SPIRE and PACS on the Herschel Space Observatory, HSO

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Our Canadian participation enabled by CSA

My research supported by

Observatory

HSO is an observatory, not a PI project.

Lots of open time (OT) to plan for, over 3 year lifetime. Opportunities for Canadian (graduate student/PDF) participation, even beyond our guaranteed time (GT).

Expensive: 10^6 €/day.

Like Spitzer and SCUBA-2, there will be large "surveys" addressing the original science drivers of the mission and/or having "legacy" value. Some will be in GT, many OT.

Focus of this talk

The emphasis here will be on what HSO measures in the continuum and therefore the science that it enables.

What science can be accomplished of course depends on the technical capabilities of the observatory and its instruments.

The technological implementation is challenging and impressive in itself and will be briefly mentioned.

Other observatories and instruments of interest

These are not the focus here, but since the science often demands multiwavelength information, one should be aware of the possibilities. Here is a subset, with continuum imaging capabilities.

IRAS (IRIS), MSX, ISO
Spitzer, Akari (ASTRO-F)
SMA, ALMA
Scuba-2 on JCMT
Planck
LMT, CCAT, etc.

Google to find out more, e.g., documents like
www.astro.cornell.edu/~haynes/rmspg/projs_a.htm

Dust emission

The continuum emission being discussed for HSO SPIRE/PACS, and SCUBA-2, is from dust.

Can be diffuse dust, dust in a debris disk, dust in a cold pre-stellar core, warmer dust around a protostar, warmer dust in a high mass star formation region, etc.,

or, in extragalactic sources, these integrated over a considerable volume – a whole galaxy in the case of cosmological studies.

Dust life cycle

Dust is everywhere there is gas (relative amount depends on metalicity of course).

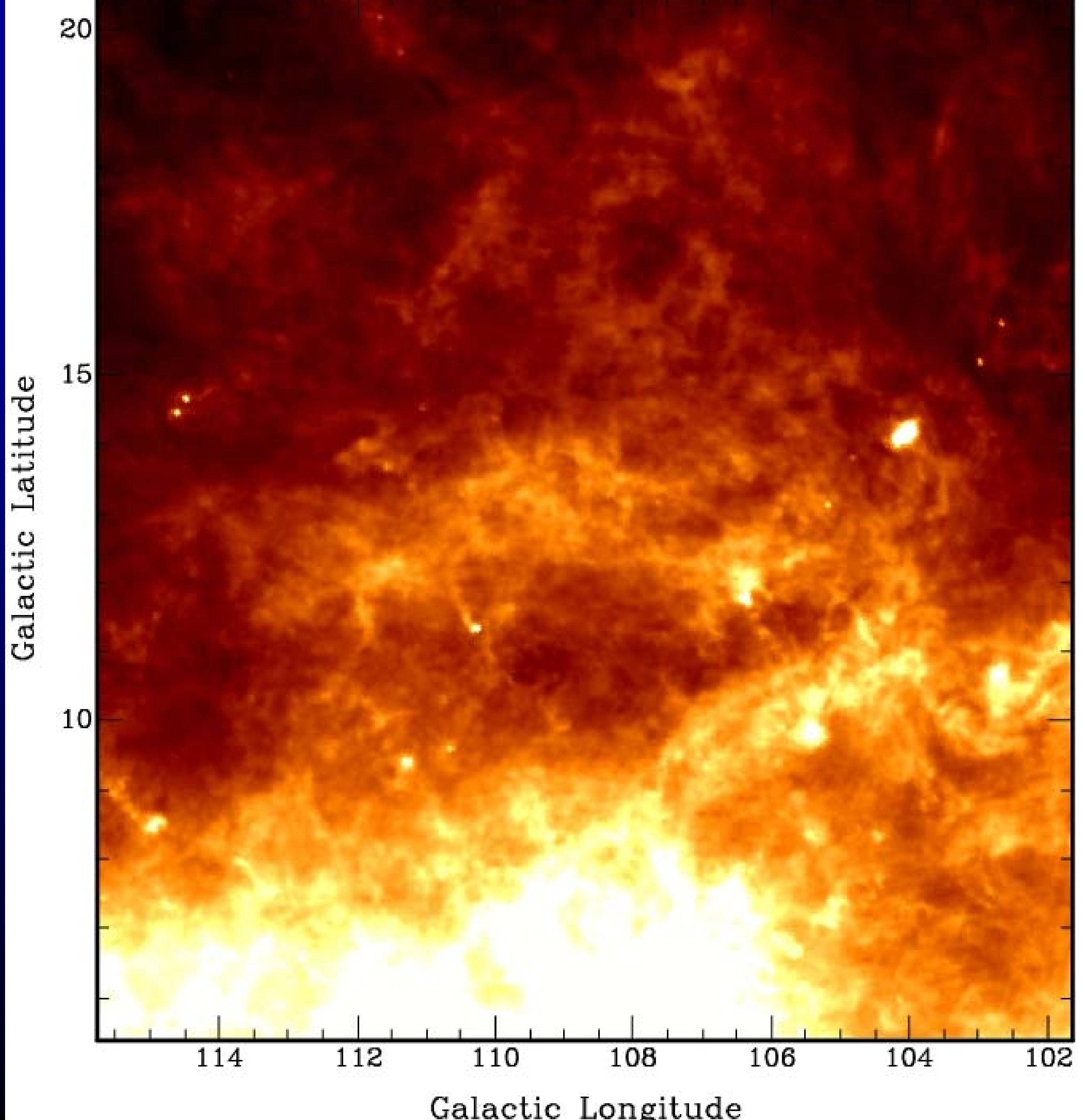
In the diffuse atomic gas, its emission is called cirrus (name often carried over to regions with higher column density or surface brightness).

As the ISM structures evolve, dust is in different environments, from atomic to molecular. Dust properties (e.g., size distribution) can evolve.

Cirrus

IRAS
100 micron
(recommend IRIS product)

Faint diffuse emission everywhere, even at high latitude



Science

The science cases for HSO SPIRE/PACS and SCUBA-2 are very similar and there is a strong overlap with Spitzer too.

Each case benefits from multi-wavelength information.

SPIRE/PACS combination is somewhat self-contained, covering 70 to 500 µm. But it is not trivial to obtain complete co-spatial coverage or to combine.

FOV and resolution

SPIRE field of view (FOV) like that of SCUBA2. 4’ by 8’. PACS FOV is smaller (longer to map).

SPIRE resolution at 250 µm like SCUBA-2 at 850 µm (15”). PACS better, about 4 times Spitzer at same wavelength (overlap with MIPS).

Sensitivity

Will be pushed to make very deep maps to extract faint sources.

In fact for mapping large areas there is a minimum depth set by the maximum scan speed; e.g., for SPIRE at 250 μm, 20 mJy/beam (1 σ). This allows one to detect, e.g., dust in 0.02 M_{sun} cool pre-stellar cores in local low mass SF regions (e.g, Taurus), at 10 σ.

Noise

Need to be aware of “noise” other than from detector/telescope (NEFD).

Cirrus confusion.

Source confusion.

Galaxies.

Cirrus confusion

Fluctuations in the background cirrus emission can hamper the ability to pick out point sources (clumps):

$$\mathrm{rms_{cirrus}} \approx 20\ \mathrm{mJy} \times \left(\frac{\lambda}{250\mu\mathrm{m}}\right)^{2.5} \times \left(\frac{\mathrm{D}}{3.5\mathrm{m}}\right)^{-2.5} \times \left(\frac{\mathrm{B}_{100}}{55\ \mathrm{MJy/sr}}\right)^{1.5}.$$

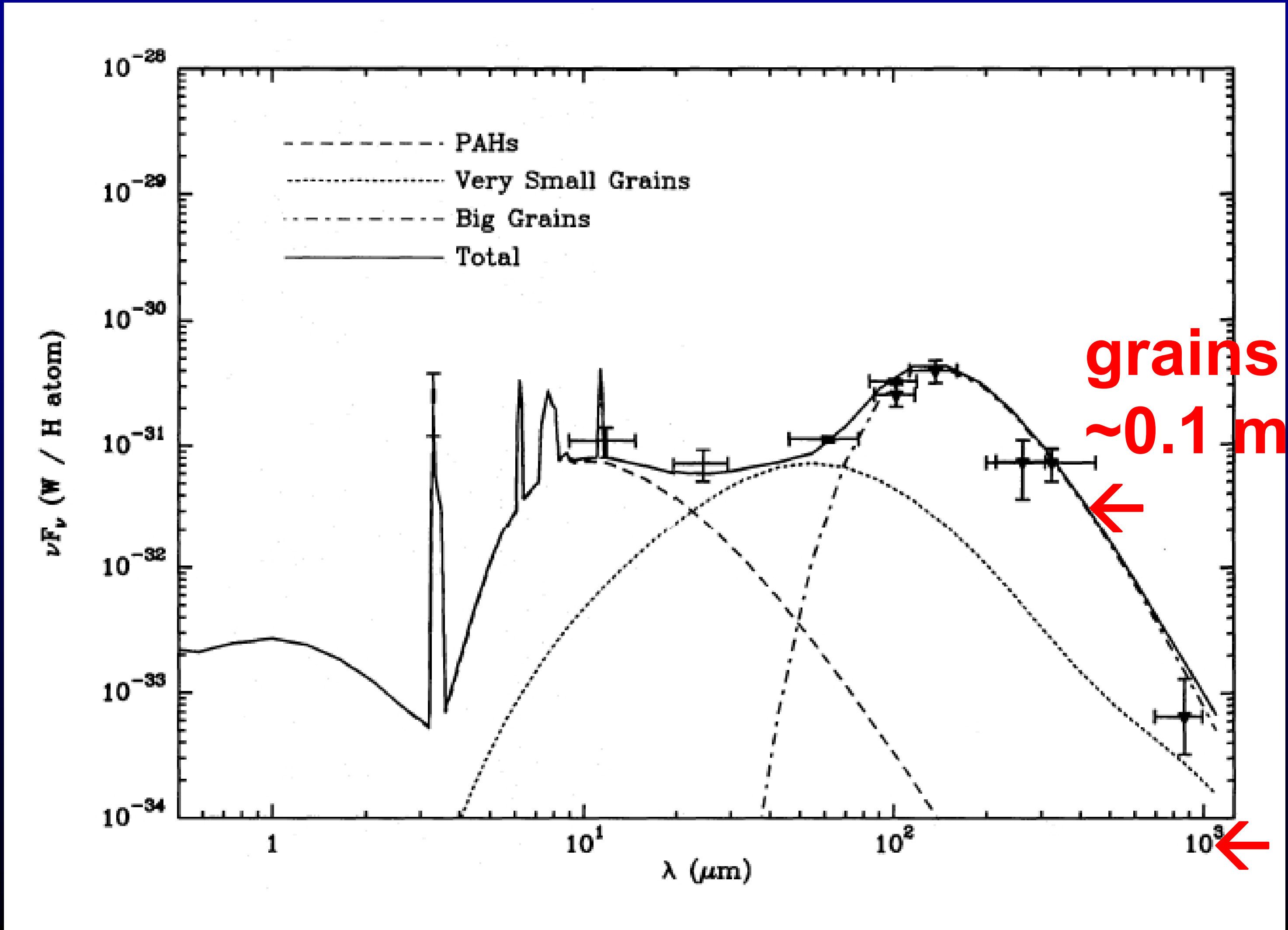
(after Gautier et al., with some assumptions).

The 2.5 comes from the slope of the observed power-spectrum of brightness fluctuations as a function of spatial frequency. Since it is (empirically) a rapidly decreasing function, then a small beam, $\theta \sim \lambda/D$, really helps. But the dependence on B (brightness) is serious, since one often wants to look in regions of high column density (e.g., in searches for cold cores in molecular clouds).

Cirrus: Lessons from IRAS, ISO

Several spectral components:

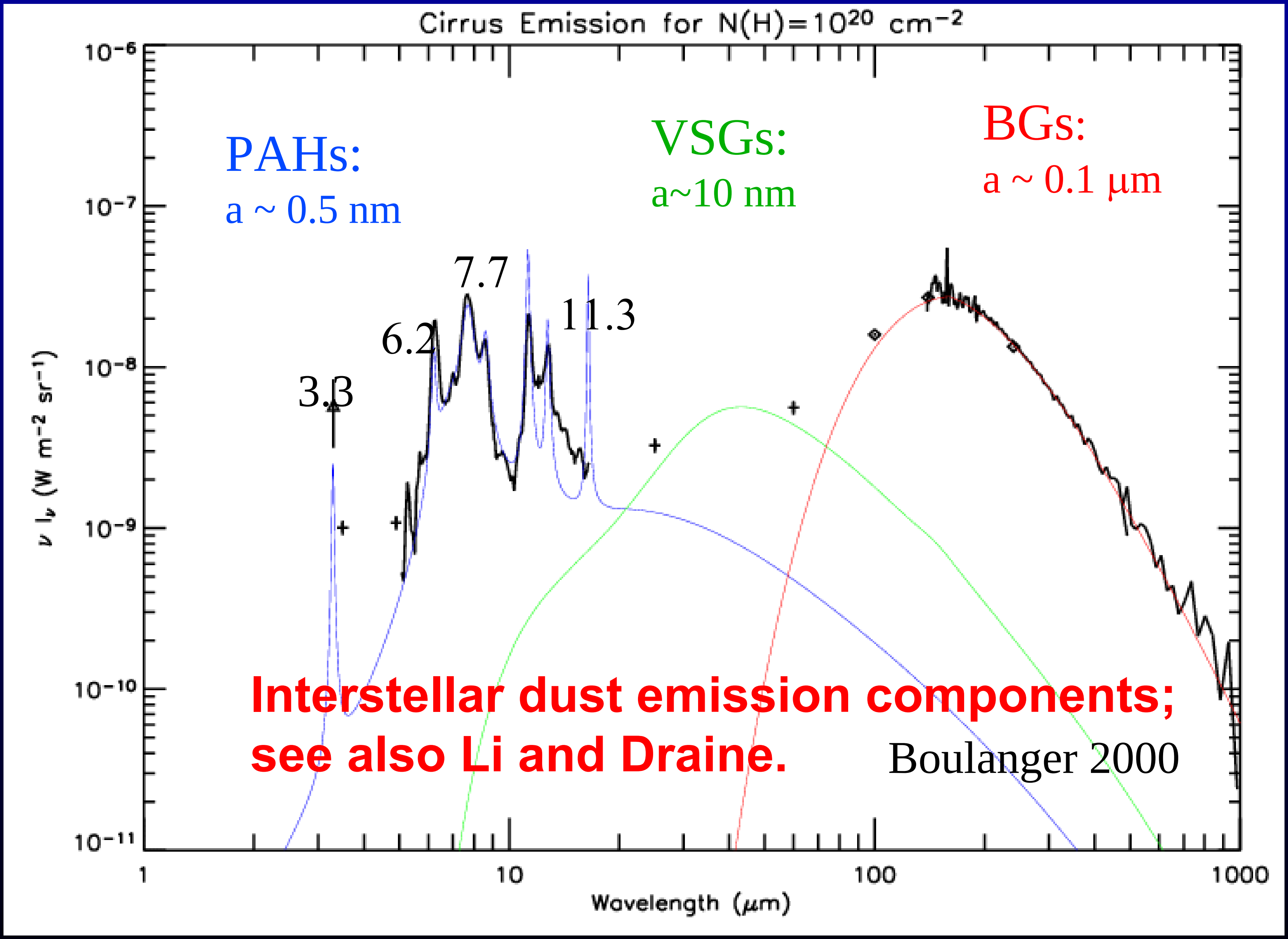
(Fig. from Desert, Boulanger, Puget 1990)



grains of size ~0.1 microns ←

← 1 mm

and COBE (FIRAS)



Origin of the Emission

Components/Mechanisms

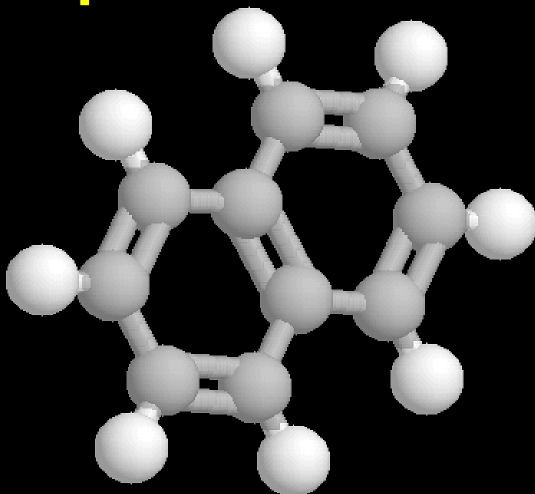
- > 100 microns: thermal emission by larger grains (size ~ 0.1 microns)
  NOTE where the peak of the spectrum is, in the submm, unconfused by VSG emission.
- 60 and 25 microns: non-equilibrium emission by smaller grains (VSG), 0.007 micron = 70 A = 7 nm
- 12 microns: non-equilibrium emission by tiny grains/PAHs, 1 nm

All of these components of course radiate at longer wavelengths too.

