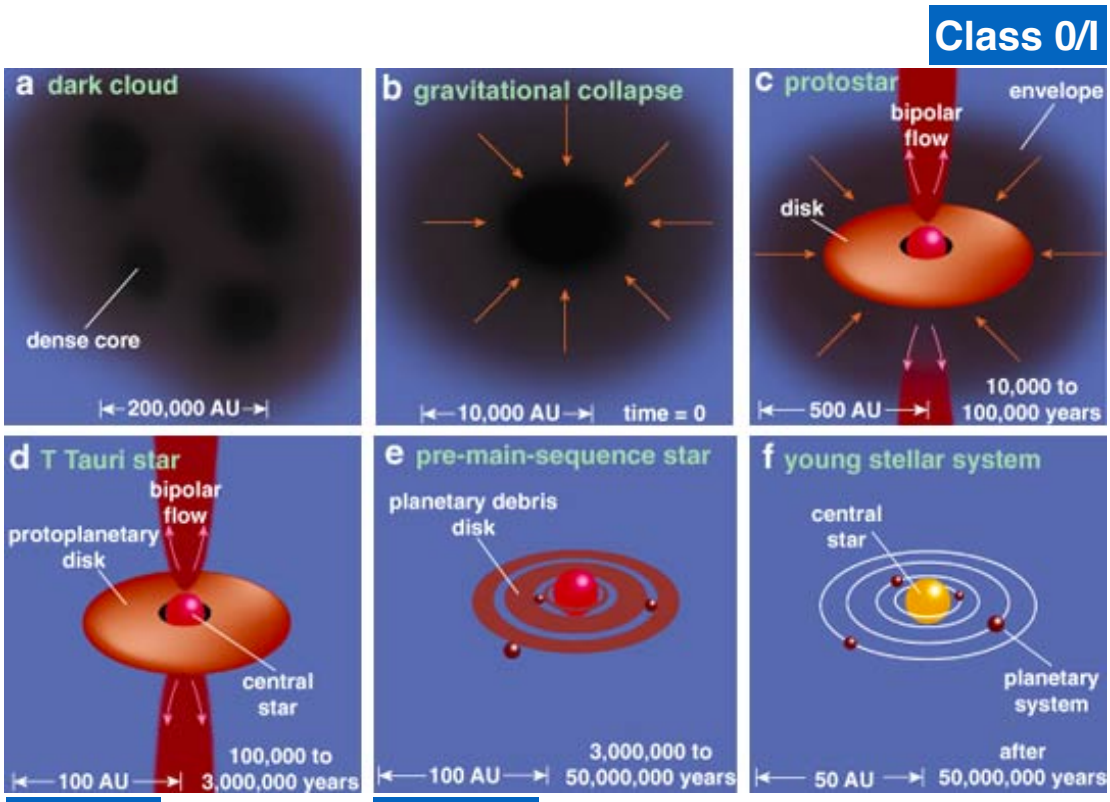
BISTRO 1 & 2

2019 Radio Telescope User's Meeting
서울대학교 평창캠퍼스
2019 August 30

권우진 (Woojin Kwon)
on behalf of the BISTRO team

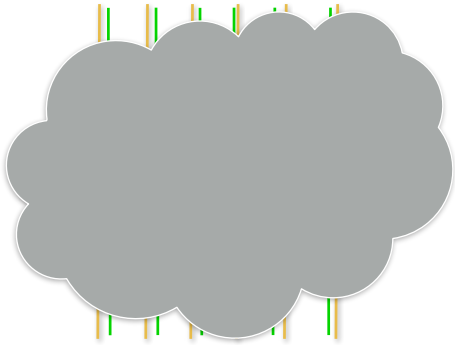
Star & Planet Formation



physicsoftheuniverse.com

B in star formation

- Gravity vs. “Pressure”
  Molecular clouds last longer than the free-fall time scale.
  Low star formation efficiency (e.g., Carpenter 2000)
- **Turbulence models**
  e.g., Hartmann et al. 2001
  random field morphology
  short time scale of star formation
- **Strong magnetic field models**
  e.g., Mouschovias 1991
  ordered field morphology
  flattened perpendicular to B fields
  relatively long time scale of star formation



Magnetic field morphology provides a tool to confront the two scenarios!

