

A P E R T I F

imaging surveys

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A P E R T I F

imaging surveys

- Apertif specs & performance
- HI science incentives
- Surveys design
- Synergies and ancillary data
- Survey operations and science exploitation



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 groningen

Kapteyn
Astronomical Institute

ASTRON



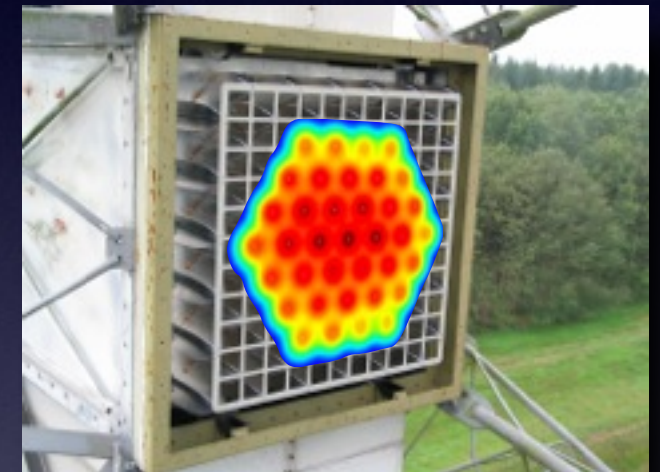
a grand proposal

WSRT upgrade - SKA pathfinder



After 45 years of service, transform the WSRT into an efficient 21 cm survey facility using phased-array technology.

	APERTIF	MFFE
# antennas/dish	121	2
# primary beams	37	1
field-of-view [deg ²]	8	0.3
freq. range [GHz]	1.13–1.75	0.12–8.7
T _{sys} [K]	70	30
aperture efficiency	75%	55%
bandwidth [MHz]	300	160
# channels	24576	1024
# dishes	12	14 (13)



APERTIF Resolution :

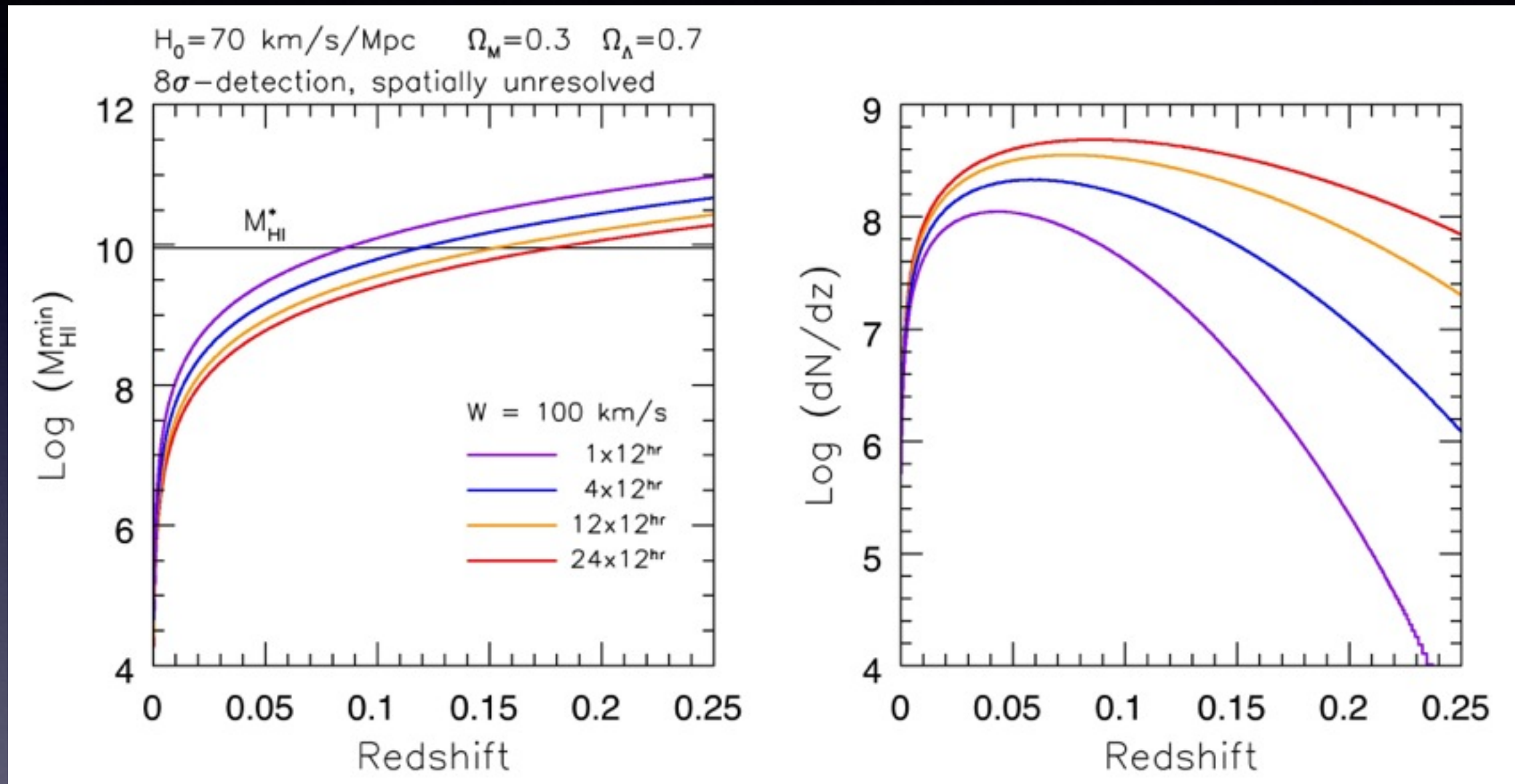
$$\Theta = (1+Z)^2 \times 15'' \times 15'' / \sin(\delta)$$

(10kpc @ D=150 Mpc)

$$R = (1+Z) \times 2.6 \text{ km/s}$$

APERTIF increases survey speed of WSRT 20x

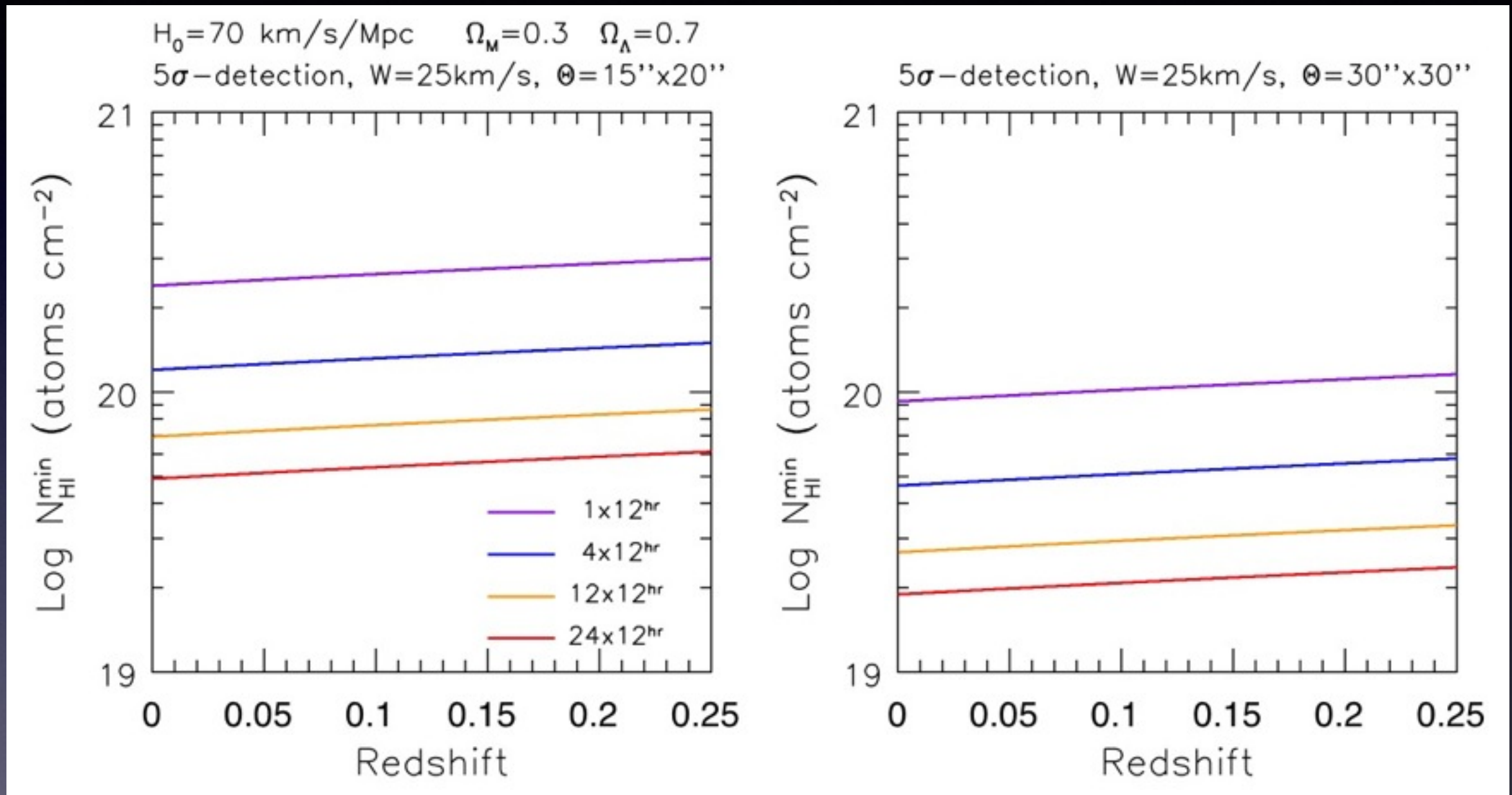
$$(A_{\text{eff}}/T_{\text{sys}})^2_{\text{MFFE-14}} = 4 \times (A_{\text{eff}}/T_{\text{sys}})^2_{\text{Apertif-12}}$$



1x12^{hr} : M_{HI}^* at $z=0.08$, $1 \times 10^{11} M_{\text{sun}}$ at $z=0.25$
 12x12^{hr} : M_{HI}^* at $z=0.16$, $3 \times 10^{10} M_{\text{sun}}$ at $z=0.25$