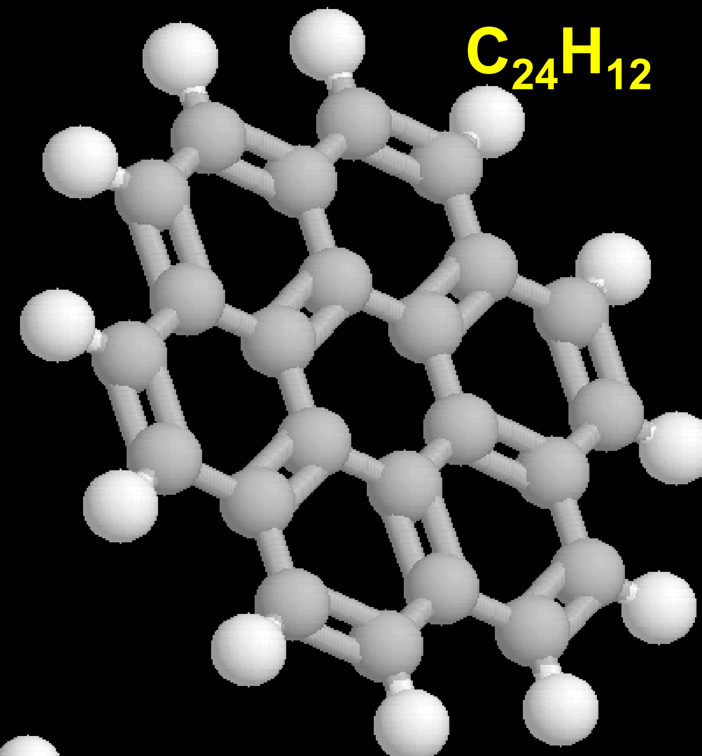
Tiny grains also spin rapidly and emit microwave radiation (related to empirically-defined “anomalous emission”).

PAHs (simple ones)

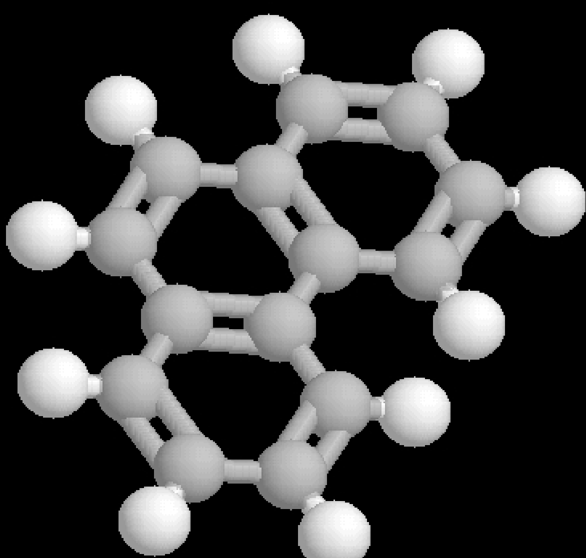
Naphthalene



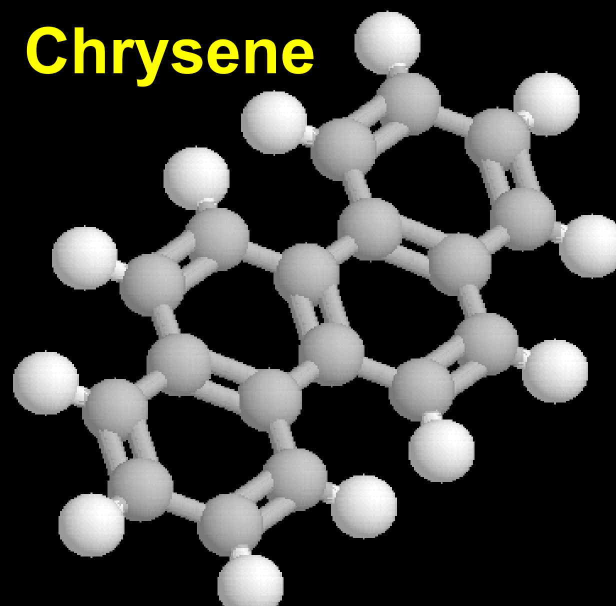
Coronene
$C_{24}H_{12}$



Phenanthrene



Chrysene



Submillimetre Spectrum

$$I_\nu = \Sigma_g \; B_\nu(T) N A Q_\nu(T) = \Sigma_g \; B_\nu(T) N V \frac{C_\nu(T)}{V} = B_\nu(T) \epsilon_T \nu^\beta$$

Total intensity is grain volume weighted, since cross section per unit volume, C/V, is size independent.

In ISM, large grains carry most of the volume.
→ Submm emission (optically thin) measures mass.

In the submillimetre the thermal emission is often characterized by T and β, the spectral index of the dust emissivity.
Is β constant (~ 2) with frequency?
Is T constant with size?
Is ε constant with T?

Spectral Index Variations

Evidence for excess emission at 217 GHz (1.5 mm)
(Archeops experiment)

Comments

- was attributed to cold dust at 5 – 7 K. But diffuse dust being that cold seems unphysical
- effect is seen everywhere (so a property of dust, not environment)

Conclusion

- beta is not constant with wavelength over the entire range of interest
  - 1.8 for lambda < 600 microns (> 500 GHz),
  - "flatter" at 1 mm,
  - 2.2 at lambda > 2 mm (< 150 GHz)
- due to intrinsic processes in amorphous grains (Bernard et al.)

Temperature and energetics

In the ISRF, the diffuse dust equilibrium T ~ 17 K.

For $\beta = 2$, bolometric grain emission ~ T^6.

Therefore, e.g., it takes 64 times as much radiation absorbed to raise T by a factor 2.

This can happen when there are local sources, e.g., an embedded star or a nearby luminous (hot) star.

For heating by such a local source, it would have to be 8 times "closer". Thus the values of T don't vary wildly.

Likewise, it takes 64 times less radiation absorbed to lower T by a factor 2. This can happen when there is significant opacity to the *incoming* radiation. High column densities (opacities) often require high densities (e.g., pre-stellar condensations).

Bolometric emission

Often the emission is measured at only a few frequencies, but if enough are observed where SED is high, then the bolometric luminosity (or flux) can be found (analytically if T and β have been deduced).

For diffuse cirrus, $L/M \sim 1\ L_{sun}/M_{sun}\ (T/17\ K)^6$

Emission is generally optically thin at these frequencies, though absorption of the radiation that heats the dust is often not.

Thus, even though emission is proportional to mass, L/M is lower for a cold pre-stellar core, because T is lower (less radiation gets in to heat the dust).

Bolometric emission (continued)

L/M can become higher once a protostar forms: self-luminous. Accretion energy, then nuclear energy becomes available, raising the local radiation field (whence T of the enshrouding).

But since T can be higher as a consequence of a local external source too, then L/M is not a unique indicator; have to examine geometry to decide what is happening.

Question: what would happen if the amount of dust were doubled in a galaxy like Arp 220? [hint: in such cases, the bolometric flux in the FIR/submm is comparable to or exceeds the optical/UV flux → emission measures SF rate.]

HSO: Where to start…

http://www.rssd.esa.int/Herschel/community_info.shtml

SPIRE

Spectral and Photometric Imaging Receiver

Cameras + iFTS (imaging Fourier transform spectrometer)

Instrument

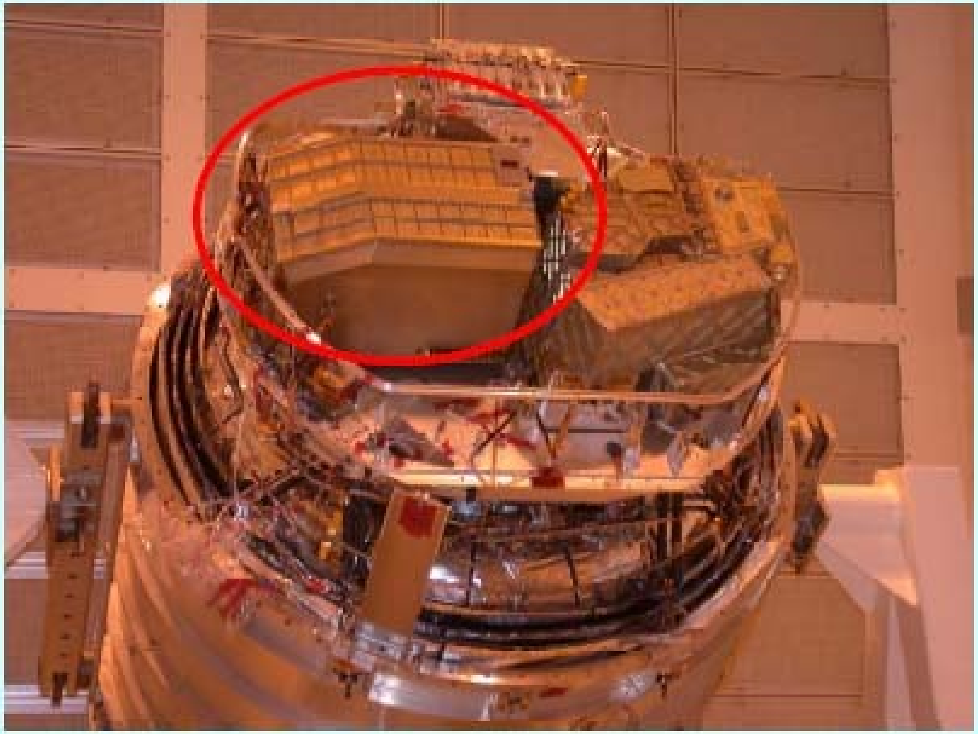
http://www.rssd.esa.int/Herschel/Publ/2006/SPIE2006_SPIRE_talk.pdf [slides below marked “Orlando”]

Science (GT KP as examples)

http://www.rssd.esa.int/Herschel/Publ/2006/AAS207_SPIRE_science.pdf [slides marked “Washington”]

Spectral and Photometric Imaging Receiver

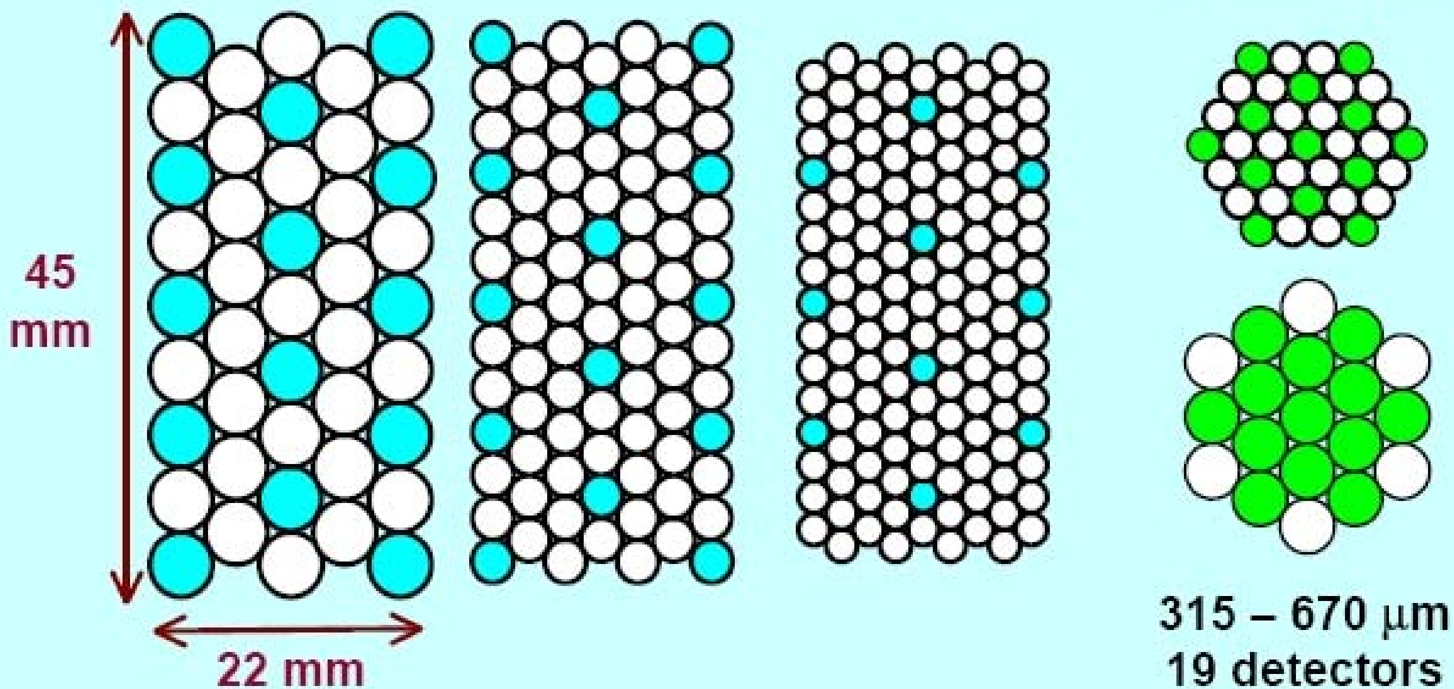
- **3-band imaging photometer**
  - 250, 360, 520 μm (simultaneous)
  - λ/Δλ ~ 3
  - 4 x 8 arcminute field of view
  - Diffraction limited beams (17, 24, 35")



- **Imaging Fourier Transform Spectrometer**
  - 200 - 670 μm (complete range covered simultaneously)
  - 2.6 arcminute field of view
  - $\Delta\sigma$ = 0.04 cm^{-1} (λ/Δλ ~ 20 - 1000 at 250 μm)

Detector Arrays (2$F\lambda$ Feedhorns)

Photometer			Spectrometer
250 μm 43 detectors	360 μm 88 detectors	520 μm 139 detectors	200 – 325 μm 37 detectors

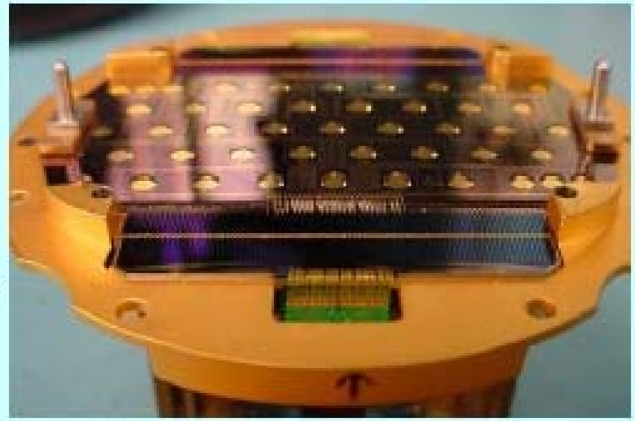


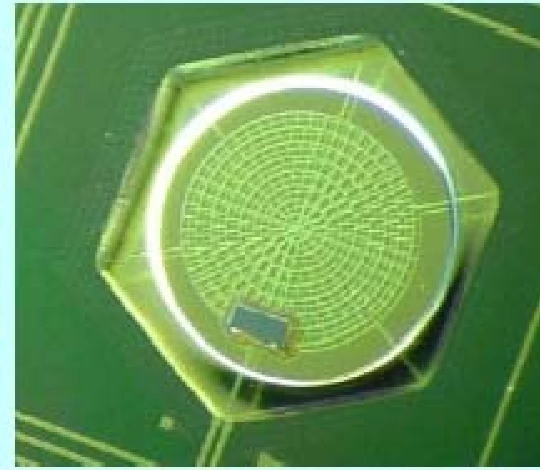
315 – 670 μm
19 detectors

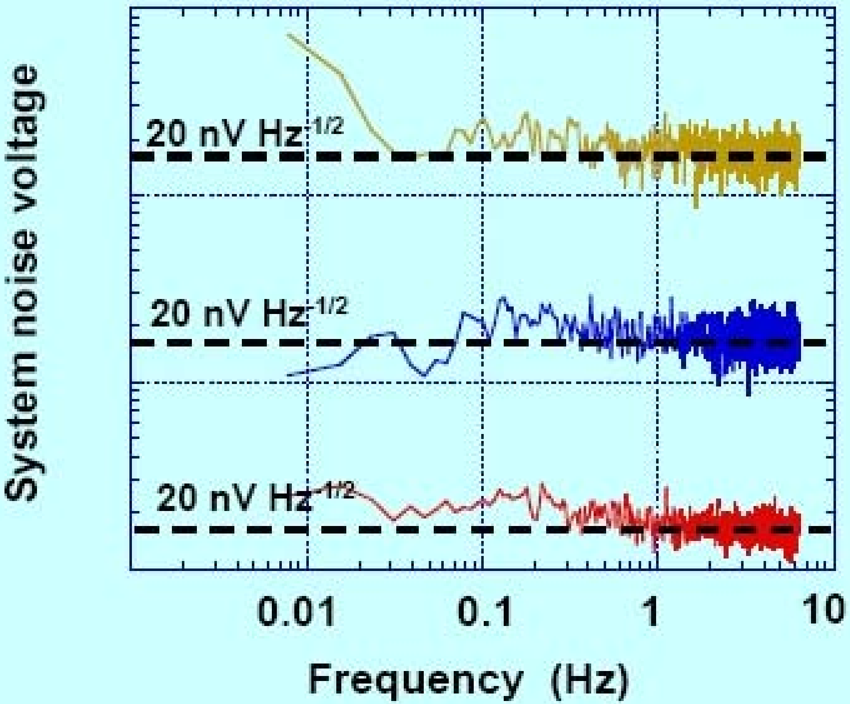
⇒ Coincident beam centres

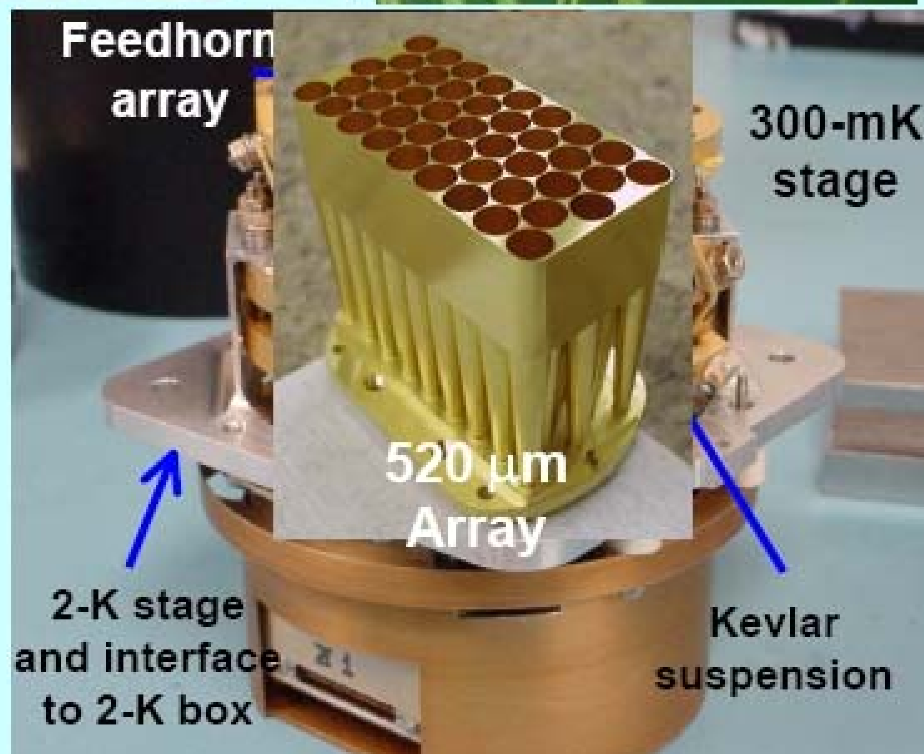
0.3-K Germanium Bolometer Arrays

- NEP ~ 3 x 10^{-17} W $Hz^{-1/2}$
- 100-K Si JFET readout
- 1/*f* noise knee < 100 mHz



