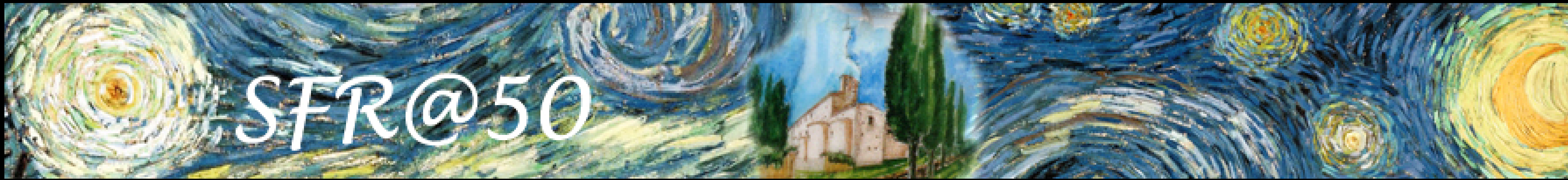


SFR@50: Filling the Cosmos with Stars

July 6-10 2009

ABBAZIA DI SPINETO

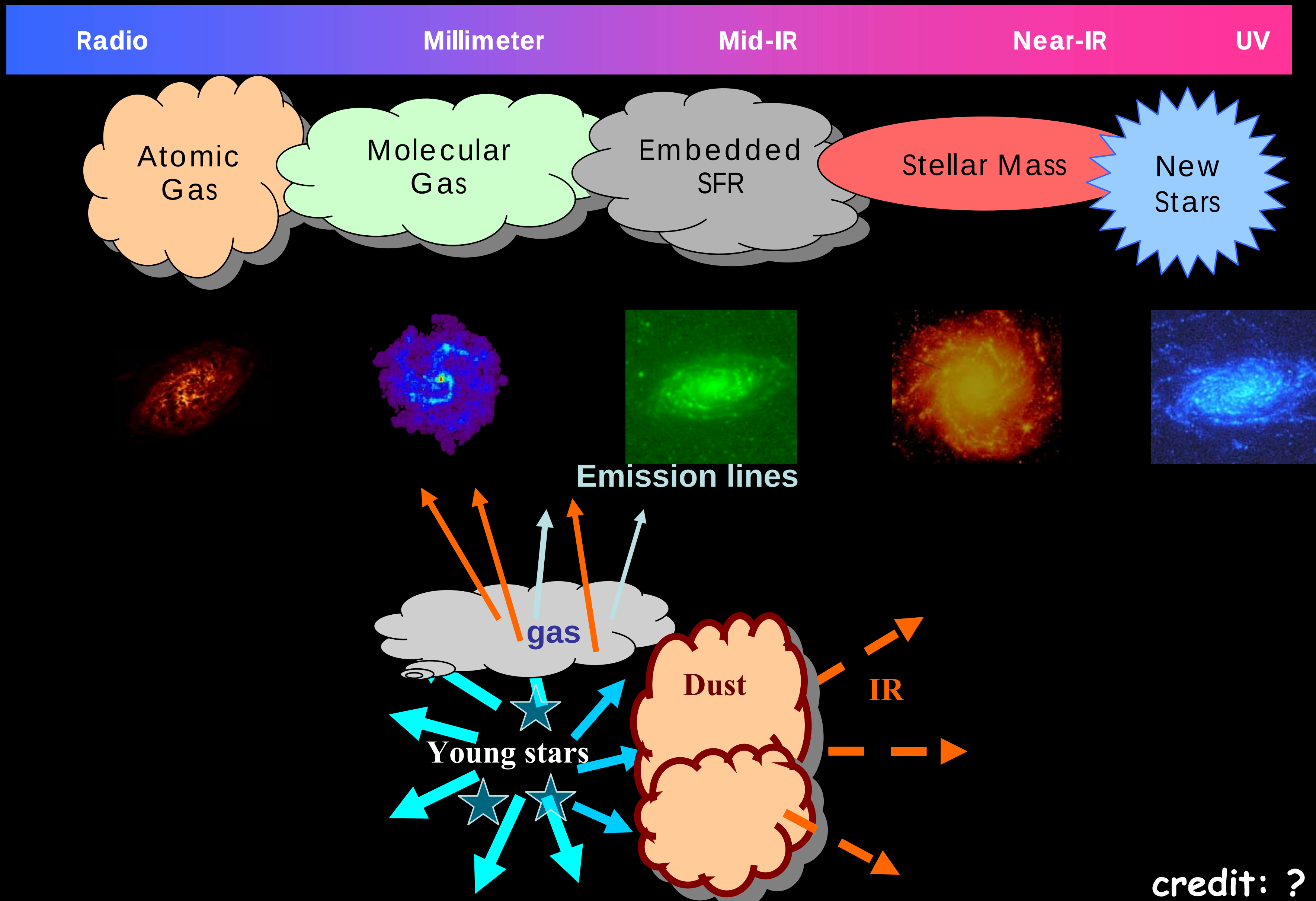
SARTEANO (SIENA), ITALY

Star Formation Rates from Brγ Observations

Hans Zinnecker, Astrophysical Institute Potsdam, Germany

AIP

What do we need to measure SF?



credit: ?