HI column density limits

5σ , $W=25$ km/s

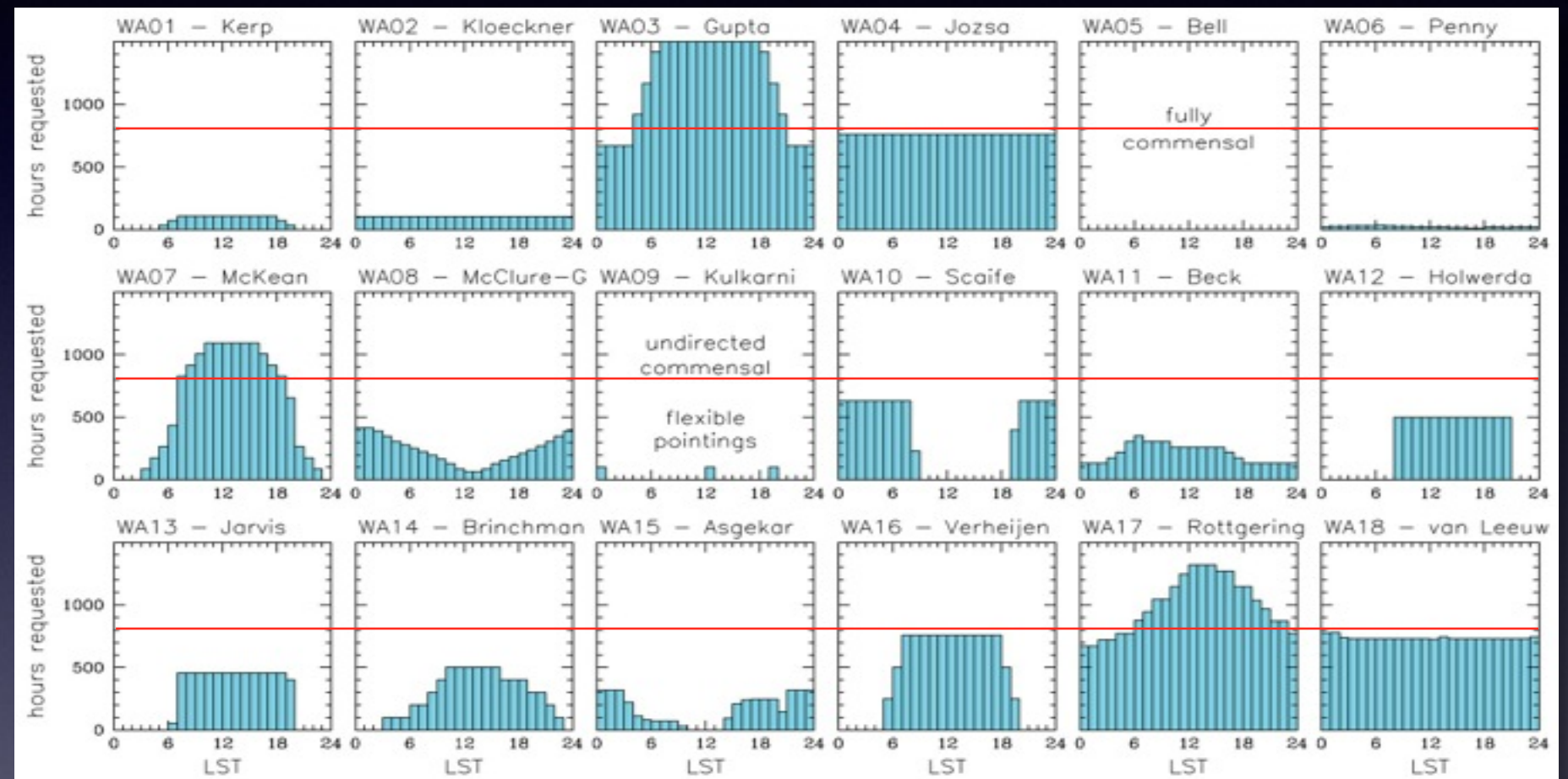


Note: smoothing to half the angular resolution reduces the survey volume at a particular linear resolution by a factor 8.



Inventory of community interest

Based on input via Expressions-of-Interest:



20 years of survey time requested

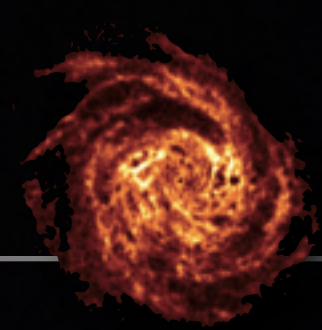


- ▶ shallow northern-sky survey (SNS)
- ▶ medium-deep survey (MDS)
- ▶ pulsar/transients survey (PTS)
- ▶ Galactic plane survey (GPS)
- ▶ commensal transients search survey

Realistic: 4-year survey period (2017–2020), 15% DD time, 75% observing efficiency, 1/4 of time dedicated to a survey

→ $6600^{\text{hr}} = 550 \times 12^{\text{hr}}$ per survey

Ambitious : full northern-sky survey (10,000 deg²)

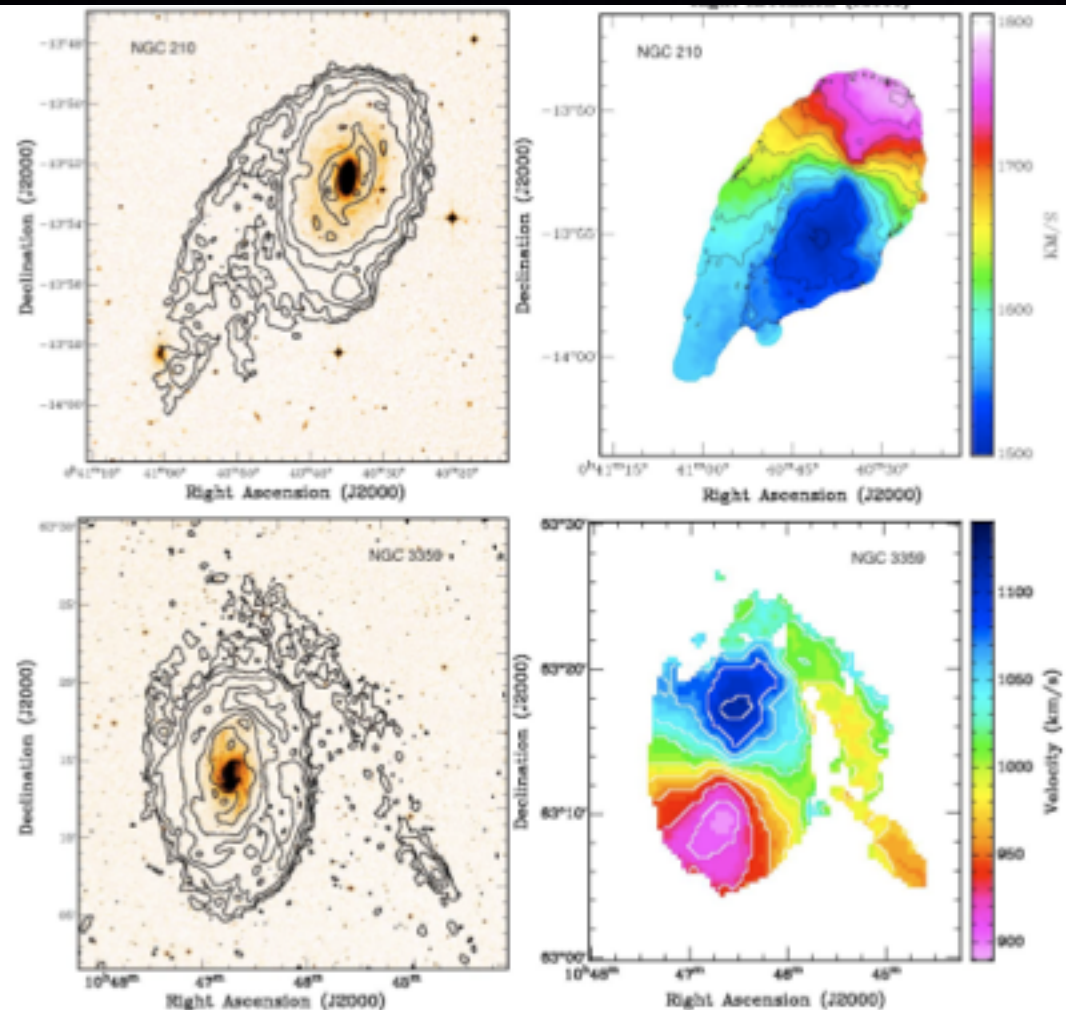


Gas & Galaxy Evolution - *resolved* HI studies

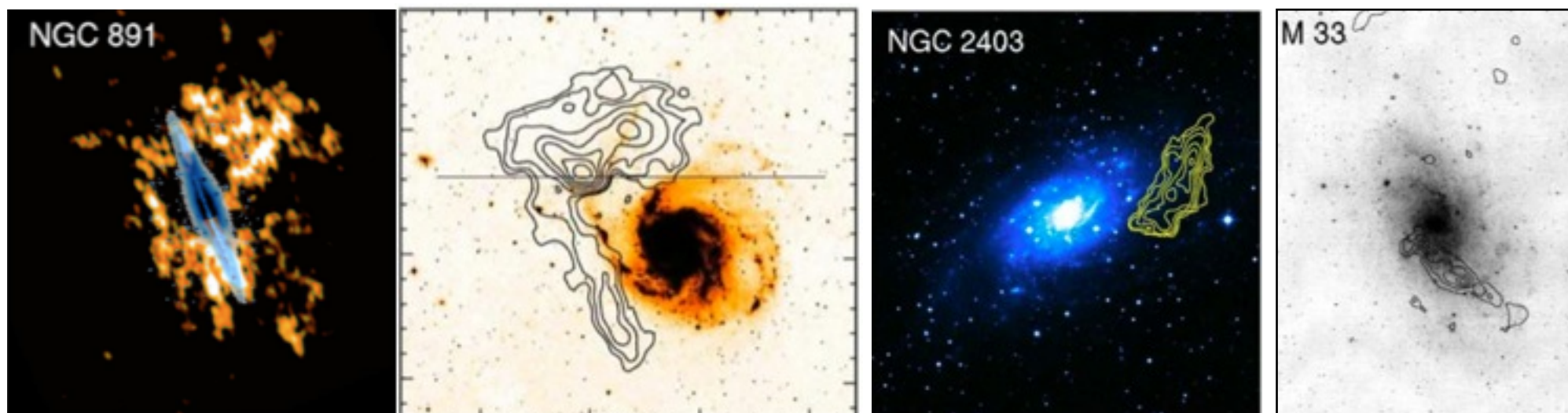
Fueling the Blue Cloud
sustaining star formation
-
building up stellar mass

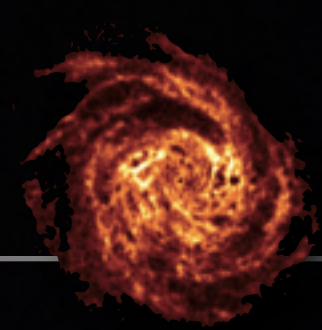
Mergers / cold accretion
and/or
Galactic Fountain / Fallback ?