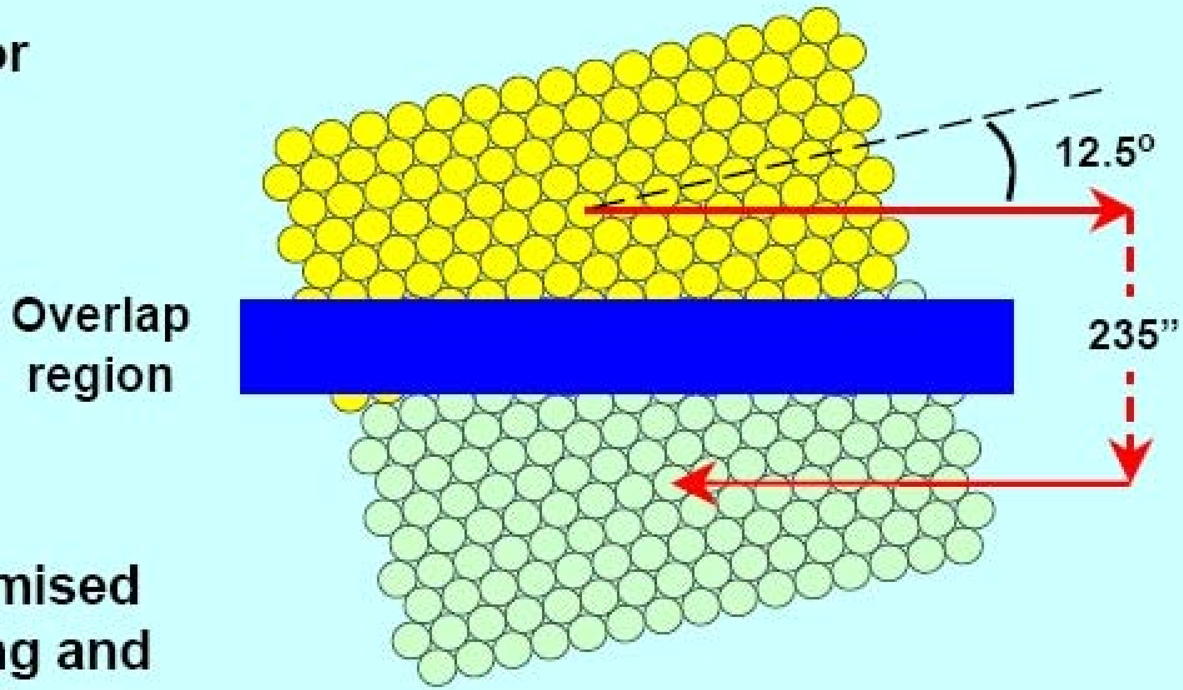






Photometer Observing Modes: Scan Map

- Most efficient mode for large-area surveys
- Telescope scans continuously at up to 60"/sec.
- Scan parameters optimised for full spatial sampling and uniform distribution of integration time



- Map of large area is built up from overlapping parallel scans

Division of SPIRE GT

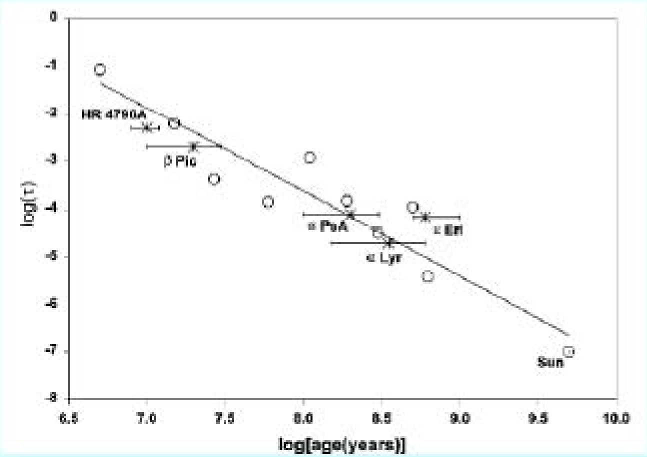
- Nominal SPIRE GT = 2000 hrs

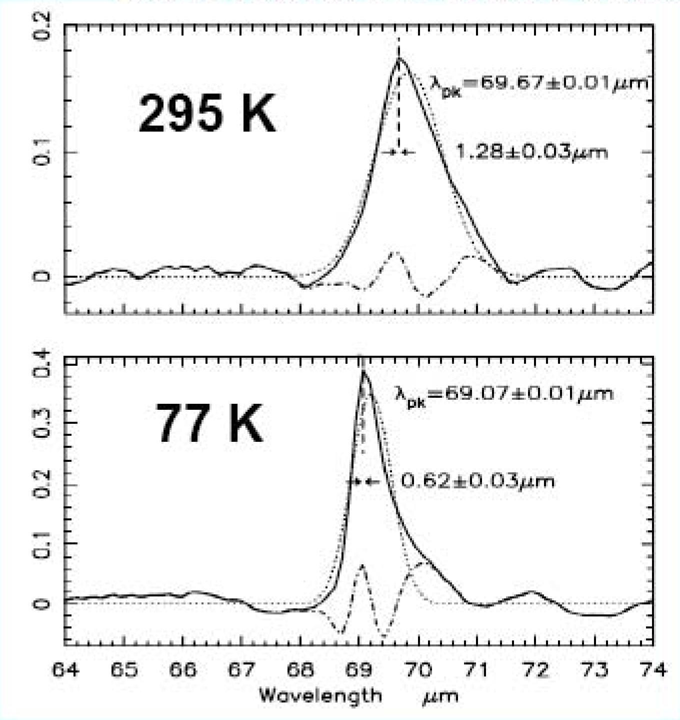
High-redshift galaxies	850 hrs
Local galaxies	300 hrs
Star formation	320 hrs
Interstellar medium	180 hrs
Solar system	50 hrs
Stellar & circumstellar	150 hrs
Reserved for small programmes	150 hrs

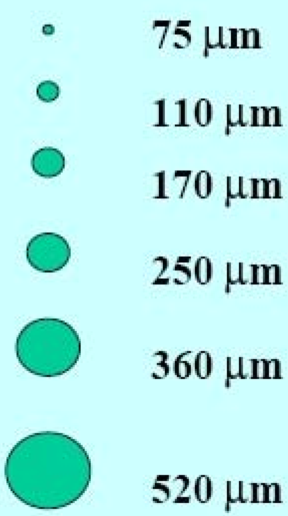
- Many programmes will involve collaboration/coordination with the PACS team

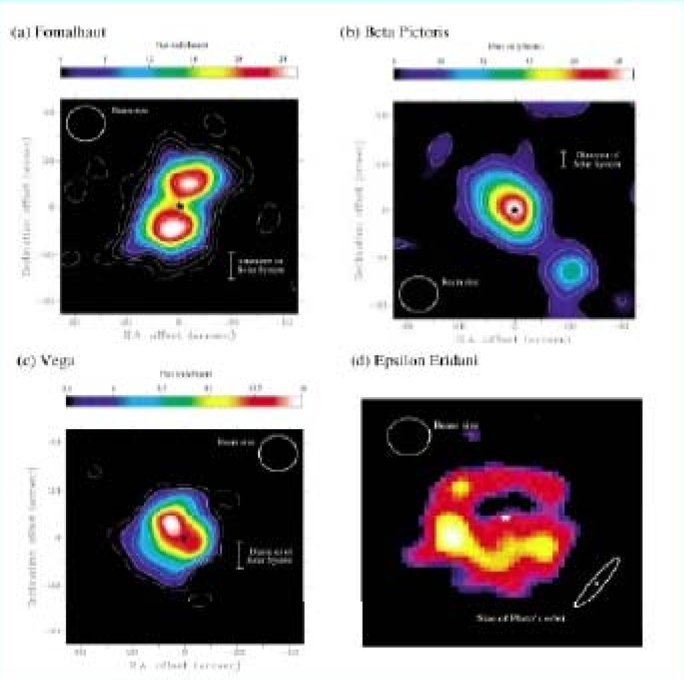
Debris Disk Evolution

- **PACS + SPIRE mapping**
  - Dust mass vs. time/evolutionary state
  - Dust morphology and properties
- **PACS + SPIRE spectroscopy**
  - Dust features, e.g., Fosterite 69 μm







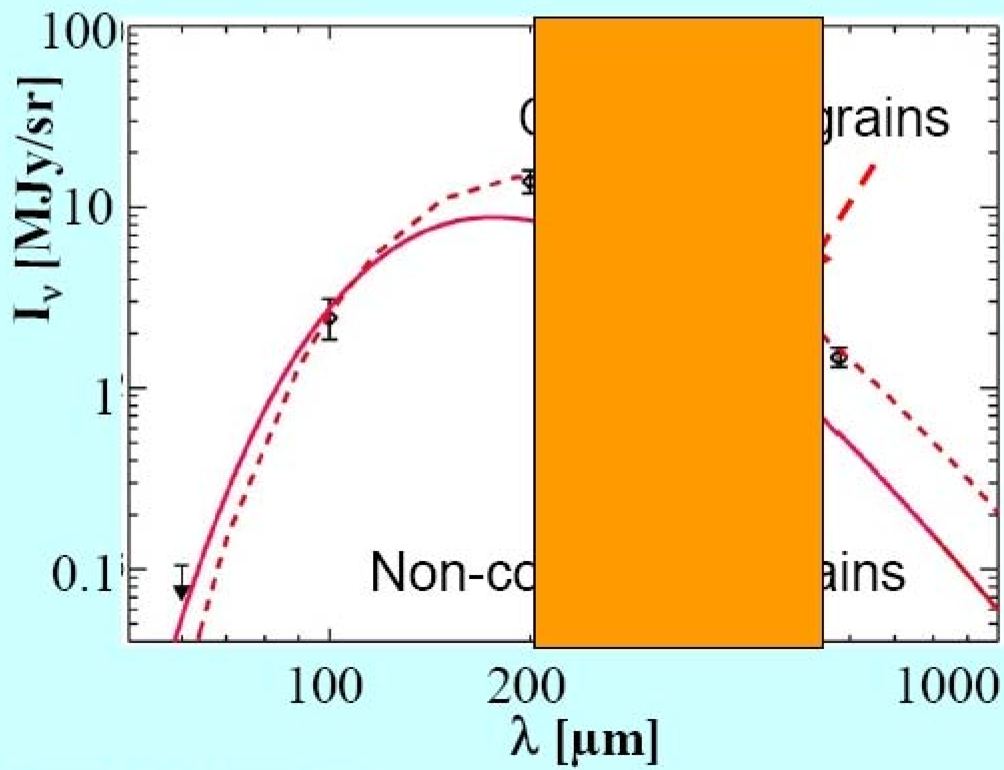


Physics and Evolution of Interstellar Dust

- **Unbiased surveys with different A_v, illumination, density, history, star forming activity**
  - Dust SED and gas physics

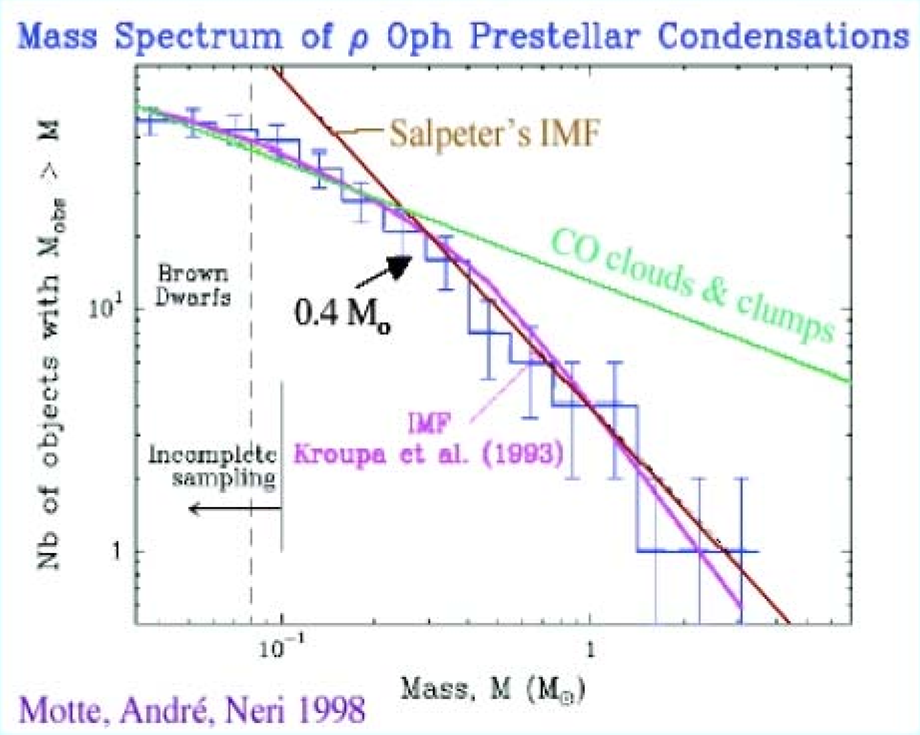
- **Processes acting on dust particles**
  - Fragmentation, coagulation, condensation, evaporation, photo processing

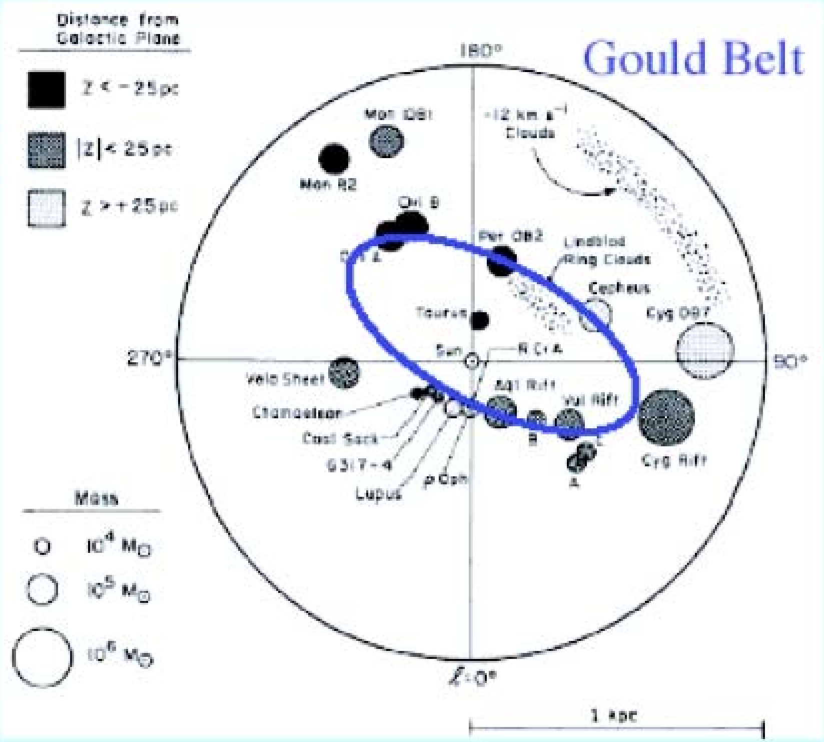
- **In all environments:**
  - Shock processed dust
  - Cirrus, molecular clouds, PDRs
  - Pre-stellar cores and protostars



Multi-band Survey of Nearby Molecular Clouds

- **Complete samples of protostars and pre-collapse condensations down to Mproto ~ 0.03 M⊙ and d ~ 1 kpc**
- SED coverage of spectral peak
- Accurate mass, luminosity, temperature, lifetimes
- IMF down to brown dwarf mass regime
- Temperature and density profiles for nearby sources





Comments re earliest stages of low mass Star Formation (SF)

Low mass SF regions: Clump mass spectrum (regardless of whether gravitationally bound?) has a slope like the initial mass funciton (IMF) for stars. Need better statistics at higher mass end (see last slide) → larger area surveys.

