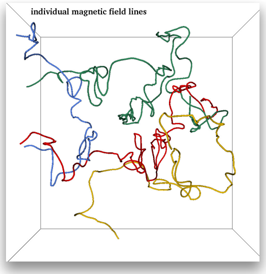
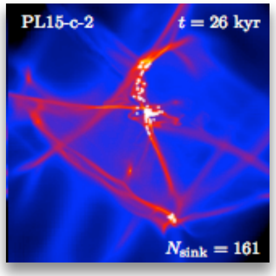
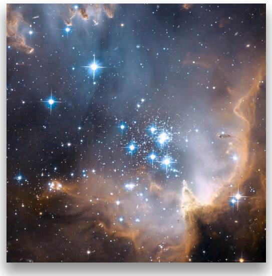
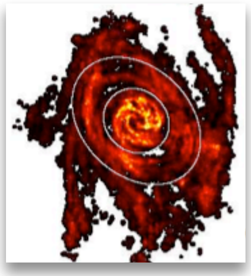
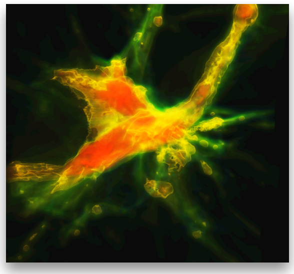
Introduction to ISM properties: from small to large scales





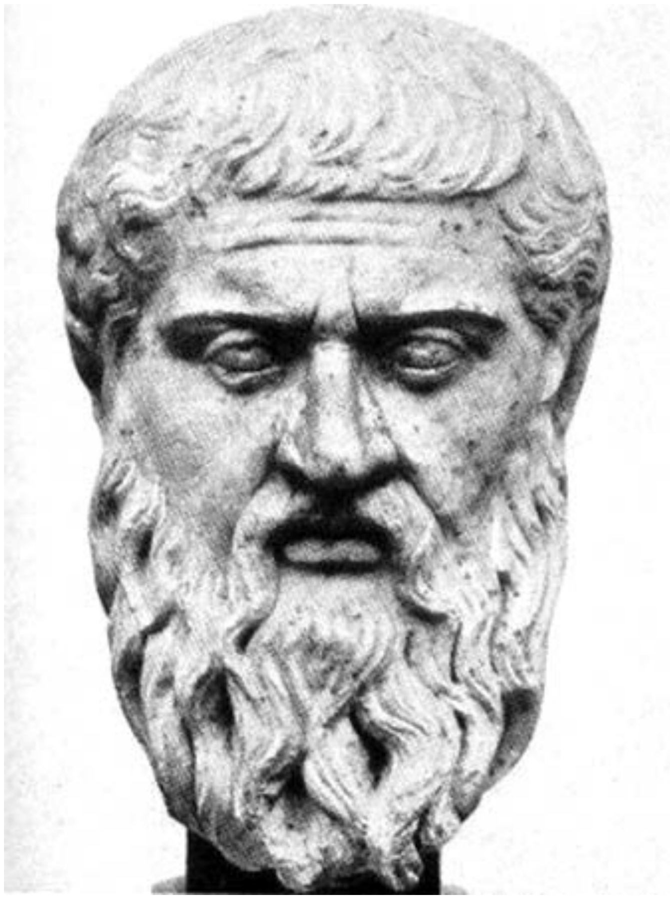






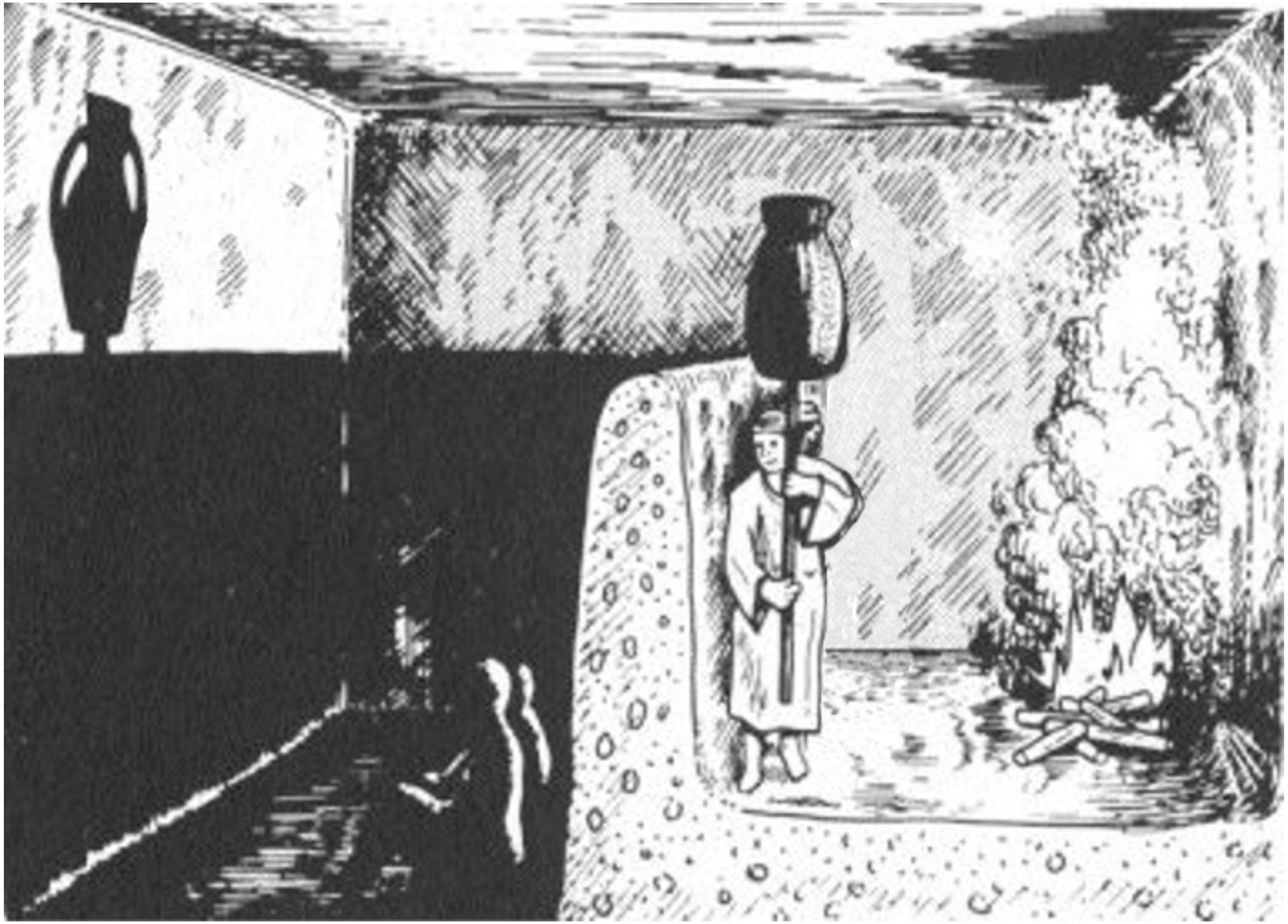
Ralf Klessen

Zentrum für Astronomie der Universität Heidelberg
Institut für Theoretische Astrophysik



Platon
428/427–348/347 BC

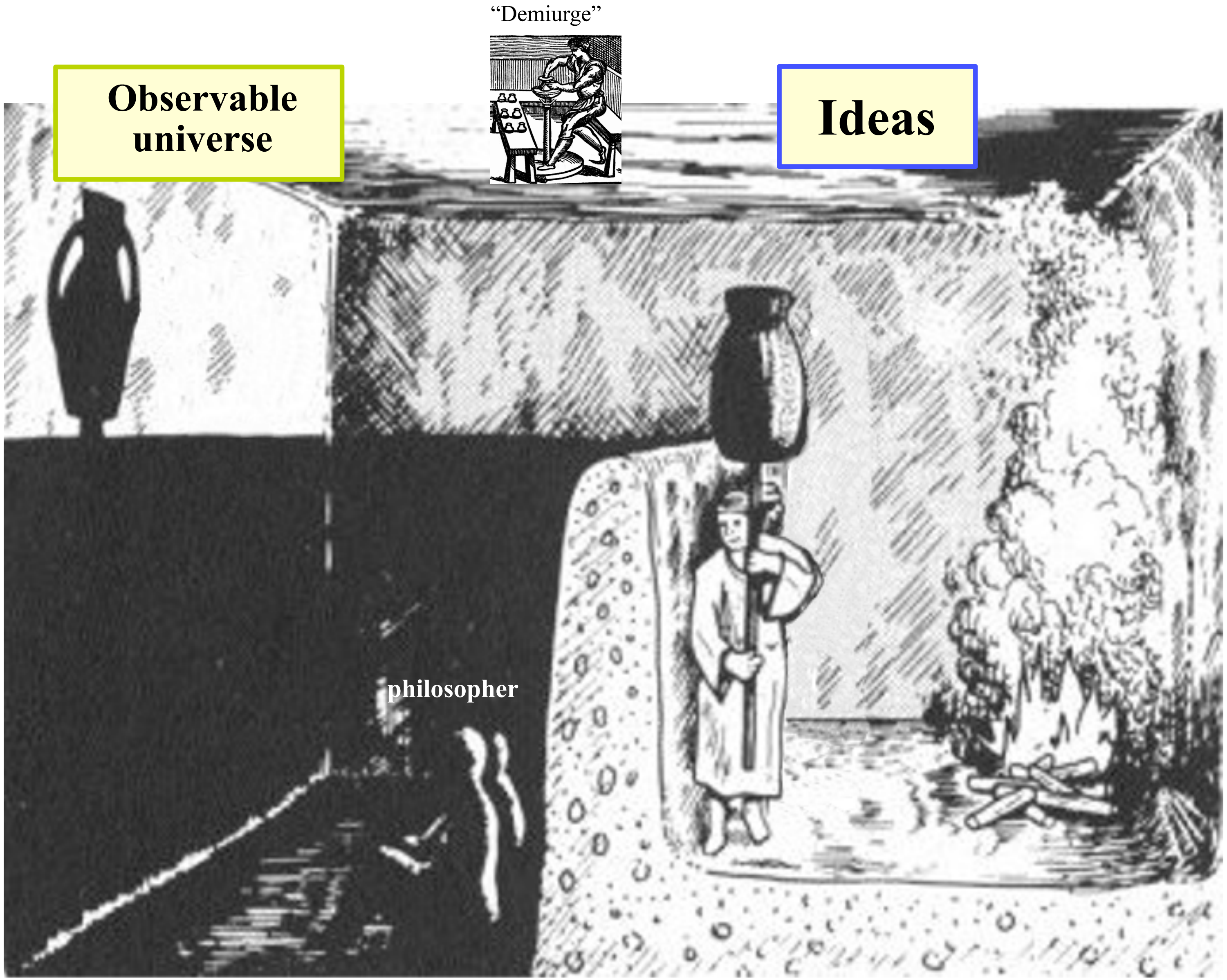
Plato's allegory of the cave*



Laszlo Szücs, image from criticalthinking-mc205.wikispaces.com

* The Republic
(514a-520a)

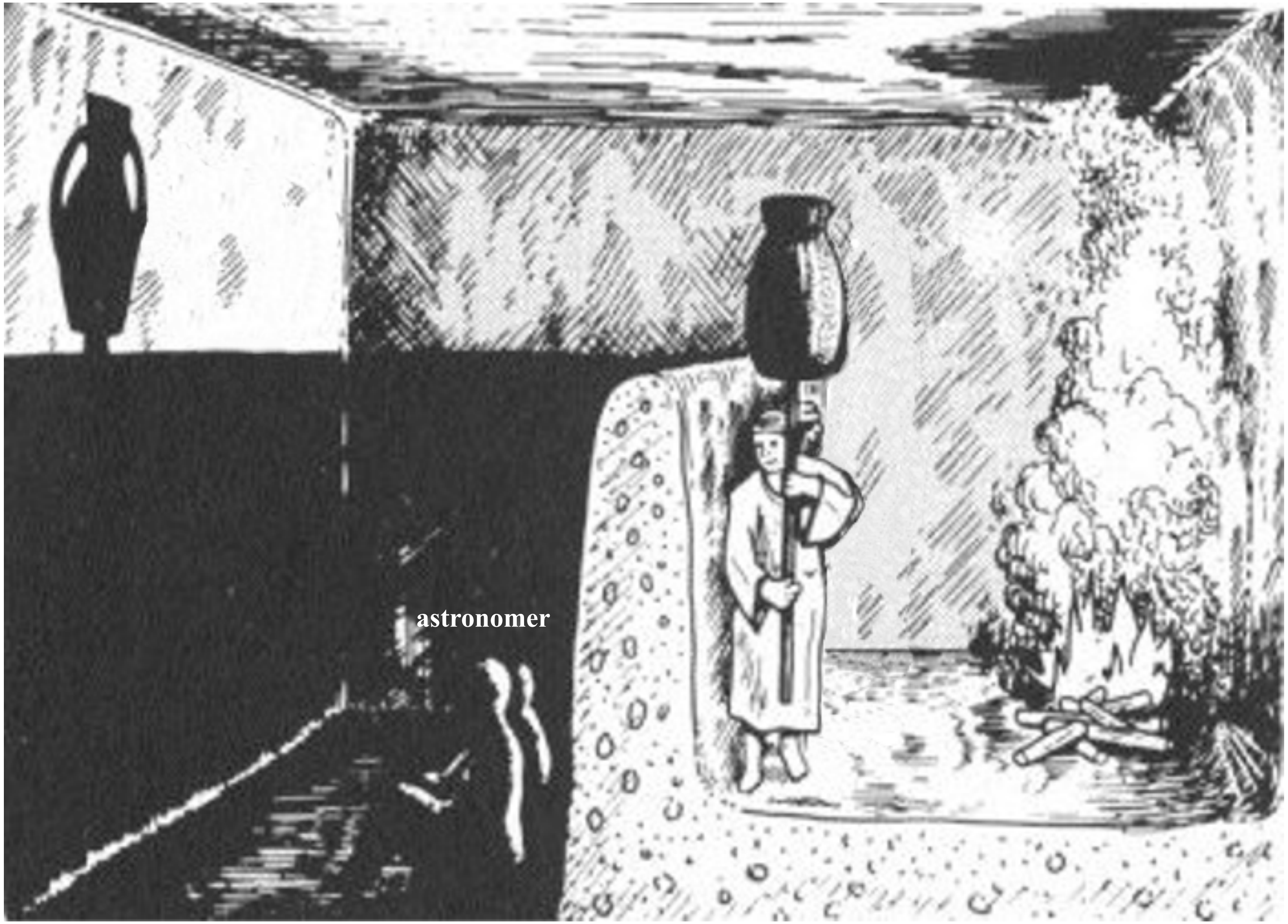
Plato's allegory of the cave*



* The Republic (514a-520a)

Laszlo Szücs, image from criticalthinking-mc205.wikispaces.com

Plato's allegory of the cave* ↔ Astronomical observations



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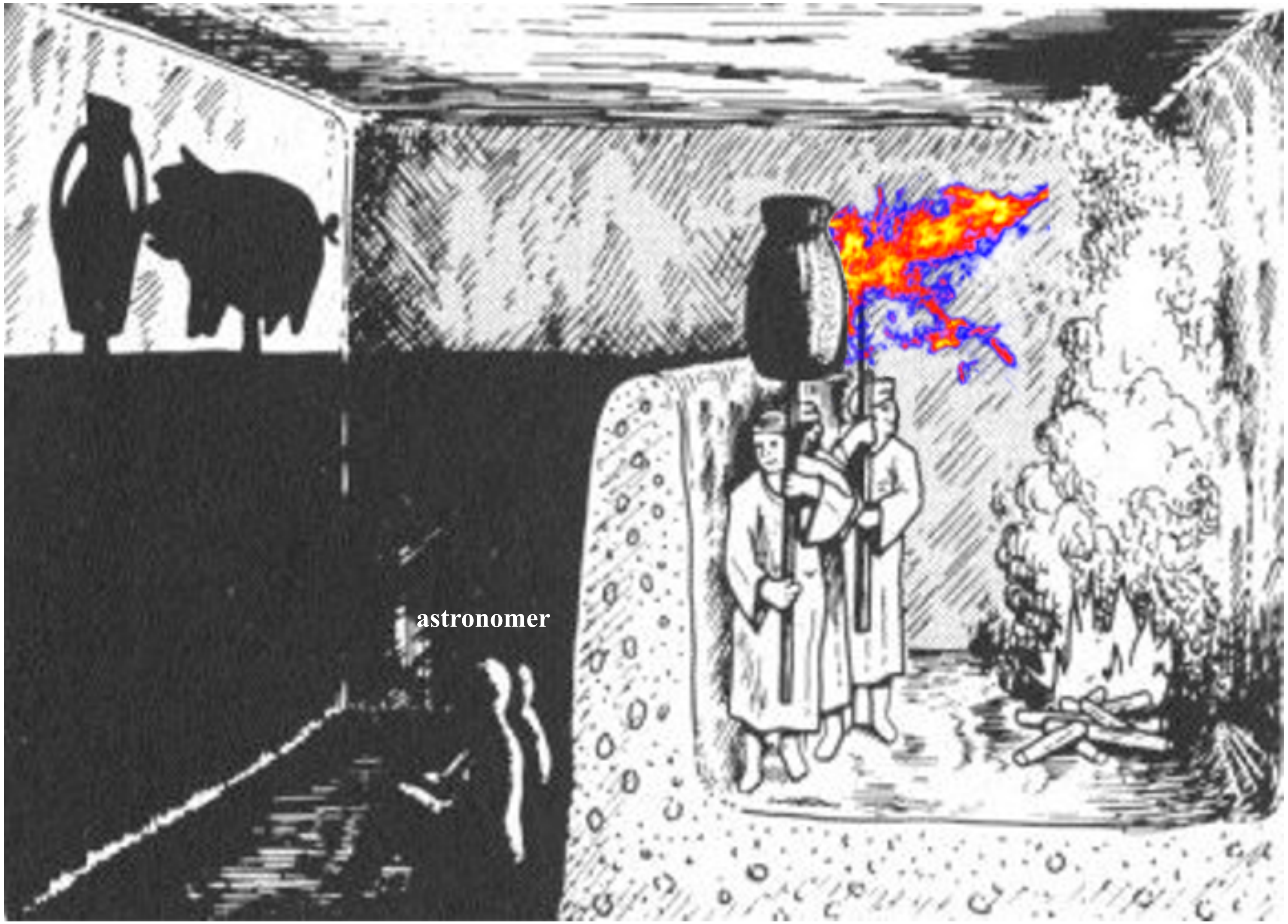

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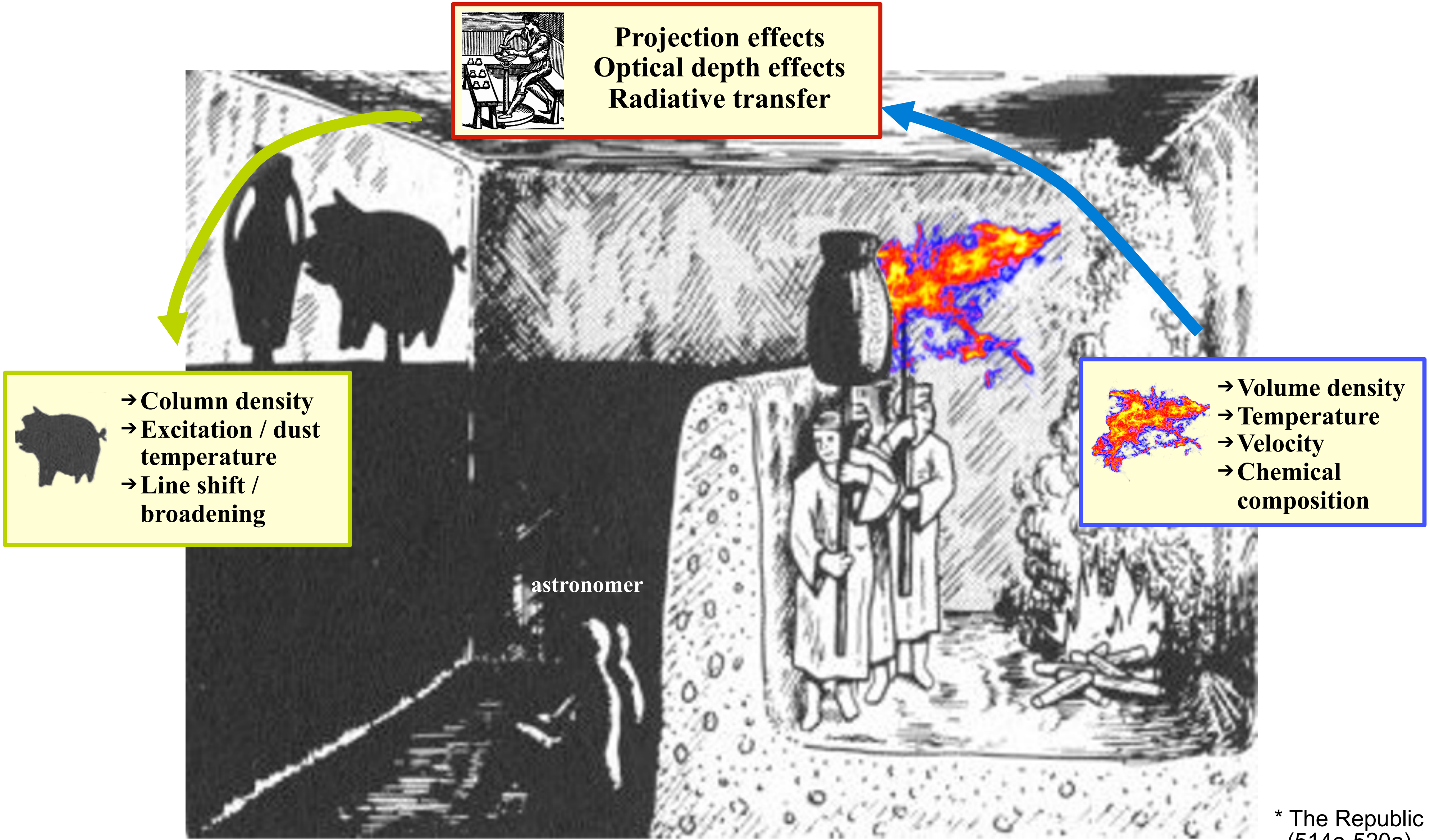

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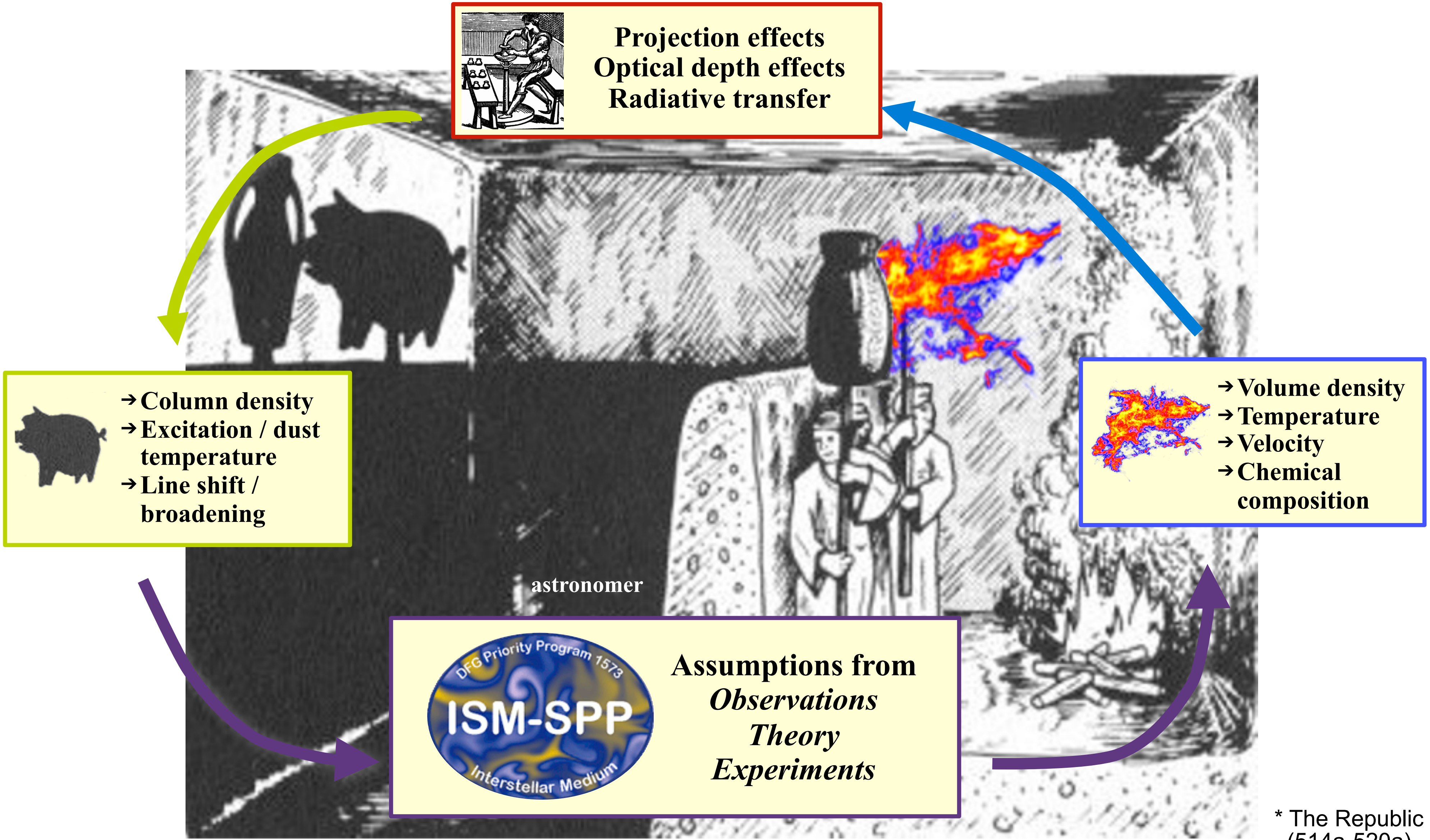


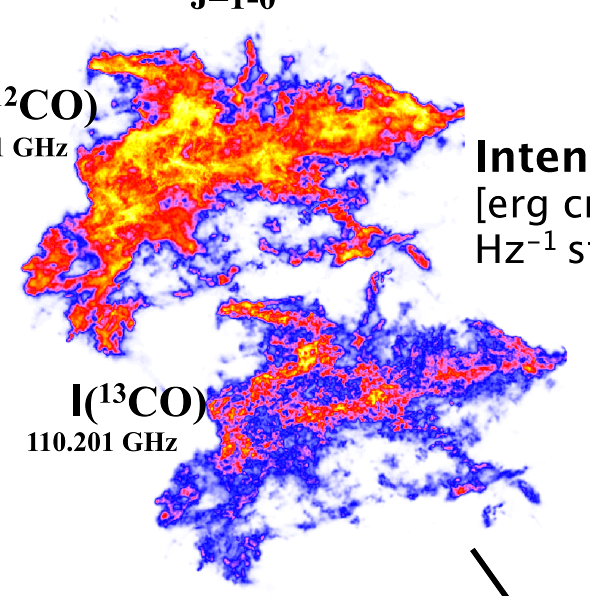
* The Republic (514a-520a)

Laszlo Szücs, image from criticalthinking-mc205.wikispaces.com

Example: from CO emission to total column density

Following Wilson et al. 2009

J=1-0



Intensity
[erg cm^{-2} s^{-1} Hz^{-1} ster^{-1}]

Brightness temperature
[K]

T_B^{12}

T_B^{13}

Assumptions I.

