Strongly star-forming galaxies with SALT spectroscopy (and AO)

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Outline

LIRGs with Spectroscopy and Adaptive Optics imaging - a survey in progress

- Sample and observations
- Projects:
  - Star-formation and SF history
  - Metallicities
  - Kinematics
  - Gas inflow/outflows
  - Super Star Clusters

Outline

LIRGs with Spectroscopy and Adaptive Optics imaging - a survey in progress

- Science goals:
  - Evolution of Super Star Clusters
  - Effects of (group) environment on galaxy transformation (cf. Tekola et al. 2012, MNRAS, 419)
  - Metallicities in galaxy interactions
  - Gas inflow/outflow and SF triggering

Processes to study along a merger sequence

- gas spirals → starburst / ULIRG → obscured AGN → QSO → elliptical galaxy

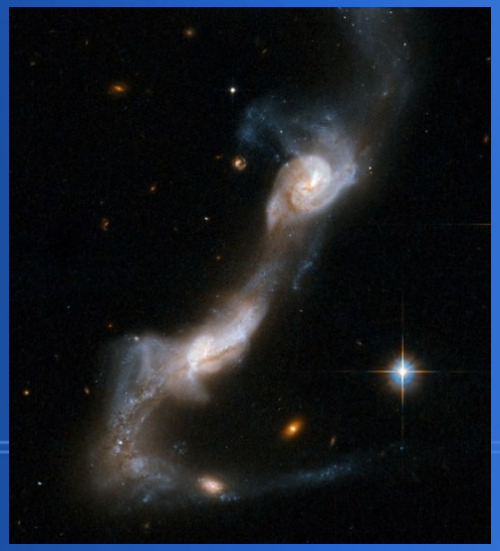
An evolutionary sequence – how is this happening exactly ?

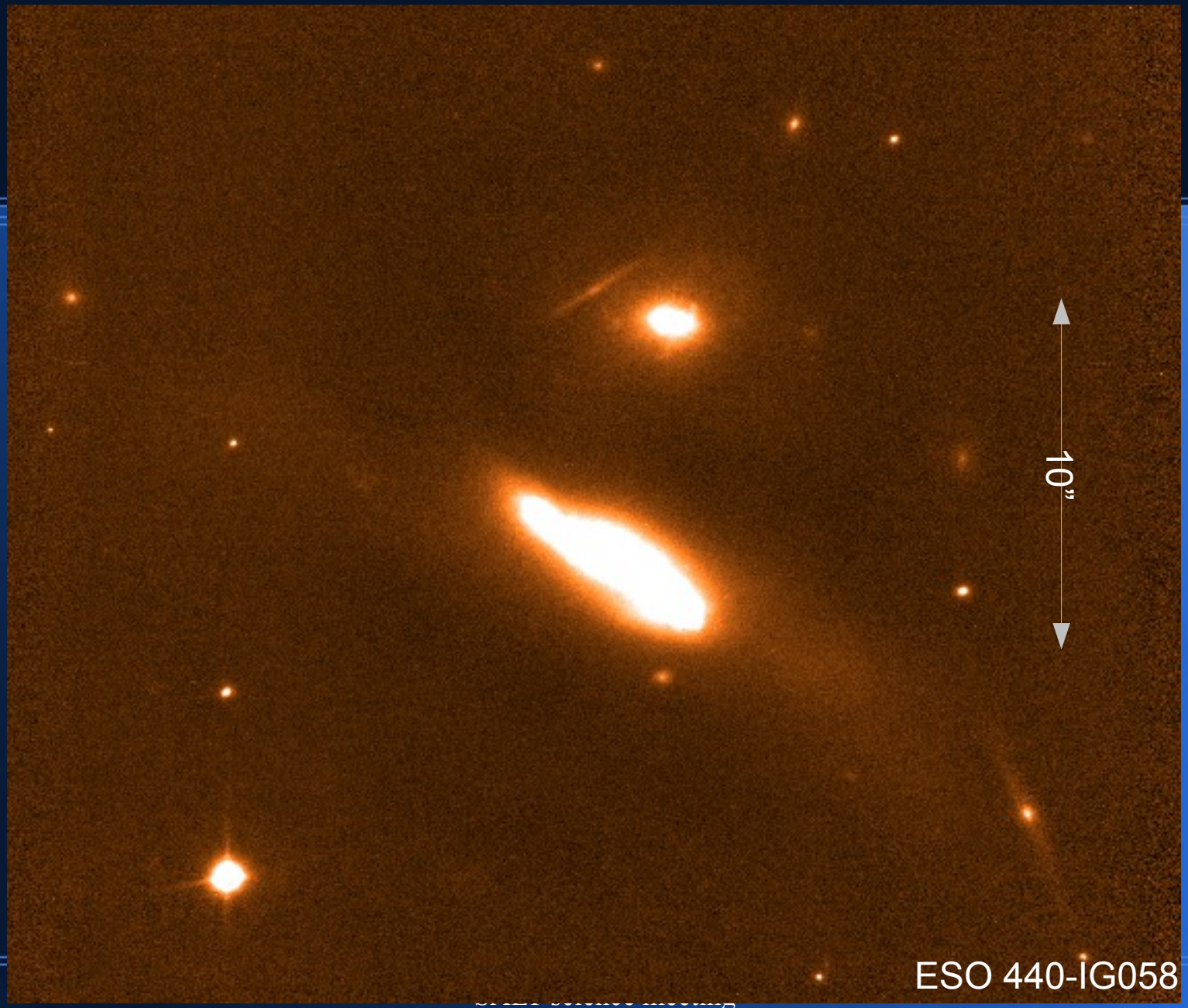
- LIRGs and ULIRGs dominate @ higher-z
- Important processes:

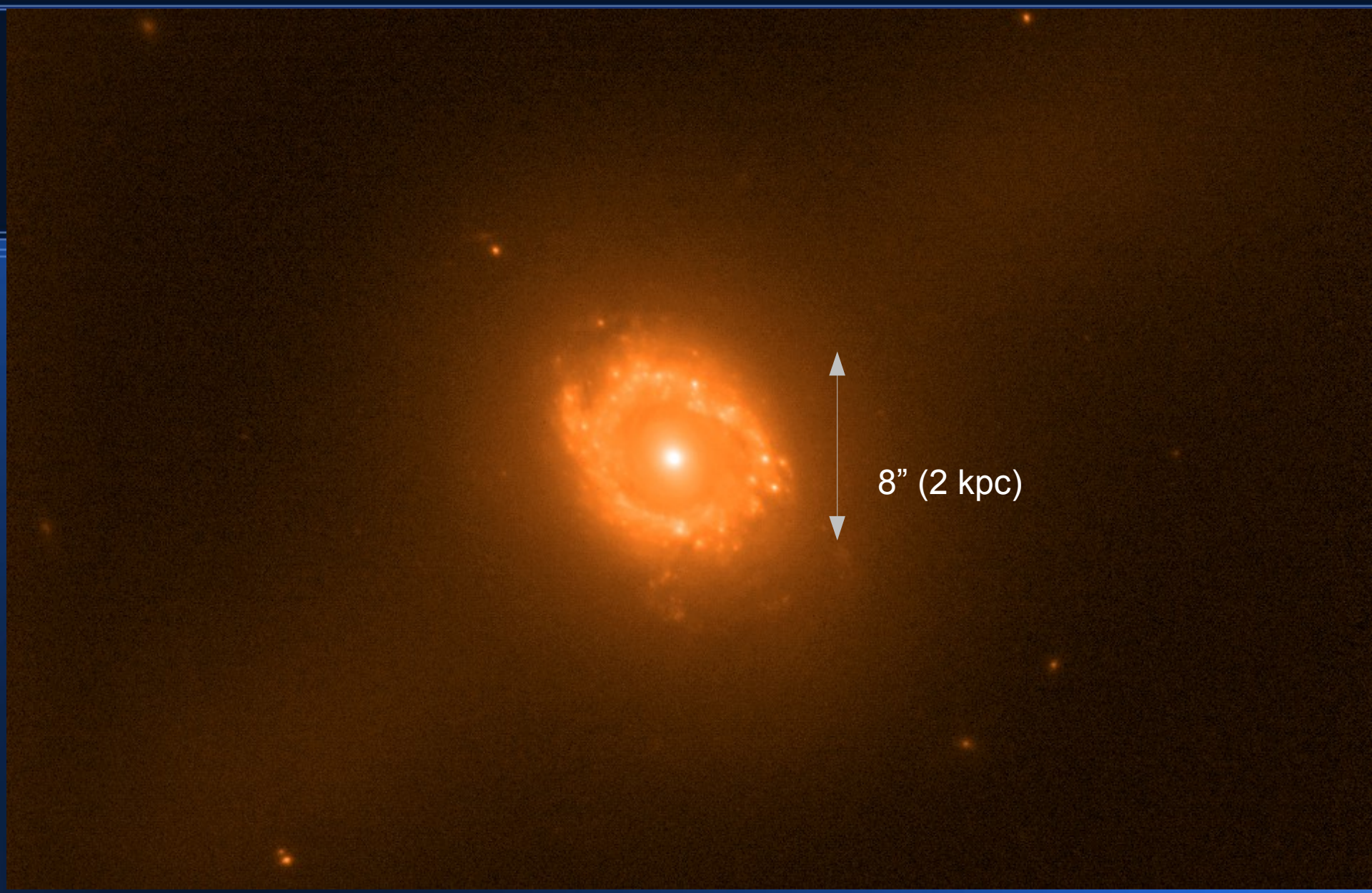
SF triggering - AGN/starburst interplay - feedback: superwinds, gas outflows and inflows

Core data set: AO data of LIRGs

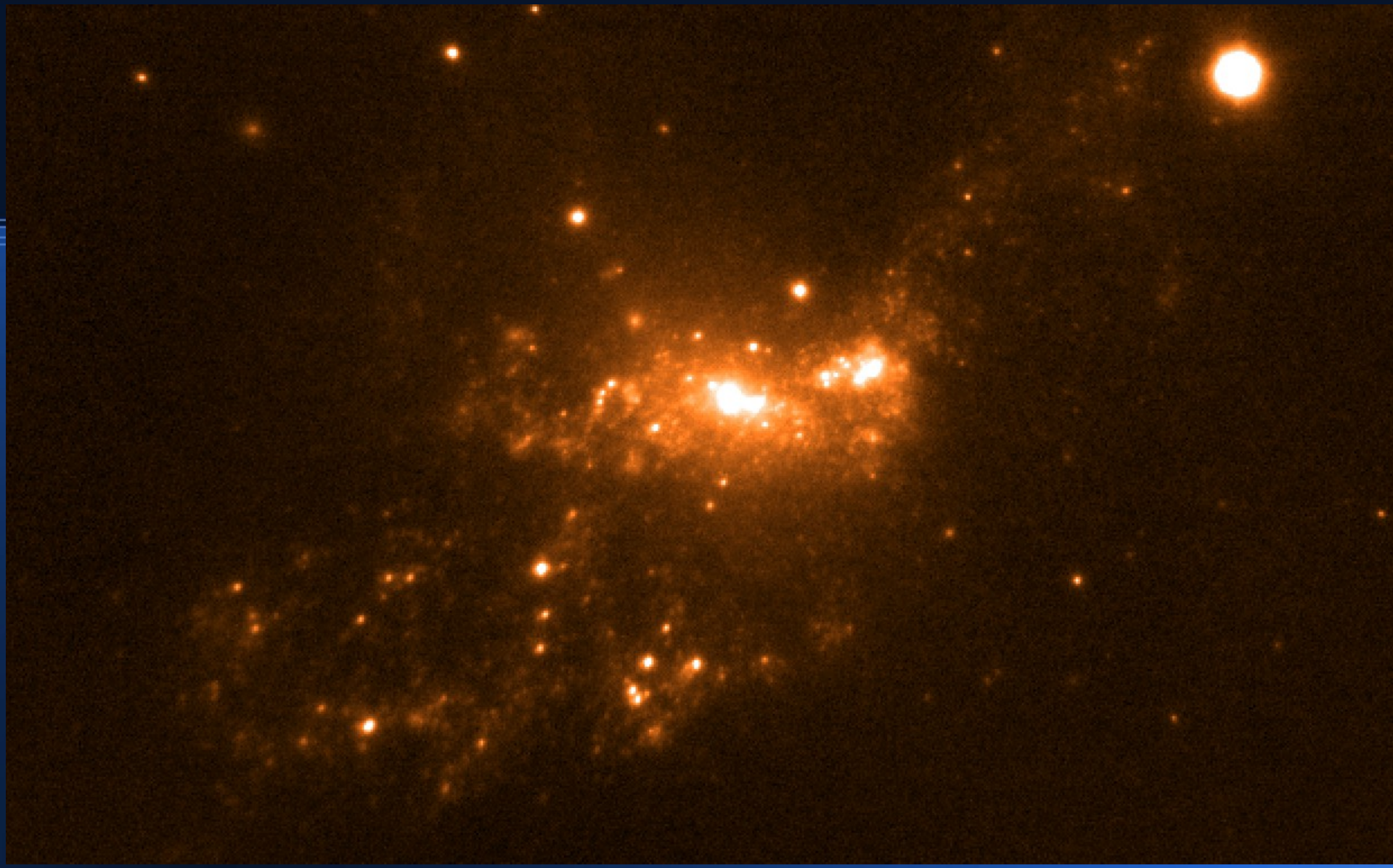
- VLT/NACO and Gemini/Altair NIR **adaptive optics** programs
  - High spatial resolution (~0.1”) K-band images of 40+ LIRGs
    - All southern Sanders et al. objects with log(IR) > 10.8 and d<200 Mpc at RA=0 to 14h and with a suitable AO-ref star.
  - Mostly at 50-120 Mpc, making physical resolutions ~20 to 60 pc
  - Wide range of interaction stages and morphologies
  - Excellent complementary data from HST, Spitzer, Galex, Herschel