But what does this mean? Would each clump form one and only one star? With what efficiency?

HSO surveys in closest clouds are sensitive to 0.01 M_{sun} (if not confused), and so probe a potential turnover in the IMF near the theoretical minimum fragment size.

Low mass star formation

Some lessons learned in nearby molecular clouds:

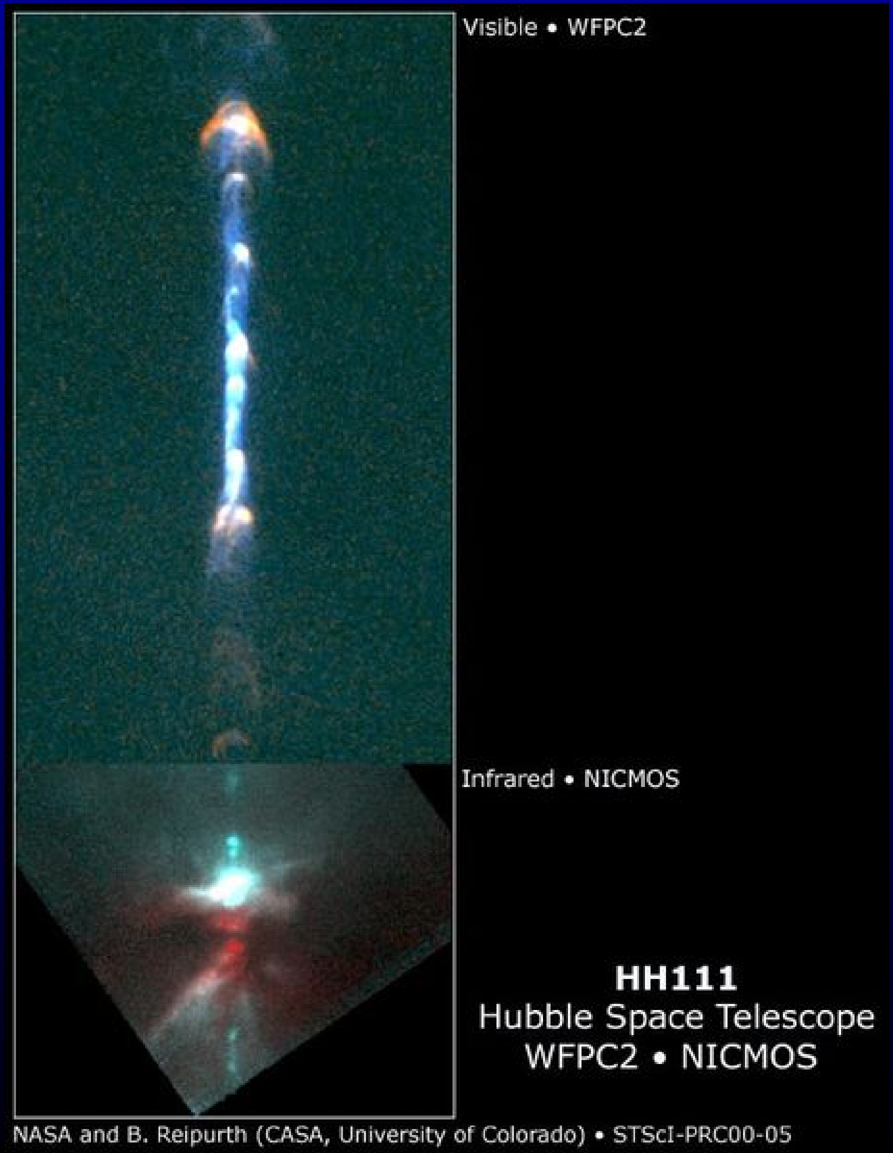
Stars form in molecular clumps and initially are completely enshrouded in the dusty material. We cannot see the star, only the radiation re-emitted by the dust.

These stars have disks, and fire out jets along the rotation axis at speeds of 100 km s^{-1} (see slide).

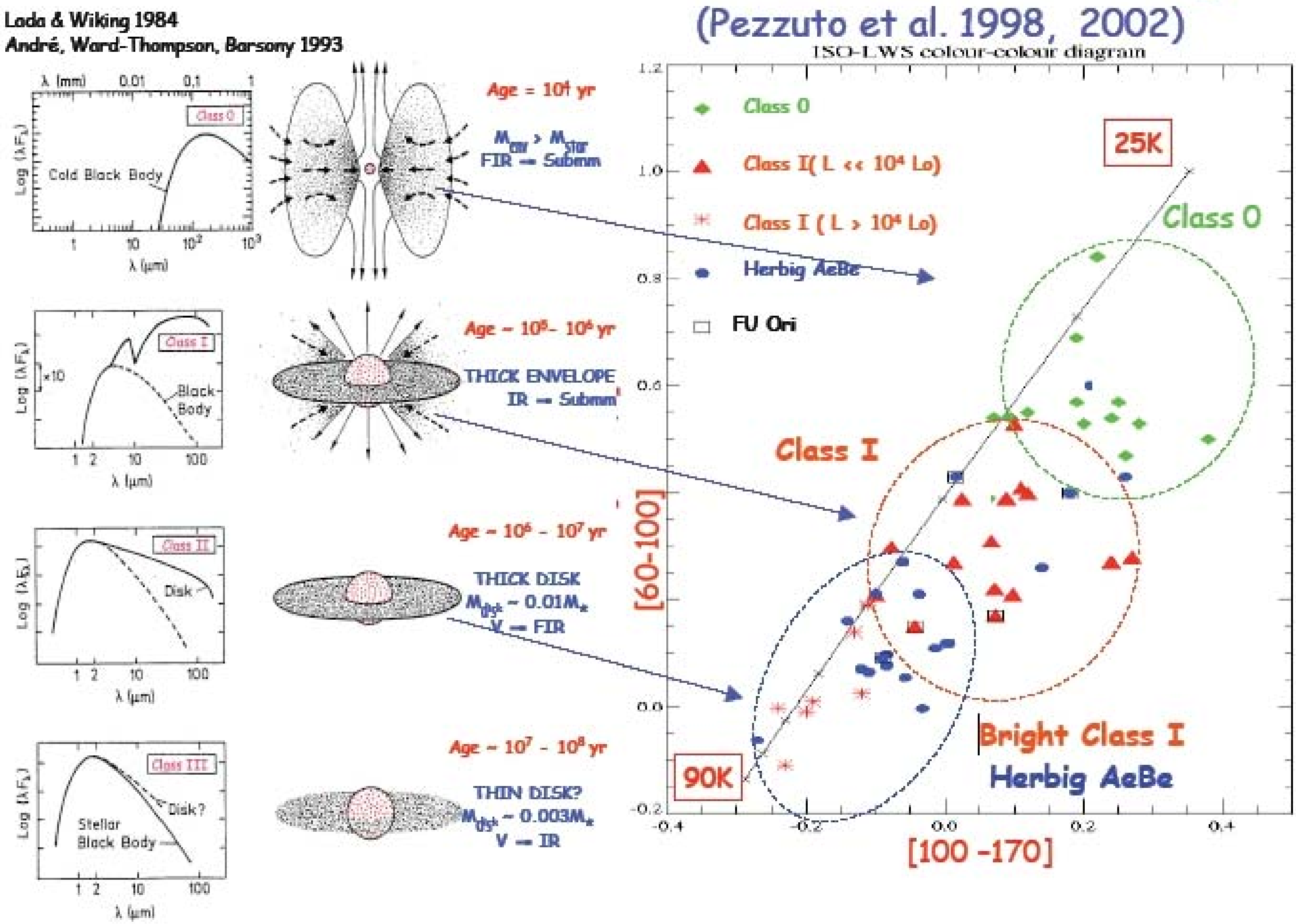
Gradually the surrounding material dissipates and the young star is revealed.

As a result, the spectral energy distribution changes dramatically (see slide).

A jet leading to a Herbig-Haro outflow



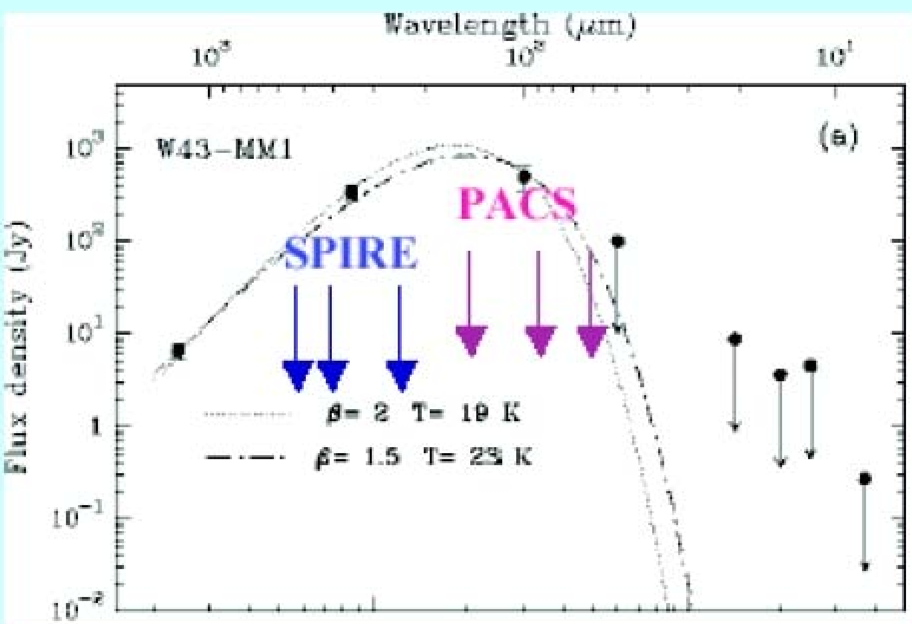
LOW MASS YSO EVOLUTION ISO LWS colour colour diagram

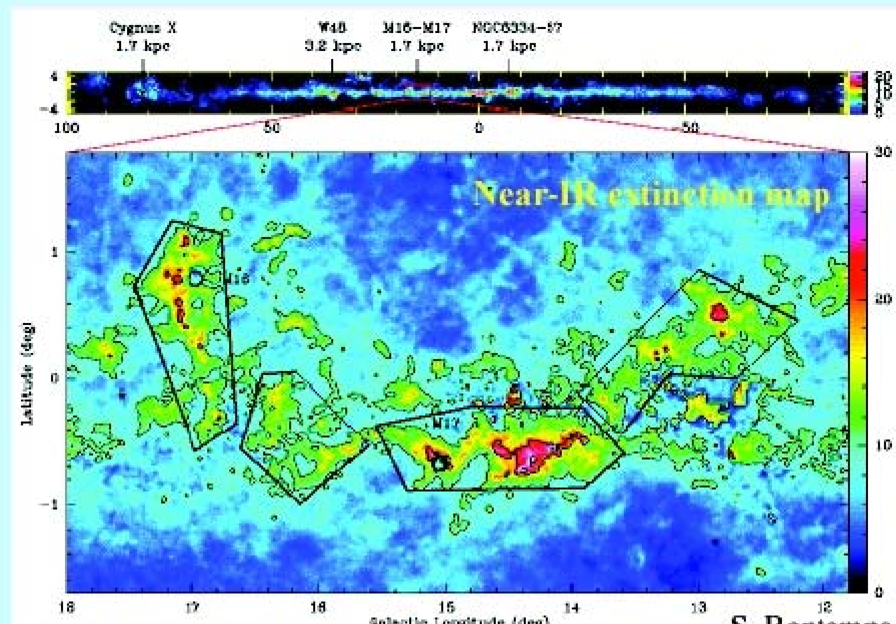


(Slide from SPIRE SAG3 GT planning; P. Andre)

High-mass Star Formation

- **PACS and SPIRE imaging and spectroscopy**
- **40 sq. deg. covering a galactic volume a few kpc in radius**
  - Unbiased census of all OB star precursors
  - Relationship with clusters, OB associations
  - Templates for extragalactic star forming regions
  - Initial conditions and evolutionary sequence
  - Role of external triggers in massive star formation
  - Direct collapse and accretion (like low-mass stars) or coalescence?

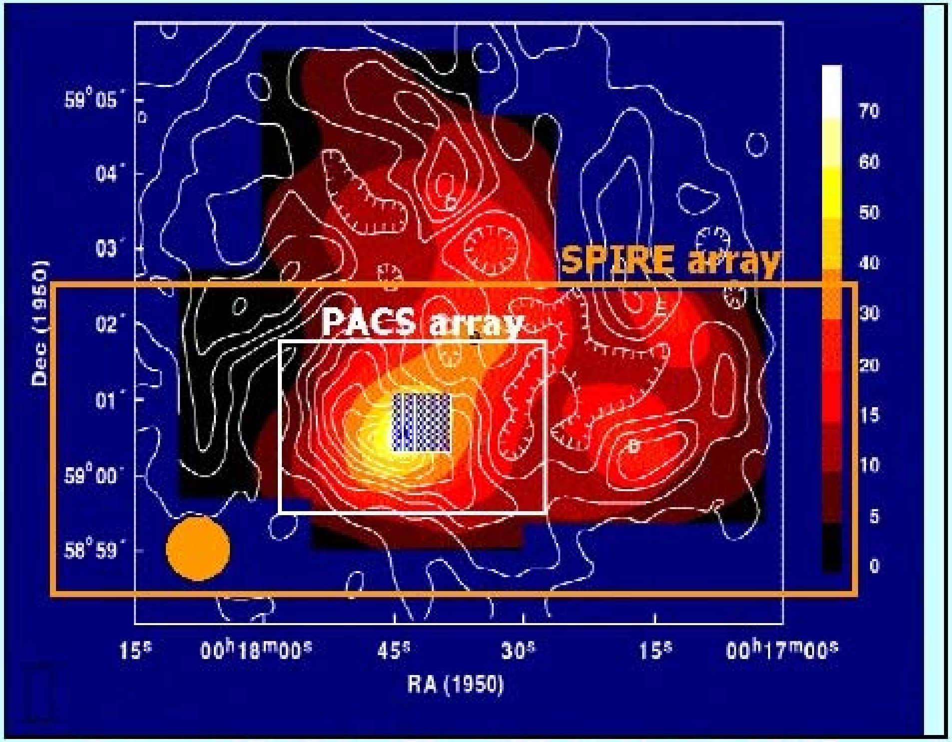




S. Bontemps

ISM in Local Galaxies

- **Sample of 15 nearby galaxies well-studied from X-ray-radio**
  - Early & late type spirals
  - Low mass spiral
  - Edge-on spiral
  - Starburst spiral
  - Starburst galaxy
  - Quiescent dwarf
  - Starburst dwarf
  - Seyferts
  - Ellipticals



Contours: HI; Color 158 mu CII Madden et al 1997

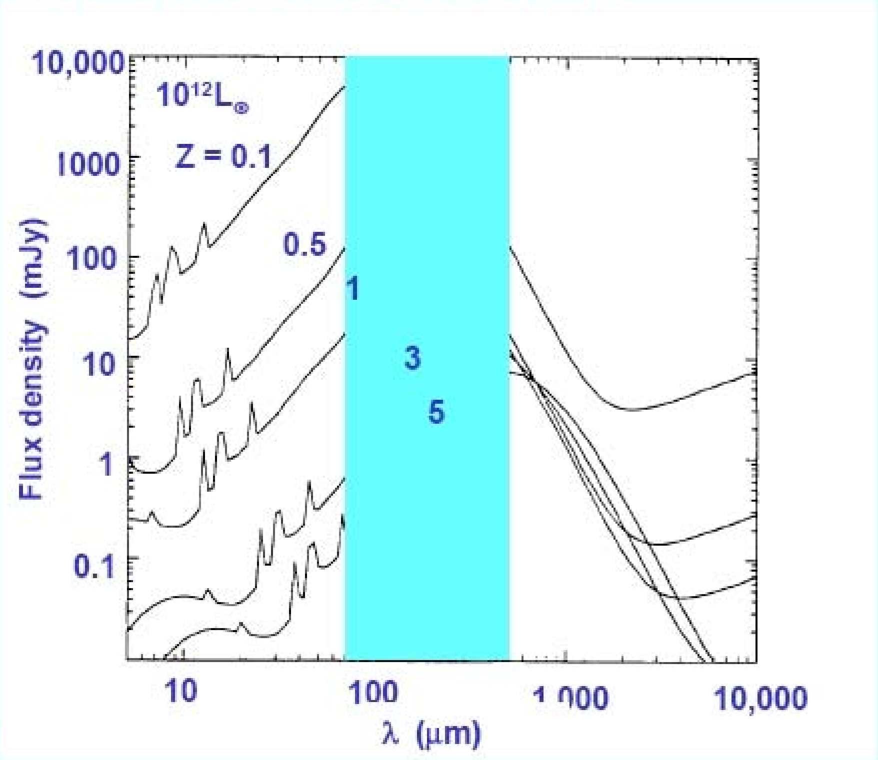
- Spatially resolved photometry, spectroscopy with PACS, SPIRE, HIFI
- Detailed SEDs and dust properties
- Chemistry/metallicity variation and evolution
- Variations inside a galaxy as well as global properties

SPIRE + PACS Extragalactic Surveys (GT + OT)

- Unbiased surveys (multi-tiered "wedding cake")
- Small areas (below confusion limit) - several 100 sq. deg.
- ~ 1,500 hrs of SPIRE and PACS GT + more in Open Time

- History of energy production
- Structure formation
- Cluster evolution
- Lensing
- CIRB fluctuations
- AGN-starburst connection
- Planck DECS fields

- Follow up spectroscopy:
  - Redshifts
  - Physics and chemical evolution



After Guiderdoni et al. MNRAS 295, 877, 1998

PACS

A Photodetector Array Camera and Spectrometer for Herschel

An imaging photometer or an integral field spectrometer over the spectral band from 57 to 210 µm.