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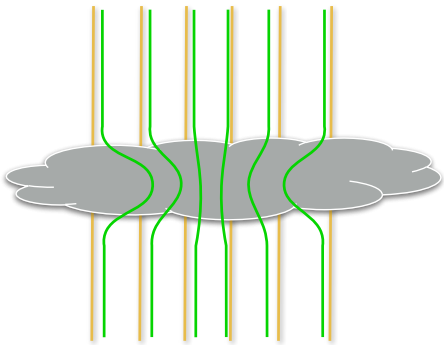
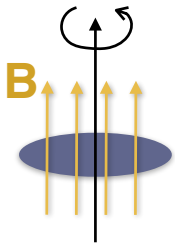
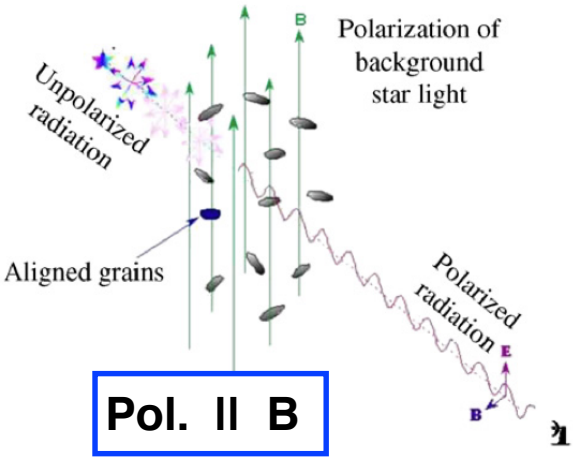


Magnetic field morphology provides a tool to confront the two scenarios!