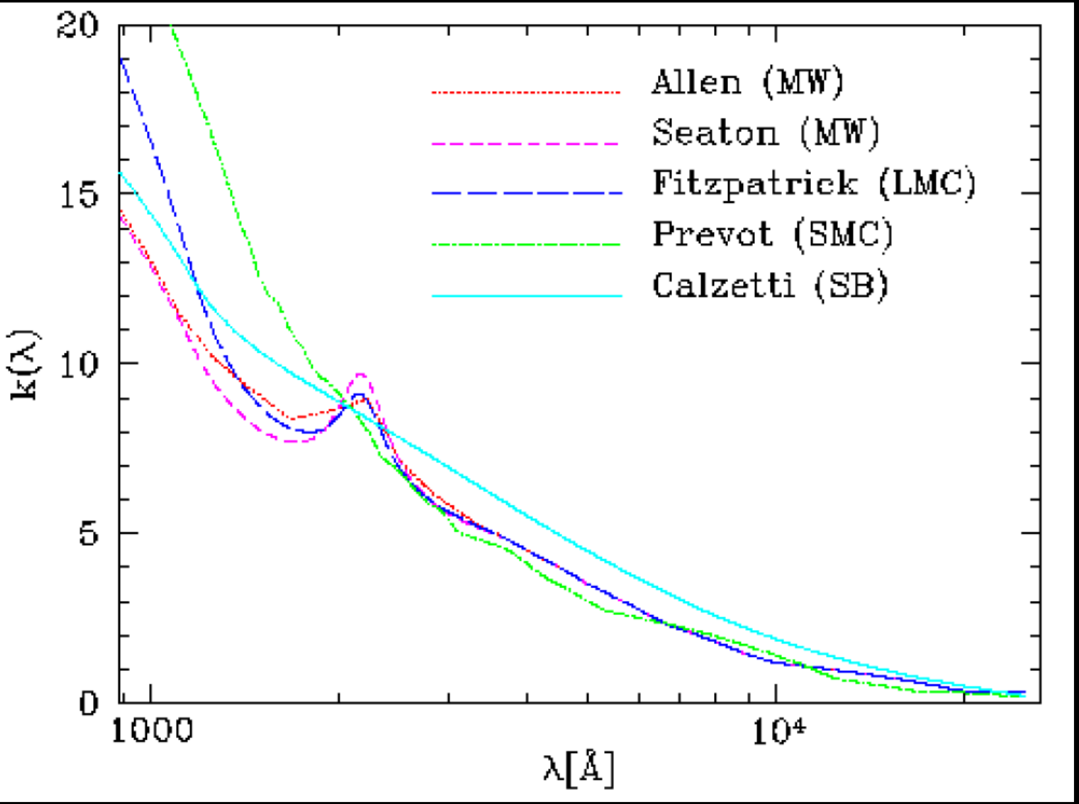
The Dual Effect of Dust:

Changes Morphology

M31 in the visible.

ISO map of M31.
(wavelength of 175 microns)
North is up, east is left.