Instrument

http://www.rssd.esa.int/Herschel/Publ/2006/SPIE2006_PACS_talk.pdf [Orlando]

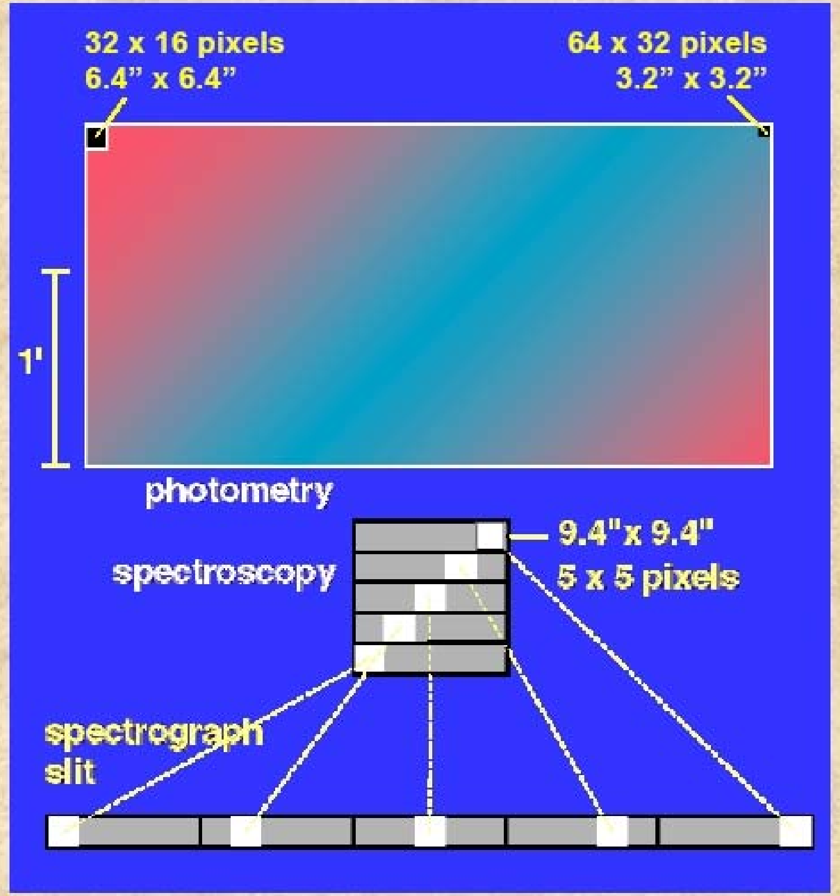
Science

http://www.rssd.esa.int/Herschel/Publ/2006/AAS207_PACS_science.pdf [Washington]

Instrument Concept

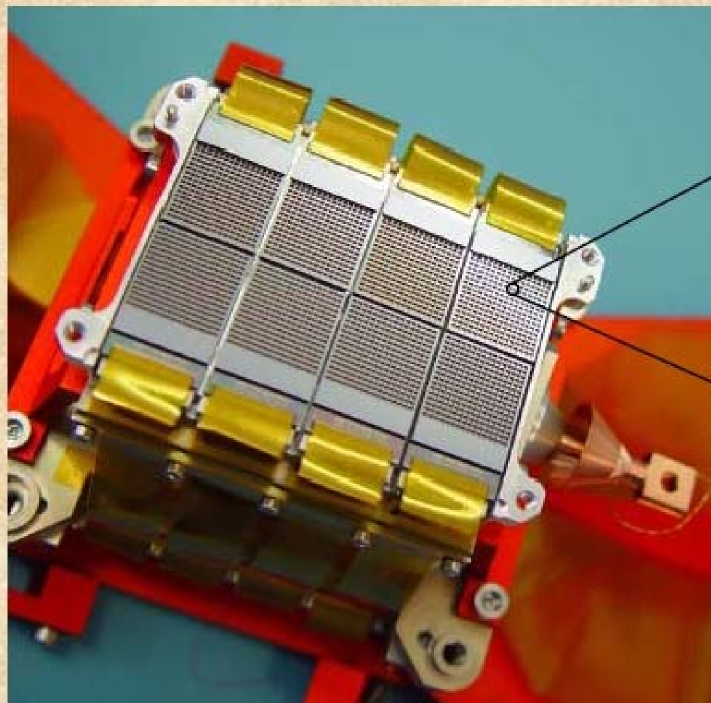
- **Imaging photometry**
  - two bands simultaneously (60-85 or 85-130 μm and 130-210 μm) with dichroic beam splitter
  - two filled bolometer arrays (32x16 and 64x32 pixels, full beam sampling)
  - point source detection limit ~4 mJy (5σ, 1h)
- **Integral field line spectroscopy**
  - range 57 - 210 μm with 5x5 pixels, image slicer, and long-slit grating spectrograph (R ~ 1500)
  - two 16x25 Ge:Ga photoconductor arrays (stressed/unstressed)
  - point source detection limit 3…20 x10^{-18} W/m^2 (5σ, 1h)

Focal Plane Footprint

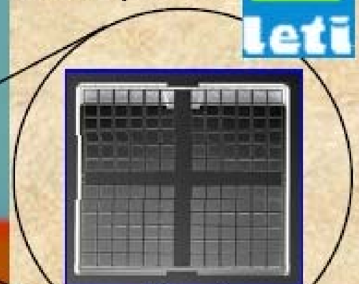


Bolometer Arrays (Photometer)

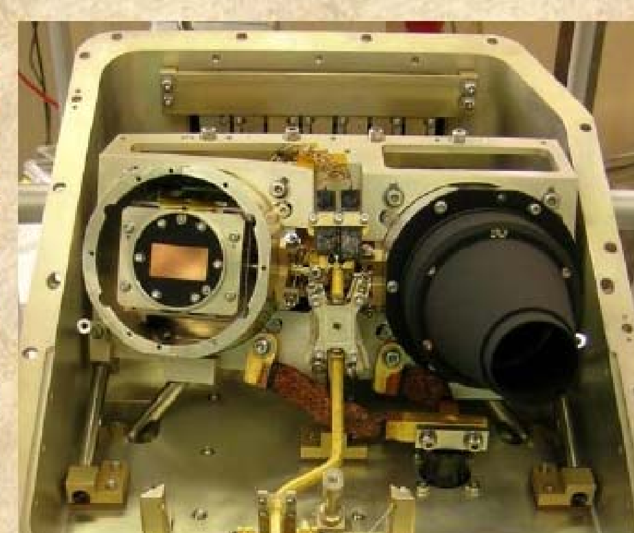
- Two filled arrays: 64x32 pixels (blue) and 32x16 pixels (red)
- Bolometers and multiplexing readout electronics operating at 0.3K
- Detector/readout noise comparable to background-noise (FM)
- Cooler hold time ~59h



Blue focal plane



Pixel



Photometer unit with blue + red focal planes and ^{3}He cooler

How to Estimate Observing Times?

- Under preparation: HSPOT (developed from Spitzer SPOT) will give accurate time budgets
- Now: A simple 'Time Guesstimator' is available for feasibility checks and rough estimates, follow the link 'Time Guesstimator' at http://pacs.ster.kuleuven.ac.be/
- Be aware of confusion limits! (0.6, 3, 11mJy)

PACS Science

GT: Different team/ownership structure

Science drivers very much like SPIRE

Often coordinated campaigns, but better resolution is traded off with lower areal coverage
→ PACS followup of areas that SPIRE surveys find to be interesting.

How will JCMT SCUBA-2 surveys fit in?

High Mass SF

GMCs are the most representative star-forming environments, yet are poorly understood.

- In what conditions do massive stars form?
- Can they form spontaneously?
- Is there a dependence on molecular cloud mass?
- Is star formation coeval?

Galactic Ecology:

Feedback:

- triggered star formation
- disruption of the parent cloud

Examining the details of how things work:

Energetics. Structure: ionization fronts, blisters, and PDRs. Evolution of dust and PAHs.

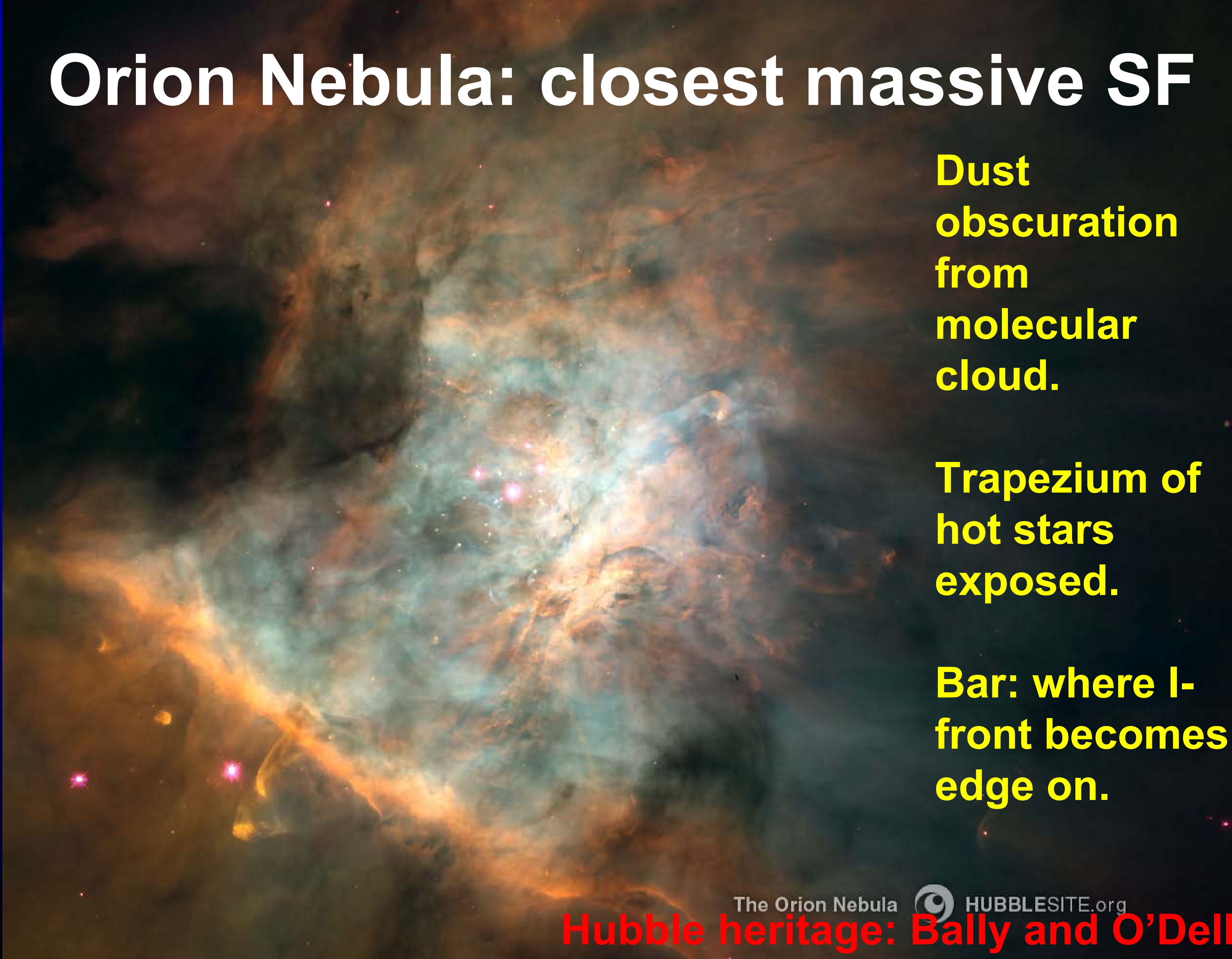
SFE: Cluster survival

GMCs (gas) are gravitationally bound.
Stars form, usually a whole cluster.
Stars disrupt the cloud and expand the gas, but leave the stars behind.

Is the stellar cluster still gravitationally bound?
Depends on the star formation efficiency (SFE), which is usually low → usually unbound.
Expanding "associations" of stars are seen (thus evidence for low SFE). These are clusters in the process of dissipating, becoming "field stars"

GMCs contain most of the molecular mass, and so statistically the Sun would have formed in a GMC; now the Sun is a field star.

Orion Nebula: closest massive SF



Dust obscuration from molecular cloud.

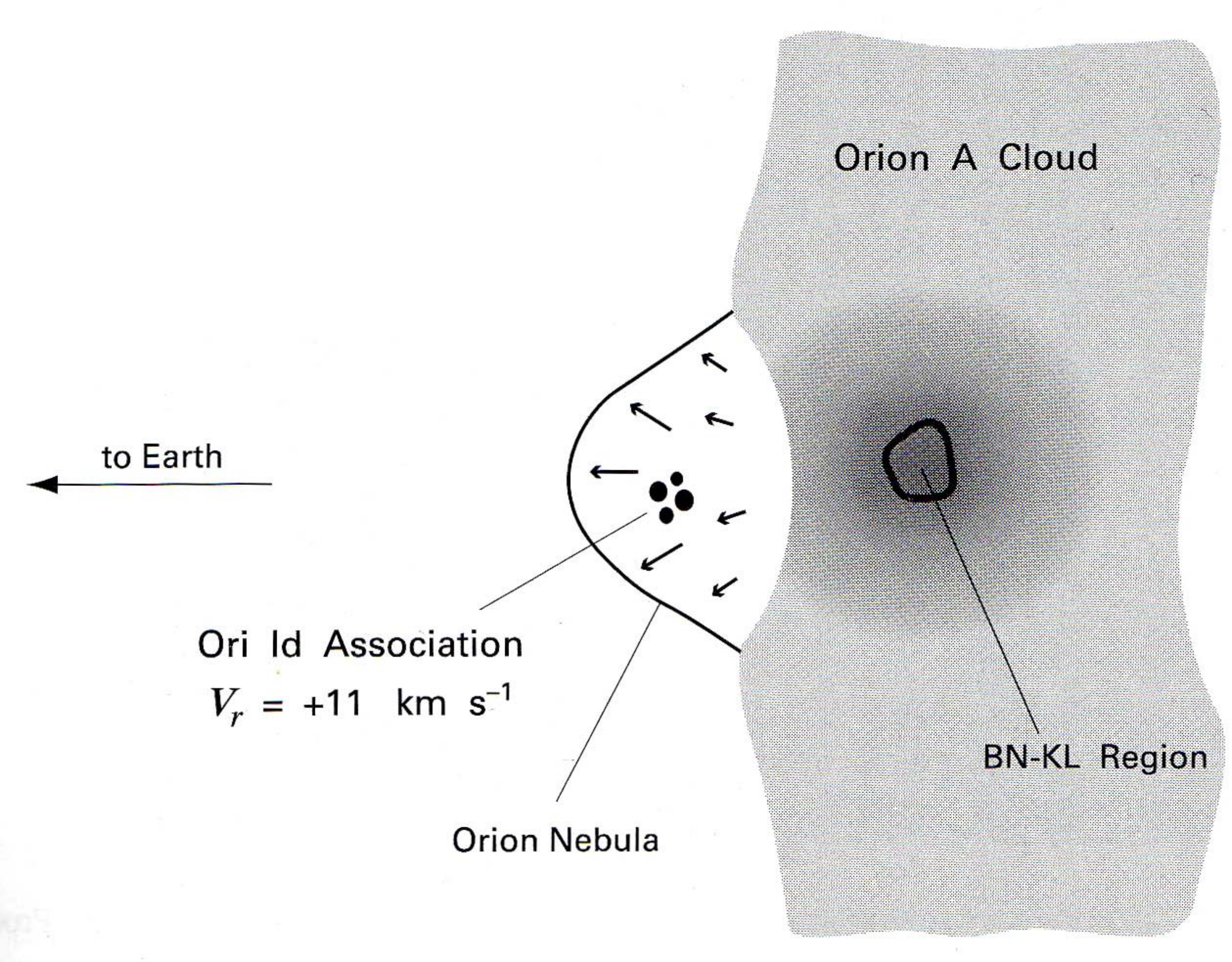
Trapezium of hot stars exposed.

