Latiatuc feleym ʒumtuchel mic vogmuc. ýſa pur es chomuv uogmuc.

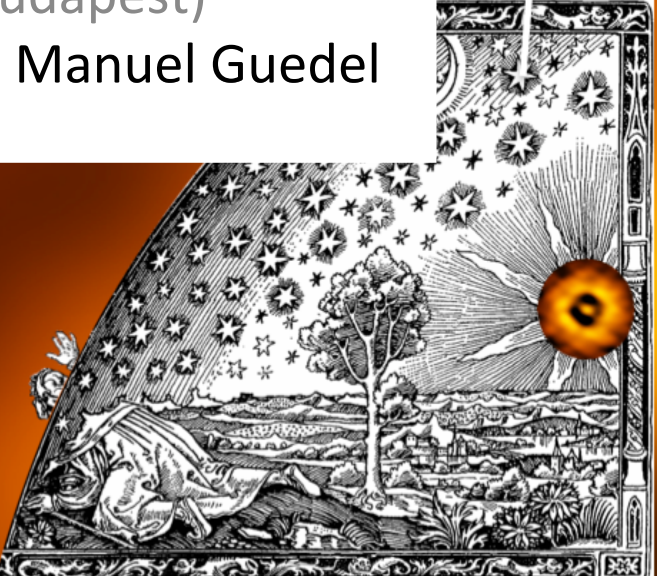
handwritten Hungarian text, 1192

Do you see my friends what we are?
We are only dust and ashes.

...

Key points of IAUS345 “Origins”

L. Viktor TÓTH
(Eötvös University & Konkoly Obs. Budapest)
In collaboration with Bruce G. Elmegreen & Manuel Guedel



advances

Observing facilities and measurements

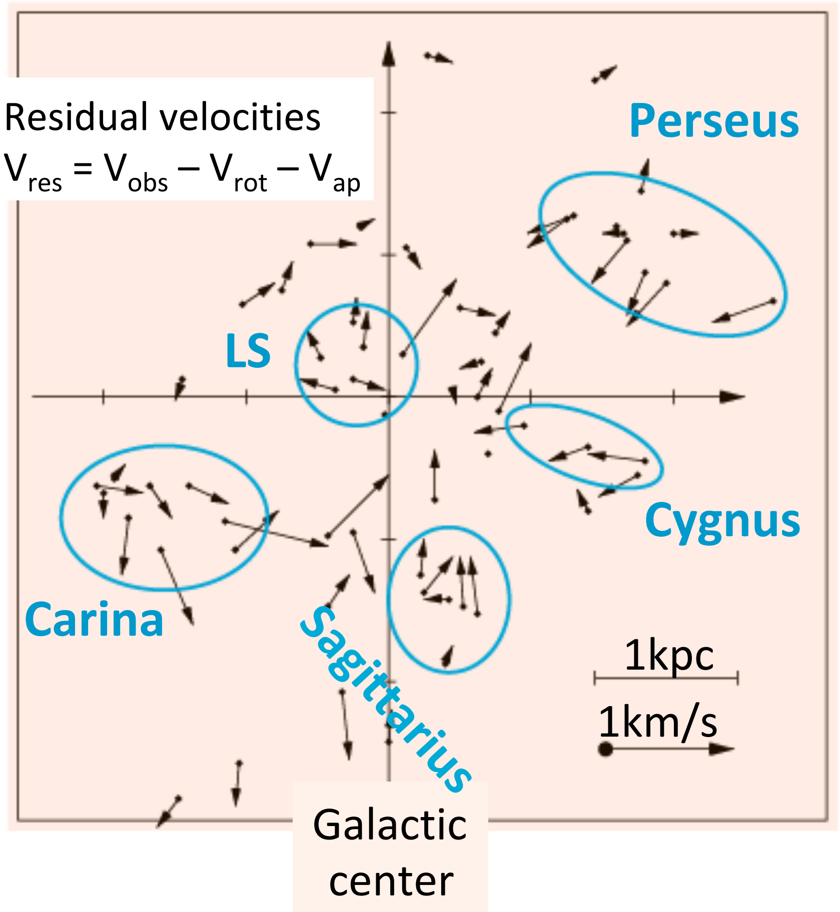
- GAIA − 3D galactic position + kinematics
- Herschel − continuum
- ALMA − continuum, molecular lines and polarization
- Planck & JCMT SCUBA − polarization

Objects

- Star clusters
- Clouds, Cores
- Filaments, striations, fibers
- Outflows, disks

Simulations

Gaia based kinematic study of OB associations



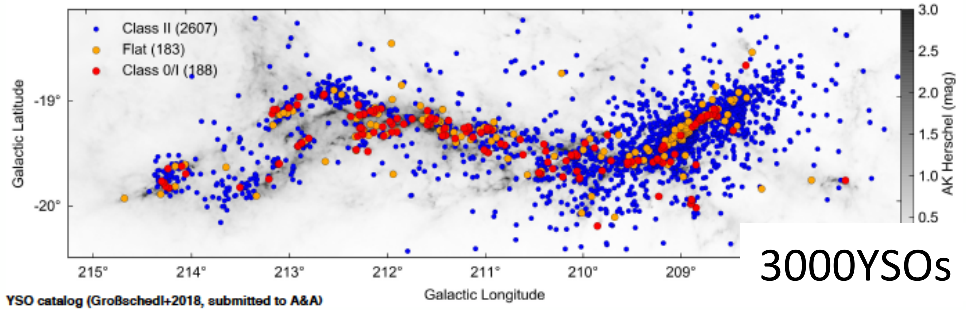
Results on OB associations with > 10 Gaia DR1 stars

- average velocity dispersion = 3.9 km/s.
- median virial mass = 7×10^5 $M_\odot$
- median stellar mass = 9×10^3 $M_\odot$
- median star-formation efficiency = 2.1%
- Expansion: Per OB1, Car OB1, Sco OB1, Ori OB1 (Melnik & Dambis 2017)
- two-component outer ring models reproduce the average residual velocities of OB associations in Per, Sgr and LS complexes.

Anna M. Melnik's talk

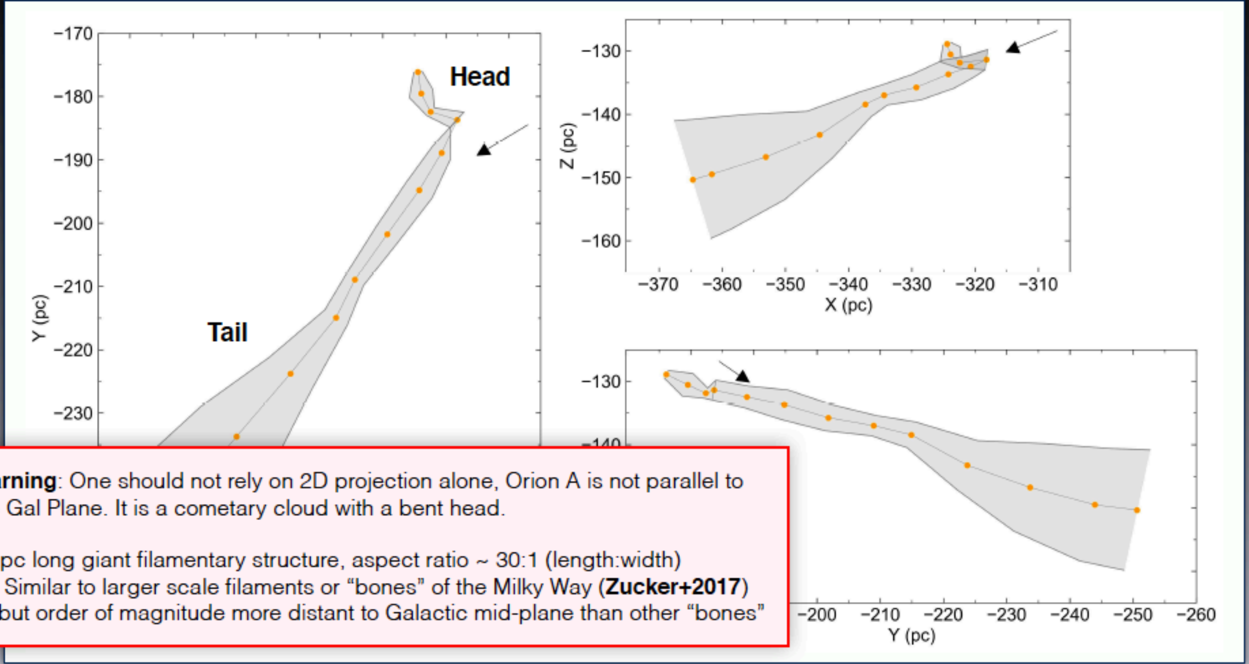
3D shape of Orion A with Gaia DR2

Josefa Großschedl



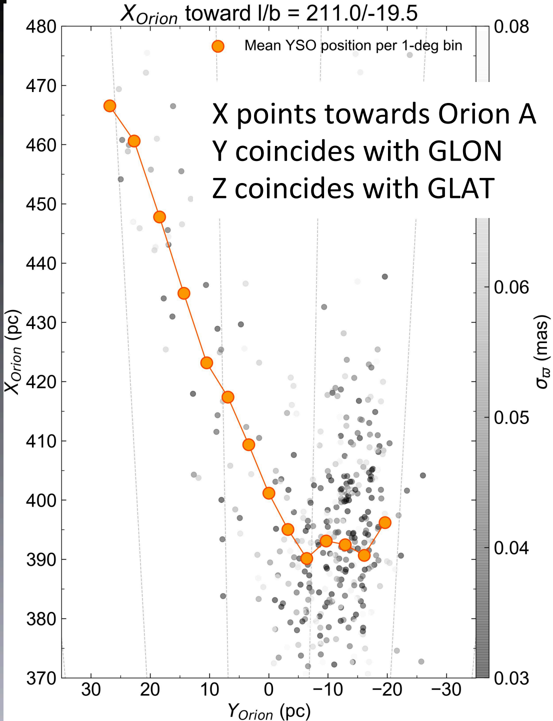
3000YSOs

3D orientation in Galactic cartesian coordinate space (XYZ)



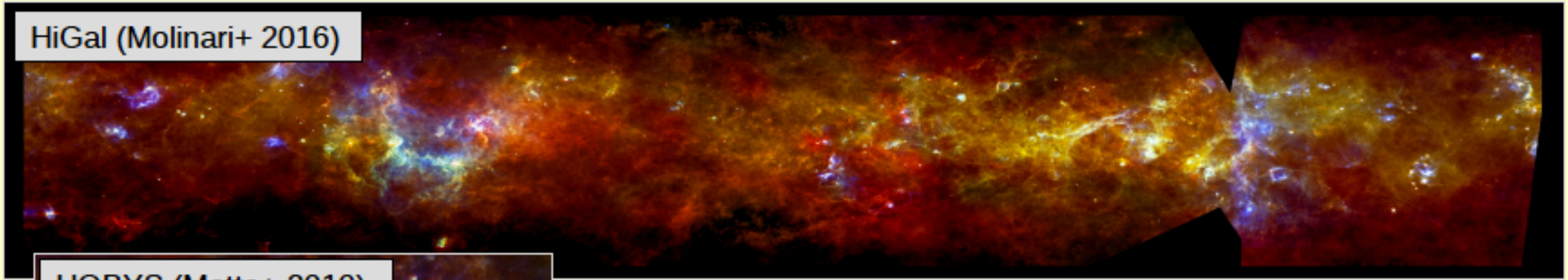
Warning: One should not rely on 2D projection alone, Orion A is not parallel to the Gal Plane. It is a cometary cloud with a bent head.