Sancisi+ 2008



Oosterloo+ 2007

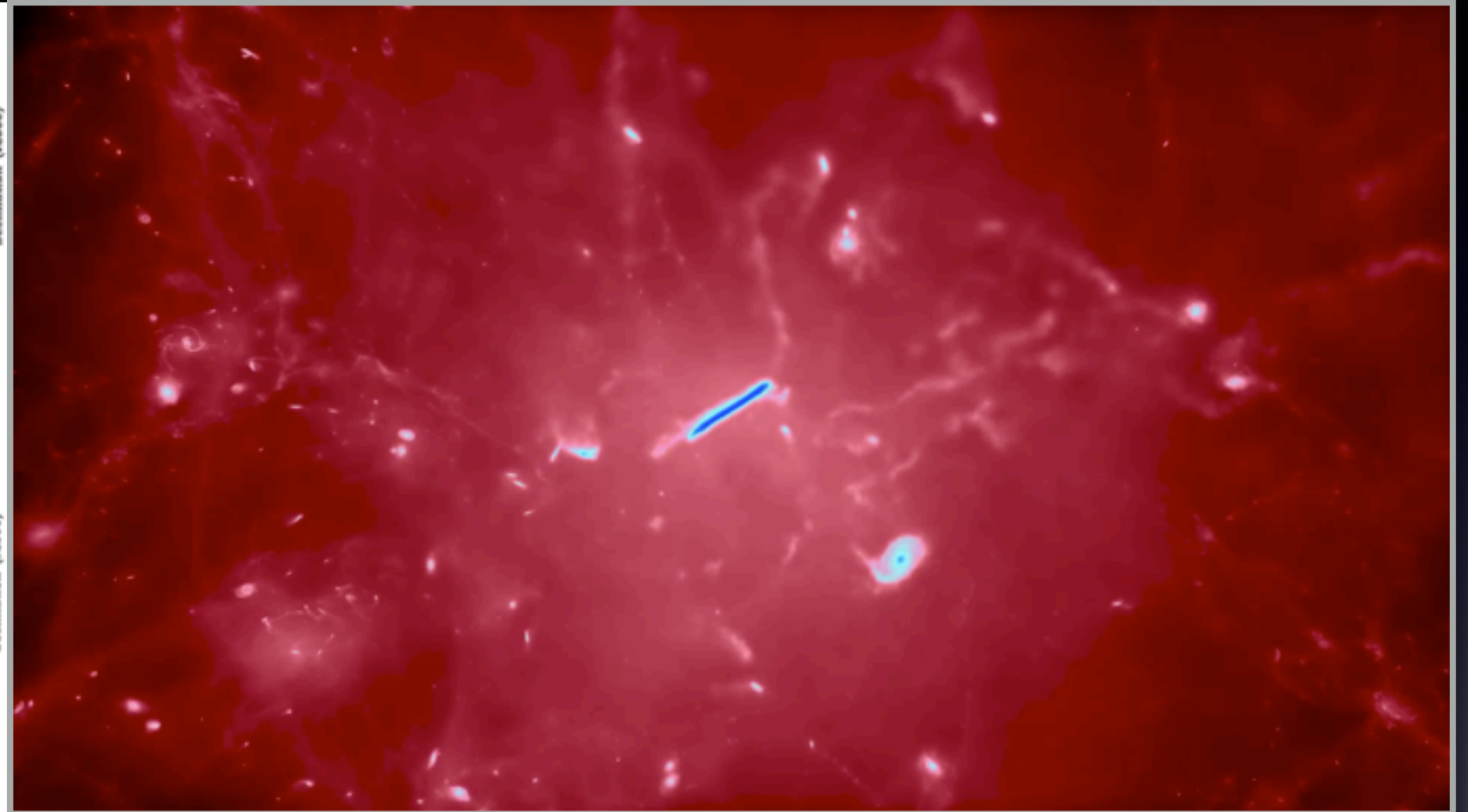
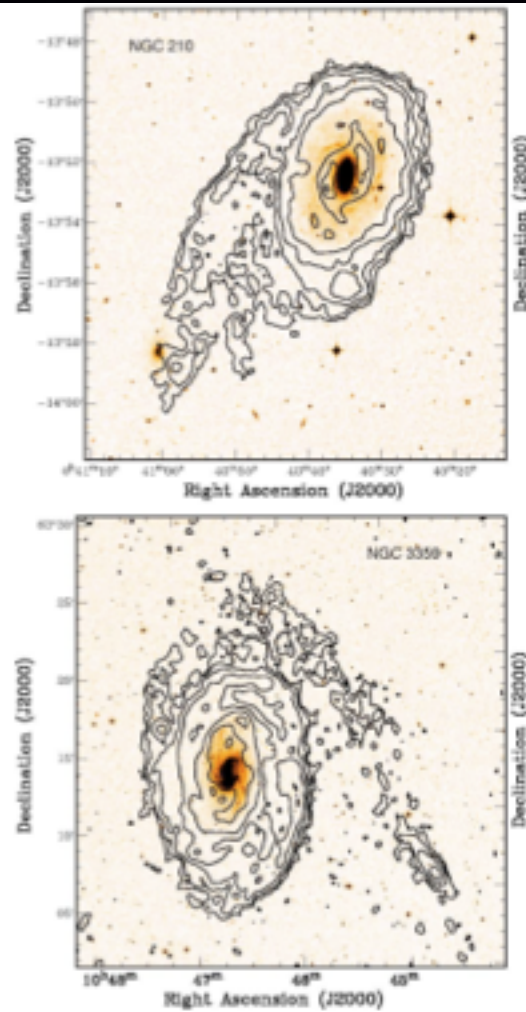




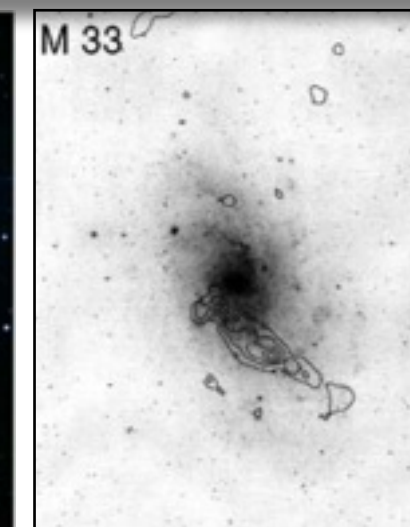
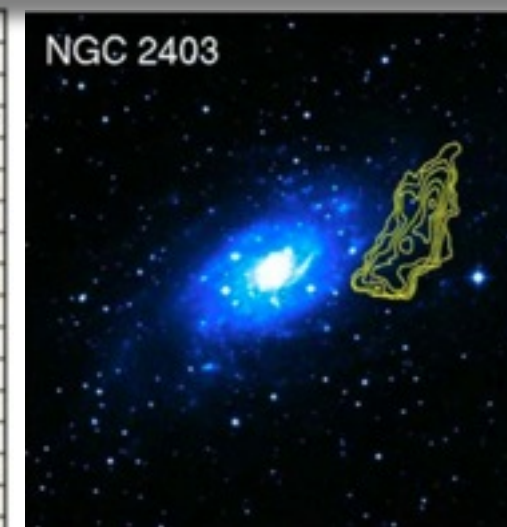
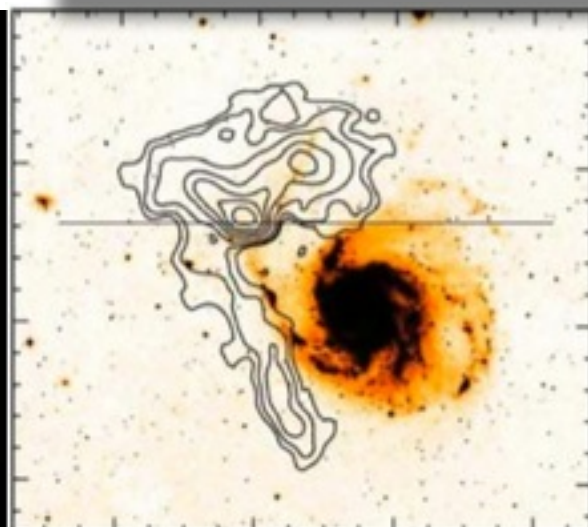
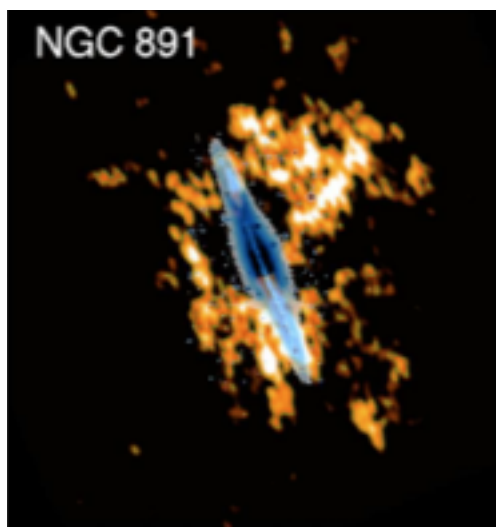
Gas & Galaxy Evolution - *resolved* HI studies

