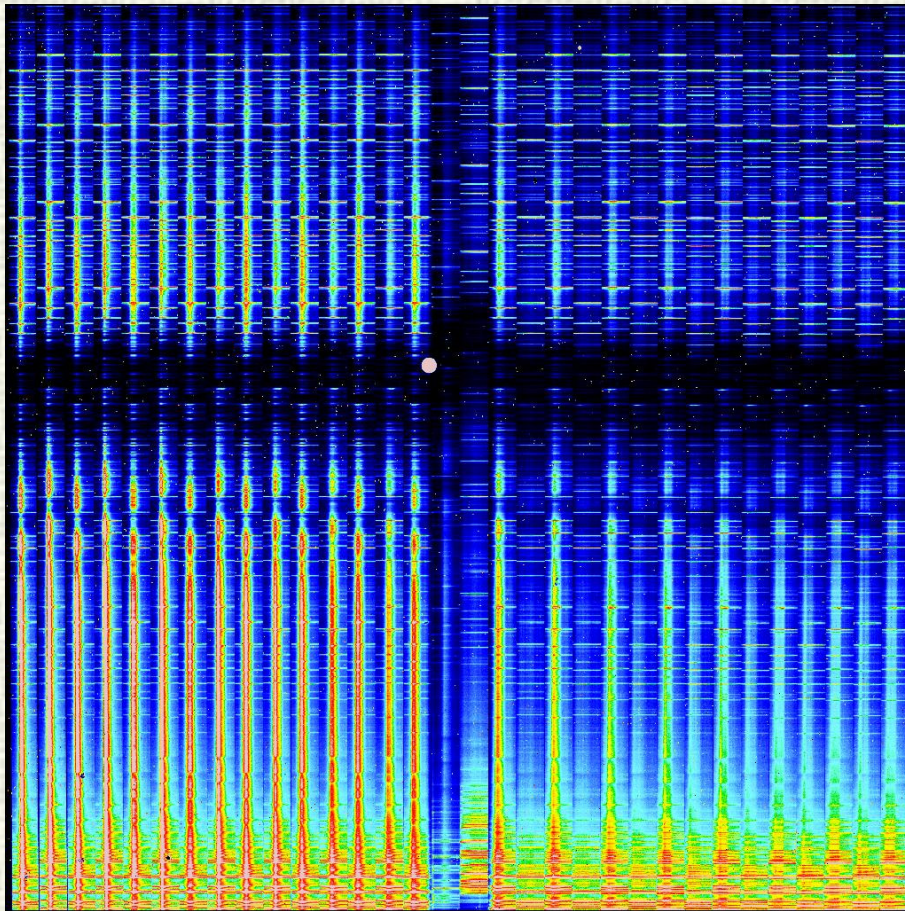**Ric Davies (MPE)**
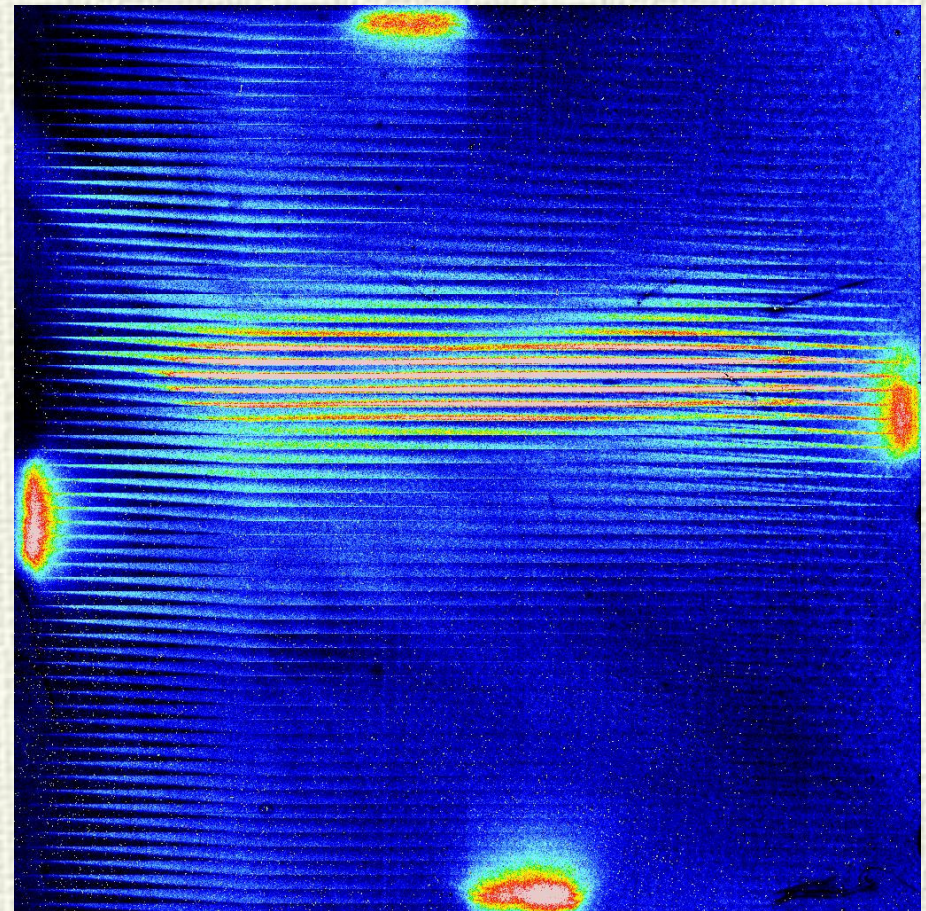
and the SINS/SINFONI team

MPE

3D2008 – Garching – 12/06/08

First step: Raw Data

Useful if raw frames are human-readable: you don't have to wait until end of a long exposure + data reduction to see what might be there:

SINFONI – image slicer

lenslets - OSIRIS

... which is easier to intuitively understand?

Data processing: The pipeline

"*One size fits all*"
doesn't work to get the best of the data:
the reduction needs
to be tailored to the data

Pipelines are often a monolithic '**black box**':

- users don't know how different parameters affect processed data
- no way of checking intermediate stages

It helps if the pipeline is **modular**:

- users can exchange modules if they think they have a better version
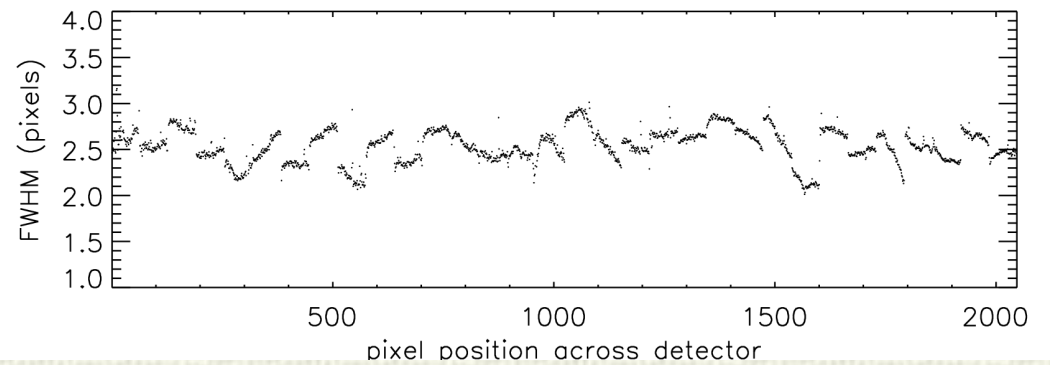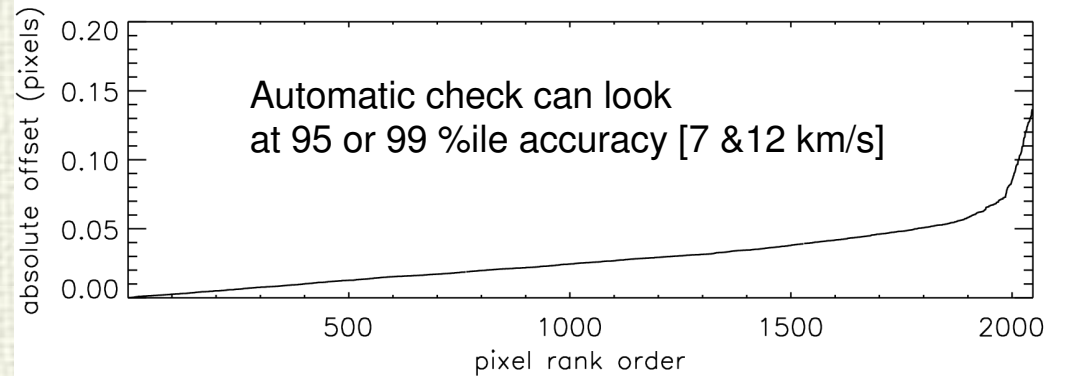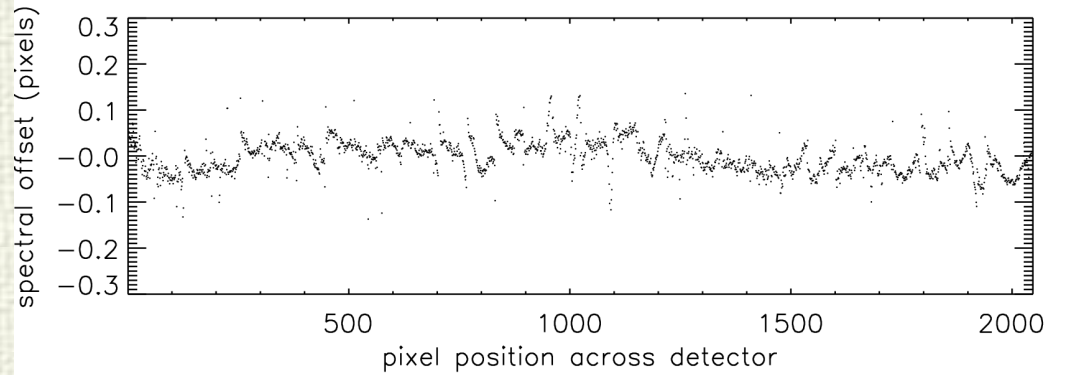- they can look at output of individual steps to see the impact

This is the philosophy e.g. behind the design of the KMOS DR software

Data processing: Checking the Calibration
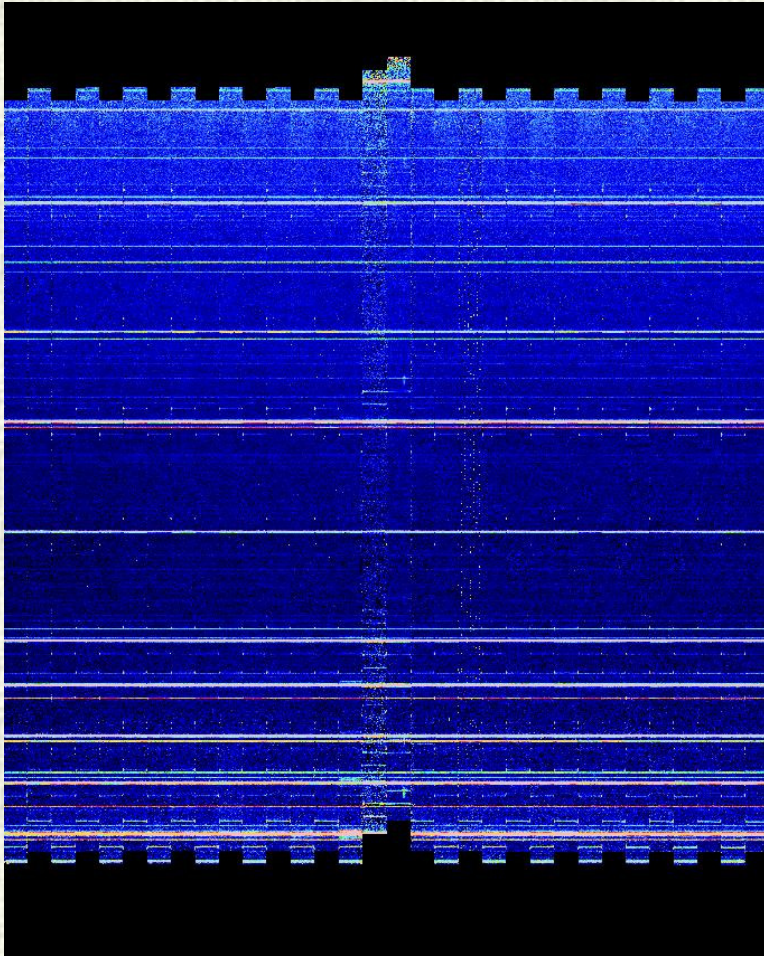
SINFONI resampled arc frame,
with slitlets aligned side-by-side

Spectral offset of a line from mean position

Automatic check can look
at 95 or 99 %ile accuracy [7 &12 km/s]

Data processing: A resampled frame

allows observer to quickly & easily spot source features, since whole
frame is visible simultaneously; easier than searching through a cube.