I(^{12}CO) is optically thick

I(^{13}CO) is optically thin

Along a line of sight uniform T_{ex} and same for ^{12}CO and ^{13}CO

$$T_{\rm ex} = 5.5/\ln\left(1 + \frac{5.5}{T_B^{12} + 0.82}\right)$$

$$\tau_{13}(v) = -\ln\left[1 - \frac{T_{\rm B}^{13}}{5.3}\left\{\exp\left(\frac{5.3}{T_{\rm ex}} - 1\right)^{-1} - 0.16\right\}^{-1}\right]$$

LTE

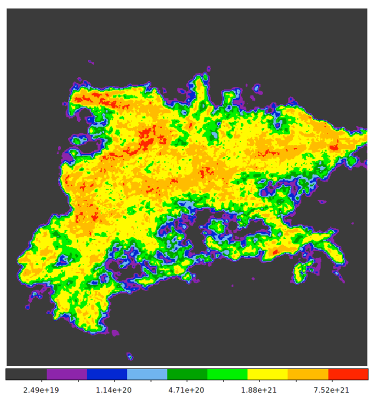
$$N(^{13}{\rm CO}) = 3.0 \times 10^{14}\,\frac{T_{\rm ex}\int \tau_{13}(v)dv}{1 - \exp(-5.3/T_{\rm ex})}$$

Assumptions II.

Uniform N(^{12}CO)/N(^{13}CO) ~ 60 *

N(H_2)/N(^{12}CO) ratio ~ 6.6×10^3 **

Column density
[cm^{-2}]



* Langer & Penzias (1990)
** Pineda et al. (2009)

Laszlo Szücs et al., in prep.

further agenda

- overview of ISM properties
- ISM and stellar birth
- global star formation relations
- CO dark H2 gas

further agenda

- overview of ISM properties
- ISM and stellar birth
- global star formation relations
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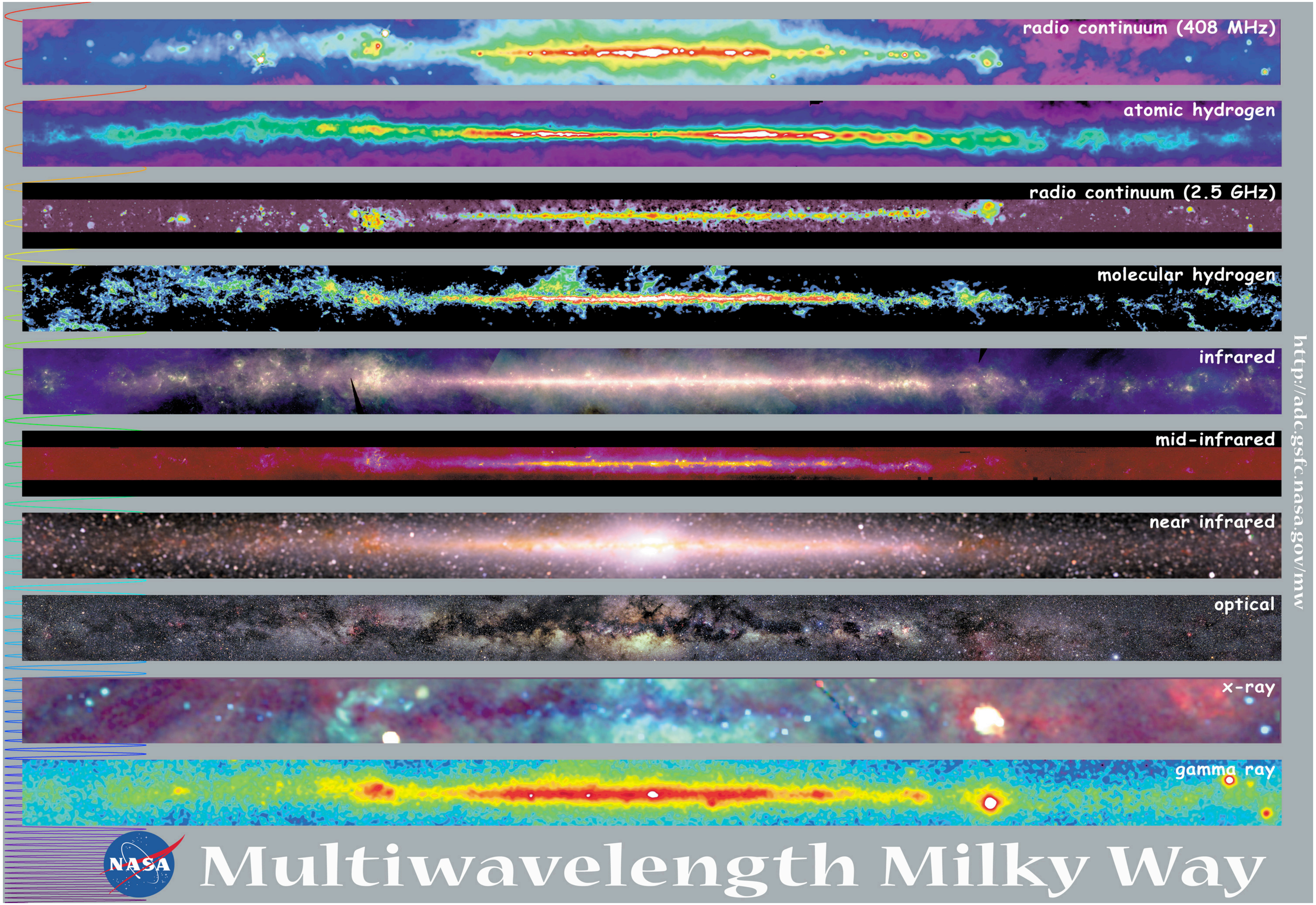
DISCLAIMER

multi-wavelength observations

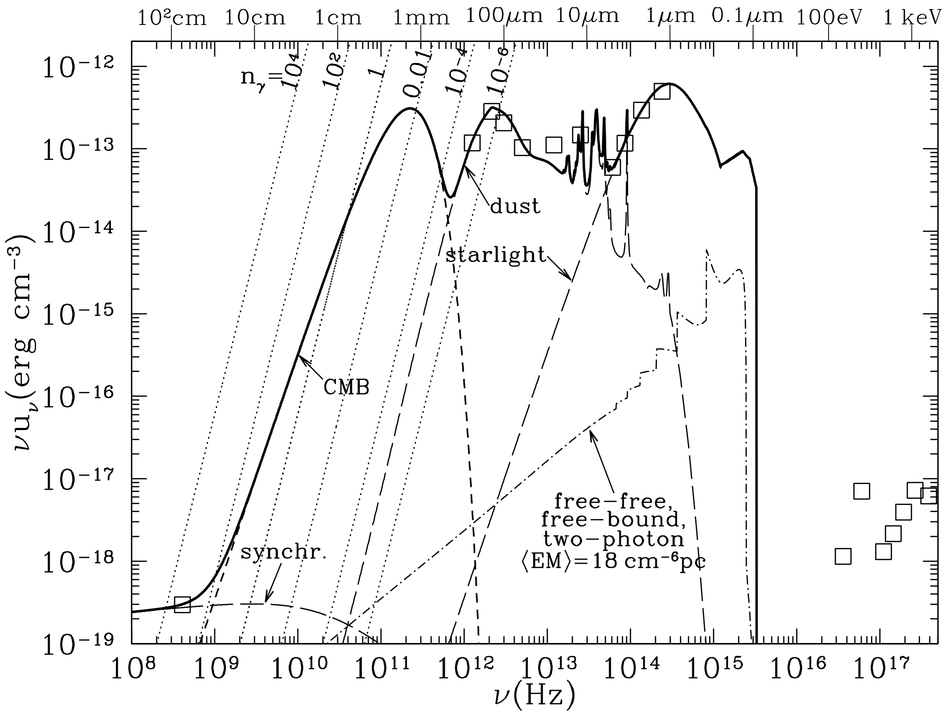
different wavelengths provide different information.

→astronomer use the full electromagnetic spectrum

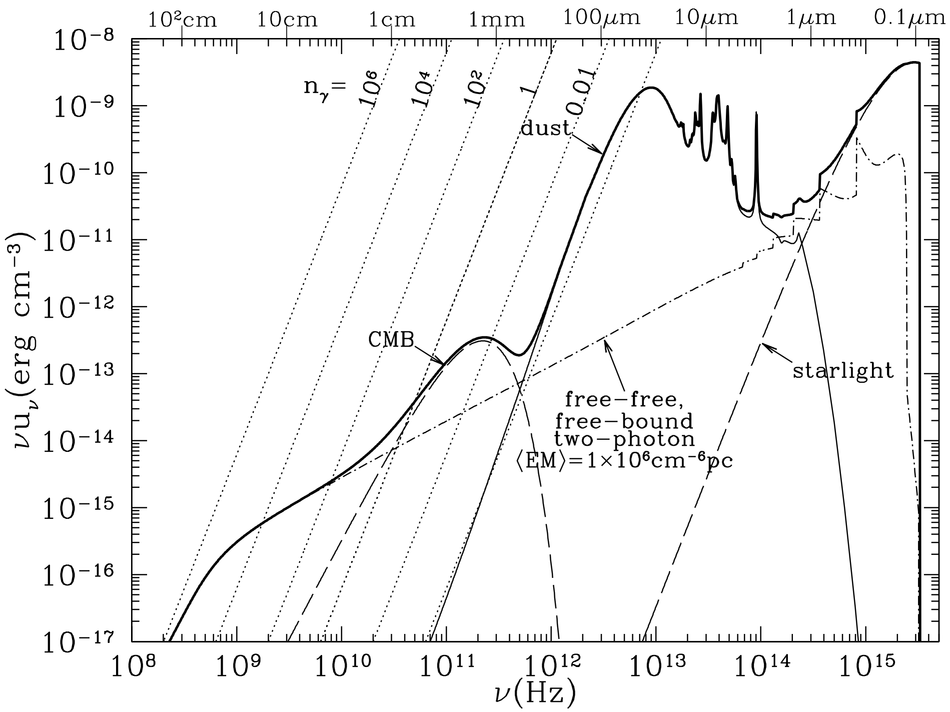
- radio: interstellar gas (line emission -> velocity information)
- sub-mm range: dust (thermal emission)
- infrared & optical: stars
- x-rays: stars (coronae), supernovae remnants (very hot gas)
- γ-rays: supernovae remnants (radioactive decay, e.g. ^{26}Al), compact objects, merging of neutron stars (γ-ray burst)


radio continuum (408 MHz)
atomic hydrogen
radio continuum (2.5 GHz)
molecular hydrogen
infrared
mid-infrared
near infrared
optical
x-ray
gamma ray
http://adc.gsfc.nasa.gov/mw
Multiwavelength Milky Way

interstellar radiation field



HI cloud in solar neighborhood



in vicinity of massive star

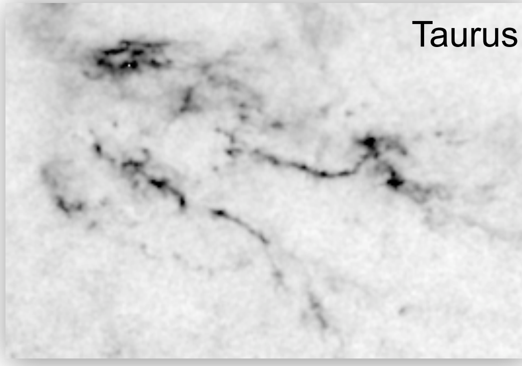
- cosmic microwave background at small frequencies (mm range)
- dust at μm wavelengths
- starlight at IR and optical frequencies (including UV and near x-rays)

Figures from Draine, B. Physics and Chemistry in the ISM (2011, Princeton)

interstellar medium (ISM)

Abundances, scaled to 1.000.000 H atoms

element		atomic number	abundance
hydrogen	H	1	1.000.000
deuterium	$_1H^2$	1	16
helium	He	2	68.000
carbon	C	6	420
nitrogen	N	7	90
oxygen	O	8	700
neon	Ne	10	100
sodium	Na	11	2
magnesium	Mg	12	40
aluminium	Al	13	3
silicium	Si	14	38
sulfur	S	16	20
calcium	Ca	20	2
iron	Fe	26	34
nickel	Ni	28	2

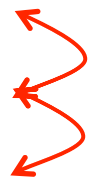


hydrogen is by far the most abundant element (more than 90% in number).

phases of the ISM

Because hydrogen is the dominating element, the classification scheme is based on its chemical state:

ionized atomic hydrogeN	*HII (H^+)*
neutraler atomic hydrogen	*HI (H)*
molecular hydrogen	*H_2*

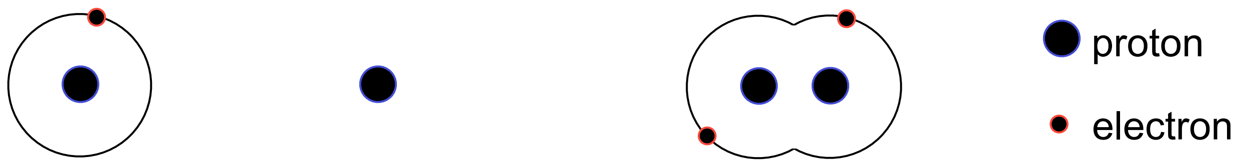


ionization

dissociation

different regions consist of almost 100% of the appropriate phase, the transition regions between HII, H and H_2 are very thin.

star formation always takes place in dense and cold molecular clouds.



phases of the ISM

Because hydrogen is the dominating element, the classification scheme is based on its chemical state:

ionized atomic hydrogeN	*HII* (H^+)	ionization
neutraler atomic hydrogen	*HI (H)*	dissociation
molecular hydrogen	H_2	

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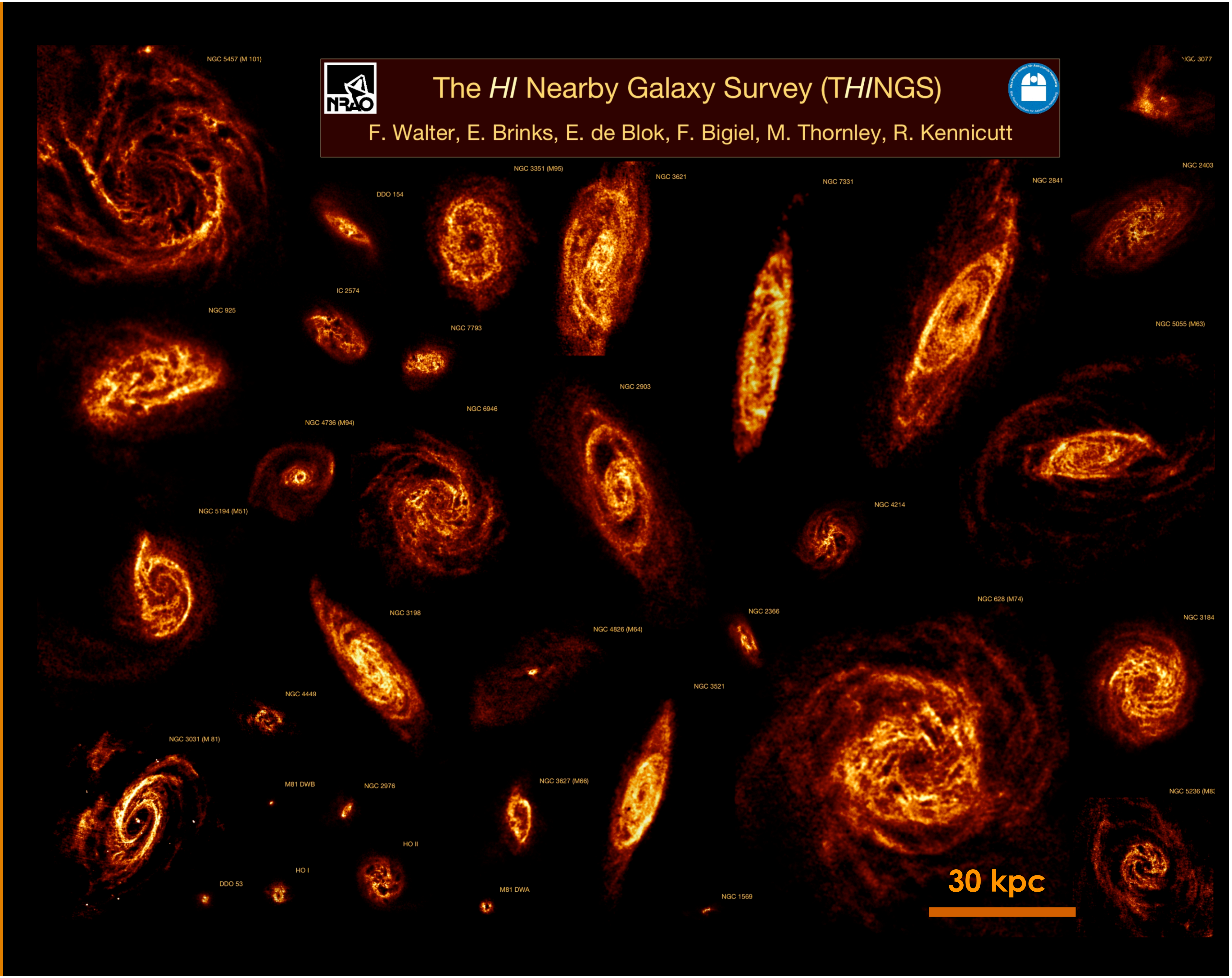
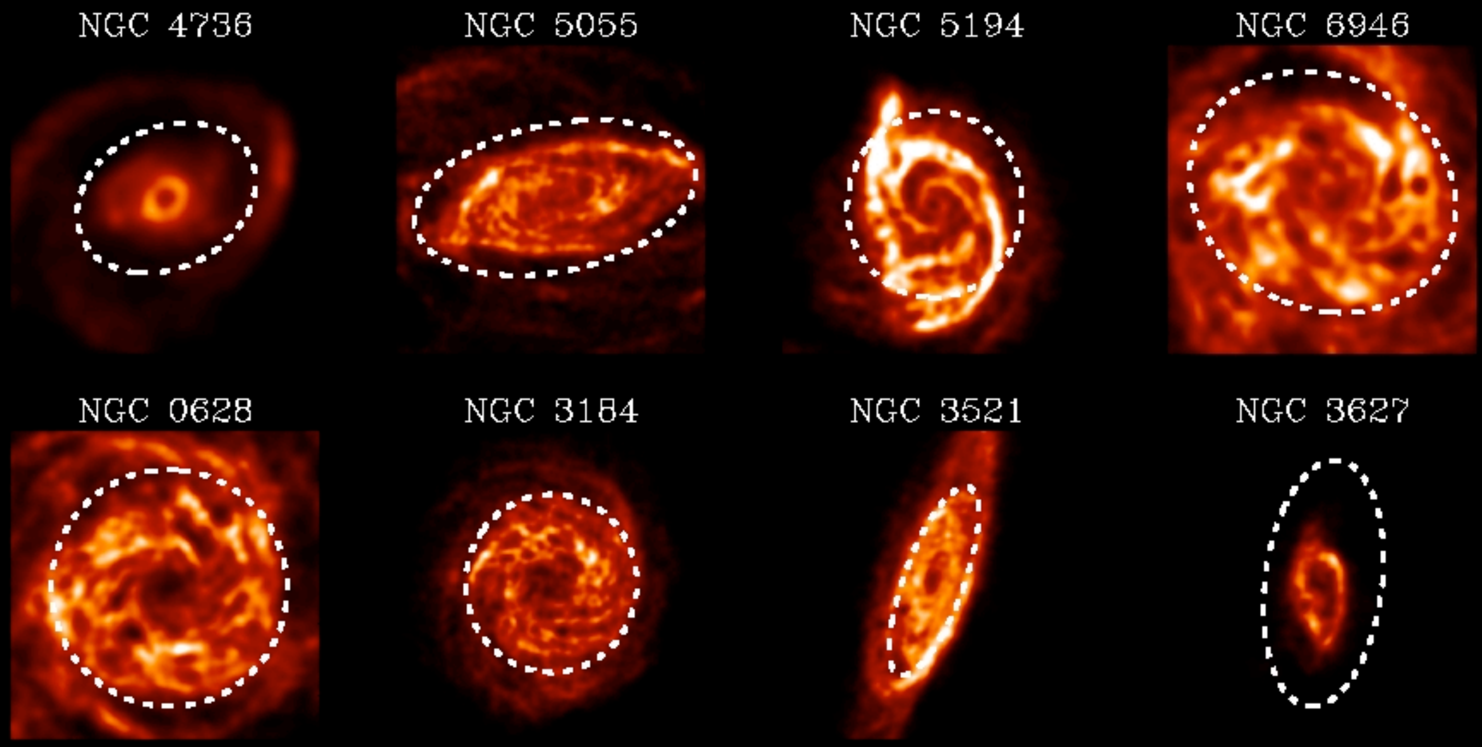
star formation always takes place in dense and cold molecular clouds.