Illustris, Vogelsberger+ '12

Sancisi+ 2008



Oosterloo+ 2007

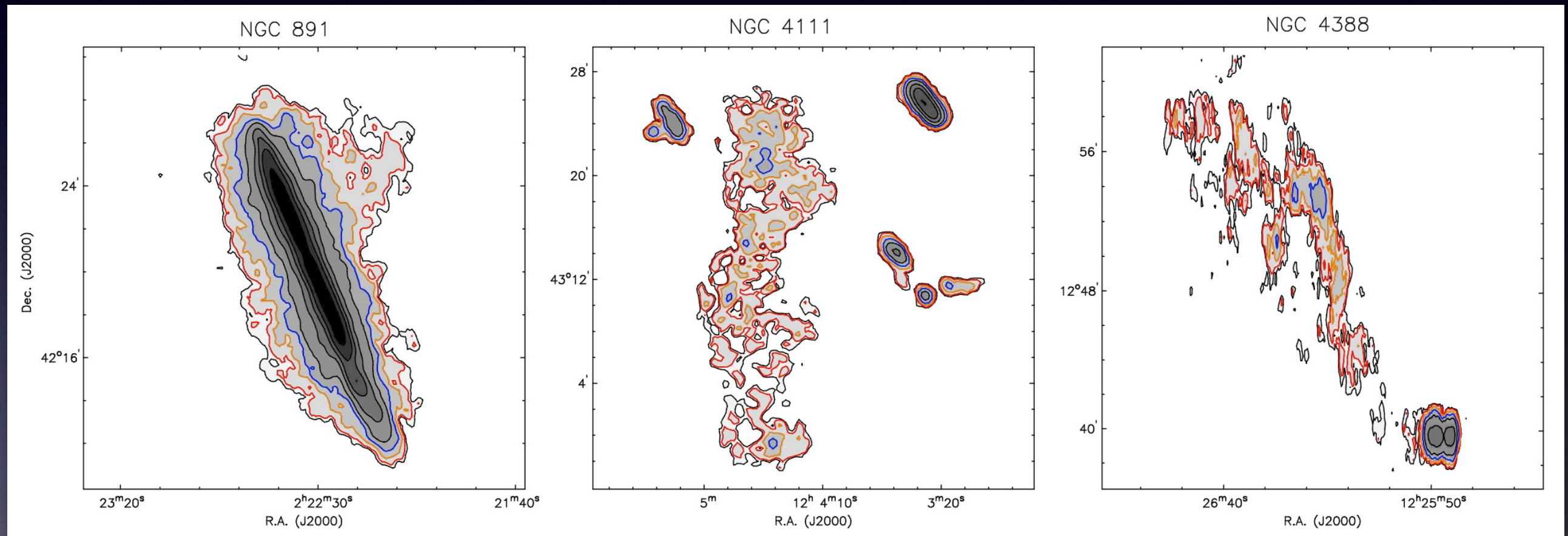


Accretion, depletion and removal of gas

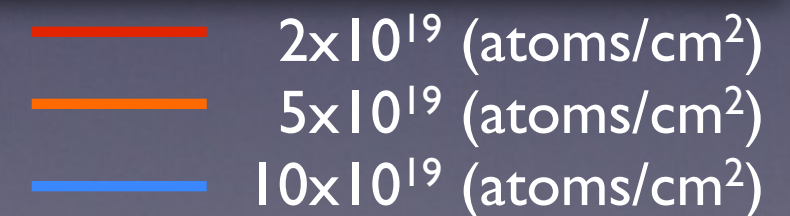
extra-planar gas

tidal stripping

ram-pressure stripping



Verheijen et al



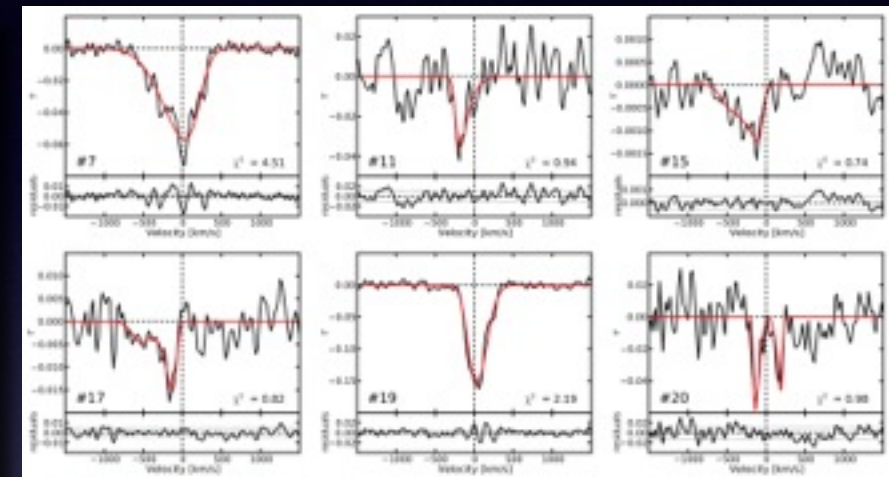
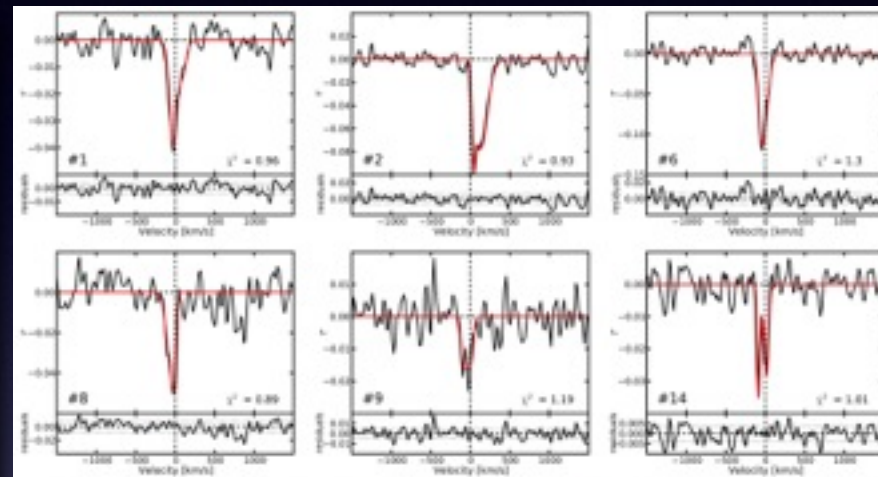
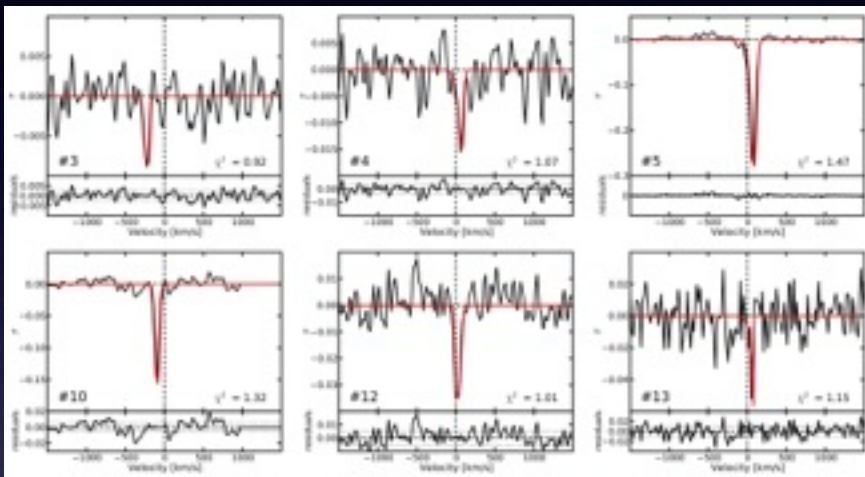
Gas disks are responsive to environmental influences and reveal processes not easily observed otherwise.

1 in 3 continuum sources have associated HI absorption

FWHM < 100 km/s

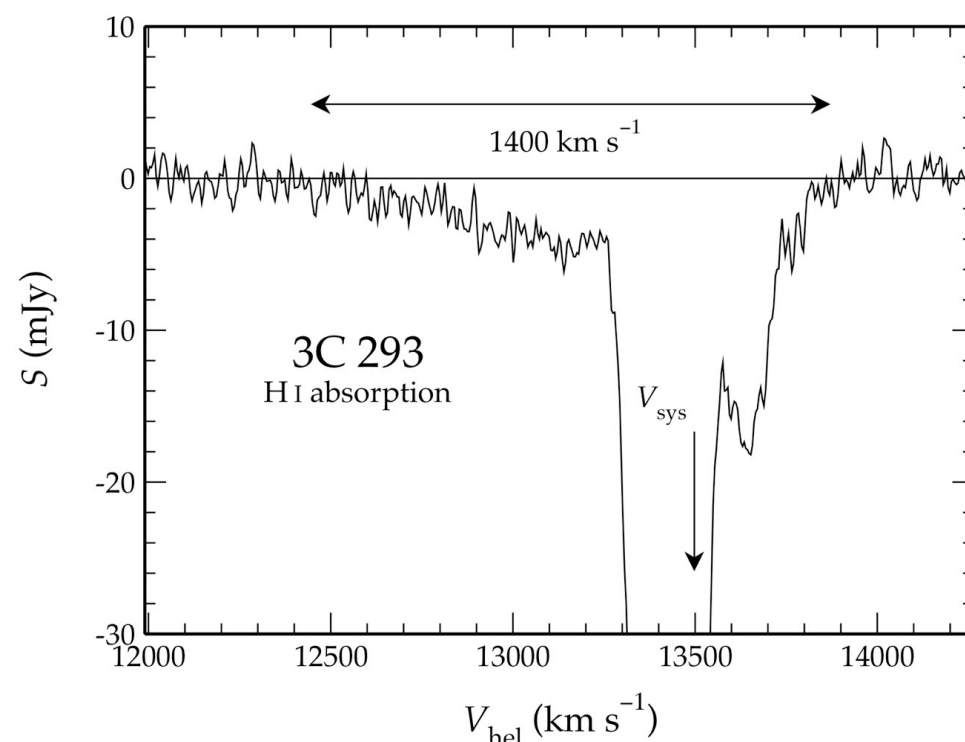
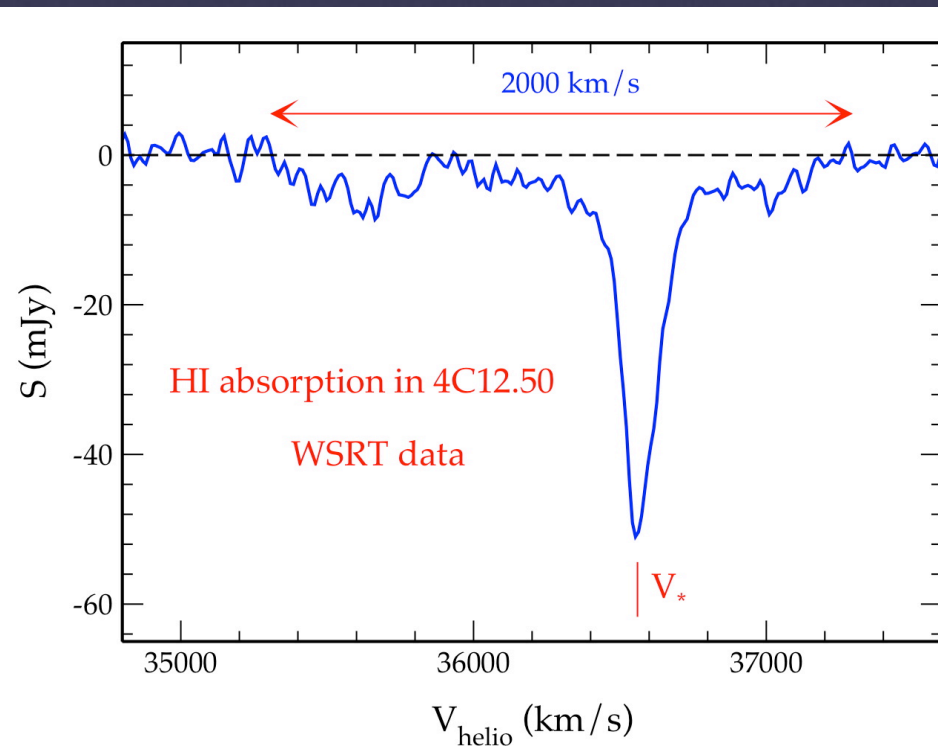
100 km/s < FWHM < 200 km/s