Causes extinction



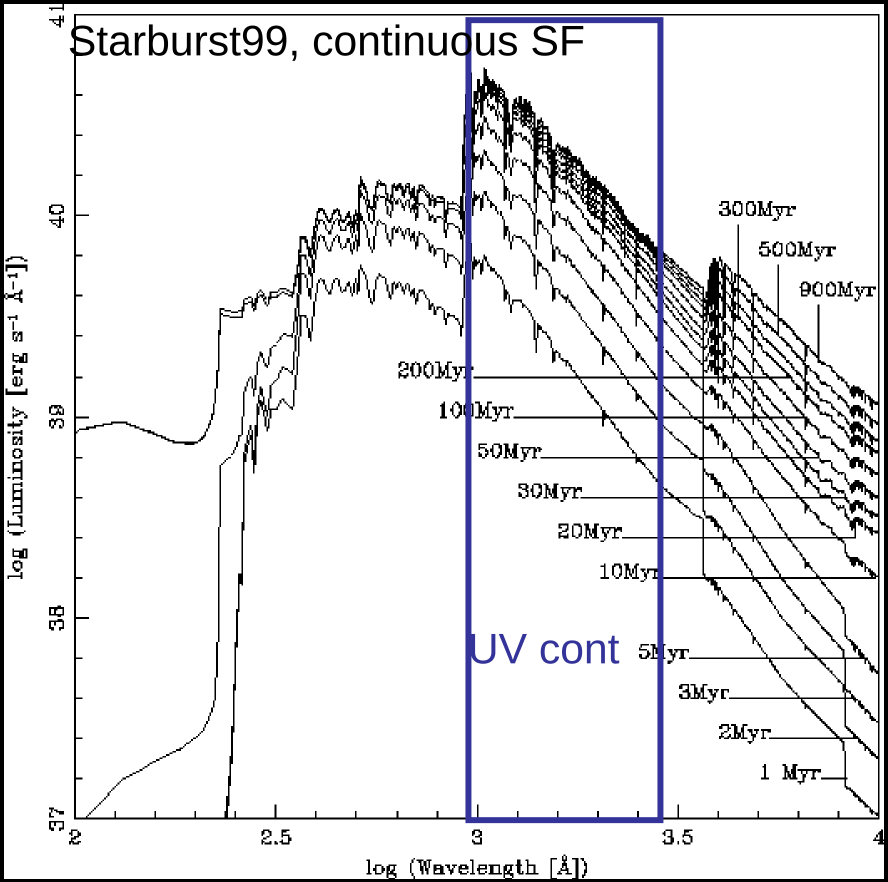
Interstellar extinction curve

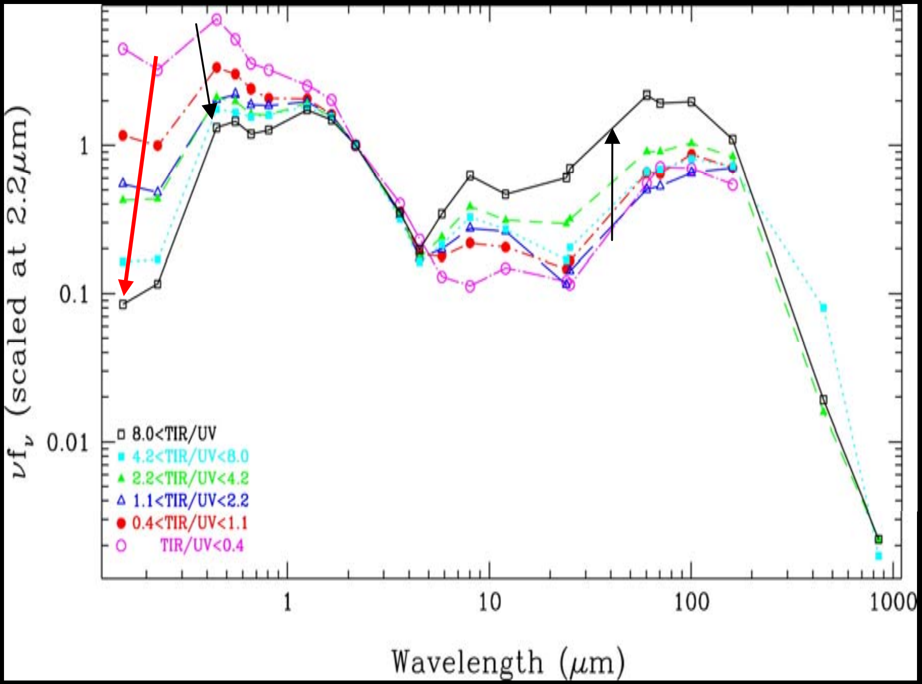
2175 Å bump Steep rise in far-UV,
$A(\lambda) \sim \lambda^{-1.8}$ in the infrared, $A_K \approx 0.1\ A_V$

The UV continuum

Very good SF tracer...

BUT....very sensitive to dust attenuation





Dale et al. 2007

Karjalainen, priv. comm.

SFR from recombination lines (Hα, Brγ)

Nebular lines re-emit the integrated stellar luminosity shortward of the Lyman limit (912 Å) ---> direct probe of young massive stars.

Only stars with $M > 10\ M_{\odot}$ and $t < 20$ Myr contribute significantly to the ionizing flux, so emission lines provide a nearly intantaneous measure of the SFR, independent of the previous SF history.

For solar abundance and Salpeter IMF (0.1 - 100 $M_{\odot}$) we have:

SFR ($M_{\odot}$/yr) = $8 \cdot 10^{-42}$ L(Hα, in erg/s)
SFR ($M_{\odot}$/yr) = $8 \cdot 10^{-40}$ L(Brγ, in erg/s)

PS. Note that the Lyc flux emitted by a massive star is prop. M^4

PhD project (Jan Ruppert, AIP/ESO)