NGC 3324, Hubble Heritage Site

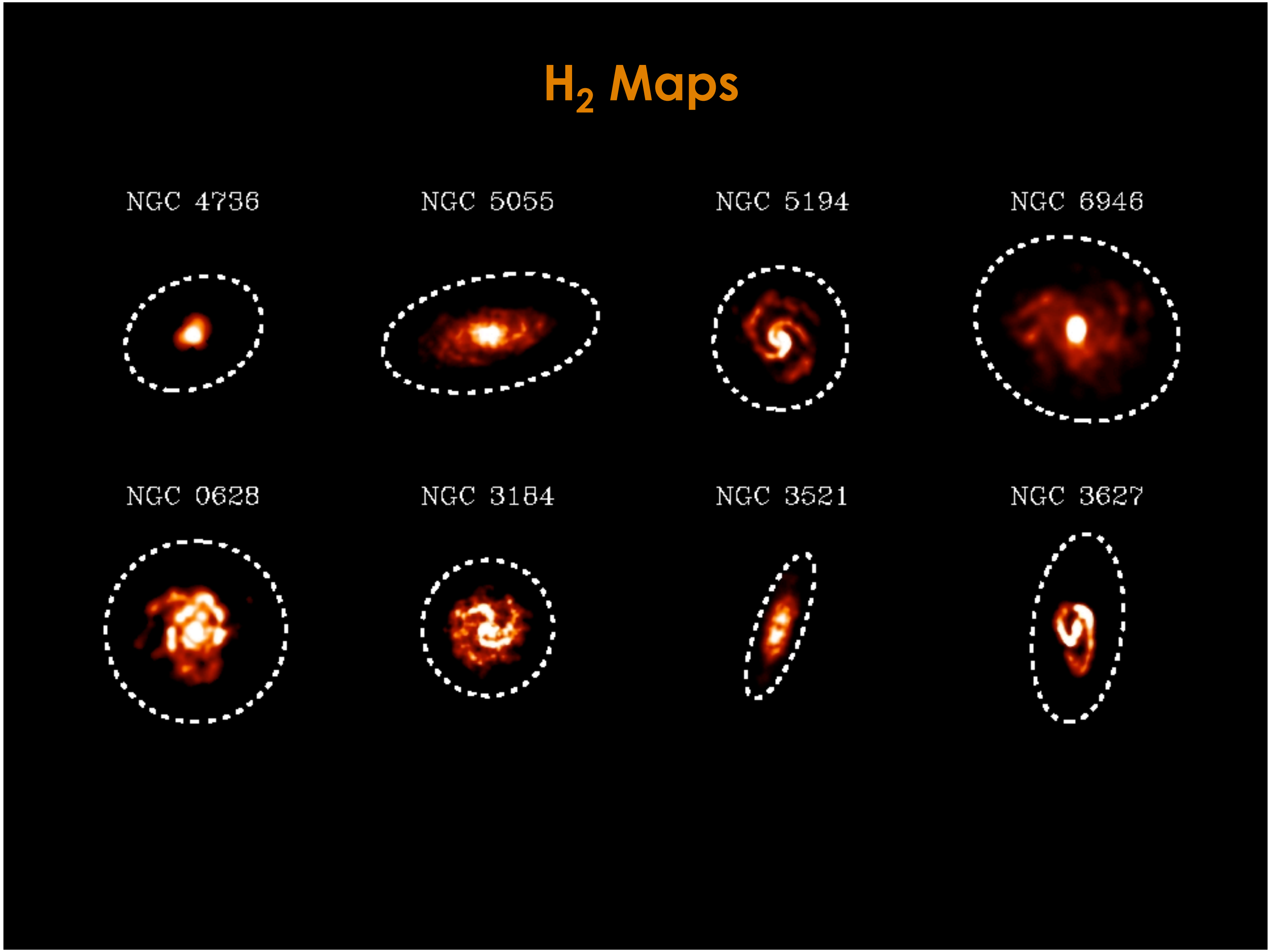
EveryTHINGS



HI Maps



galaxies from THINGS and HERACLES survey
(images from Frank Bigiel, ZAH/ITA)



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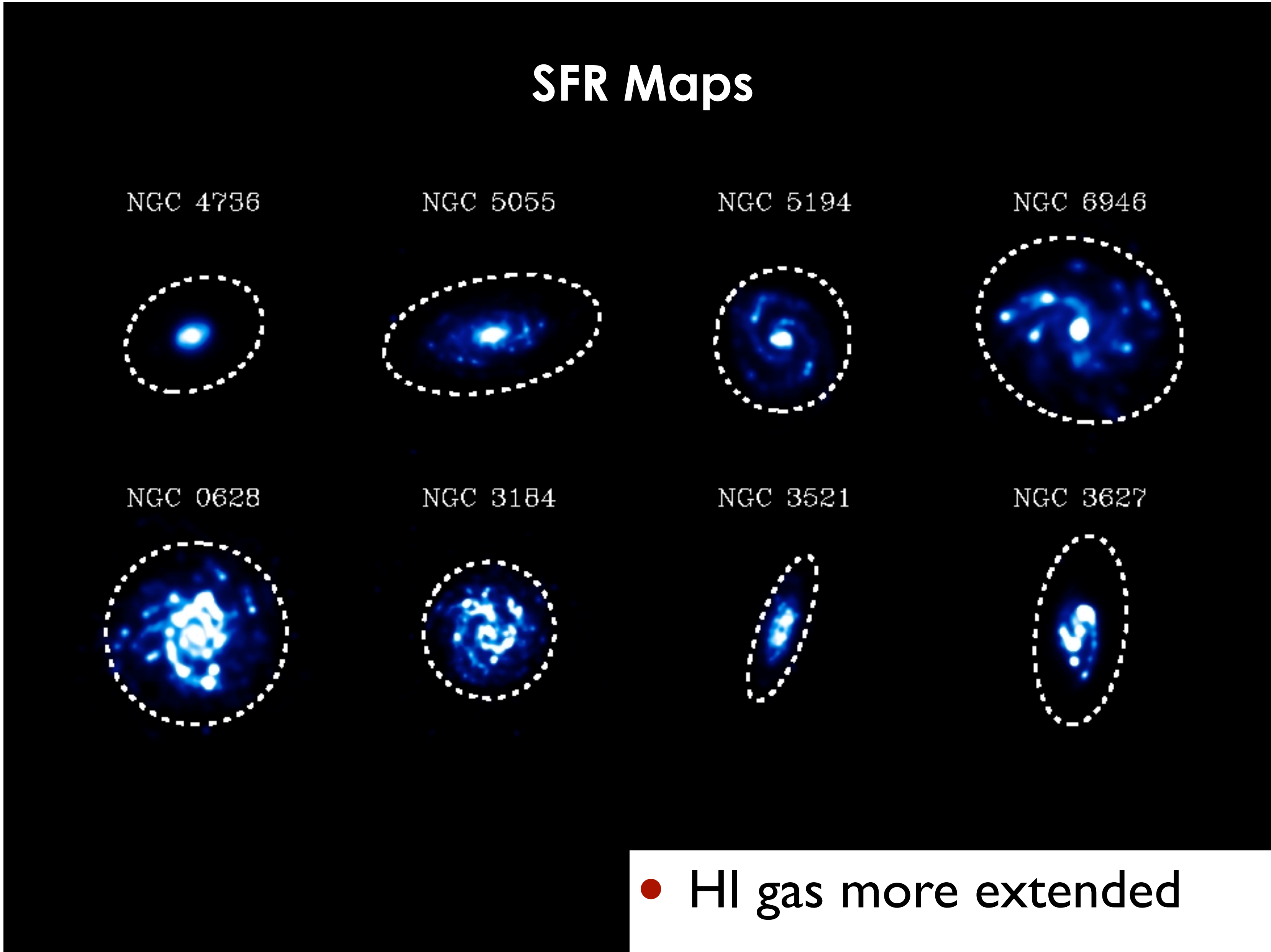
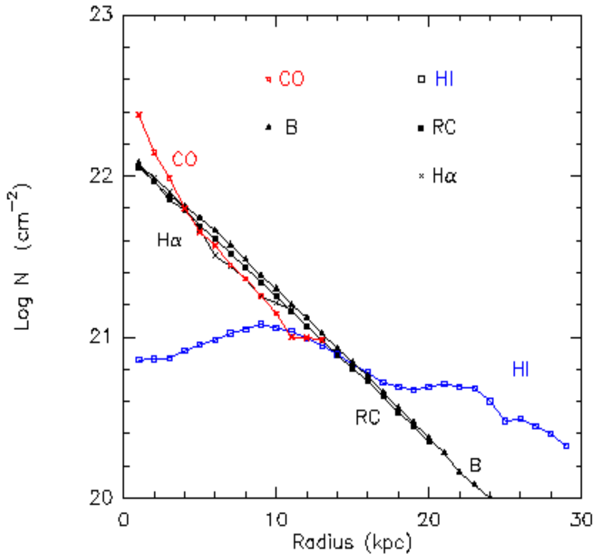


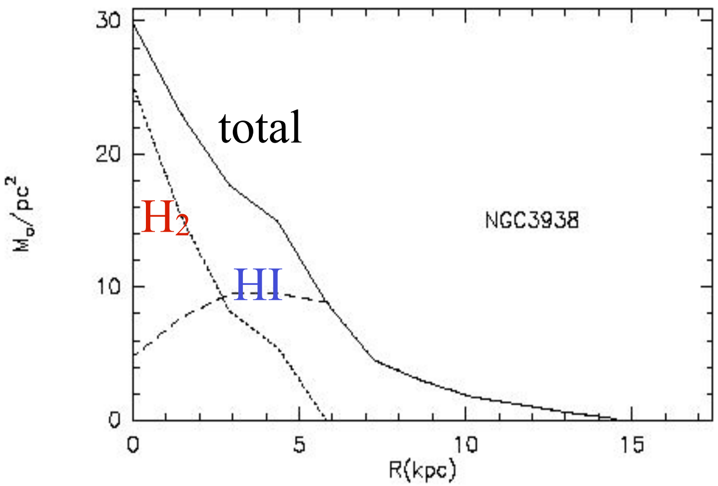
- HI gas more extended
- H2 and SF well correlated

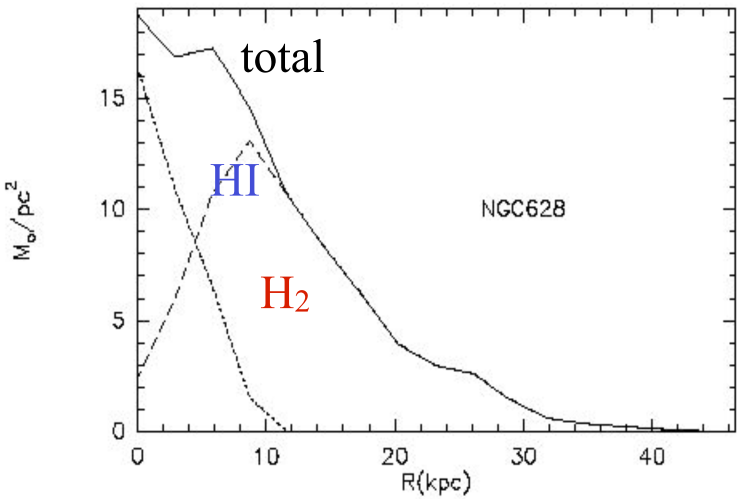
galaxies from THINGS and HERACLES survey
(images from Frank Bigiel, ZAH/ITA)

radial distribution in spirals

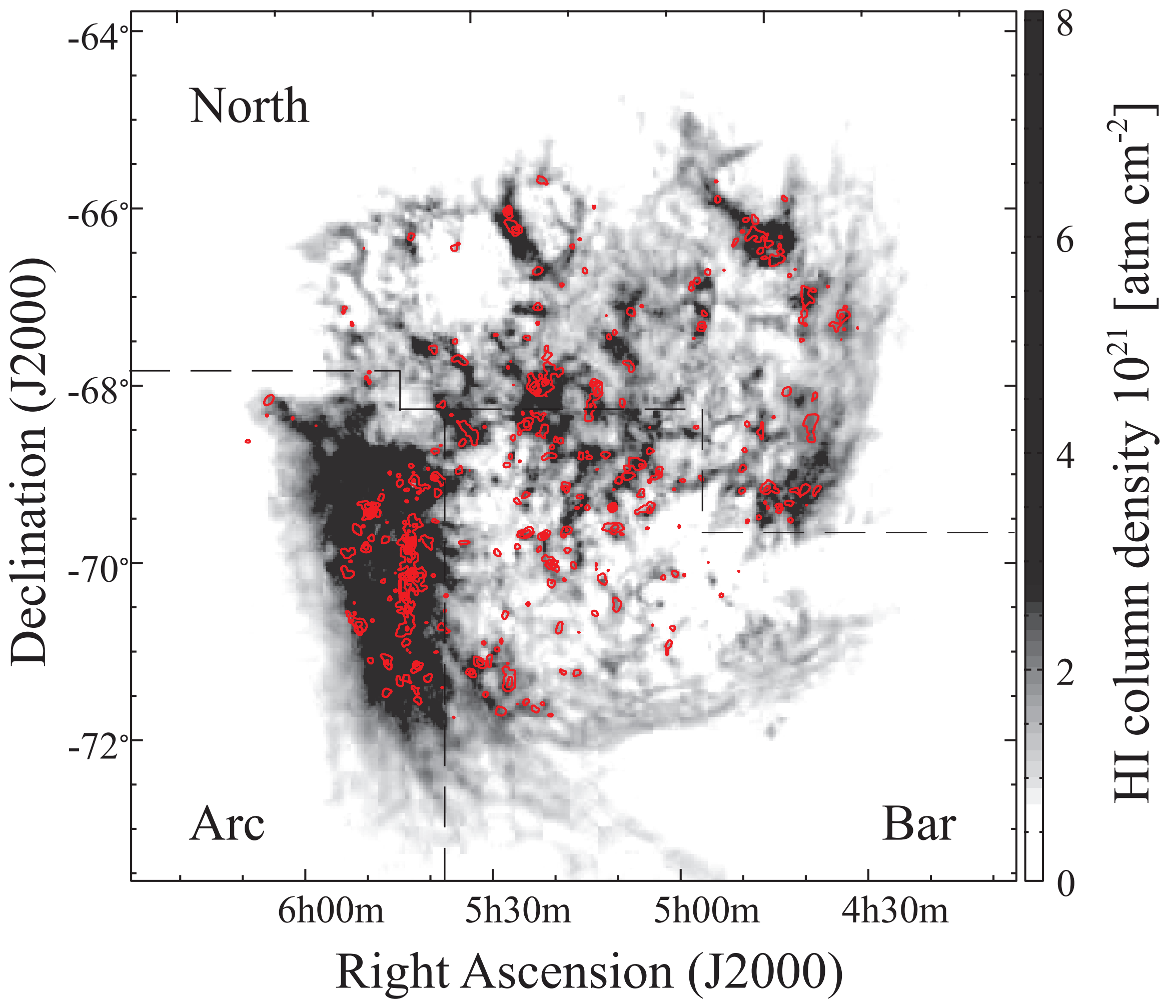
- HI versus H_2:
  - H_2 is restricted to the optical disk
  - while the HI extends 2 - 4 x optical radius
- HI hole or depression in the centers, sometimes compensated by H_2
- often H_2 is exponential like stars, HI does *not* follow in most cases







transition between H_2 and HI



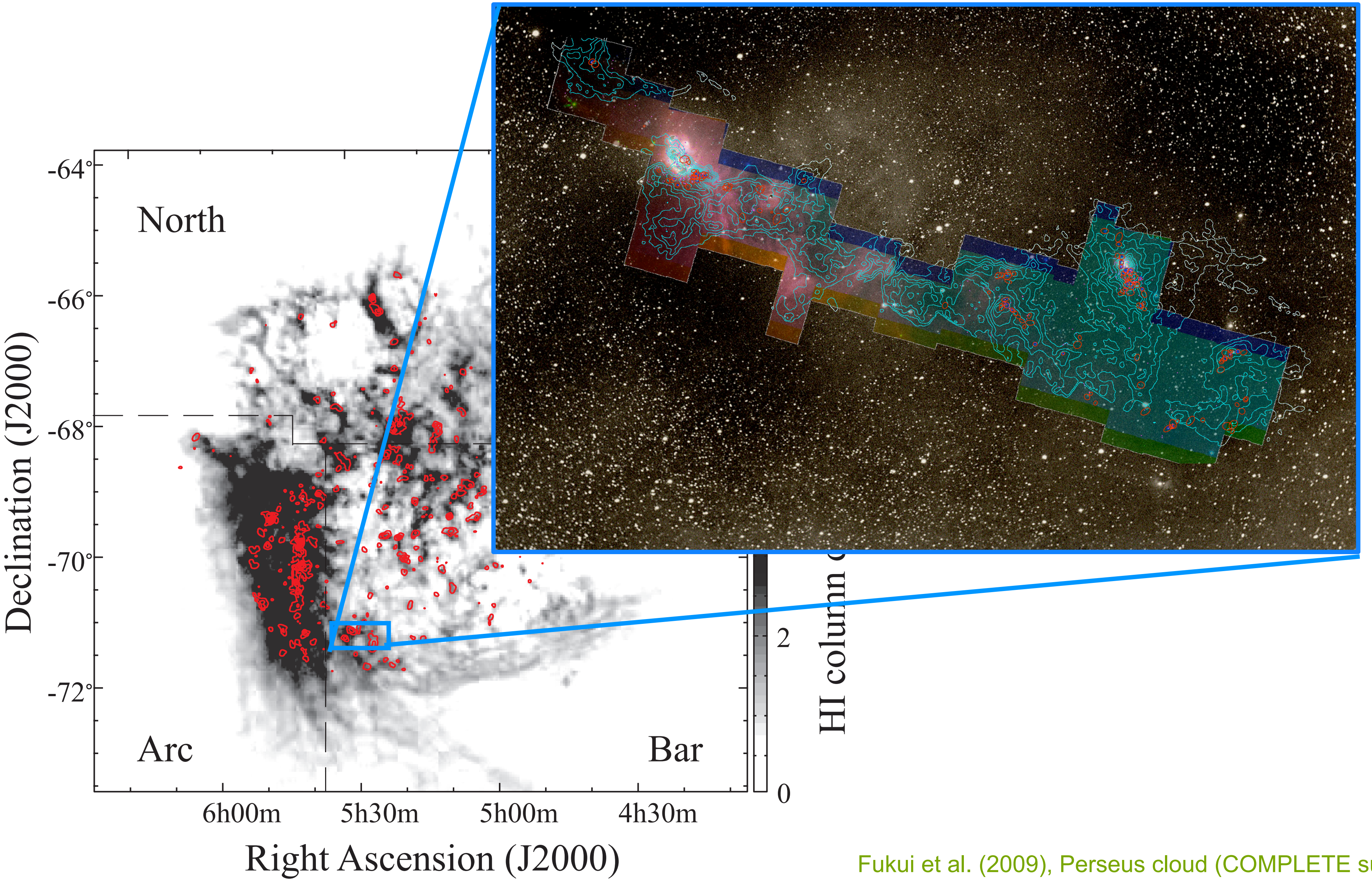
Fukui et al. (2009)

Idea:

Molecular clouds form at *stagnation points* of large-scale convergent flows, mostly triggered by global (or external) perturbations. Their internal turbulence is driven by accretion, i.e. by the process of cloud formation

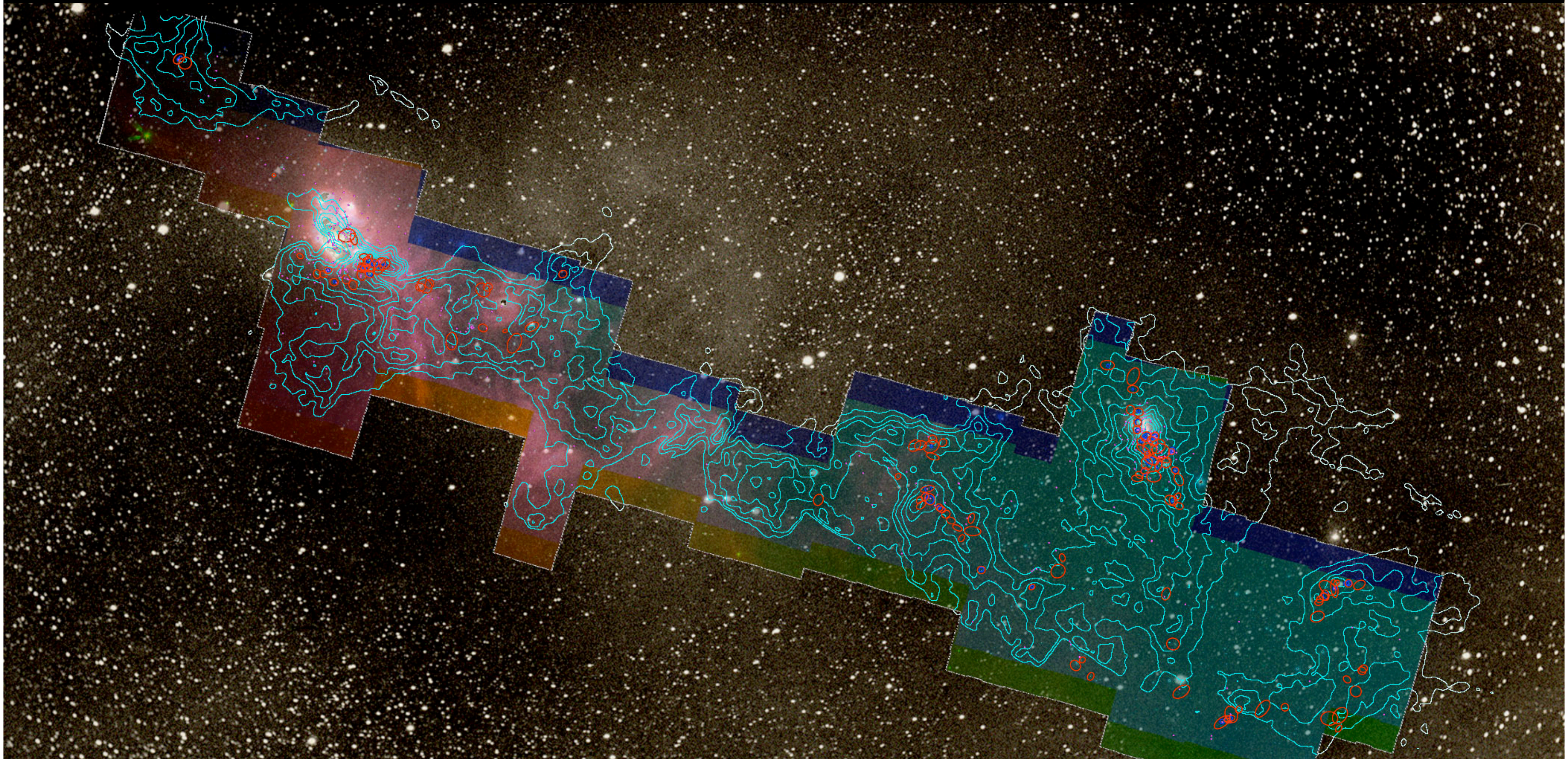
- molecular clouds grow in mass
- this is inferred by looking at molecular clouds in different evolutionary phases in the LMC (Fukui et al. 2008, 2009)
- accretion driven turbulence (Klessen & Hennebelle 2010)

zooming in ...