FWHM > 200 km/s



Gereb+ '14

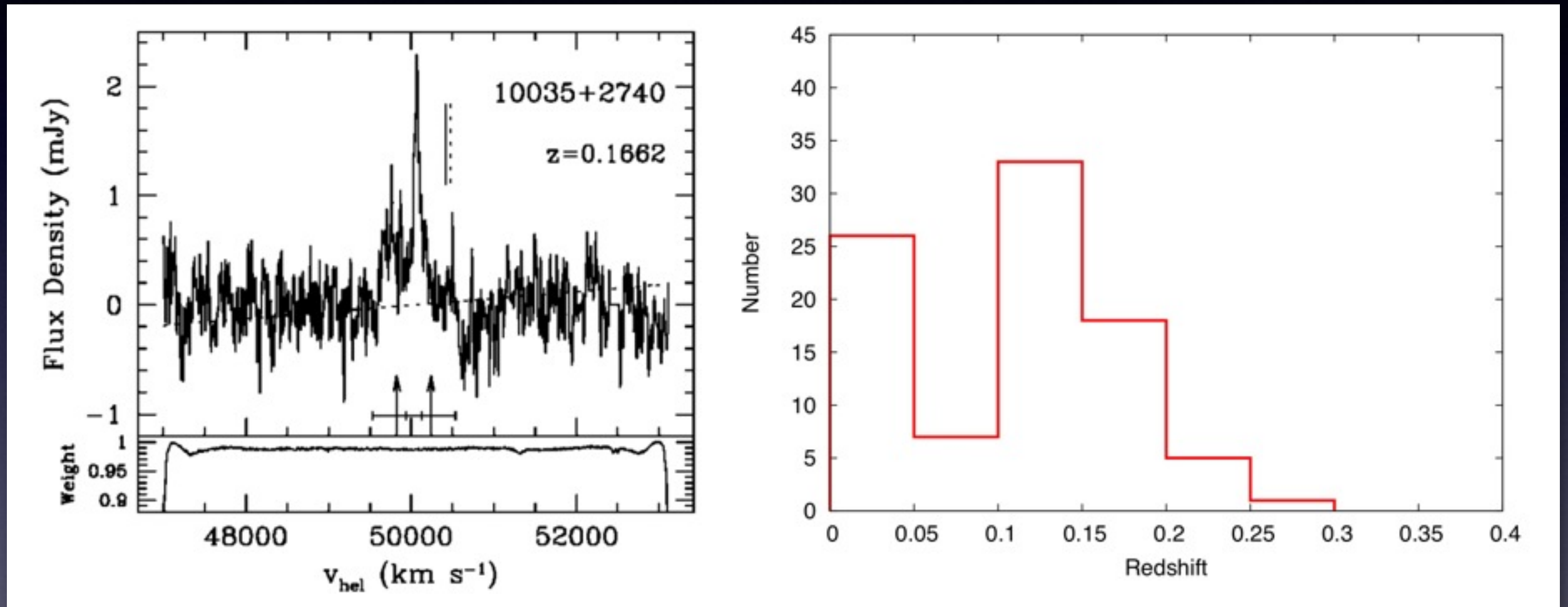
High-velocity outflows from AGNs



Requires a
stable bandpass.

Morganti+

identify sites of intense star formation



Darling & Giovanelli, 2003

detectable at higher redshifts - trace cosmic evolution of major mergers.

1430-1130 MHz $\rightarrow 0.17 < Z < 0.47$ for OH

Guiding principles:

- ▶ public, legacy-type surveys (archival science)
based on ideas from 18 Expressions-of-Interest++
- ▶ maximum ancillary data availability
- ▶ community involvement & commitment
- ▶ collaborate, compromise, consolidate
- ▶ be ambitious yet realistic
- ▶ simplicity
few observing modes, fixed pointing grid
- ▶ staged delivery of data and science

July 2015: Draft Survey Programme
Ground Rules for involvement
(surveys to be carried out by the community)

Apertif Survey Team:

- Tom Oosterloo (ASTRON/Groningen)
- Raffaella Morganti (ASTRON/Groningen)
- Erwin de Blok (ASTRON)
- Thijs van der Hulst (Groningen)
- Joeri van Leeuwen (ASTRON/Amsterdam)
- Lister Staveley-Smith (UWA/ICRAR)
/ Gyula Jozsa (SKA-SA)
- Marc Verheijen (Groningen)

→ January 2016: Apertif Survey Plan (under review)

Three imaging and one pulsar/transients surveys :

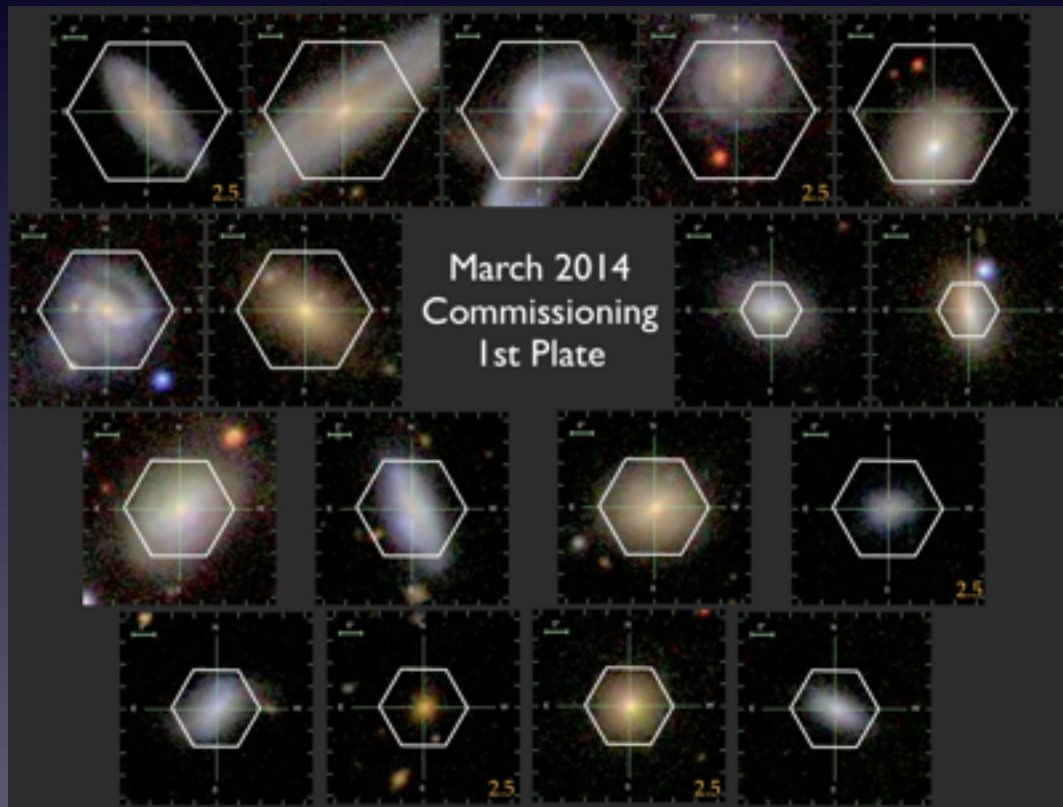
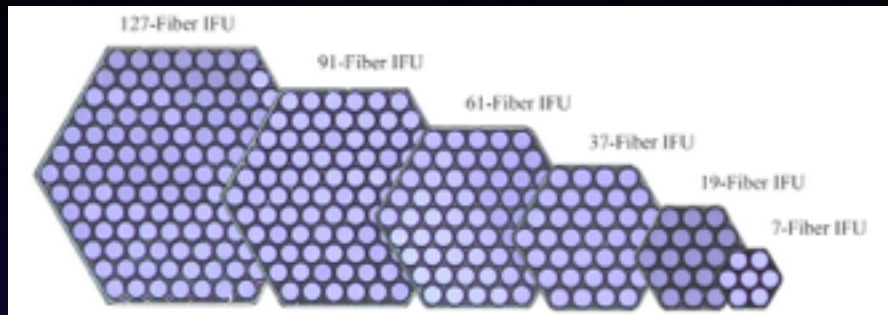
- Shallow ($1 \times 12^{\text{hr}}$), large-area ($\sim 3500 \text{ deg}^2$) imaging
overlap with SDSS, PanStarrs-I, MaNGA, Califa, HetDex, S⁴G
- Medium-deep ($N \times 12^{\text{hr}}$), medium-area ($\sim 350 \text{ deg}^2$) imaging
overlap with H-Atlas+Coma, CVn, HetDex, Perseus-Pisces
- Apertif-LOFAR ($4 \times 12^{\text{hr}}$, ~ 10 fields of 10 deg^2) imaging
- Wide-field pulsar and transients survey (3^{hr} , 15.000 deg^2)
triggers LOFAR for accurate FRB positions

All surveys combined should result in an uniform LST coverage.