10"
ESO 440-IG058



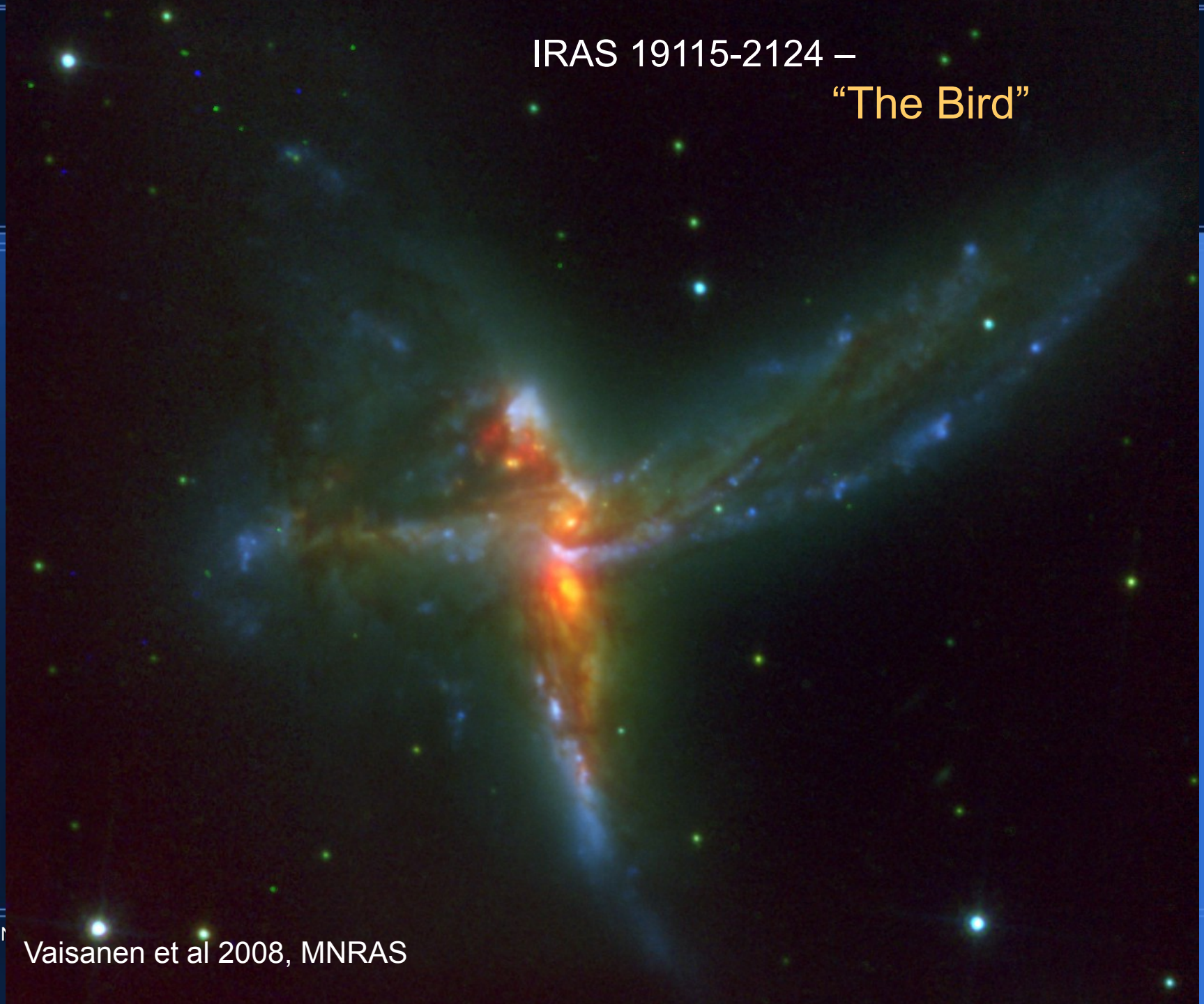
NGC 1819



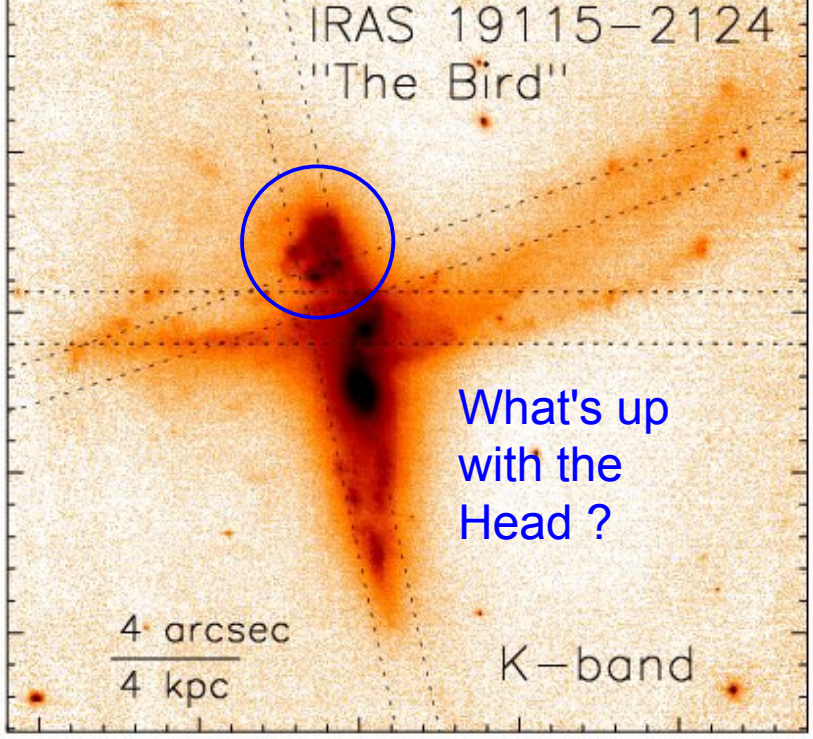
ESO 221-IG008

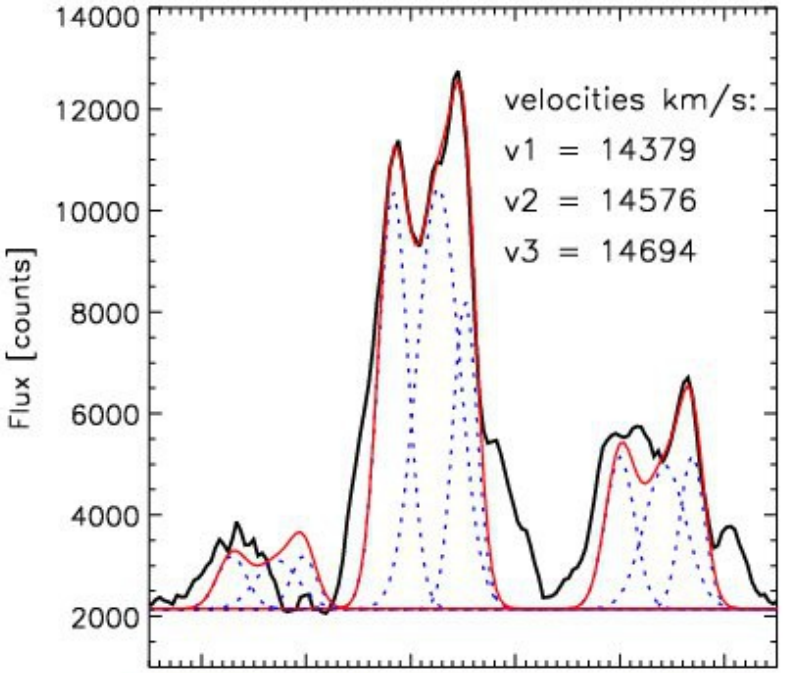
SALT spectroscopic work

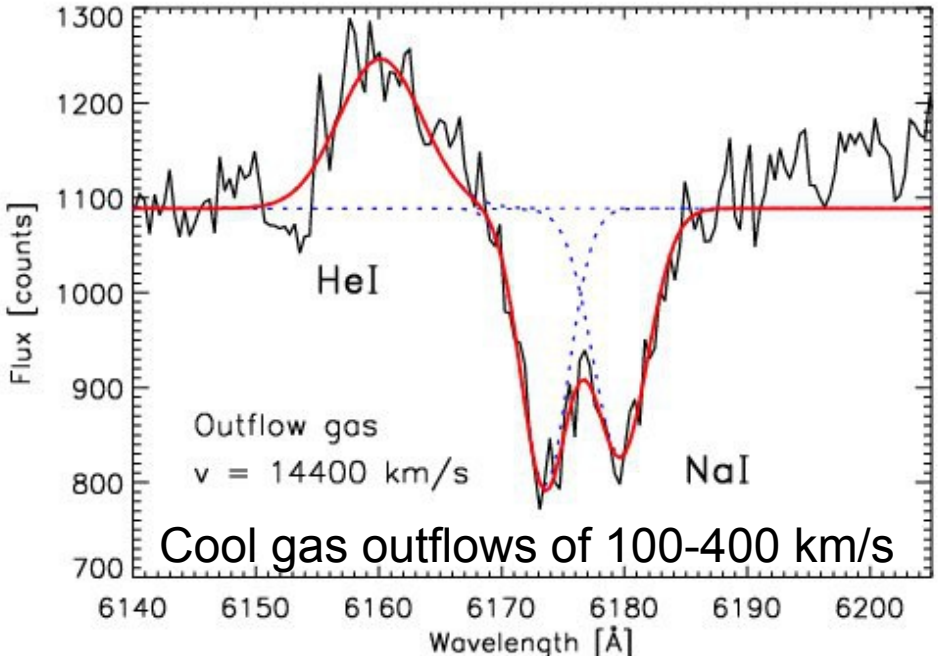
- Ongoing spectral follow-up with SALT (2011-2013). Whole sample with:
  - PG900 LS mode (R~1000) for metallicities, extinctions and SP-fitting
  - PG1800 (R~3000) at H and NaD for kinematics and gas inflows
  - Half dozen targets observed so far (plus late 2006 pilot object)
  - Spectral modelling with UlySS (Koleva et al.) and perhaps Starlight?
  - Kinematics and dynamical masses – helping to piece together history
  - Metallicities and extinctions from spectra help in photometric modelling