Brγ NIR imaging of obscured starburst galaxies to detect embedded HII regions and derive Hα flux convert to OB star formation rate (Kennicutt 1998) and, via IMF extrapolation, derive local/total SFR

however:

only test data so far (NGC 7793, NGC 3603 Carina)

uncertainty in derived SFR due to IMF extrapolation

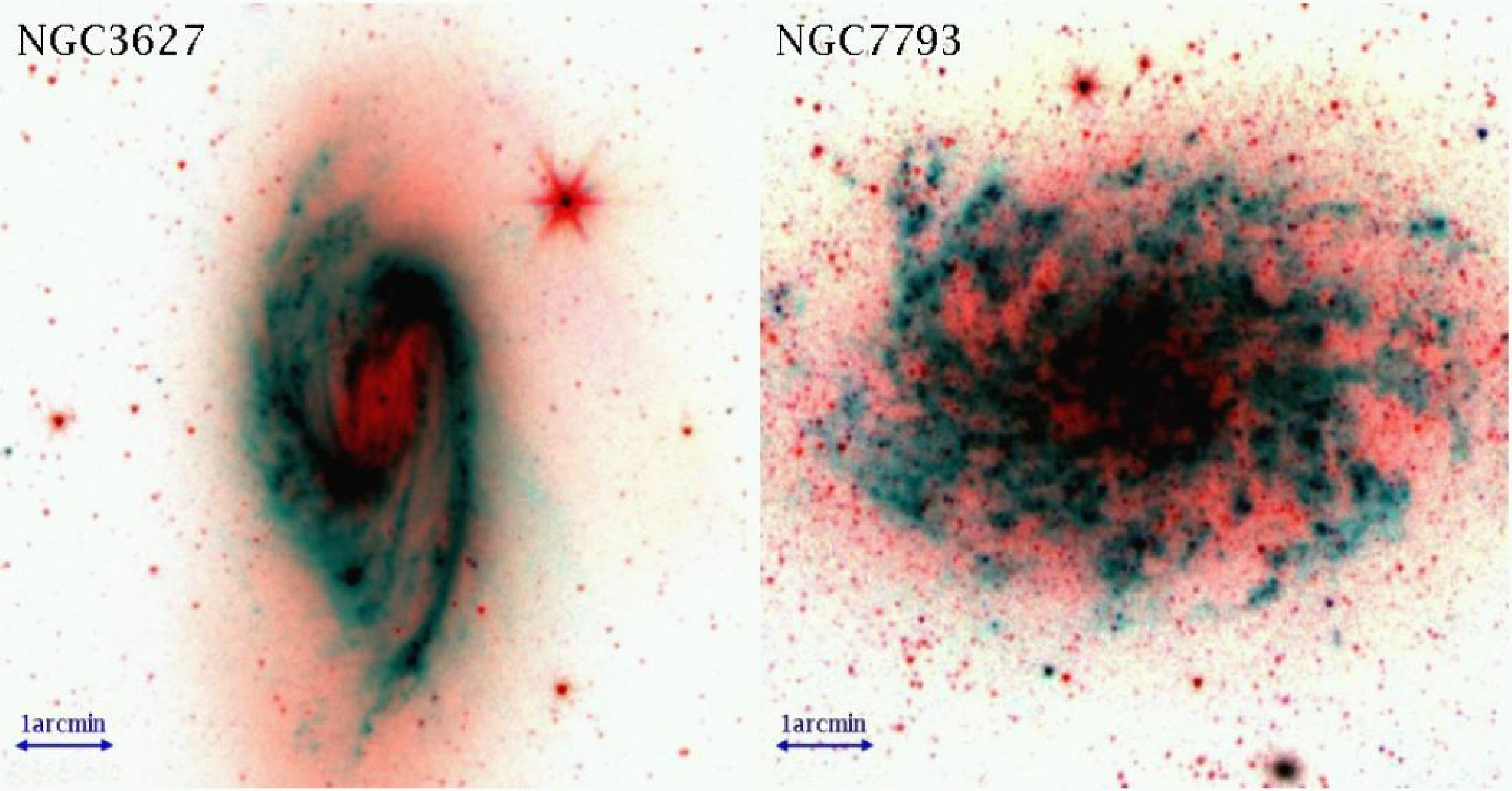


Fig. 2: These two additional images obtained from the Spitzer web gallery, also scaled to the HAWK-I FoV, demonstrate the suitability of HAWK-I for the study proposed here; HAWK-I is capable of covering our target galaxies in one pointing (almost).

Brackett gamma

hydrogen recombination line, n = 7 → 4, 2.166 micron

proxy for Hα, but Brγ 10 times less dust extinction

weak line: I(Hα) = 100 I(Brγ), Menzel Case B theory

need for large 8m-class telescope, wide-field of view

problems:

narrow-band filter (1%), redshift less than 1500 km/s

high NIR-background (K-band continuum + OH airglow)