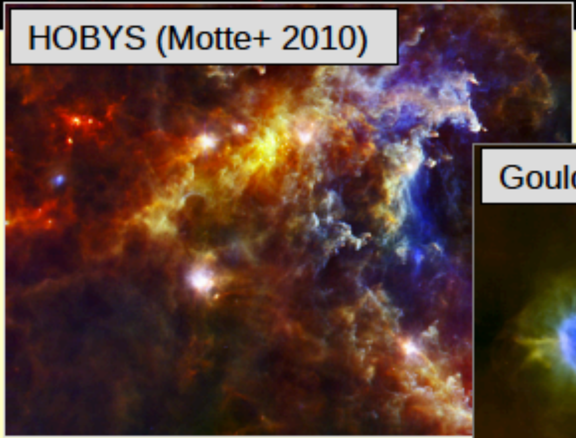
90 pc long giant filamentary structure, aspect ratio ~ 30:1 (length:width)
=> Similar to larger scale filaments or "bones" of the Milky Way (**Zucker+2017**)
… but order of magnitude more distant to Galactic mid-plane than other "bones"

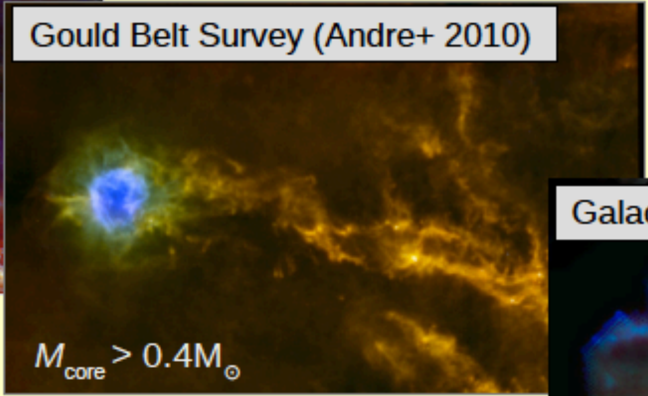


X points towards Orion A
Y coincides with GLON
Z coincides with GLAT

Herschel 70-500μm resolved cloud structure down to A_V~1, $N(H_2)$~$10^{21}cm^{-2}$







Mika Juvela's talk

Stars form mostly in cloud filaments

Filaments → cores

Mika Juvela's talk

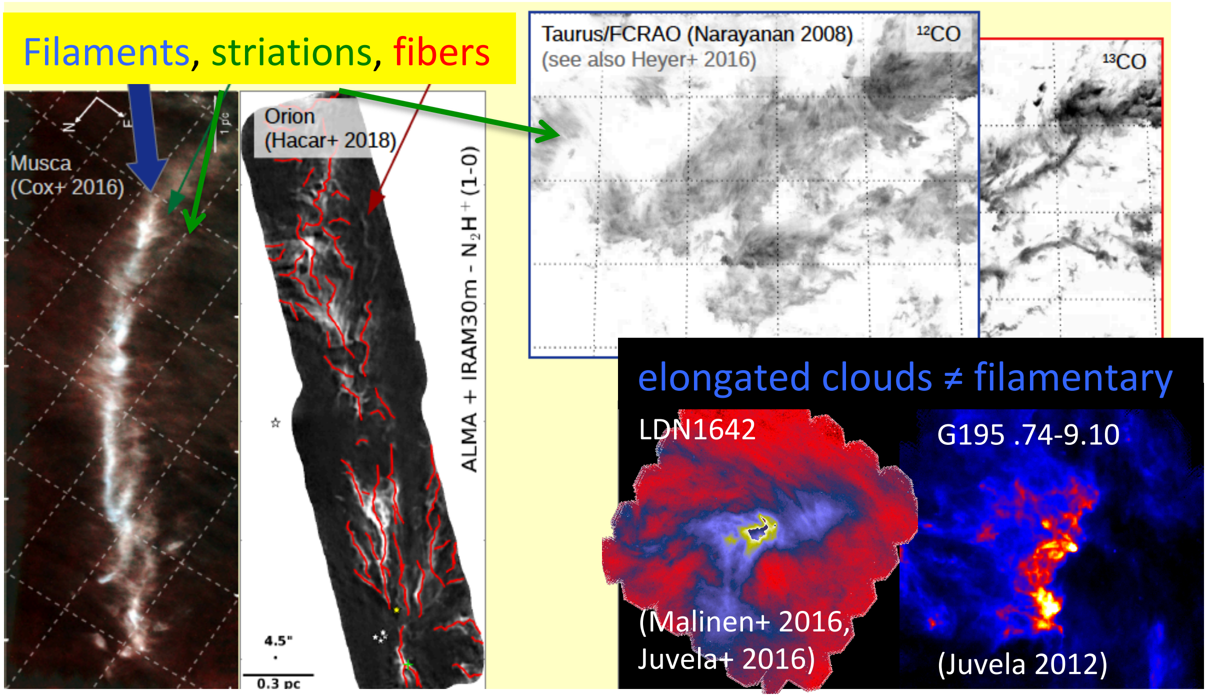
Observations:

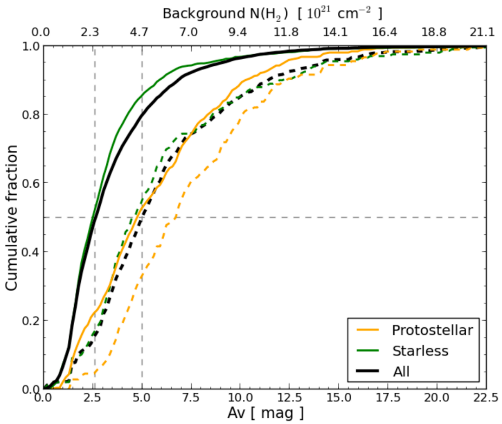
cores form on critical filaments

$M_{cr} \sim 2\, c_s^2 / G \sim 16 M_\odot/pc$

at T=10K, above $A_V \sim$ 5-10

(Enoch+07; André+14, Könyves+15; Marsh+16; Bresnahan+ 17; Rivera-Ingraham+ 16,17)



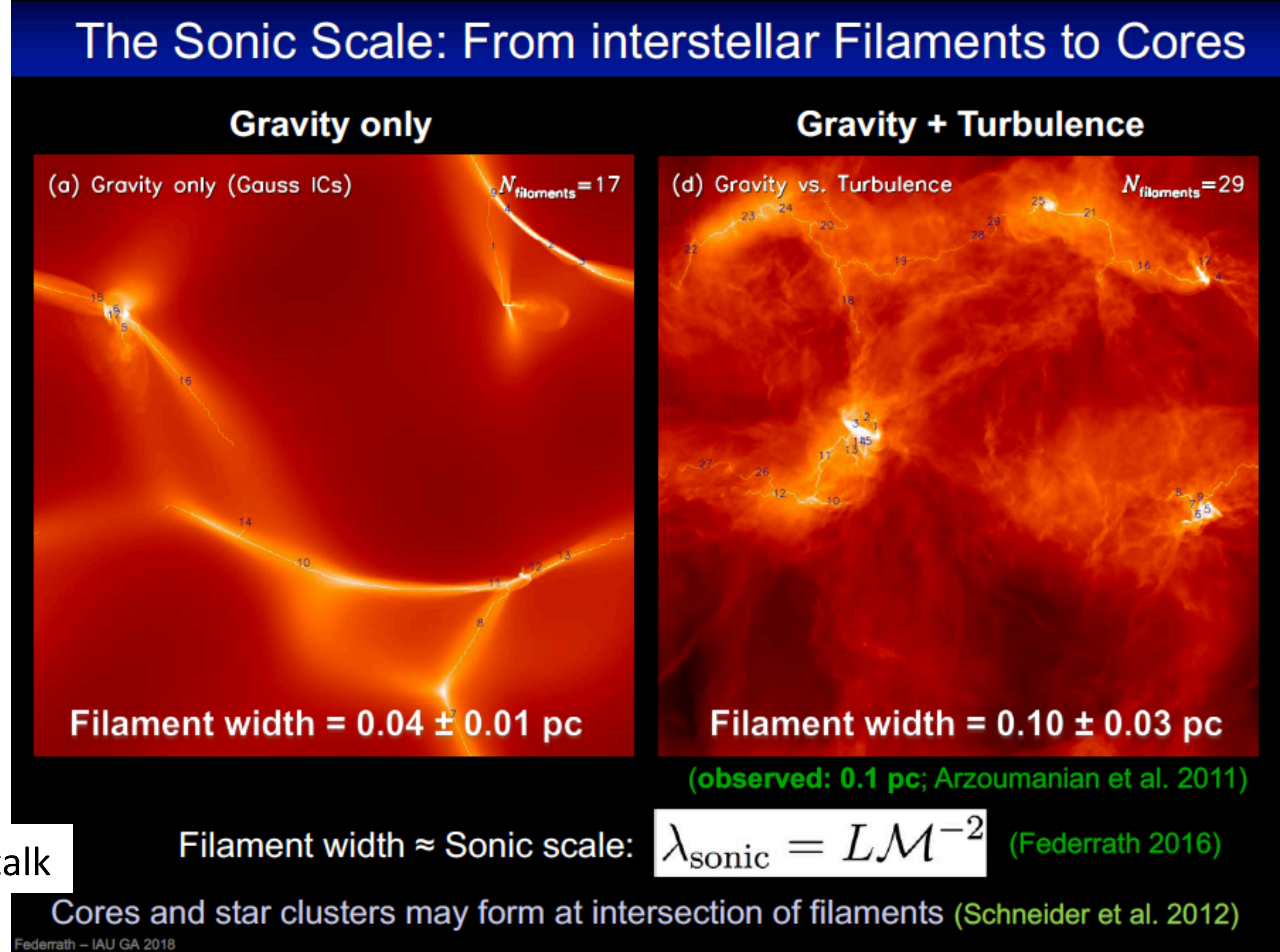


T_d dependent A_V treshold
Montillaud+ 2015

Theory on filaments:

- Basic characteristic of (M)HD turbulence (Vázquez-Semadeni 94, Padoan+01, Hennebelle+ 08, Li +10, André+ 14)
- Striations and fibers: Chen & Ostriker 14; Inutsuka+ 15; Clarke+ 2018

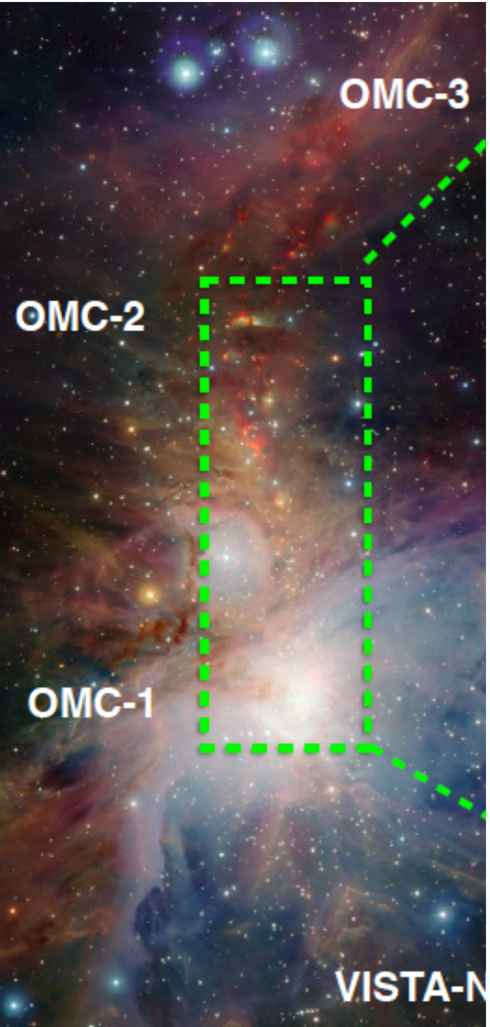
Modeling core and star cluster formation on filaments