Polarization vs. magnetic fields

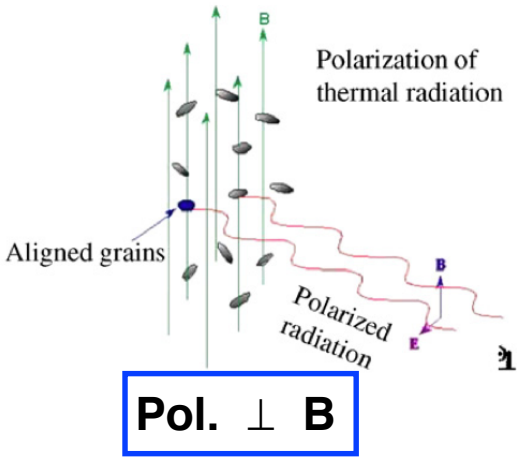


Background extinction
: visible, near-IR



Pol. ll B

Dust thermal emission
: far-IR, sub/mm

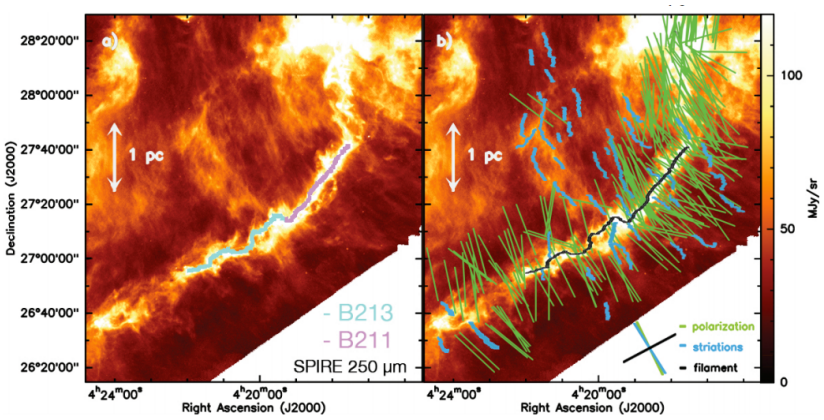


Pol. ⊥ B

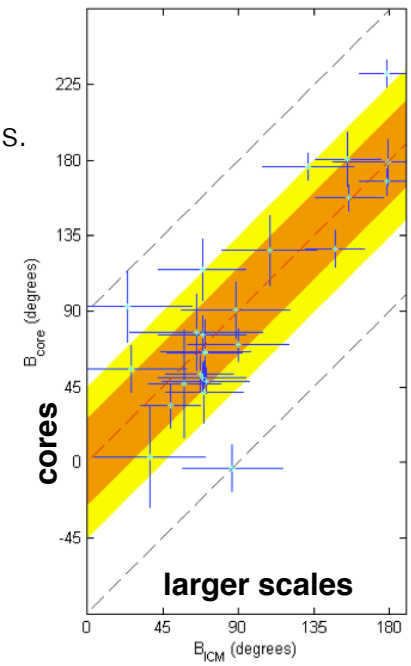
Lazarian 2007

B in large scales (> 1000 au)

- Ordered fields in filamentary structures
- Consistent fields down to cores
- Magnetic fields play a significant role in theses scales.



Palmeirim et al. 2013



Li et al. 2009, 2014

BISTRO

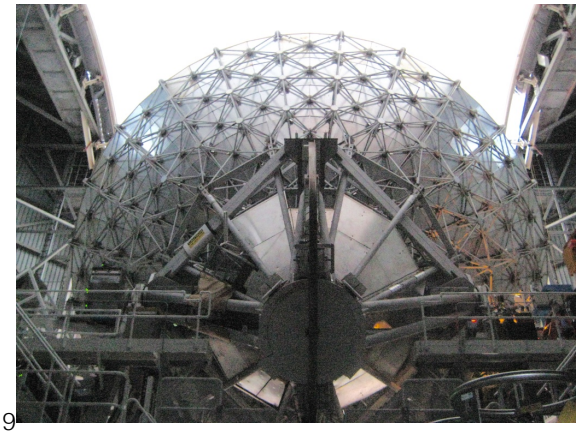
- **B**-fields **I**n **ST**ar-forming **R**egin **O**bservations
- JCMT POL-2 project
- Aims to map Gould Belt star-forming regions in dust polarization at 850 μm for intermediate field structures (1000—10000 au scales)
- PIs
  Derek Ward-Thompson (UK)
  Pierre Bastien (Canada), Tetsuo Hasegawa (Japan),
  Woojin Kwon (Korea), Shih-Ping Lai (Taiwan), Keping Qiu (China)
- Members >130 (28 in BISTRO-Korea)
- 224 hours (16 fields x 14 hours/field) awarded: 2016—2018
- BISTRO-2: 224 hours, farther/massive star forming regions

Scientific Goals

- To map the magnetic field within cores and filaments, on scales of ~1000–10000 au
- To determine magnetic field strengths in nearby molecular clouds using the Chandrasekhar-Fermi method (through synthesis with Gould Belt Survey HARP data)
- To investigate the relative importance of magnetic fields and turbulence to star formation
- To test the model of magnetic funneling of material onto filaments (André et al. 2013; Palmeirim et al. 2013)
- To investigate the role of magnetic fields in shaping protostellar evolution
- To investigate the effect of magnetic fields on bipolar outflows from young protostars

JCMT

- James Clerk Maxwell Telescope
- Mauna Kea, Hawaii
- Operated by East Asian Observatory since 2015: KASI, NAOC, ASIAA, NAOJ
- 15 m single dish
  HARP: Heterodyne Array Receiver Program, 16 pixels, 325—375 GHz
  SCUBA-2 (+ POL-2): Submillimeter Common-User Bolometer Array 2, 10000 pixels, 450/850 μm
  Namakanui ("Big-Eyes", from 2019B): heterodyne receivers at 86, 230, 345 GHz
- CADC: Canadian Astronomy Data Centre
- Starlink: reduction tool