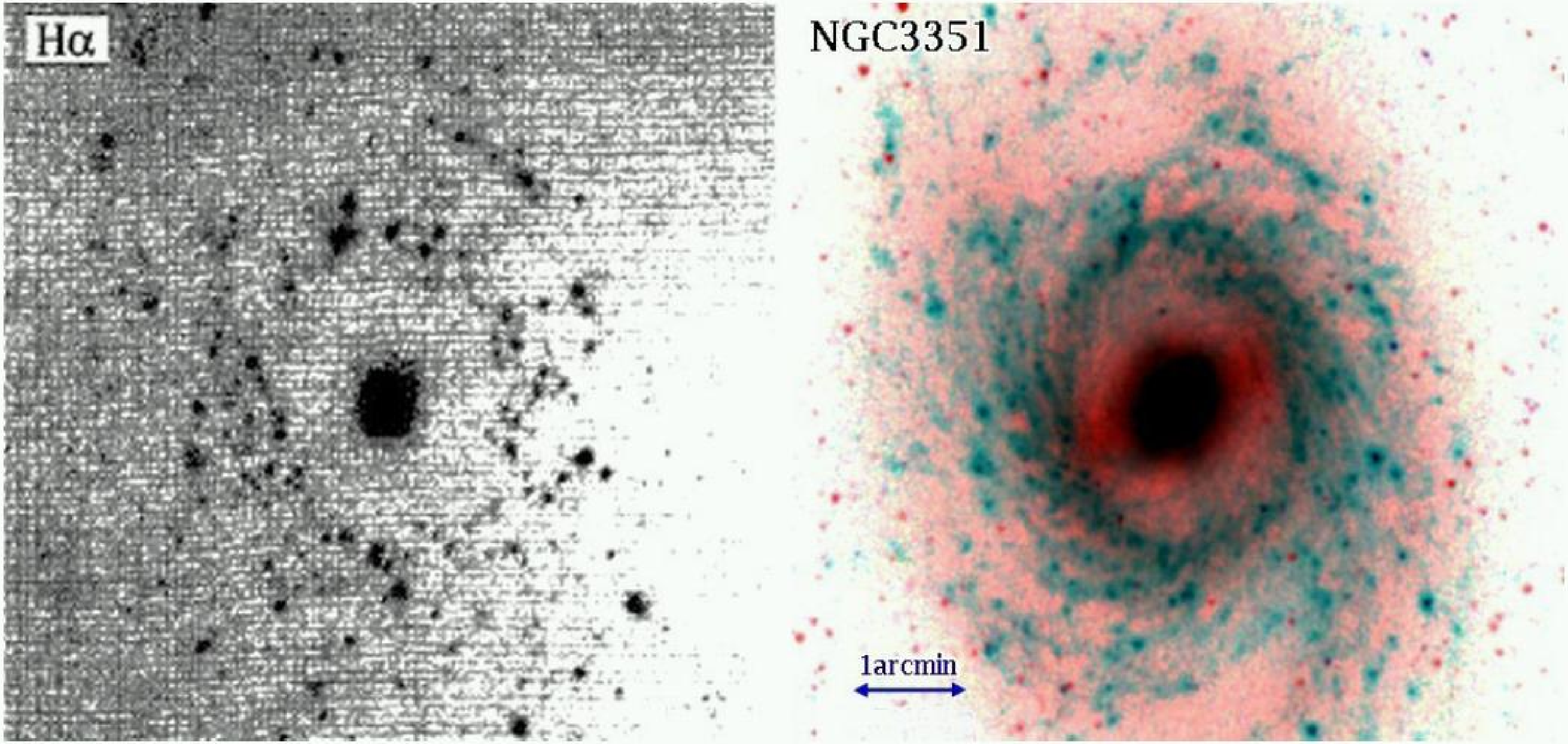


Fig. 1: The figure on the left shows the spatial Hα distribution in the NGC3351 galaxy (SBb type), revealing the strong clumpiness of Hα leading to at least one hundred HII regions in this galaxy (Young et al. 1996). The right panel shows the corresponding Spitzer composite image with the dark parts being 5.8 and 8.0μm data, taken from the Spitzer web gallery. The images shown are approximately full scale to one whole HAWK-I FoV of $7.5' \times 7.5'$.

HAWK-I camera (VLT)

JHK, Brγ, H_2 filters

7.5 x 7.5 arcmin large FOV, ~ 0.1 arcsec pixels

cf. Grosbol poster: K-band imaging (high SB knots)

S/N = 10 in 30 min for HII region Brγ at 10 Mpc

competition from space:

cf. Calzetti (2007): Paα 1.87 μm (HST/NICMOS)

24 micron Spitzer imaging observations (SINGS SFR)