OH lines
horizontal

NGC4945

object
continuum
trace vertical

object
emission
lines
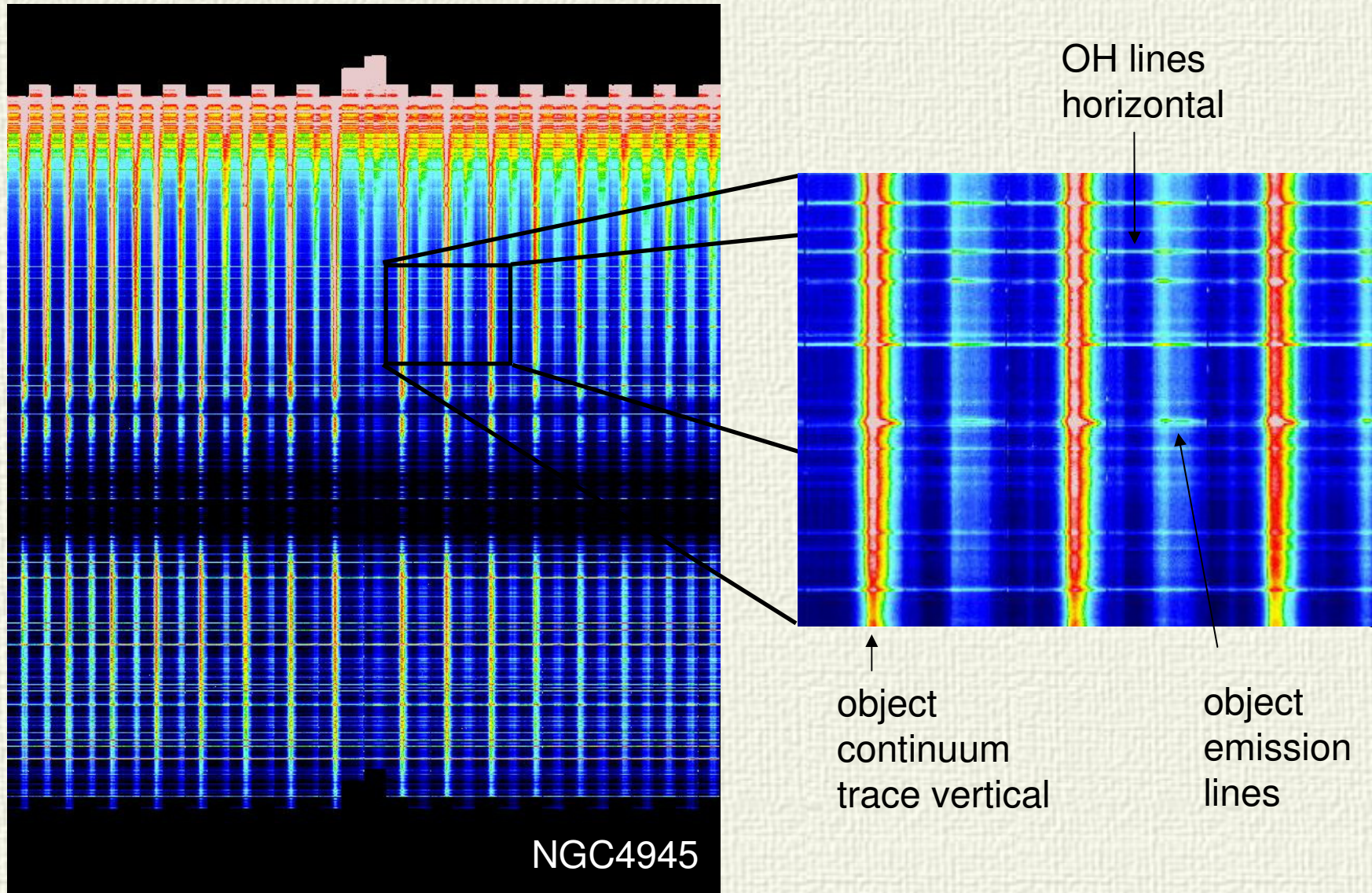
Creating the cube: Interpolation

Standard view:
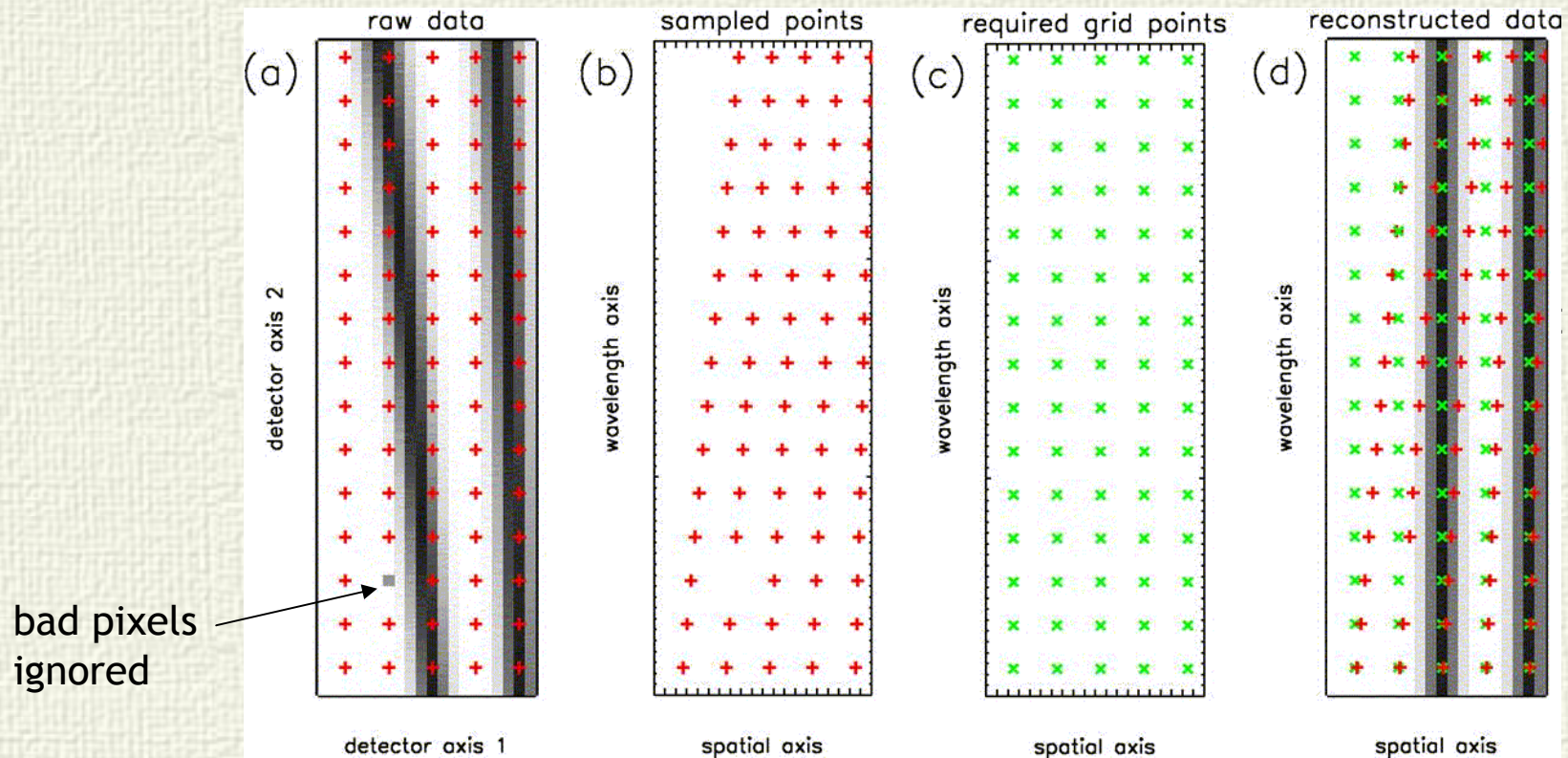create mathematical functions (e.g. polynomials) which enable one to correct spectral & spatial curvature on the detector. However many steps required, correlated noise, bad pixel growth …

Alternative view:
create look-up tables which associate each measured value with its spectral & spatial position in the final (reconstructed) frame

bad pixels ignored

Creating the cube: A single interpolation in 3D

- you can combine frames during interpolation
- choose sampling of reconstructed data (e.g. to match another instrument)
- smooth data during reconstruction (e.g. if data is really noisy)
- etc…

- various methods applicable:

'**nearest neighbour**' (zero order) – no interpolation actually needed; noise properties of raw data are preserved. Perhaps a good option for really faint sources, if some compromise on spatial/spectral exactness is acceptable.