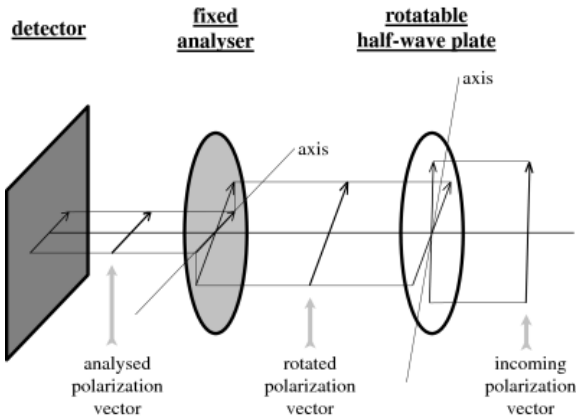
POL-2: The Instrument

Credit: POL-2 User Manual

Half-wave plate
(2Hz rotation)

Fixed analysers

- A single-beam imaging polarimeter
- Measure linear polarization (Stokes Q & U)



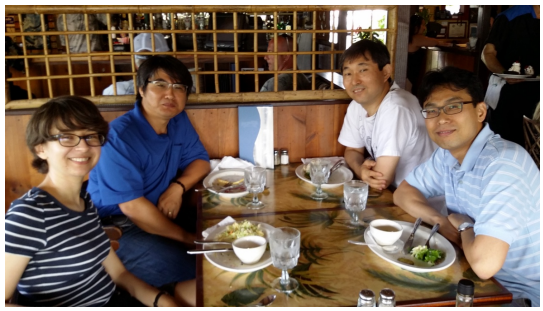
Credit: POLPACK documentation/SUN 233

From Kate Pattle's slides

Targets

- 16 fields and allocation (not final): 16 fields x 14 hours/field = 224 hours
  Observations started in 2016 May
  all the data have been obtained as of Jan. 2019!!!

  Auriga - Vietnam/EAO
  IC5146 - Taiwan
  Ophiuchus (3 fields) - Japan/**Korea**/China
  L1689B - UK
  Orion A - 'consortium' survey paper (UK)
  Orion B - **Korea**
  Perseus B1 - Canada
  NGC1333 (2 fields) - Canada/Japan
  Serpens (2 fields) - **Korea**/Taiwan
  Taurus B211/213 (2 fields) - Japan/China
  Perseus L1455 - Canada



BISTRO-2

- Farther and massive star forming regions (2017—2019)
  - 224 hours (16 fields) : 74% data as of 2019 Aug. 28

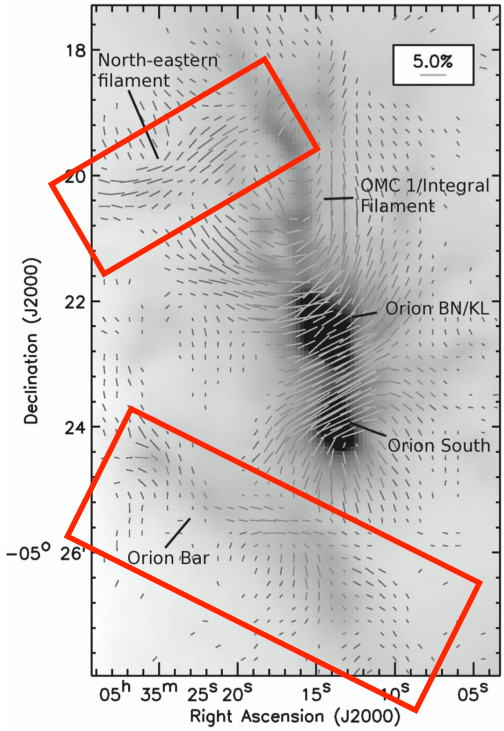
Source	Right Ascension	Declination	Weather Band
L1495			
IC348	03:43:57.0	+32:01:56	2
Orion A Field 1	05:35:16.6	−05:18:46	2
Orion A Field 2	05:35:26.4	−05:10:02	2
Orion A Field 3	05:35:23.7	−05:01:18	2
Mon R2	06:07:46.9	−06:23:04	1
Rosette Field 1	06:34:14.7	+04:20:15	2
Rosette Field 2	06:34:06.4	+04:24:58	2
NGC 2264 Field 1	06:41:11.3	+09:29:24	2
NGC 2264 Field 2	06:41:02.6	+09:35:41	2
NGC 6334 Field 1	17:20:52.4	−35:45:48	2
NGC 6334 Field 2	17:20:21.5	−35:54:45	2
M16	18:18:52.4	−13:49:57	2
Serpens South			2
DR15	20:21:43.7	+37:26:12	2
DR21	20:39:01.1	+42:21:17	1