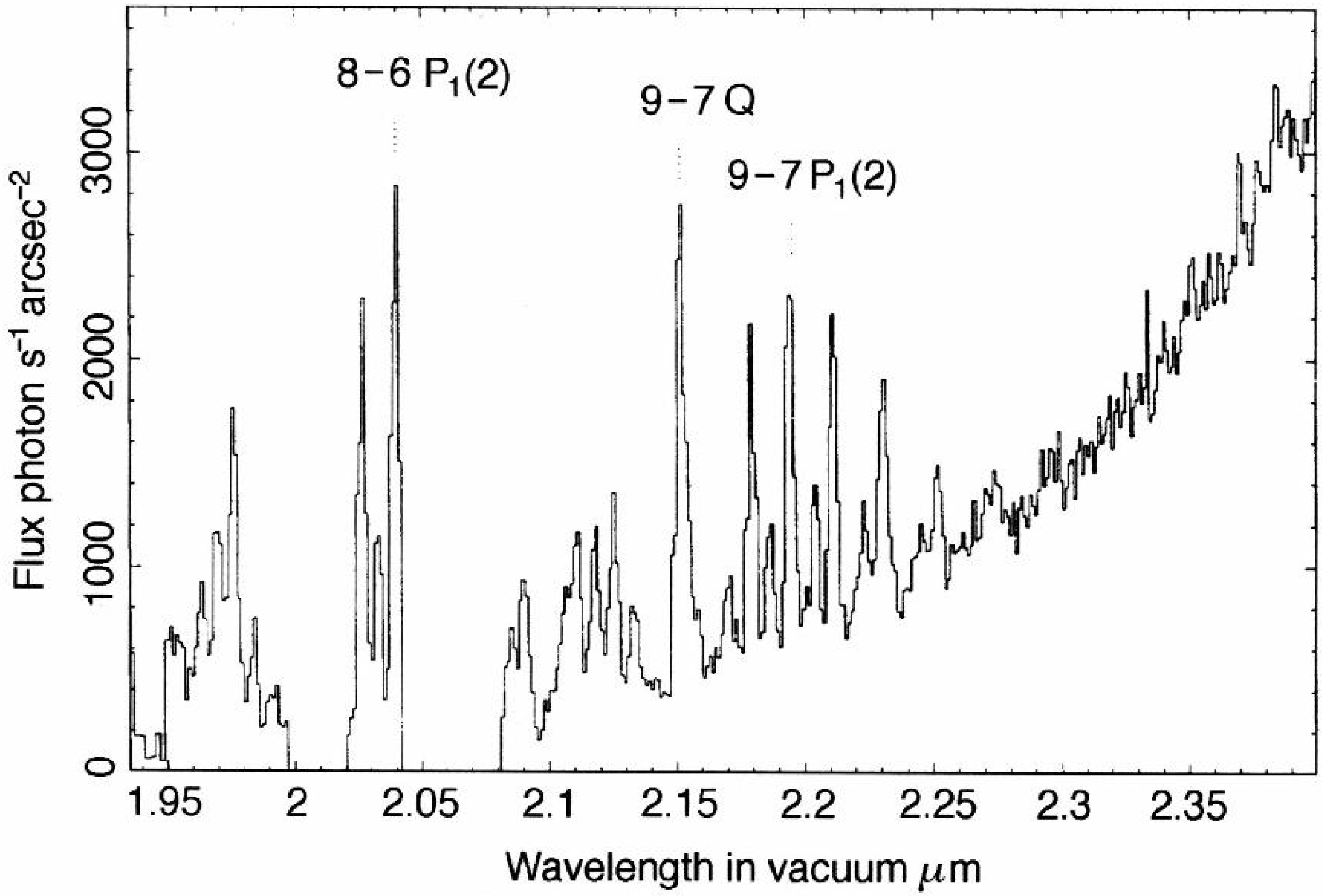
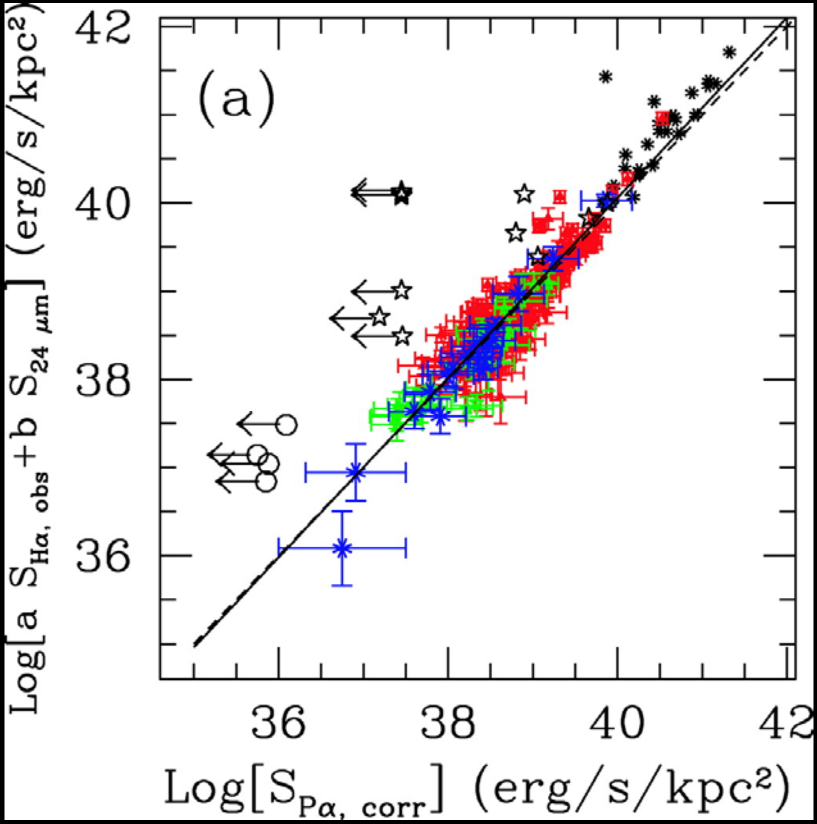


Fig. 2.6. Airglow emission in the *K*-band; from Ramsey, Mountain and Geballe (1992).