Bar: where I-front becomes edge on.

Hubble heritage: Bally and O'Dell

Orion Nebula blister geometry

Ionized by massive stars near the front surface of the closest (450 pc) GMC.

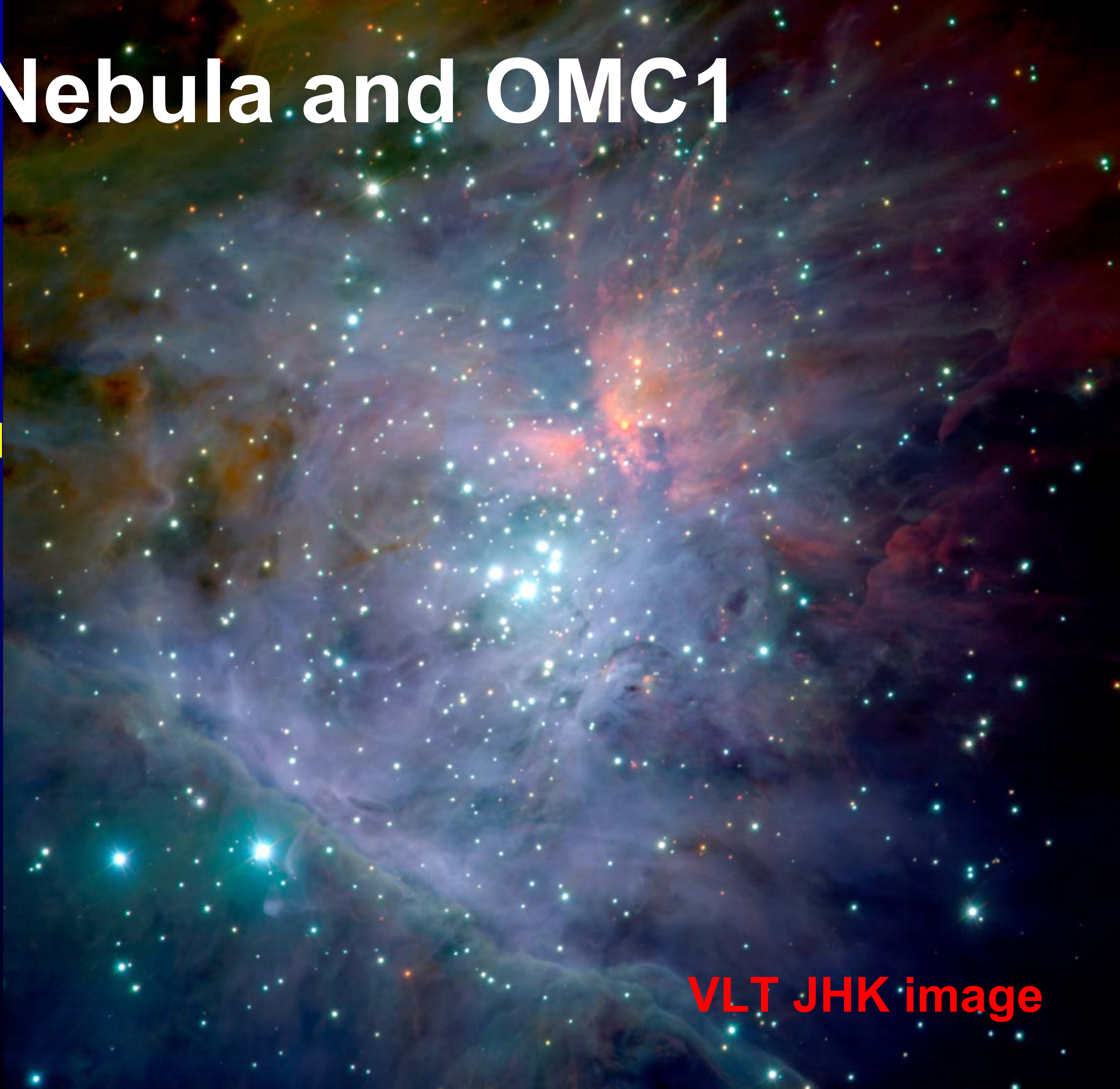


Cartoon after Stahler and Palla.

Orion Nebula and OMC1

JHK image.

Red hue is from K-band shock-excited H_2 in the background molecular cloud OMC1 where there is also on-going star formation.



A large cluster has formed

While it is the massive hot stars that are causing the ionization, there are many more lower mass young stars.

Some of these have very interesting features, e.g., disks of gas and dust (like around other young stars, and like the disk from which the planets in our Solar System formed).

Confusion -- a serious limitation to be aware of

Illustrate with the Orion cluster.

~1000 stars in 0.6 pc cube (4' square). With a 20" beam, there are 12^2 beams. Thus even at this distance (450 pc), had the cloud been observed in the pre-stellar clump stage, all of the clumps could not have been distinguished from one another.

Trapezium: 4 massive stars within one 20" beam. Worse for more distant massive SF regions. What did precursor clump look like?

Confusion less serious in low mass SF regions, since star density lower and 3 times closer. But still, when searching to the limit (0.01 M_{sun}), one has to be wary.

Other famous H II regions

Lots of surrounding molecular gas and dust. These molecular clouds are being severely disrupted, which will eventually terminate star formation.

Dense regions are highlighted; these have the potential to form more stars.

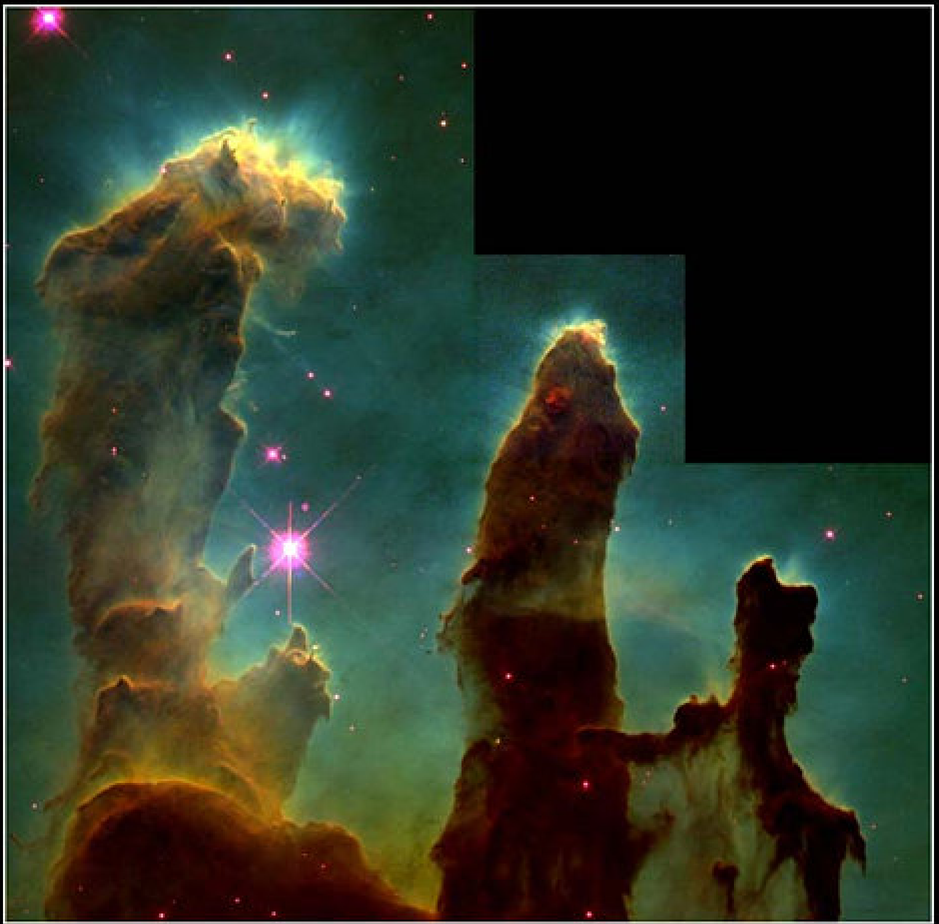
But externally-heated dust near hot stars is also highlighted. Watch for biases in the clump mass spectrum; are the clumps that are being counted self-gravitating?

Eagle Nebula (M 16)

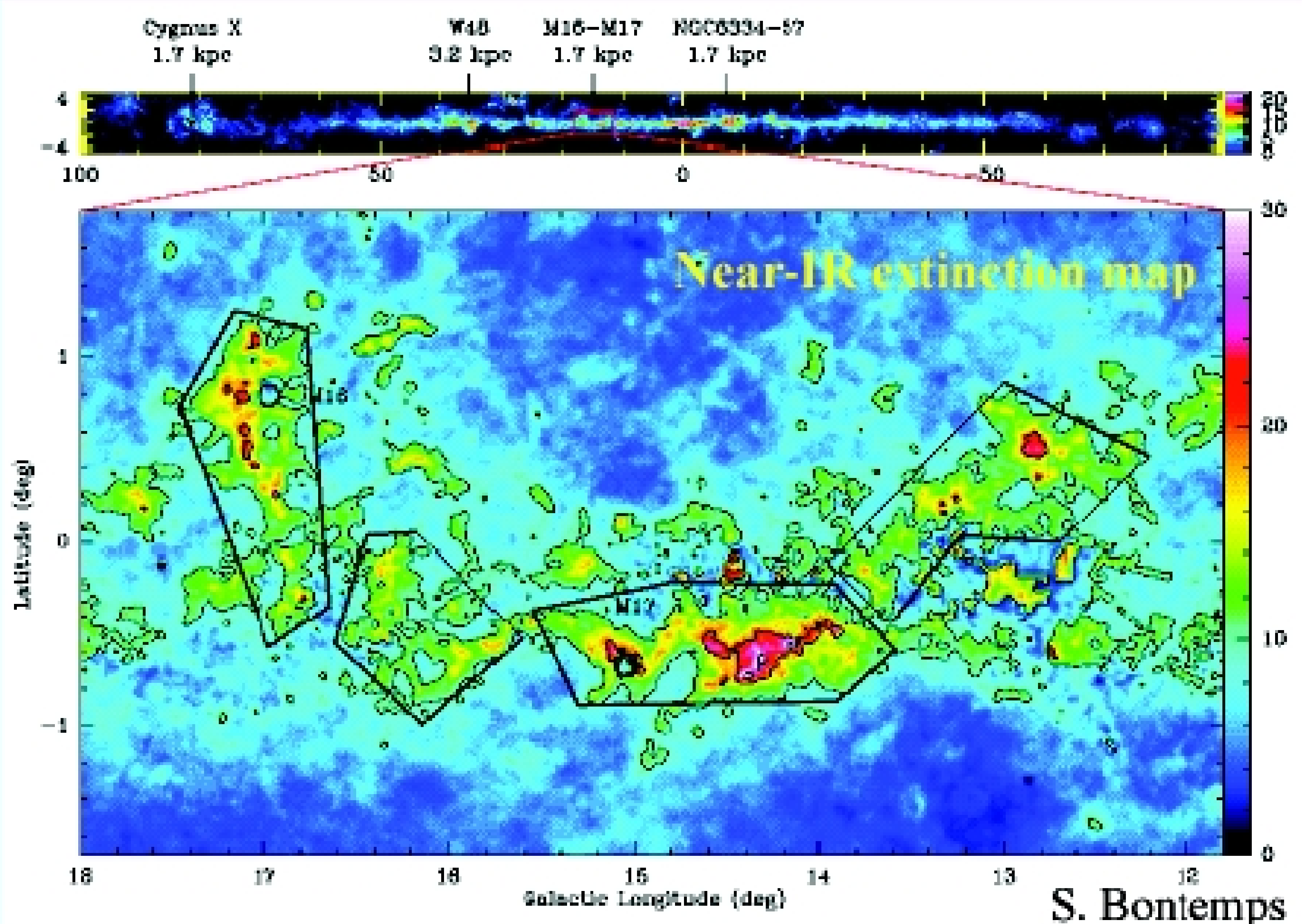
Star cluster with massive stars. Residual molecular material nearby.

Gendler

M 16 detail



Gaseous Pillars · M16 HST · WFPC2
PRC95-44a · ST ScI OPO · November 2, 1995
J. Hester and P. Scowen (AZ State Univ.), NASA



Cygnus X
1.7 kpc
W43
M16-M17
1.7 kpc
1.7 kpc
Near-IR extinction map
M16
M17
Latitude (deg)
Galactic Longitude (deg)
S. Bontemps

Great nebula in Carina

Many of the most massive stars known in the Galaxy.

Massive star which has had a major eruption and mass loss in the last 200 years.

Regions of high-mass SF

This is quite complicated!

It is hard to see 0.01 M_{sun} fragments. But there certainly is structure on larger scales. It has a FLATTER mass spectrum, unlike low mass SF regions.

An H II region is a signpost of recent star formation. In the surrounding molecular clouds are there stars yet to form?

Are there any simple regions with a single ionizing star that look like a Stromgren sphere?

Massive Star Formation in a "simple" Molecular Cloud in the Perseus Arm

Spontaneous (i.e., non-triggered) formation of low mass stars seems common-place in nearby clouds.

But what of high mass stars?

We (with Ballantyne, Kerton, Johnstone) found an example, KR 140, in a molecular cloud in the Perseus arm (2 kpc away), where a massive 25 M_{sun} star appears to have formed spontaneously, well away from the nearest major star-forming activity in W3.

FIR Point Sources

Infrared point sources seen by IRAS located near the periphery are of interest because they might be associated with the formation of other stars, perhaps even induced by the expansion of the H II region.

We have made use of SCUBA submillimetre data to reveal the varied nature of the IRAS infrared sources.

Three IRAS "point" sources are actually pieces of the limb-brightened edge of KR 140.

Two IRAS sources outside the H II region are internally heated and have B-star luminosities. These protostars are younger than VES 735, the exposed O star that produces the HII region (not all star formation is coeval).

Cold cores

With SCUBA on JCMT we discovered a number of relatively cold submillimetre sources not visible in the IRAS data, ranging in size from 0.2 to 0.7 pc and in mass from 0.5 to 130 M_{sun}.

Many appear to be gravitationally bound and if in virial equilibrium require non-thermal pressure support.

Upon loss of such support they could be sites of future star formation, i.e., they could be cold pre-stellar cores.

Gravitational instability?

$M_J = M_{BE} = 1.4\, M_{Sun}\, (T/10\ K)^{3/2}\, (n_H/10^4\ cm^{-3})^{-1/2}$

(after Stahler and Palla).

Unstable for $M_{clump} > M_{BE}$ (the mass of the "critical" Bonner-Ebert sphere).

Not coeval

Several embedded protostars have in fact been found in this field too.

Thus there are simultaneously:

- A massive O star with a fully-developed H II region
- Embedded protostars
- Pre-stellar cores.

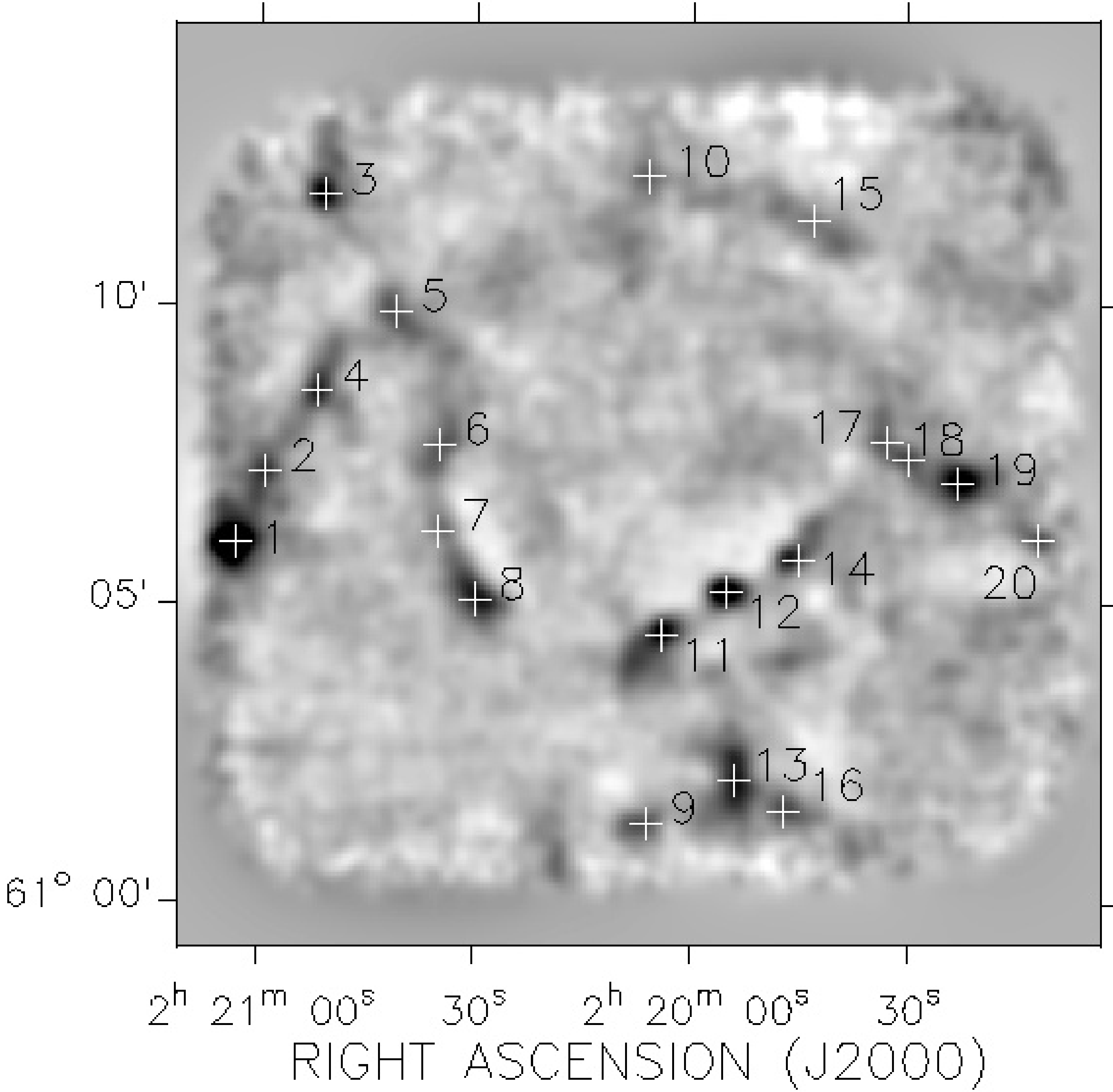
Star formation in this region is not completely coeval, spanning several million years. Not efficient initially.