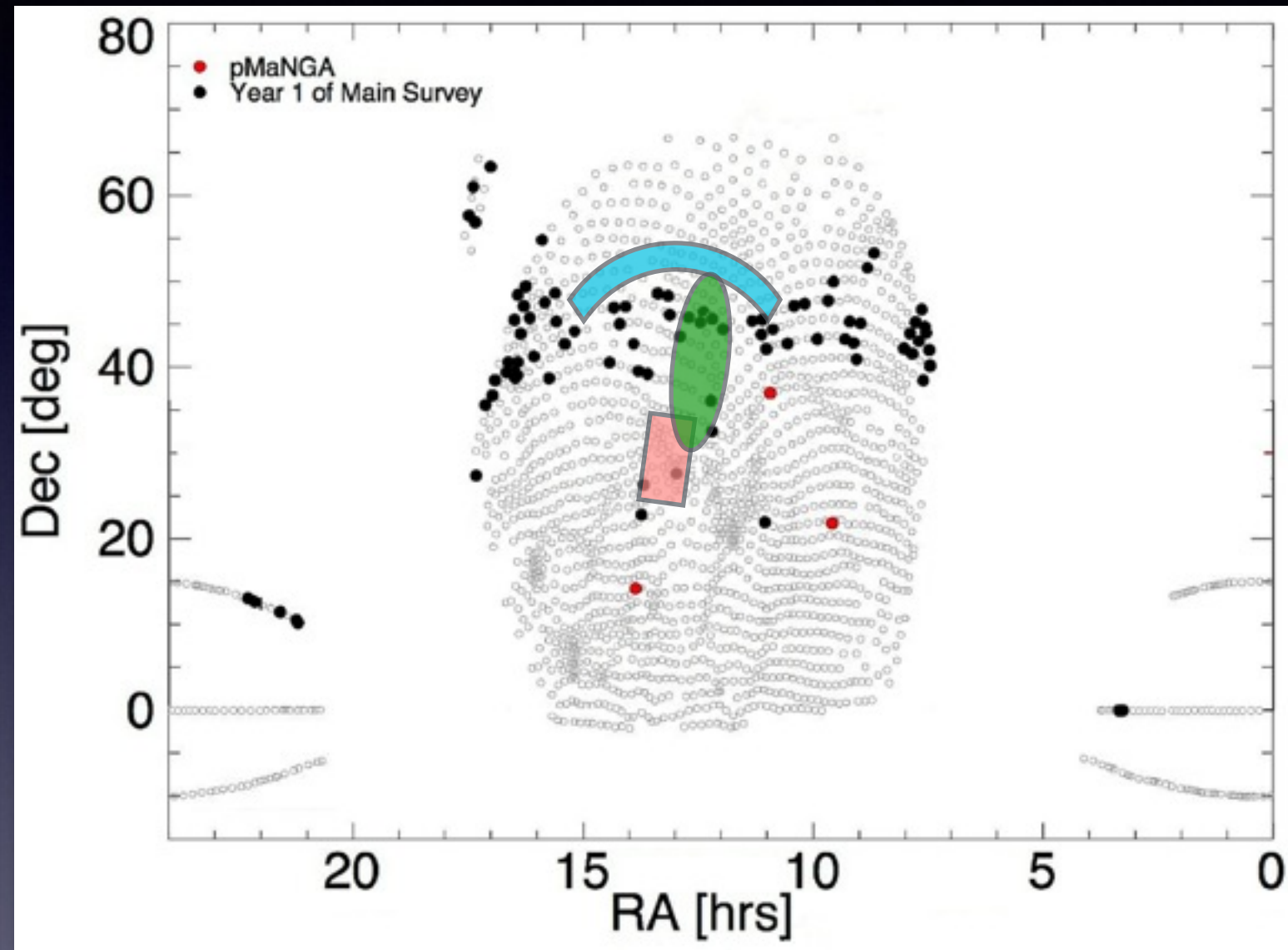


Synergy - MaNGA

A SDSS-IV multi-IFU survey of 10^4 nearby galaxies at $z \approx 0.03$

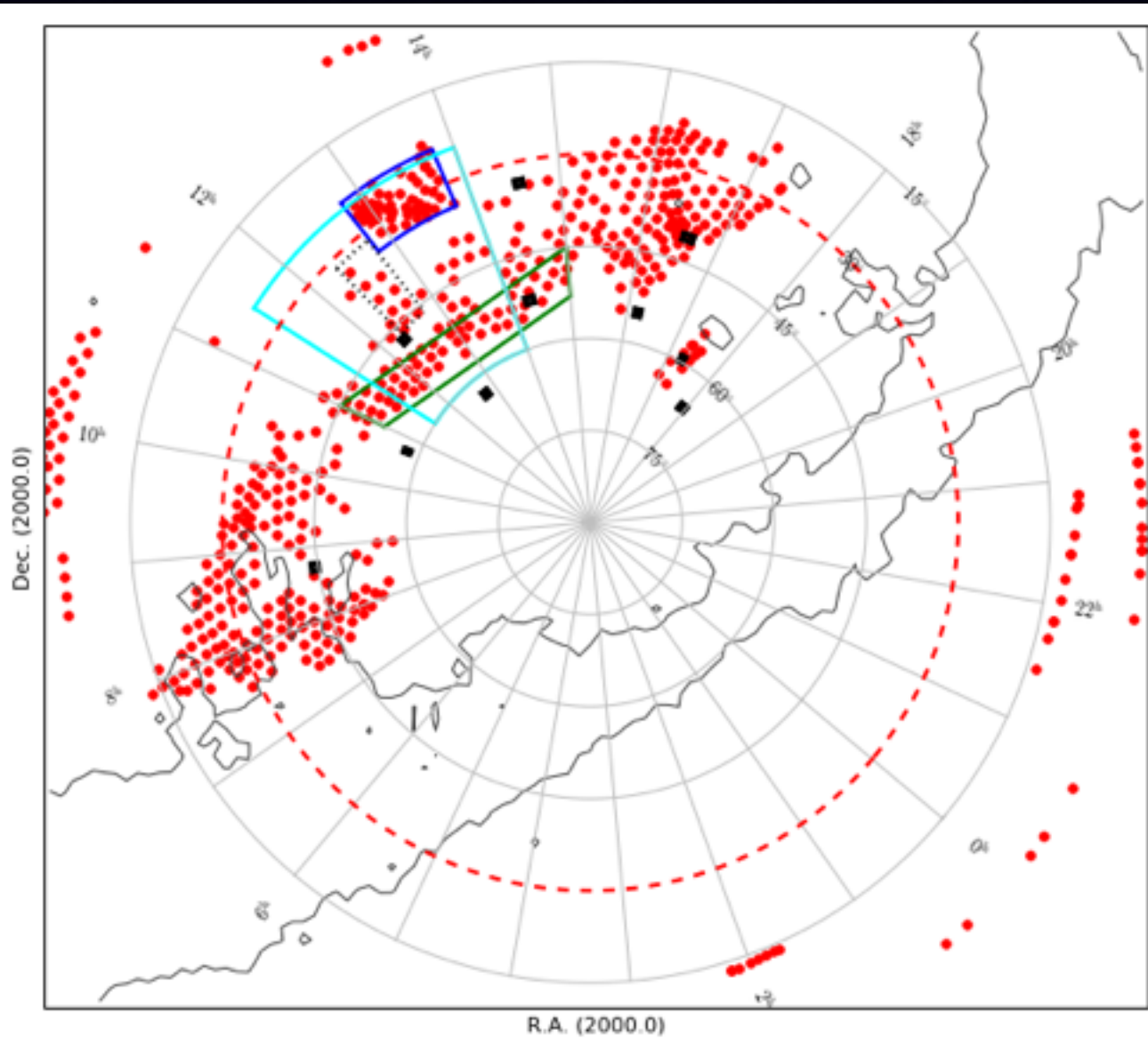


- ▶ 2" fibers
- ▶ 17 IFU's per 7 deg² field
- ▶ 12"–32" FoV per IFU
- ▶ 360–1000 nm
- ▶ R=2000

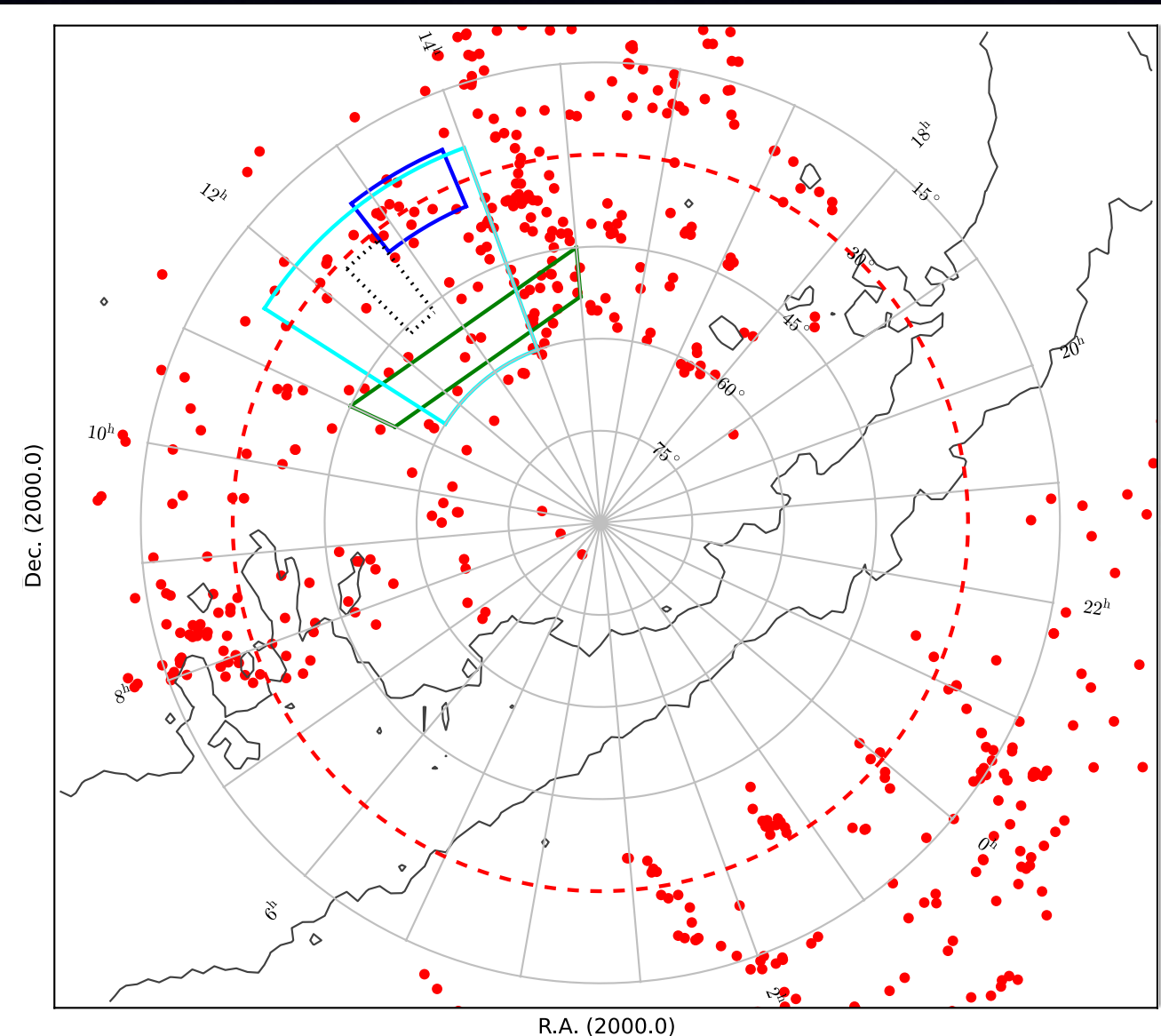


Apertif Survey Plan

MaNGA fields

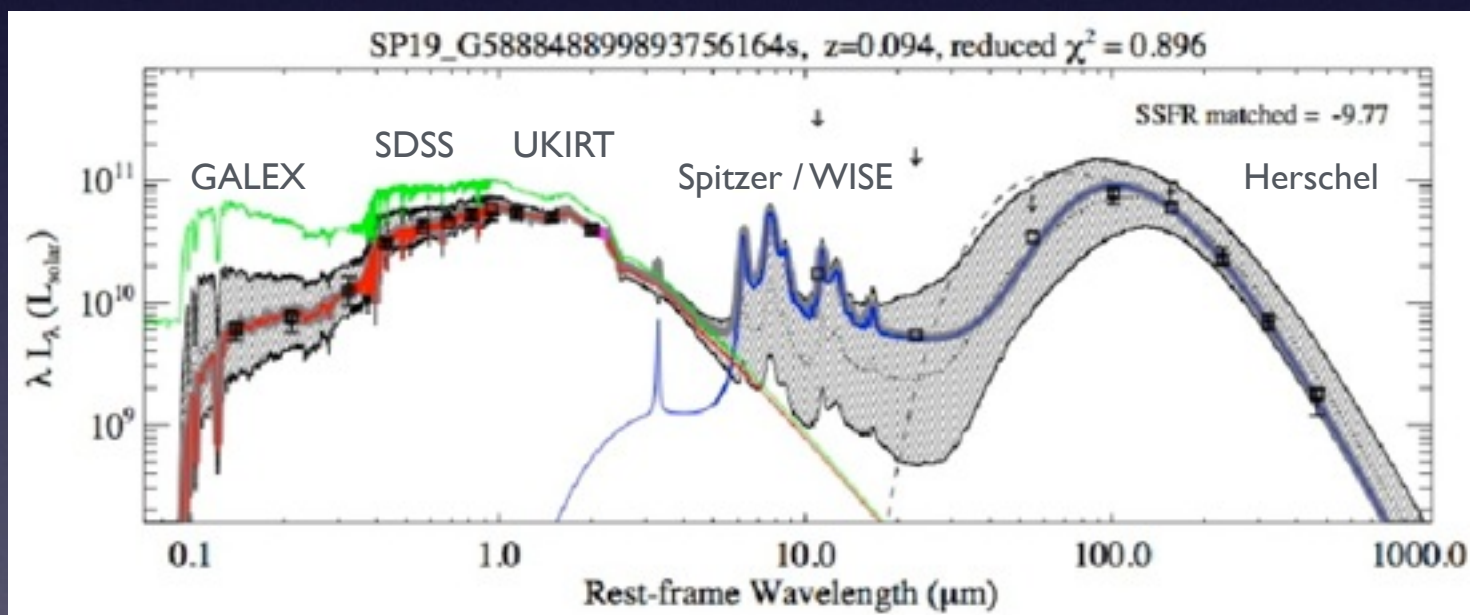


Califa pointings



Blind Herschel PACS/SPIRE imaging of North Galactic Pole region ($\sim 150 \text{ deg}^2$)