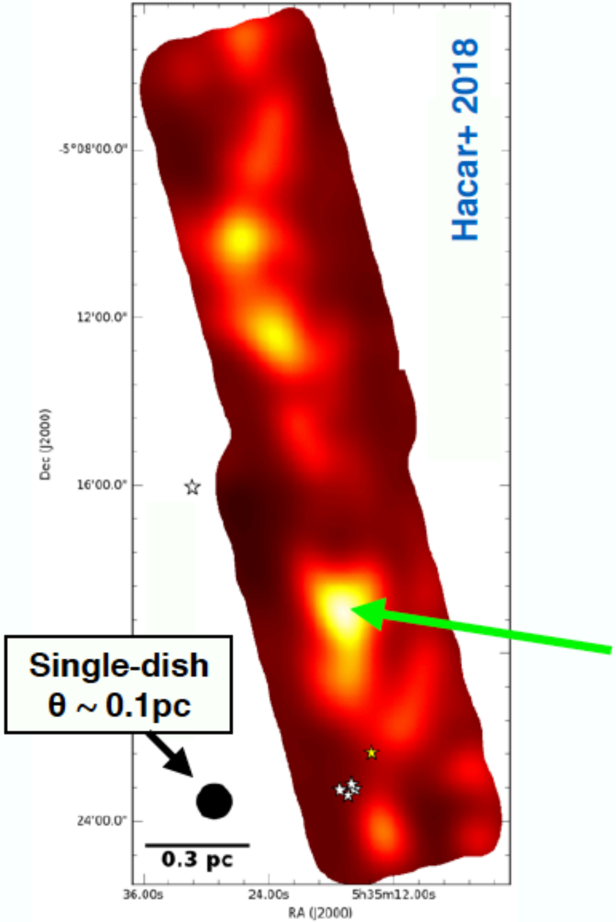


Christoph Federrath’s talk

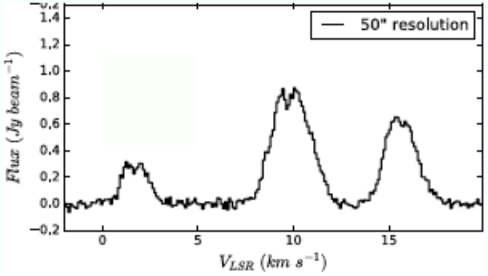
ISF: a Rosetta Stone in the ALMA era

Alvaro Hacar





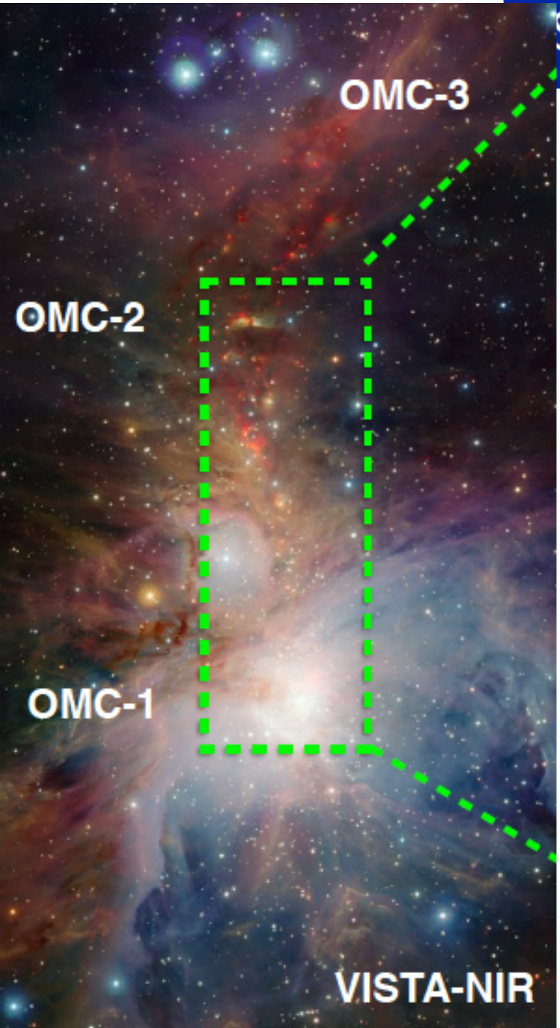
1x supersonic line

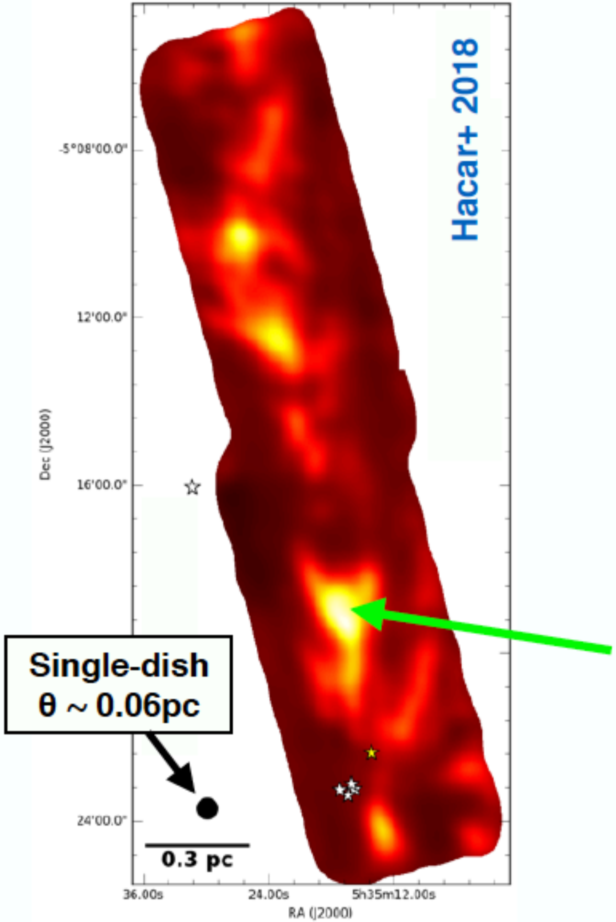


N_2H^+ lines

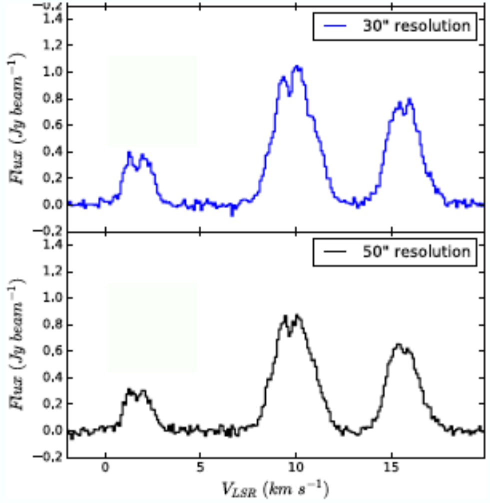
SF: a Rosetta Stone in the ALMA era

Alvaro Hacar

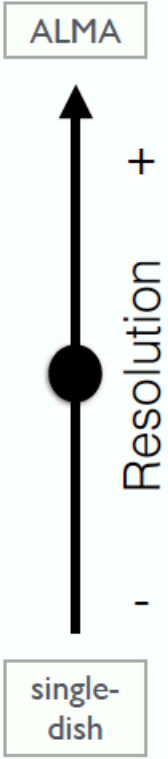


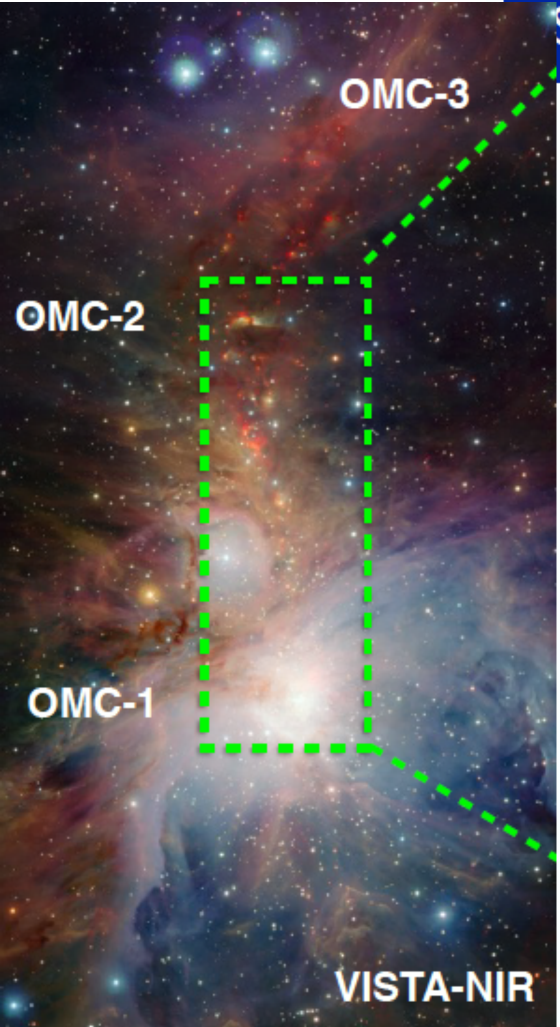


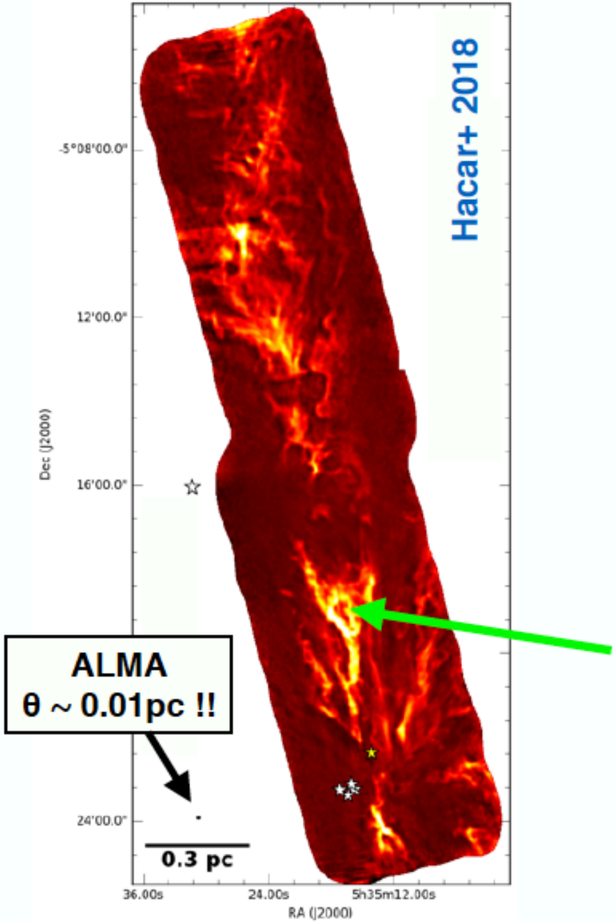
2x transonic lines

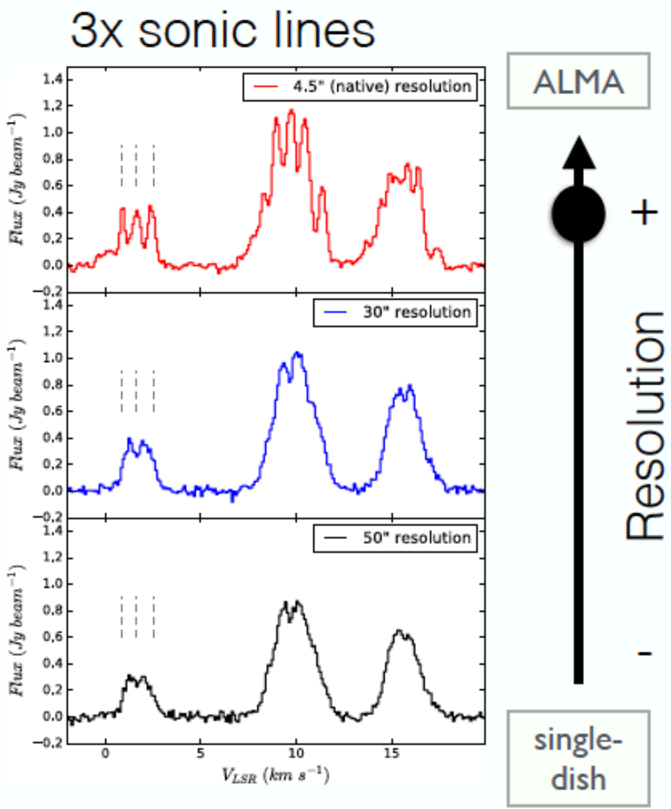


N_2H^+ lines




OMC-3
OMC-2
OMC-1
VISTA-NIR


Hacar+ 2018
ALMA
θ ~ 0.01pc !!
0.3 pc
-5°08'00.0"
12'00.0"
16'00.0"
24'00.0"
Dec (J2000)
36.00s
24.00s
5h35m12.00s
RA (J2000)

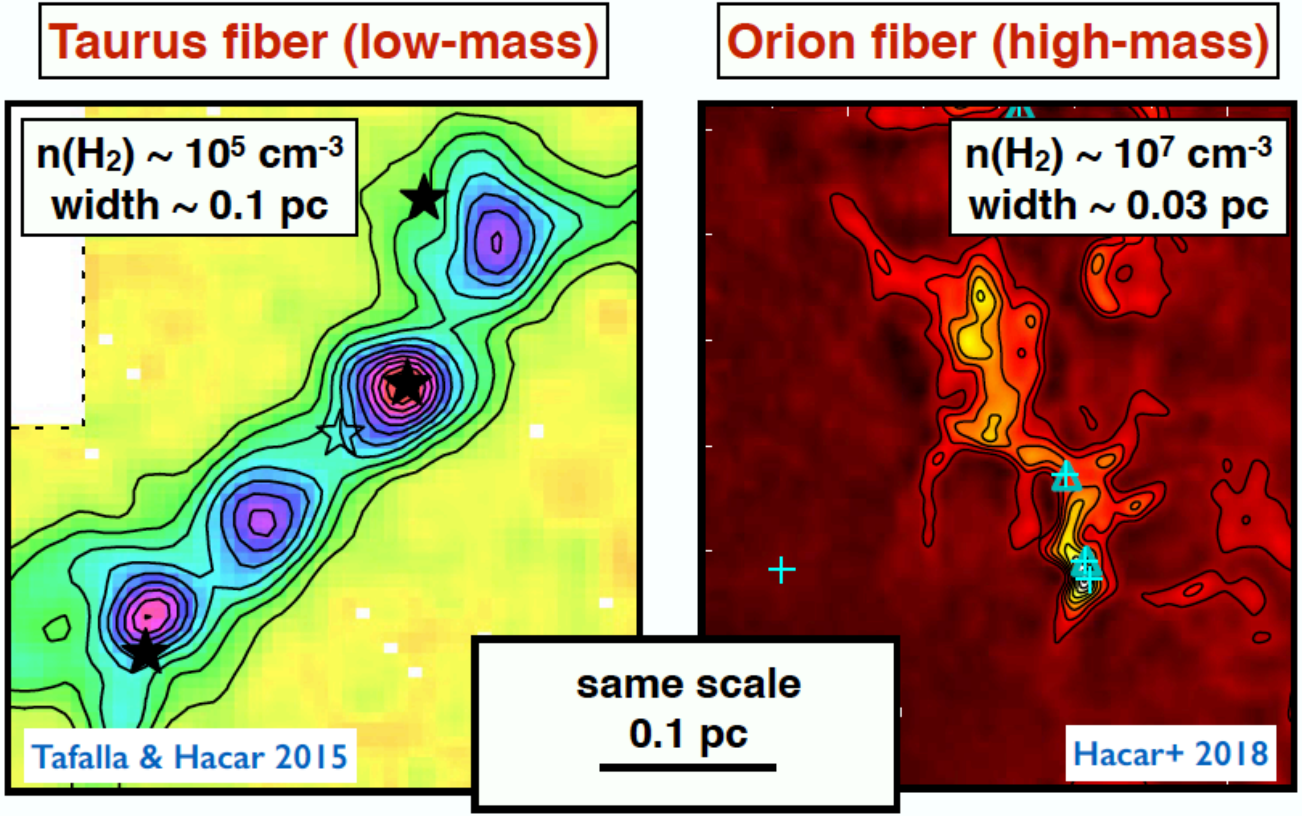

3x sonic lines
4.5" (native) resolution
30" resolution
50" resolution
Flux (Jy beam^{-1})
V_{LSR} (km s^{-1})
ALMA
+
Resolution
-
single-dish