Glass J.S. 1999, Handbook of Infrared Astronomy, Cambridge University Press

combining Hα (unobscured SF) and 24 μm (obscured SF)

Calzetti et al. 2007, Kennicutt et al. 2007



$$SFR(M_\odot\ yr^{-1}) = 5.3\ 10^{-42}\ (L(H\alpha_{obs}) + 0.031\ L_{24\mu m})\ (erg\ s^{-1})$$

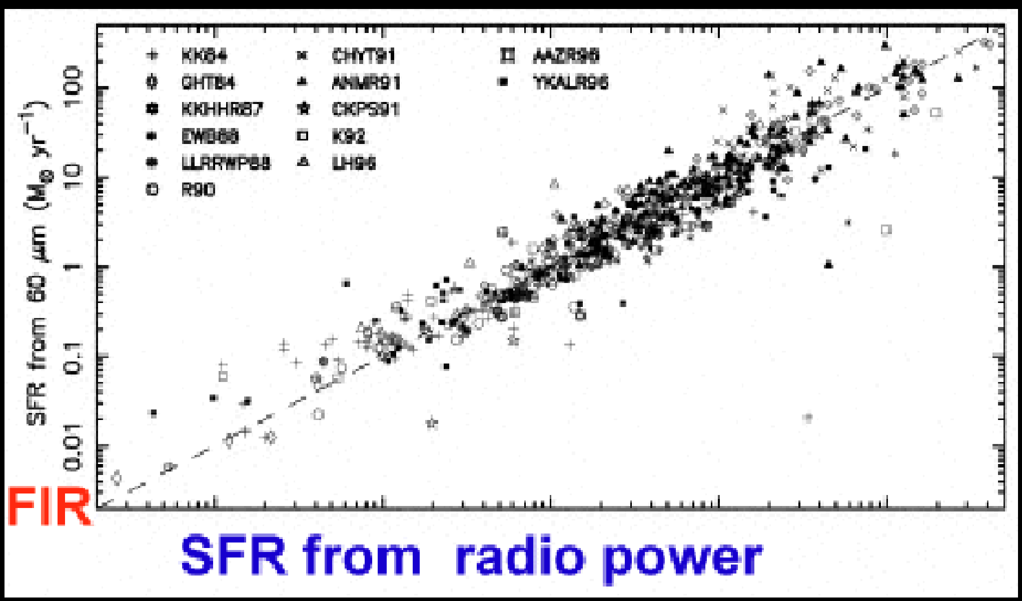
Star Formation Rates (SFR) from Radio Continuum

Very tight correlation between SFRs from FIR and radio.

Same massive young stars produce synchrotron emission (e.g. supernovae) and FIR emission

SFR can also be estimated from the number of O stars required to produce thermal free-free continuum emission.

No dust extinction but can be difficult to separate thermal and non-thermal components