'**linear**' (1st order) – e.g. kriging (a standard method in geophysics), which is an 'optimal linear interpolator', in the sense that it yields the smallest uncertainty on the interpolated point. Makes use of partial correlation between nearby pixels (i.e. PSF information); uncertainties are provided by default.

'**quadratic**' (2nd order) – e.g. Modified Shepard's method. performs quadratic interpolation from 15-20 data points within a specified radius.
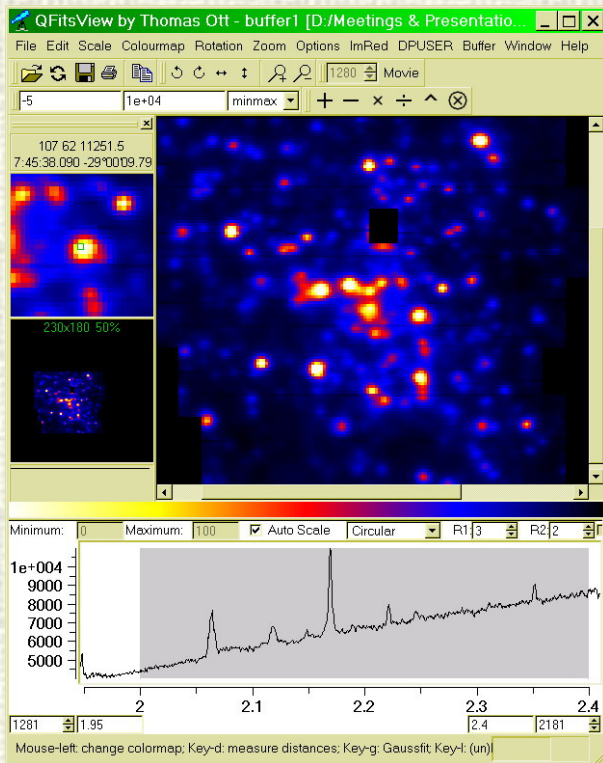
The principle was tested on NACO prism data; will next be attempted on SINFONI data to be implemented for KMOS
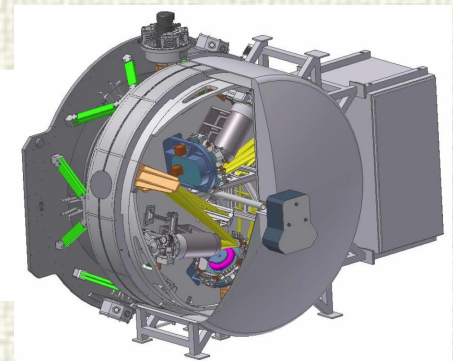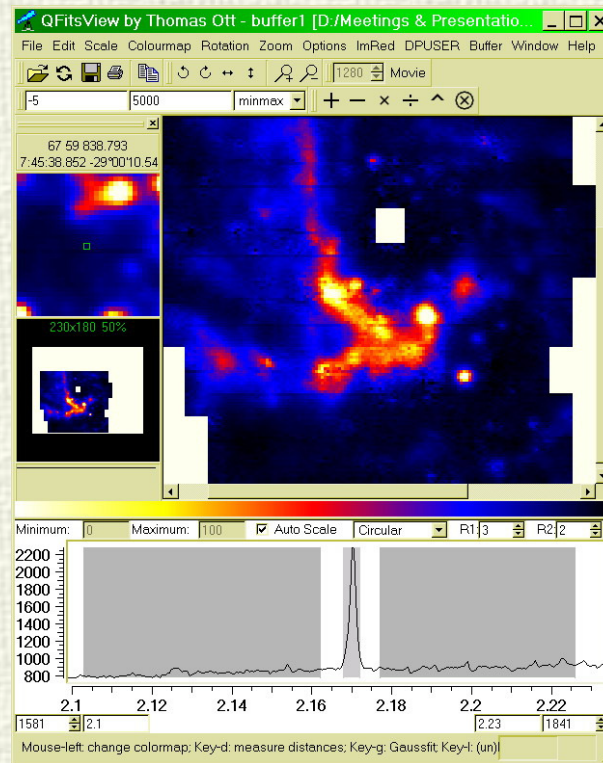
Visualizing the reduced cube: QFitsView
(by Thomas Ott, MPE)

A great tool that allows to visualize and analyze any standard fits data which has a cartesian coordinate grid. **New release available since yesterday!**
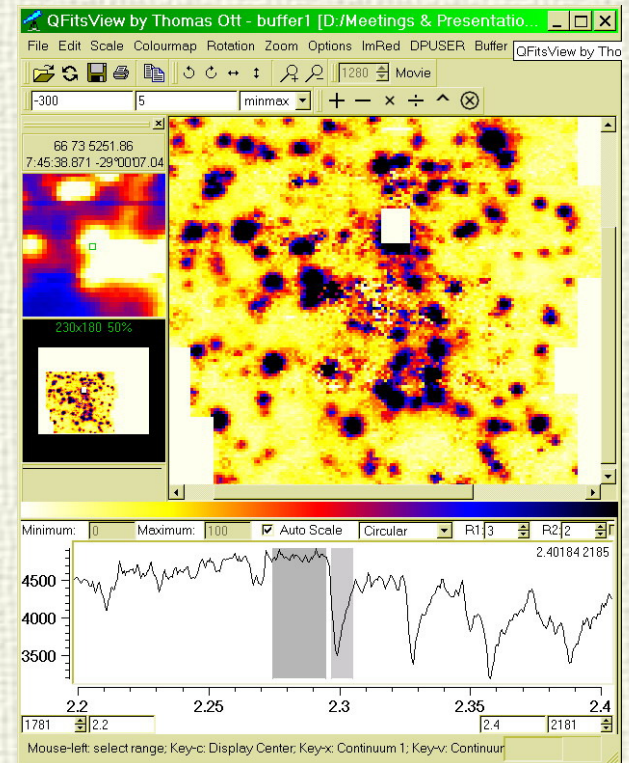
E.g. 400MB mosaic of the Galactic Center