N_2H^+ lines

Density dependence of the fiber widths

Alvaro Hacar's talk

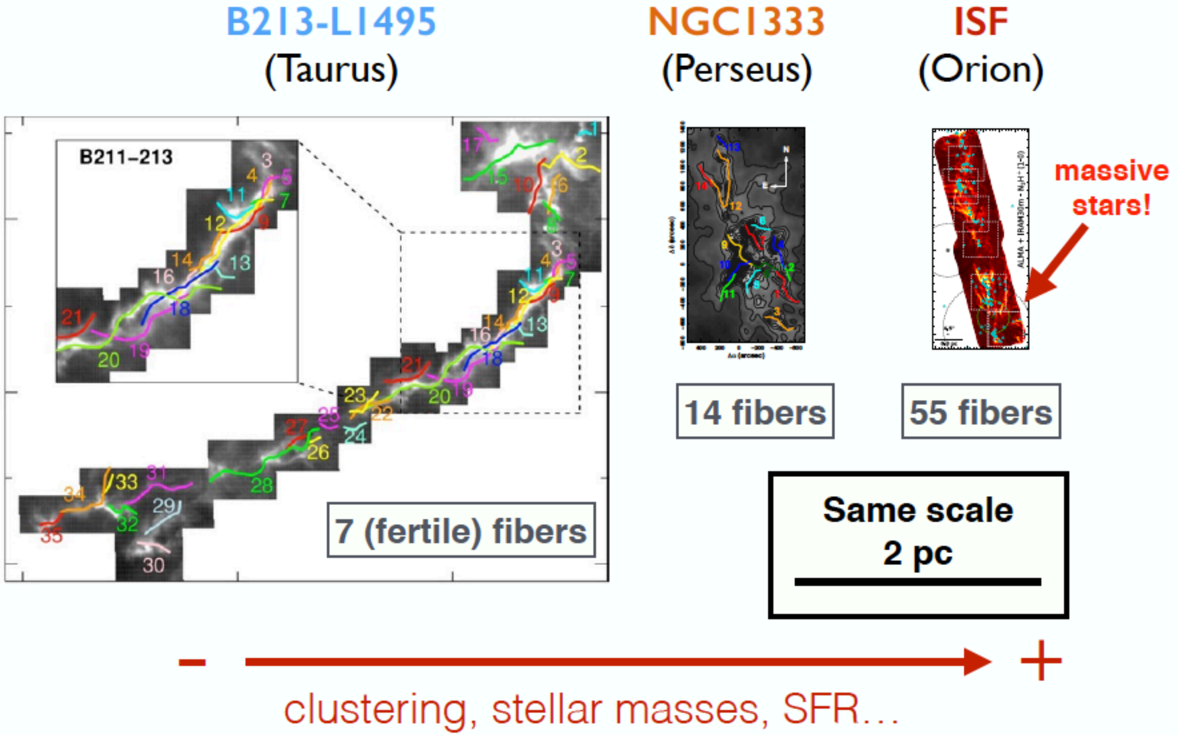
- Orion fibers are narrower and denser than the Tau fibers
- they are also much more fertile
- Stars form on fibers
- Massive stars form at the fiber junctions



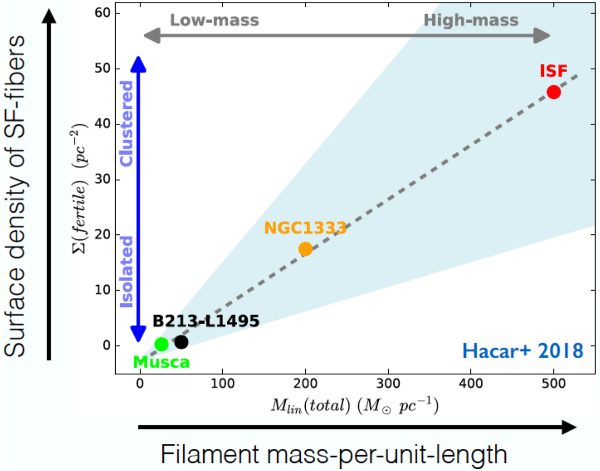
Same physics at different densities

Unified model of star formation – with fibers

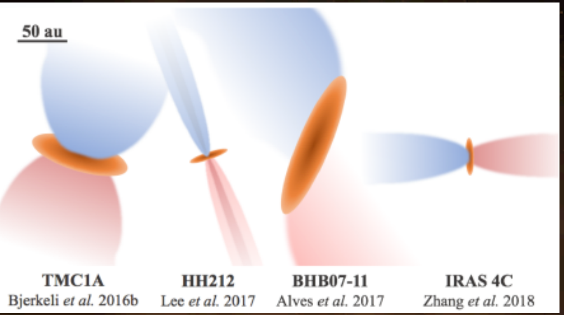
Fibers in low, intermediate and high mass filaments



- (Trans-)sonic and stable in all environments
- Different length & width depending on gas density
- Different SF-modes originated on the Σ(fibers)

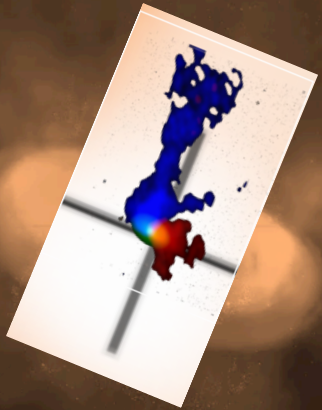


Alvaro Hacar



Outflows resolved (0.04” 6AU)

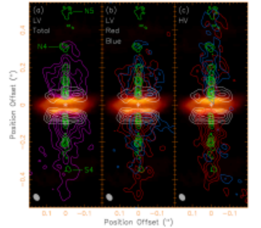
Per Bjerkeli’s talk



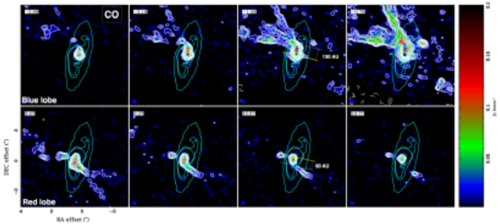
Wind launching

Other recent examples

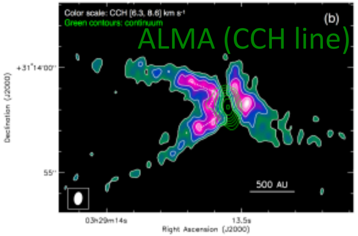
HH212 (Lee et al., 2017)



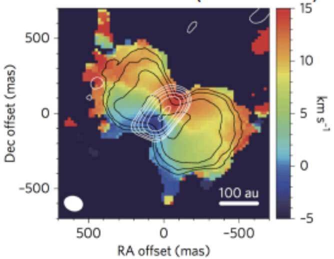
BHB07-11 (Alves et al., 2017)

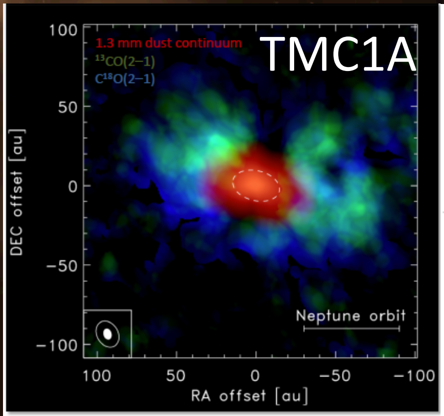


IRAS 4C (Zhang et al., 2018)

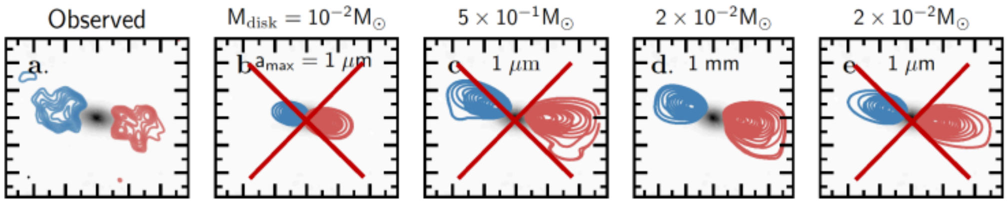


Orion Source I (Hirota et al., 2017)





Harsono, et al. 2018, *Nature Astronomy*



Observed $C^{18}O$

Canonical model gas-to-dust=100 **grains up to 1 μm size**

shows strong $C^{18}O$ emission in central region

Massive disk

would be unstable

Large grains

up to 1 mm size

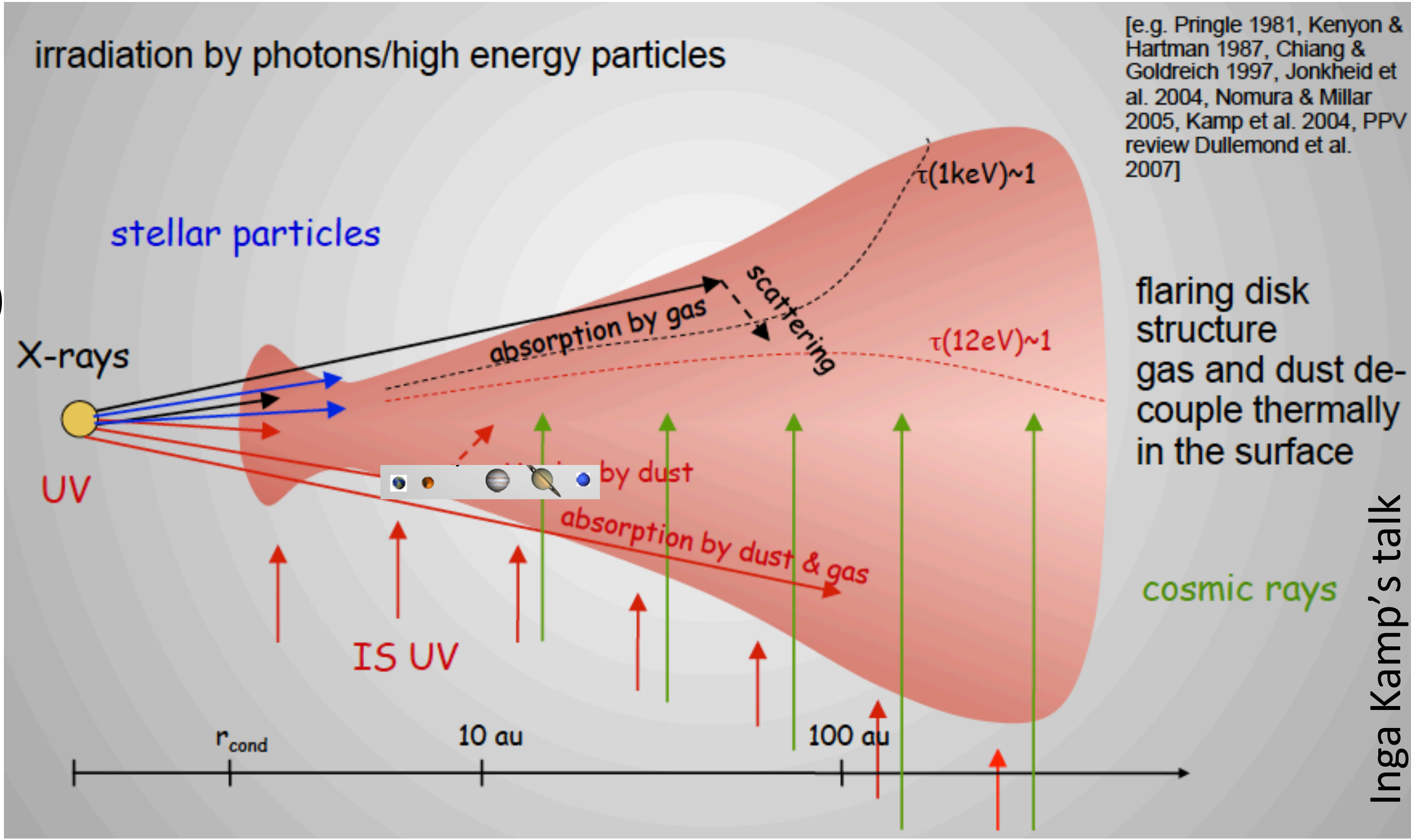
Flat disk

not consistent with temperature structure of disk that is actively accreting from envelope

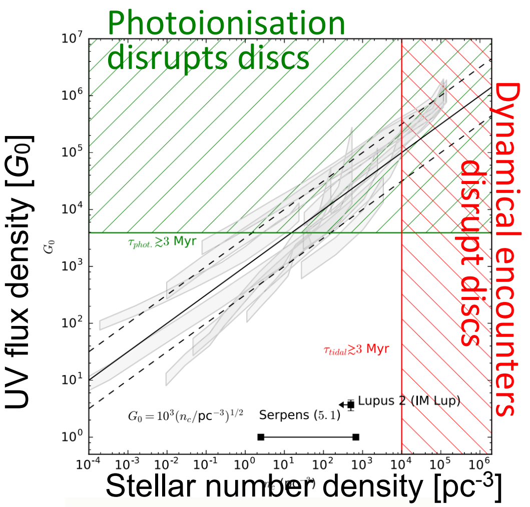
Bjerkeli+16, Harsono+18

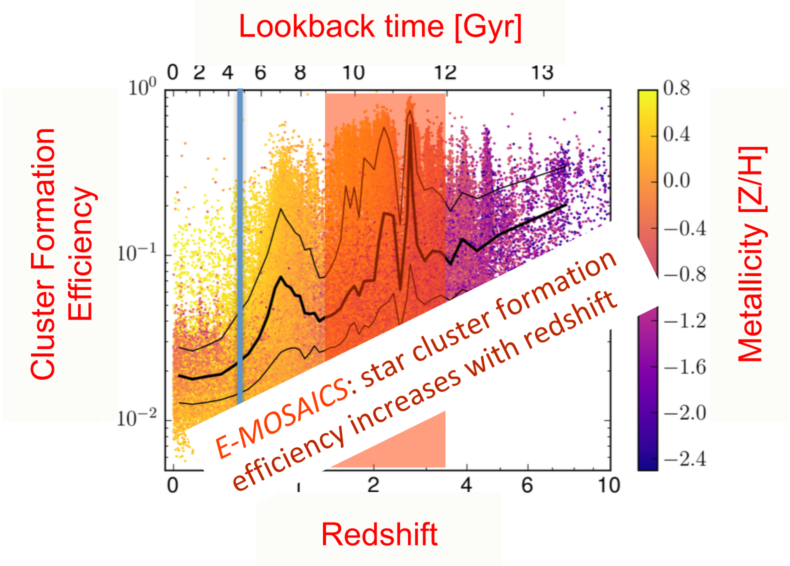
Disk ionisation – partly by external UV field

