Results

Spectroscopy of Very Low Mass Stars and Brown Dwarfs in the LOSFR.

Enlarging the census down to the planetary mass domain in C69

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ESO, Garching

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Outline



Introduction

- Low mass SF
- The Lambda Orionis Star Forming Region
- Goals



Our surveys

Photometry and X-rays

3 F

Results

- SED analysis
- C69 Age estimation
- Activity and accretion
- Disks Properties
- Spatial distribution
- The IMF of Collinder 69



Introduction 000

Low mass SF Theory











 Turbulent fragmentation (Padoan & Nordlund, 2002. Hennebelle & Chabrier. 2008. Chabrier & Hennebelle, 2011):

density enhancements \rightarrow decrease the Jeans mass

- Ejection scenario (Reipurth & Clarke 2001): stellar embryos ejected before accreting enough mass for H burning.
- Photoevaporation (Whitworth & Zinnecker 2004): winds from massive nearby stars \rightarrow lost envelopes of protostellar cores.
- Disk fragmentation (Goodwin & Whitworth, 2007) and Stamatellos et al 2007): scaled up version of planets.

Hogerheilde 1998, after Shu et al. 1987





- A. ~8-10 Myr ago, the λ Ori region was composed of a starless, roughly linear string of dense molecular clouds.
- B. Over the next few Myr, stars began to form in the densest portions of this cloud chain. 6 Myr ago, a dozen OB stars formed near λ Ori's present-day position while lowmass stars formed in all productive areas of the star-forming complex.
- C. ~1 Myr ago, one of the O stars became a supernova. The blast quickly dispersed all of the parent core, creating the molecular ring, the large HII region, and the nearby HI structures.
- D. Today we see the fossil distribution of young stars within the molecular ring, as well as the remnants of the B30 and B35 clouds within the ionized region.



- Spectroscopically confirm the lowest mass members of the three associations (including Brown Dwarfs and IPMOS).
- Build complete census for the three regions.
- Relate properties of individual sources (acc. rates, etc.) with three different environments (ages).
- Build a very complete IMF for Collinder 69 from \sim 20 M $_{\odot}$ down to the planetary mass domain (shared mechanism of formation for low mass domain?).
- "Test" the Supernova hypothesis.

Results

Conclusions

Photometric and X-ray surveys





| Theoretical model se | ervices | | Documents Models | Services 🌆 🁔 | | | | |
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| LOri003 Bayo et al. (2008) | | | | | | | | |

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| LOri005 | CFHT_R | 6582 3.07 | 9827e-15 2.8 | 36626e-17 | 3.079827e-1 | 5 2.83662 | 6e-17 | Delet | e | | |
| L Ori007 | CFHT_I | 8228 4.57 | 9084e-15 4.2 | 17492e-17 | 4.579084e-1 | 5 4.21749 | 2e-17 | Delet | e | | |
| LOri008 | 2MASS_J | 12350 4.53 | 8110e-15 1.0 | 86736e-16 | 4.538110e-15 | 5 1.08673 | 6e-16 | Delet | e | | |
| LOri009 | 2MASS_H | 16620 3.08 | 5872e-15 7.6 | 73922e-17 | 3.085872e-1 | 5 7.67392 | 2e-17 | Delet | e | | |
| L Ori010 | 2MASS_Ks | 21590 1.67 | 0090e-15 2.9 | 22599e-17 | 1.670090e-1 | 5 2.92259 | 9e-17 | Delet | e | | |
| LOri011 | IRAC_I1 | 35634 5.34 | 7884e-16 1.4 | 77675e-18 | 5.347884e-16 | 6 1.47767 | 5e-18 | Delet | 0 | | |
| LOri012 | IRAC_I2 | 45110 3.14 | 8220e-16 8.6 | 98853e-19 | 3.148220e-16 | 6 8.69885 | 3e-19 | Delet | 0 | | |
| LOri013 | IRAC_I3 | 57593 1.96 | 8669e-16 1.0 | 87927e-18 | 1.968669e-16 | 6 1.08792 | 7e-18 | Delet | 0 | | |
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| LOri018 | Apply exce | ss from IRAC_I | | | | | | | | | |
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C69. Spectroscopic Characterization