Sets the stage for feedback to terminate star formation before entire cloud is transformed into stars.

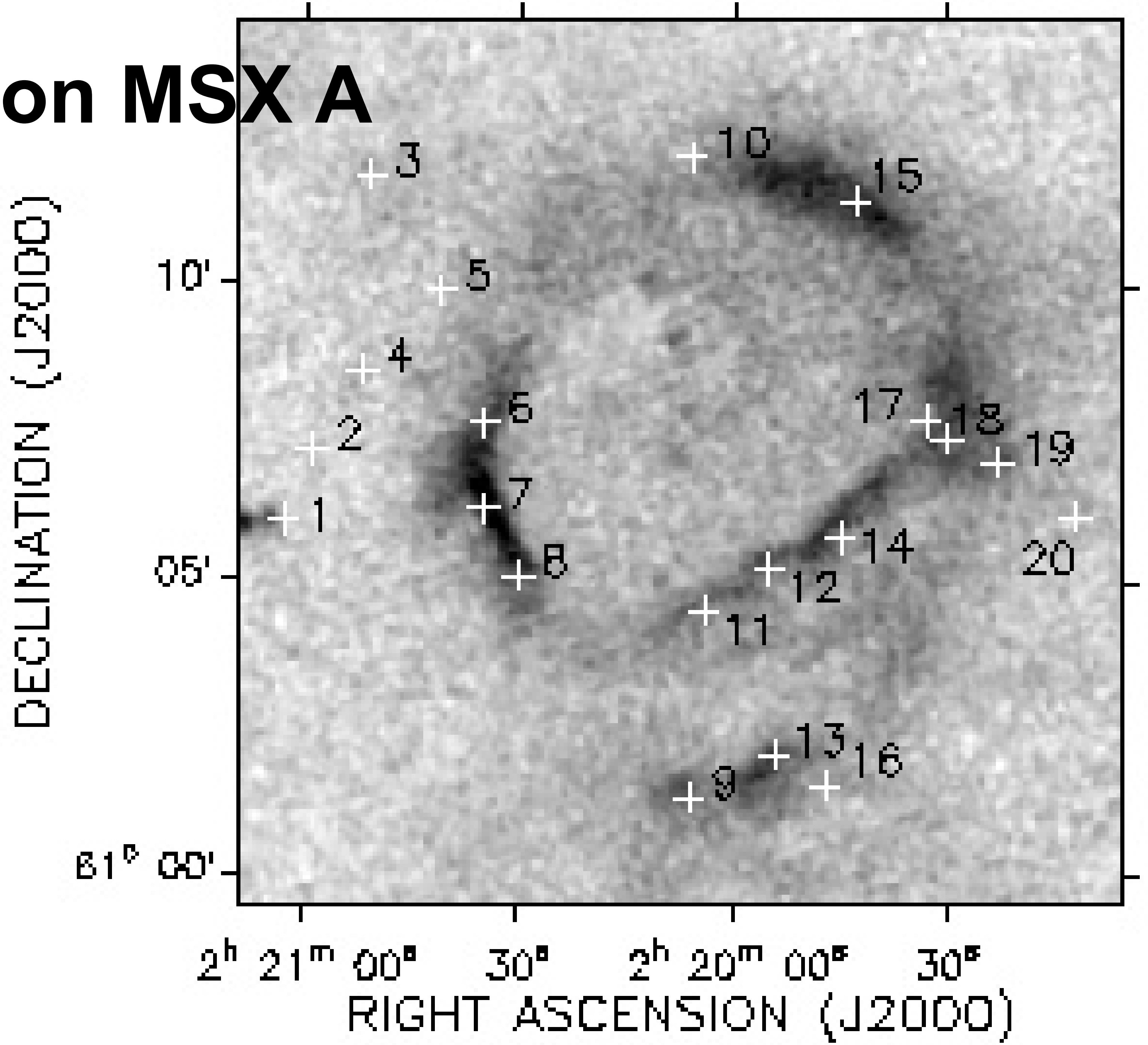
Scuba Sources at 850 microns

Low spatial frequencies suppressed!!

(Note equatorial coordinates.)



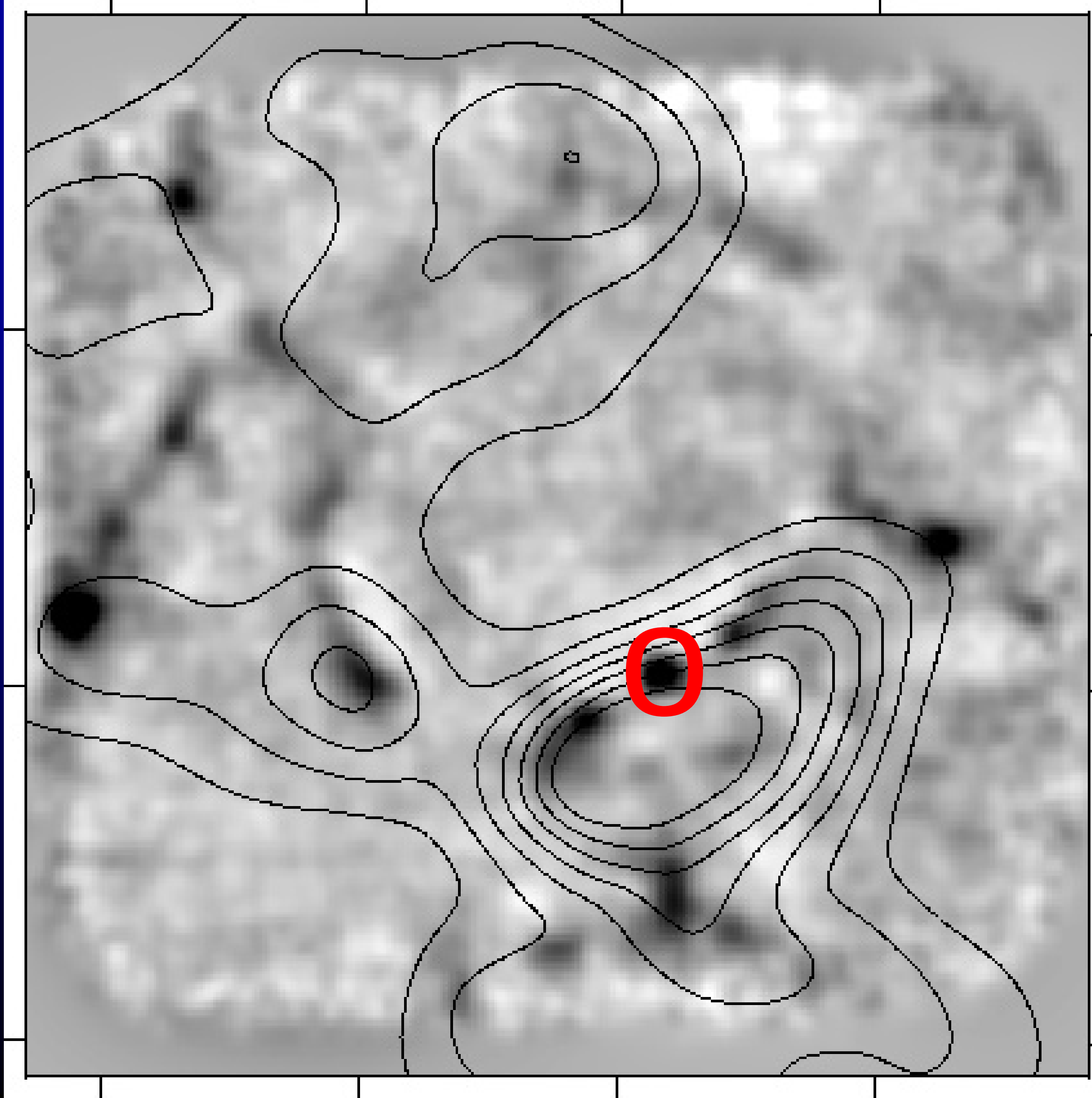
Scuba on MSX A



CO Cloud at Systemic Velocity

Clumps and 8-micron ridge aligned along edge of CO cloud.

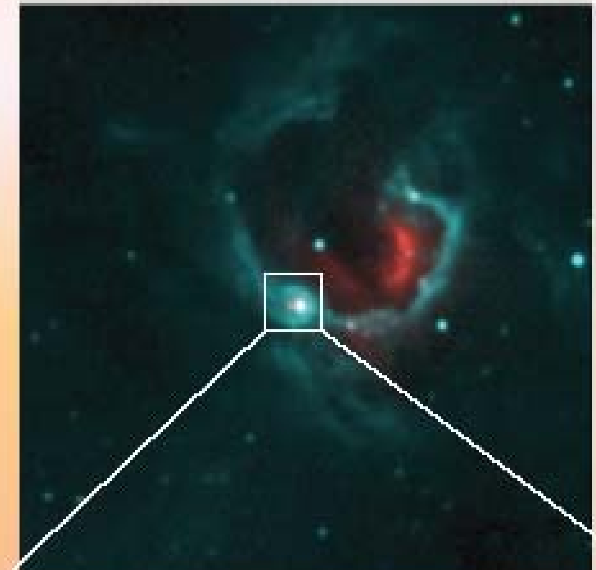
Source 12 marked for future reference.



Another example: slide from SPIRE SAG3 GT planning; P. Andre)

Hot PDRs

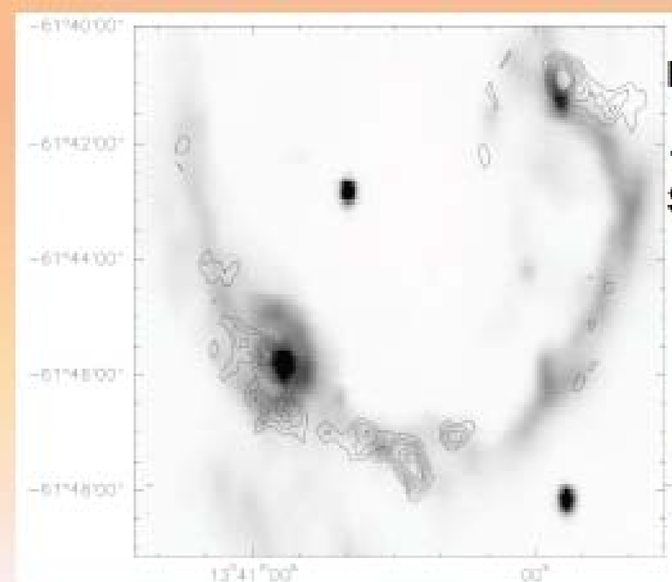
Zones of triggered massive-star formation



MSX-A (blue) 8μm
MSX-E (red) 21μm

DSS-R (blue)
MSX-A (red)

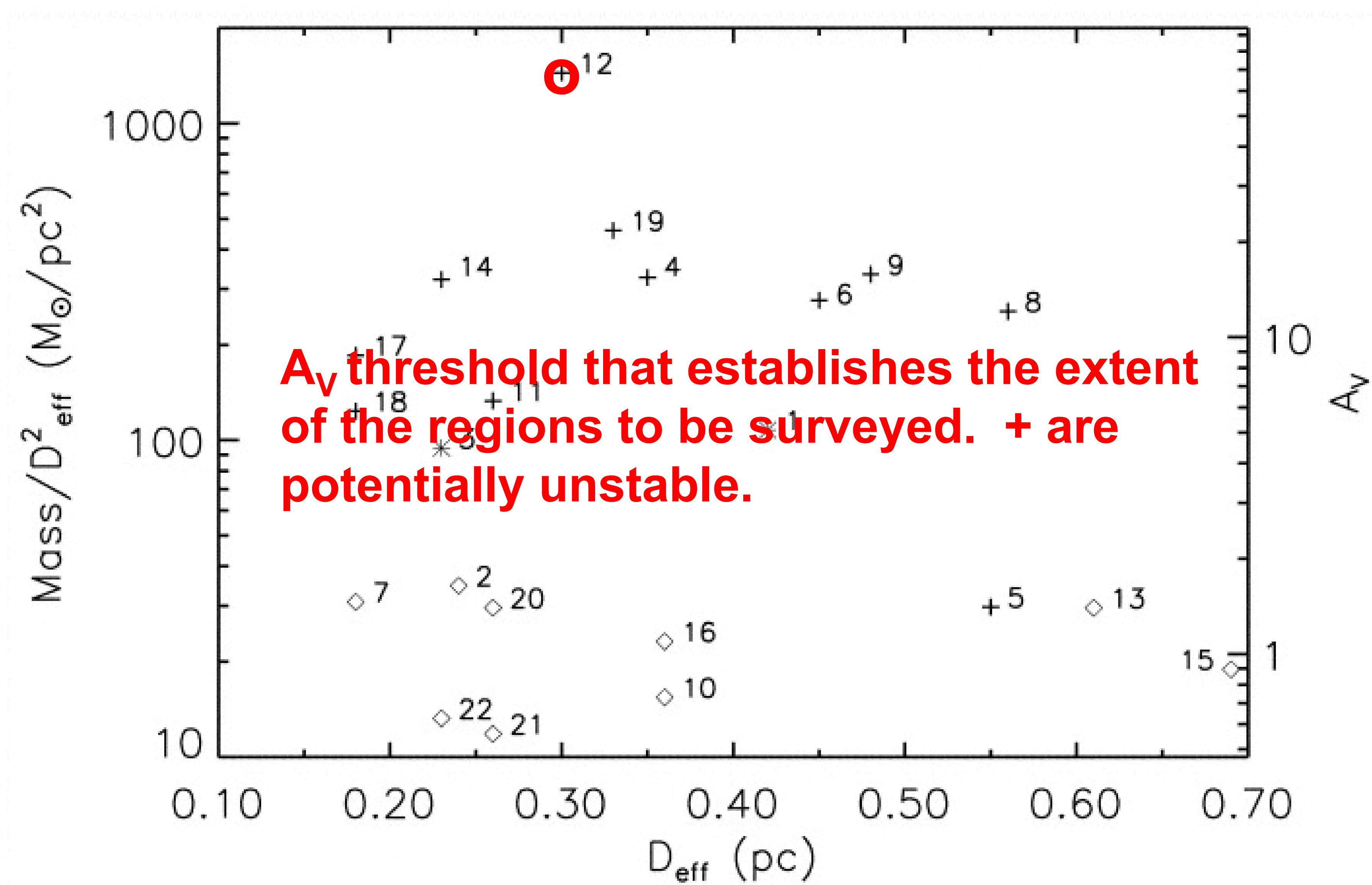
JHK
NTT



MSX-A (black)

1.3mm (contours SEST-SIMBA)

Column Density of Clumps



(Slide from SPIRE SAG3 GT planning; P. Andre)

Science Objectives

Open issues on the earliest phases of high-mass star formation

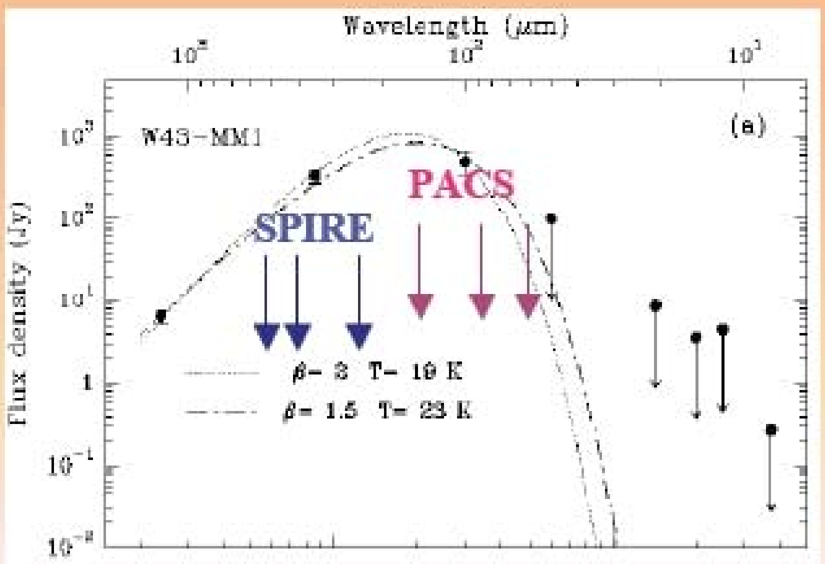
- Basic formation mechanism: accretion or coalescence ?
- Do high-mass pre-stellar cores exist ? Are they warmer, denser than low-mass pre-stellar cores ?
- Detailed evolutionary sequence ? Relative lifetimes of high-mass pre-stellar cores, Class 0 protostars, hot cores, and infrared UC HII regions ?