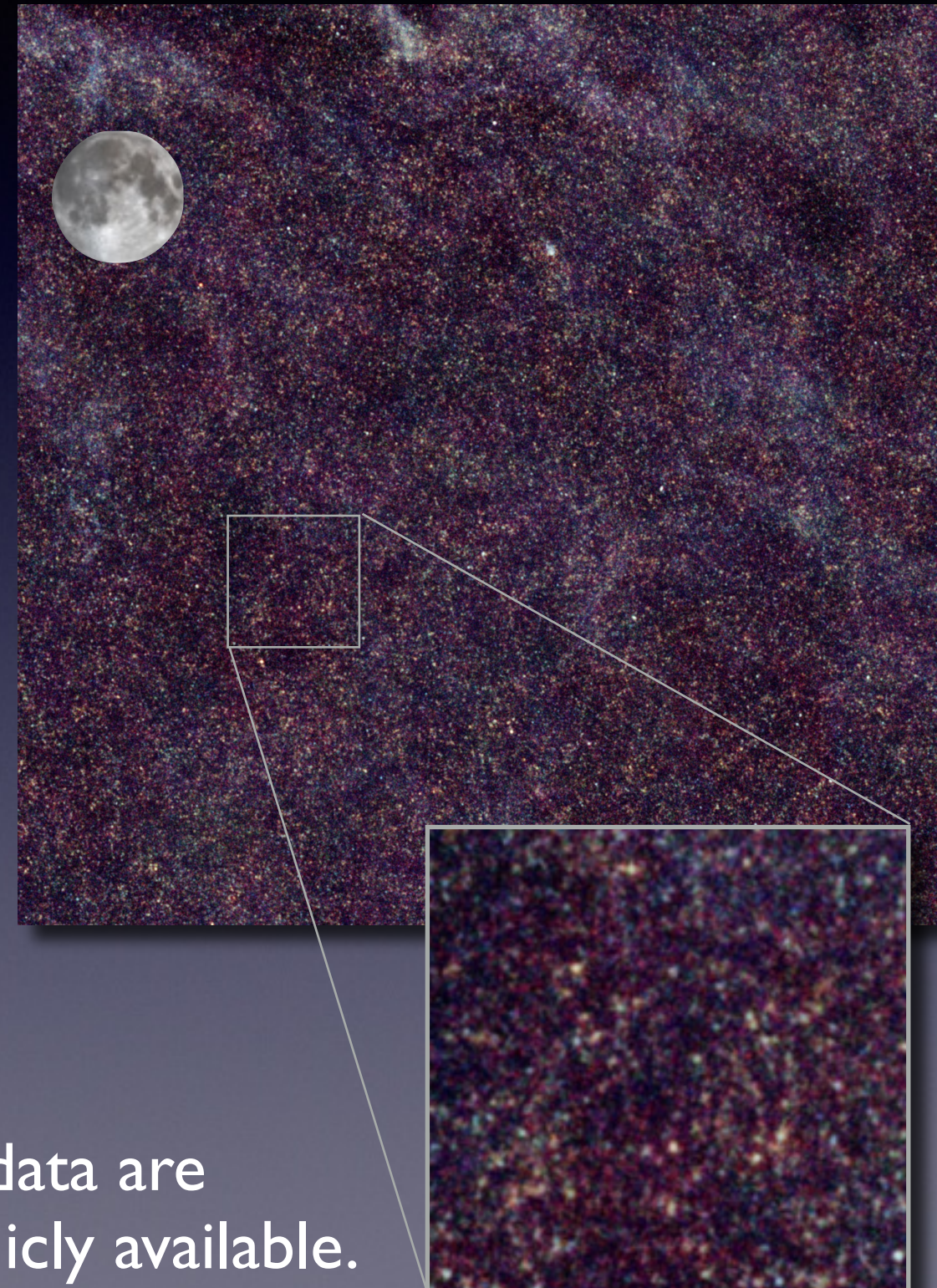
PACS: 110, 170 μm $\sim 500 \text{ sources/deg}^2$
 SPIRE: 250, 350, 500 μm $\Theta = 18''$ at 250 μm



Complete SED reconstruction:

- ▶ Total energy output
- ▶ Star Formation Rates
- ▶ Dust masses and temperatures

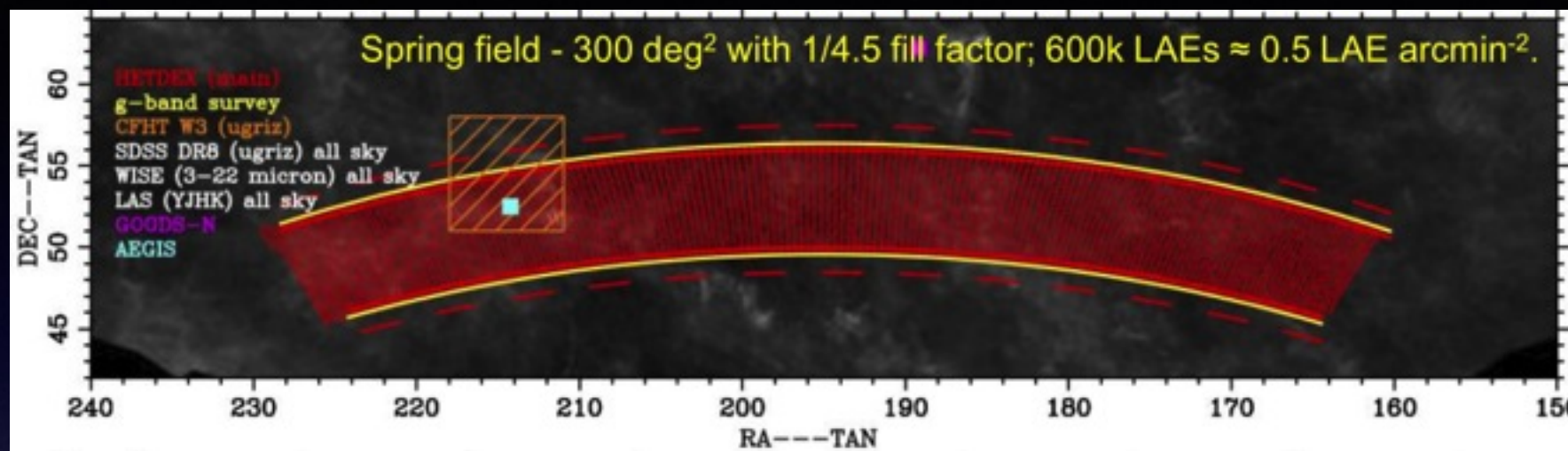
1/12th of NGP field, including Coma



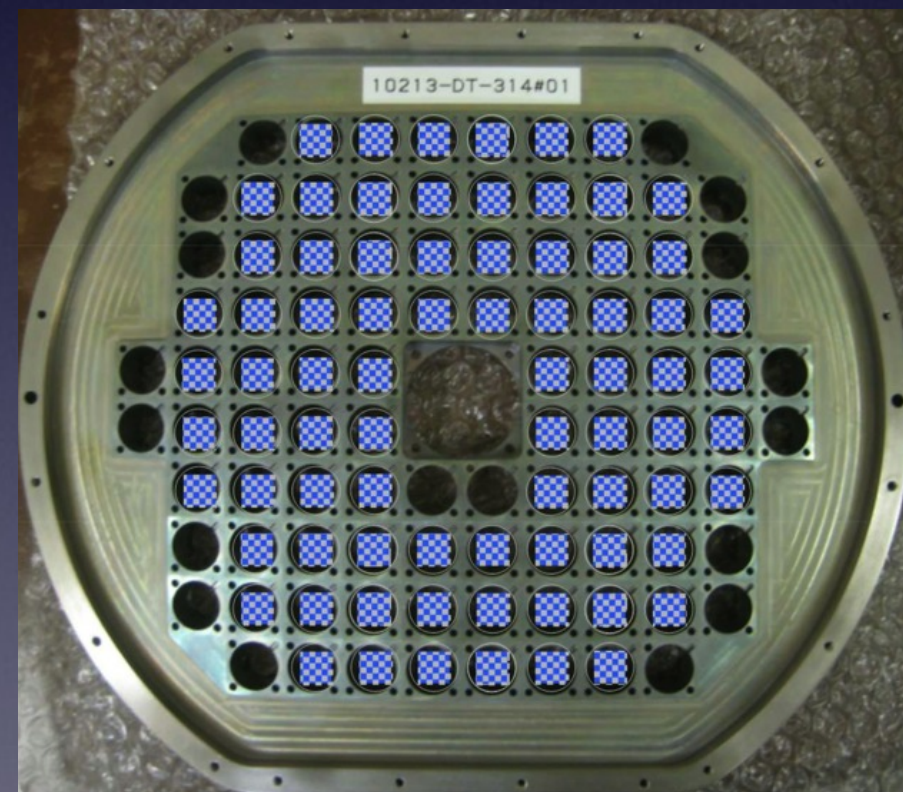
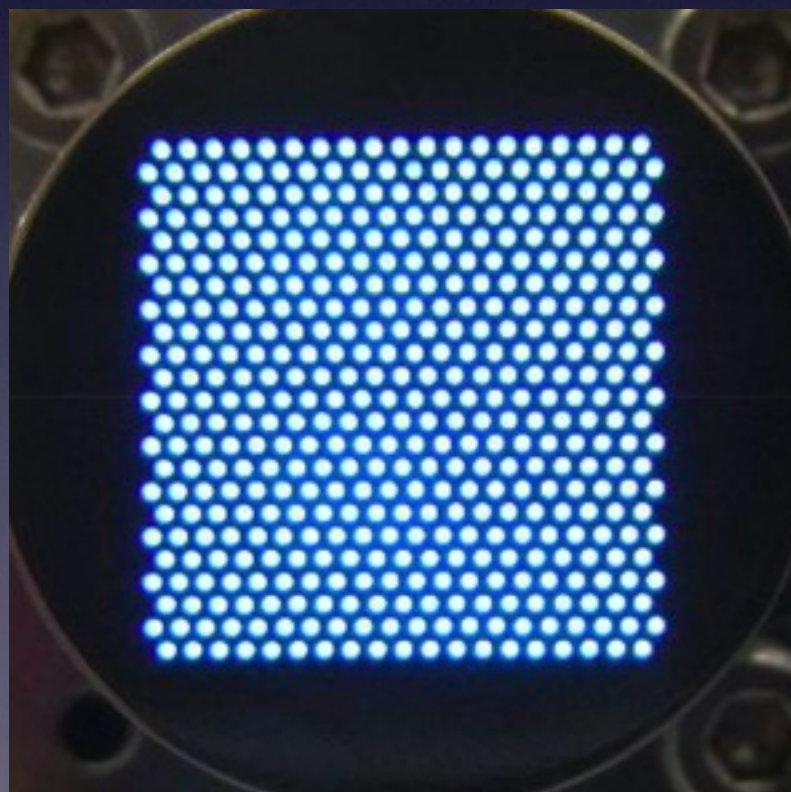
All data are publicly available.