Publications

- **9 papers published/accepted, several papers in prep.**
  1. Ward-Thompson et al. 2017: Orion A
  2. Pattle et al. 2017: Orion A (2G)
  3. Jungmi Kwon et al. 2018: Oph-A
  4. Soam et al. 2018: Oph-B
  5. Pattle et al. 2018: M16
  6. Junhao Liu et al. 2019: Oph-C
  7. Jia-Wei Wang et al. 2019: IC5146
  8. Simon Coude et al. 2019: B1
  9. Pattle et al. 2019: Oph-A/B/C (2G)

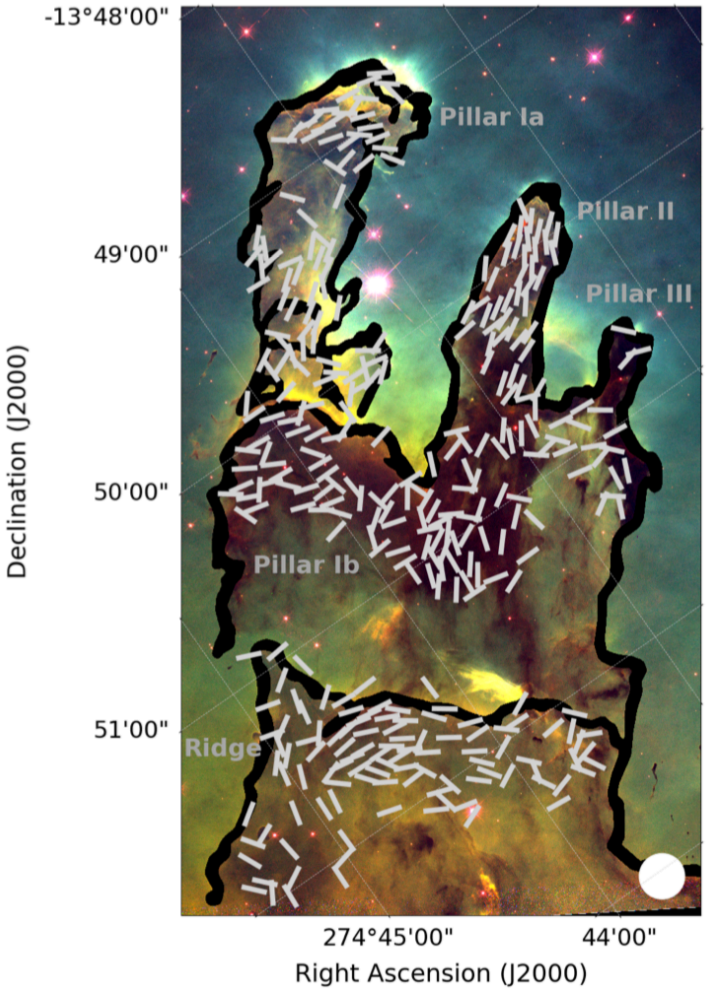
  Several papers in preparation including
  Hwang et al. in prep: Orion A (2G)
  Kwon et al. in prep: Serpens Main SE
  Lyo et al. in prep: Orion B