Fukui et al. (2009), Perseus cloud (COMPLETE survey)

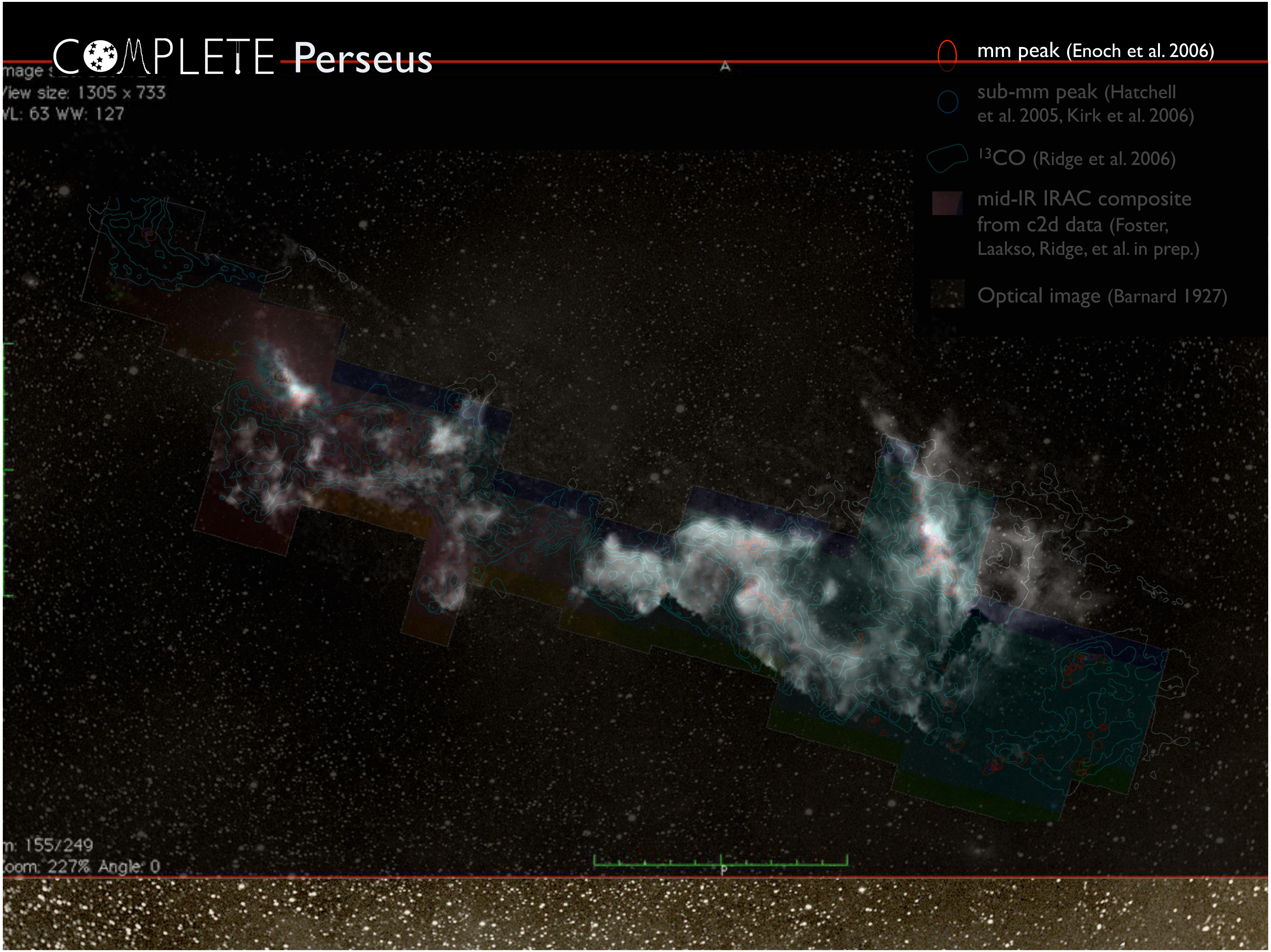
COMPLETE = COordinated Molecular Probe Line Extinction Thermal Emission Survey of Star-Forming Regions

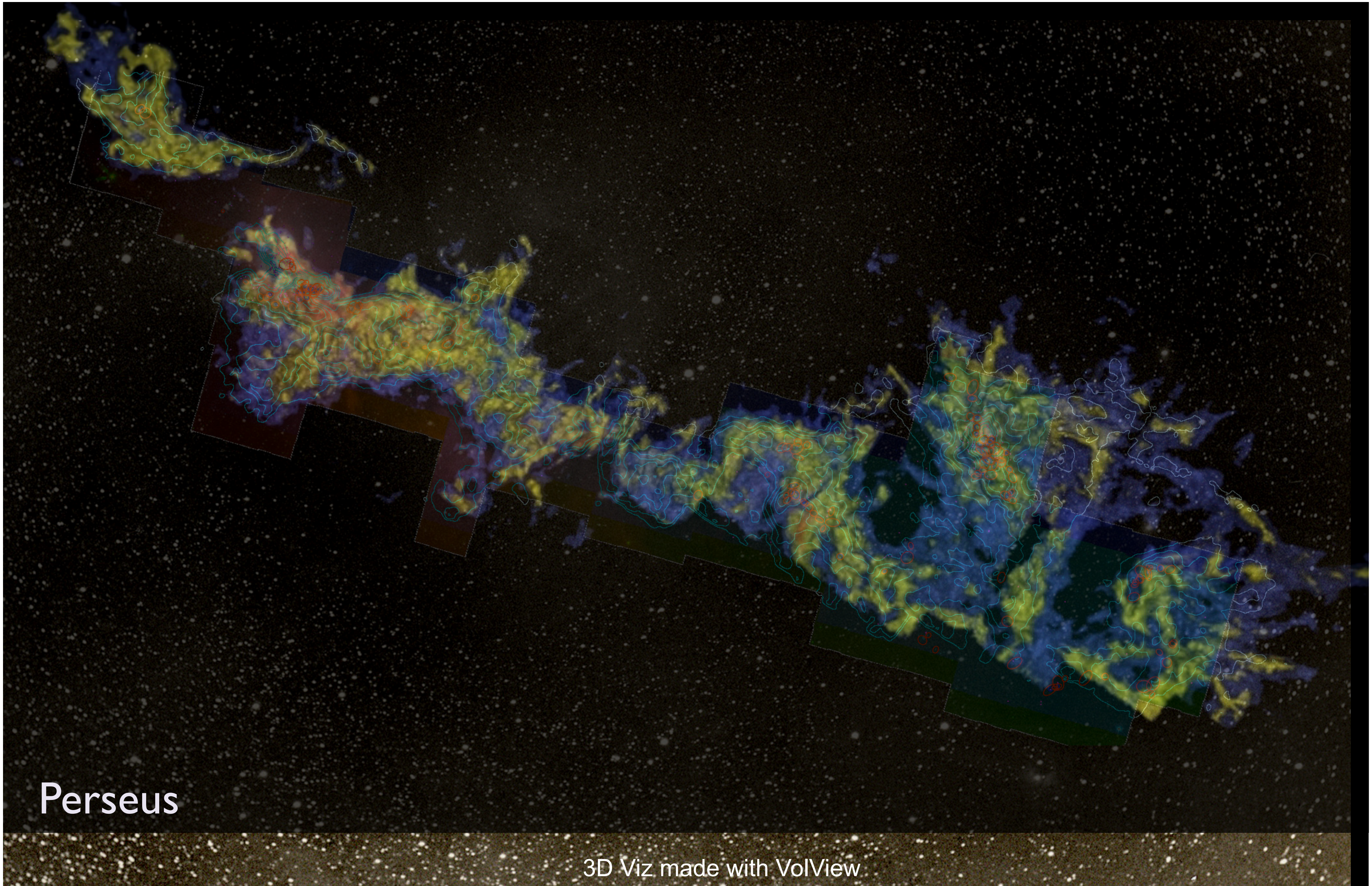


COMPLETE Collaborators, Summer 2008:

Alyssa A. Goodman (CfA/IIC)
João Alves (Calar Alto, Spain)
Héctor Arce (Yale)
Michelle Borkin (IIC)
Paola Caselli (Leeds, UK)
James DiFrancesco (HIA, Canada)
Jonathan Foster (CfA, PhD Student)
Katherine Guenthner (CfA/Leipzig)
Mark Heyer (UMASS/FCRAO)
Doug Johnstone (HIA, Canada)
Jens Kauffmann (CfA/IIC)
Helen Kirk (HIA, Canada)
Di Li (JPL)
Jaime Pineda (CfA, PhD Student)
Erik Rosolowsky (UBC Okanagan)
Rahul Shetty (CfA)
Scott Schnee (Caltech)
Mario Tafalla (OAN, Spain)

COMPLETE Perseus





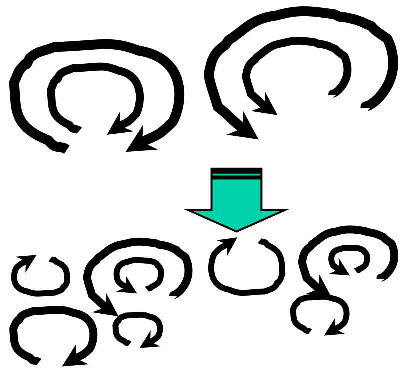
AstroMed@IIC

COMPLETE

properties of turbulence

- laminar flows turn *turbulent* at *high* *Reynolds* numbers

$$Re = \frac{\text{advection}}{\text{dissipation}} = \frac{VL}{\nu}$$



V= typical velocity on scale L, $\nu = \eta/\rho$ = kinematic viscosity,
turbulence for Re > 1000 → typical values in ISM 10^8-10^{10}

- Navier-Stokes equation (transport of momentum)

$$\rho\frac{d\vec{v}}{dt} = \rho\left(\frac{\partial\vec{v}}{\partial t} + (\vec{v}\cdot\vec{\nabla})\vec{v}\right) = -\vec{\nabla}P + \eta\,\vec{\nabla}^2\vec{v} + \left(\frac{\eta}{3} + \zeta\right)\vec{\nabla}(\vec{\nabla}\cdot\vec{v})$$

shear viscosity

bulk viscosity

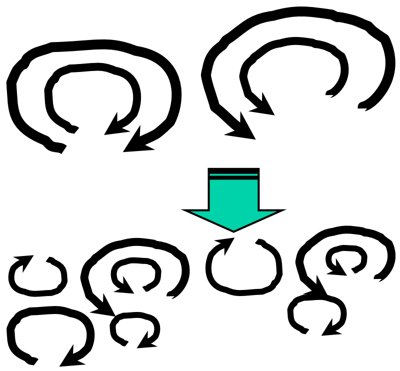
$$\sigma_{ij} \equiv \eta\left(\frac{\partial v_i}{\partial x_j} + \frac{\partial v_j}{\partial x_i} - \frac{2}{3}\delta_{ij}\frac{\partial v_k}{\partial x_k}\right) + \zeta\delta_{ij}\frac{\partial v_k}{\partial x_k}$$

viscous stress tensor

properties of turbulence

- laminar flows turn *turbulent* at *high* *Reynolds* numbers

$$Re = \frac{\text{advection}}{\text{dissipation}} = \frac{VL}{\nu}$$

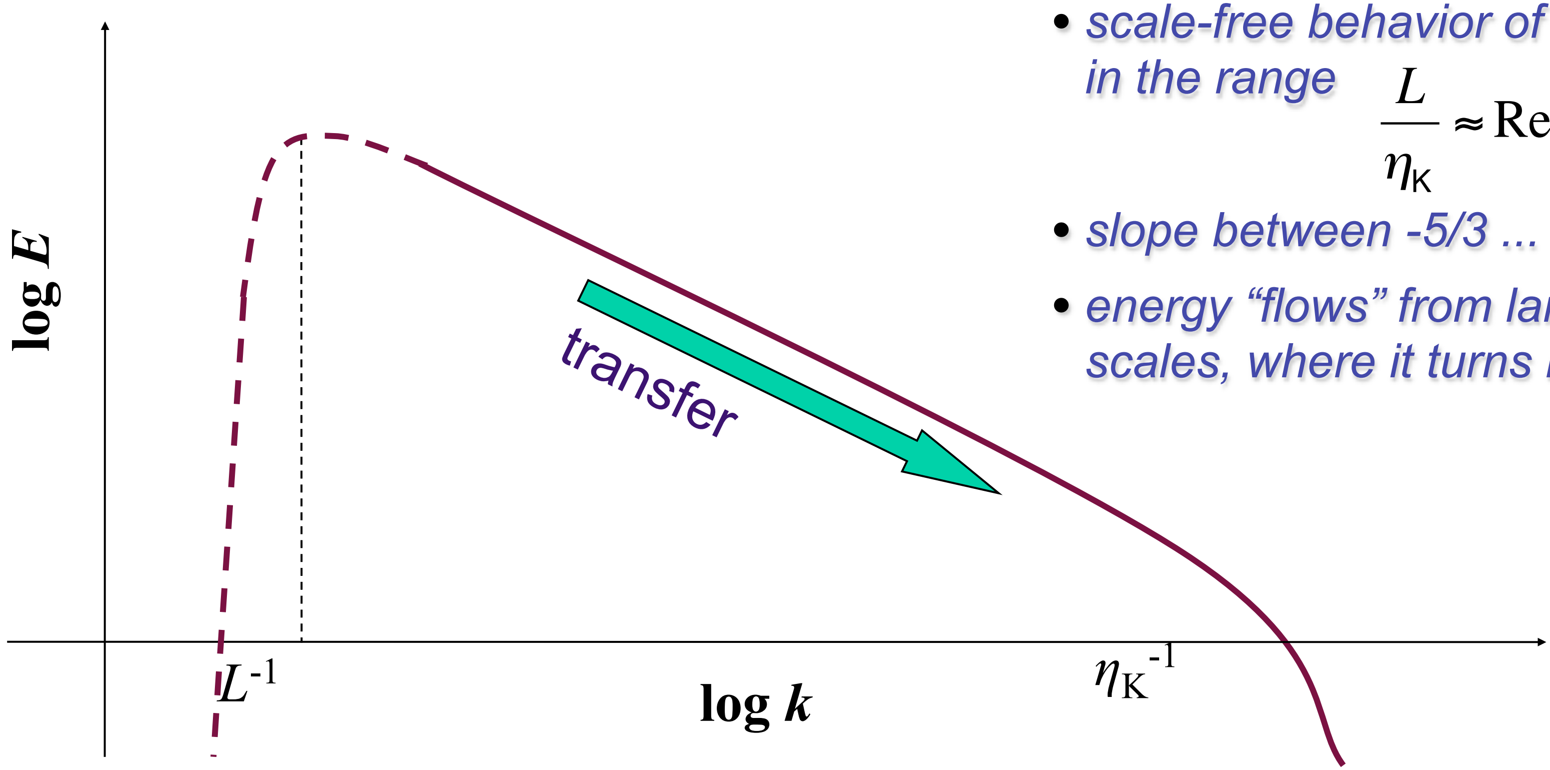


V= typical velocity on scale L, $\nu = \eta/\rho$ = kinematic viscosity,
turbulence for Re > 1000 → typical values in ISM 10^8-10^{10}

- vortex streching --> turbulence is intrinsically anisotropic
  (only on large scales you may get
  homogeneity & isotropy in a statistical sense;
  see Landau & Lifschitz, Chandrasekhar, Taylor, etc.)

(ISM turbulence: shocks & B-field
cause additional inhomogeneity)

turbulent cascade in ISM

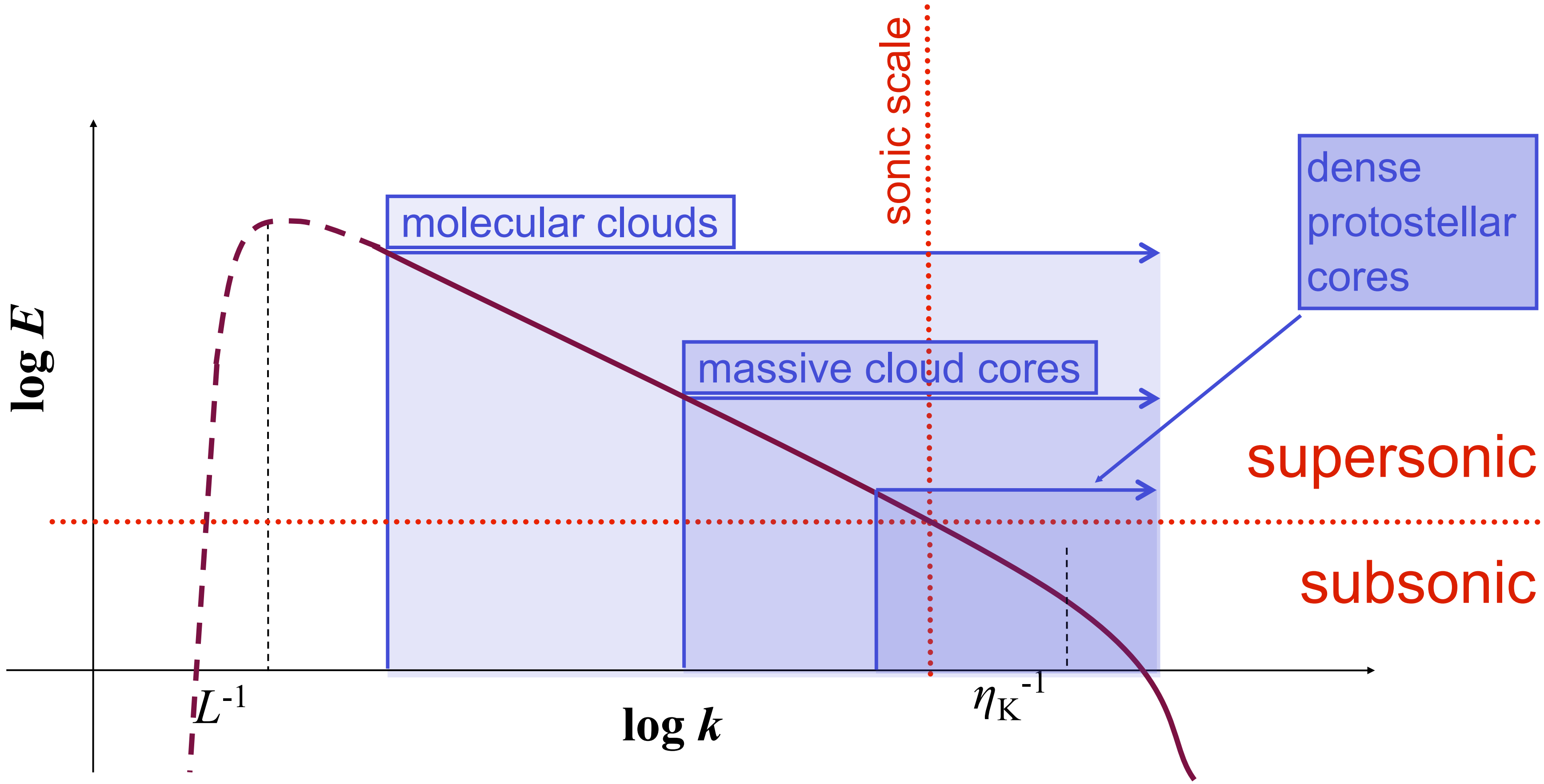


- *scale-free behavior of turbulence in the range* $\frac{L}{\eta_K} \approx \mathrm{Re}^{3/4}$
- *slope between -5/3 ... -2*
- *energy "flows" from large to small scales, where it turns into heat*

energy source & scale
NOT known
(supernovae, winds,
spiral density waves?)

dissipation scale not known
(ambipolar diffusion,
molecular diffusion?)

turbulent cascade in ISM



energy source & scale
NOT known
(supernovae, winds,
spiral density waves?)

$\sigma_{rms} << 1$ km/s
$M_{rms} \leq 1$
$L \approx 0.1$ pc

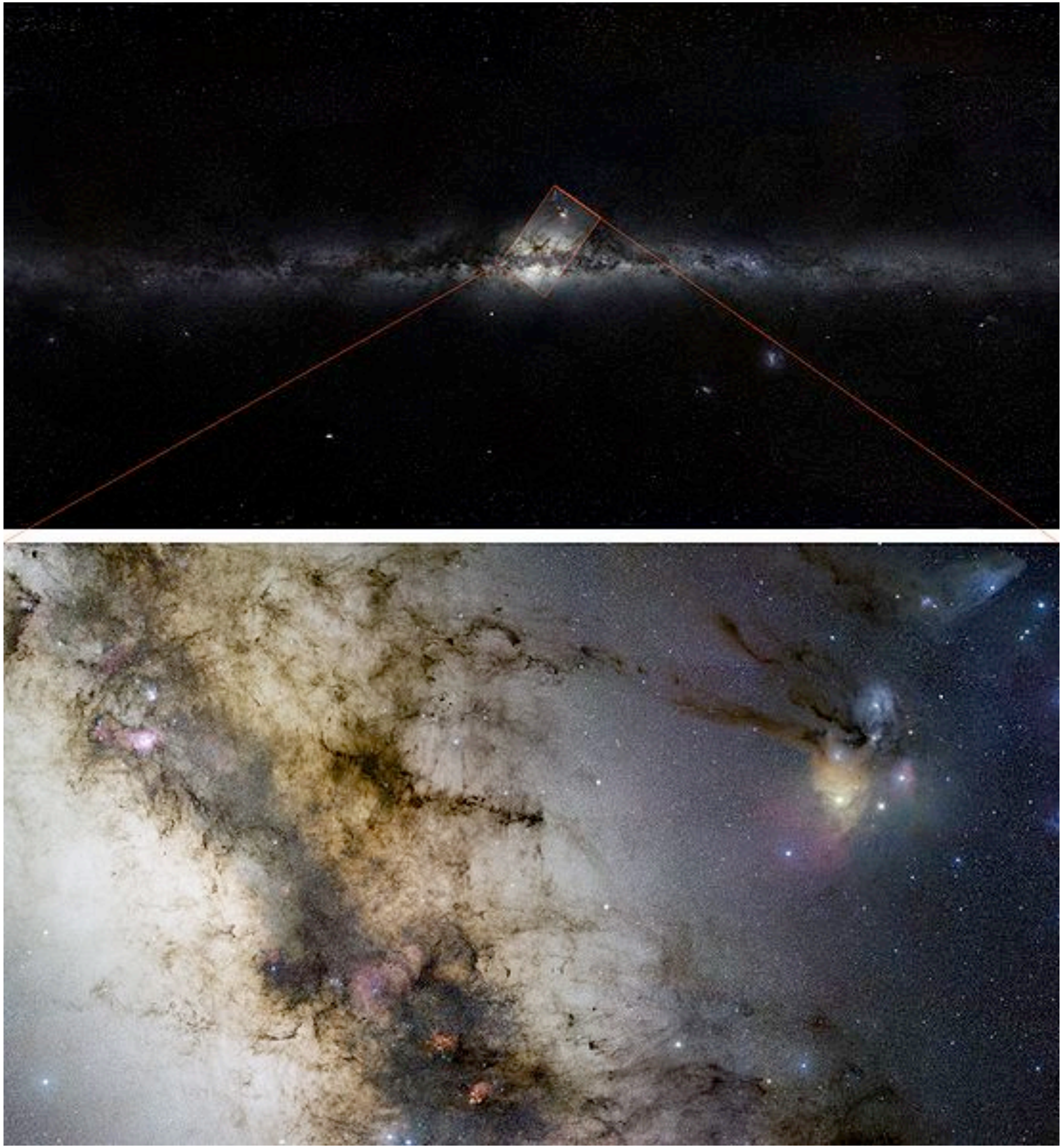
dissipation scale not known
(ambipolar diffusion,
molecular diffusion?)

statistical characteristics of turbulence

- two point statistics
  - power spectrum of velocity (in Fourier space)
  - structure function of velocity (note: compare v, $\rho^{1/2}v$, $\rho^{1/3}v$ at two different locations)
  - PCA: principle component analysis (e.g. Heyer & Schloerb 1997, Heyer et al. 2006, Roman-Duval et al. 2011)
  - CVI: centroid velocity increment (e.g. Lis et al. 1996, Klessen 2000, Hily-Blant et al. 2008, Federrath et al. 2010)
  - Δ variance: wavelet analysis of density (e.g. Stutzki et al. 1998, Bensch et al. 2001, Ossenkopf et al. 2008)

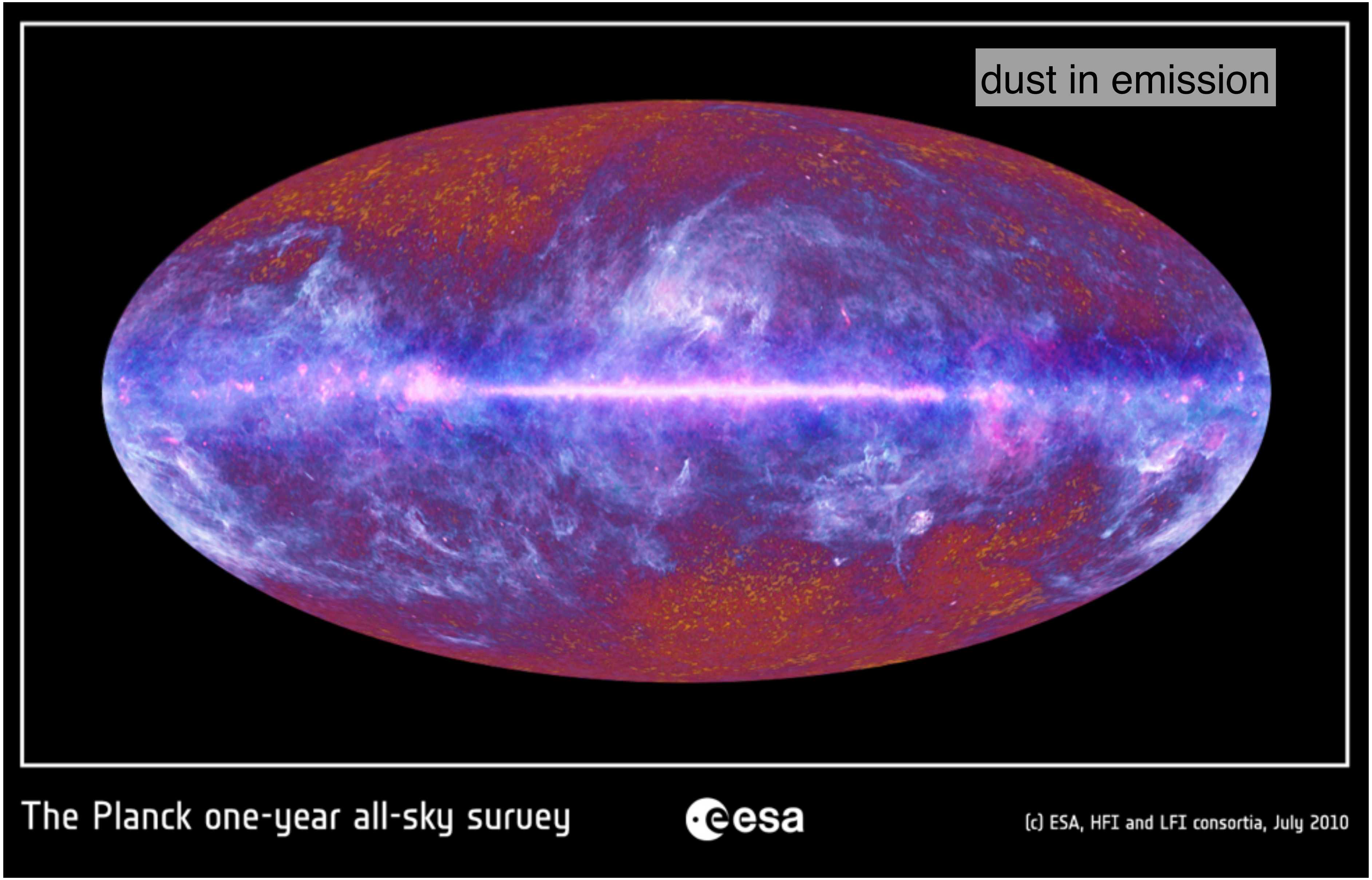
- one point statistics
  - probability distribution function (PDF) of density
  - observations: only *column* density PDF
  - probability distribution function (PDF) of velocity