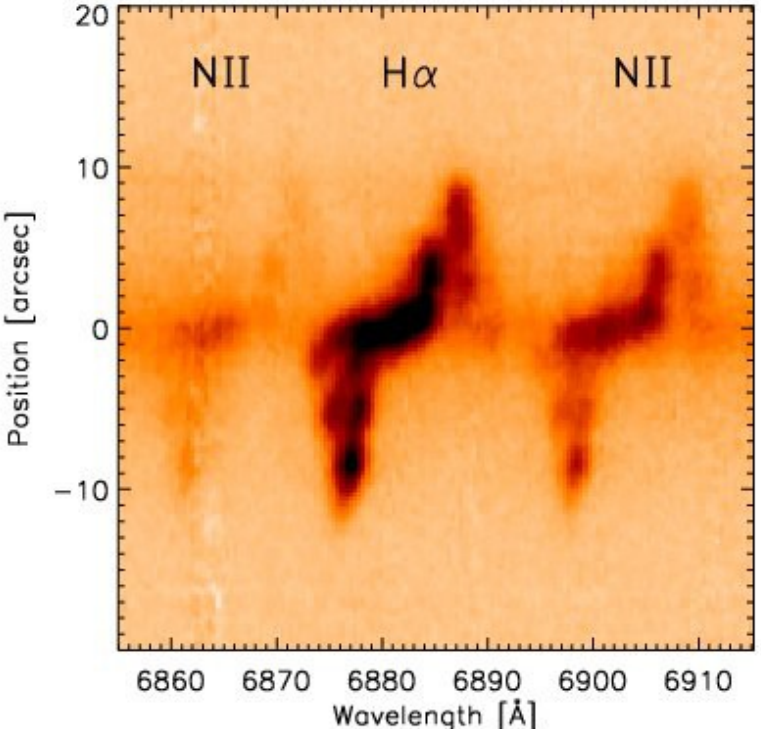
Vaisanen et al 2008, MNRAS







Cool gas outflows of 100-400 km/s

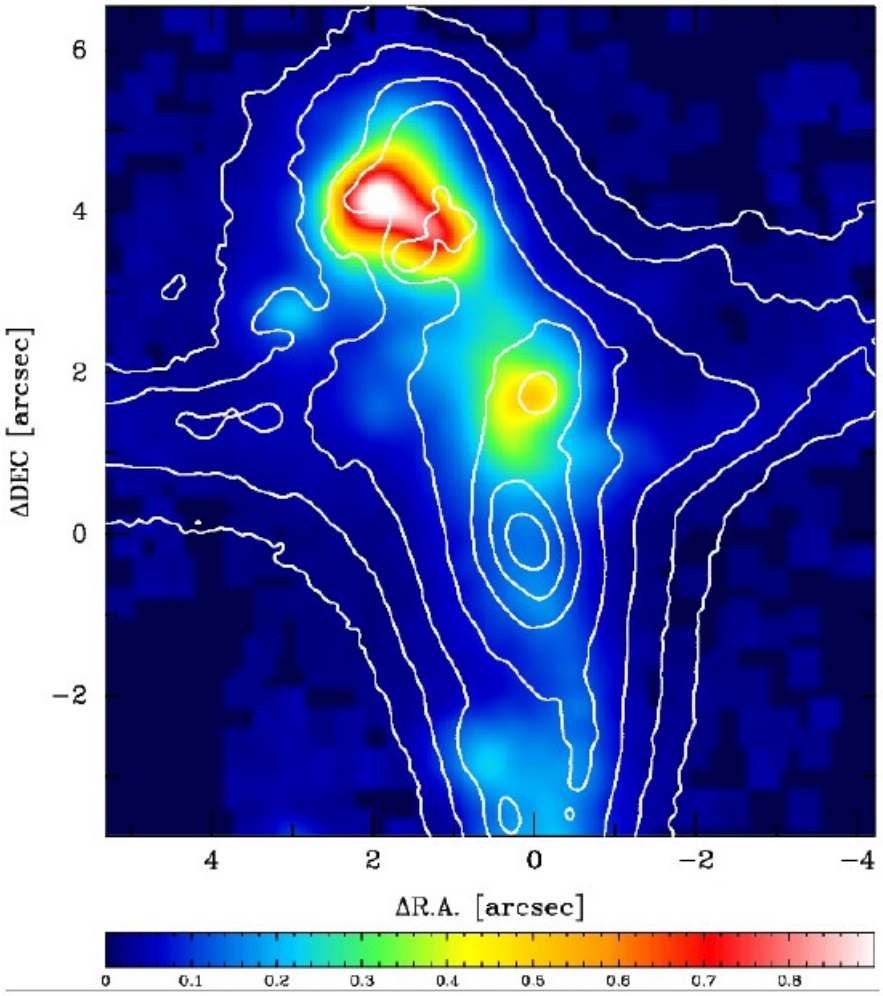


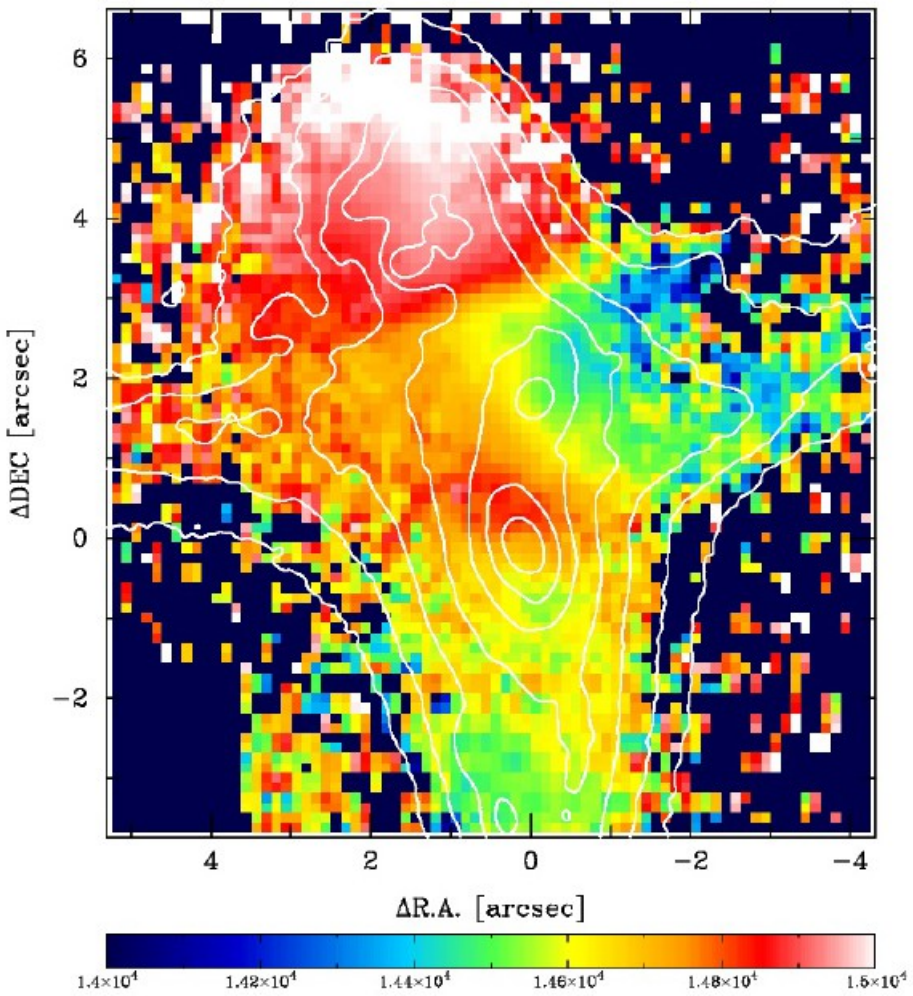
Bird - New data with SINFONI and VISIR

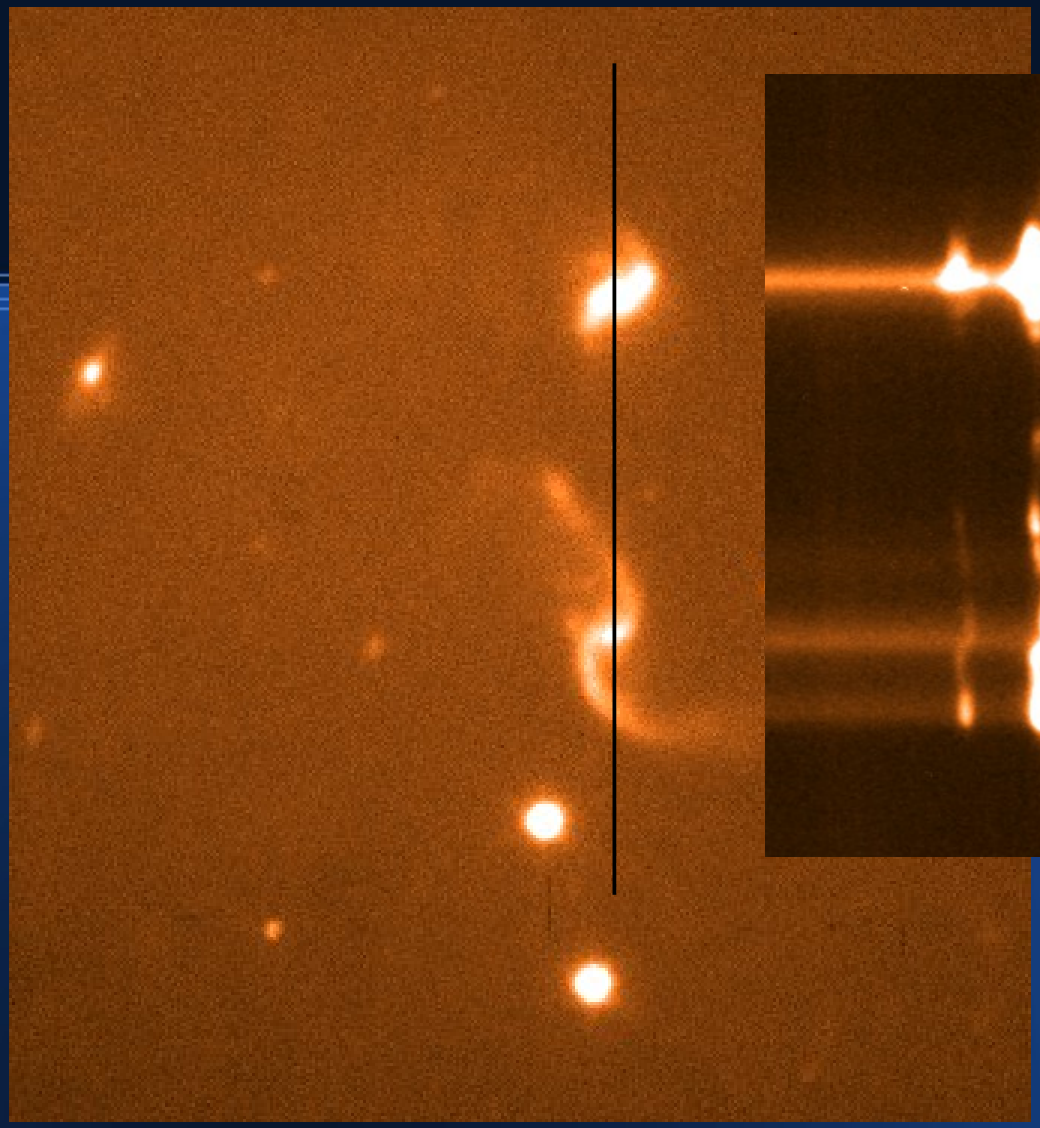
spectacular off-nuclear starburst in the Bird

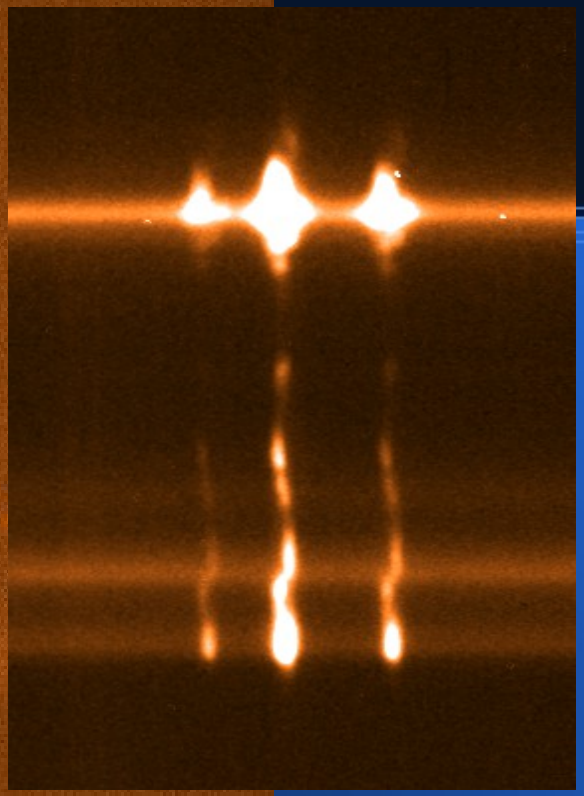
[Vaisanen, Reunanen, Kotilainen, et al. (in prep.)]