- external UV
- external X-rays
- CRs
- (stellar radiation)
- (stellar particles)



Inga Kamp's talk





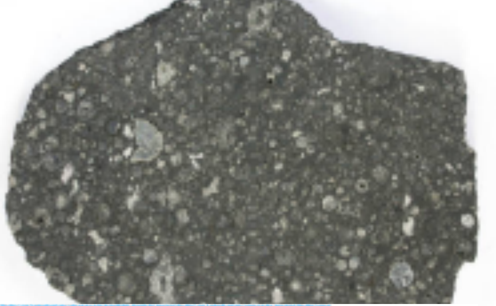
planetary systems shaped by galactic environment

- Photoionisation dominates in clusters of massive stars
- External photoevaporation limits the maximum radius of (proto-)planetary discs and shortens disc lifetimes
- The fraction of planetary systems potentially subject to these influences is environmentally dependent
- Range: few % at present (7% in the current solar neighbourhood) to 50% when most stars in the Milky Way formed
- Galaxy mergers: Mpc-scale events affecting AU-scale properties of planetary systems
- old planetary systems are more likely formed in clusters, because the cluster formation efficiency decreased in time

J. M. Diederik Kruijssen's talk; Kruijssen 12; Pfeffer, Kruijssen+18; Winter, Kruijssen+ in prep.

Cloud-to-disk infall included in disk chemistry model

Francesco Pignatale's talk

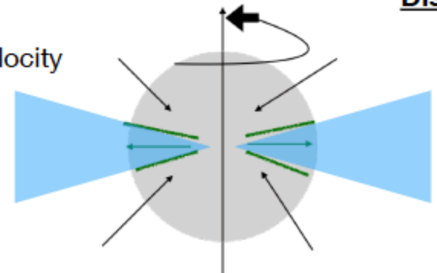


What is the origin of the complexity & diversity of chondrites?

- Formation of Solar System material starts during the assembling of the protoplanetary disk
- Disk chemistry determined by time/ location of dust injection and dust thermal properties

MODEL: COUPLING CLOUD+DISK+CHEMISTRY

Collapse model: Shu (1977)
- Spherical and isothermal cloud
- Rigid rotation and constant angular velocity
- Constant rate of infall



Disk model: Hueso & Guillot (2005)
– α disk
Yang & Ciesla (2012)

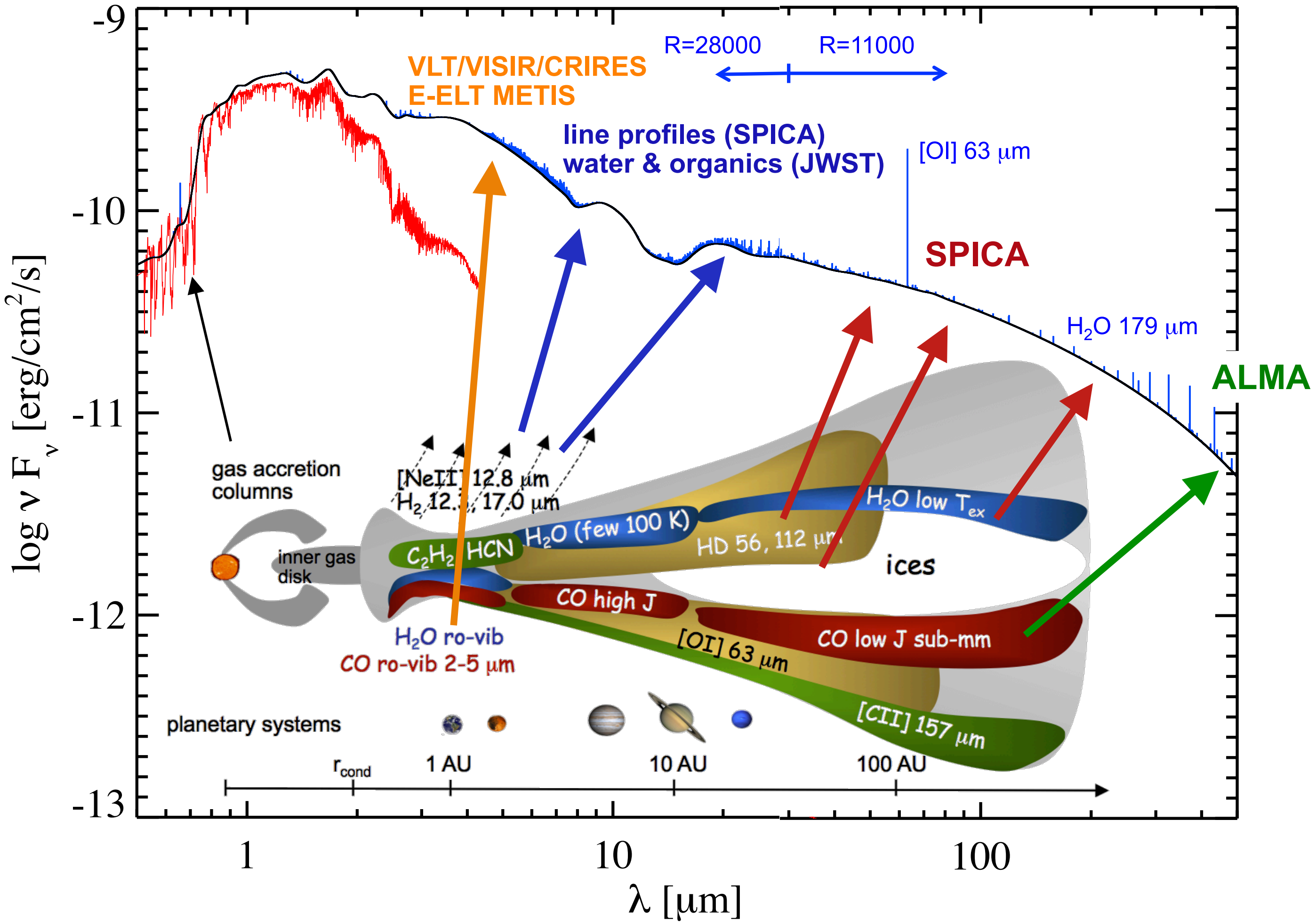
coupling cloud infall + disk evolution + chemistry

- o 1D disk with a source term for the material infall
- o grain growth/fragmentation
- o dead zone, radiative and viscous heating, advection and diffusion
- o thermodynamic equilibrium: species in gas and solid form

CLOUD: gas and dust are homogeneous and with Solar Composition
GAS: $H_2(g)$
DUST: refractories (1650 K) silicates (1500 K) metal (1550 K) troilite (650 K) water-ice (160 K), CO-ice (25 K)

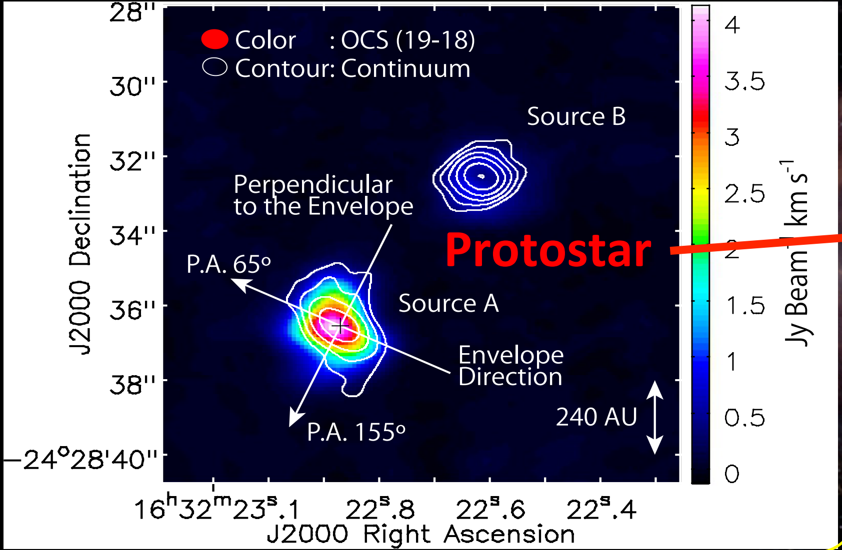
Charnoz et al. (under review)
Pignatale et al. (submitted)

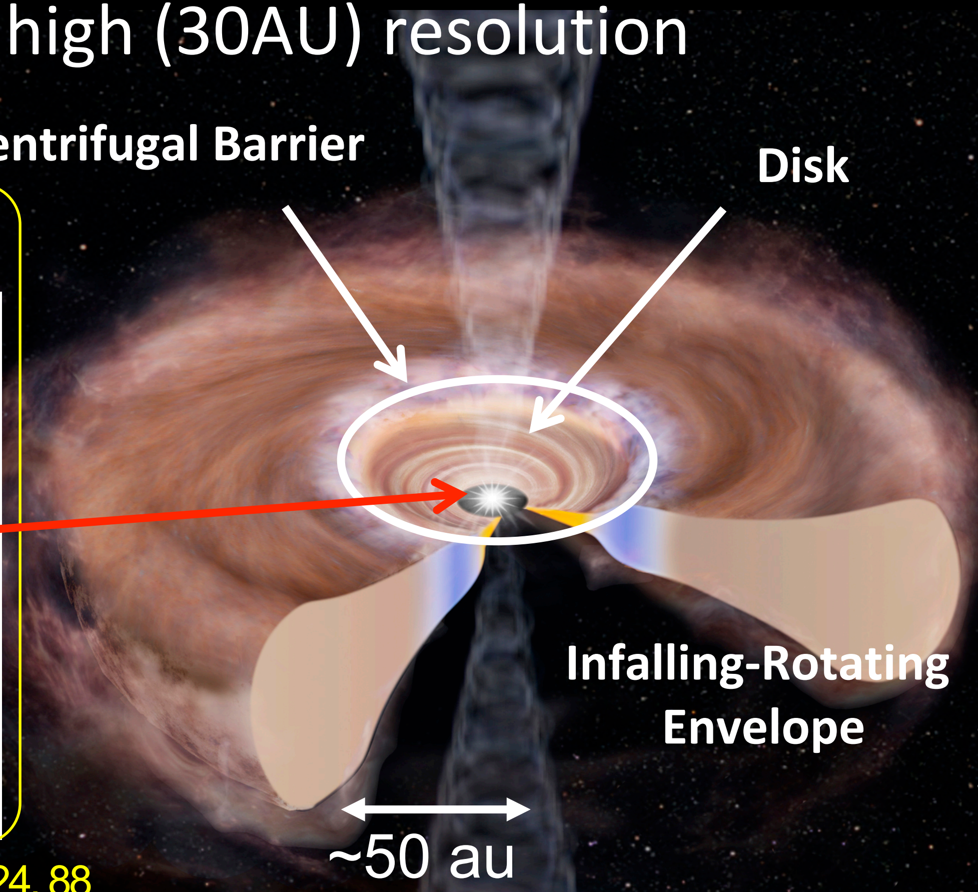
Observing disks now and in the future



Inga Kamp's talk

Drastic Chemical Change in Disk-Forming Regions observed with very high (30AU) resolution



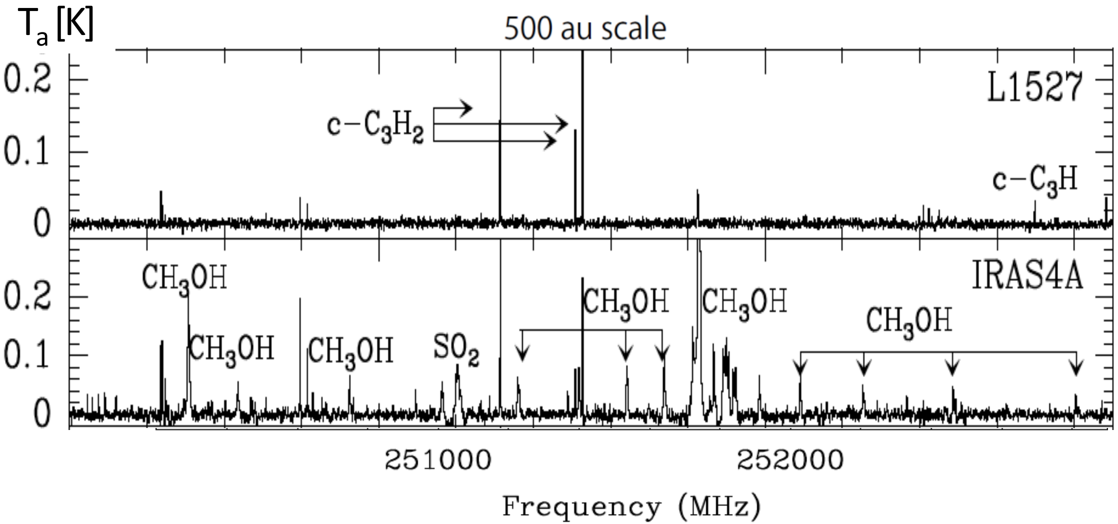


Yoko Oya's slide

IRAS 16293-2422 Source A: Oya et al., 2016, ApJ, 824, 88

Press release: http://www.almaobservatory.org/en/press-release/alma-discovers-a-rotating-ring-of-complex-organic-molecules/