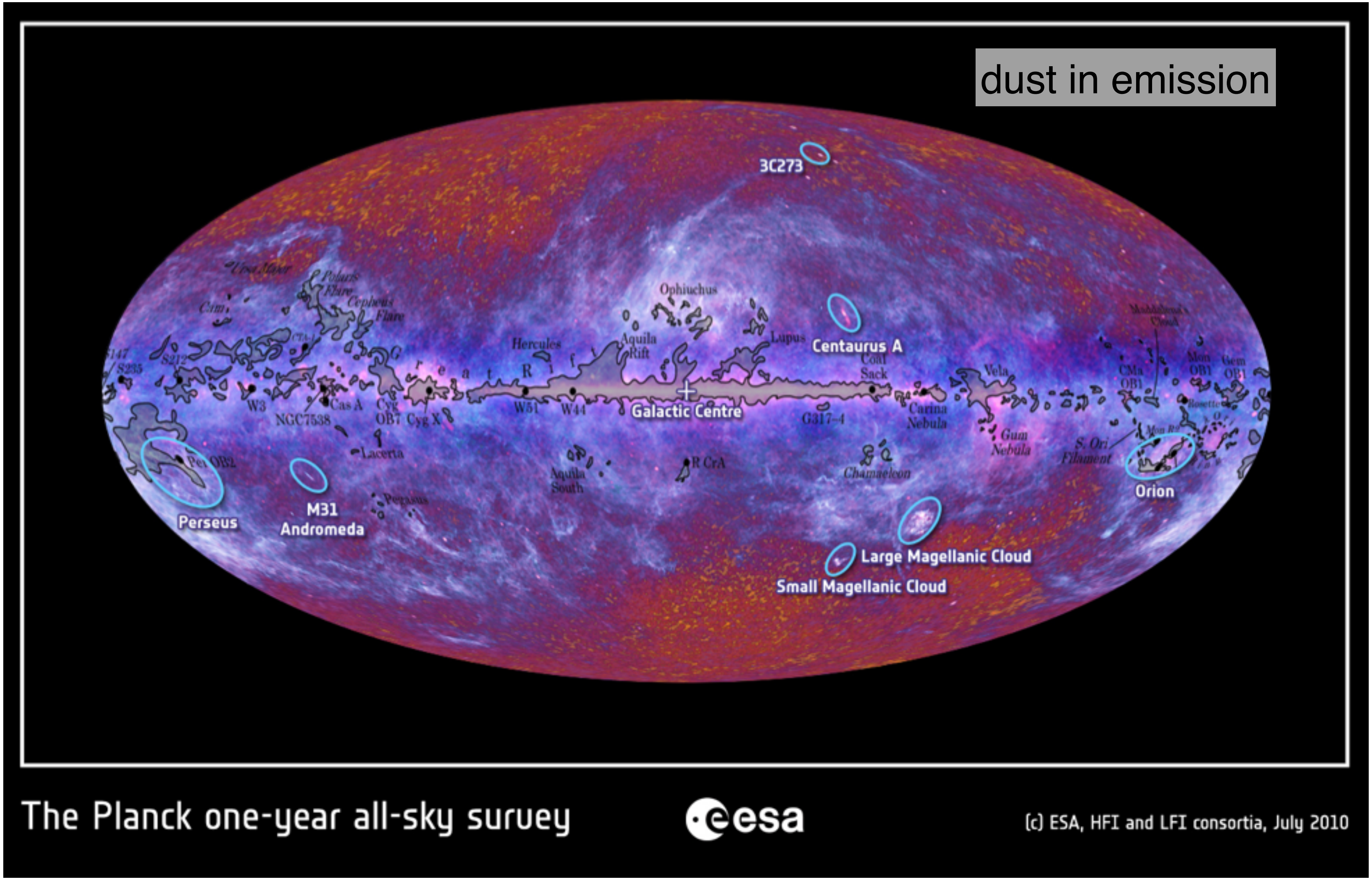
dust



Milky way starscape taken from Paranal.(ESO)

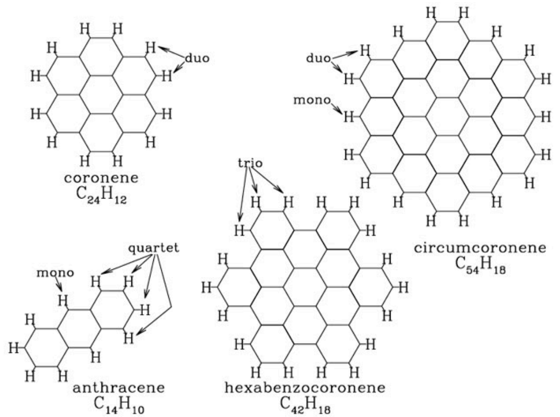
Milky way starscape taken from Paranal.(ESO)


dust in emission
The Planck one-year all-sky survey
esa
(c) ESA, HFI and LFI consortia, July 2010

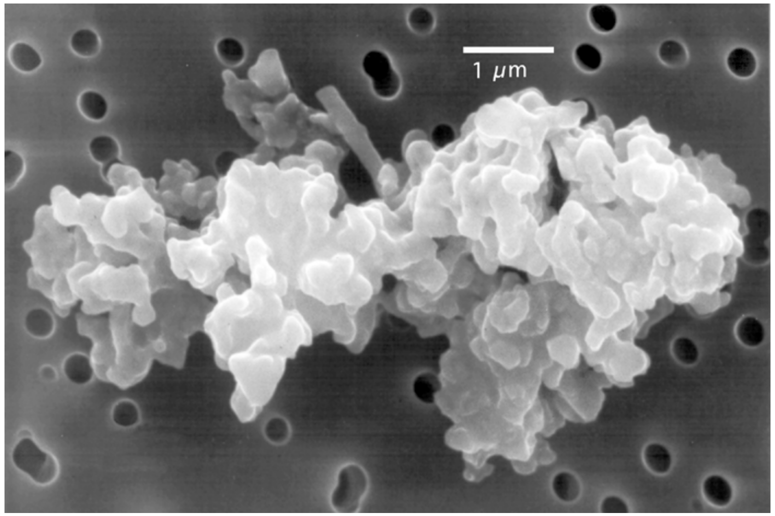

dust in emission
3C273
Ophiuchus
Centaurus A
Hercules
Aquila Rift
Lupus
Coal Sack
Galactic Centre
W51
W44
G317-4
Carina Nebula
Vela
Gum Nebula
Cas A
NGC7538
W3
Cyg OB7
Cyg X
Lacerta
Pegasus
Aquila South
R CrA
Chamaeleon
S. Ori Filament
Orion
Perseus
M31
Andromeda
Large Magellanic Cloud
Small Magellanic Cloud
The Planck one-year all-sky survey
esa
(c) ESA, HFI and LFI consortia, July 2010

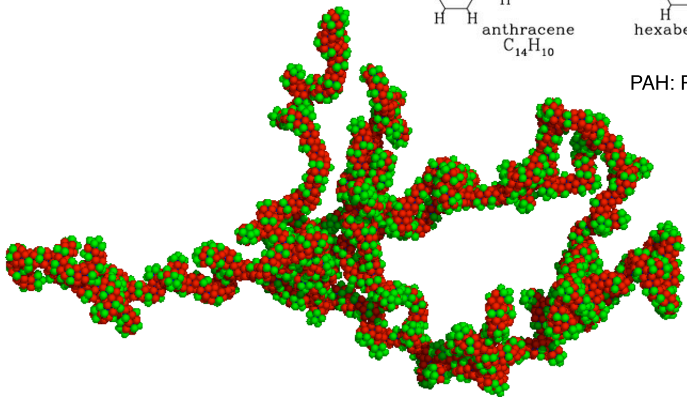
interstellar dust

- large variations in size and composition: from a few dozens of molecules (PAHs) to little kernels of a few micrometer diameter
- typically complex, fractal structure with large surface compared to the volume (ßen Oberfläche im Vergleich zum Volumen
- dust is important catalyst for chemical reactions in the ISM (example: formation of H_2 on surface of dust grains)



PAH: Polyaromatische Hydrokarbonate



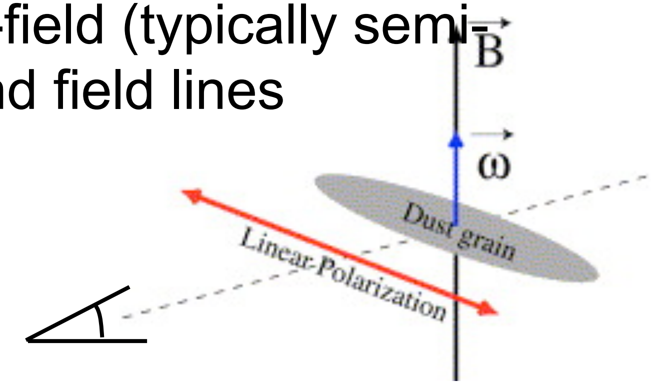


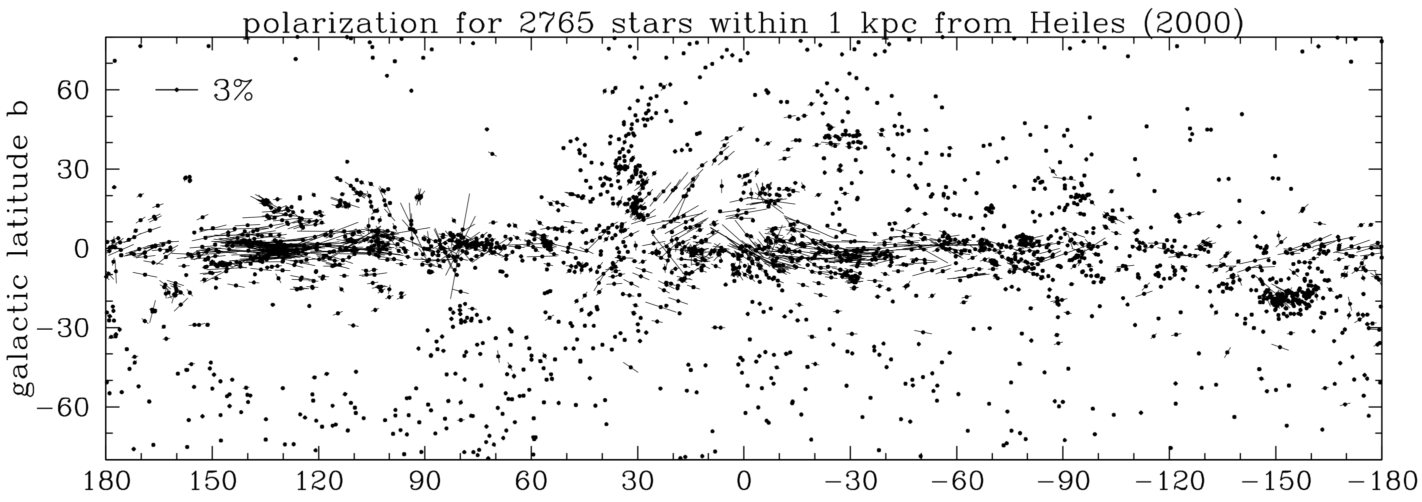
Quelle: E. L. Wright (UCLA), im Netz: Wikepedia

Quelle: Brownlee & Jessberger (in Jessberger et al, 2001, in Interstellar Dust),
im Netz: Wikipedia

dust and magnetic fields

- dust leads to polarization of star light
- polarization degrees up to 5%
- reason: elongated dust particles aligned with B-field (typically semi-minor axis parallel to field line) and rotate around field lines
- important information about Galactic B-fields





Abbildungen 21.3 aus Draine (2011)

cosmic rays

- cosmic rays are highly relativistic particles
- mostly proton, also electrons
- sources: hot stars, supernova remnants, quasars
- additional acceleration in expanding supernova shells (multiple "scattering" on magnetic field lines, Fermi effect)
- energy range E = 10^8 - 10^{20} eV
- move along magnetic field lines (also some diffusion $\perp$ to B) with gyro radius

$$r_G = 10^{-6} pc \frac{E[GeV]}{B[\mu G]}$$

- up to 10^{16} eV confined to Milky Way
- lifetime ~ 2 Myr

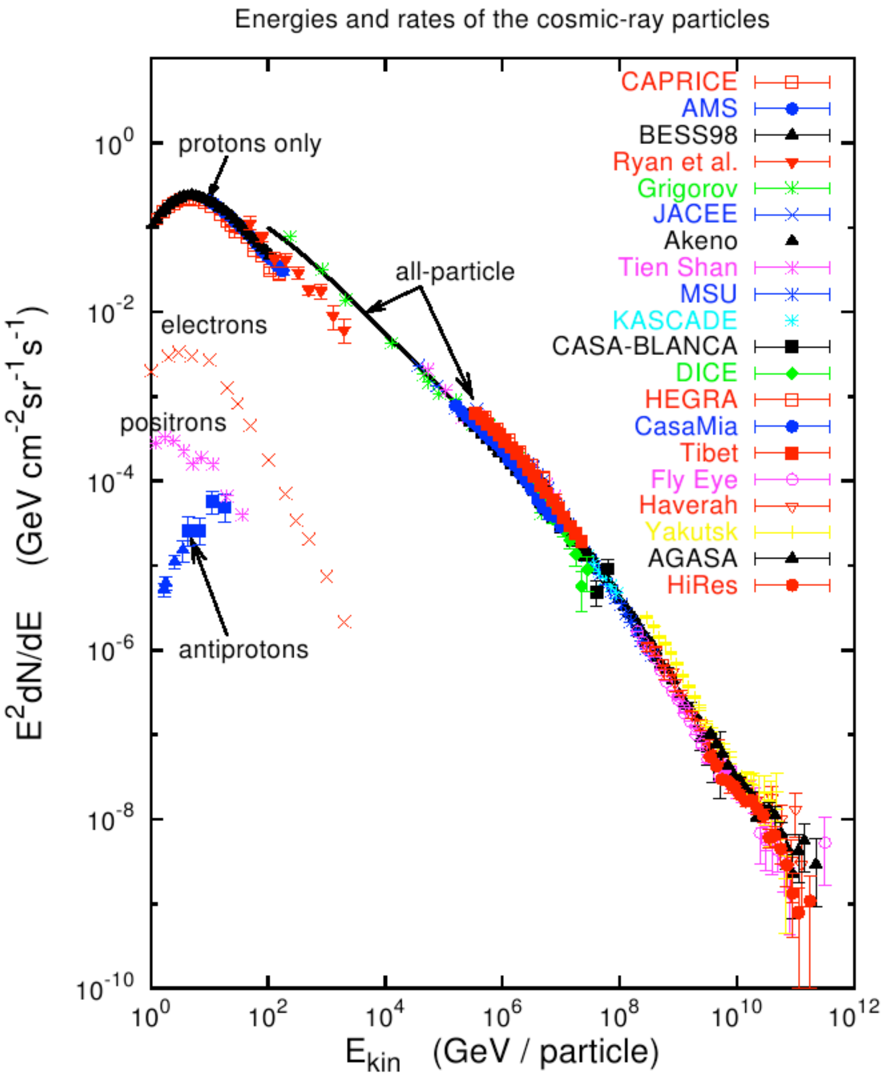
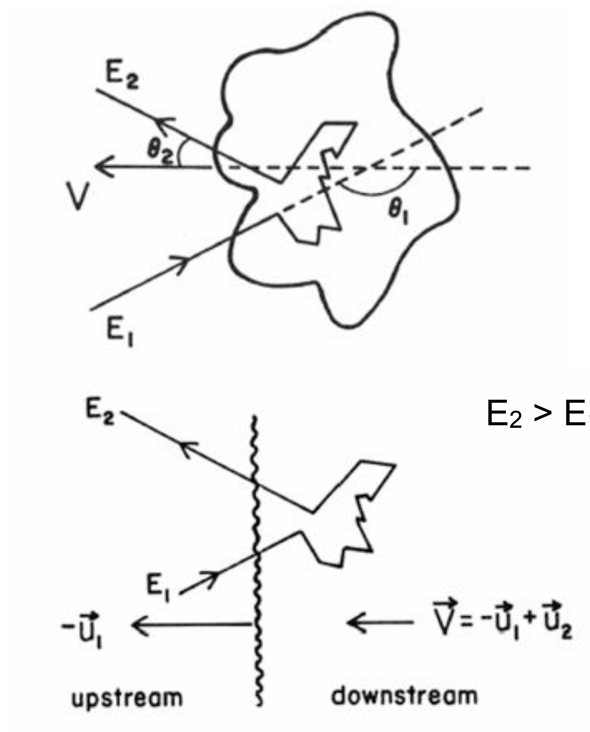


Abbildung: Hillas (2006, arXiv:astro-ph/0607109)

cosmic rays

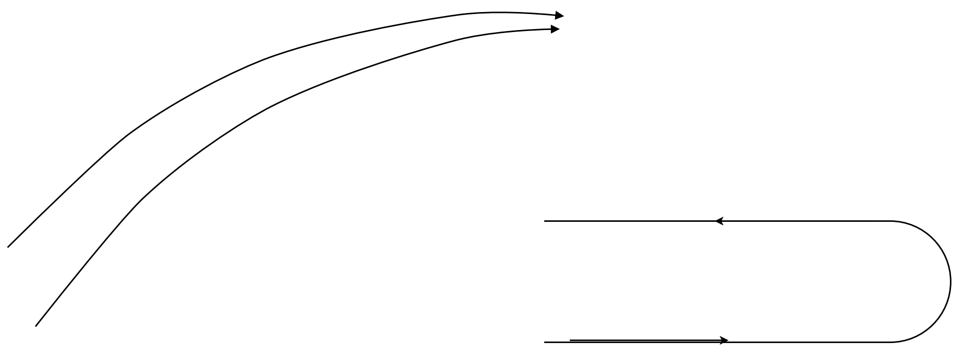
- cosmic rays are highly relativistic particles
- mostly proton, also electrons
- sources: hot stars, supernova remnants, quasars
- additional acceleration in expanding supernova shells (multiple “scattering” on magnetic field lines, Fermi effect)

- Fermi mechanism: acceleration of charged particles in magnetized shocks
- particles can be reflected in inhomogeneities of the magnetic field and gain energy



$E_2 > E_1$

Gaisser, T. (1990, COSMIC RAY AND PARTICLE PHYSICS (CAMBRIDGE UNIV. PRESS 1990)



energy densities in local ISM

Component		$u(\mathrm{eV\,cm^{-3}})$	Note
Cosmic microwave background	$(T_{\mathrm{CMB}} = 2.725\,\mathrm{K})$	0.265	a
Far-infrared radiation from dust		0.31	b
Starlight ($h\nu < 13.6\,\mathrm{eV}$)		0.54	c
Thermal kinetic energy $(3/2)nkT$		0.49	d
Turbulent kinetic energy $(1/2)\rho v^2$		0.22	e
Magnetic energy $B^2/8\pi$		0.89	f
Cosmic rays		1.39	g

a Fixsen & Mather (2002).
b Chapter 12.
c Chapter 12.
d For $nT = 3800\,\mathrm{cm^{-3}}\,\mathrm{K}$ (see §17.7).
e For $n_{\mathrm{H}} = 30\,\mathrm{cm^{-3}}$, $v = 1\,\mathrm{km\,s^{-1}}$, or $\langle n_{\mathrm{H}} \rangle = 1\,\mathrm{cm^{-3}}$, $\langle v^2 \rangle^{1/2} = 5.5\,\mathrm{km\,s^{-1}}$.
f For median $B_{\mathrm{tot}} \approx 6.0\,\mu\mathrm{G}$ (Heiles & Crutcher 2005).
g For cosmic ray spectrum X3 in Fig. 13.5.

Table 1.5 from Draine, B. Physics and Chemistry in the ISM (2011, Princeton)

energy densities in local ISM

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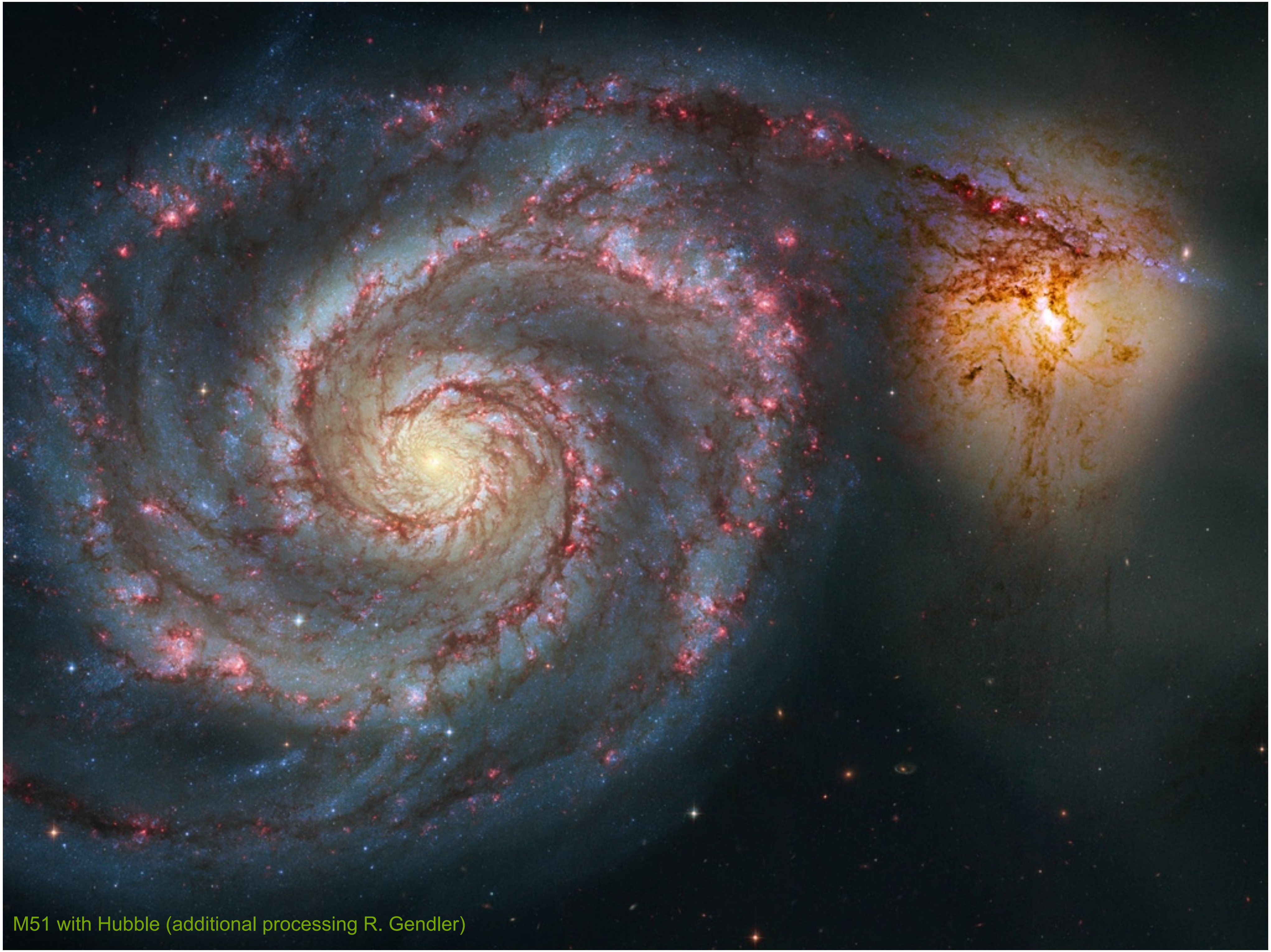
f For median $B_{\mathrm{tot}} \approx 6.0\,\mu\mathrm{G}$ (Heiles & Crutcher 2005).

g For cosmic ray spectrum X3 in Fig. 13.5.