Pa α



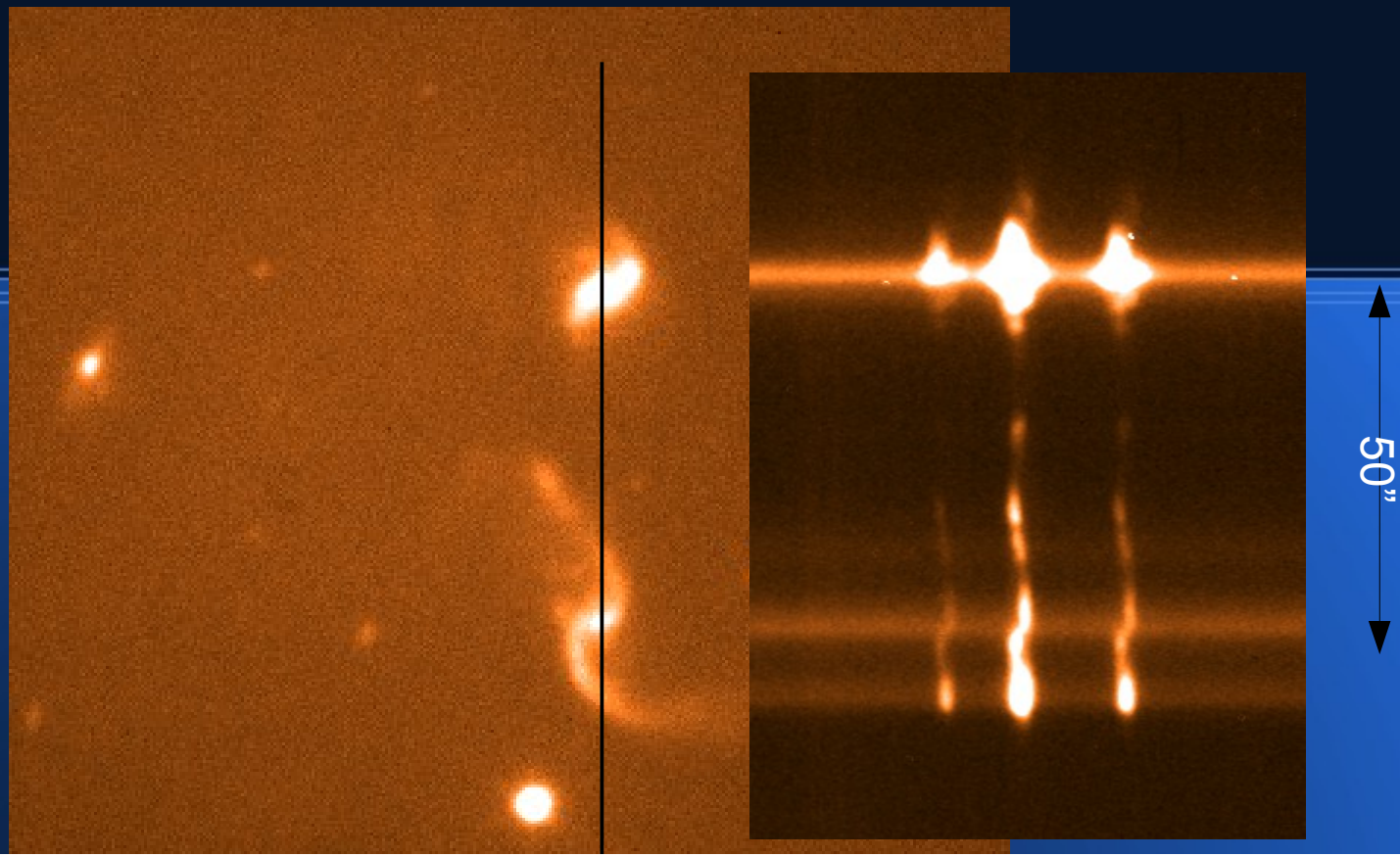


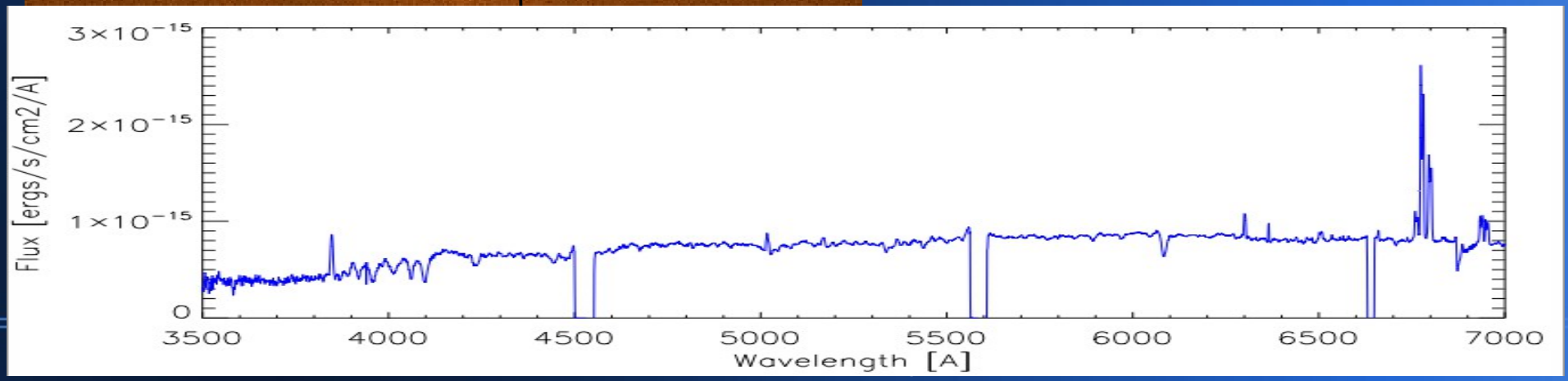




50”

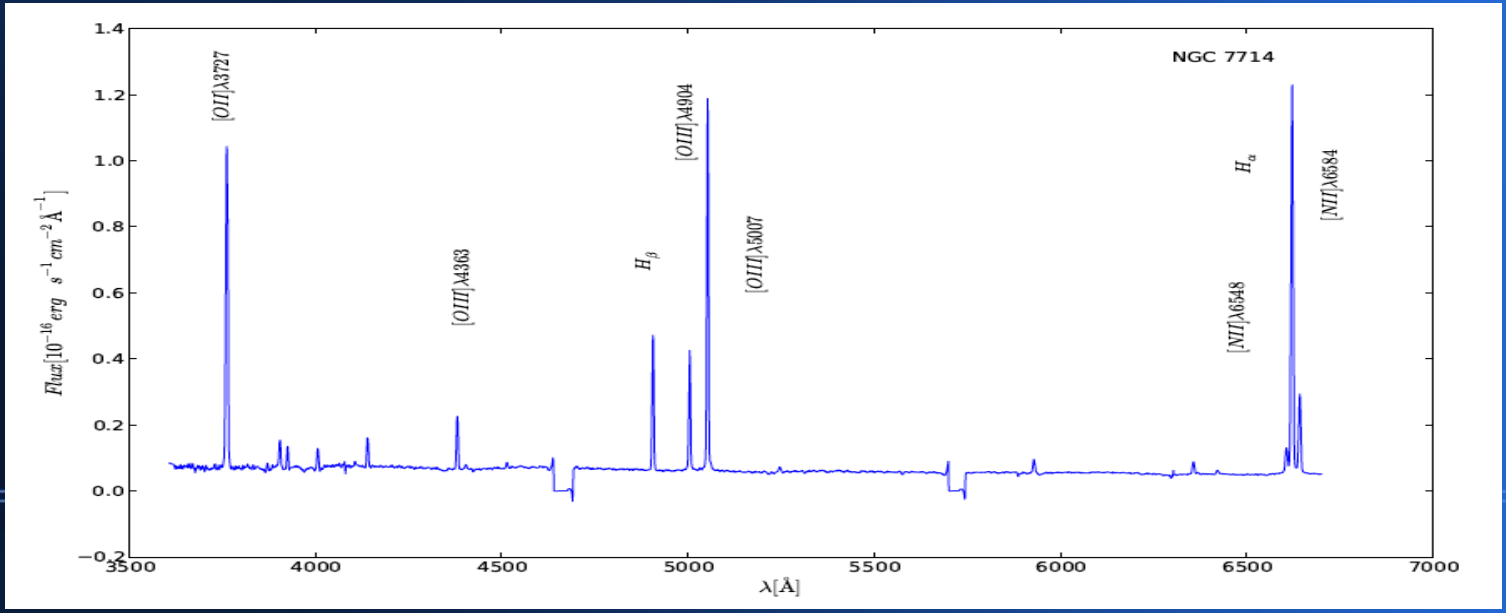
MCG-02-01-051/2


50”


Flux [ergs/s/cm2/A]
3×10⁻¹⁵
2×10⁻¹⁵
1×10⁻¹⁵
0
3500
4000
4500
5000
5500
6000
6500
7000
Wavelength [A]

Metallicities

- Central abundances are shown to be lower and gradients shallower in interacting pairs (Rupke et al. 2008, Rich et al. 2012). We can expand these studies quite significantly. Time scales and conditions of mixing?
  - We use direct methods (Kniazev et al.) if [OIII] λ4363 auroral line available (several lower metallicity cases do show it).
  - [OII] λ3727 often available, using calibrated R_{23} – method and N2 and N2O3 methods for breaking degeneracies (eg. Kewley & Ellison 2008).



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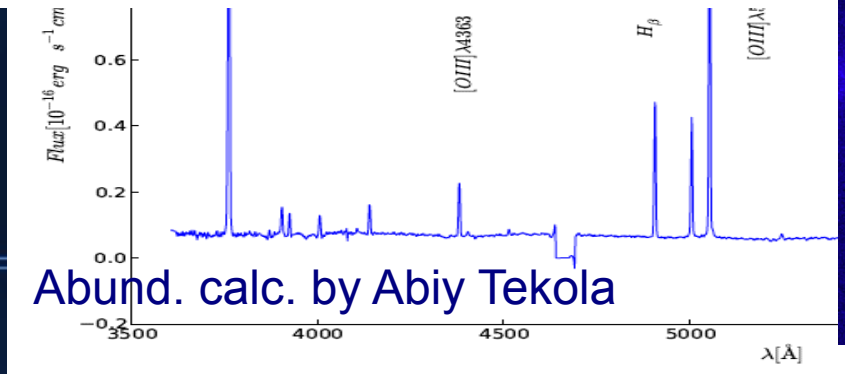
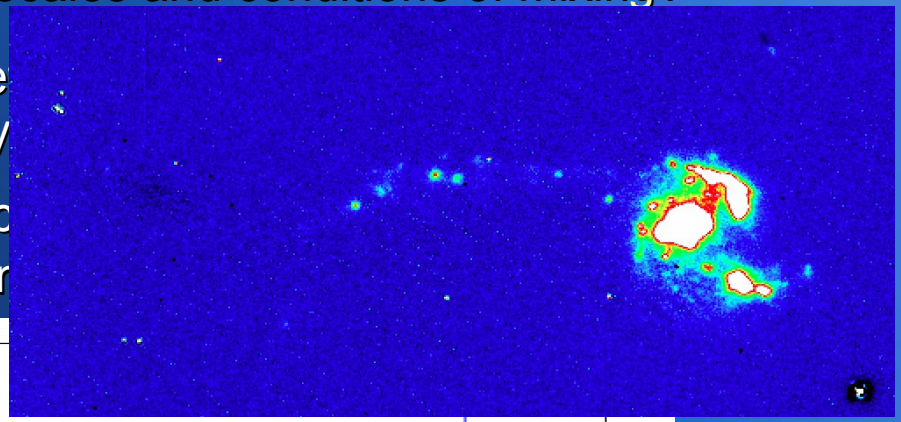
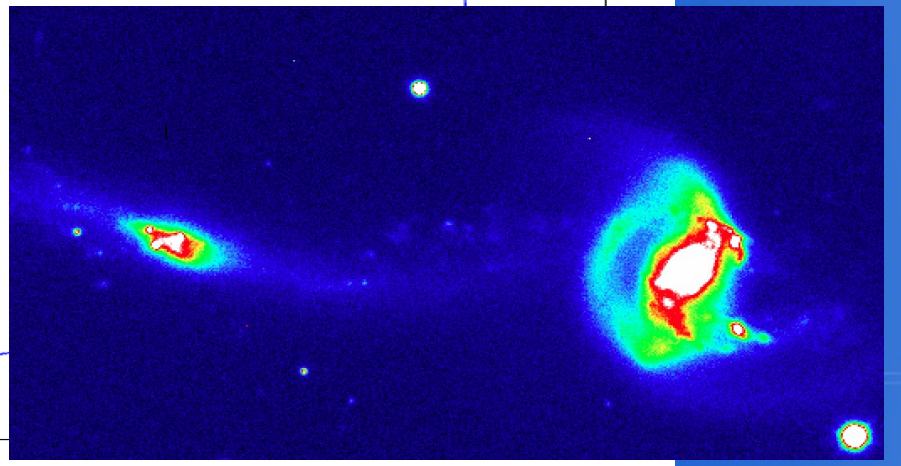
$C(\mathrm{H}\beta)$	0.3±0.01110
EW(abs)(Å)	0.8±0.141
$12 + log(O/H)$	8.039
T_e(O III)(K)	13000±5166.051
T_e(O II)(K)	12645.0±3688.560
T_e(S III)(K)	12397.6±6330.479