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VOSA

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Model fit

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Best fit results

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|---------|-----------|------------|-----------|---------------|-------------|--------|----------|------|----------------|--------------|----------------|-------------------|------------|------------------------------------|-------------------------------------|------------------|------------------------------------|-------|
| LOri001 | 83.446583 | 9.9273611 | 400.000 | COND00 | 4000 | 2.5 | 0.0 | | 8.03e+1 | 1.30e-20 | 1.84e-10 | 1.26e-12 | 0.49 | 9.19e-1 | 6.26e-3 | 79594 | 9/9 | Syn.8 |
| LOri002 | 84.043167 | 10.148583 | 400.000 | Kurucz | 3750 | 0.00 | -1.50 | | 6.46e+1 | 1.80e-20 | 1.96e-10 | 1.42e-12 | 0.49 | 9.77e-1 | 7.07e-3 | 79594 | 9/9 | Syn.8 |
| LOri003 | 83.981000 | 9.9420833 | 400.000 | Kurucz | 4000 | 0.00 | 0.20 | | 1.04e+1 | 1.09e-20 | 1.59e-10 | 1.11e-12 | 0.46 | 7.92e-1 | 5.56e-3 | 21590 | 5/9 | Syn.8 |
| LOri004 | 83.948125 | 9.7640278 | 400.000 | NextGen | 3900 | 5.0 | 0.0 | | 1.98e+1 | 1.17e-20 | 1.55e-10 | 1.07e-12 | 0.45 | 7.71e-1 | 5.32e-3 | 21590 | 5/9 | Syn.8 |
| LOri005 | 83.473542 | 0.7400000 | **** **** | | | ~ ~ | ~ ^ | | · · · · · · | 101-00 | 1 10 | 1 000 10 | A 44 | · · · · · | · · · · · | 79594 | 9/9 | Syn.8 |
| LOri006 | 83.817750 | | | | | | | | | | | | | | | 21590 | 5/9 | Syn.8 |
| LOri007 | 83.623125 | | | | 100115 | | | | | | | 10 | 1100 | | | 21590 | 5/9 | Syn.8 |
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| LOri015 | 83.591000 | , (er | 1 | | | | | • | e. | | - MPE 1 | | | | | 79594 | 9/9 | Syn.8 |
| LOri016 | 83.806250 | 11. 10~-10 | | | | | 1.1 | | щ | n-n <u>∃</u> | 10. | | | | | 21590 | 5/9 | Syn.8 |
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| LOri018 | 84.069125 | 187-19- | | | | | | | | | | | | | | 21590 | 5/9 | Syn.8 |
| LOri019 | 83.807042 | | | 1074 | | | | 10 | -5 | | | 11 | | ź | ×1(| 21590 | 5/9 | Syn.8 |
| LOri020 | 83.739875 | | | | λ(A) | | | | | | | 2 | (A) | | | 21590 | 5/9 | Syn.8 |
| LOri021 | 83.778917 | | | | | | | | | | | | | | | 79594 | 9/9 | Syn.8 |
| LOri022 | 83.963958 | 9.9196667 | 400.000 | NextGen | 3800 | 5.0 | 0.0 | | 2.89e+1 | 7.05e-21 | 8.31e-11 | 5.78e-13 | 0.48 | 4.15e-1 | 2.88e-3 | 57593 | 8/9 | Syn.8 |
| LOri023 | 83.990208 | 9.7929444 | 400.000 | NextGen | 3900 | 5.0 | 0.0 | | 2.63e+1 | 6.10e-21 | 7.86e-11 | 5.84e-13 | 0.48 | 3.92e-1 | 2.91e-3 | 79594 | 9/9 | Syn.8 |
| LOri024 | 83.737958 | 9.9100278 | 400.000 | COND00 | 3900 | 2.5 | 0.0 | | 2.00e+1 | 5.86e-21 | 7.69e-11 | 6.48e-13 | 0.46 | 3.84e-1 | 3.23e-3 | 21590 | 5/9 | Syn.8 |
| LOri025 | 84.084083 | 9.7338889 | 400.000 | Kurucz | 3500 | 1.50 | -2.50 | | 1.57e+1 | 9.26e-21 | 7.81e-11 | 9.72e-13 | 0.46 | 3.89e-1 | 4.85e-3 | 21590 | 5/9 | Syn.8 |