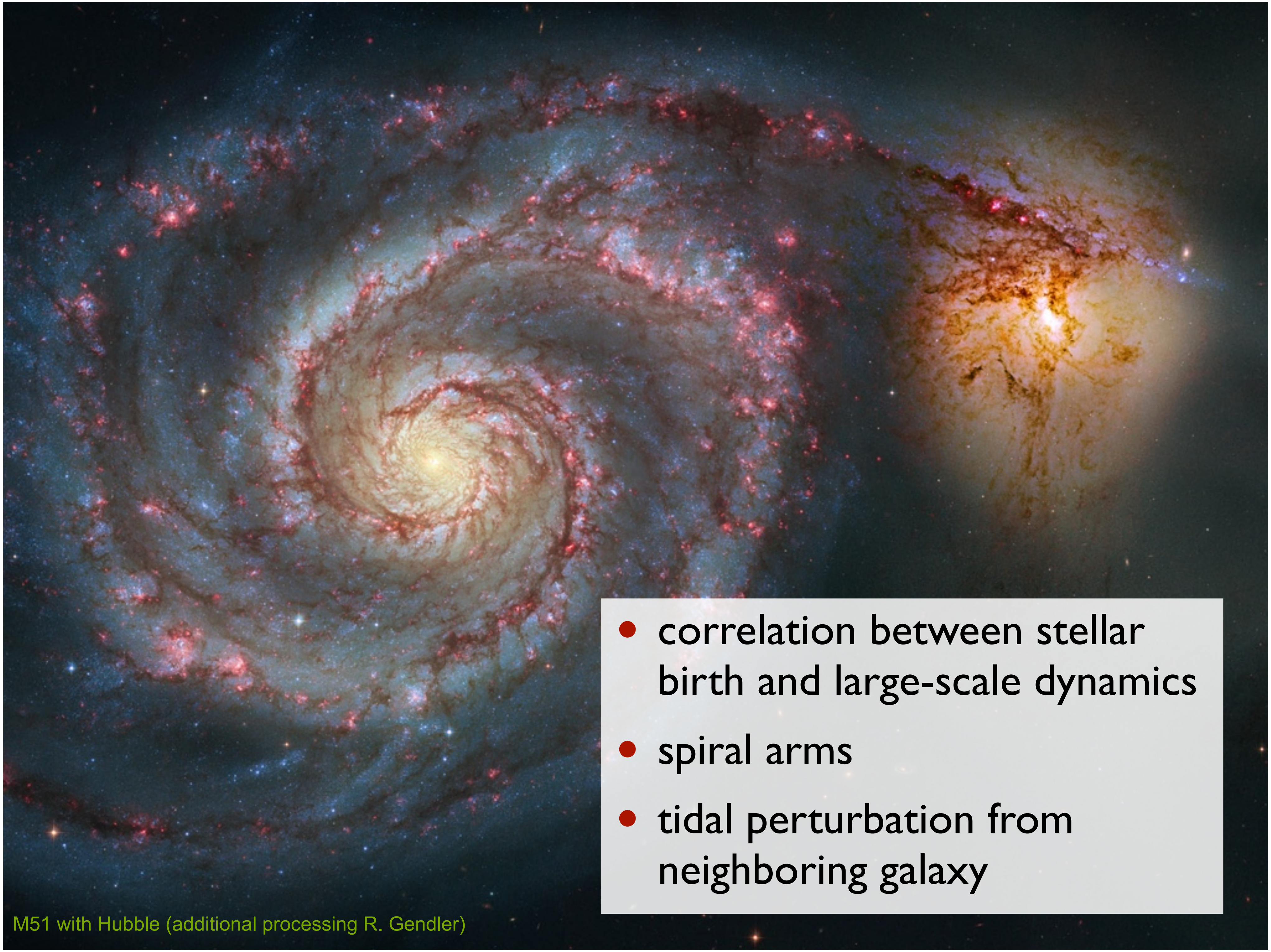
seems too low, molecular cloud density more like 300 $\mathrm{cm^{-3}}$ or HI velocities more like 10 km/s

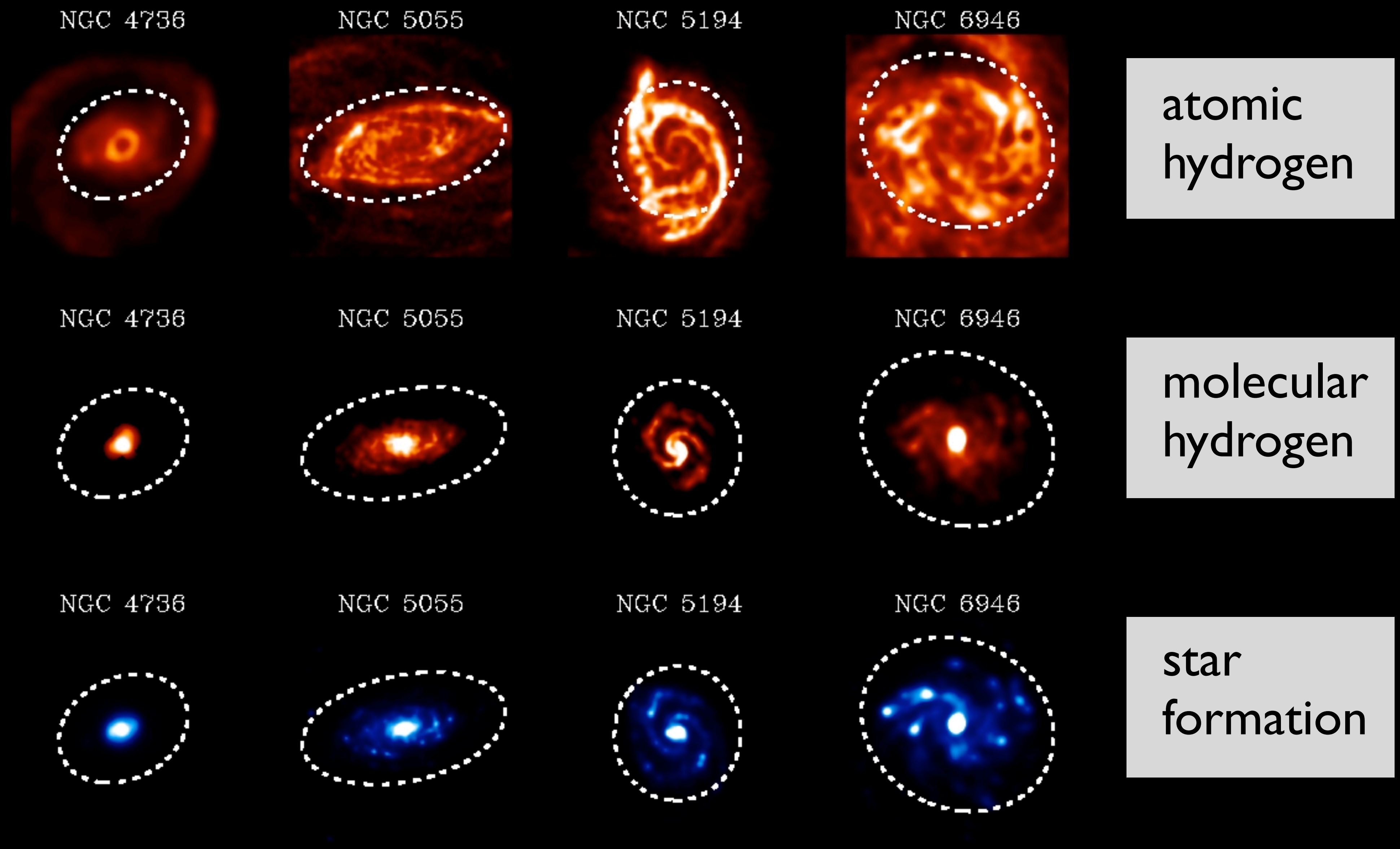
Table 1.5 from Draine, B. Physics and Chemistry in the ISM (2011, Princeton)

ISM and stellar birth

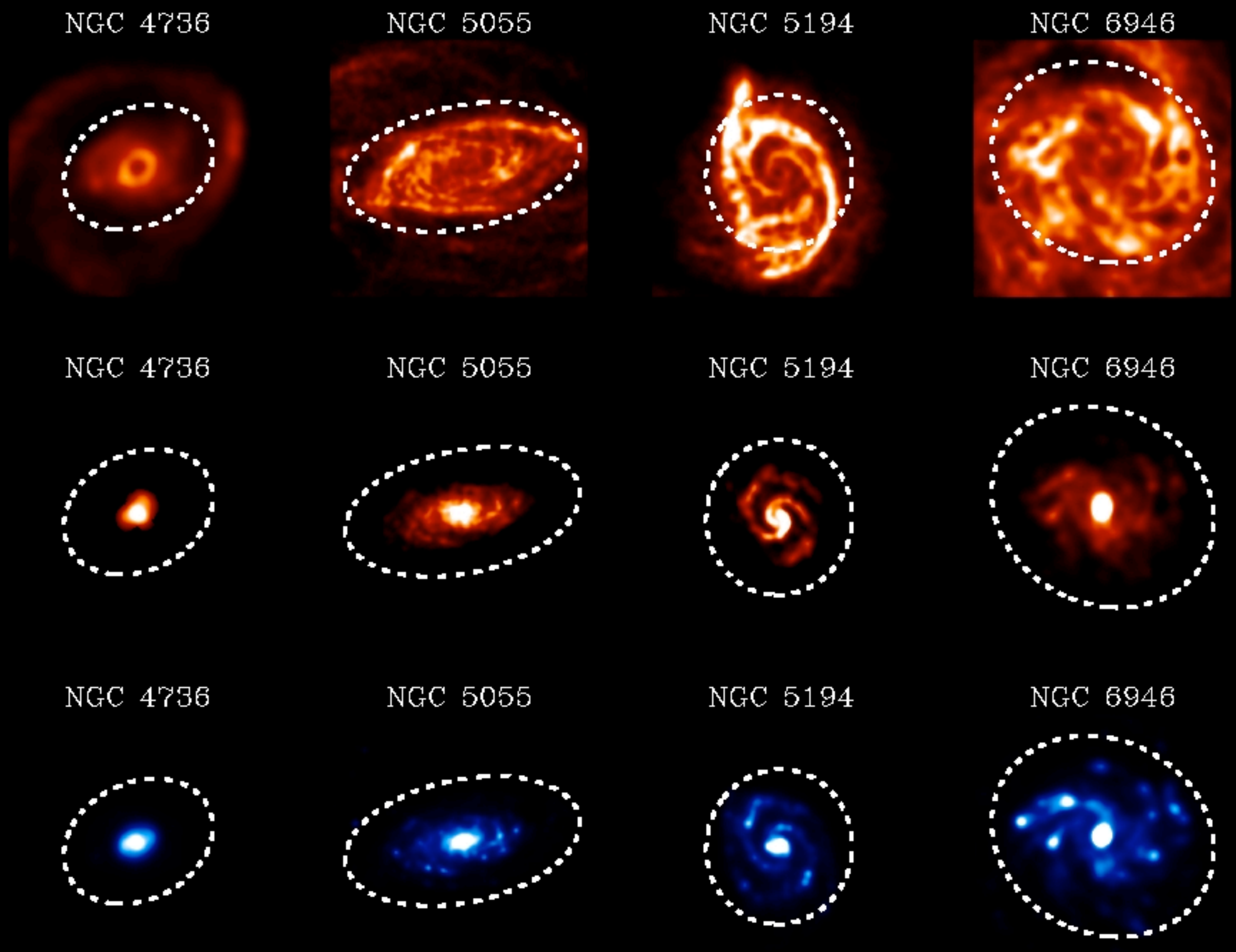


M51 with Hubble (additional processing R. Gendler)


correlation between stellar birth and large-scale dynamics
spiral arms
tidal perturbation from neighboring galaxy
M51 with Hubble (additional processing R. Gendler)



galaxies from THINGS and HERACLES survey
(images from Frank Bigiel, ZAH/ITA)



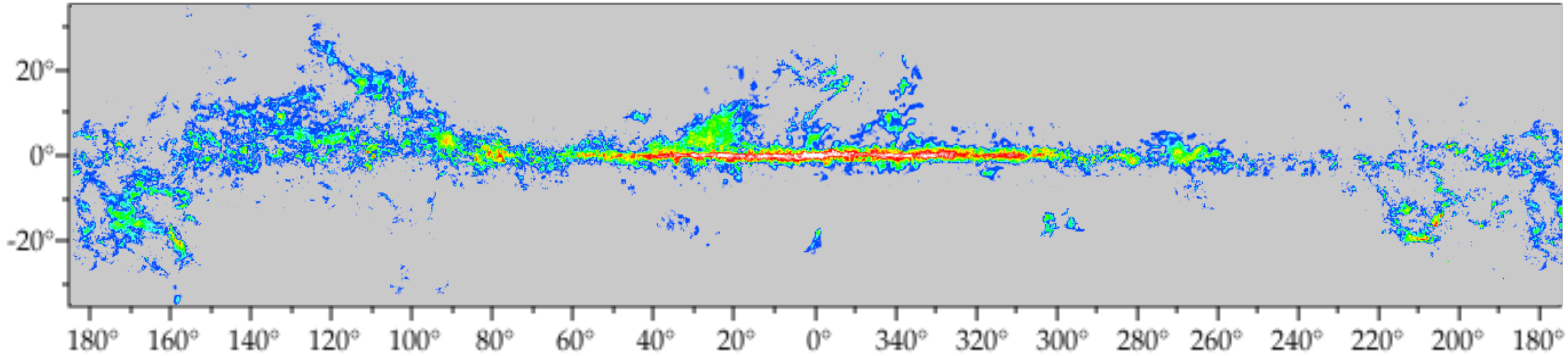
atomic hydrogen

molecular hydrogen

star formation

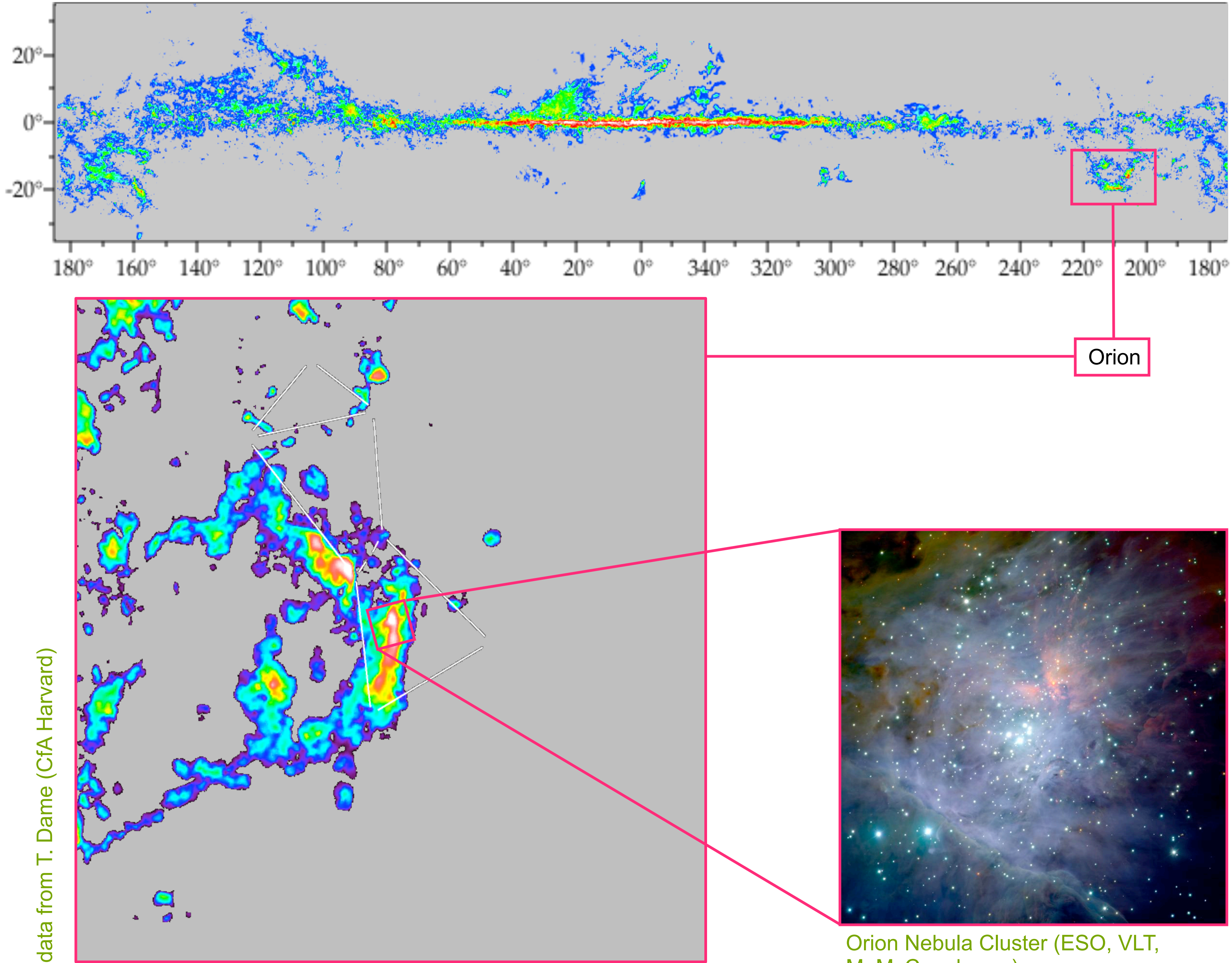
- HI gas more extended
- H2 and SF well correlated

galaxies from THINGS and HERACLES survey
(images from Frank Bigiel, ZAH/ITA)



distribution of molecular gas in the Milky Way as traced by CO emission

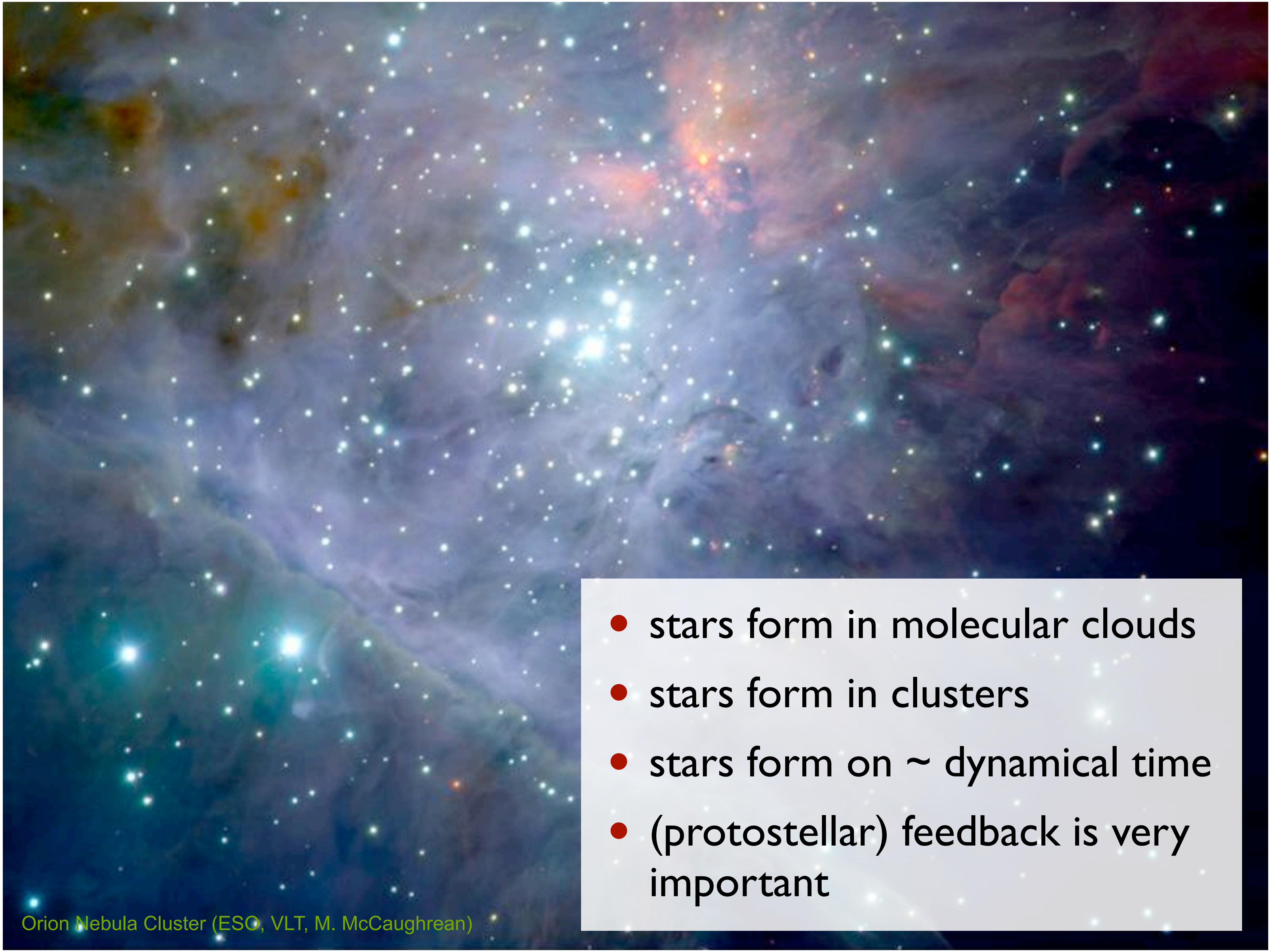
data from T. Dame (CfA Harvard)



data from T. Dame (CfA Harvard)

Orion Nebula Cluster (ESO, VLT, M. McCaughrean)


Orion Nebula Cluster (ESO, VLT, M. McCaughrean)

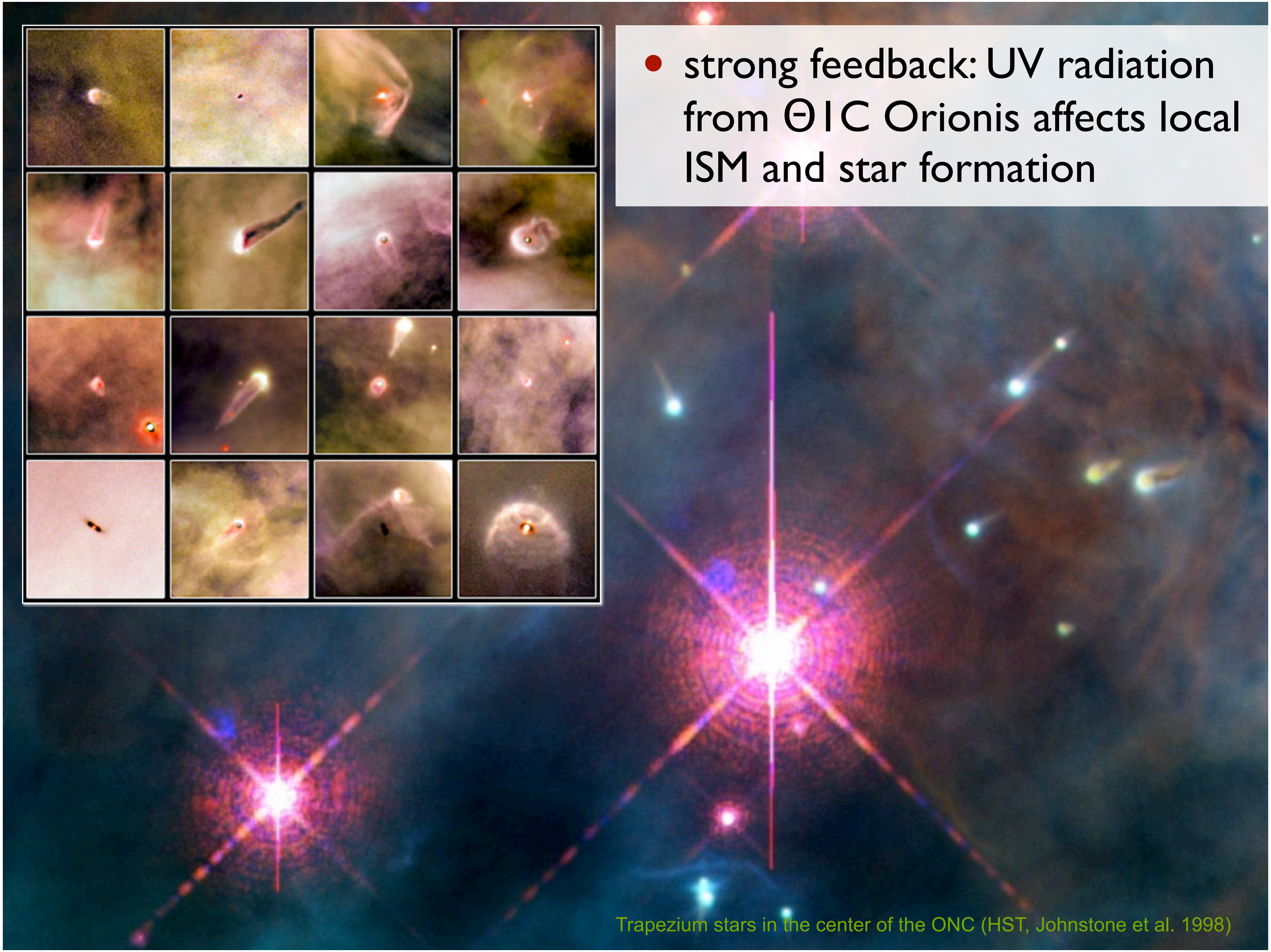


Orion Nebula Cluster (ESO, VLT, M. McCaughrean)