- Working groups for 2nd generation papers



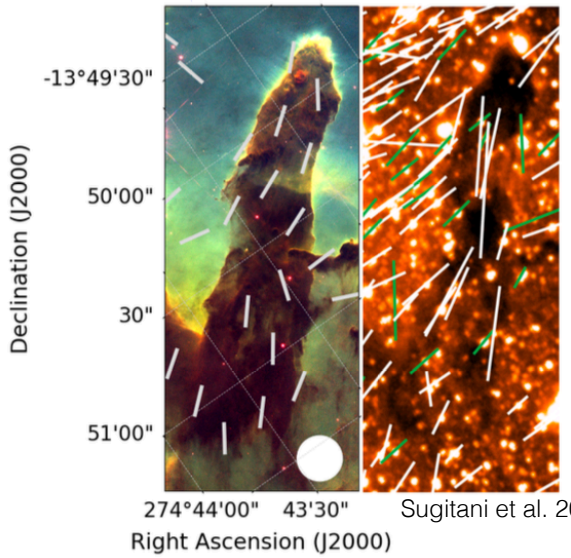
News

- Follow-up projects
  ALMA: cycle6 1, cycle7 2 (not approved)
  SOFIA: 2018 (HAWC+), approved (filler)
- White paper for a new 850 micron MKID camera
  led by Ray Furuya, Kate Pattle, Simon Coude
- BISTRO-3 under discussion
- At the coming JCMT User's Meeting in Taiwan
  3rd face-to-face meeting likely on Nov. 8



M16
Eagle Nebula

- Pillars of Creation (d ~ 1.8 kpc)
- Origin?
  Obstruction of shock front vs.
  Turbulent instability

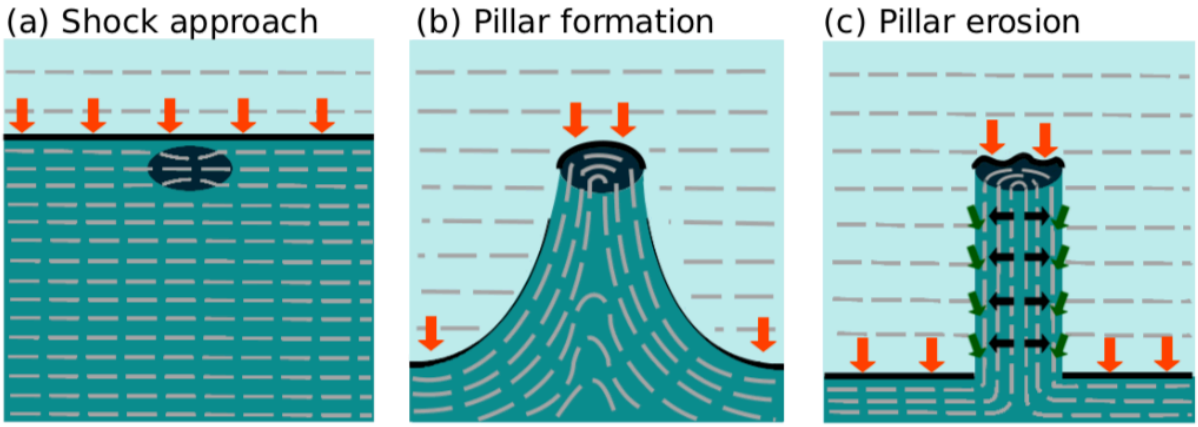


Sugitani et al. 2007

Pattle et al. 2018

M16 Eagle Nebula

- B ~ 170-320 μG
- Pillars formed by cold, dense gas obstruction of shock front
- Pillars' wall supported by magnetic fields



Pattle et al. 2018

BISTRO(2)-Korea Members

- Quang Nguyen-Luong: from Japan, through Korea, to Canada
- Gwanjeong Kim: to Japan (Nobeyama, Nov. 1, 2017)
- Archana Soam: to USA (NASA, July 15, 2018)

- Members (22+6)