High angular resolution ALMA spectroscopy – Disk Chemical Characteristics



(Lefloch +2018 MNRAS)

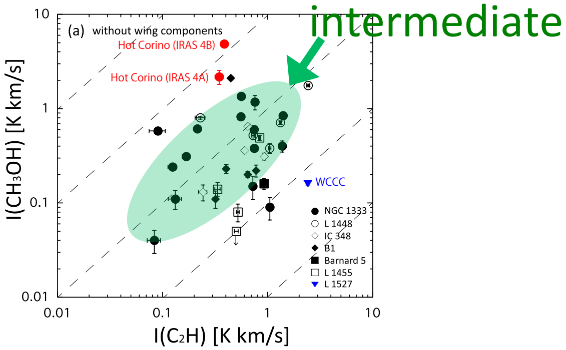
Warm Carbon-Chain Chemistry (WCCC)

- Extended component
- Carbon-chain molecules

Hot corino chemistry

- Compact component
- Complex organic molecules

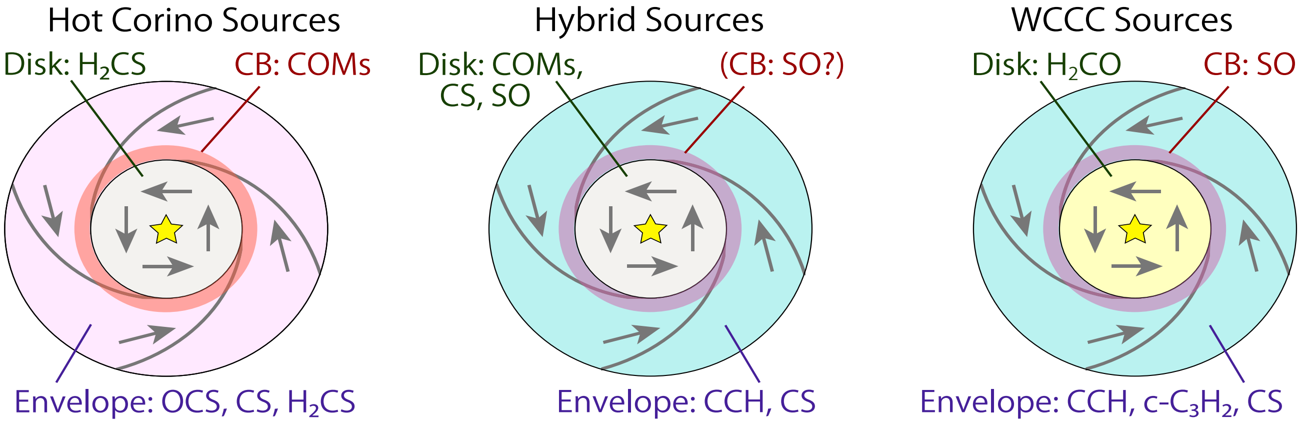
Perseus sources with IRAM 30 m Higuchi + 2018



Yoko Oya's talk

Few 10 au Scale View of disks

- Infalling-rotating motion and its centrifugal barrier (CB)
- Chemical change across the CB in each source
  - → Chemical heritage from the envelope to the disk.
- Chemical variation among sources
  - Standard case?: Extended WCCC + Compact HC



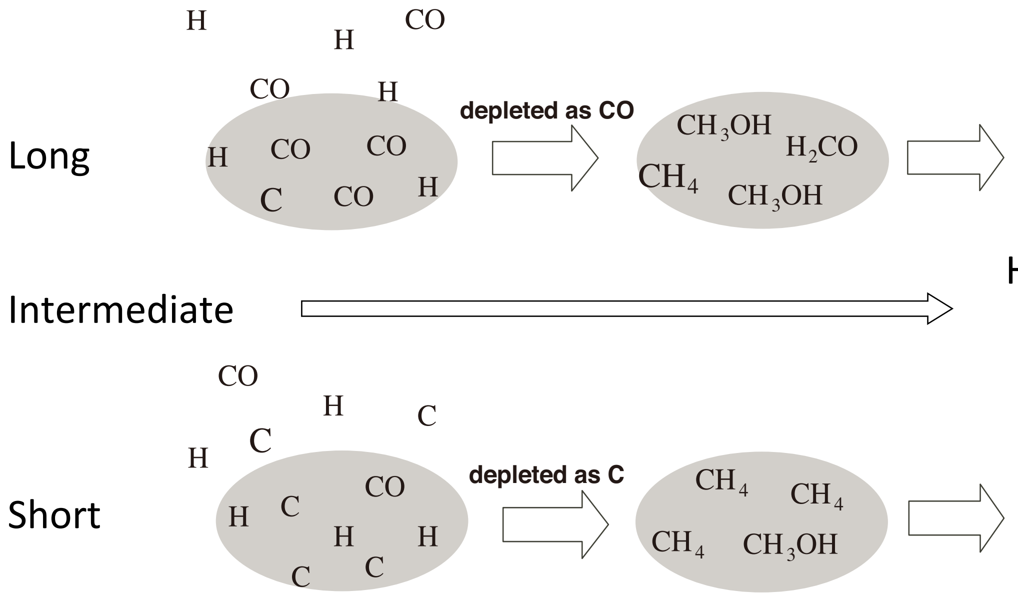
Yoko Oya's talk

Origin of the Chemical Diversity

Carbon chemistry and the duration time scale for the starless-core Phase

– Conversion of C to CO: $\tau_{chem} \sim 3 \times 10^5$ yr

Standard?



Hot Corino Chemistry (IRAS 16293)
Complex organic molecules
$HCOOCH_3$ $(CH_3)_2O$, etc.

Hybrid Chemistry (B335, L483)
Complex organic molecules
+ Carbon-chains

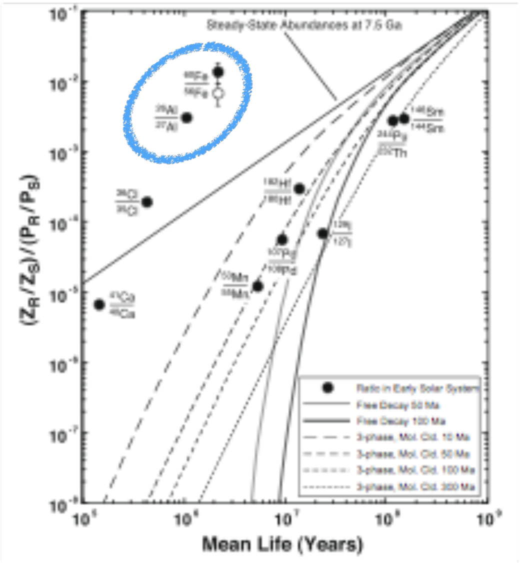
WCCC (L1527, TMC-1A, IRAS 15398-3359)
Carbon-chain molecules

Yoko Oya's slide

→ *Diversity of the chemistry on dust grains*

^{26}Al debate starting point: Significant quantities of short-lived radioisotopes (SLR) in early Solar System

Yusuke Fujimoto & Edward Young's talks

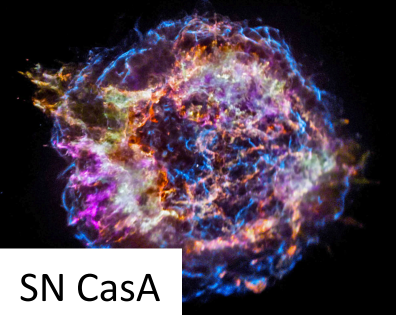


High abundance ratios in meteorites

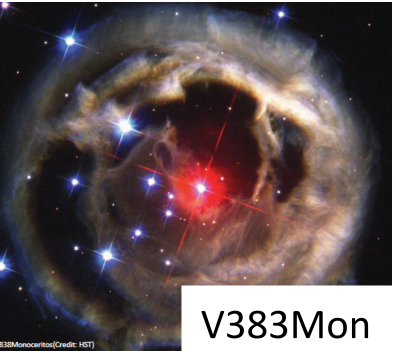
- $^{26}Al/^{27}Al$ ~ 5e-5 (Lee +1976, Jacobsen +2008)
- $^{60}Fe/^{56}Fe$ ~ 1e-8 or 1e-6 (Tang & Dauphas 2012, Mishra & Goswami 2014, Telus +2018)

Solar birth environment came to have these SLRs

- Chance encounters between pre-solar materials and a variety of nucleosynthesis sources (e.g., stars)
- Self-enrichment in massive star-forming regions (SFRs) with extensive averaging



SN CasA



V383Mon

W-R127

Sources of ^{26}Al:

Collapse SN (too high $^{60}Fe/^{56}Fe$)

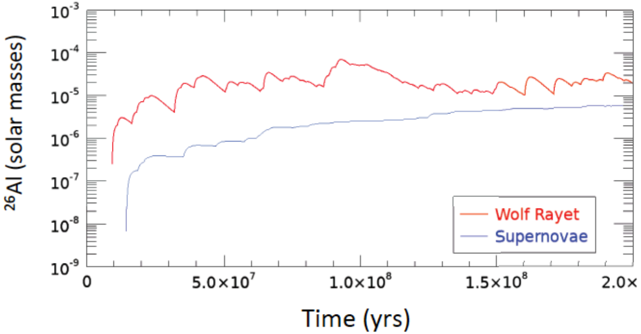
- M > 8M progenitors
- 3-30 Myr to evolve
- SN trigger

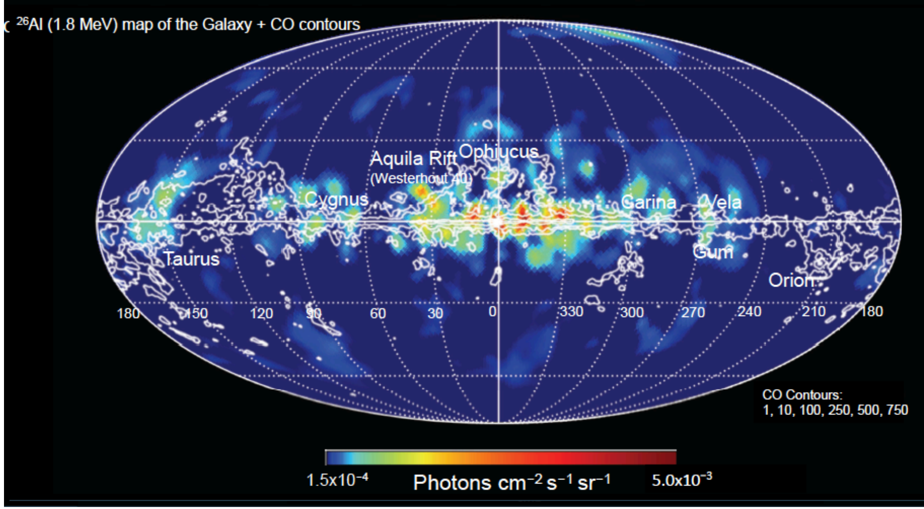
AGB stars (too little ^{107}Pd)

- C factories
- M < 8M progenitors
- 30 Myr-few Gyr to evolve

Wolf-Rayet (45-70% of ^{26}Al)

- M > 8M progenitors
- 3-30 Myr to evolve



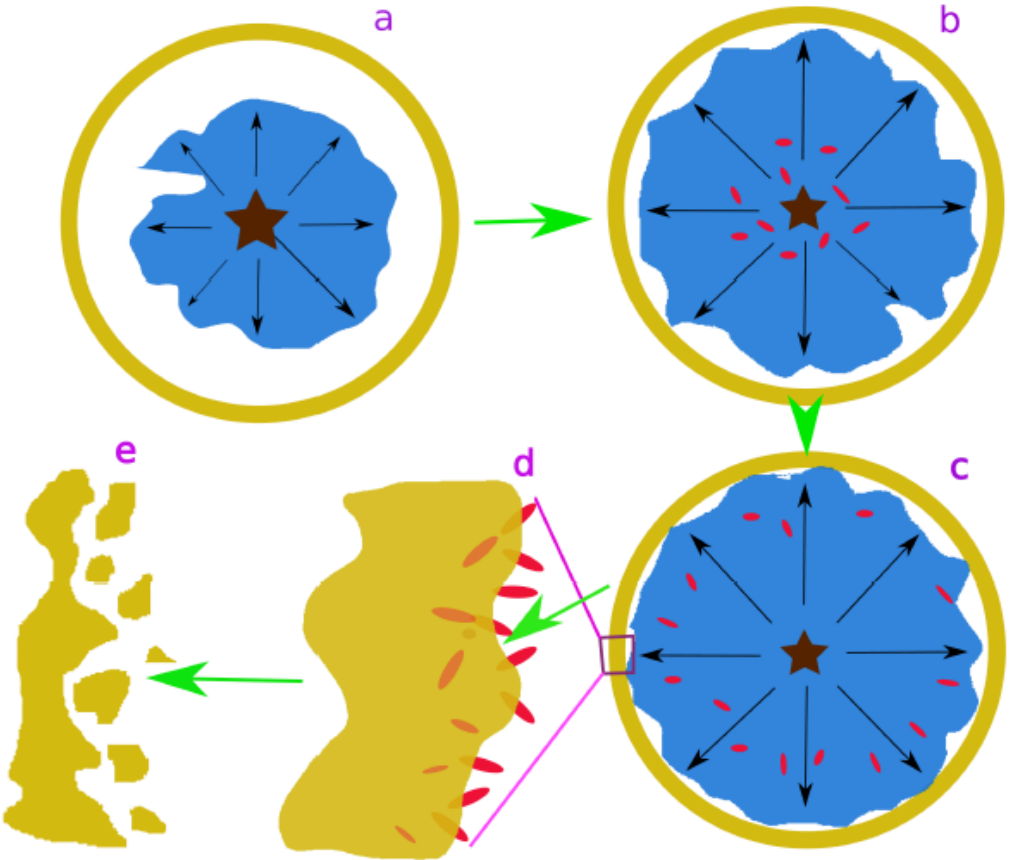


Analogue for the Solar birth environment
Edward D. Young's talk

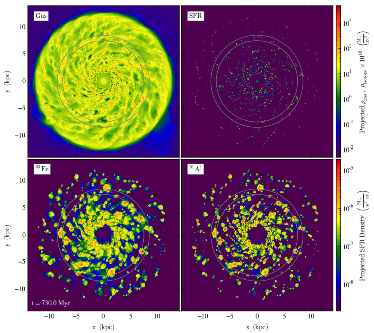
Fast mixing of ^{26}Al isotopes with dust particles as carriers