Integrated flux   Bry emission line map   CO2-0 absorption map

QFitsview available from: http://www.mpe.mpg.de/~ott/QFitsView/

Emission Line Extraction: flux, velocity, dispersion

1. Moments

☺ quick & easy
☺ copes with arbitrary line profiles in a consistent way
😐 works well for high signal-to-noise
☹ strongly affected by outliers
☹ results can depend on range within which moments are calculated

<div style="text-align: right">PREFERRED BY RADIO/MM COMMUNITY</div>

2. Gaussian Fitting

☺ quick & easy
☺ less affected by outliers
☹ sometimes tries to fit a single noise spike
☹ an a priori line profile assumed

3. Convolution of unresolved line profile with a Gaussian

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☹ slow, particularly when calculating uncertainties
☺ robust against noise spikes (which can easily be rejected)
☺ dispersion is intrinsic (i.e. instrumental broadening is by definition taken out)
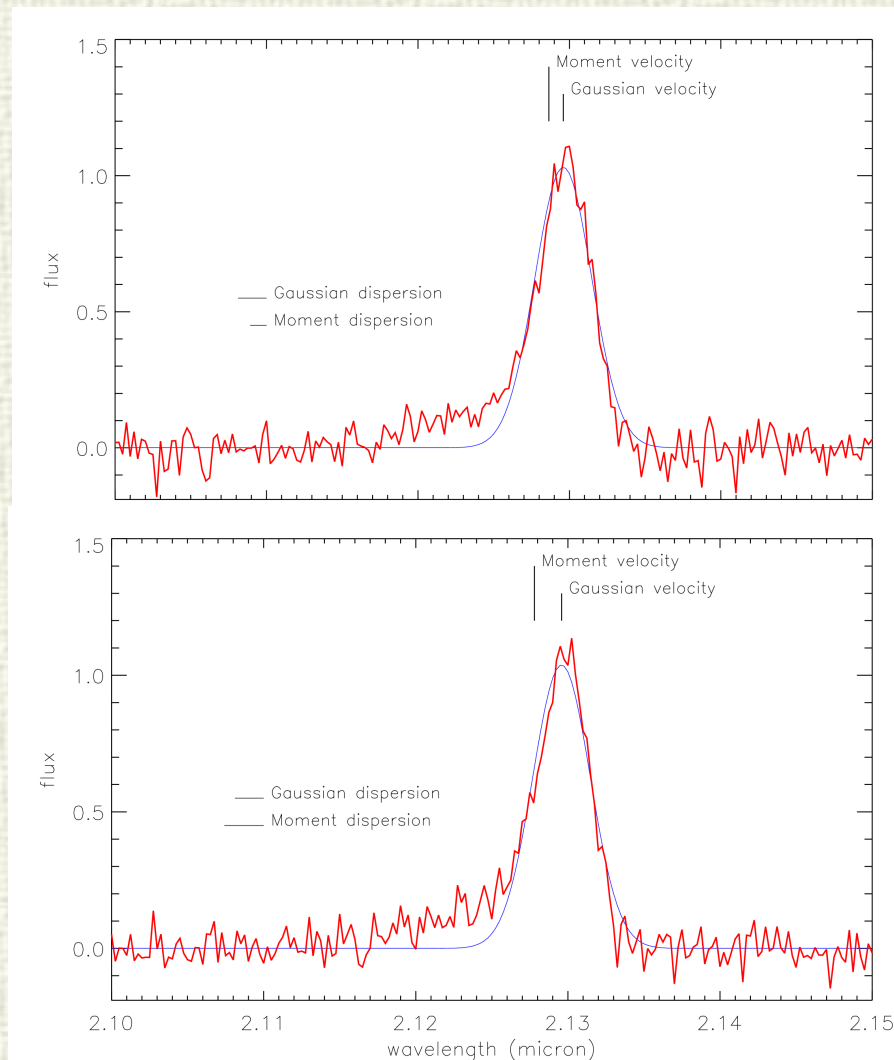
Emission Line Extraction: what are you actually measuring?

Moments: centroid position of full profile
Gaussian & Convolution: position of dominant component

Gaussian (fitting or convolution) is consistent each time, but misses the red tail

Moments are affected by noise – need a threshold clipping, but this may also clip off parts of the line profile

There is no better solution: it depends on what you want to measure!