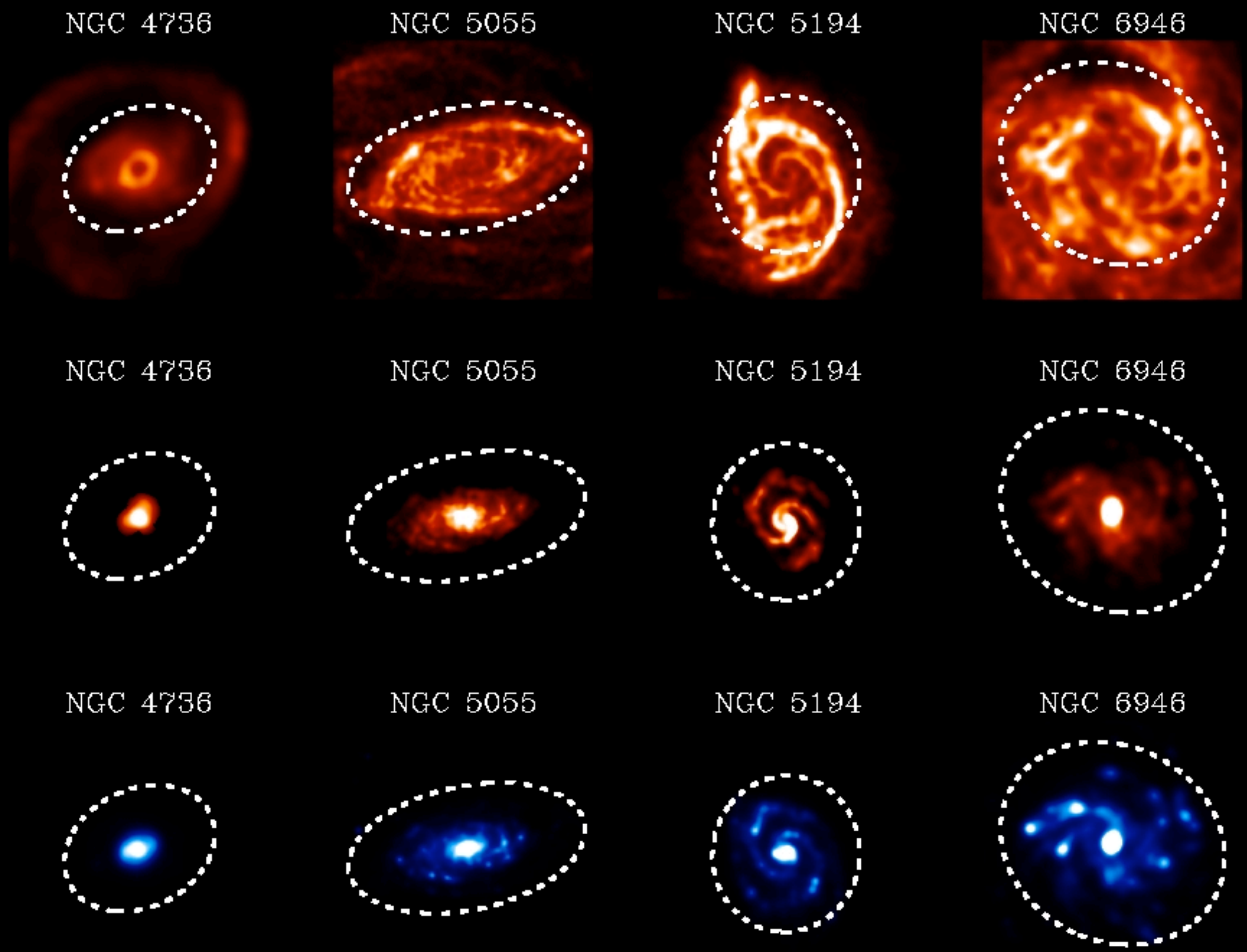
- stars form in molecular clouds
- stars form in clusters
- stars form on ~ dynamical time
- (protostellar) feedback is very important

Trapezium stars in the center of the ONC (HST, Johnstone et al. 1998)

- strong feedback: UV radiation from Θ1C Orionis affects local ISM and star formation



Trapezium stars in the center of the ONC (HST, Johnstone et al. 1998)



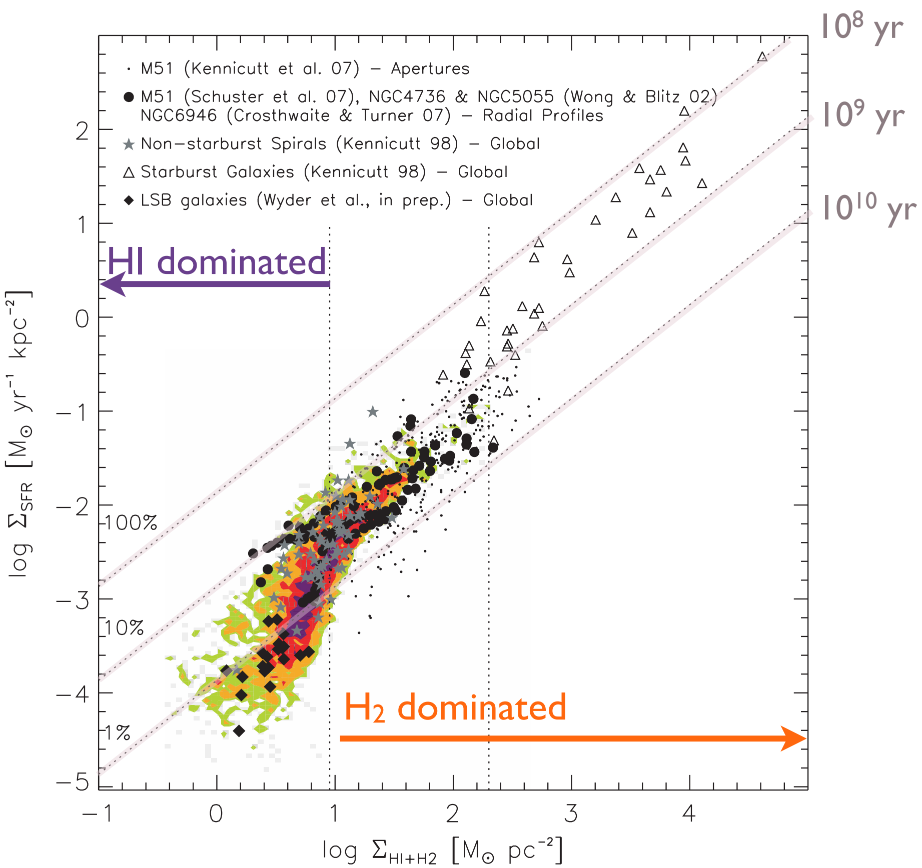
atomic hydrogen

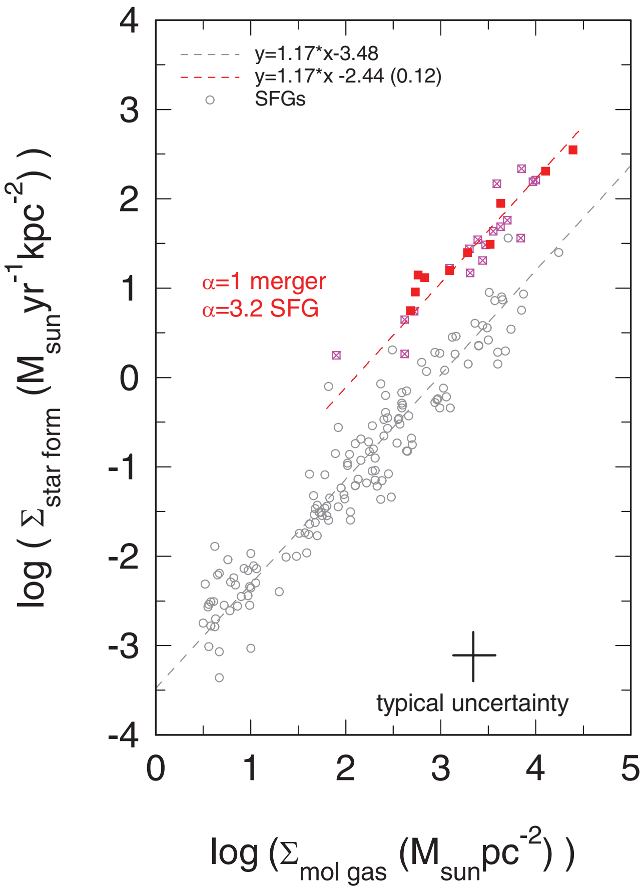
molecular hydrogen

star formation

- relation between gas density and star formation density

galaxies from THINGS and HERACLES survey
(images from Frank Bigiel, ZAH/ITA)



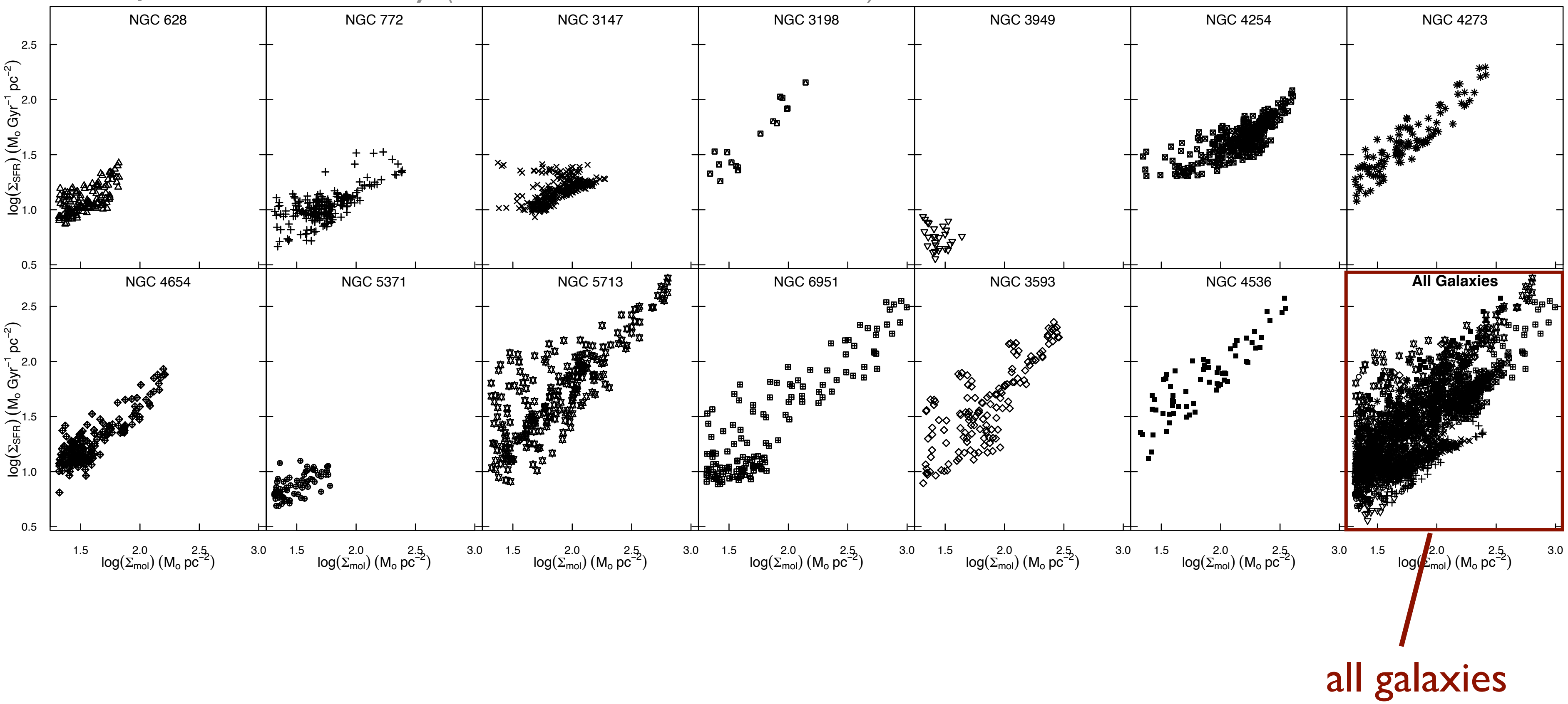


Bigiel et al. (2008, AJ, 136, 2846)

Genzel et al. (2010, MNRAS, AJ, 407, 2091)

- standard model: roughly linear relation between H_2 and SFR
- standard model: roughly constant depletion time: few x 10^9 yr
- super linear relation between total gas and SFR

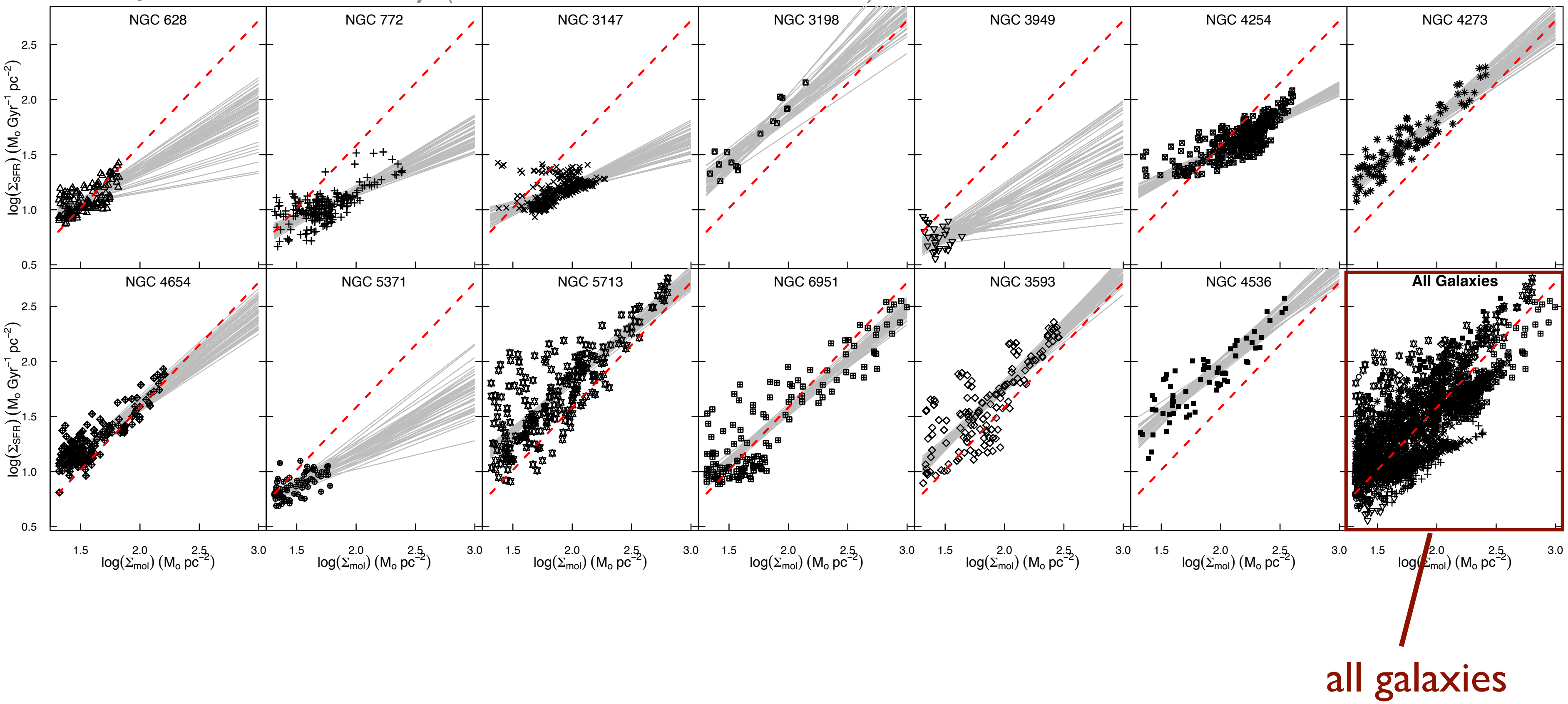
data from STING survey (Rahman et al. 2011, 2012)



- QUIZ: do you see a universal Σ_{H2} - Σ_{SFR} relation?

Shetty et al. (2013, MNRAS in press, arXiv:1306.2951, see also Shetty, Kelly, Bigiel, 2013, MNRAS, 430, 288)

data from STING survey (Rahman et al. 2011, 2012)



- QUIZ: do you see a universal Σ_{H2} - Σ_{SFR} relation?
- ANSWER: - probably not
  - in addition, the relation often is sublinear

Shetty et al. (2013, MNRAS in press, arXiv:1306.2951, see also Shetty, Kelly, Bigiel, 2013, MNRAS, 430, 288)

Hierarchical Bayesian models give more reliable estimates of the *slope* and the *intercept* of a power-law fit compared to least-square fits (or bisector fits).

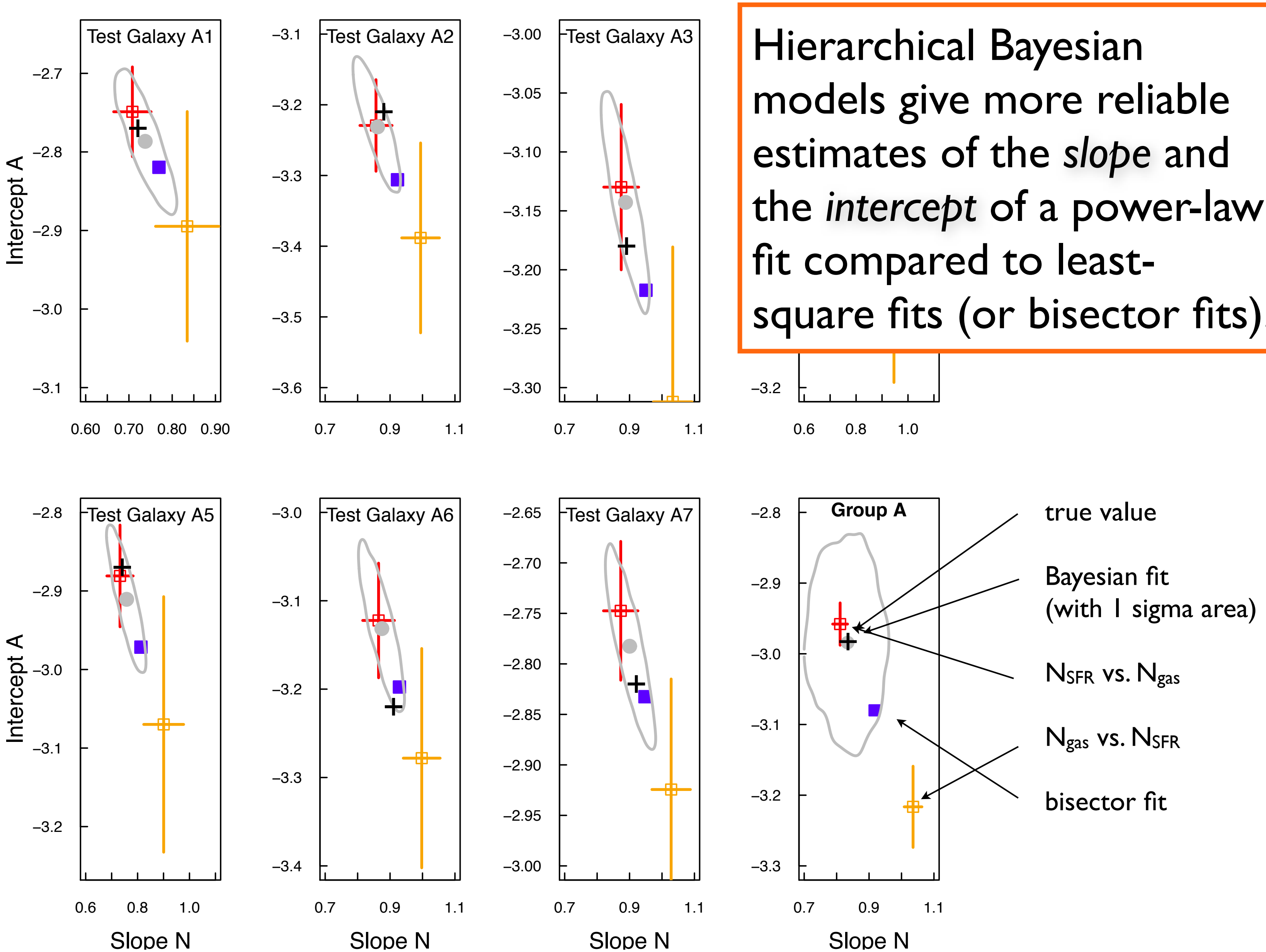
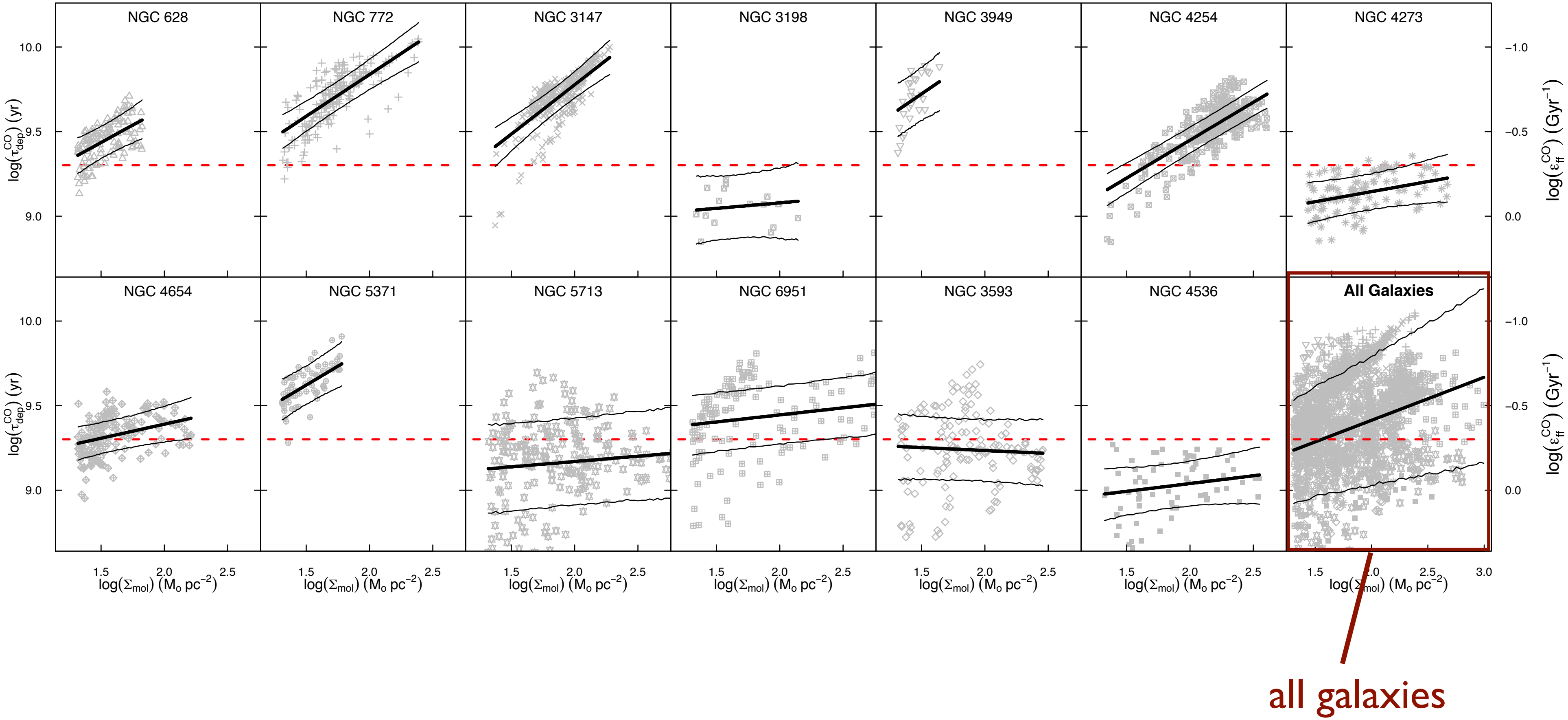


Figure 1. Slope and intercept of test galaxies in Group A. Black cross shows the true values. Red and orange squares show the OLS($\Sigma_{SFR}|\Sigma_{mol}$) and OLS($\Sigma_{mol}|\Sigma_{SFR}$) results, with their 1σ uncertainties, respectively. The gray circles indicate the estimate provided by the median of hierarchical Bayesian posterior result, and the contours mark the 1σ deviation. The filled blue squares mark the bisector estimates. The last panel on the bottom row shows the group parameters and fit estimates.