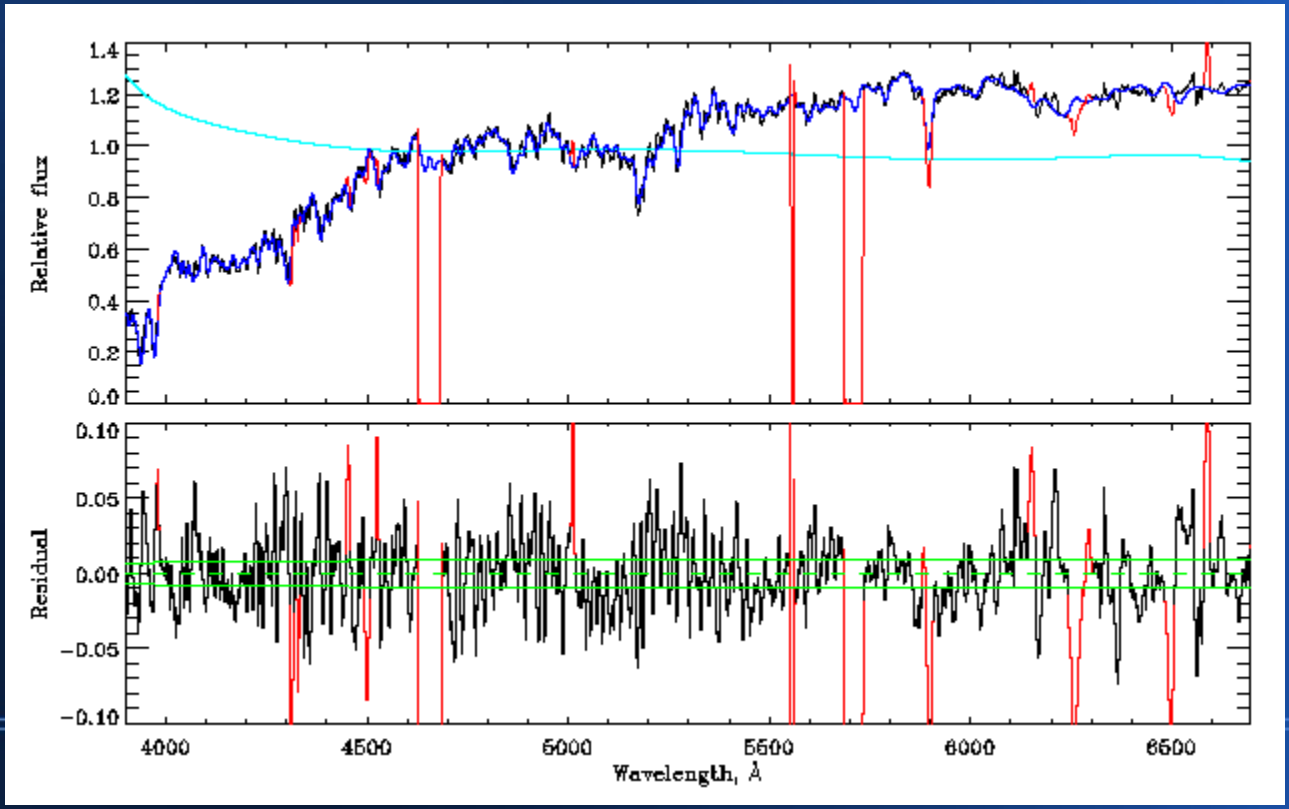
Abund. calc. by Abiy Tekola





Stellar populations and kinematics

- Spatially resolved stellar population ages, metallicities, star-formation histories – starting with 'easier' galaxies, most LIRGs will have complicated histories (young + older)



NGC 1553
(Barway et al., in prep.)
UlySS fit by Rajin Ramphul showing a 6 Gyr main pop.

Continuum fits used to subtract stellar abs from emission lines studies

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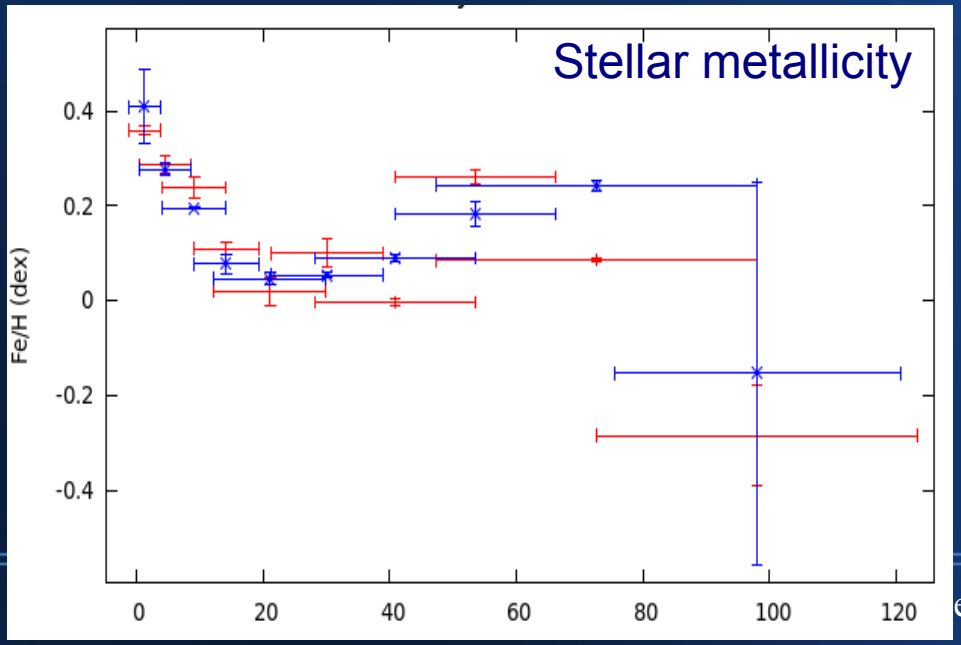
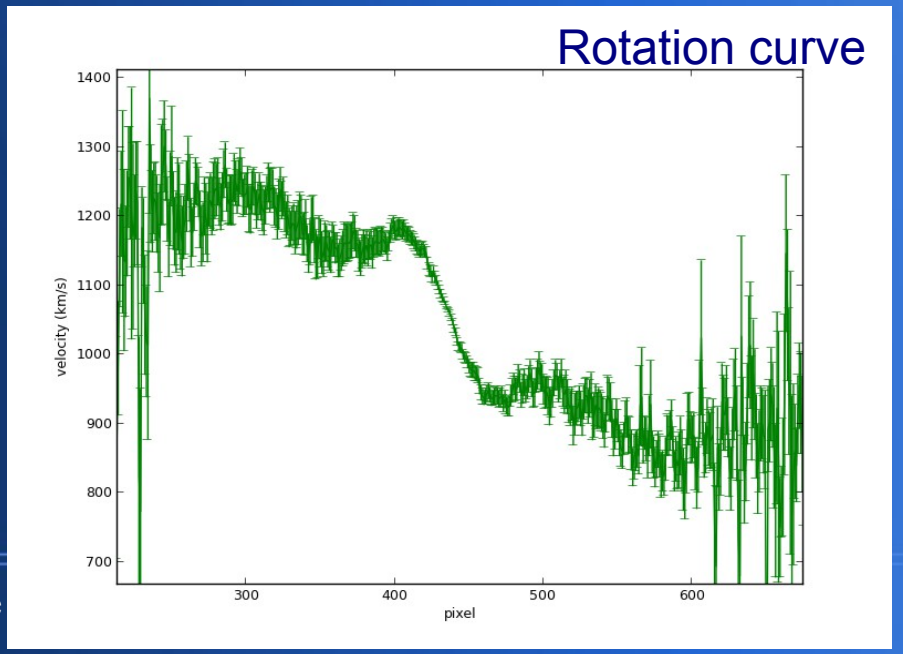
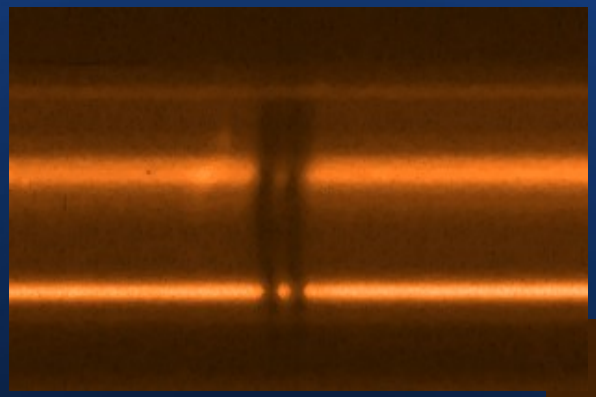




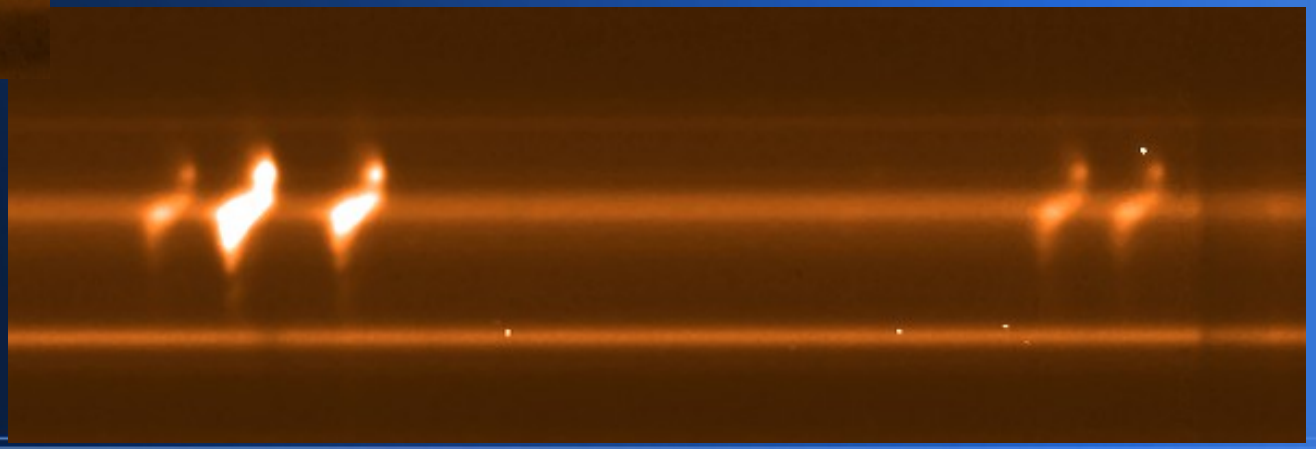
Gas flows – example from IRAS 18293-3413

- New SALT spectrum confirms minor companion, and shows very strong cool-gas motions, galaxy wide 10+ kpc scale winds.



Na I D (and He I)

Hα, [NII] and [SII]