Emission Line Extraction: LINEFIT

- Flux, velocity, & dispersion maps are calculated via moments &
    convolution of unresolved line profile
- Error maps are generated based on derived or input error cube
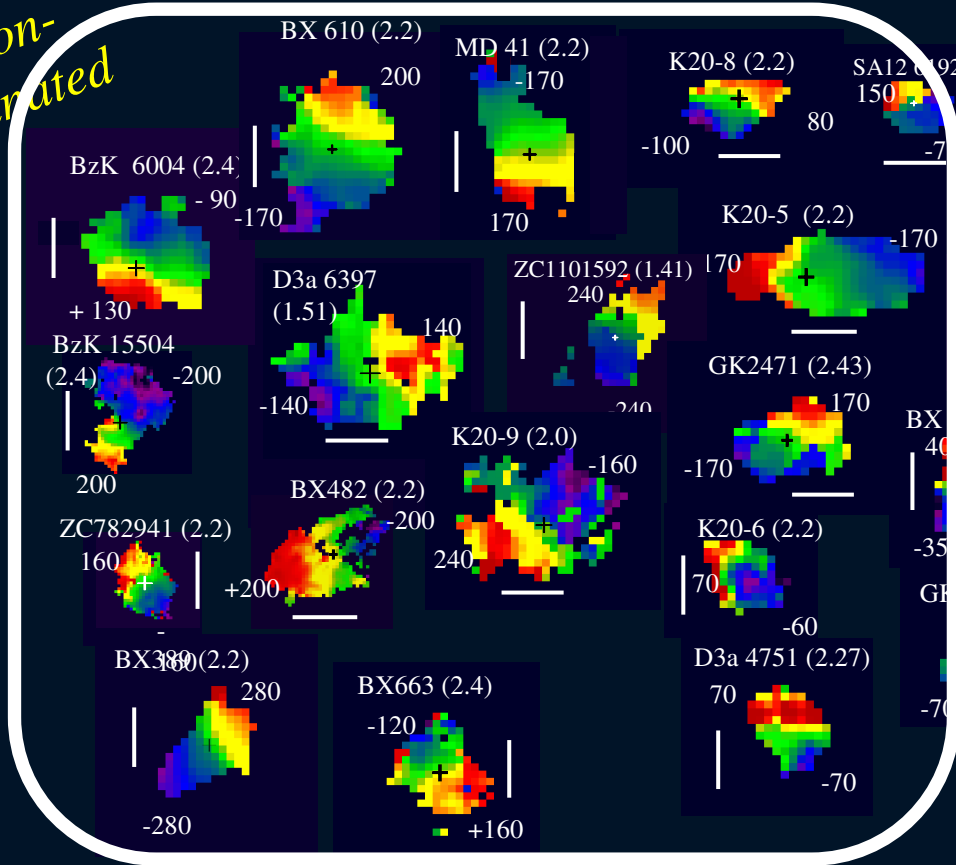   using Monte Carlo techniques
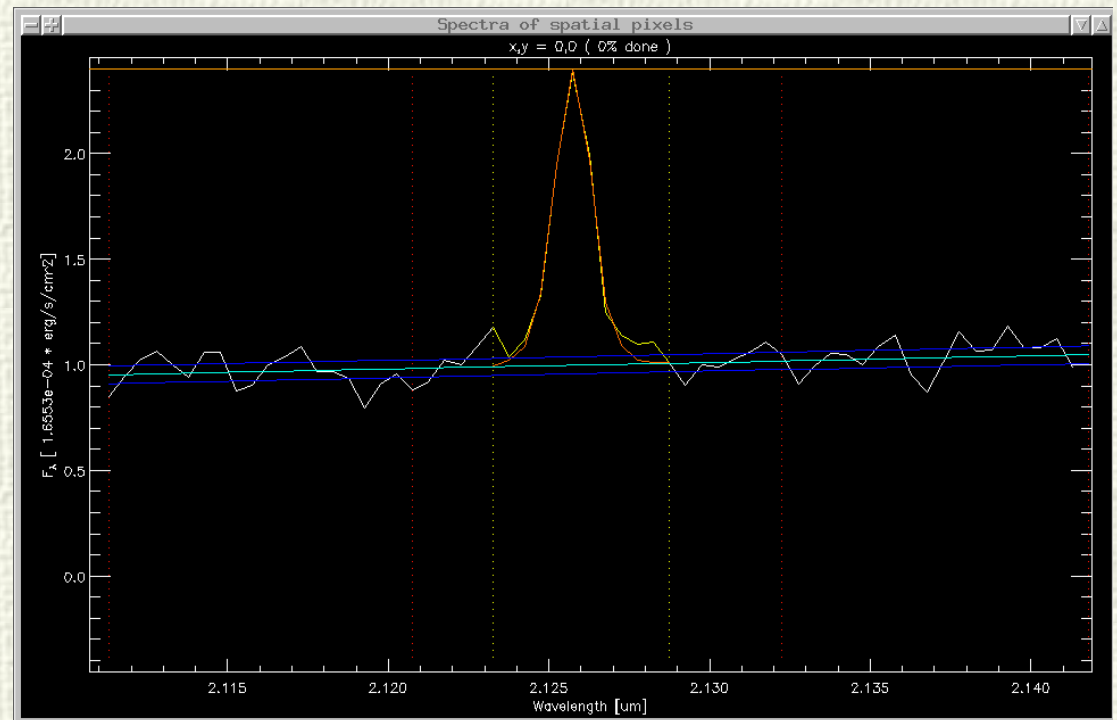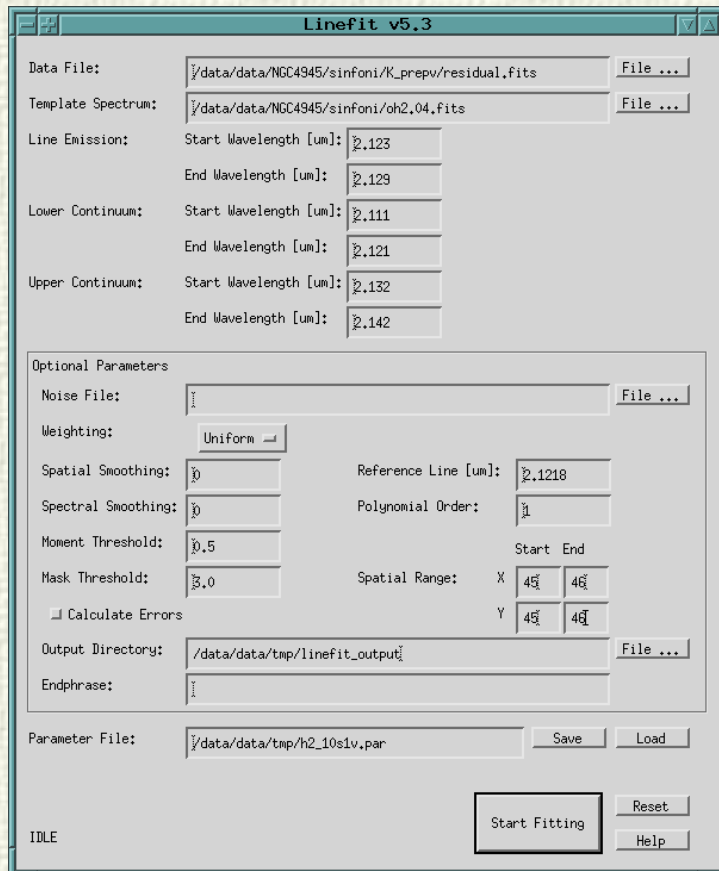
Davies et al. in preparation

Modeling the kinematics: an example from SINS
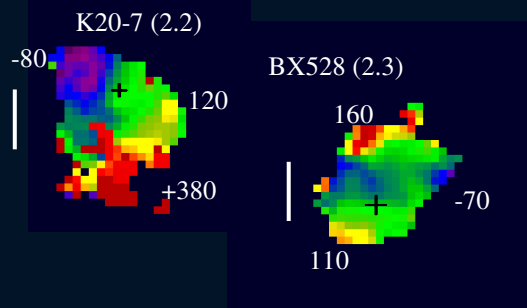

rotation-dominated

dispersion dominated

merger

1" (8 kpc)

THE SINS SURVEY

An example: modeling rotating disks at z~2

⇨ We want to measure automatically (i.e. robustly and fast) the main dynamical parameters of the SINS galaxies with prominent rotation signatures using the full dynamical information from IFU:

- Rotation centre, Scale length, Inclination and Position angle
- Total dynamical mass
- σ_0, the dispersion term not due to rotation

⇨ To do that we search the disks model that better reproduces the features observed, with a χ^2 minimization using a ***Genetic Algorithm*** simulating evolution by natural selection:

- No good initial guesses needed
- Smart way to converge in a reasonable time without mapping the whole parameter space