	Data reduction team		
Kyung Hee Univ.	Jeong-Eun Lee	*Yong-Hee Lee*	*Hyeong-Sik Yun*
Chungnam Nat. U.	Jungyeon Cho		
KASI	Do-Young Byun	Minho Choi	Eun Jung Chung
	Il-Gyo Jeong	Ji-hyun Kang	Miju Kang
	Sung-ju Kang	Mi-Ryang Kim	Jongsoo Kim
	Kee-Tae Kim	Thiem Hoang	Shinyoung Kim
	Chang Won Lee	Sang-Sung Lee	Tie Liu
	ARan Lyo	Hyunju Yoo	**Woojin Kwon**
	Jihye Hwang	*Geumsook Park*	*Ilseung Han*
	Hyeseung Lee	*Yunhee Choi*	Kyoung Hee Kim

Korea Activities

- **Oph B**: Archana Soam (published)
- **Serpens Main SE**: Woojin Kwon
- **Orion B**: A-Ran Lyo
- Orion A (2G) and **Mon R2 (BISTRO-2)**: Jihye Hwang
- A new technique for estimating magnetic field strength, applied to Orion A: Hyeseung Lee, Jungyeon Cho
- Obs. supports, F2F meeting in 2018, SOFIA project

BISTRO-Korea Meetings

- 2016 April 1: BISTRO-Korea meeting at KASI for field selection
- 2016 July 5: BISTRO-Korea workshop for updates and data reduction (17 participants, 1st bistro of BISTRO-Korea)
- 2016 Oct 5: BISTRO-Korea meeting (KASI, 14 participants)
- 2016 Oct 27: BISTRO-Korea-DR
- 2016 Nov 10: BISTRO-Korea-DR
- 2016 Nov 28: BISTRO-Korea meeting (KASI, 15 participants)
- 2016 Dec 26: BISTRO-Korea-DR
- 2017 Jan 23: BISTRO-Korea-DR
- 2017 Feb 9: BISTRO-Korea meeting
- 2017 Feb 15: 1st BISTRO face-to-face meeting in Nanjing
- 2017 Mar 27: BISTRO-Korea-DR
- 2017 May 10: BISTRO-Korea-DR
- 2017 May 30: BISTRO-Korea meeting
- 2017 Jul 3: BISTRO2 target selection meeting
- 2017 Sep 26: BISTRO-Korea meeting
- 2017 Nov 24: BISTRO-Korea meeting (with Kate Pattle)
- 2017 Dec 5: BISTRO-Korea-DR
- 2017 Dec 21: BISTRO-Korea-DR
- 2018 Jan 5: BISTRO-Korea-DR
- 2018 Jan 24: BISTRO-Korea meeting
- 2018 Jan 30: 2nd BISTRO face-to-face meeting in Seoul
- 2018 Jul 11: BISTRO-Korea meeting
- 2018 Aug 2: BISTRO-Korea-DR
- 2018 Aug 23: BISTRO-Korea-DR
- 2018 Sep 14: BISTRO-Korea-DR
- 2018 Oct 22: BISTRO-Korea-DR
- 2018 Nov 22: BISTRO-Korea-DR
- 2018 Dec 10: BISTRO-Korea-DR
- 2019 Jan 15: BISTRO-Korea-DR
- 2019 Mar 13: BISTRO-Korea meeting
- 2019 Apr 26: BISTRO-Korea-DR
- 2019 May 29: BISTRO-Korea-DR

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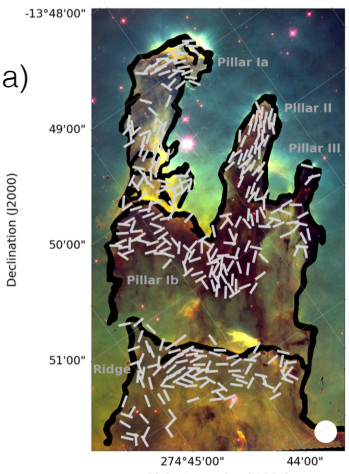

Pattle et al. 2018