C69. Spectroscopic Characterization

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| LOri001 | | Here you | can see | , for each m | odel, | the relative | probability | found for eac | h | | | |
| LOri002 | | parameter. | | | | | | | | | | |
| LOri003 | | Only those | with a p | robability high | er thar | n 1e-5 are sh | own. | | | | | |
| LOri004 | | | | | | | | | | | | |
| LOri005 | The N | lextGen M | odel At | mosphere g | rid. | Deeds at 1994 | | | | | | |
| LOri006 | meta. | Probability | 1099 | Probability | eff | Probability | | | | | | |
| LOri007 | 0.0 | 1.000000 | 5.0 | 0.999242 | 4000 | 1.000000 | | | | | | |
| LOri008 | | | 5.5 | 0.000756 | | | | | | | | |
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| LONOT | 55 | 0.034216 | | | | | | | | | | |
| LOH012 | | 0.004210 | - | | | | | | | | | |
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| LONOIS | 2.5 | 0.891237 | 4000 | 1.000000 | | | | | | | | |
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| LOri020 | -2.50 | 0.233853 | 0.50 | 0.000167 | 4000 | 1.000000 | | | | | | |
| LOri021 | -2.00 | 0.657809 | 1.00 | 0.016678 | | | | | | | | |
| LOri022 | -1.50 | 0.103494 | 1.50 | 0.285839 | | | | | | | | |
| LOri023 | -1.00 | 0.004745 | 2.00 | 0.655479 | | | | | | | | |
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| LOri027 | | | | | | | | | | | Bavo et a | al. (2008 |

| Introduc | |
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| | |

Results



Spectroscopic confirmation of candidates

- Alkali lines \Rightarrow youth indicators
- Emission lines ⇒ activity and accretion

Results

Conclusions

Alkali: signpost of youth



Lambda (A)

Alkali: signpost of youth



Results

Conclusions

Alkali: signpost of youth



| Our surveys | Results | Conclusions |
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The youth of C69



| Our surveys | Results | Conclusions |
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The youth of C69



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Results ○○○○●○○○○○ Conclusions

Alkali variability



| Intro | |
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Results

Conclusions

Alkali variability



| Our surveys | Results | Conclusions |
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| Our surveys o | Results ○○○○○○●○○○ | Conclusions |
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Distinguishing between accretion and activity



Saturation criteria Barrado y Navascués & Martin (2003)

| Our surveys o | Results ○○○○○○●○○○ | Conclusions |
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Saturation criteria Barrado y Navascués & Martin (2003)

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Disks Properties and distribution

Disk and diskless populations unevenly distributed \Rightarrow Not consistent with SN hypothesis.

Stellar disk fraction 28.5%

Sub-stellar disk fraction >30%

Barrado y Navascués et al. (2004) 40% Scholz et al. (2007) 37.9% for Upper-Sco

Accretors fraction

sub-stellar 18%

Scholz et al. (2007) 31% for Upper Sco (low-mass and sub-stellar)



Introduction

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Spatial distribution of the members



Homogeneous distribution of both BDs and stars

⇒ Caveats to ejection scenario

Results

Conclusions

IMF of Collinder 69



 $R_{SS} = \frac{N(0.02 \le M/M_{\odot} \le 0.08)}{N(0.08 \le M/M_{\odot} \le 10)}$

Briceño et al. (2002)

Collinder 69 \Rightarrow 0.06

~ Taurus

Briceño et al. (2002)

< Taurus

revised by Guieu et al (2006)

< ONC

Kroupa et al. (2003)

Results

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IMF of Collinder 69



C69. Spectroscopic Characterization



- Complete census of ~175 spectroscopicaly confirmed members plus 60 photom. probable members.
- Physical parameters derived for the spectroscopic sample: Spectral Type, Hα and Li I equivalent width, accretion rates, etc.
- Age study: upper limit of 20 Myr, optimal 5 Myr.
- One of the most complete spectroscopic IMF reported so far (from $\sim 20 M_{\odot}$ down to 20 M_{Jup} ; the photometric reaches 8_{Jup})
- No evidence of mass segregation (caveats on ejection scenario for BD formation)
- Study of the disks properties: Not consistent with SN scenario

Bayo et al. (2011)

THANK YOU!!!