A *blind* IFU survey
using VIRUS on HET

22% fill factor over 300 deg²



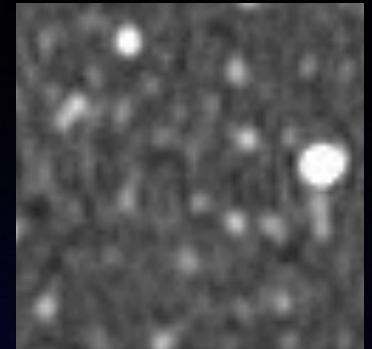
- ▶ 1.5" fibers
- ▶ 448 fibers/IFU, 78 IFUs
- ▶ 350-550 nm
 - Ly- α : $Z=1.9-3.5$
 - [OII] : $Z=0-0.48$
 - H β : $Z=0-0.13$
 - [OIII] : $Z=0-0.10$
- ▶ R=700



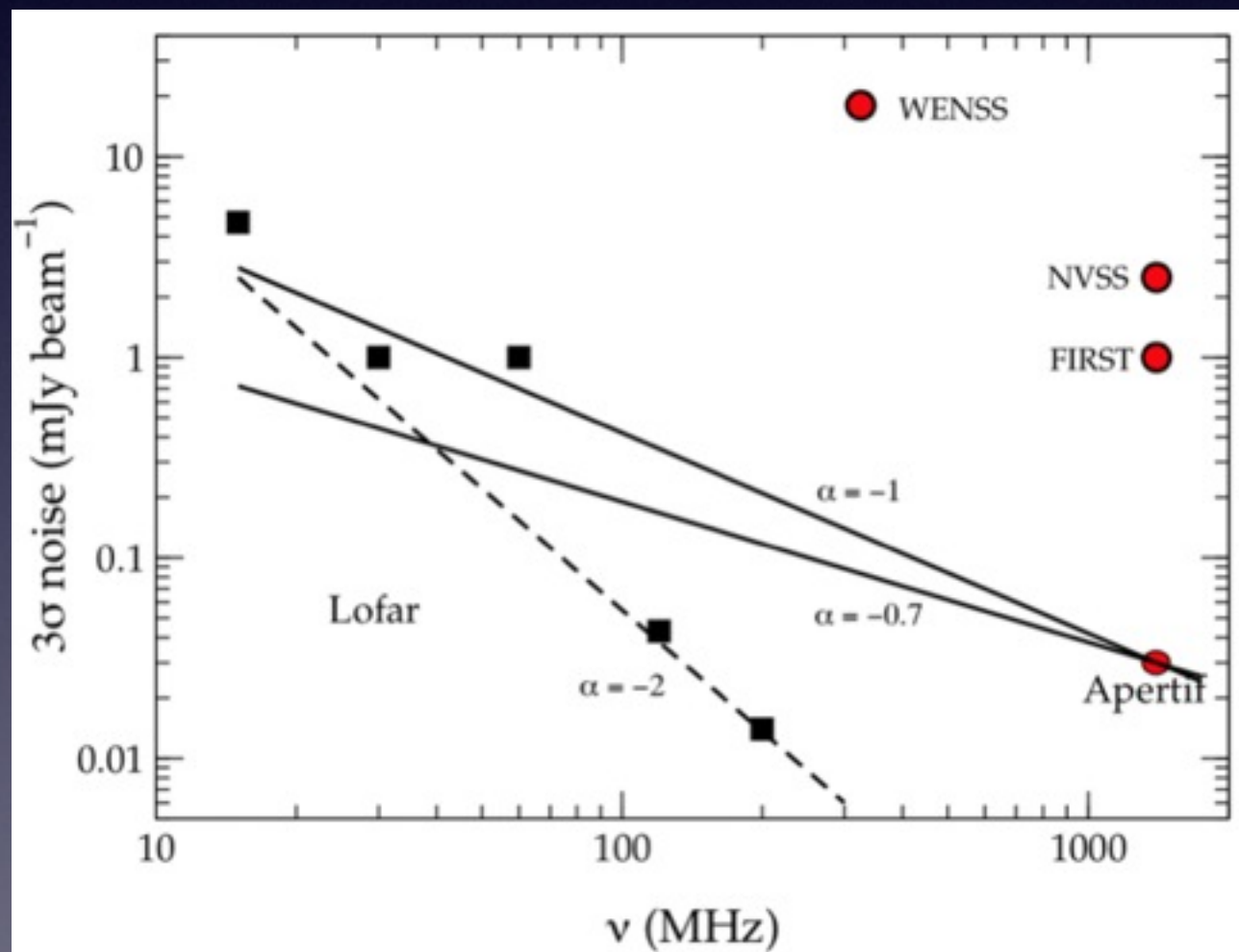
16 arcmin
50" spacing

$\sim 10^5$ [OII] redshifts in Apertif bandwidth ($Z \lesssim 0.25$)

Confusion-limited continuum maps by Apertif will detect the same star forming galaxies as LOFAR.



7 μ Jy 1.2 GHz map

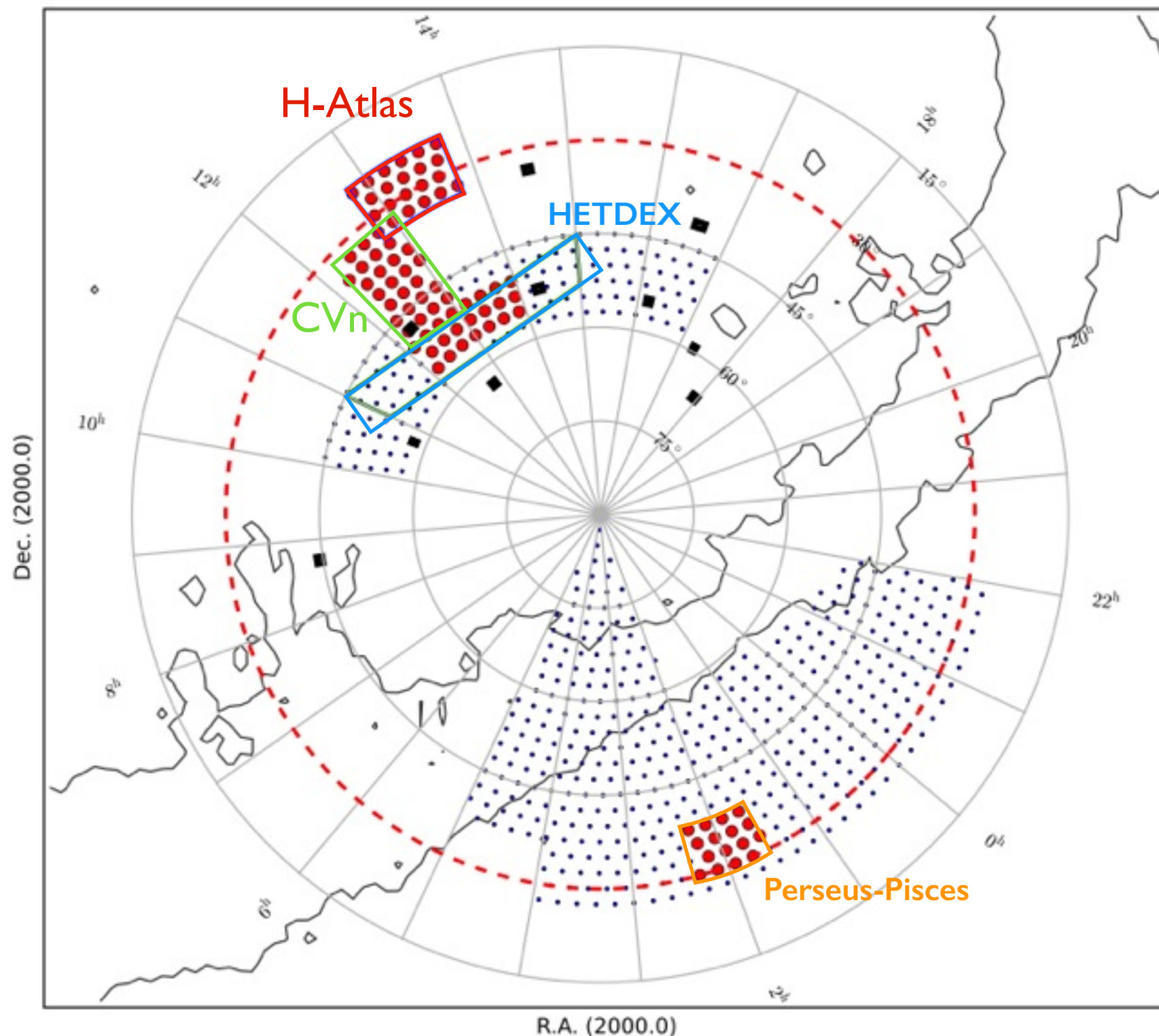


- higher-resolution LOFAR maps will facilitate source identification
- distinguish SF galaxies from steep-spectrum sources

Also:

- ▶ galaxy cluster radio halos
- ▶ radio relics
- ▶ ...

Apertif Survey Plan



- Shallow Northern Survey
- Medium-Deep Survey
- LOFAR fields

Pointing grid and survey boundary details to be determined.

Two observing modes:

- imaging in maxi-short configuration
- transient searches in Nx144m configuration

Each configuration is operational for weeks/months

Apertif Survey Team (i.e. the community) is responsible for :

- ▶ Scheduling observations
- ▶ Quality Assessment
- ▶ Flagging, calibration and analysis of data
- ▶ Delivery of data products into archive
- ▶ Publishing

Daily operations by Survey Astronomers on Duty (SADs)
provided by AST members (students, postdocs, faculty).

Goal : legacy value of survey data through Long-Term Archive

The AST is responsible for:

- Level 0 : quality-controlled raw visibilities (~1 TB/12hr)

- Level 1 : flagged and calibrated visibilities (tables)

- Level 2 : continuum-subtracted line cubes and cont./pol. image

The SWGs are responsible for :

- Level 3 : source catalogs (positions, redshifts, fluxes, line widths...)

- Level 4 : higher order products (HI maps, vel. fields, RM cubes...)

- Level 5 : science-specific products (mass models, kin. analysis...)

Annual data releases after proprietary periods.

- SNS : 6 months after final observation of previous year

- MDS : survey uniformity determines release schedule



Scientific exploitation of Apertif surveys

Project-based and carried out by SWGs under auspices of the AST.

Each SWG has a representative on the AST and may consist of

- several Individual Researchers (e.g. students/postdocs) and/or
- Project Teams focussing on a particular topic

Each IR/PT within a SWG provides

- a focused and realistic research plan
- a timeline of activities
- a publication plan
- an overview of data products to be generated

The AST monitors and coordinates activities of SWGs to avoid conflicts of interest and to protect student projects.

Two observing modes (imaging and transients)

Two imaging depths

Survey areas driven by science (synergies) and efficiency

Survey operations done by the community

Mar - Jul : tech. and sci. commissioning with limited array

August : full array available for early science

mid 2017: start of surveys through 2020