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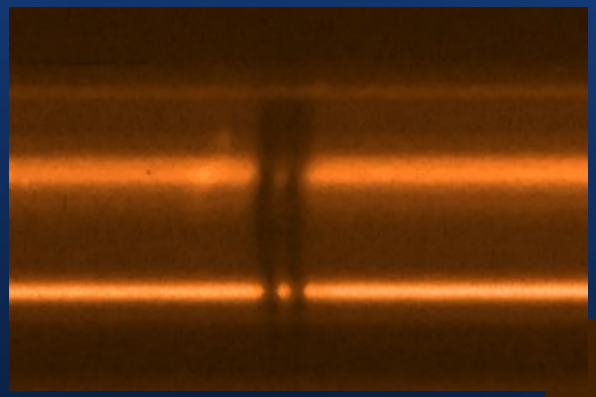
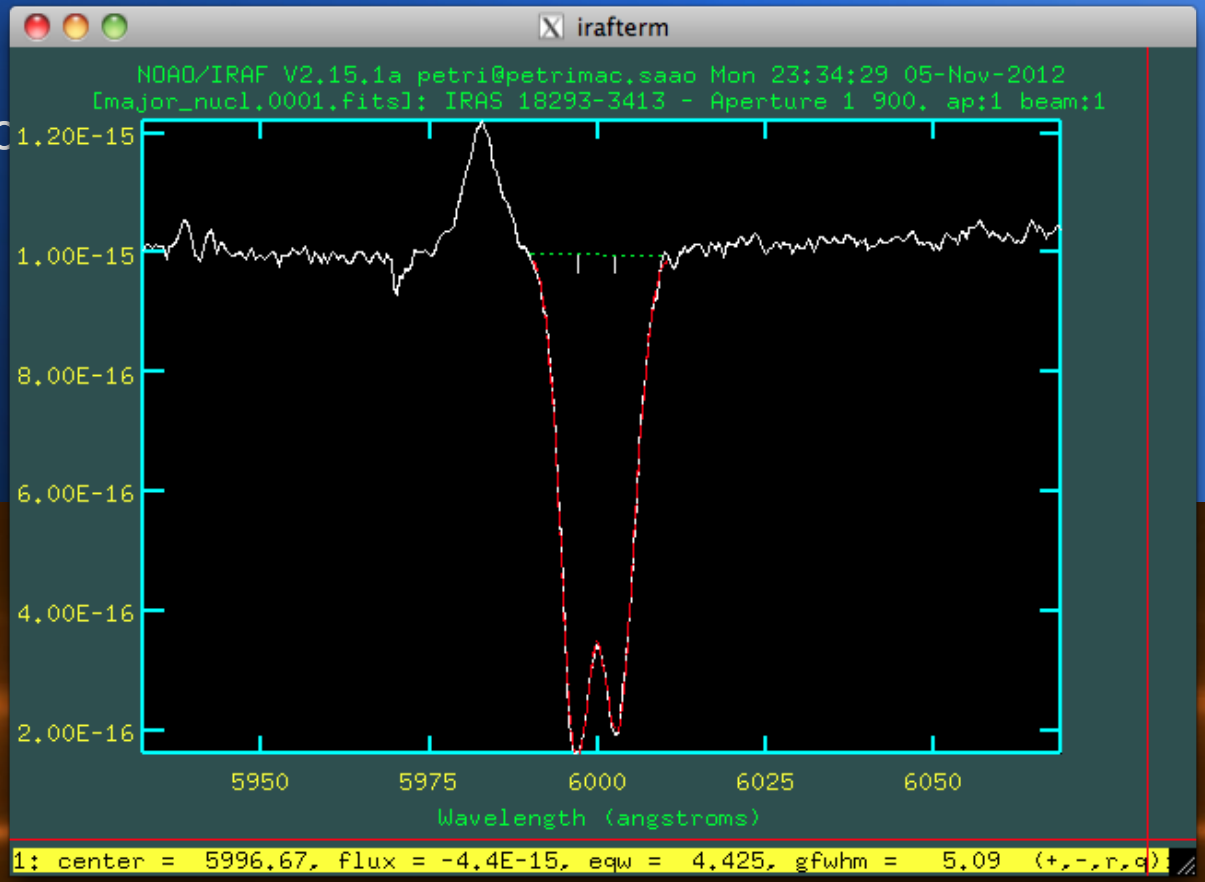
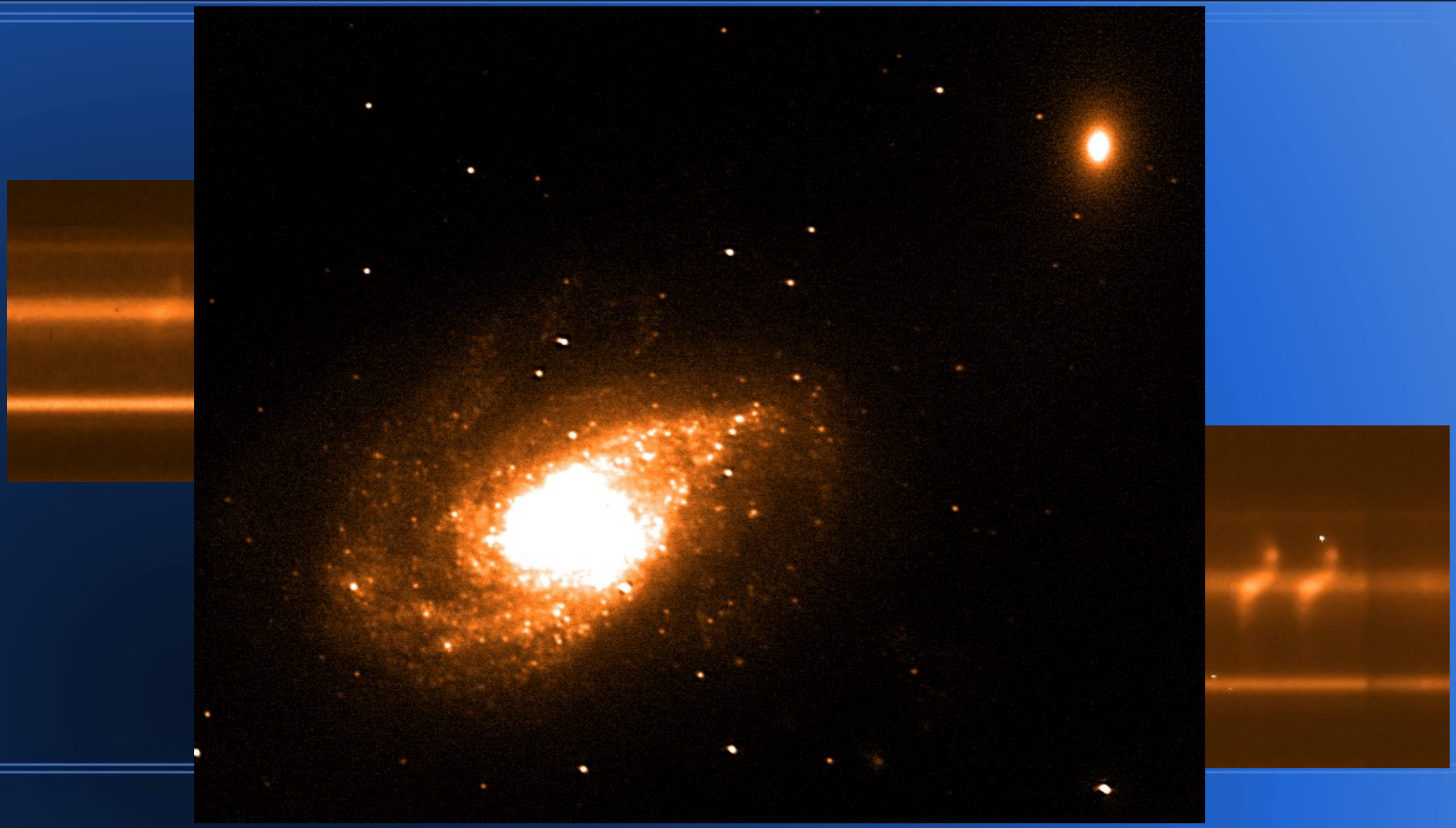


Na I D (and He I)

We will derive spatially resolved cool gas mass loss rates as function of metallicity, SFR, etc.



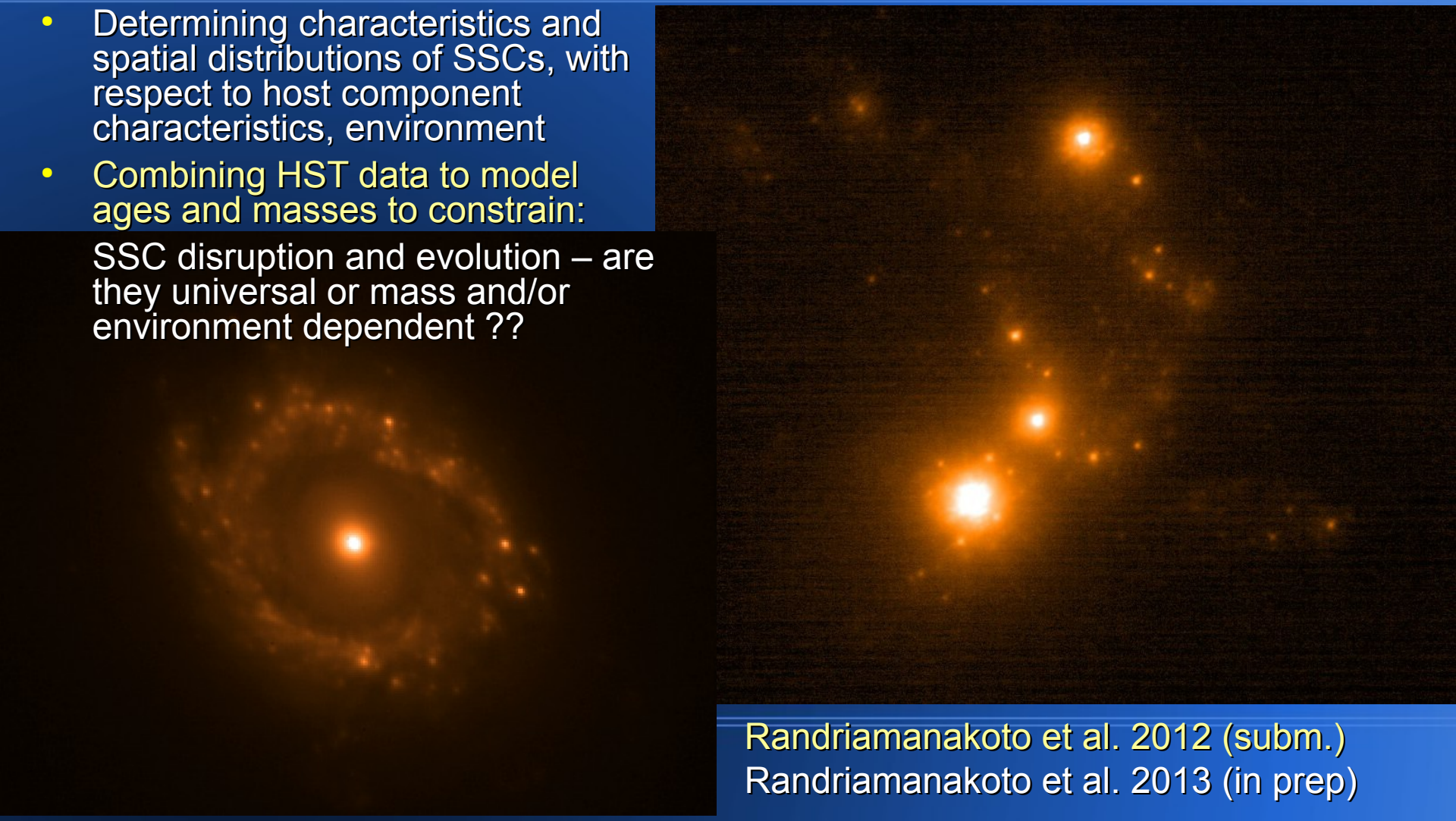
Gas flows – example from IRAS 18293-3413



Super star clusters (SSCs)

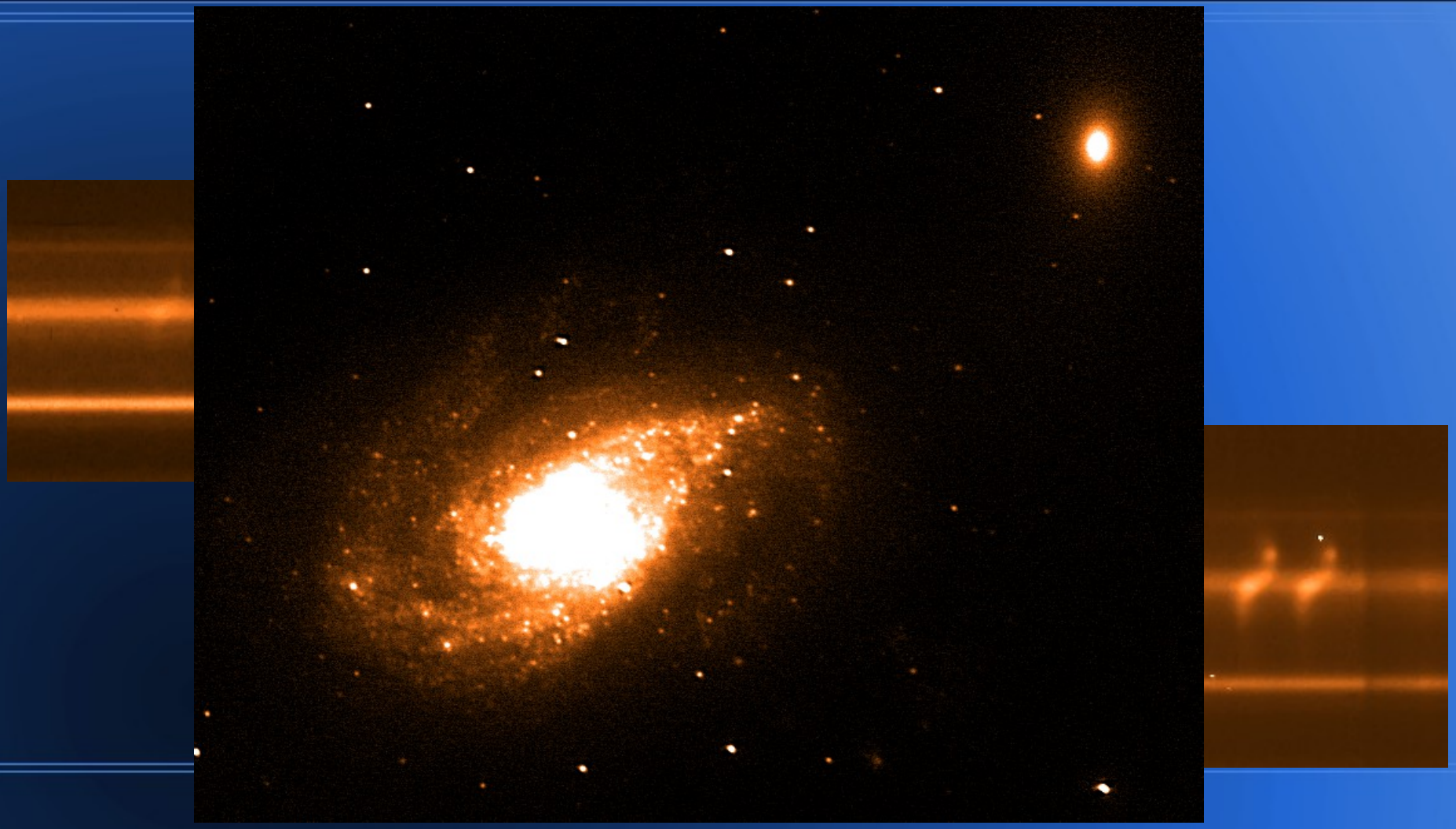
- Determining characteristics and spatial distributions of SSCs, with respect to host component characteristics, environment
- Combining HST data to model ages and masses to constrain:

  SSC disruption and evolution – are they universal or mass and/or environment dependent ??