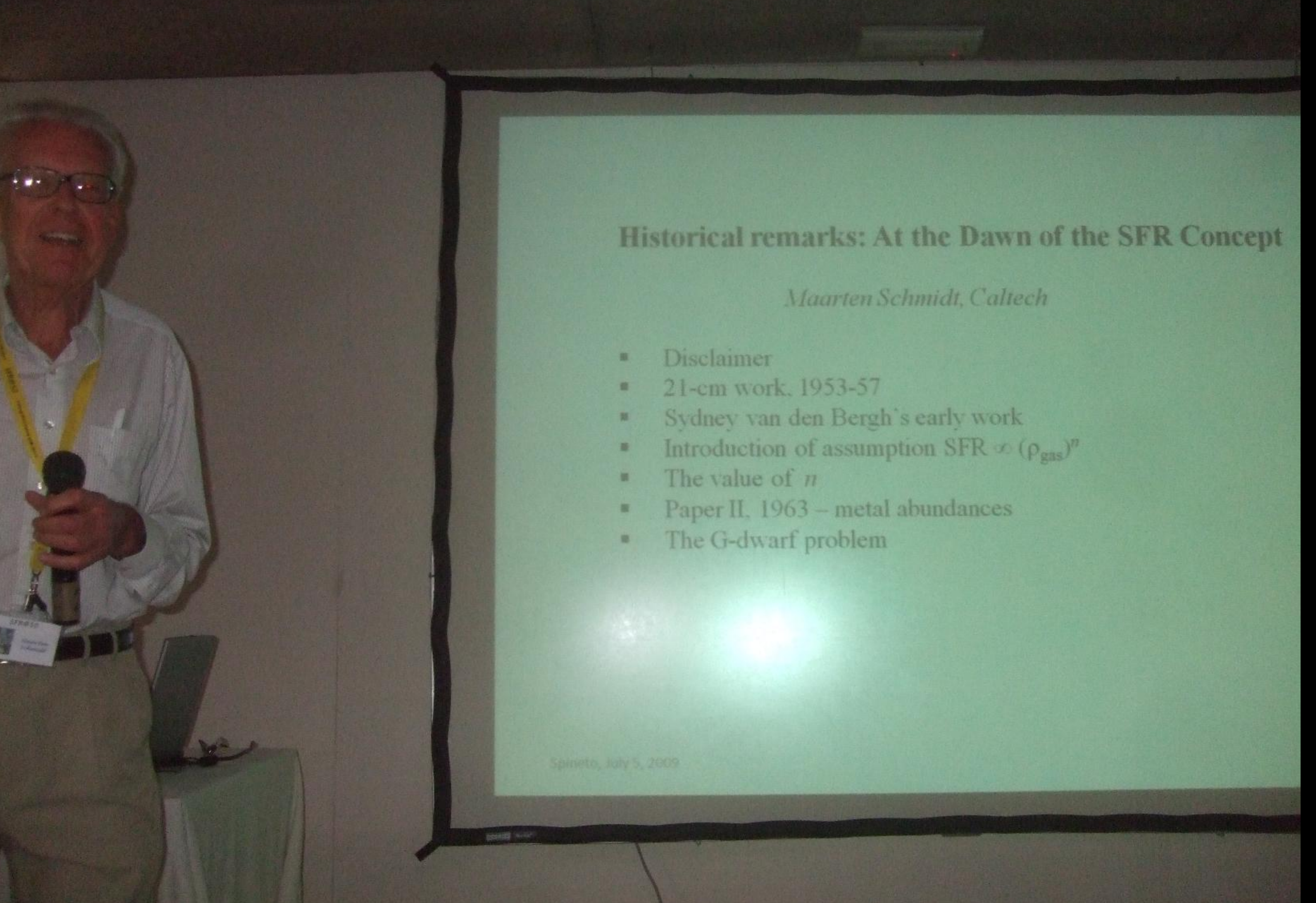
Infra-red continuum

$$SFR_{FIR}(M \geq 5M_\odot) = \frac{L_{60\,\mu m}}{5.1\times10^{23}\,WHz^{-1}}\,M_\odot yr^{-1}$$

Total Radio Continuum

$$SFR_{1.4}(M \geq 5M_\odot) = \frac{L_{1.4}}{4.0\times10^{21}\,WHz^{-1}}\,M_\odot yr^{-1}$$

Karjalainen, priv. comm.


Historical remarks: At the Dawn of the SFR Concept
Maarten Schmidt, Caltech
Disclaimer
21-cm work, 1953-57
Sydney van den Bergh's early work
Introduction of assumption SFR ∝ (ρgas)n
The value of n
Paper II, 1963 – metal abundances
The G-dwarf problem
Spineto, July 5, 2009


SFR@50
Lessons from the First 50 Years
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M51
Herschel/PACS
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start

THE ASTROPHYSICAL JOURNAL

AN INTERNATIONAL REVIEW OF SPECTROSCOPY AND
ASTRONOMICAL PHYSICS

VOLUME 129 MARCH 1959 NUMBER 2

THE RATE OF STAR FORMATION

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Mount Wilson and Palomar Observatories
Carnegie Institution of Washington, California Institute of Technology
Received October 29, 1958

$$\rho_{SFR} = a\,\rho^{n}_{gas}$$

THE RATE OF STAR FORMATION. II. THE RATE OF FORMATION OF STARS OF DIFFERENT MASS

Maarten Schmidt
Mount Wilson and Palomar Observatories
Carnegie Institution of Washington, California Institute of Technology
Received October 8, 1962

$$\Sigma_{SFR} = A\,\Sigma^{N}_{gas}$$

Stages of Scientific Discovery

SCHMIDT

- **Discovery** (that eureka moment, "Holy ----!")
- **Characterisation, phenomenology**
  - number counts, classification (Types I, II, III, Ia, IIc...), channel maps, "JPEG science", "MPEG science"
  - complete samples, correlations, trends
- **Synthesis, integration**
  - theoretical interpretation (observational confirmation)
  - acceptance, widespread application, second-order discoveries, (over)interpretation
- **Maturation, challenge, conflict**
  - skepticism, contradition
  - [illegible] and dementia, re-discovery