- Efficient in finding the true absolute minimum even in a very complex topology
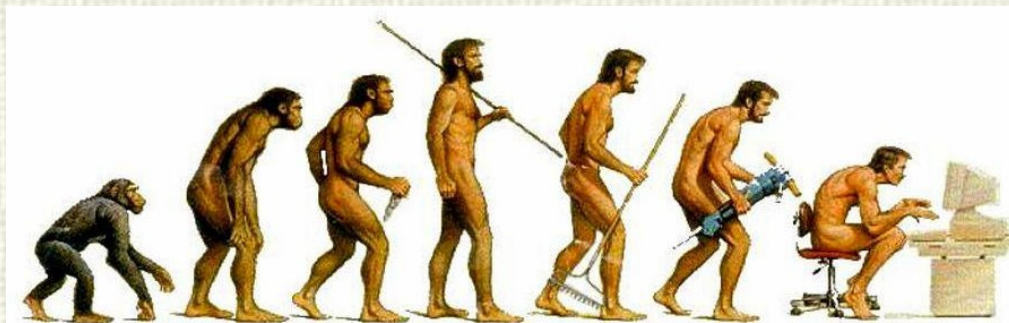
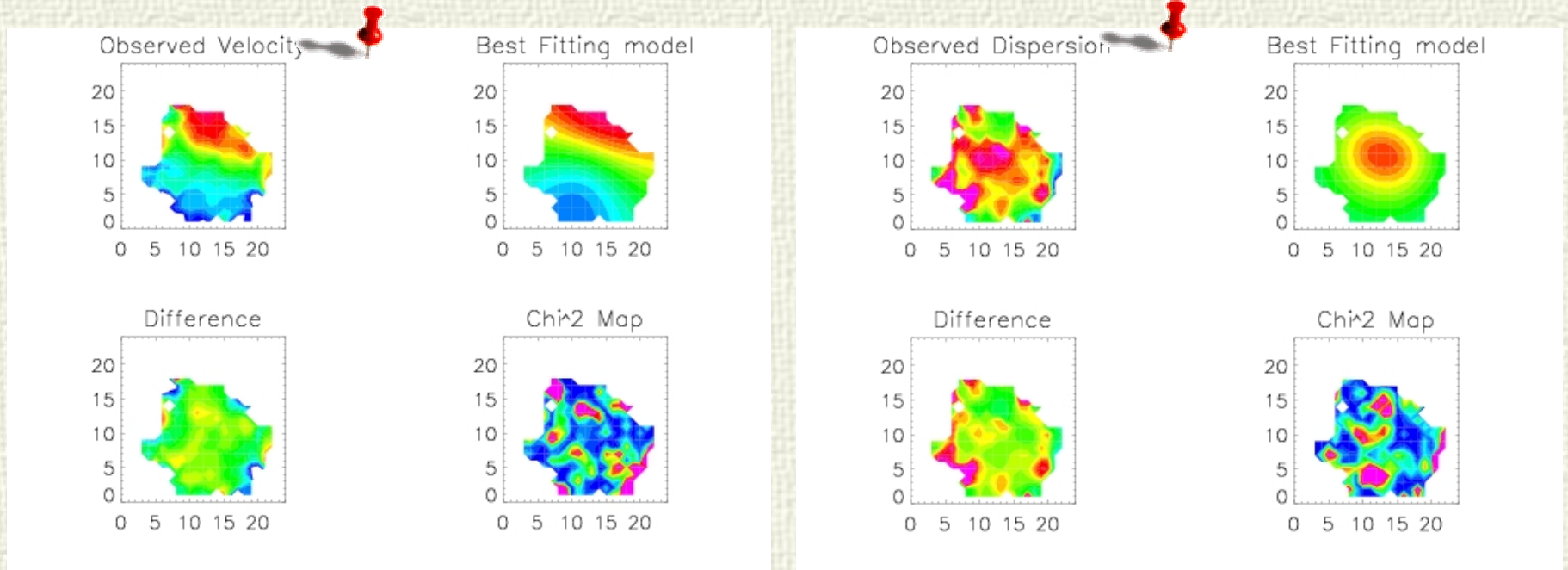# Genetic fitting of the SINS galaxies

- An exponential disk model is compared with both the observed Velocity and Dispersion maps of the Hα line emission via Genetic fitting

- The disk model is *convolved* with the observed beam, reduced to the *pixel sampling* of the observations and compared with the observed maps
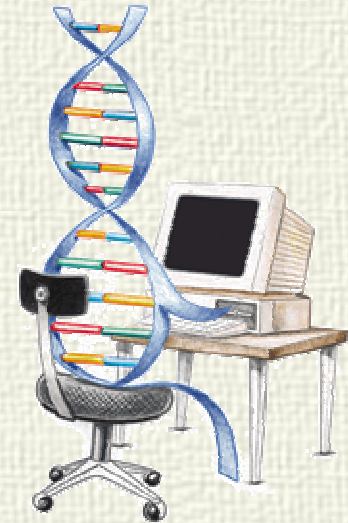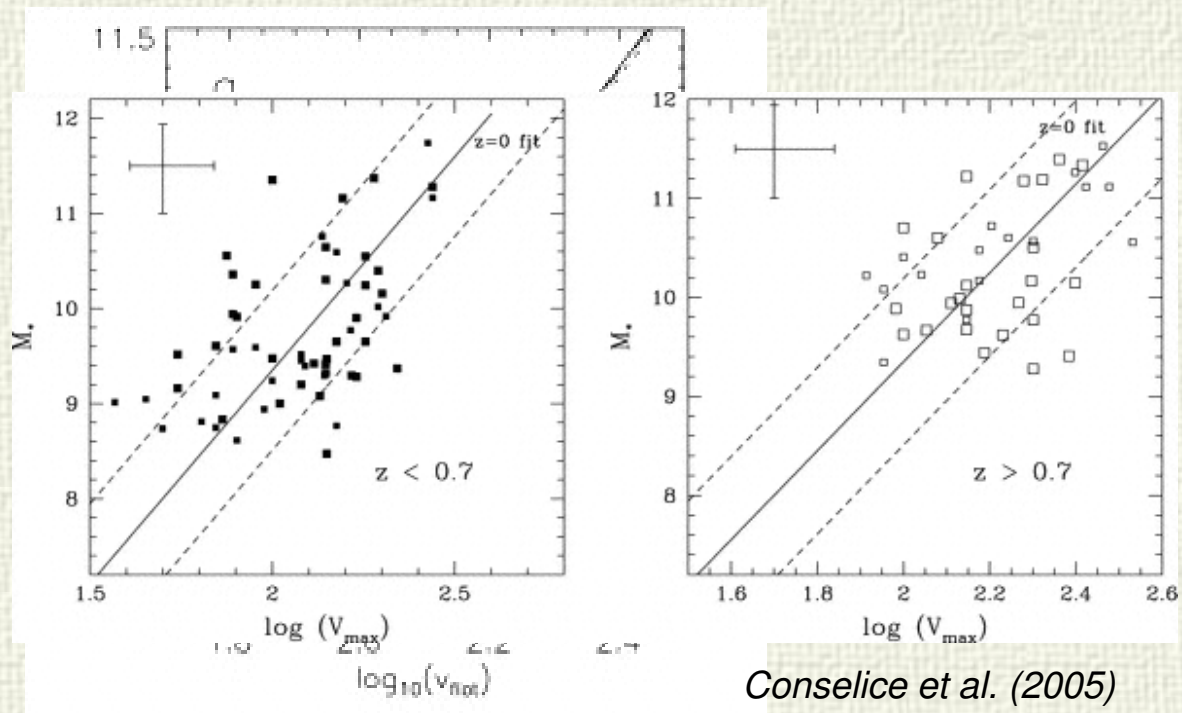
BX610 *(z=2.211)*

The Tully-Fisher relation

The T-F relation correlates the absolute magnitude (or stellar mass) of disk galaxies with their maximum rotational velocity. Therefore it directly links the mass of the dark halo with the stellar mass of its disks.