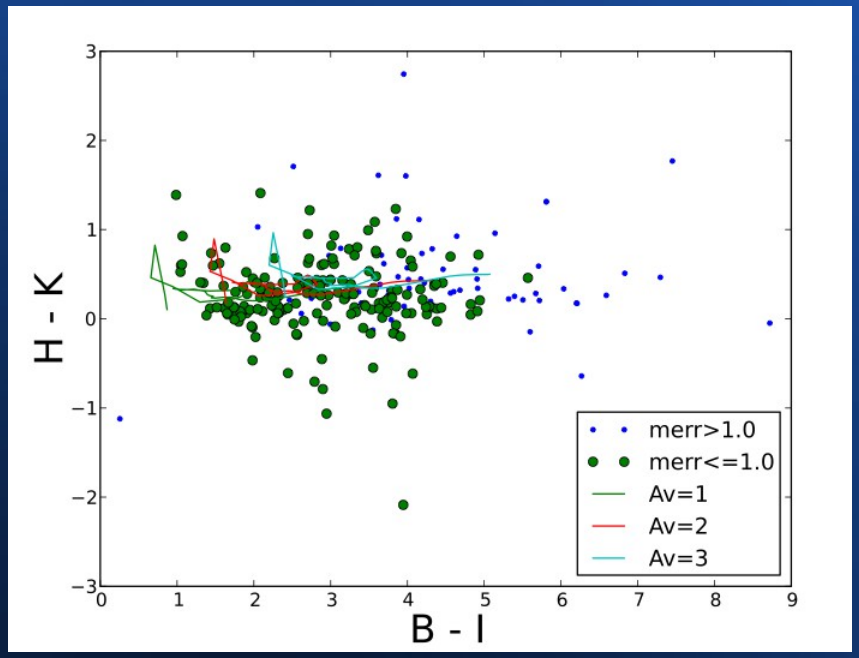


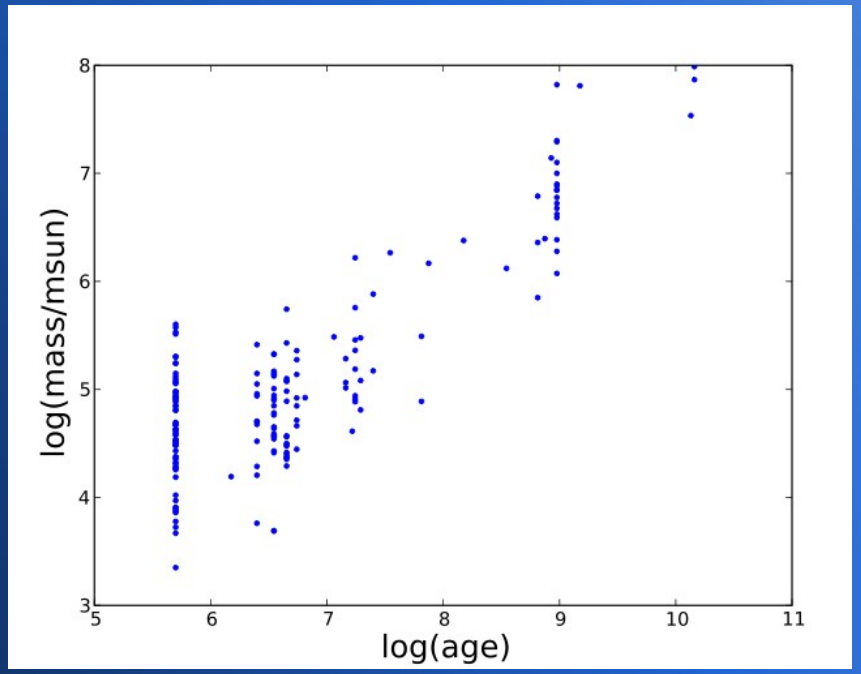
Randriamanakoto et al. 2012 (subm.)
Randriamanakoto et al. 2013 (in prep)

SSCs – example from IRAS 18293-3413



SSCs – example from IRAS 18293-3413

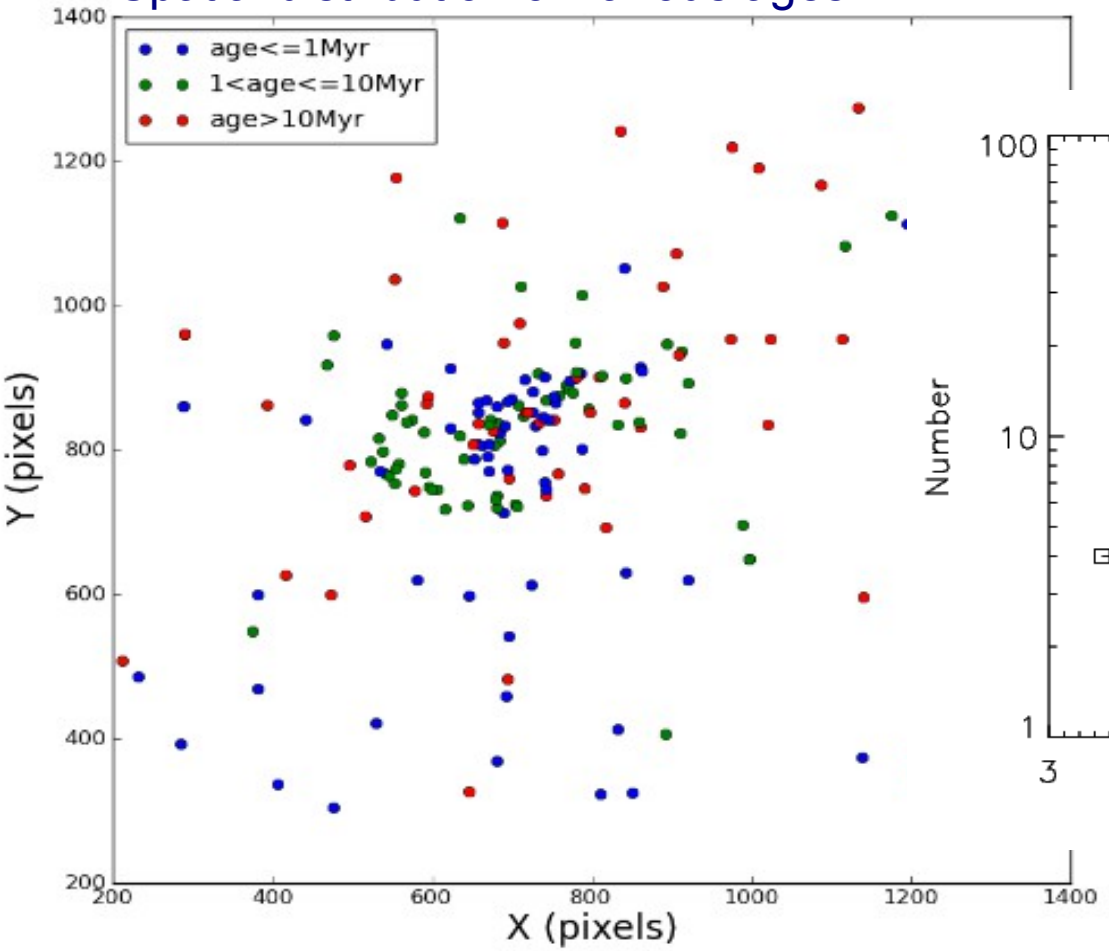




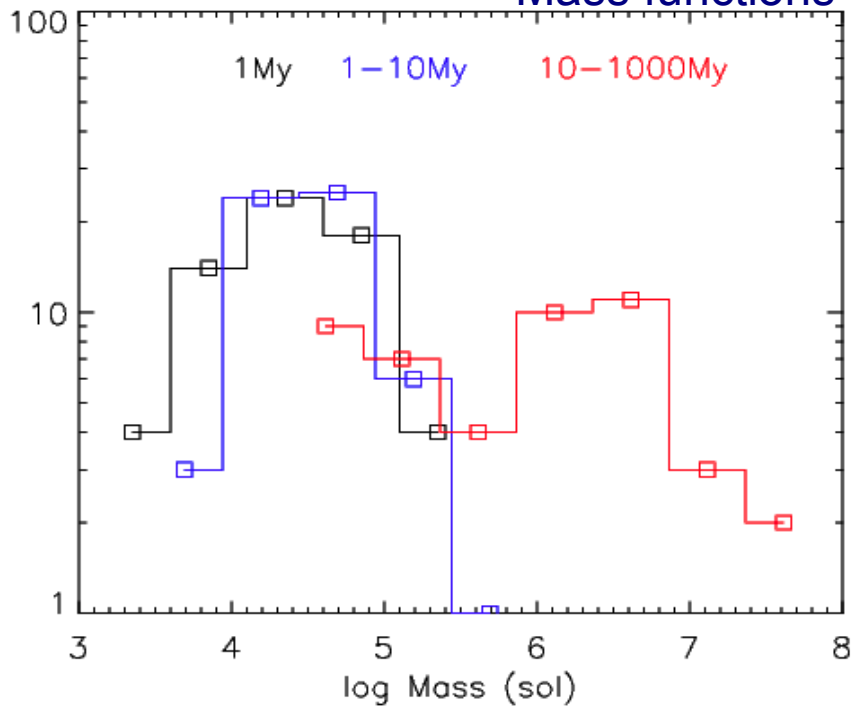
Over 200 SSCs detected from VLT & HST images. Modelled using SB99, GALEV, and Zackrisson et al models. SALT spectra crucial for extinctions and metallicity constraints.
[Randriamanakoto et al. 2013; Vaisanen et al. 2013]