- in the model with triggered star formation
- inside the shell of a Wolf-Rayet Bubble
- as the Origin of the Solar System
- dust grains survive and can carry out ^{26}Al to the shell
- may be accreted

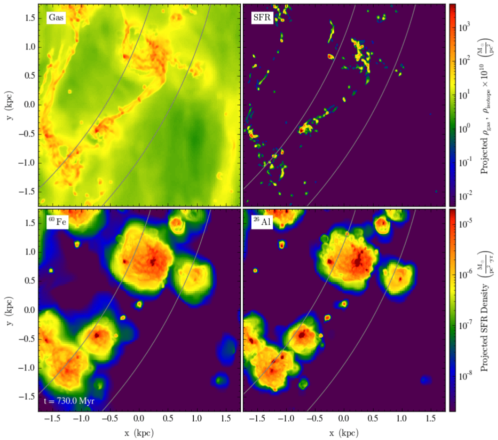
Vikram V. Dwarkadas



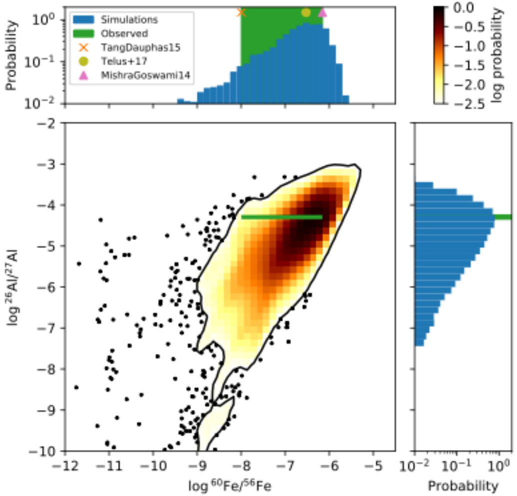
^{26}Al debate
Chemo-hydrodynamical simulations of the entire Milky Way



- Enzo: 3D adaptive mesh refinement HD code
- isotope injection from SNe and stellar winds, and time decay



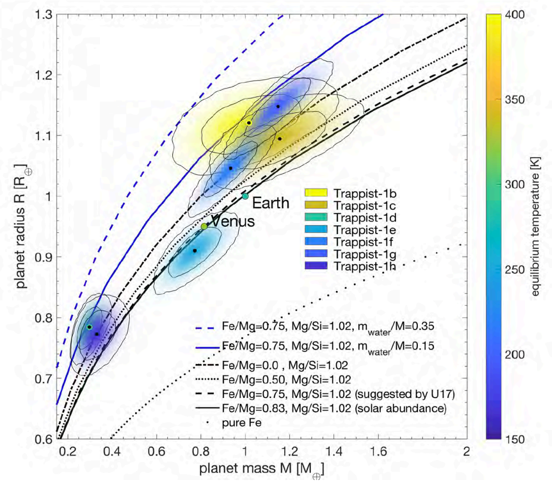
- star formation is correlated with galactic scale
- almost all stars form in pre-enriched gas by previous stellar feedback

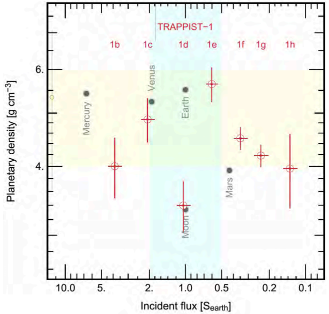


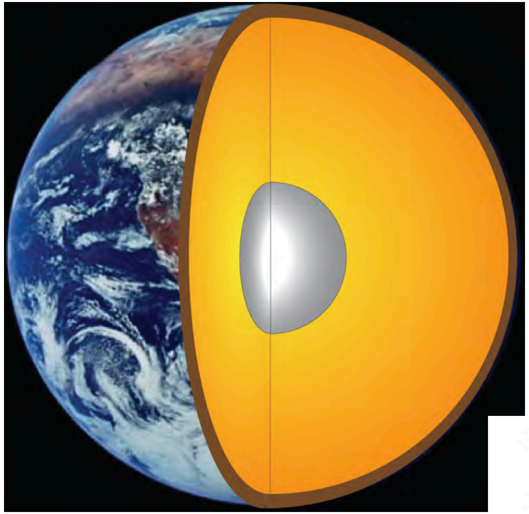
The solar abundance ratios of the SLR are well within normal range. (Our Sun is not atypical!)

Yusuke Fujimoto+2018, in press in MNRAS

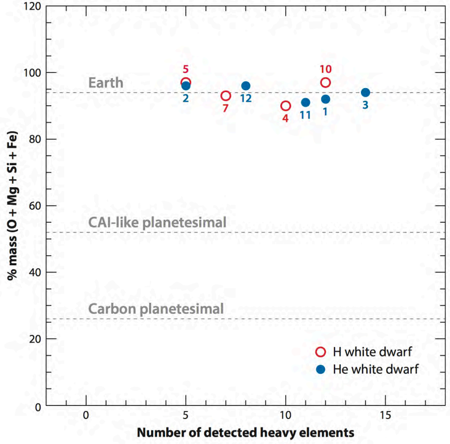
Planets – chemistry, size, etc.





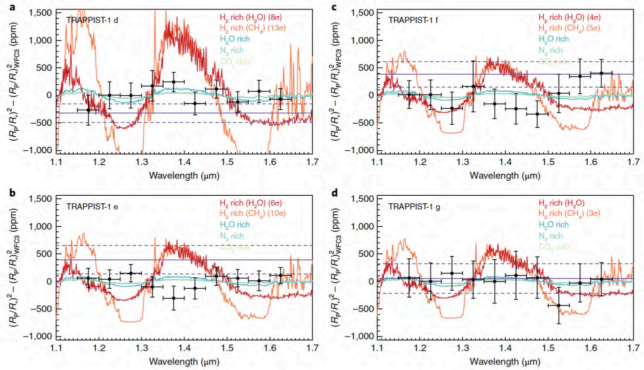


Earth
Carbon ~0.05%
Water ~0.1%
Silicates 63%
Iron 31%

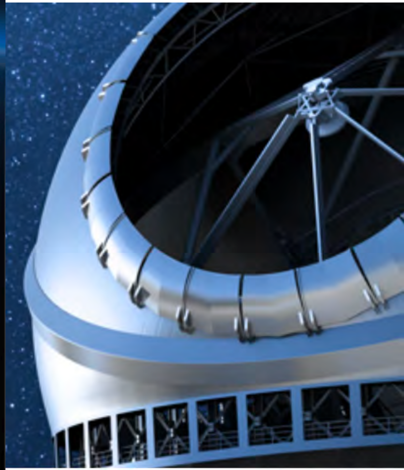


Jura & Young 2014

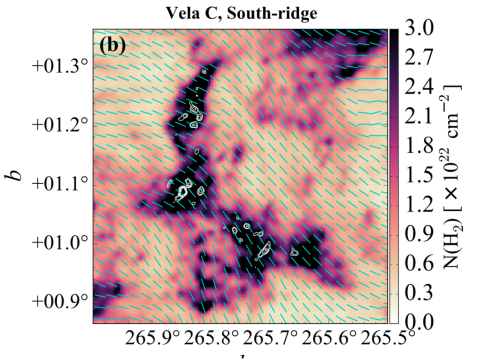
Trappist system atmospheres



E-ELT and TMT with direct imaging capabilities

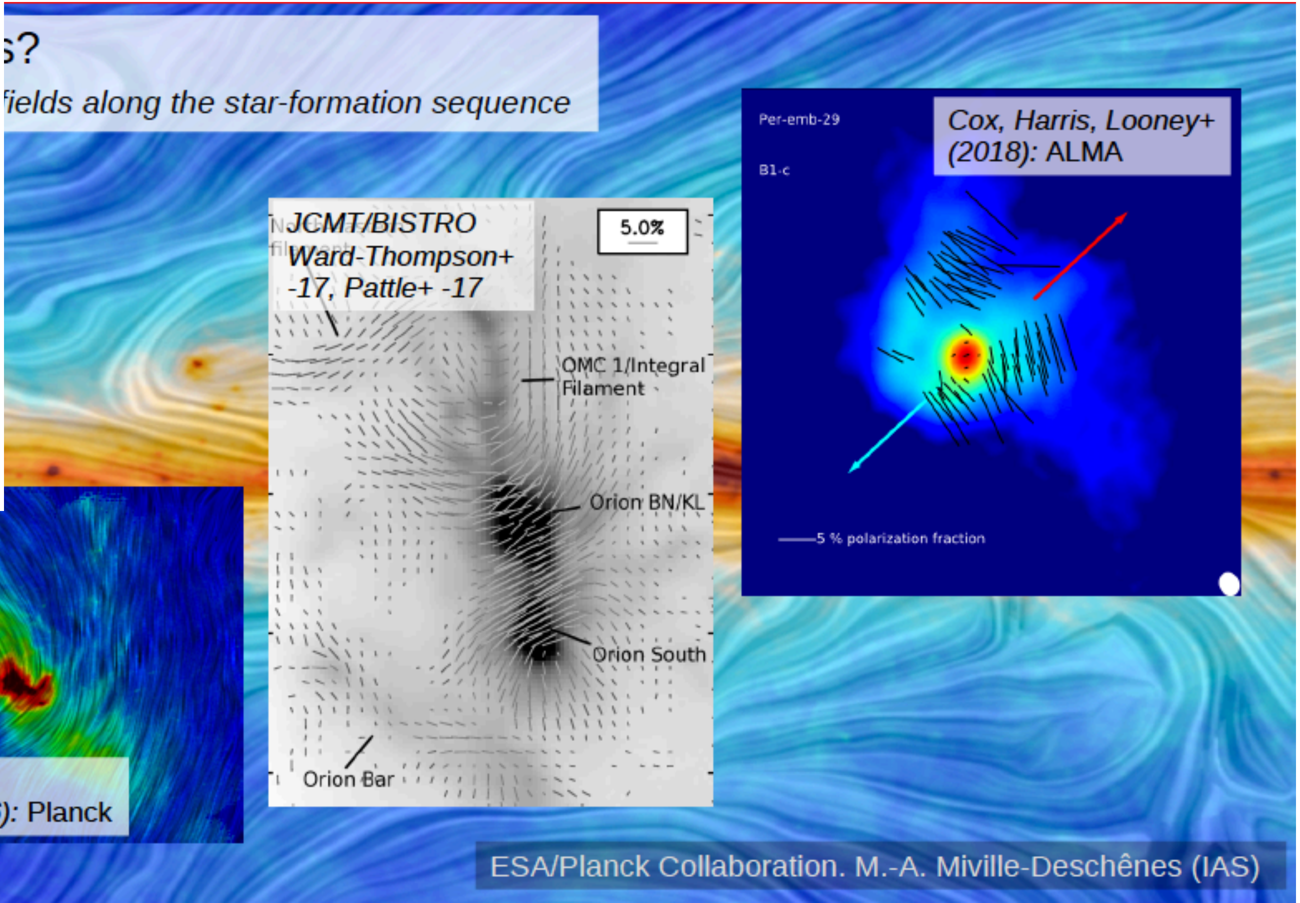


Magnetic fields on cloud, filament and core scale



Green 2016

H_2 column density 8HERSCHEL) with ATCA NH_3 (1, 1) moment zero contours and BLASTPol 500 μm polarisation