→ **Unbiased search for high-mass pre-stellar cores and Class 0 objects** in nearby complexes (d ~ 2 kpc) => Herschel @200 µm HPBW ~ 0.1 pc

ground-based submm

through multi-λ submm observations

Temperatures expected to span a wide range from < 10 K (cold pre-stellar cores) to > 100 K (hot cores)



Tdust ~ 20 K (Motte et al. 2003)

COLD DUST (unique contribution)

Need to measure the cold-prestellar cores, for low mass stars over the peak in the mass spectrum

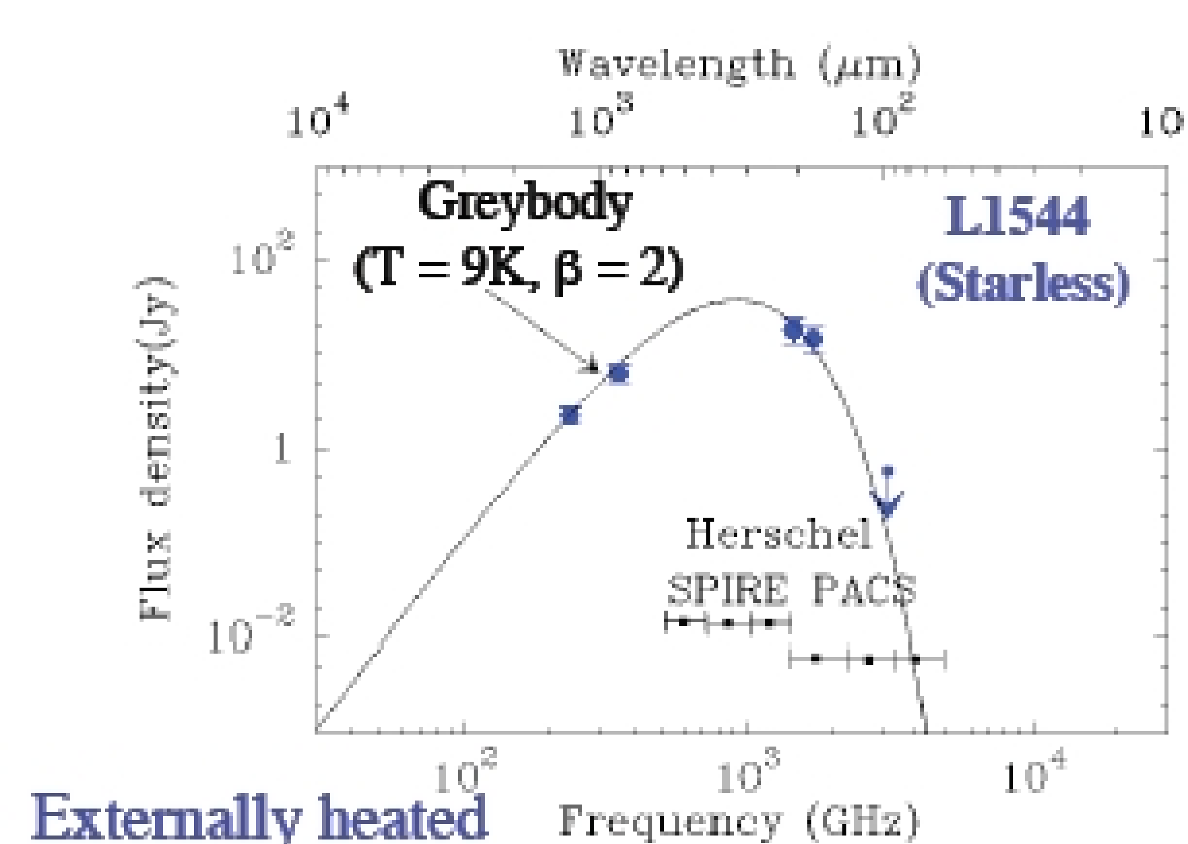
Search at high A_V (see threshold slide).

10 K → Sub-mm or THz astronomy

BLAST/SPIRE spectra

Sub-mm: 250, 350, 500 microns like SPIRE

Optimal wavelengths for constraining T (and β)



Submm-only objects whose SEDs peak @ λ ~ 100-400 μm

Many New Galactic Plane Surveys

BLAST (balloon-borne precursor of SPIRE): several regions of plane surveyed during northern flight June 2005; more from Antarctica December 2006.

Spitzer: MIPS-GAL (25, 70 microns). Underway

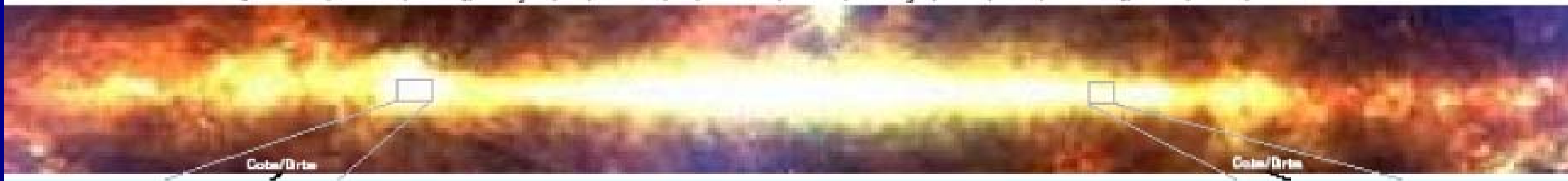
JCMT: JPS with SCUBA-2 (850 microns). Approved

Herschel: SPIRE GT (approved) and HI-GAL Open Time KP (planned – contact me)

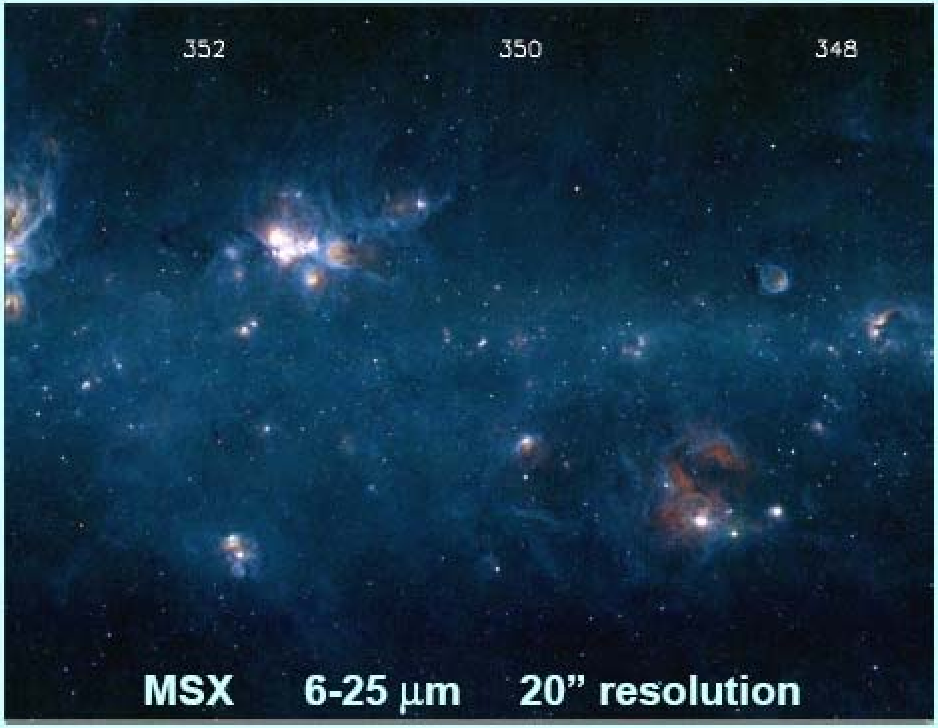
HIGAL (Open Time)

HERSCHEL INFARED GALACTIC PLANE SURVEY

B. Ali, S. Molinari, B. Swinyard, M. Barlow, J.P. Bernard, F. Boulanger, L. Testi, G. White & the Hi-GAL Team



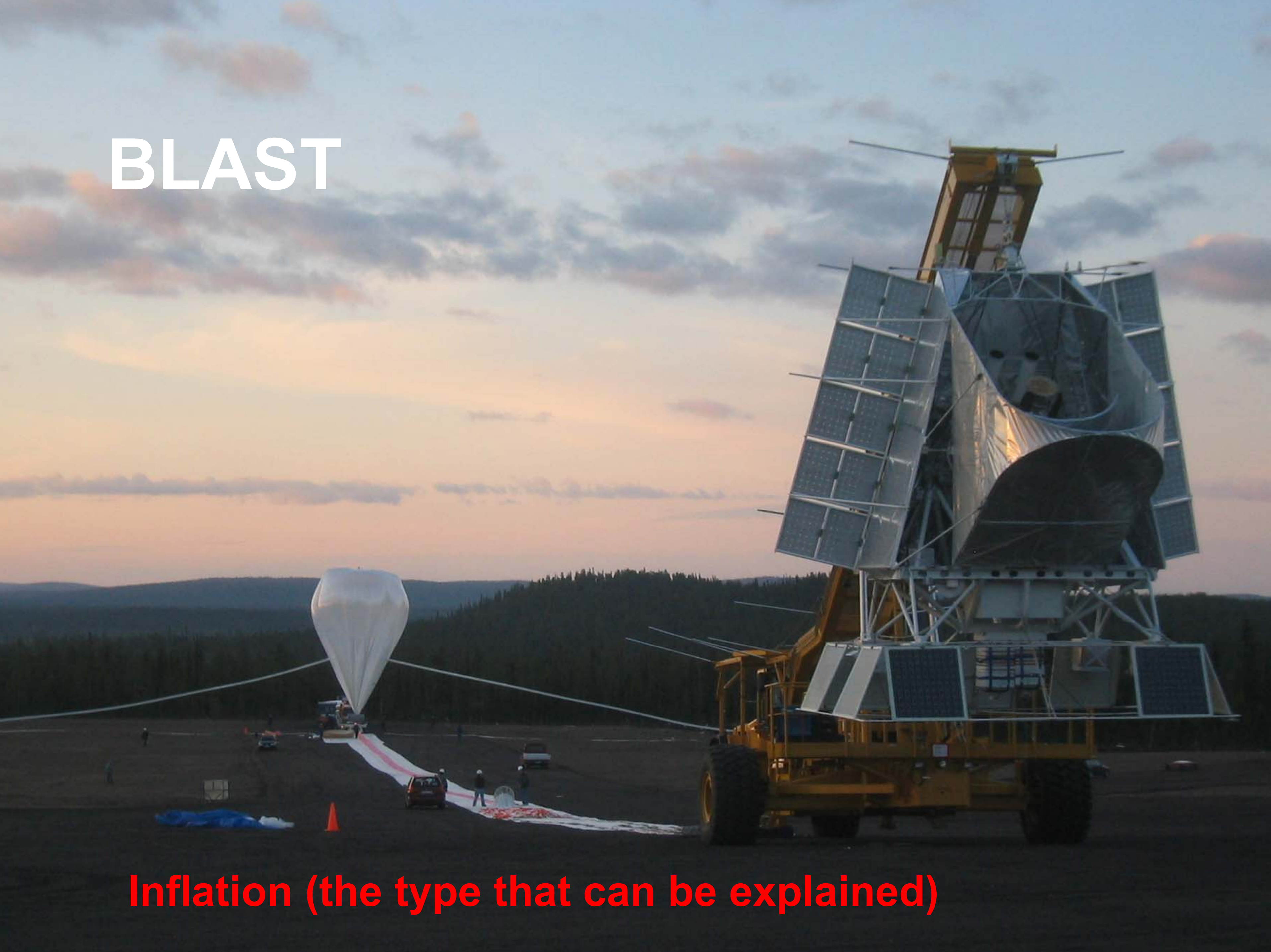
- **Compete multi-band galactic plane survey to ~20 mJy rms**
  - Census of all observable galactic star forming regions
  - Wide range of masses and evolutionary stages
  - High-mass and triggered star formation
  - Global properties of the ISM dust and molecular clouds
  - Supernova remnants; stellar mass ejection into the ISM

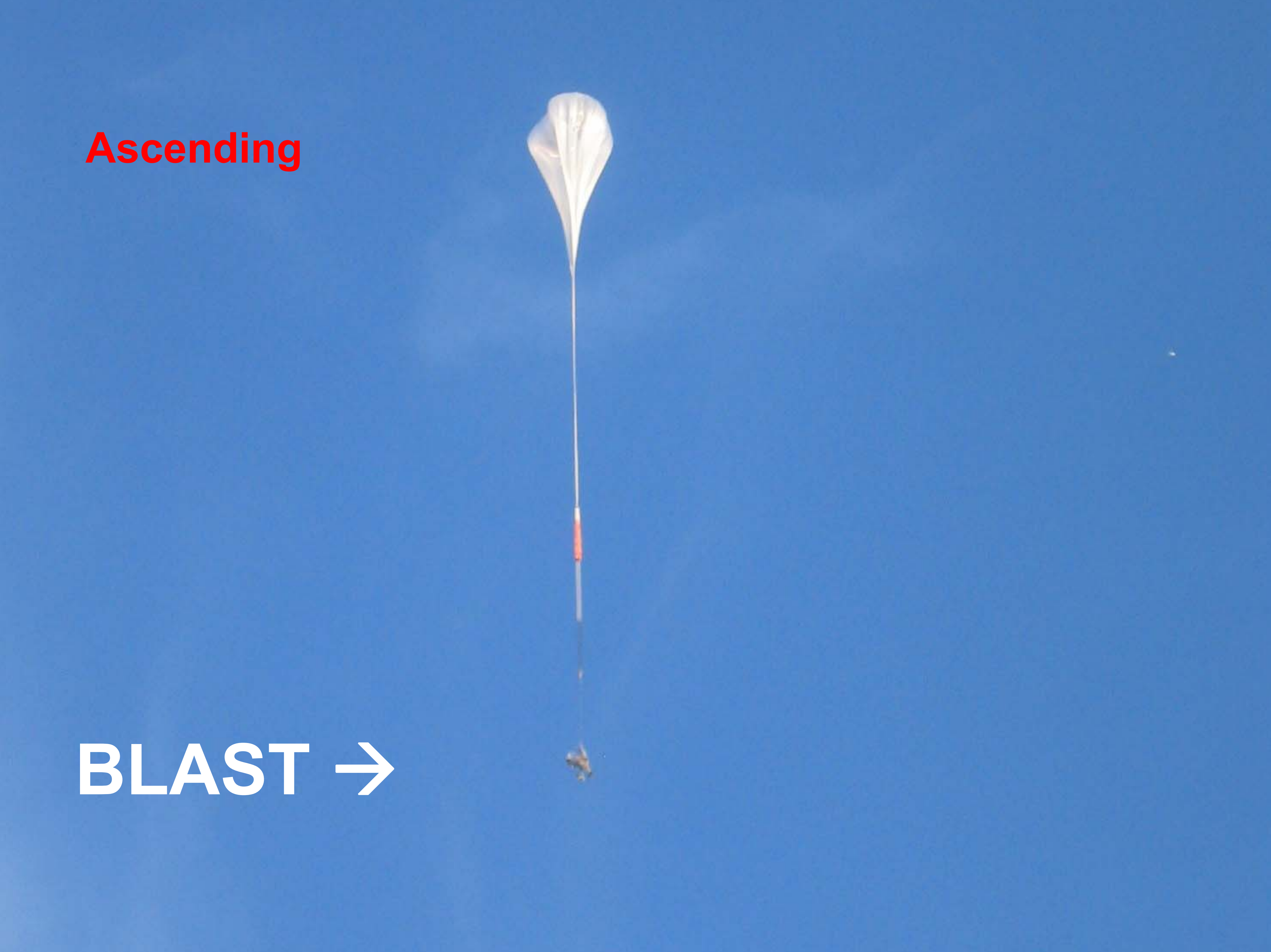



Star cameras
BLAST
Pre-launch preparations for June 2005 northern flight
from Kiruna, Sweden to Victoria Island, Canada

BLAST

With baffling, solar panels, telemetry…


BLAST
Inflation (the type that can be explained)


Ascending
BLAST →

BLAST

At float, 40 km

The End