SSCs – example from IRAS 18293-3413

Spatial distribution of various ages

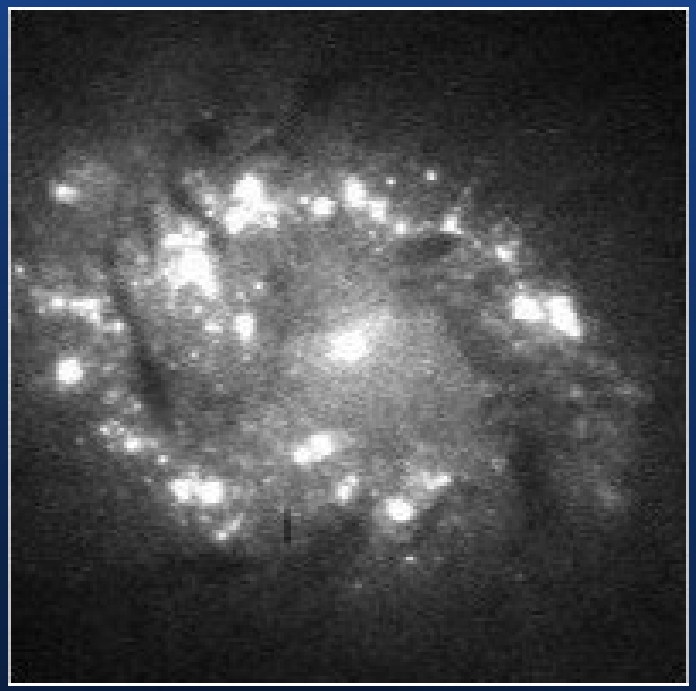


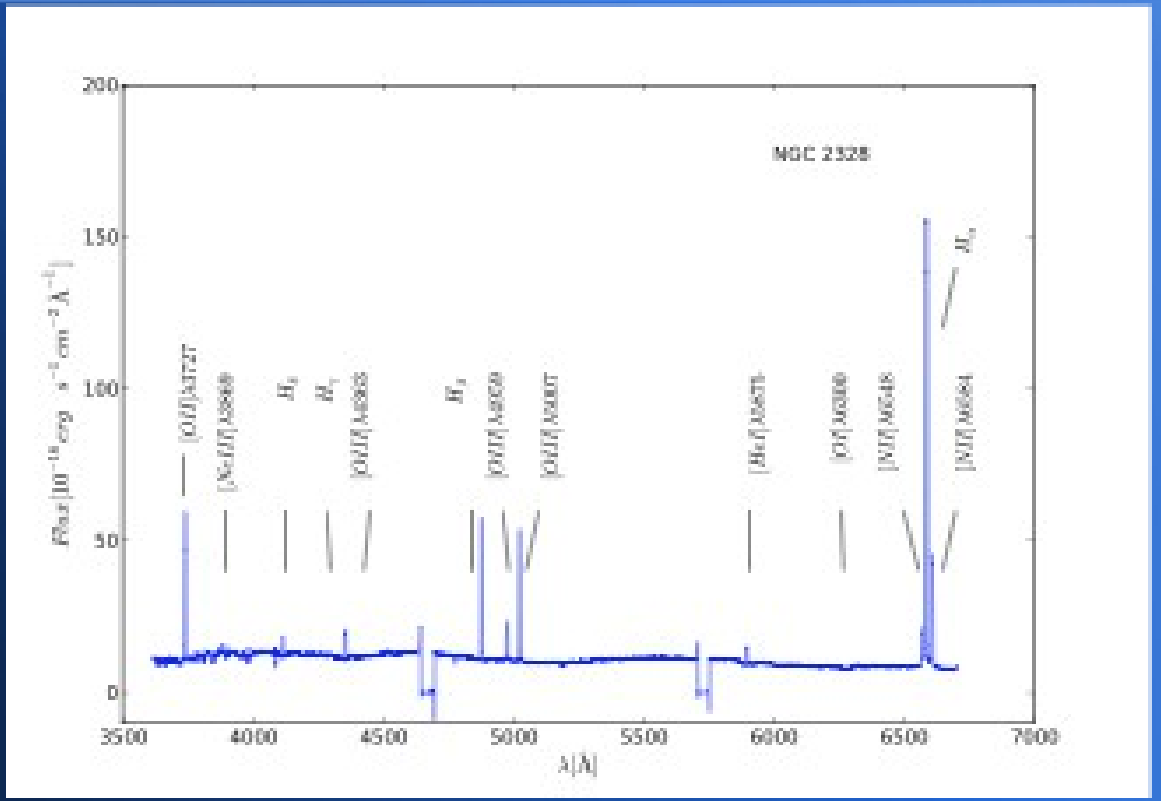
Mass functions

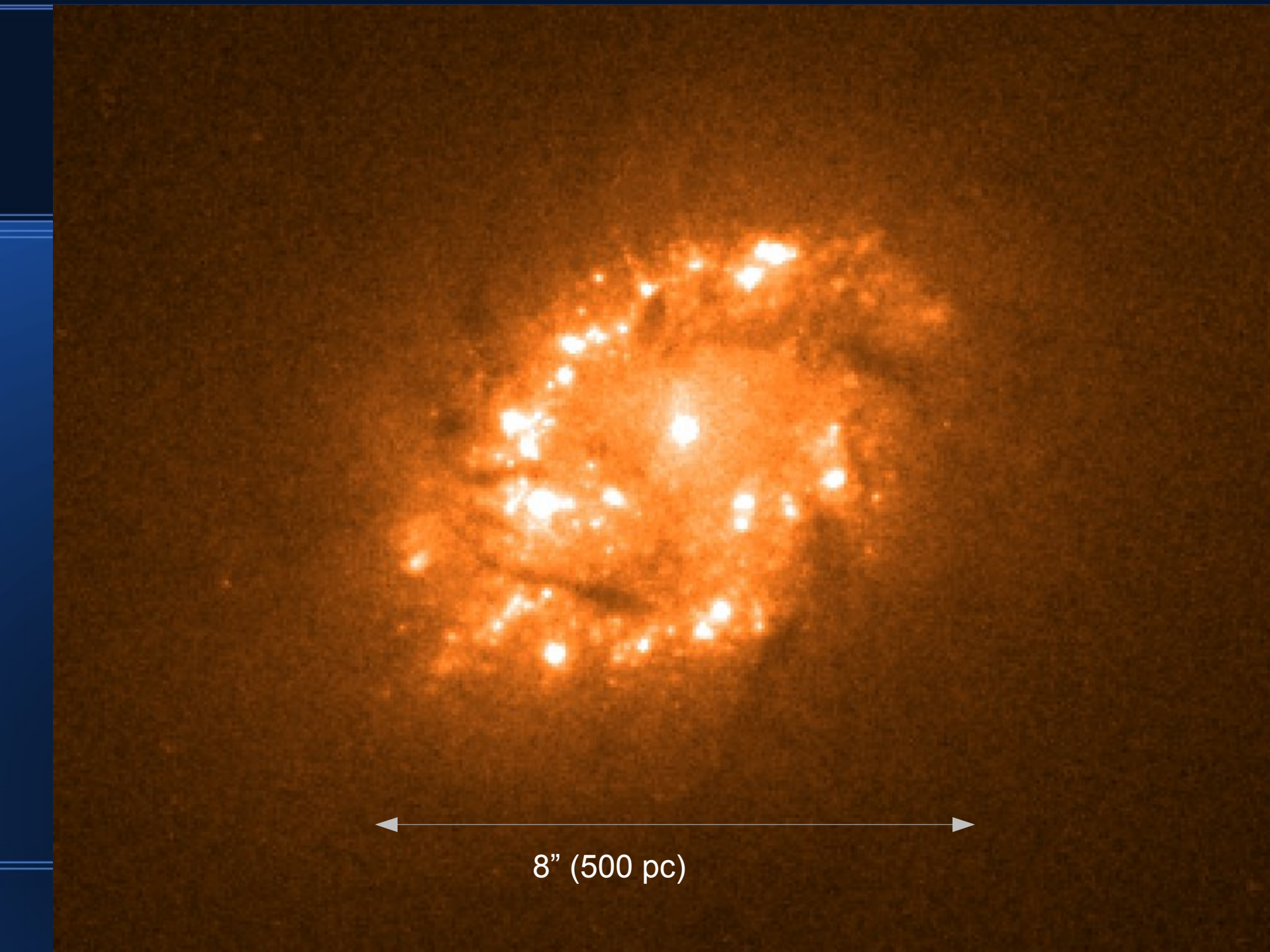


NGC 2328 – SSCs in inner ring of an S0

(Barway, Vaisanen, Randriamanakoto, Ramphul, Tekola, Kniazev, et al.)



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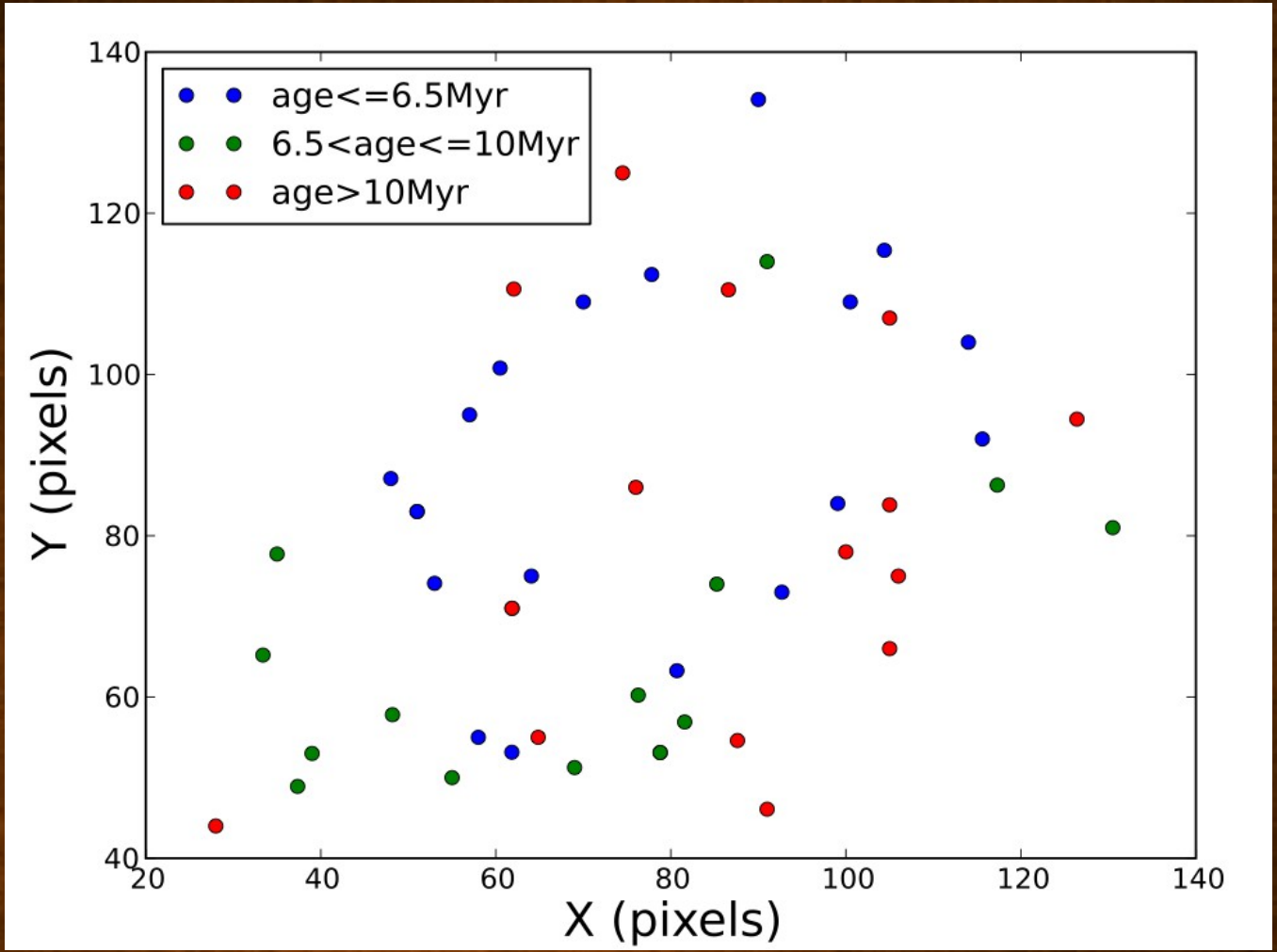
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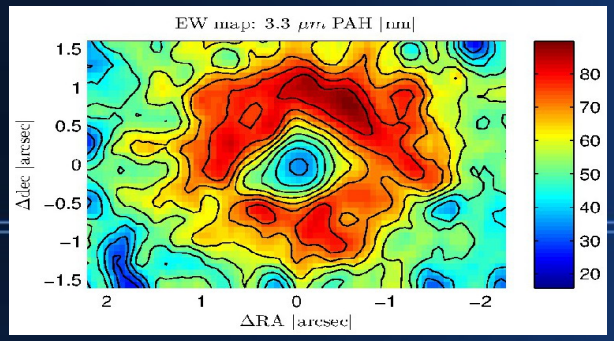
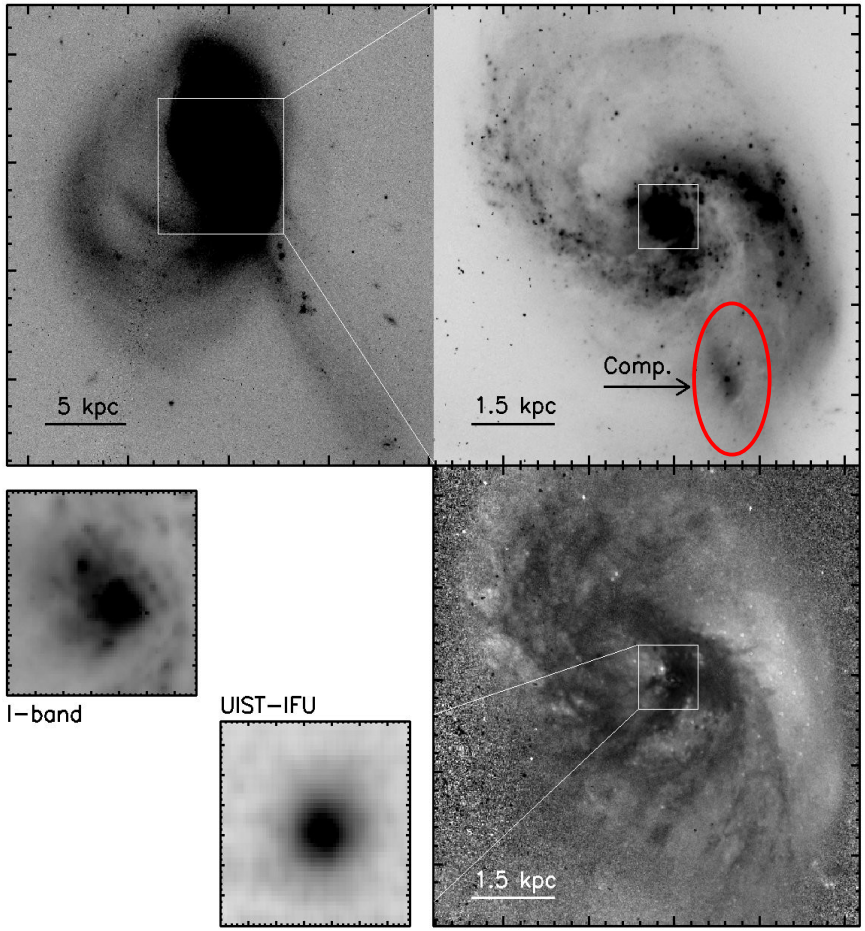
Bringing it together: case of NGC 1614

- When kinematics, SF characteristics including SSCs, and SP ages are put in place, we can construct target history, constrain models
- NGC1614 - 1:5 mass-ratio edge-on minor companion at 3rd approach
- 2nd passage ~50 Myr ago, trigger of strong central starburst
- Companion has lost most of its mass, the linear tidal tail is its former disk population





Vaisanen, Rajpaul,et al. 2012, MNRAS, 420

Summary

- Luminous IR-galaxies provide a sample of targets to study a variety of key phenomena especially related to triggering of star-formation, SB vs. AGN activity in interactions, effects of feedback
- A survey of 40 LIRGs (NACO, SALT, etc.) ongoing.
- Nice complementarity of high-res imaging, and SALT spectra
- Individual LIRGs (e.g. Bird) do not always easily fit in the simplest “gas-rich spirals to obscured AGN to ellipticals” -scenario.
- Super Star clusters vs. violent SF and metallicity studies ongoing
- Hoping to finish bulk of sample during 2012-2, and mop up during 2013-1. Couple of MSc and PhD thesis in progress as well as several papers.