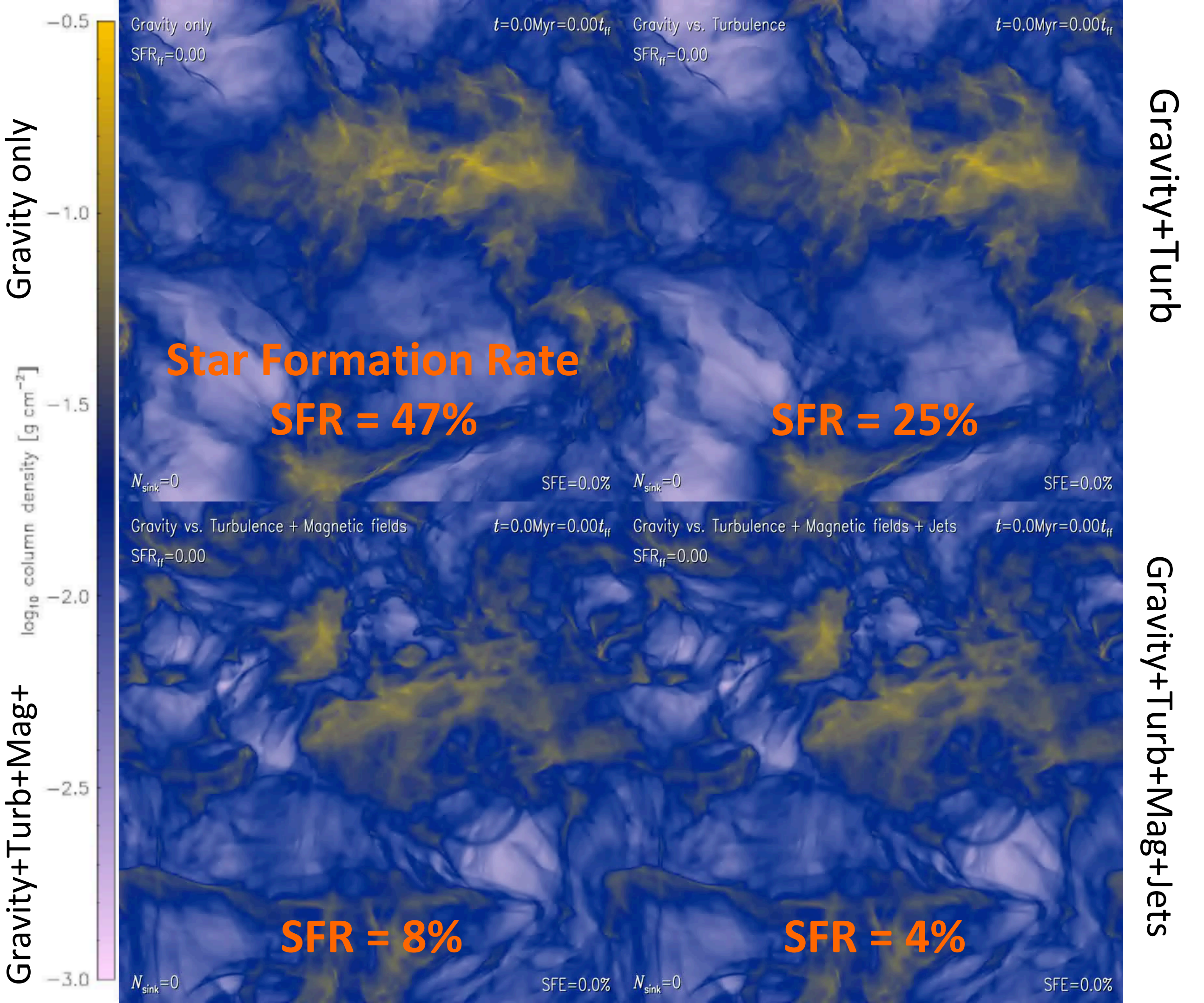
Mika Juvela’s and Maria Cunningham’s talks

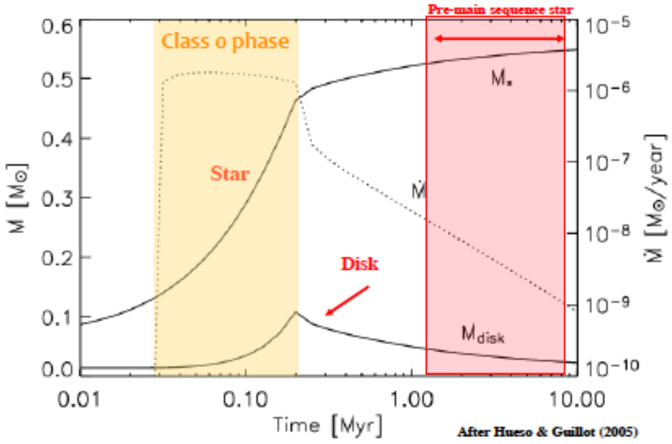
Modeling turbulence, B fields, outflows

- Variation of column density with time
- Turbulence + magnetic fields and jet/outflow **feedback** can produces realistic star formation rates
- Supersonic sheet compression
- Sonic scales on filaments

Federrath + 2015, MNRAS, 450, 4035

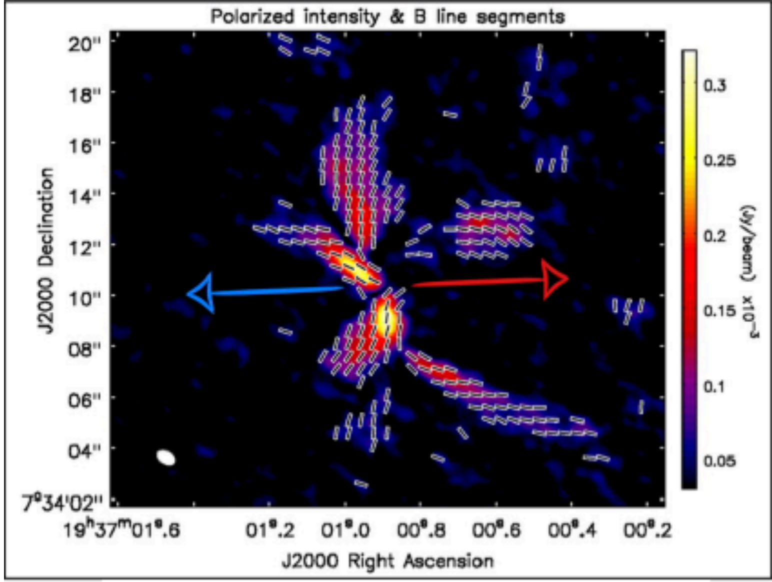
Christoph Federrath's talk

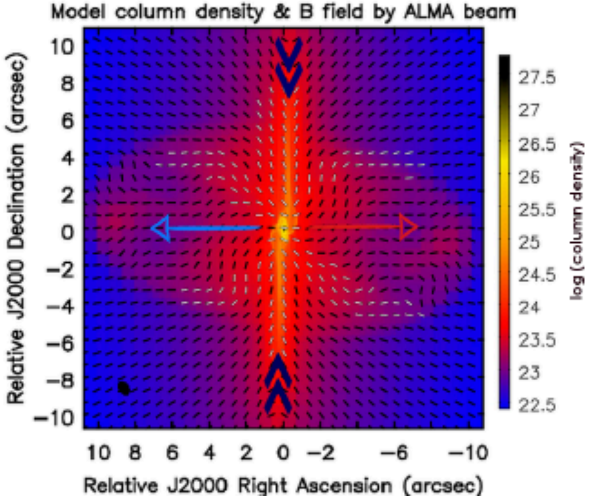




Simple hydrodynamics predicts the existence of ≥100 AU disks at the beginning of the Class o phase
(10⁴ yrs after beginning of collapse).

B fields with high resolution

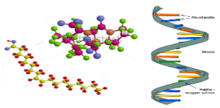




- Disks appear already at the protostellar phase
- All protostellar envelopes are magnetized to some level
- A magnetically-regulated collapse in B335
- Comparison to synthetic observations of non-ideal MHD models of protostellar collapse
- Maury+2018

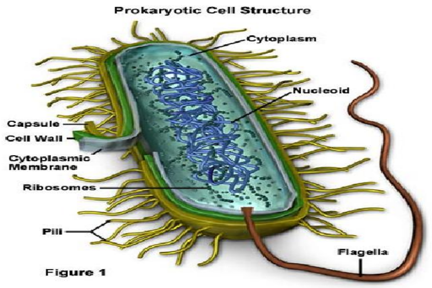
Anaëlle Maury's talk

The hard question: *Understanding the process…*



?

ca. 3.5 billion yrs ago



Molecular System (10^{-21}g)

Molecular Assembly (10^{-12}g)
not thermodynamics (messing things up)

E. Schrödinger (1945) – **"we must be prepared to find it (living matter) working in a manner that cannot be reduced to the ordinary laws of physics"**
(= thermodynamic principles and randomness)

The Persistence Principle

A general rule governing change in both physical ***and*** biological worlds

Unchanging things **don't** change, and changing things **do** change, until they change into things that don't…

LOGICAL!

Nature uses this principle to make persistent forms

Life replicates!

R. Pascal, A. Pross, *Chem. Comm.* 2015

R. Pascal, A. Pross, *J. Syst. Chem.* 2014

Two Evolutionary Paths Toward Persistence

Nature drives toward persistent forms

Boltzmann

Probability Theory

$S = k_B \log W$

‘Regular’ world

random

Thermodynamic Stability

Replicative world

multiplicative

Dynamic Kinetic Stability

Exponential Growth

Malthus

$dX/dt = kXM - gX = 0$

Both processes underpinned by mathematics –

two maths for persistence, two material forms

Theory by Addy Pross

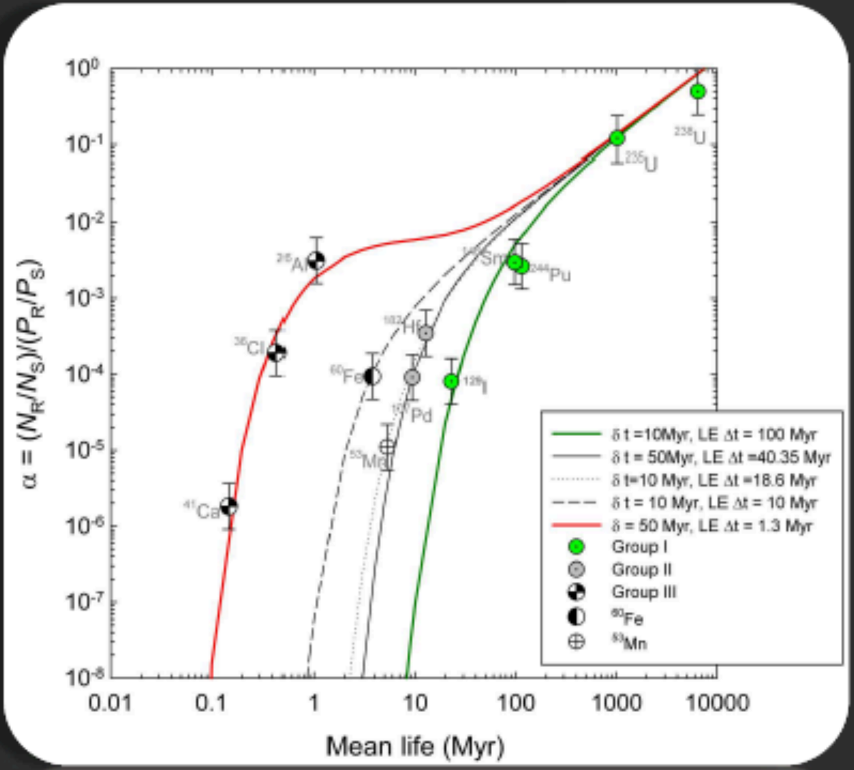
A szőlő a napsugaraktul érik;
Mig édes lett, hány napsugár
Lehelte rája élte melegét,
Hány százezer, hány miljom napsugár?...
A földet is sugárok érlelik, de
Ezek nem nap sugárai, hanem
Az embereknek lelkei…

Sun-rays ripen the grapes.
How many rays does it take?
How many millions should exhale its heat
While that grape becomes sweet?
Our Earth ripens always.
By human souls as rays.

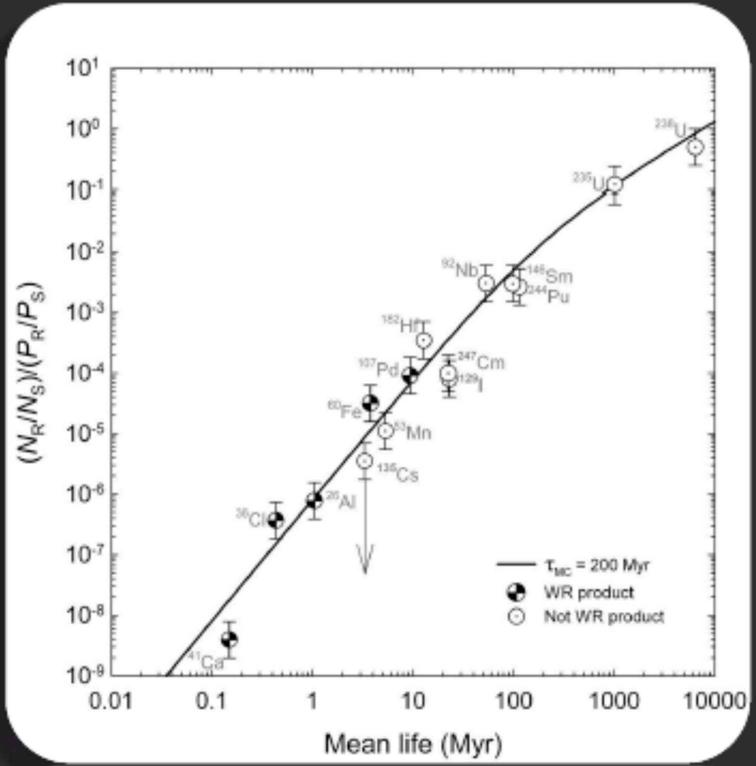
Sándor Petőfi (1848)

Mixing in molecular clouds

“Catastrophism”



“Uniformitarianism”



Edward D. Young