Shetty et al. (2013, MNRAS, 430, 288)

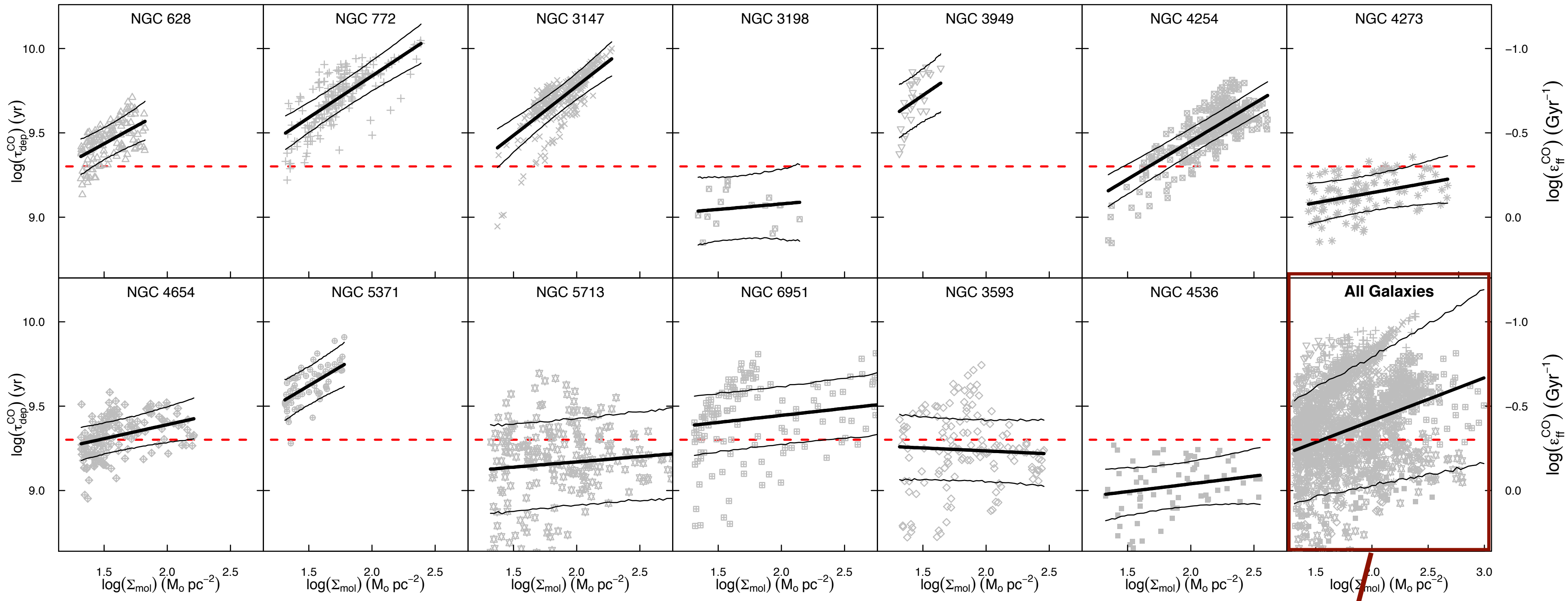
data from STING survey (Rahman et al. 2011, 2012)



Hierarchical Bayesian model for STING galaxies indicate *varying depleting times.*

Shetty et al. (2013, arXiv:1306.2951)

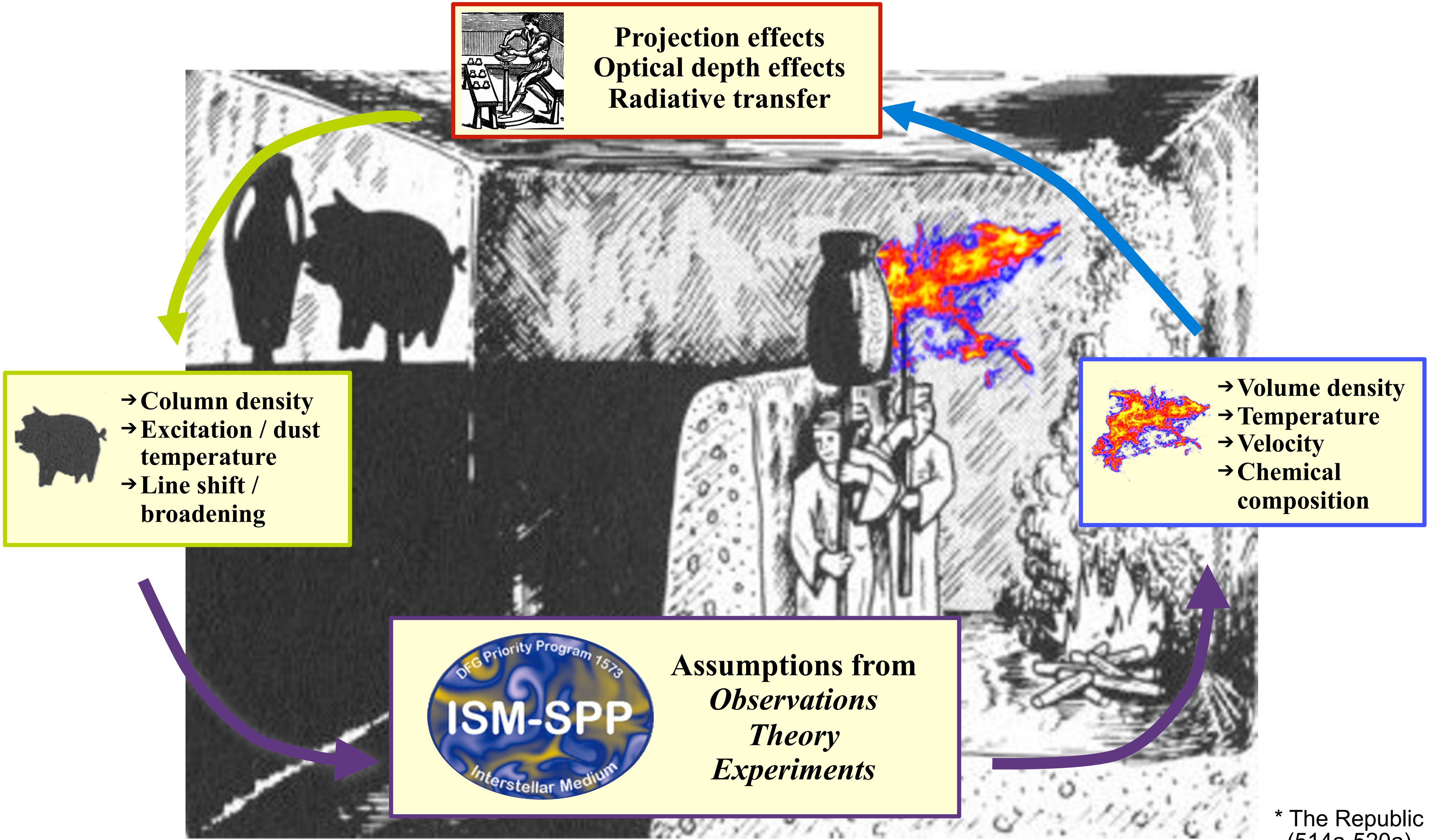
data from STING survey (Rahman et al. 2011, 2012)



physical origin of this behavior?

- maybe strong shear in dense arms (example M51, Meidt et al. 2013)...
- maybe non-star forming H_2 gas becomes traced by CO at high column densities (i.e. high extinctions)...

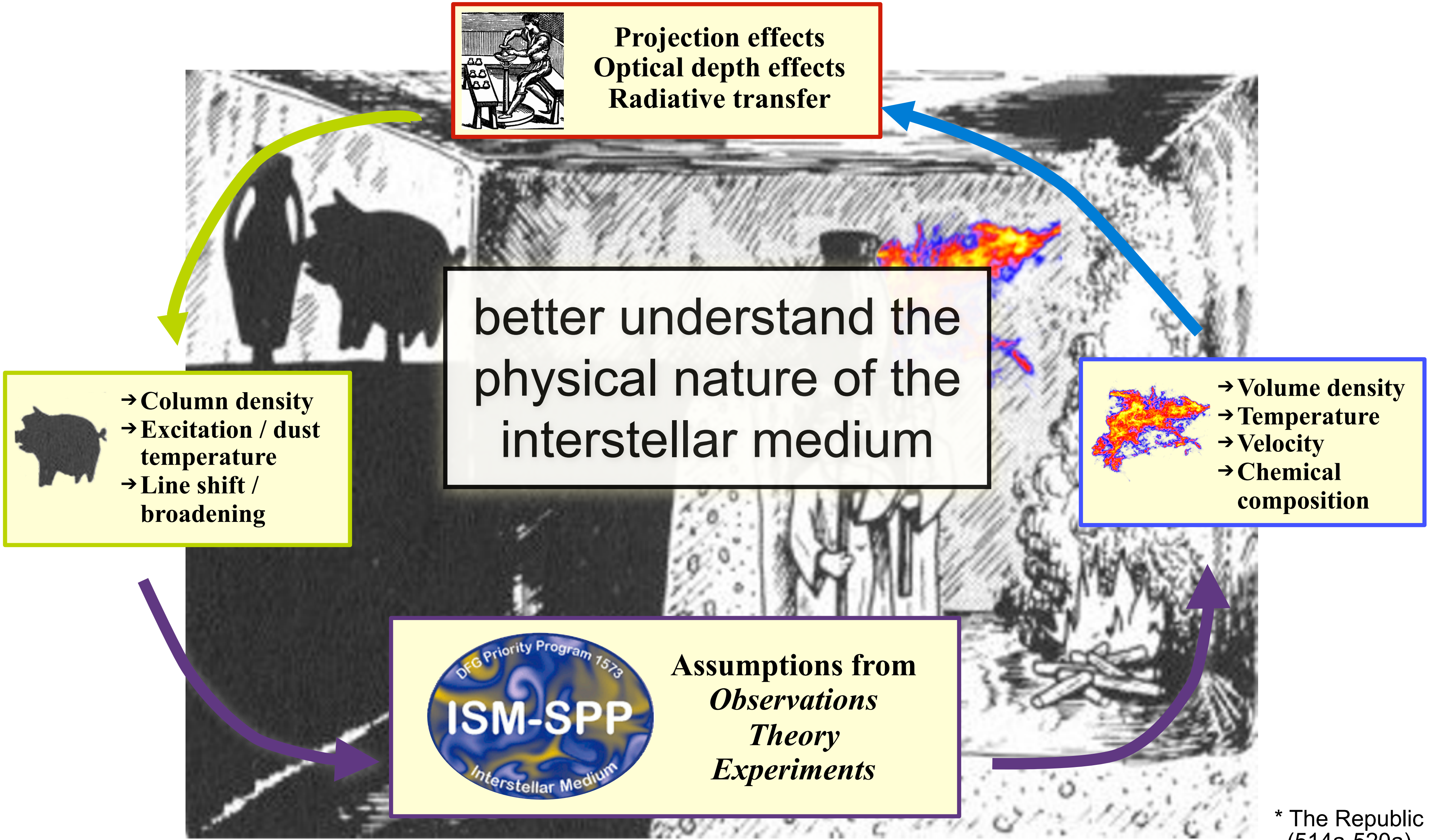
Shetty et al. (2013, MNRAS submitted, arXiv:1306.2951, see also Shetty, Kelly, Bigiel, 2013, MNRAS, 430, 288)



* The Republic (514a-520a)

Laszlo Szücs, image from criticalthinking-mc205.wikispaces.com

goal of this conference



* The Republic (514a-520a)

Laszlo Szücs, image from criticalthinking-mc205.wikispaces.com

MONDAY

09:00 **Andreas Burkert** (USM/LMU) .... **Welcome**

► **Introduction to ISM properties: from small to large scales**
Chair: Henrik Beuther

09:15 **Ralf Klessen** (ZAH/ITA, University of Heidelberg) .... **Review**
Introduction to ISM properties: from small to large scales

► **The multi-phase ISM** Chair: Henrik Beuther

09:55 **Stefanie Walch** (MPA, Garching) .... **Review**
The multi-phase ISM

10:35 Coffee and Tea Break / Poster Viewing

11:05 **Kazunari Iwasaki** (Nagoya University) .... **Contributed**
Turbulent structure in bistable interstellar medium: a self-sustaining mechanism

11:20 **Evangelia Ntormousi** (SAp/CEA Saclay) .... **Contributed**
The thickness distribution of interstellar filaments

11:35 **Peter Scicluna** (ESO) .... **Contributed**
Anomalous extinction: The degeneracy between dust composition and geometry

11:50 **Hans Zinnecker** (Deutsches SOFIA Institut) .... **Contributed**
Latest GREAT results from SOFIA

► **Molecular cloud properties** Chair: Cornelia Jäger

12:05 **Alvaro Hacar** (University of Vienna) .... **Review**
Molecular cloud properties

12:45 Lunch Break / Poster Viewing

14:15 **Joao Alves** (University of Vienna) .... **Contributed**
The structure of molecular clouds from 1000 AU to Orion

14:30 **Doris Arzoumanian** (IAS Orsay) .... **Contributed**
Properties of interstellar filaments observed with Herschel and 3D magnetic field structure derived from the polarization parameters observed with Planck

14:45 **Gesa Bertrang** (ITAP, University of Kiel) .... **Contributed**
Magnetic Fields in Bok globules

15:00 **Jouni Kainulainen** (MPIA, Heidelberg) .... **Contributed**
Effect of turbulence on the density statistics of molecular clouds:
an observational view

15:15 **Rowan Smith** (ZAH/ITA, University of Heidelberg) ...... **Contributed**
Filamentary Structures in the ISM

15:30 Coffee and Tea Break / Poster Viewing

► **Turbulence in the ISM** Chair: Stefanie Walch

16:00 **Fabian Heitsch** (University of North Carolina Chapel Hill) .... **Review**
Turbulence in the ISM

16:30 **Patrick Hennebelle** (SAp/CEA Saclay) .... **Review**
Molecular cloud formation in converging flows

17:00 **Paul Clark** (ZAH/ITA, University of Heidelberg) .... **Contributed**
On the characteristic mass of stars in stellar clusters

17:15 **Jo Barnes** (University of St Andrews) .... **Contributed**
Photoionization of the diffuse ionised gas in an MHD supernova-driven turbulent Interstellar Medium

17:30 **Edith Falgarone** (LERMA/LRA ENS).................. **Contributed**
The molecular richness of diffuse ISM: a tracer of turbulent dissipation

17:45 **Welcome Reception**

TUESDAY

► **Collapse of molecular clouds and the IMF** Chair: Simon Glover

9:00 **Matthew Bate** (University of Exeter) .... **Review**
Collapse of molecular clouds and the IMF

9:40 **Paula Stella Teixeira** (University of Vienna) .... **Contributed**
Tracing the fragmentation of OMC1-north filament with the Submillimeter Array

9:55 **Enrique Vazquez-Semadeni** (CRyA, UNAM)......... **Contributed**
Filament formation and star formation regulation in collapsing molecular clouds

10:10 **Katharine Johnston** (MPIA, Heidelberg) .... **Contributed**
The structure and star-forming fate of the Galactic centre cloud G0.253+0.016

10:25 Coffee and Tea Break / Poster Viewing

► **Laboratory Astrophysics** Chair: Simon Glover

10:55 **Cornelia Jäger** (Universität Jena) .... **Review**
Laboratory Studies of Dust Formation and Processing

11:35 **Holger Kreckel** (MPIK, Heidelberg)................... **Contributed**
Combining experimental techniques for comprehensive astrophysical case studies

11:50 **Andreas Wolf** (MPIK, Heidelberg) .... **Contributed**
Laboratory studies on electron collisions of atomic and molecular ions

► **Chemical processes in the ISM** Chair: Dominik Schleicher

12:05 **Simon Glover** (ZAH/ITA, University of Heidelberg)........... **Review**
Chemical processes in the ISM: Gas and molecules

12:35 Lunch Break / Poster Viewing

14:05 **Thomas Henning** (MPIA, Heidelberg) .... **Review**
Chemical processes in the ISM: Dust

14:35 **Marta Alves** (Institut d'Astrophysique Spatiale (IAS)) ... **Contributed**
Galactic dust as seen by Planck

14:50 **Henrik Beuther** (MPIA, Heidelberg) .... **Contributed**
Formation signatures and carbon budget of molecular clouds

15:05 **Bastian Gundlach** (TU Braunschweig)............... **Contributed**
Experimental investigation of the collision properties of micrometer-sized water ice particles

15:20 **Ralf Siebenmorgen** (ESO) .... **Contributed**
Dust in the diffuse interstellar medium:
Extinction, emission, linear and circular polarization

15:35 Coffee and Tea Break / Poster Viewing

16:05 **Svitlana Zhukovska** (MPIA, Heidelberg) .... **Contributed**
Dust-to-gas ratio as a clue to the galactic evolution

TUESDAY

► **Dependence of star formation on ISM properties**
Chair: Svitlana Zhukovska

16:20 **Adam Leroy** (NRAO, Charlottesville)....................... **Review**
Dependence of star formation on ISM properties

17:00 **Diederik Kruijssen** (MPA, Garching)................. **Contributed**
An uncertainty principle for star formation -
why galactic scaling relations break down below a certain spatial scale

17:15 **Sarah Ragan** (MPIA, Heidelberg)..................... **Contributed**
Herschel and APEX study of the initial condition of high-mass star formation

17:30 **Javier A. Rodon** (ESO)............................. **Contributed**
Deuteration and fragmentation in massive star-forming regions

17:45 **Amelia Stutz** (MPIA, Heidelberg) .... **Contributed**
Connecting diverse molecular cloud environments with nascent protostars in Orion

WEDNESDAY

► **Stellar feedback in the ISM** Chair: Enrique Vazquez-Semadeni

9:00 **Mordecai-Mark Mac Low** (AMNH, New York).............. **Review**
Stellar feedback in the ISM

9:40 **Joanne Dawson** (CSIRO Astronomy and Space Science) **Contributed**
Molecular cloud formation in stellar feedback flows:
Observing, demonstrating, quantifying

9:55 **James Dale** (Excellence Cluster Universe)............. **Contributed**
Disruption of GMCs by photoionization and stellar winds - setting the stage for supernovae.

10:10 **Matthias Gritschneder** (Univ. California, Santa Cruz).. **Contributed**
The evolution of molecular clouds under the influence of ionizing radiation

10:25 **Andrea Gatto** (MPA, Garching) .... **Contributed**
Feedback-driven turbulence in the multi-phase ISM

10:40 Coffee and Tea Break / Poster Viewing

11:10 **Thomas Peters** (Universität Zürich) .... **Contributed**
Understanding ultracompact H II regions

11:25 **Eric Keto** (Harvard-Smithsonian Center for Astrophysics) **Contributed**
An analytic model for the dynamics of the ionized outflows of massive protostars

11:40 **Thomas Preibisch** (USM/LMU)...................... **Contributed**
Deciphering the violent interaction between very massive stars and their natal clouds in the Carina Nebula Complex

11:55 **Dominique Meyer** (AIfA, Bonn) .... **Contributed**
Models for the circumstellar medium of massive runaway stars

12:10 **Jonathan Mackey** (AIfA, Bonn) .... **Contributed**
Dynamics of H II regions around exiled O stars

12:25 Lunch Break / Poster Viewing

14:00 **Guided tour through Munich including visit to Nymphenburg Castle**

18:00 **Conference Dinner**

THURSDAY

▶ The magnetised ISM — Chair: Rowan Smith

09:00 **Ellen Gould Zweibel** (University of Wisconsin) .... **Review**
The magnetised ISM: Theory

09:30 **Richard Crutcher** (University of Illinois) .... **Review**
The magnetized ISM: Observations

10:00 **Francois Boulanger** (Institut d'Astrophysique Spatiale) **Contributed**
Mapping the structure of the Galactic magnetic field with Planck

10:15 **Alex Hill** (CSIRO Astronomy & Space Science) .... **Contributed**
Magnetic fields in high velocity clouds

10:30 Coffee and Tea Break / Poster Viewing

11:00 **Stefan Reißl** (Univ. Kiel) .... **Contributed**
Multi-wavelength polarization measurements tracing the ISM magnetic field

11:15 **Dominik Schleicher** (Institut für Astrophysik Göttingen) **Contributed**
The far-infrared - radio correlation:
Star formation and magnetic field amplification in the ISM

▶ ISM on Galactic Scales — Chair: Rowan Smith

11:30 **Alberto Bolatto** (University of Maryland) .... **Review**
ISM on galactic scales: Observations

12:00 **Andreas Burkert** (USM/LMU) .... **Review**
ISM on galactic scales: Theory

12:30 Lunch Break / Poster Viewing

▶ ISM on Galactic Scales — Chair: Mordecai-Mark Mac Low

14:00 **Brent Groves** (MPIA, Heidelberg) .... **Contributed**
Dust luminosity as a tracer of gas mass and gas heating

14:15 **Manuel Behrendt** (MPE, Garching) .... **Contributed**
Structure formation and evolution in gas-rich disk systems

14:30 **Maria Kapala** (MPIA, Heidelberg) .... **Contributed**
The survey of lines in M31 (SLIM): Investigating the origins of [CII] emission

14:45 **Jin Koda** (Stony Brook University) .... **Contributed**
Evolution of molecular gas in spiral galaxies

15:00 **Martin Krause** (MPE, Garching) .... **Contributed**
Superbubbles as a physical process in the ISM

15:15 **Ute Lisenfeld** (Universidad Granada) .... **Contributed**
Star formation and molecular gas outside galaxies

15:30 Coffee and Tea Break / Poster Viewing

16:00 **Andreas Schruba** (MPE, Garching) .... **Contributed**
The resolved ISM of our nearest spiral galaxy

16:15 **Rahul Shetty** (ZAH/ITA, University of Heidelberg) ...... **Contributed**
The sub-linear and non-universal Kennicutt-Schmidt relationship

16:30 **Javier Zaragoza-Cardiel** (IAC) .... **Contributed**
Two regimes of star formation

THURSDAY

▶ The ISM in the extreme environment of galactic centers — Chair: Avishai Dekel

16:45 **Steven Longmore** (Liverpool John Moores University)...... **Review**
The ISM in the extreme environment of galactic centers

17:25 **Timothy Davis** (ESO)............................... **Contributed**
The ISM in the extreme environment of early-type galaxies

17:40 **Vladimir Dogiel** (P.N.Lebedev Institute of Physics)..... **Contributed**
Physical processes of gas ionization in the Galactic Center
and the origin of 6.4 keV and absorption H_3^+ Lines from there

FRIDAY

▶ Cosmic rays and their impact on the ISM — Chair: Ellen Gould Zweibel

09:00 **Tsuyoshi Inoue** (Aoyama Gakuin University)............... **Review**
Cosmic rays and their impact on the ISM

09:40 **Sabrina Casanova** (MPIK, Heidelberg)............... **Contributed**
Cosmic ray propagation in molecular clouds

09:55 **Philipp Girichidis** (MPA, Garching) .... **Contributed**
Cosmic ray driven Galactic outflows and the evolution of cosmic ray spectra

10:10 **Miwa Goto** (USM/LMU).............................. **Contributed**
The cosmic-ray ionization rate in the Central parsec of the Galaxy

10:25 **Ruizhi Yang** (Purple Mountain Observatory)........... **Contributed**
Probing cosmic rays in nearby giant molecular clouds with the Fermi Large Area Telescope

10:40 Coffee and Tea Break / Poster Viewing

▶ The ISM at high redshift — Chair: Ellen Gould Zweibel

11:10 **Linda Tacconi** (MPE, Garching)........................... **Review**
The ISM at high redshift: Observations

11:40 **Avishai Dekel** (The Hebrew University) .... **Review**
The ISM at high redshift: Theory

12:10 **Muhammad Latif** (Institute for Astrophysics, Göttingen) **Contributed**
Turbulence and the formation of supermassive black holes at high redshift

12:25 **Thorsten Naab** (MPA, Garching)..................... **Contributed**
Outflows and the multi-phase turbulent structure of the ISM in high-redshift galaxies

12:40 Lunch Break and End of Conference

Emergency phone numbers

Ambulances, Fire & Rescue Service, Police 112
Doctor on duty 116 117

LOC

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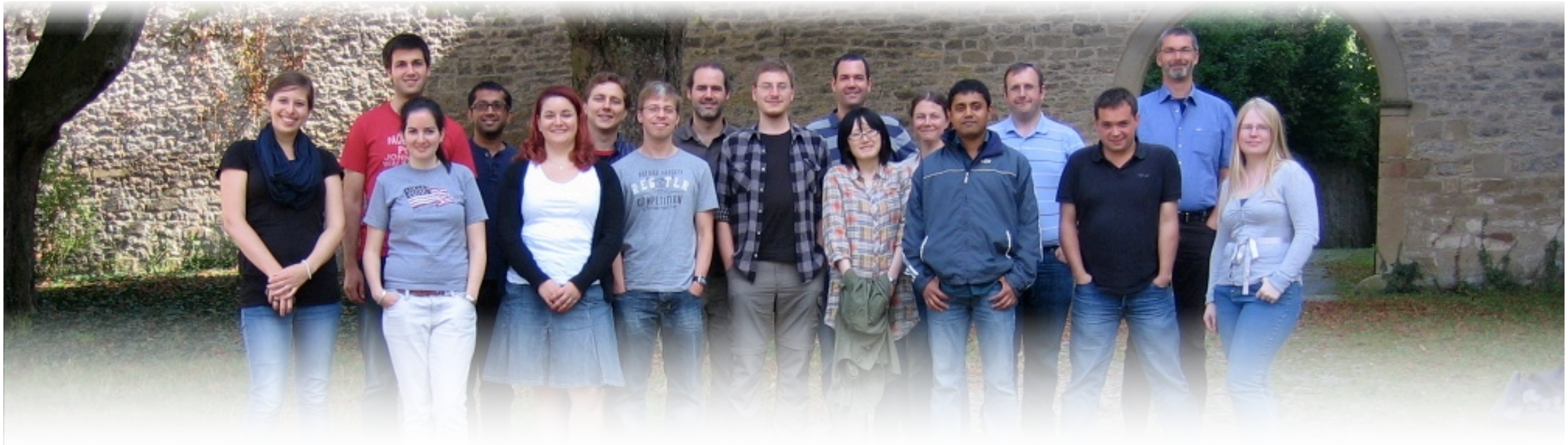
Alessandro Ballone .... +49 (0)176 7074 3224
Manuel Behrendt .... +49 (0)171 10 89 380
Katharina Fierlinger .... +49 (0)157 7596 0405
Stephanie Pekruhl

THANKS

thanks to ...



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