Bell & de Jong (2001)

Conselice et al. (2005)

• The limited data at higher redshift (e.g. Conselice et al. 05; Kassin et al. 07) suggest that the zero-point of the relation evolves only modestly in luminosity at higher redshift, and that no evolution is found for the stellar mass TF relation up to z=1.2

An example: The z~2.5 Tully-Fisher relation

Thanks to SINFONI 3D data we can push the study of the Tully-Fisher relation evolution **up to z~2.5**, placing observational constraints on the assembly history of the halos and stellar masses

- z~1.5
- z~2.5
- Simulated
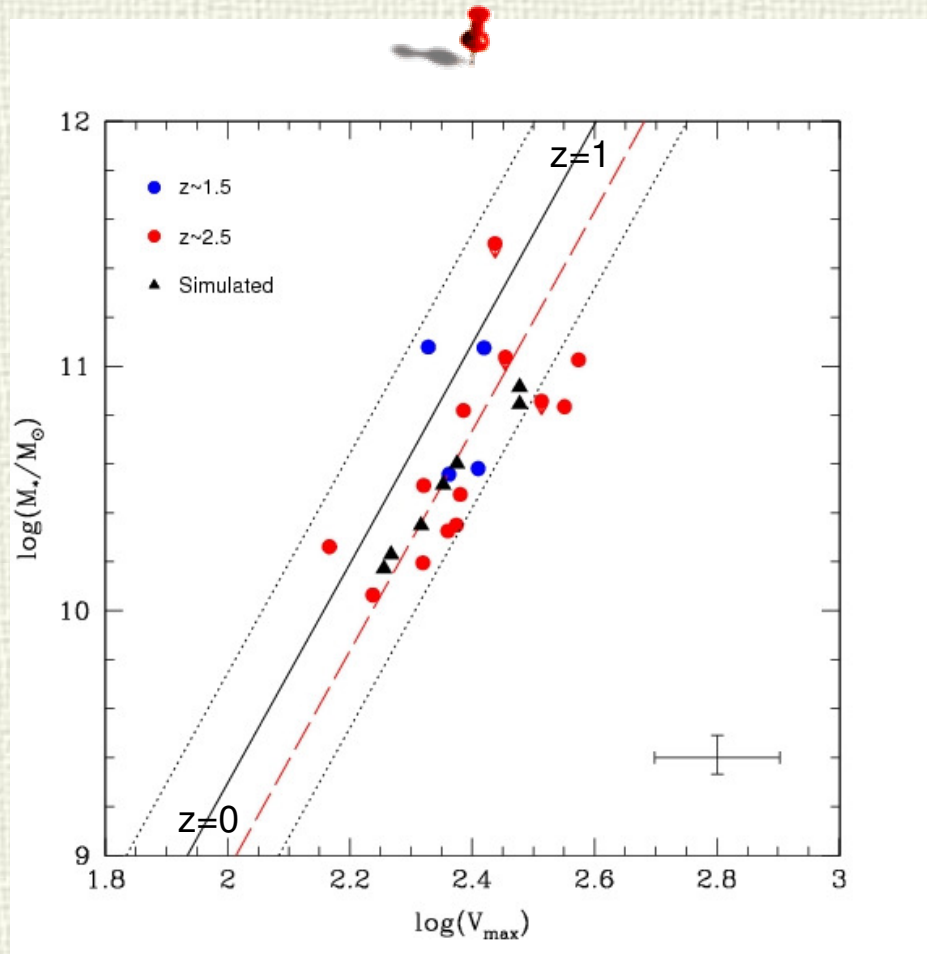
• We observe a remarkably low scatter compared to z~1

• The slope seems not to evolve since z=0, but a shift of the zero point of the relation at z=2.5 is detected (a factor ~1.25 higher V_{max} for a $M=6\cdot10^{10}$ M_* galaxy)

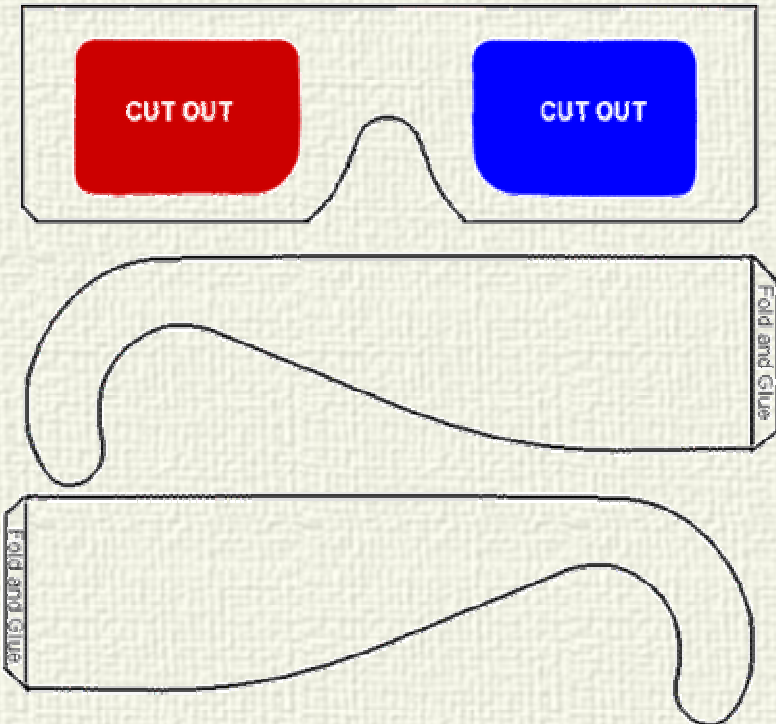At those redshifts different models predict a zero-point shift of the relation, as observed, e.g.:
- Sommer-Larsen et al. 03, 08
- Somerville et al. 2008

Cresci et al. 2008

Summary

... but if you are still really desperate...

• IFU 3D data are providing a great wealth of information, but require ad hoc tools

• Pipeline processing: modular pipelines, human readable data and step-by-step checking and diagnosis allow to exploit the best from the data and avoid time wasting

• Visualizing and extracting information from your cube: many nice tools available, but no unique recipe

• An example of application: thanks to 3D data, it is now possible to study and model the dynamics of z~2.5 galaxies

• An evolution of the zero-point of the Tully-Fisher relation is detected at z~2.5

CUT OUT

CUT OUT

Fold and Glue

Fold and Glue

1) Color your glasses with crayons, markers, or paint
2) Cut the pieces out around the outside black lines
3) Cut out the red and blue eyepieces
4) Tape or glue colored cellophane to the back of the glasses to cover the eyeholes. Use red cellophane on the left eyepiece, and blue on the right eyepiece.
5) Fold the flaps on the earpieces and tape or glue to the glasses, like shown below.
6) When the glue's done drying, put on the glasses and explore our web site!

Materials:

tape or glue
scissors
red and blue cellophane

left   right

Attach   Attach